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Presents methodology and data sources used to identify the mineral processing sectors and waste streams. Provides individual commodity reviews, which include a commodity section describing its uses and giving pertinent statistics, a detailed process description with process flow diagrams, and a process waste stream section that identifies individual waste streams. Appendices include detailed explanations of methodology used to estimate annual waste generation rates for the individual waste streams, work sheet for waste stream assessment, definitions for classifying mineral processing waste streams, recycling work sheets for individual mineral processing waste streams, listing of waste streams generated by mineral production activities by commodity, mineral processing sectors generating hazardous wastes, mineral processing sectors not generating hazardous wastes, and a list of commenters.

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This technical background document, *Identification and Description of Mineral Processing Sectors and Waste Streams*, was submitted for public review to EPA's RCRA Docket # F-95-PH4A-FFFFF. It provides supplementary information and support for the January 25, 1996 Supplemental Proposed Rule, *Land Disposal Restrictions---Supplemental Proposal to Phase IV: Clarification of Bevill Exclusion for Mining Wastes, Changes to the Definition of Solid Waste for Mineral Processing Wastes, Treatment Standards for Characteristic Mineral Processing Wastes, and Associated Issues* (61 FR 2338). The Agency has received comments from the public on this document and has listed these comments and Agency responses in the final section of the document. The Agency finalizes this document as of May 1, 1998 and submits it to RCRA Docket # F-98-2P4F-FFFFF to provide supplementary information and support for the May 1, 1998 Final Rule, *Land Disposal Restrictions Phase IV: Final Rule Promulgating Treatment Standards for Metal Wastes and Mineral Processing Wastes; Mineral Processing Secondary Materials and Bevill Exclusion Issues; Treatment Standards for Hazardous Soils, and Exclusion of Recycled Wood Preserving Wastewaters.*

DISCLAIMER

This document is intended solely to provide information to the public and the regulated community regarding the wastes that are potentially subject to the requirements of this rule. This information was also utilized by the Agency to assist in evaluating the potential impacts on the industry associated with complying with the rule. While the guidance contained in this document may assist the industry, public and federal and state regulators in applying statutory and regulatory requirements of RCRA, the guidance is not a substitute for those legal requirements; nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, States or the regulated community. Based on the circumstances, the conclusions in this document may not apply to a particular situation, and EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where determined to be appropriate based on the facts of the case and applicable statutes and regulations.

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I. EXECUTIVE SUMMARY

The purpose of this executive summary is to describe EPA's review of mineral commodities that may generate hazardous wastes as defined by RCRA Subtitle C. These wastes and the facilities and commodity sectors that generate them may be affected by the establishment of Land Disposal Restrictions for mineral processing wastes. Through a series of rulemakings (see Background below) EPA has established and applied criteria to determine which mineral processing wastes are no longer exempt from Subtitle C regulation. These wastes are termed "newly identified" mineral processing wastes.

Any newly identified mineral processing waste that exhibits one or more of the four characteristics of a hazardous waste if disposed on the land must be made subject to the Land Disposal Restrictions (LDRs). Accordingly, EPA has promulgated treatment standards (Best Demonstrated Available Technology, or BDAT) for newly identified mineral processing wastes.

EPA reviewed the 36 industrial sectors (commodities) and 97 different general categories of wastes identified in a previously published Advanced Notice of Public Rule Making (ANPRM) (October 21, 1991). EPA also reviewed a listing of more than 100 mineral commodities prepared by the U.S. Bureau of Mines (Bureau of Mines' 1987 Minerals Year Book, 1989-1995 Mineral Commodities Summary, and 1985 Mineral Facts and Problems). This information, in addition to data collected in previous EPA studies, was used to compile a comprehensive list of mineral commodity sectors. In the process, the Agency identified a total of 62 mineral commodities that could generate mineral processing waste streams that could potentially exhibit one of the characteristics of a RCRA hazardous waste.

The Agency used publicly available information to prepare a draft technical background document (TBD) on the production of particular mineral commodities and associated operations that generate mineral processing wastes. This draft was made available for public comment in January 1996 (docket No. F-95-PH4A-FFFFF). Numerous public comments were submitted to the Agency addressing the draft TBD. In addition, although the Agency did not request further comments on the draft TBD in a subsequent Federal Register notice articulating modifications to the proposed Phase 4 LDR rule (62 FR 26041), several comments were submitted that included process information or other data that were relevant to the TBD; these comments may be found in docket No. F-97-2P4P-FFFFF. This final TBD addresses and provides EPA's responses to all of these comments and information contained therein, where appropriate.

The Agency cautions that this document should not be construed to be an exclusive list of mineral processing and associated waste streams; other types of mineral processing wastes may exist. Moreover, the omission or inclusion of a waste stream in this background document does not relieve the generator from the responsibility for correctly determining whether each of its particular wastes is covered by the Bevill mining waste exclusion. This report has been extensively revised from the previous draft and should be used as guidance for EPA.

A. METHODS AND DATA SOURCES

1. Background

Under the provisions of the Mining Waste Exclusion of the Resource Conservation and Recovery Act (RCRA), solid waste from the extraction, beneficiation, and processing of ores and minerals is exempt from regulation as hazardous waste under Subtitle C of RCRA, as amended. The Mining Waste Exclusion was established in response to §3001(b)(3) of the statute (also known as the "Bevill Amendment"), which was added in the 1980 Solid Waste Disposal Act Amendments. The Bevill Amendment precluded EPA from regulating these wastes (as well as several other "special wastes") until the Agency performed a study and submitted a Report to Congress, as directed by §8002, and determined either to promulgate regulations under Subtitle C or that such regulations were unwarranted, (i.e., that the Exclusion should continue), as directed by §3001(b)(3)(C) of the statute. In response to the Bevill Amendment, EPA modified its final hazardous waste regulations in November 1980 to reflect this new

exemption, and issued a preliminary and very broad interpretation of the scope of its coverage ("solid waste from the exploration, mining, milling, smelting and refining of ores and minerals" (45 FR 76618, November 19, 1980)).

In 1984, the Agency was sued for failing to complete the required Report to Congress and regulatory determination in conformance with the statutory deadline (*Concerned Citizens of Adamstown v. EPA*, No. 84-3041, D.D.C., August 21, 1985). In responding to this lawsuit, EPA explained that it planned to propose a narrower interpretation of the scope of the Exclusion, and proposed to the Court two schedules: one for completing the §8002 studies of mineral extraction and beneficiation wastes and submitting the associated Report to Congress, and one for proposing and promulgating a reinterpretation for mineral processing wastes. In so doing, the Agency, in effect, split the wastes that might be eligible for exclusion from regulation into two groups: mining (extraction and beneficiation) wastes and mineral processing wastes. The Court agreed to this approach and established a schedule for completing the two initiatives.

The Report to Congress on mining wastes was published on December 31, 1985, and on July 3, 1986 (51 FR 24496) EPA published the regulatory determination for these wastes, which stated that, in the Agency's judgment, Subtitle C regulation of these wastes was unwarranted. In keeping with its agreement, EPA also proposed to narrow the scope of the Mining Waste Exclusion for mineral processing wastes on October 2, 1985 (50 FR 40292). In this proposal, however, the Agency did not specify the criteria that it used to distinguish the mineral processing wastes that qualified for the Exclusion from those that did not.

In response to the proposed rule, many companies and industry associations "nominated" wastes that they believed should be retained within the Exclusion. Faced with an inability at that time to articulate criteria that could be used to distinguish exempt from non-exempt wastes and the approaching Court-ordered deadline for final action, EPA withdrew its proposal on October 9, 1986 (51 FR 36233); the Agency was promptly sued by a coalition of environmental/public interest groups. In July 1988, the Court in *Environmental Defense Fund v. EPA* held that EPA's withdrawal of the 1985 proposal was arbitrary and capricious, and ordered the Agency to define the specific mineral processing wastes that were eligible for the Mining Waste Exclusion. The Court also directed the Agency to restrict the scope of the Exclusion to include only "large volume, low hazard" wastes, based upon the legislative history of the special wastes concept.

During the three years that followed this decision, EPA proposed and promulgated several rules that redefined the boundaries of the Exclusion for mineral processing wastes. These rulemaking notices included explicit criteria for defining mineral beneficiation and processing, and large volume and low hazard, as well as evaluations of which specific mineral industry wastes were in conformance with these criteria and thus, eligible for special waste status. This rulemaking process was completed with the publication of final rules on September 1, 1989 (54 FR 36592) and January 23, 1990 (54 FR 2322). EPA's evaluations led to the finding that only 20 specific mineral processing wastes fulfilled the newly promulgated special wastes criteria; all other mineral processing wastes were removed from the Mining Waste Exclusion. The 20 special wastes were studied in a comprehensive Report to Congress published on July 30, 1990. Subsequently, EPA ruled, after considering public comment and performing additional analysis, that Subtitle C regulation was unwarranted for these 20 waste streams.

How LDR Relates to Mineral Processing Wastes

As a consequence of the rulemaking process described above, all but 20 mineral processing wastes have been removed from the Mining Waste Exclusion. These newly non-exempt wastes have the same regulatory status as any other industrial solid waste. That is, if they exhibit characteristics of hazardous waste or are listed as hazardous wastes, they must be managed in accordance with RCRA Subtitle C or equivalent state standards. Existing waste characterization data suggest that some of these wastes may exhibit the characteristic of toxicity for metals (waste codes D004-D011), corrosivity (D002), and/or reactivity (D003).

EPA considers these wastes to be "newly identified" because they were brought into the RCRA Subtitle C system after the date of enactment of the Hazardous and Solid Waste Act (HSWA) Amendments on November 8, 1984. EPA declined to include newly identified wastes within the scope of the Land Disposal Restrictions (LDRs) for Subtitle C characteristic hazardous wastes ("Third Third" Rule) published on June 1, 1990, deciding instead to promulgate additional treatment standards (Best Demonstrated Available Technology, or BDAT) in several phases

that were to be completed in 1997. The rationale for this decision is articulated at 55 FR 22667. In brief, at that time, EPA had not performed the technical analyses necessary to determine whether the treatment standards being promulgated for characteristic hazardous wastes were feasible for the newly non-exempt mineral processing wastes. The issue was further complicated by the fact that the list of non-exempt wastes was not final at that time, because the regulatory determination for the 20 wastes studied in the 1990 Report to Congress had not yet been promulgated. The boundaries of the Exclusion have now been firmly established, and the Agency is ready to characterize and establish treatment standards for all newly identified hazardous mineral processing wastes.

More recent work performed by OSW's Waste Treatment Branch (WTB) on the composition and other characteristics of the mineral processing wastes that have been removed from the Exclusion suggests that some of these wastes may pose unique treatability and/or capacity problems. Accordingly, there was a need for EPA to perform further data collection and analysis activities in order to develop BDAT treatment standards that are both adequately protective and achievable.

2. Scope of the Report

In order to provide the necessary foundation to both develop a fully comprehensive inventory of mineral commodity sectors, facilities, and waste streams that may be affected by the LDRs program and identify applicable treatment technologies, EPA conducted an extensive effort to collect information. Specifically, EPA: (1) conducted electronic literature searches; (2) reviewed documents, including the 1989 mineral processing survey instruments (NSSWMPF), public comments on the 1991 ANPRM, and various articles and conference proceedings; (3) reviewed documents prepared by the Office of Solid Waste, various Agency contractors, state regulatory authorities, and the Bureau of Mines (BOM); (4) reviewed the "Mineral Commodity Summaries" prepared by the BOM; and (5) contacted BOM Commodity Specialists. Information collected included detailed process descriptions and identification of waste streams. In addition, in preparing this final Technical Background Document, EPA carefully considered and, where appropriate, incorporated or otherwise addressed new information and suggested corrections to the draft document offered in public comment on the Agency's proposed rules (61 FR 2338, 62 FR 26041) and supporting documents. These comments were submitted to, and may be found in, docket Nos. F-95-PH4A-FFFFF and F-97-2P4P-FFFFF, respectively. The specific methodology that EPA employed for this effort is described in detail in Section 3, Methods and Data Sources, below.

Based on this information, EPA prepared 49 separate analyses covering the 62 commodity groups presented in Exhibit 1-1. Each analysis includes the following:

- A commodity summary describing the uses and salient statistics of the particular mineral commodity;
- A process description section with detailed, current process information and process flow diagram(s); and
- A process waste stream section that identifies -- to the maximum extent practicable -- individual waste streams, sorted by the nature of the operation (i.e., extraction/beneficiation or mineral processing).[1] Within this section, EPA also identified:
  - waste stream sources and form (i.e., wastewater (<1 percent solids and total organic content), 1-10 percent solids, and >10% solids);
  - Bevill-Exclusion status of the waste stream (i.e., extraction/beneficiation waste stream, mineral processing waste stream, or non-uniquely associated waste stream);

[1] EPA strongly cautions that the process information and identified waste streams presented in the commodity analysis reports should not be construed to be the authoritative list of processes and waste streams. These reports represent a best effort, and clearly do not include every potential process and waste stream. Furthermore, the omission of an actual waste stream (and thus its not being classified as either an extraction/beneficiation or mineral processing waste in this report) does not relieve the generator from its responsibility of correctly determining whether the particular waste is covered by the Mining Waste Exclusion.

- waste stream characteristics (total constituent concentration data, and statements regarding whether the waste stream exhibits or is expected to exhibit one of the RCRA hazardous waste characteristics of toxicity, ignitability, corrosivity, or reactivity);

- annual generation rates (reported or estimated);

- management practices (e.g., tank treatment and subsequent NPDES discharge, land disposal, or in-process recycling); and

- whether the waste stream is being (or could potentially be) recycled, and thus be classified as either as a sludge, by-product, or spent material.

The list provided in this report represents EPA's best effort to date, and generators continue to be responsible for determining whether any wastes omitted from these lists are non-exempted and subject to Subtitle C controls.

3. Methodology and Major Data Sources

EPA researched and obtained information characterizing the mineral processing operations and wastes associated with the mineral commodities listed in Exhibit 1-1. This information was used by EPA both to update existing data characterizing mineral processing wastes obtained through past Agency efforts and to obtain characterization information on newly identified waste streams not previously researched.

To provide the necessary foundation to both (1) develop a fully comprehensive inventory of mineral commodity sectors, facilities, and waste streams that may be affected by the LDRs program and (2) identify applicable treatment technologies, EPA embarked on an information collection program. Specifically, to capitalize on information collected through past efforts, as well as to collect more recent data, we conducted the following activities:

- Reviewed mineral processing survey instruments (NSSWMPF) and public comments (submitted in response to the 1991 ANPRM) for process-related information (e.g., process flow diagrams, waste characterization data, and waste management information) contained in our in-house files.

- Reviewed numerous documents provided by EPA (e.g., contractor reports and various Bureau of Mines reports) for process-related information.

- Reviewed the 1993, 1994, and 1995 "Mineral Commodity Summaries" prepared by the Bureau of Mines (BOM) for salient statistics on commodity production.[2]

- Reviewed and summarized damage case information presented in the "Mining Sites on the National Priorities List, NPL Site Summary Reports" to support work on assessing the appropriateness of the Toxicity Characteristic Leaching Procedure (TCLP) for mineral processing wastes.

- Contacted the BOM (now USGS) Commodity Specialists associated with the commodity sectors of interest to (1) obtain current information on mining companies, processes, and waste streams, and (2) identify other potential sources of information.

- Retrieved applicable and relevant documents from the BOM's FAXBACK document retrieval system. Documents retrieved included monthly updates to salient statistics, bulletins, and technology review papers.

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[2] Following elimination of the U.S. Bureau of Mines in 1995, responsibility for certain mineral commodity-related activities was transferred to the U.S. Geological Survey (USGS).

- Conducted an electronic query of the 1991 Biennial Reporting System (BRS) for waste generation and management information on 34 mineral processing-related Standard Industrial Classification (SIC) numbers.

- Conducted an electronic literature search for information related to mineral processing and waste treatment technologies contained in numerous technical on-line databases, including: NTIS, Compendex Plus, METADEX, Aluminum Industry Abstracts, ENVIROLINE, Pollution Abstracts, Environmental Bibliography, and GEOREF.

EPA searched for relevant information (published since 1990) on the mineral commodities listed in Exhibit 1-1. We chose 1990 as the cutoff year so as not to duplicate past information collection activities conducted by EPA and EPA contractors, and to obtain information on mineral processes "retooled" since clarification of the Bevill Amendment to cover truly "high volume, low hazard" wastes.

In preparing the commodity sector reports, EPA used its established definitions and techniques for establishing which operations and waste streams might be subject to LDR standards. EPA decisions concerning whether individual wastes are within the scope of the RCRA Mining Waste Exclusion were based upon a number of different factors. The Agency examined these factors in sequence, in such a way as to yield unambiguous and consistent decisions from sector to sector. The step-wise methodology used for this analysis is presented below:

1. Ascertain whether the material is considered a solid waste under RCRA.

2. Establish whether the waste and the operation that generates it are uniquely associated with mineral production.

3. Determine whether the waste is generated by a mineral extraction, beneficiation, or processing step.

4. Determine whether the waste is generated by a primary mineral processing step, and, more generally, whether or not primary mineral processing occurs in the sector/within a process type.

5. Check to see whether the waste, if a processing waste, is one of the 20 special wastes from mineral processing.

This analytical sequence results in one of three outcomes: 1) the material is not a solid waste and hence, not subject to RCRA; 2) the material is a solid waste but is exempt from RCRA Subtitle C because of the Mining Waste Exclusion; or 3) the material is a solid waste that is not exempt from RCRA Subtitle C and is subject to regulation as a hazardous waste if it is listed as a hazardous waste or it exhibits any of the characteristics of hazardous waste.[3]

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[3] RCRA Subtitle C regulations define toxicity as one of the four characteristics of a hazardous waste. EPA uses the Toxicity Characteristic Leaching Procedure (TCLP) to assess whether a solid waste is a hazardous waste due to toxicity. In today's final rule, EPA is reinstating the application of the TCLP to mineral processing wastes in response to a Court remand. For further discussion, see the preamble to today's final rule.

EXHIBIT 1-1

MINERAL COMMODITIES OF POTENTIAL INTEREST

1) Alumina
2) Aluminum
3) Ammonium Molybdate
4) Antimony
5) Arsenic Acid
6) Asphalt (natural)
7) Beryllium
8) Bismuth
9) Boron
10) Bromine (from brines)
11) Cadmium
12) Calcium Metal
13) Cerium, Lanthanides, and Rare Earth metals
14) Cesium/Rubidium
15) Chromium
16) Coal Gas
17) Copper
18) Elemental Phosphorus
19) Ferrochrome
20) Ferrochrome-Silicon
21) Ferrocolumbium
22) Ferromanganese
23) Ferromolybdenum
24) Ferrosilicon
25) Gemstones
26) Germanium
27) Gold and Silver
28) Hydrofluoric Acid
29) Iodine (from brines)
30) Iron and Steel
31) Lead
32) Lightweight Aggregate
33) Lithium (from ores)
34) Lithium Carbonate
35) Magnesia (from brines)
36) Magnesium
37) Manganese and MnO_2
38) Mercury
39) Mineral Waxes
40) Molybdenum
41) Phosphoric Acid
42) Platinum Group Metals
43) Pyrobitumens
44) Rhenium
45) Scandium
46) Selenium
47) Silicomanganese
48) Silicon
49) Soda Ash
50) Sodium Sulfate
51) Strontium
52) Sulfur
53) Synthetic Rutile
54) Tantalum/Columbium
55) Tellurium
56) Tin
57) Titanium/TiO_2
58) Tungsten
59) Uranium
60) Vanadium
61) Zinc
62) Zirconium/Hafnium

NOTE: This list represents EPA's best efforts at identifying mineral commodities that may generate mineral processing wastes. Omission or inclusion on this list does not relieve the generator of the responsibility for appropriately managing wastes that would be subject to RCRA Subtitle C requirements.

EPA used waste stream characterization data obtained from numerous sources to document whether a particular waste stream exhibits one (or more) of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity). Due to the paucity of waste characterization data (particularly, TCLP data), EPA used total constituent data (if available) or engineering judgment to determine whether a particular waste exhibits one of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity).

When data were available, EPA used actual waste generation rates reported by facilities in various Agency survey instruments and background documents. To account for the general lack of data for many of the mineral commodity sectors and waste streams, the Agency developed a step-wise method for estimating mineral processing waste stream generation rates when actual data were unavailable. Specifically, EPA developed an "expected value" estimate for each waste generation rate using draft industry profiles, supporting information, process flow diagrams, and professional judgment. From the "expected value" estimate, EPA developed upper and lower bound estimates, which reflect the degree of uncertainty in our data and understanding of a particular sector, process, and/or waste in question. The precise methodology employed for determining waste generation rates varied depending on the quantity and quality of available information.

To determine waste stream management practices, EPA reviewed process descriptions and process flow diagrams obtained from numerous sources, including Kirk-Othmer (several editions), EPA's Effluent Guideline Documents (see sector reports for specific references), EPA survey instruments, and the literature. Because the available process descriptions and process flow diagrams varied considerably in both quality and detail, EPA often needed to interpret the information to determine how specific waste streams are managed. For example, process descriptions and process flow charts found through the Agency's electronic literature search process often focus on the production process of the mineral product and omit any description or identification of how or where waste streams are managed. In such cases, the Agency has used professional judgment to determine how and where specific waste streams are managed. Specifically, EPA considered (1) how similar waste streams are managed at mineral processing facilities for which the Agency has management practice information, (2) the waste form and whether it is amenable to tank treatment, (3) generation rates, and (4) proximity of the point of waste generation to the incoming raw materials, intermediates, and finished products, to predict the most likely waste management practice.

As was the case for the other types of waste stream-specific information discussed above, EPA was unable to locate published information showing that many of the identified mineral processing waste streams were being recycled. Therefore, the Agency developed a work sheet to assist EPA staff in making consistent determinations of whether the mineral processing waste streams could potentially be recycled, reused, or recovered. This work sheet, shown in Appendix C, was designed to capture the various types of information that could allow one, when using professional judgment, to determine whether a particular waste stream could be recycled or whether it contains material of value. If EPA determined that the waste stream is or could be fully/partially recycled, it initially used the definitions provided in 40 CFR §§ 260.10 and 261.1 to categorize each waste stream as either a by-product, sludge, or spent material. In today's final rule, however, these distinctions have been eliminated in the context of the primary minerals industry. This final document nonetheless contains references to this former classification scheme, because it is used extensively in other analyses (e.g., the Regulatory Impact Analysis) that EPA has prepared in support of today's rule.

EPA, through the process of researching and preparing mineral commodity analysis reports for the mineral commodities, identified a total of 553 waste streams that are believed to be generated at facilities involved in mineral production operations. The Agency then evaluated each of the 553 waste streams to remove waste streams that would not be affected by the Phase IV LDRs. Specifically, EPA removed the following materials:

- All of the extraction and beneficiation waste streams;
- The "Special 20" Bevill-Exempt mineral processing waste streams;
- Waste streams that are known to be fully recycled in process; and

- All of the mineral processing waste streams that do not or are unlikely to exhibit one or more of the RCRA characteristics of a hazardous waste (based on either actual analytical data or professional judgment).

Finally, as noted above, EPA made a number of corrections and other modifications to the draft TBD in response to new information provided in written comments received in response to the two proposed rules and the draft TBD.

As a result of this evaluation process, EPA narrowed the potential universe of waste streams that could potentially be affected by the Phase IV LDRs to the 133 hazardous mineral processing waste streams presented in Exhibit 1-2.

4. Caveats and Limitations of Data Analysis

The results and information presented in this report are based primarily on a review of publicly available information. The accuracy and representativeness of the collected information are only as good as the source documents. As a result of this limited data quality review, EPA notes that in some instances, Extraction Procedure (EP) leachate data reported by various sources are greater than 1/20th of the associated total constituent concentrations. Generally, one would expect, based on the design of the EP testing procedure, the total constituent concentrations to be at least 20-times the EP concentrations. This apparent discrepancy, however, can potentially be explained if the EP results were obtained from total constituent analyses of liquid wastes (i.e., EP tests conducted on wastes that contain less than one-half of one percent solids content are actually total constituent analyses).

In addition, to present mineral commodity profiles that were as complete as possible, EPA used a step-wise methodology for estimating both annual waste generation rates and waste characteristics for individual waste streams when documented waste generation rates and/or analytical data were not available. EPA's application of this methodology to estimate waste generation rates resulted in the development of low, medium, and high annual waste generation rates for non-wastewaters and wastewaters that were bounded by zero and 45,000 metric tons/yr/facility and by zero and 1,000,000 metric tons/yr/facility, respectively (the thresholds for determining whether a waste stream was a high volume, Bevill-exempt waste). Due to the paucity of waste characterization data (particularly, TCLP data), EPA used total constituent data (if available) or best engineering judgment to determine whether a particular waste exhibited one of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity).

To determine whether a waste might exhibit the characteristic of toxicity, EPA first compared 1/20th of the total constituent concentration of each TC metal to its respective TC level[4]. In cases where total constituent data were not available, EPA then used best engineering judgment to evaluate whether the waste stream could potentially exhibit the toxicity characteristic for any of the TC metals. For example, if a particular waste stream resulted through the leaching of a desired metal from an incoming concentrated feed, we assumed that the precipitated leach stream contained high total constituent (and therefore, high leachable) concentrations of non-desirable metals, such as arsenic. Continuing through the step-wise methodology, we relied on EPA's best engineering judgment to determine, based on our understanding of the nature of a particular processing step that generated the waste in question, whether the waste could possibly exhibit one (or more) of the characteristics of ignitability, corrosivity, or reactivity. The Agency acknowledges the inherent limitations of this conservative, step-wise methodology and notes that it is possible that EPA may have incorrectly assumed that a particular waste does (or does not) exhibit one or more of the RCRA hazardous waste characteristics.

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[4] Based on the assumption of a theoretical worst-case leaching of 100 percent and the design of the TCLP extraction test, where 100 grams of sample is diluted with two liters of extractant, the maximum possible TCLP concentration of any TC metal would be 1/20th of the total constituent concentration.

B. MINERAL OPERATIONS THAT MAY GENERATE HAZARDOUS WASTE

1. Introduction

EPA collected, evaluated for relevance (both applicability and age), and compiled publicly available information to prepare 49 analyses covering 62 commodity groups. Each commodity analysis consists of a commodity summary describing the uses of and salient statistics pertaining to the particular commodity, a process description section with detailed, current process information and process flow diagram(s), and a process waste stream section that identifies -- to the maximum extent practicable -- individual wastes, sorted by the nature of the operation (i.e., extraction/beneficiation or mineral processing).

Through this process, EPA identified a total of 553 waste streams from a review of all mineral sectors. After careful analysis, EPA determined that 40 commodity sectors generated a total of 358 waste streams that could be classified as mineral processing wastes, 133 of which are believed to exhibit one or more of the characteristics of a hazardous waste. At this time, EPA has insufficient information to determine whether the following commodity sectors also generate wastes that could be classified as mineral processing wastes: Bromine, Gemstones, Iodine, Lithium, Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium.

EPA strongly cautions that the process information and identified waste streams presented in the commodity reports should not be construed as an authoritative list of processes and waste streams. These reports represent a best effort, and clearly do not include every potential process and waste stream affected by today's final rule. Furthermore, the omission of an actual waste stream (and thus it's not being classified as either an extraction/beneficiation or mineral processing waste in this report) does not relieve the generator from its responsibility of correctly determining whether the particular waste is covered by the Mining Waste Exclusion.

2. Alphabetical Listing of Mineral Commodities and Waste Streams

A listing of the mineral commodity sectors that are likely to generate newly identified hazardous wastes is presented in Exhibit 1-2. Exhibit 1-2 also presents a brief description of the production operations used to generate the mineral processing wastes, estimated/reported annual waste generation rates, and the specific RCRA characteristics causing individual wastes to be hazardous. This table lists only those mineral processing wastes which EPA believes are or may be hazardous. The Agency's assumptions concerning the characteristics of the wastes are indicated in Exhibit 1-2 as follows:

Y	=	known to be hazardous
Y?	=	suspected to be hazardous
N?	=	suspected to be not hazardous
N	=	believed to be not hazardous

EXHIBIT 1-2

LISTING OF HAZARDOUS MINERAL PROCESSING WASTES BY COMMODITY SECTOR

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Alumina and Aluminum Metallurgical grade alumina is extracted from bauxite by the Bayer process and aluminum is obtained from this purified ore by electrolysis via the Hall-Heroult process. The Bayer process consists of the following five steps: (1) ore preparation, (2) bauxite digestion, (3) clarification, (4) aluminum hydroxide precipitation, and (5) calcination to anhydrous alumina. In the Hall-Heroult process, aluminum is produced through the electrolysis of alumina dissolved in a molten cryolite-based bath, with molten aluminum being deposited on a carbon cathode.	Cast house dust	19	19	19	19	23			Y			Y			N?	N?	N?
	Electrolysis waste	58	58	58	58	23					Y?				N?	N?	N?
Antimony Primary antimony is usually produced as a by-product or co-product of mining, smelting, and refining of other antimony-containing ores such as tetrahedrite or lead ore. Antimony can be produced using either pyrometallurgical processes or a hydrometallurgical process. For the pyrometallurgical processes, the method of recovery depends on the antimony content of the sulfide ore, and will consist of either volatilization, smelting in a blast furnace, liquation, or iron precipitation. Antimony also can be recovered hydrometallurgically by leaching and electrowinning.	Autoclave filtrate	NA	0.32	27	54	6	Y?		Y?		Y?	Y?			Y?	N?	N?
	Stripped anolyte solids	0.19	0.19	0.19	0.19	2	Y?								N?	N?	N?
	Slag and furnace residue	21	21	21	21	6					Y?				N?	N?	N?
Beryllium Bertrandite and beryl ores are treated using two separate processes to produce beryllium sulfate, $BeSO_4$: a counter-current extraction process and the Kjellgren-Sawyer process. The intermediates from the two ore extraction processes are combined and fed to another extraction process. This extraction process removes impurities solubilized during the processing of the bertrandite and beryl ores and converts the beryllium sulphate to beryllium hydroxide, $Be(OH)_2$. The beryllium hydroxide is further converted to beryllium fluoride, BeF_2, which is then catalytically reduced to form metallic beryllium.	Chip treatment wastewater	NA	0.2	100	2000	2				Y?					N?	N?	N?
	Spent barren filtrate	55	55	55	55	1							Y		N?	N?	N?
	Filtration discard	NA	0.2	45	90	2					Y?				N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Bismuth Bismuth is recovered mainly during the smelting of copper and lead ores. Bismuth-containing dust from copper smelting operations is transferred to lead smelting operations for recovery. At lead smelting operations bismuth is recovered either by the Betterton-Kroll process or the Betts Electrolytic process. In the Betterton-Kroll process, magnesium and calcium are mixed with molten lead to form a dross that contains bismuth. The dross is treated with chlorine or lead chloride and oxidized by using air or caustic soda to remove impurities. In the Betts Electrolytic process, lead bullion is electrolyzed. The resulting impurities, including bismuth, are smelted, reduced and refined.	Alloy residues	NA	0.1	3	6	1					Y?				N?	N?	N?
	Spent caustic soda	NA	0.1	6.1	12	1					Y?				N?	N?	N?
	Electrolytic slimes	NA	0	0.02	0.2	1					Y?				N?	N?	N?
	Lead and zinc chlorides	NA	0.1	3	6	1					Y?				N?	N?	N?
	Metal chloride residues	3	3	3	3	1					Y?				N?	N?	N?
	Slag	NA	0.1	1	10	1					Y?				N?	N?	N?
	Spent electrolyte	NA	0.1	6.1	12	1					Y?				N?	N?	N?
	Spent soda solution	NA	0.1	6.1	12	1					Y?				Y?	N?	N?
	Waste acid solutions	NA	0.1	6.1	12	1									Y?	N?	N?
	Waste acids	NA	0	0.1	0.2	1									Y?	N?	N?
Cadmium Cadmium is obtained as a byproduct of zinc metal production. Cadmium metal is obtained from zinc fumes or precipitates via a hydrometallurgical or a pyrometallurgical process. The hydrometallurgical process consists of the following steps: (1) precipitates leached with sulfuric acid, (2) cadmium precipitated with a zinc dust addition, (3) precipitate filtered and pressed into filter cake, (4) impurities removed from filter cake to produce sponge, (5) sponge dissolved with sulfuric acid, (6) electrolysis of solution, and (7) cadmium metal melted and cast. The pyrometallurgical process consists of the following steps: (1) cadmium fumes converted to water- or acid-soluble form, (2) leached solution purified, (3) galvanic precipitation or electrolysis, and (4) metal briquetted or cast.	Caustic washwater	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Copper and lead sulfate filter cakes	NA	0.19	1.9	19	2			Y?		Y?				N?	N?	N?
	Copper removal filter cake	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Iron containing impurities	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Spent leach solution	NA	0.19	1.9	19	2	Y?		Y?		Y?				Y?	N?	N?
	Lead sulfate waste	NA	0.19	1.9	19	2			Y?		Y?				N?	N?	N?
	Post-leach filter cake	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Spent purification solution	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Scrubber wastewater	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Spent electrolyte	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Zinc precipitates	NA	0.19	1.9	19	2			Y?						N?	N?	N?
Calcium Calcium metal is produced by the Aluminothermic method. In the Aluminothermic method, calcium oxide, obtained by quarrying and calcining calcium limestone, is blended with finely divided aluminum and reduced under a high temperature vacuum. The process produces 99% pure calcium metal which can be further purified through distillation.	Dust with quicklime	0.04	0.04	0.04	0.04	1									Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Chromium and Ferrochromium Chromite ore is prepared for processing using several methods, depending on the ore source and the end use requirements, although many of these beneficiation operations may not be conducted in the United States. Either ferrochromium or sodium chromate is initially produced, and may be sold or further processed to manufacture other chromium compounds, as well as chromium metal. Ferrochromium is made by smelting chromite ore in an electric arc furnace with flux materials and carbonaceous redcutant.	ESP dust	3	3	3	3	1				Y			Y		N?	N?	N?
	GCT sludge	NA	0.03	0.3	3	1				Y?					N?	N?	N?
Coal Gas Coal is crushed and gasified in the presence of steam and oxygen, producing carbon dioxide and carbon monoxide, which further react to produce carbon oxides, methane and hydrogen. The product gas is separated from the flue gas, and is processed and purified to saleable methane.	Multiple effects evaporator concentrate	NA	0	0	65	1	Y						Y		N?	N?	N?
Copper Copper is recovered from ores using either pyrometallurgical or hydrometallurgical processes. In both cases, the copper-bearing ore is crushed, ground, and concentrated (except in dump leaching). Pyrometallurgical processing can take as many as five steps: roasting, smelting, converting, fire refining, and electrorefining. Hydrometallurgical processing involves leaching, followed by either precipitation or solvent extraction and electrowinning.	Acid plant blowdown	5300	5300	5300	5300	10	Y		Y	Y	Y	Y	Y	Y	Y	N?	N?
	APC dusts/sludges	NA	1	220	450	10	Y?								N?	N?	N?
	Waste contact cooling water	13	13	13	13	10	Y?								N?	N?	N?
	Tankhouse slimes	4	4	4	4	10	Y?				Y?		Y?	Y?	N?	N?	N?
	Spent bleed electrolyte	310	310	310	310	10	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Spent furnace brick	3	3	3	3	10				Y?					N?	N?	N?
	Process wastewaters	4900	4900	4900	4900	10	Y		Y		Y	Y	Y?		Y	N?	N?
	WWTP sludge	6	6	6	6	10			Y?		Y?				N?	N?	N?
Elemental Phosphorus Phosphate rock or sintered/agglomerated fines are charged into an electric arc furnace with coke and silica. This yields calcium silicate slag and ferrophosphorus, which are tapped. Dusts are removed from the furnace offgases and phosphorus is removed from the dusts by condensation.	Andersen Filter Media	0.46	0.46	0.46	0.46	2			Y						N?	N?	N?
	Precipitator slurry	160	160	160	160	2			Y?						N?	Y	Y
	NOSAP slurry	160	160	160	160	2									N?	N?	Y
	Phossy Water	670	670	670	670	2			Y?						N?	Y	Y
	Furnace scrubber blowdown	410	410	410	410	2			Y						Y	N?	N?
	Furnace Building Washdown	700	700	700	700	2			Y						N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Fluorspar and Hydrofluoric Acid Raw fluorspar ore is crushed, ground, and concentrated. Acid grade fluorspar (a pure form of concentrate) is mixed with sulfuric acid in a heated retort kiln, reacting to produce hydrogen fluoride gas and fluorogypsum. The gas is cooled, scrubbed, and condensed, and sold as either hydrofluoric acid solution or anhydrous hydrogen fluoride.	Off-spec fluosilicic acid	NA	0	15	44	3									Y?	N?	N?
Germanium Germanium is recovered as a by-product of other metals, mostly copper, zinc, and lead. Germanium-bearing residues from zinc-ore processing facilities, a main source of germanium metal, are roasted and sintered. The sintering fumes, containing oxidized germanium, are leached with sulfuric acid to form a solution. Germanium is precipitated from the solution by adding zinc dust. Following precipitation, the germanium concentrates are refined by adding hydrochloric acid or chlorine gas to produce germanium tetrachloride, which is hydrolyzed to produce solid germanium dioxide. The final step involves reducing germanium dioxide with hydrogen to produce germanium metal.	Waste acid wash and rinse water	NA	0.4	2.2	4	4	Y?		Y?	Y?	Y?		Y?	Y?	Y?	N?	N?
	Chlorinator wet air pollution control sludge	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Hydrolysis filtrate	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Leach residues	0.01	0.01	0.01	0.01	3			Y?		Y?				N?	N?	N?
	Spent acid/leachate	NA	0.4	2.2	4	4	Y?				Y?				Y?	N?	N?
	Waste still liquor	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	Y?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Gold and Silver Gold and Silver may be recovered from either ore or the refining of base metals. Extracted ore is crushed or ground and then subjected to oxidation by roasting, autoclaving, bio-oxidation, or chlorination, and then cyanide leaching (heap, vat, or agitation). The metals are recovered by activated carbon loading or the Merrill Crowe process. Activated carbon loading involves bringing precious metal leach solutions into contact with activated carbon by the carbon-in-column, carbon-in-pulp, or carbon-in-leach process. Gold and silver are then separated by acid leaching or electrolysis. The Merrill Crowe process consistes of filtering and deaerating the leach solution and then precipitating the precious metals with zinc powder. The solids are filtered out, melted and cast into bars. The recovery of precious metals from lead refinery slimes is a normal part of the operation called "desilverizing." Lead from previous stages of refining is brought into contact with a zinc bath which absorbs the precious metals. Base metals are removed and the dore is sent to refining.	Slag	NA	0.1	360	720	16								Y?	N?	N?	N?
	Spent furnace dust	NA	0.1	360	720	16								Y?	Y?	N?	N?
Lead Lead ores are crushed, ground, and concentrated. Pelletized concentrates are then fed to a sinter unit with other materials (e.g., smelter byproducts, coke). The sintered material is then introduced into a blast furnace along with coke and fluxes. The resulting bullion is drossed to remove lead and other metal oxides. The lead bullion may also be decopperized before being sent to the refining stages. Refining operations generally consist of several steps, including (in sequence) softening, desilverizing, dezincing, bismuth removal and final refining. During final refining, lead bullion is mixed with various fluxes and reagents to remove remaining impurities.	Acid plant sludge	14	14	14	14	3									Y?	N?	N?
	Baghouse incinerator ash	NA	0.3	3	30	3			Y		Y				N?	N?	N?
	Slurried APC Dust	7	7	7	7	3			Y		Y				N?	N?	N?
	Solid residues	0.4	0.4	0.4	0.4	3					Y?				N?	N?	N?
	Spent furnace brick	1	1	1	1	3					Y				N?	N?	N?
	Stockpiled miscellaneous plant waste	NA	0.3	67	130	3			Y		Y				N?	N?	N?
	WWTP solids/sludges	380	380	380	380	3			Y?		Y?				Y	N?	N?
	WWTP liquid effluent	2600	2600	2600	2600	3					Y?				Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Magnesium and Magnesia from Brines Magnesium is recovered through two processes: (1) electrolytic and (2) thermal. In electrolytic production with hydrous feed, magnesium hydroxide is precipitated from seawater and settled out. The underflow is dewatered, washed, reslurried with wash water, and neutralized with HCL and H_2SO_4. The brine is filtered, purified, dried, and fed into the electrolytic cells. Alternatively, surface brine is pumped to solar evaporation ponds, where it is dried, concentrated, and purified. The resulting powder is melted, fed into the electrolytic cells, and then casted. The two thermal production processes for magnesium are the carbothermic process and the silicothermic process. In the carbothermic process, magnesium oxide is reduced with carbon to produce magnesium in the vapor phase, which is recovered by shock cooling. In the silicothermic process, silica is reacted with carbon to give silicon metal which is subsequently used to produce magnesium. Magnesia is produced by calcining magnesite or magnesium hydroxide or by the thermal decomposition of magnesium chloride, magnesium sulfate, magnesium sulfite, nesquehonite, or the basic carbonate.	Cast house dust	NA	0.076	0.76	7.6	1		Y?							N?	N?	N?
	Smut	26	26	26	26	2		Y							N?	N?	N?
Mercury Mercury currently is recovered only from gold ores. Sulfide-bearing gold ore is roasted, and the mercury is recovered from the exhaust gas. Oxide-based gold ore is crushed and mixed with water, and sent to a classifier, followed by a concentrator. The concentrate is sent to an agitator, where it is leached with cyanide. The slurry is filtered and the filtrate is sent to electrowinning, where the gold and mercury are deposited onto stainless steel wool cathodes. The cathodes are sent to a retort, where the mercury vaporizes with other impurities. The vapor is condensed to recover the mercury which is then purified.	Dust	0.007	0.007	0.007	0.007	7						Y?			N?	N?	N?
	Quench water	NA	63	77	420	7					Y?	Y?			N?	N?	N?
	Furnace residue	0.077	0.077	0.077	0.077	7						Y?			N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Molybdenum, Ferromolybdenum, and Ammonium Molybdate Production of molybdenum and molybdenum products, including ammonium molybdate, begins with roasting. Technical grade molybdic oxide is made by roasting concentrated ore. Pure molybdic oxide is produced from technical grade molybdic oxide either by sublimation and condensing, or by leaching. Ammonium molybdate is formed by reacting technical grade oxide with ammonium hydroxide and crystallizing out the pure molybdate. Molybdenum powder is formed using hydrogen to reduce ammonium molybdate or pure molybdic oxide. Ferromolybdenum is typically produced by reaction of technical grade molybdic oxide and iron oxide with a conventional metallothermic process using silicon and/or aluminum as the reductant.	Flue dust/gases	NA	1.1	250	500	11					Y?				N?	N?	N?
	Liquid residues	1	1	1	1	2	Y?		Y?		Y?		Y?		N?	N?	N?
Platinum Group Metals Platinum-group metals can be recovered from a variety of different sources, including electrolytic slimes from copper refineries and metal ores. The production of platinum-group metals from ore involves mining, concentrating, smelting, and refining. In the concentrating step, platinum ore is crushed and treated by froth flotation. The concentrates are dried, roasted, and fused in a smelter furnace, which results in the formation of platinum-containing sulfide matte. Solvent extraction is used to separate and purify the six platinum-group metals in the sulfide matte.	Slag	NA	0.0046	0.046	0.46	3					Y?		Y?		N?	N?	N?
	Spent acids	NA	0.3	1.7	3	3					Y?			Y?	Y?	N?	N?
	Spent solvents	NA	0.3	1.7	3	3					Y?			Y?	N?	Y?	N?
Rare Earths Rare earth elements are produced from monazite and bastnasite ores by sulfuric and hydrochloric acid digestion. Processing of rare earths involves fractional crystallization and precipitation followed by solvent extraction to separate individual rare earth elements from one another. Ion exchange or calcium reduction produces highly pure rare earths in small quantities. Electrolytic reduction of rare earth chlorides followed by crushing produces a complex alloy of rare earth metals commonly known as mischmetal.	Spent ammonium nitrate processing solution	14	14	14	14	1									Y	N?	N?
	Electrolytic cell caustic wet APC sludge	NA	0.07	0.7	7	1									Y?	N?	N?
	Process wastewater	7	7	7	7	1					Y				Y?	N?	N?
	Spent scrubber liquor	NA	0.1	500	1000	1									Y?	N?	N?
	Solvent extraction crud	NA	0.1	2.3	4.5	1									N?	Y?	N?
	Spent lead filter cake	NA	0.17	0.21	0.25	1					Y?				N?	N?	N?
	Waste solvent	NA	0.1	50	100	1									N?	Y?	N?
	Wastewater from caustic wet APC	NA	0.1	500	1000	1				Y?	Y?				Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Rhenium In general, rhenium is recovered from the off-gases produced when molybdenite, a byproduct of the processing of porphyry copper ores for molybdenum, is roasted. During the roasting process, molybdenite concentrates are converted to molybdic oxide and rhenium is converted to rhenium heptoxide. The rhenium oxides are sublimed and carried off with the roaster flue gas. Rhenium is then recovered from the off-gases by the following five steps: (1) scrubbing; (2) solvent extraction or ion exchange; (3) precipitation (addition of H_2S and HCl) and filtration; (4) oxidation and evaporation; and (5) reduction.	Spent barren scrubber liquor	NA	0	0.1	0.2	2							Y?		N?	N	N
	Spent rhenium raffinate	88	88	88	88	2					Y?				N?	N?	N?
Scandium Scandium is generally produced by small bench-scale batch processes. The principal domestic scandium resource is fluorite tailings containing thortveitite and associated scandium-enriched minerals. Scandium can be recovered from thortveitite using several methods. Each method involves a distinct initial step (i.e., acid digestion, grinding, or chlorination) followed by a set of common recovery steps, including leaching, precipitation, filtration, washing, and ignition at 900 C to form scandium oxide.	Spent acids	NA	0.7	3.9	7	7									Y?	N?	N?
	Spent solvents from solvent extraction	NA	0.7	3.9	7	7									N?	Y?	N?
Selenium The two principle processes for selenium recovery are smelting with soda ash and roasting with soda ash. Other methods include roasting with fluxes, during which the selenium is either volatilized as an oxide and recovered from the flue gas, or is incorporated in a soluble calcine that is subsequently leached for selenium. In some processes, the selenium is recovered both from the flue gas and from the calcine. To purify the crude selenium, it is dissolved in sodium sulfite and filtered to remove unwanted solids. The resulting filtrate is acidified with sulfuric acid to precipitate selenium. The selenium precipitate is distilled to drive off impurities.	Spent filter cake	NA	0.05	0.5	5	3							Y?		N?	N?	N?
	Plant process wastewater	66	66	66	66	2					Y				Y	N?	N?
	Slag	NA	0.05	0.5	5	3							Y?		N?	N?	N?
	Tellurium slime wastes	NA	0.05	0.5	5	3							Y?		N	N?	N?
	Waste solids	NA	0.05	0.5	5	3							Y?		N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Synthetic Rutile Synthetic rutile is manufactured through the upgrading of ilmenite ore to remove impurities (mostly iron) and yield a feedstock for production of titanium tetrachloride through the chloride process. The various processes developed can be organized in three categories: (1) processes in which the iron in the ilmenite ore is completely reduced to metal and separated either chemically or physically; (2) processes in which iron is reduced to the ferrous state and chemically leached from the ore; and (3) processes in which selective chlorination is used to remove the iron. In addition, a process called the Benelite Cyclic process uses hydrochloric acid to leach iron from reduced ilmenite.	Spent iron oxide slurry	45	45	45	45	1			Y?	Y?					N?	N?	N?
	APC dust/sludges	30	30	30	30	1			Y?	Y?					N?	N?	N?
	Spent acid solution	30	30	30	30	1			Y?	Y?					Y?	N?	N?
Tantalum, Columbium, and Ferrocolumbium Tantalum and columbium ores are processed by physically and chemically breaking down the ore to form columbium and tantalum salts or oxides, and separating the columbium and tantalum salts or oxides from one another. These salts or oxides may be sold, or further processed to reduce the salts to the respective metals. Ferrocolumbium is made by smelting the ore with iron, and can be sold as a product or further processed to produce tantalum and columbium products.	Digester sludge	1	1	1	1	2									Y?	N?	N?
	Process wastewater	150	150	150	150	2	Y?		Y?	Y?	Y?		Y?		Y	N?	N?
	Spent raffinate solids	2	2	2	2	2									Y?	N?	N?
Tellurium The process flow for the production of tellurium can be separated into two stages. The first stage involves the removal of copper from the copper slimes. The second stage involves the recovery of tellurium metal and purification of the recovered tellurium. Copper is generally removed from slimes by aeration in dilute sulfuric acid, oxidative pressure-leaching with sulfuric acid, or digestion with strong acid. Tellurous acid (in the form of precipitates) is then recovered by cementing, leaching the cement mud, and neutralizing with sulfuric acid. Tellurium is recovered from the precipitated tellurous acid by the following three methods: (1) direct reduction; (2) acid precipitation; and (3) electrolytic purification.	Slag	NA	0.2	2	9	2							Y?		N?	N?	N?
	Solid waste residues	NA	0.2	2	9	2							Y?		N?	N?	N?
	Waste electrolyte	NA	0.2	2	20	2					Y?		Y?		N?	N?	N?
	Wastewater	NA	0.2	20	40	2							Y?		Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Titanium and Titanium Dioxide Titanium ores are utilized in the production of four major titanium-based products: titanium dioxide (TiO_2) pigment, titanium tetrachloride ($TiCl_4$), titanium sponge, and titanium ingot/metal. The primary titanium ores for manufacture of these products are ilmenite and rutile. TiO_2 pigment is manufactured through either the sulfate, chloride, or chloride-ilmenite process. The sulfate process employs digestion of ilmenite ore or TiO_2-rich slag with sulfuric acid to produce a cake, which is purified and calcined to produce TiO_2 pigment. In the chloride process, rutile, synthetic rutile, or high-purity ilmenite is chlorinated to form $TiCl_4$, which is purified to form TiO_2 pigment. In the chloride-ilmenite process, a low-purity ilmenite is converted to $TiCl_4$ in a two-stage chlorination process. Titanium sponge is produced by purifying $TiCl_4$ generated by the chloride or chloride-ilmenite process. Titanium sponge is cast into ingots for further processing into titanium metal.	Pickle liquor and wash water	NA	2.2	2.7	3.2	3			Y?	Y?	Y?				Y?	N?	N?
	Scrap milling scrubber water	NA	4	5	6	1			Y?	Y?	Y?		Y?		N?	N?	N?
	Smut from Mg recovery	NA	0.1	22	45	2									N?	N?	Y
	Leach liquor and sponge wash water	NA	380	480	580	2				Y?	Y?				Y	N?	N?
	Spent surface impoundment liquids	NA	0.63	3.4	6.7	7				Y?	Y?				N?	N?	N?
	Spent surface impoundments solids	36	36	36	36	7				Y?	Y?				N?	N?	N?
	Waste acids (Sulfate process)	NA	0.2	39	77	2	Y			Y			Y	Y	Y	N	N
	Waste acids (Chloride process)	49	49	49	49	7				Y?	Y?		Y?		Y	N	N
	WWTP sludge/solids	420	420	420	420	7				Y?					N	N	N
Tungsten Tungsten production consists of four distinct stages: (1) ore preparation, (2) leaching, (3) purification to APT, and (4) reducing APT to metal. Ore preparation involves gravity and flotation methods. Concentration is usually accomplished by froth flotation, supplemented by leaching, roasting, or magnetic or high tension separation. The concentrate is then processed to APT via either sodium tungstate or tungstic acid (which was digested with aqueous ammonia) to solubilize the tungsten as ammonia tungstate. Further purification and processing yields APT. APT is converted to tungsten oxide by calcining in a rotary furnace. Tungsten oxides are reduced to metal powder in high temperature furnaces. Tungsten carbide is formed by reducing APT or tungsten oxides in the presence of carbon.	Spent acid and rinse water	NA	0	0	21	6									Y?	N?	N?
	Process wastewater	NA	2.2	4.4	9	6									Y?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Uranium Uranium ore is recovered using either conventional milling or solution mining (*in situ leaching*). Beneficiation of conventionally mined ores involves crushing and grinding the extracted ores followed by a leaching circuit. *In situ* operations use a leach solution to dissolve desirable uraniferous minerals from deposits in-place. Uranium in either case is removed from pregnant leach liquor and concentrated using solvent extraction or ion exchange and precipitated to form yellowcake. Yellowcake is then processed to produce uranium fluoride (UF_6), which is then enriched and further refined to produce the fuel rods used in nuclear reactors.	Waste nitric acid from UO2 production	NA	1.7	2.5	3.4	17									Y?	N?	N?
	Vaporizer condensate	NA	1.7	9.3	17	17									Y?	N?	N?
	Superheater condensate	NA	1.7	9.3	17	17									Y?	N?	N?
	Slag	NA	0	8.5	17	17									N?	Y?	N?
	Uranium chips from ingot production	NA	1.7	2.5	3.4	17									N?	Y?	N?
Zinc Zinc-bearing ores are crushed and undergo flotation to produce concentrates of 50 to 60% zinc. Zinc is then processed through either of two primary processing methods: electrolytic or pyrometallurgical. Electrolytic processing involves digestion with sulfuric acid and electrolytic refining. In pyrometallurgical processing, calcine is sintered and smelted in batch horizontal retorts, externally-heated continuous vertical retorts, or electrothermic furnaces. In addition, zinc is smelted in blast furnaces through the Imperial Smelting Furnace process, which is capable of recovering both zinc and lead from mixed zinc-lead concentrates.	Acid plant blowdown	130	130	130	130	1	Y		Y	Y	Y?	Y?	Y	Y	Y	N	N
	Waste ferrosilicon	17	17	17	17	1					Y?				N?	N?	N?
	Process wastewater	5000	5000	5000	5000	3	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Discarded refractory brick	1	1	1	1	1	Y?		Y?	Y?	Y?				N?	N?	N?
	Spent cloths, bags, and filters	0.15	0.15	0.15	0.15	3			Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent goethite and leach cake residues	15	15	15	15	3	Y		Y	Y	Y?	Y?	Y	Y	N?	N?	N?
	Spent surface impoundment liquids	1900	1900	1900	1900	3			Y?						Y	N?	N?
	WWTP Solids	0.75	0.75	0.75	0.75	3	Y?		Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent synthetic gypsum	16	16	16	16	3	Y?		Y		Y?				N?	N?	N?
	TCA tower blowdown	0.25	0.25	0.25	0.25	1			Y?		Y?	Y?	Y?		Y?	N?	N?
	Wastewater treatment plant liquid effluent	2600	2600	2600	2600	3			Y?						N?	N?	N?

EXHIBIT 1-2 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Zirconium and Hafnium The production processes used at primary zirconium and hafnium manufacturing plants depend largely on the raw material used. Six basic operations may be performed: (1) sand chlorination, (2) separation, (3) calcining, (4) pure chlorination, (5) reduction, and (6) purification. Plants that produce zirconium and hafnium from zircon sand use all six of these process steps. Plants which produce zirconium from zirconium dioxide employ reduction and purification steps only.	Spent acid leachate from Zr alloy prod.	NA	0	0	850	2									Y?	N?	N?
	Spent acid leachate from Zr metal prod.	NA	0	0	1600	2									Y?	N?	N?
	Leaching rinse water from Zr alloy prod.	NA	34	42	51	2									Y?	N?	N?
	Leaching rinse water from Zr metal prod.	NA	0.2	1000	2000	2									Y?	N?	N?

1/ Corr., Ignit., and Rctv. refer to the RCRA hazardous characteristics of corrosivity, ignitability, and reactivity.

C. SUMMARY OF FINDINGS

EPA has determined that 48 commodity sectors generate a total of 553 waste streams that could be classified as either extraction/beneficiation or mineral processing wastes. After careful review, EPA determined that 40 commodity sectors generate a total of 358 waste streams that could be classified as mineral processing wastes.

Of the 358 mineral processing waste streams identified by the Agency, EPA has sufficient information (based on either analytical test data or engineering judgment) to determine that 133 waste streams (from 30 commodity sectors) are possibly RCRA hazardous wastes because they exhibit one or more of the RCRA hazardous waste characteristics. Exhibit 1-3 identifies the mineral processing commodity sectors that are likely to generate RCRA hazardous mineral processing wastes and therefore are likely to be subject to the Land Disposal Restrictions. Exhibit 1-3 also summarizes the total number of hazardous waste streams by sector and the estimated total volume of hazardous wastes generated annually. At this time, however, EPA has insufficient information to determine whether the following sectors also generate wastes that could be classified as hazardous mineral processing wastes: Bromine, Gemstones, Iodine, Lithium, Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium.

EXHIBIT 1-3

IDENTIFICATION OF HAZARDOUS MINERAL PROCESSING WASTE STREAMS LIKELY SUBJECT TO THE LDRS

Mineral Processing Commodity Sectors	Number of Waste Streams 1/	Estimated Annual Generation Rate (1,000 mt/yr) (Rounded to the Nearest 2 Significant Figures)		
		Low Estimate	Medium Estimate	High Estimate
Alumina and Aluminum	2	77	77	77
Antimony	3	22	48	75
Beryllium	3	55	200	2,100
Bismuth	10	3.7	35	73
Cadmium	11	2.1	21	210
Calcium Metal	1	0.040	0.040	0.040
Chromium and Ferrochromium	2	3.0	3.3	6.0
Coal Gas	1	0	0	65
Copper	8	10,500	10,800	11,000
Elemental Phosphorus	6	2,100	2,100	2,100
Fluorspar and Hydrofluoric Acid	1	0	15	45
Germanium	6	0.84	5.0	9.2
Gold and Silver	2	0.2	720	1400
Lead	8	3,000	3,080	3,200
Magnesium and Magnesia from Brines	2	26	27	34
Mercury	3	63	77	420
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	2	2.1	250	500
Platinum Group Metals	3	0.45	3.5	6.5
Rare Earths	8	21	1,050	2,100

EXHIBIT 1-3 (Continued)

Mineral Processing Commodity Sectors	Number of Waste Streams 1/	Estimated Annual Generation Rate (1,000 mt/yr) (Rounded to the Nearest 2 Significant Figures)		
		Low Estimate	Medium Estimate	High Estimate
Rhenium	2	88	88	88
Scandium	2	1.4	7.8	14
Selenium	5	66	68	86
Synthetic Rutile	3	100	100	100
Tantalum, Columbium, and Ferrocolumbium	3	150	150	150
Tellurium	4	0.80	26	78
Titanium and Titanium Dioxide	9	890	1,050	1,250
Tungsten	2	2.2	4.4	30
Uranium	5	6.8	32	58
Zinc	11	9,800	9,800	9,800
Zirconium and Hafnium	4	34	1,000	4,500
TOTAL:	133	27,016	30,838	39,575

1/ In calculating the total number of waste streams per mineral sector, EPA included both non-wastewaters and wastewater mineral processing wastes and assumed that each of the hazardous mineral processing waste streams were generated in all three waste generation scenarios (low, medium, and high).

Exhibit 1-4 identifies those solid wastes from the processing of ores and minerals that are exempt from RCRA Subtitle C regulation (as defined in 40 CFR Part 261.4(b)(7).

EXHIBIT 1-4

1	Slag from primary copper processing
2	Slag from primary lead processing
3	Red and brown muds from bauxite refining
4	Phosphorgympsum from phosphoric acid production
5	Slag from elemental phosphorus production
6	Gasifier ash from coal gasification
7	Process wastewater from coal gasification

EXHIBIT 1-4 (continued)	
8	Calcium sulfate wastewater treatment plant sludge from primary copper processing
9	Slag tailings from primary copper processing
10	Fluorogypsum from hydrofluoric acid production
11	Process wastewater from hydrofluoric acid production
12	Air pollution control dust/sludge from iron blast furnaces
13	Iron blast furnace slag
14	Treated residue from roasting/leaching of chrome ore
15	Process wastwater from primary magnesium processing by the anhydrous process
16	Process wastewater fromphosphoric acid productions
17	Basic oxigen furnace and open hearth furnace air pollution control dust/sludge from carbon steel production
18	Basic oxygen furnace and open hear furnace slag from carbon steel production
19	Chloride proces waste solids from titanium tetrachloride production
20	Slag from primary zinc processing

D. Structure of the Document

The remainder of this document is organized into three additional sections. Section II discusses the data sources and methodology used to develop the mineral commodity reports and to identify waste streams potentially subject to RCRA Subtitle C. Section III presents the individual commodity summaries describing the uses of and salient statistics pertaining to the particular commodity, a process description section with detailed, current process information and process flow diagram(s), and waste streams generated by each process. Section IV summarizes the findings of this study.

E. Disclaimer

This document is intended solely to provide information to the public and the regulated community regarding the wastes that are potentially subject to the requirements of this rule. This information was also utilized by the Agency to assist in evaluating the potential impacts on the industry associated with complying with the rule. While the guidance contained in this document may assist the industry, public and federal and state regulators in applying statutory and regulatory requirements of RCRA, the guidance is not a substitute for those legal requirements; nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, States or the regulated community. Based on the circumstances, the conclusions in this document may not apply to a particular situation, and EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where determined to be appropriate based on the facts of the case and applicable statutes and regulations.

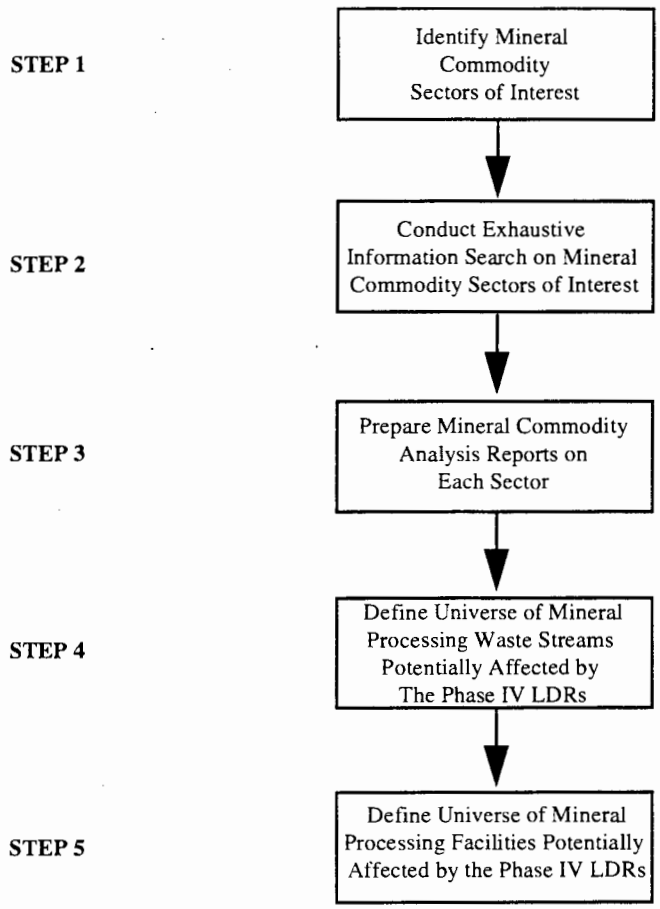
II. METHODS AND DATA SOURCES

This chapter details EPA's step-wise methodology for both defining the universe of mineral processing sectors, facilities, and waste streams potentially affected by the proposed Phase IV Land Disposal Restrictions and estimating the corresponding waste volumes.

The Agency developed a step-wise methodology that began with the broadest possible scope of inquiry to ensure that EPA captured all of the potentially affected mineral commodity sectors and waste streams. The Agency then narrowed the focus of its data gathering and analysis at each subsequent step. The specific steps and sources of data employed throughout this analysis are described below, and are summarized in Exhibit 2-1.

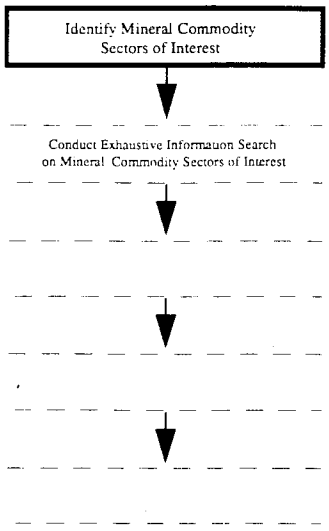
EXHIBIT 2-1

Overview of the Agency's Methodology for Defining the Universe of Potentially Affected Mineral Processing Waste Streams



A. Identify Mineral Commodity Sectors of Interest

Step One



EPA reviewed the 36 industrial sectors (commodities) and 97 different general categories of wastes previously developed and published in the October 21, 1991 Advanced Notice of Public Rule Making (ANPRM). EPA also reviewed the U.S. Bureau of Mines' 1991 Minerals Yearbook, 1995 Mineral Commodities Summary, and the 1985 Mineral Facts and Problems. The Agency reviewed this comprehensive listing of all of the mineral commodity sectors and removed from further consideration all non-domestically produced mineral commodities; all inactive mineral commodities, such as nickel; and all mineral commodities generated from operations known not to employ operations that meet the Agency's definition of mineral processing.[1] As a result of this process, EPA identified a total of 62 mineral commodities that potentially generate "mineral processing" waste streams of interest. These mineral commodity sectors are listed in Exhibit 2-2.

The Agency notes that Exhibit 2-2 represents EPA's best efforts at identifying mineral commodities that may generate mineral processing wastes. Omission or inclusion on this list does not relieve the generator of the responsibility of appropriately managing wastes that would be subject to RCRA Subtitle C requirements.

B. Conduct Exhaustive Information Search

EPA researched and obtained information characterizing the mineral processing operations and wastes associated with the mineral commodities listed in Exhibit 2-2. This information was used by EPA both to update existing data characterizing mineral processing wastes obtained through past Agency efforts and to obtain characterization information on newly identified waste streams not previously researched.

To provide the necessary foundation to develop a fully comprehensive inventory of mineral commodity sectors, facilities, and waste streams that might be affected by the Phase IV LDRs program, EPA embarked on an ambitious information collection program. Specifically, to capitalize on information collected through past efforts, as well as to collect more recent data, the Agency conducted the following activities:

- Reviewed mineral processing survey instruments (NSSWMPF) and public comments (submitted in response to the 1991 ANPRM) for process-related information (e.g., process flow diagrams, waste characterization data, and waste management information) contained in our in-house files.

- Reviewed numerous documents (e.g., Bureau of Mines publications, the Randol Mining Directory and other Industrial Directories, and various Agency contractor reports) for process-related information.

- Reviewed trip reports prepared both by EPA and its contractors from sampling visits and/or inspections conducted at approximately 50 mineral processing sites located throughout the United States.

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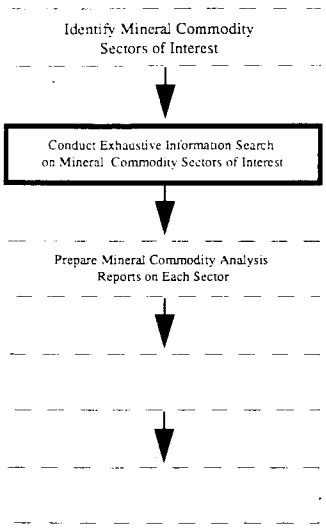
[1] Sectors that employ operations that mill (e.g., grind, sort, wash), physically separate (e.g., magnetic, gravity, or electrostatic separation, froth flotation), concentrate using liquid separation (e.g., leaching followed by ion exchange), and/or calcine (i.e., heat to drive off water or carbon dioxide), and use no techniques that the Agency considers to be mineral processing operations (e.g., smelting or acid digestion) are unaffected by the Phase IV LDRs.

EXHIBIT 2-2

MINERAL COMMODITIES OF POTENTIAL INTEREST

1)	Alumina	32)	Lightweight Aggregate
2)	Aluminum	33)	Lithium (from ores)
3)	Ammonium Molybdate	34)	Lithium Carbonate
4)	Antimony	35)	Magnesia (from brines)
5)	Arsenic Acid	36)	Magnesium
6)	Asphalt (natural)	37)	Manganese and MnO_2
7)	Beryllium	38)	Mercury
8)	Bismuth	39)	Mineral Waxes
9)	Boron	40)	Molybdenum
10)	Bromine (from brines)	41)	Phosphoric Acid
11)	Cadmium	42)	Platinum Group Metals
12)	Calcium Metal	43)	Pyrobitumens
13)	Cerium, Lanthanides, and Rare Earths	44)	Rhenium
14)	Cesium/Rubidium	45)	Scandium
15)	Chromium	46)	Selenium
16)	Coal Gas	47)	Silicomanganese
17)	Copper	48)	Silicon
18)	Elemental Phosphorus	49)	Soda Ash
19)	Ferrochrome	50)	Sodium Sulfate
20)	Ferrochrome-Silicon	51)	Strontium
21)	Ferrocolumbium	52)	Sulfur
22)	Ferromanganese	53)	Synthetic Rutile
23)	Ferromolybdenum	54)	Tantalum/Columbium
24)	Ferrosilicon	55)	Tellurium
25)	Gemstones	56)	Tin
26)	Germanium	57)	Titanium/TiO_2
27)	Gold and Silver	58)	Tungsten
28)	Hydrofluoric Acid	59)	Uranium
29)	Iodine (from brines)	60)	Vanadium
30)	Iron and Steel	61)	Zinc
31)	Lead	62)	Zirconium/Hafnium

Step Two



- Reviewed sampling data collected by EPA's Office of Research and Development (ORD), EPA's Office of Water (OW), and Agency survey data collected to support the preparation of the 1990 Report to Congress.

- Reviewed the 1993, 1994, and 1995 "Mineral Commodity Summaries" prepared by the U.S. Bureau of Mines (BOM) for salient statistics on commodity production.

- Partially reviewed and summarized damage case information presented in the "Mining Sites on the National Priorities List, NPL Site Summary Reports" to support work on assessing the appropriateness of the Toxicity Characteristic Leaching Procedure (TCLP) for mineral processing wastes.

- Contacted the BOM Commodity Specialists associated with the commodity sectors of interest to (1) obtain current information on mining companies, processes, and waste streams, and (2) identify other potential sources of information.

- Retrieved applicable and relevant documents from the BOM's FAXBACK document retrieval system. Documents retrieved included monthly updates to salient statistics, bulletins, and technology review papers.

- Conducted an electronic query of the 1991 Biennial Reporting System (BRS) for waste generation and management information on 34 mineral processing-related Standard Industrial Classification (SIC) numbers.

- Conducted an electronic literature search for information related to mineral processing and waste treatment technologies contained in numerous technical on-line databases, including: NTIS, Compendex Plus, METADEX, Aluminum Industry Abstracts, ENVIROLINE, Pollution Abstracts, Environmental Bibliography, and GEOREF.

B.1 Review of Hard Copy Reports, Comments, and Survey Instruments

Using the information obtained from our in-house files and the various BOM and contractor documents, EPA was able to find process flow diagrams for the following 27 commodities:

- Alumina
- Aluminum
- Antimony
- Bismuth
- Cerium/Lanthanides/Rare Earth Metals
- Cesium/Rubidium
- Coal Gas
- Copper
- Elemental Phosphorus
- Germanium
- Gold and Silver
- Hydrofluoric Acid
- Iron and Steel
- Lead
- Lightweight Aggregate
- Magnesium
- Mercury
- Molybdenum
- Phosphoric Acid
- Rhenium
- Scandium
- Soda Ash
- Synthetic Rutile
- Titanium/TiO_2
- Tungsten
- Uranium
- Zinc

EPA also found either less detailed or fewer (in number) process flow diagrams for all of the remaining mineral commodities except:

- Ammonium Molybdate
- Asphalt (natural)
- Ferrocolumbium
- Ferromolybdenum
- Ferrosilicon
- Gemstones
- Mineral Waxes
- Pyrobitumens
- Silicomanganese

EPA has been unable to locate any process information for the above nine commodities. All of the process-related information that we retrieved was then photocopied and filed by commodity.

B.2 Electronic Literature Search

EPA devised a search strategy and performed an electronic literature search for journal articles, conference reports, technical reports and bulletins, books, doctoral dissertations, patents, and news articles containing information related to the production of mineral commodities, and the characterization and treatment of mineral processing wastes. We searched the on-line databases summarized below in Exhibit 2-3.

Using the on-line databases summarized in Exhibit 2-3, we searched for relevant information (published since 1990) on the mineral commodities listed in Exhibit 2-2 using the keywords presented in Exhibit 2-4. We chose 1990 as the cutoff year so as not to duplicate past information collection activities conducted by EPA and EPA contractors, and to obtain information on mineral processes "retooled" since clarification of the Bevill Exclusion to address truly "high volume, low hazard" mineral processing wastes.

Accordingly, using the strategy outlined in Exhibit 2-4, an article would have been selected if anywhere in either the title, record descriptors, or full text, one of the mineral commodities listed in Exhibit 2-2 and the keywords (waste, residue, wastewater, sludge, slag, dust, or blowdown) with one or more modifiers was found. For example, if a particular record had the industrial sector - "alumina" or "aluminum" <u>and</u> the keyword - "waste" <u>and</u> the modifier - "characteristics", the database record would have been selected. Unfortunately, this search strategy proved to be too expansive; the first search for information on alumina and aluminum turned up over 3,000 citations. We therefore elected to modify the search strategy by requiring the commodity, keyword, and modifier to be present in either the title or record descriptor (and not in the full text). This modification allowed for a more manageable number of citations -- 1,242 titles.

To conserve resources, we first reviewed the results of the literature search output which contained the full title of the selected record to see if the article seemed promising. If, based on our review of the title the record appeared promising, we then requested the full abstract. We then reviewed the full abstract to further screen the appropriateness of the record. If the abstract appeared relevant, we then ordered the document. Using the alumina/aluminum example, we reviewed the 1,242 title citations and determined that it was necessary to request full abstracts for 333 of the title citations. Using this protocol, we identified a total of 10,298 citations relating to one or more of the commodities listed in Exhibit 2-2. We then reviewed the title citations and requested a total of 1,776 full abstracts. Lastly, based on our review of the abstracts, we requested a total of 863 documents (using a tracking system to ensure that a selected reference material was not requested more than once). The top five industrial sectors that appear to be the most studied (based on number of citations meeting our search strategy specifications) are the following:

- Iron and Steel (1,460 titles);
- Alumina/Aluminum (1,242 titles);
- Copper (1,081 titles);
- Chromium (833 titles); and
- Lead (800 titles).

EXHIBIT 2-3

SUMMARY OF ON-LINE DATABASES SEARCHED

Databases	Description	Subjects Covered	Sources
NTIS Dates Covered 1964 to the present. File Size 1,639,906 records as of 1/93. Update Frequency Biweekly.	The NTIS database consists of government-sponsored research, development, and engineering plus analyses prepared by federal agencies, their contractors, or grantees. It is the means through which unclassified, publicly available, unlimited distribution reports are made available for sale from agencies such as NASA, DDC, DOE, EPA, HUD, DOT, Department of Commerce, and some 240 other agencies. In addition, some state and local government agencies now contribute their reports to the database. Truly multi-disciplinary, this database covers a wide spectrum of subjects including: administration and management, agriculture and food, behavior and society, building, business and economics, chemistry, civil engineering, energy, health planning, library and information science, materials science, medicine and biology, military science, transportation, and much more.	Administration and Management -- Aeronautics and Aerodynamics -- Agriculture and Food -- Astronomy and Astrophysics -- Atmospheric Sciences -- Behavior and Society -- Biomedical Technology and Engineering -- Building Industry Technology -- Business and Economics -- Chemistry -- Civil Engineering -- Communication -- Computers, Control, and Information Theory -- Electrotechnology -- Energy -- Environmental Pollution and Control -- Health Planning -- Industrial and Mechanical Engineering -- Library and Information Sciences -- Materials Sciences -- Mathematical Sciences -- Medicine and Biology -- Military Sciences -- Missile Technology -- Natural Resources and Earth Sciences -- Navigation, Guidance, and Control -- Nuclear Science and Technology -- Ocean Technology and Engineering -- Photography and Recording Devices -- Physics -- Propulsion and Fuels -- Space Technology -- Transportation -- Urban and Regional Technology.	The NTIS database represents the reports of four major U.S. federal government agencies: U.S. Department of Energy (DOE), U.S. Department of Defense (DoD), U.S. Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), plus many other agencies.
COMPENDEX PLUS Dates Covered 1970 to the present. File Size 3,015,116 records as of 1/93. Update Frequency Weekly.	The COMPENDEX PLUS database is the machine-readable version of the Engineering Index (monthly/annual), which provides abstracted information from the world's significant engineering and technological literature. The COMPENDEX database provides worldwide coverage of approximately 4,500 journals and selected government reports and books. Subjects covered include: civil, energy, environmental, geological, and biological engineering; electrical, electronics, and control engineering; chemical, mining, metals, and fuel engineering; mechanical, automotive, nuclear, and aerospace engineering; and computers, robotics, and industrial robots. In addition to journal literature, over 480,000 records of significant published proceedings of engineering and technical conferences formerly indexed in Ei ENGINEERING MEETINGS are included.	Aeronautical and Aerospace Engineering -- Applied Physics (High Energy, Plasma, Nuclear and Solid State) -- Bioengineering and Medical Equipment -- Chemical Engineering, Ceramics, Plastics and Polymers, Food Technology -- Civil and Structural Engineering, Environmental Technology -- Electrical, Instrumentation, Control Engineering, Power Engineering -- Electronics, Computers, Communications -- Energy Technology and Petroleum Engineering -- Engineering Management and Industrial Engineering -- Light and Optical Technology -- Marine Engineering, Naval Architecture, Ocean and Underwater Technology -- Mechanical Engineering, Automotive Engineering and Transportation -- Mining and Metallurgical Engineering, and Materials Science.	Publications from around the world are indexed, including approximately 4,500 journals, publications of engineering societies and organizations, approximately 2,000 conferences per year, technical reports, and monographs.

EXHIBIT 2-3 (Continued)

SUMMARY OF ON-LINE DATABASES SEARCHED

Databases	Description	Subjects Covered	Sources
METADEX Dates Covered 1966 to the present. File Size 911,907 records as of 1/93. Update Frequency Monthly.	The METADEX (Metals Abstracts/Alloys Index) database, produced by Materials Information of ASM International and the Institute of Metals, provides comprehensive coverage of international metals literature. The database corresponds to the printed publications: Review of Metal Literature (1966-1967), Metals Abstracts (1968 to the present), Alloys Index (1974 to the present), Steels Supplement (1983-1984), and Steels Alert (January - June 1985). The Metals Abstracts portion of the file includes references to about 1,200 primary journal sources. Alloys Index supplements Metals Abstracts by providing access to the records through commercial, numerical, and compositional alloy designations; specific metallic systems; and intermetallic compounds found within these systems.	Materials -- Processes -- Properties -- Products -- Forms -- Influencing Factors.	Each month over 3,000 new documents from a variety of international sources are scanned and abstracted for the ASM database, with intensive coverage of appropriate journals, conference papers, reviews, technical reports, and books. Dissertations, U.S. patents, and government reports have been included since 1979, British (GB) patents since 1982, and European (EP) patents since 1986.
ALUMINUM INDUSTRY ABSTRACTS Dates Covered 1968 to the present. File Size 172,000 records as of 7/93. Update Frequency Monthly.	ALUMINUM INDUSTRY ABSTRACTS (AIA), formerly World Aluminum Abstracts (WAA), provides coverage of the world's technical literature on aluminum, ranging from ore processing through applications. The AIA database includes information abstracted from approximately 2,300 scientific and technical journals, government reports, conference proceedings, dissertations, books, and patents. All aspects of the aluminum industry, aside from mining, are covered.	Aluminum Industry - General -- Ores, Extraction of Alumina and Aluminum -- Melting, Casting, and Foundry -- Physical and Mechanical Metallurgy -- Business Information -- Extractive Metallurgy -- Metalworking, Fabrication, and Finishing -- Engineering Properties and Tests -- Quality Control and Tests -- End Uses of Aluminum -- Aluminum Intermetallics -- Patents.	The AIA database includes information abstracted from approximately 2,300 scientific and technical journals, patents, government reports, conference proceedings, dissertations, books, and other publications.
ENVIROLINE Dates Covered January 1, 1971 to the present. File Size 165,000 records as of 10/93. Update Frequency Monthly.	ENVIROLINE covers the world's environmental related information. It provides indexing and abstracting coverage of more than 1,000 international primary and secondary publications reporting on all aspects of the environment. These publications highlight such fields as management, technology, planning, law, political science, economics, geology, biology, and chemistry as they relate to environmental issues.	Air Pollution -- Environmental Design & Urban Ecology -- Energy -- Environmental Education -- Food and Drugs -- General Environmental Topics -- International Environmental Topics -- Land Use & Pollution -- Noise Pollution -- Non-Renewable Resources -- Oceans and Estuaries -- Population Planning & Control -- Radiological Contamination -- Renewable Resources -- Terrestrial -- Water -- Toxicology & Environmental Safety -- Transportation -- Waste Management -- Water Pollution -- Weather Modification & Geophysical Change -- Wildlife.	ENVIROLINE draws material from over 1,000 scientific, technical, trade, professional, and general periodicals; conference papers and proceedings; government documents; industry reports; newspapers; and project reports.

EXHIBIT 2-3 (Continued)

SUMMARY OF ON-LINE DATABASES SEARCHED

Databases	Description	Subjects Covered	Sources
POLLUTION ABSTRACTS Dates Covered 1970 to the present. File Size 185,551 records as of 1/93. Update Frequency Bimonthly.	POLLUTION ABSTRACTS is a leading resource for references to environmentally related literature on pollution, its sources, and its control.	Air Pollution -- Environmental Action -- Freshwater Pollution -- Land Pollution -- Marine Pollution -- Noise -- Radiation -- Sewage and Wastewater Treatment -- Toxicology and Health -- Waste Management.	References in POLLUTION ABSTRACTS are drawn from approximately 2,500 primary sources from around the world, including books, conference papers/proceedings, periodicals, research papers, and technical reports.
ENVIRONMENTAL BIBLIOGRAPHY Dates Covered 1973 to the present. File Size 451,702 records as of 1/93. Update Frequency Bimonthly (4,000 records per update).	ENVIRONMENTAL BIBLIOGRAPHY provides access to the contents of periodicals dealing with the environment. Coverage includes periodicals on water, air, soil, and noise pollution, solid waste management, health hazards, urban planning, global warming, and many other specialized subjects of environmental consequence.	Air -- Energy -- Human and Animal Ecology -- Land Resources -- Nutrition and Health -- Water Resources.	More than 400 of the world's journals concerning the environment are scanned to create ENVIRONMENTAL BIBLIOGRAPHY.

EXHIBIT 2-3 (Continued)

SUMMARY OF ON-LINE DATABASES SEARCHED

Databases	Description	Subjects Covered	Sources
GEOREF Dates Covered 1785 to the present (North American material). 1933 to the present (worldwide material). File Size 1,818,777 records as of 1/93. Update Frequency Monthly (approximately 6,700 records per update).	GEOREF, the database of the American Geological Institute (AGI), covers worldwide technical literature on geology and geophysics. GEOREF corresponds to the print publications Bibliography and Index of North American Geology, Bibliography of Theses in Geology, Geophysical Abstracts, Bibliography and Index of Geology Exclusive of North America, and the Bibliography and Index of Geology. GEOREF organizes and indexes papers from over 3,500 serials and other publications representative of the interests of the twenty professional geological and earth science societies that are members of the AGI.	Areal Geology -- Economic Geology -- Energy Sources -- Engineering Geology -- Environmental Geology -- Extraterrestrial Geology -- Geochemistry -- Geochronology -- Geomorphology -- Geophysics -- Hydrology -- Marine Geology -- Mathematical Geology -- Mineralogy -- Mining Geology -- Paleontology -- Petrology -- Seismology -- Stratigraphy -- Structural Geology -- Surficial Geology.	GEOREF is international in coverage with about 40 percent of the indexed publications originating in the United States and the remainder from outside the U.S. Publications of international organizations represent about 7 percent of the file. The database includes coverage of over 3,500 journals as well as books and book chapters, conference papers, government publications, theses, dissertations, reports, maps, and meeting papers.
MATERIALS BUSINESS FILE Dates Covered 1985 to the present. File Size 83,228 records as of 1/93. Update Frequency Monthly.	MATERIALS BUSINESS FILE covers technical and commercial developments in iron and steel, nonferrous metals, composites, plastics, etc. Over 1,300 publications including magazines, trade publications, financial reports, dissertations, and conference proceedings are reviewed for inclusion. Subjects covered are grouped into nine categories: 1) Fuel, Energy Usage, Raw Materials, Recycling; 2) Plant Developments and Descriptions; 3) Engineering, Control and Testing, Machinery; 4) Environmental Issues, Waste Treatment, Health and Safety; 5) Product and Process Development; 6) Applications, Competitive Materials, Substitution; 7) Management, Training, Regulations, Marketing; 8) Economics, Statistics, Resources, and Reserves; and 9) World Industry News, Company Information, and General Issues.	Fuel, Energy Usage, Raw Materials, Recycling -- Plant Developments and Descriptions -- Environmental Issues, Waste Treatment, Health and Safety -- Product and Process Development -- Applications, Competitive Materials, Substitution -- Management, Training, Regulations, Marketing -- Economics, Statistics, Resources, and Reserves -- World Industry News, Company Information, and General Issues.	Each month over 1,300 magazines, trade publications, journals, financial reports, dissertations, and conference proceedings are reviewed and abstracted from worldwide sources.

EXHIBIT 2-4

KEYWORDS AND SEARCH STRATEGY

		Keywords		Modifiers
Industrial Sector	with	Waste -- or -- Residue -- or -- Wastewater -- or -- Sludge -- or -- Slag -- or -- Dust -- or -- Blowdown	with	Characteristics -- or -- Composition -- or -- Properties -- or -- Recovery -- or -- Recycling -- or -- Reduction -- or -- Generation -- or -- Management -- or -- Treatment

Finally, as part of the electronic literature search, we queried the Chemical Economics Handbook (CEH) database prepared by SRI International and last updated in February 1994. Due to the high cost of using the database (i.e., $85 per record -- each chemical is divided into numerous records -- and $3 per minute of on-line time), we only attempted to retrieve information on the following ten commodities for which published information is extremely limited or absent:

- Arsenic Acid
- Asphalt (natural)
- Ferroalloys (all of them)
- Manganese
- Pyrobitumens
- Rare Earths
- Rubidium
- Tantalum/Columbium
- Waxes (mineral)
- Zirconium/Hafnium

Limited process information was available only for ferroalloys, manganese, rare earths, waxes (natural), and zirconium/hafnium.

B.3 Contacts with Bureau of Mines

EPA contacted commodity experts at the U.S. Bureau of Mines in an attempt to collect up-to-date information on the names and locations of the facilities within each mineral sector. We also attempted to obtain process and waste characterization information; however, only a limited number of commodity specialists were able to provide such technical information. We present below in Exhibit 2-5, a listing of the Bureau of Mines personnel contacted by EPA.

EXHIBIT 2-5

LIST OF PERSONAL COMMUNICATIONS

Contacts	Telephone Nos.	Commodity Sectors
John Blossom	202-501-9435	Molybdenum Rhenium
Larry Cunningham	202-501-9443	Columbium (niobium) Tantalum
Joseph Gambogi	202-501-9390	Zirconium/Hafnium
James Hedrick	202-501-9412	Cerium Lanthanides Rare Earths Scandium
Henry Hillard	202-501-9429	Vanadium
Steve Jasinski	202-501-9418	Mercury Selenium Tellurium
Thomas Jones	202-501-9428	Manganese
Deborah Kramer	202-501-9394	Beryllium
Peter Kuck	202-501-9436	Cadmium
Roger Loebenstein	202-501-9416	Arsenic Acid Platinum Group Metals
John Lucas	202-501-9417	Gold
Phyllis Lyday	202-501-9405	Bromine Iodine
McCaulin	202-501-9426	Antimony
Dave Morris	202-501-9402	Elemental Phosphorus Phosphoric Acid
Joyce Ober	202-501-9406	Lithium
John Papp	202-501-9438	Chromium Ferrochrome Ferrochrome-silicon
Robert Reese	202-501-9413	Cesium Rubidium Silver
Erol Sehnke	202-501-9421	Alumina Aluminum Germanium
Gerald Smith	202-501-9431	Tungsten

B.4 Review of Outside Data/Reports

In light of both the significant changes in the regulatory status of many of these wastes and the passing of several years since the 1991 ANPRM was published, EPA also reviewed several additional information sources:

- Sampling Data from EPA's Office of Research and Development
- Data from the Effluent Guidelines from the Office of Water
- Survey Data contained in the 1990 Report to Congress
- Publications from the Bureau of Mines, Randol Mining Directory, and other Industrial Directories and Sources
- Files available form the Waste Treatment Branch and the Special Wastes Branch in OSW
- Industry Profiles
- Comments and Information received through the 1991 ANPRM

to (1) determine which industrial commodities and waste streams are still generated today and (2) identify new commodities and/or waste streams that should be added to the existing universe.

EPA also queried the 1991 Biennial Reporting System (BRS) for waste generation and management information on 34 mineral processing-related Standard Industrial Classification (SIC) numbers. Specific information requested included:

- RCRA Facility Identification No.
- Location (City & State)
- Source Code
- Waste Volume
- EPA Hazardous Waste ID No.(s)
- Facility Name
- Origin Code
- Form Code
- On-site/Off-site Management

As shown in Exhibit 2-6, the 1991 BRS contained data for 24 of the 34 mineral processing-related SIC numbers (71 percent). We note that several of these SICs encompass a wide variety of mineral/inorganic chemical products. For example, SIC 2819 represents "Industrial Inorganic Chemicals, Not Elsewhere Classified," which includes more than 170 products ranging from activated carbon, alkali metals, and alumina to tin salts, water glass, and zinc chloride. Although some of these materials are outside the scope of primary mineral processing, there was no effective way to screen these products from the BRS search.

Also shown in Exhibit 2-6 is the relative ranking of the quantity of available information contained in the BRS (1 being the greatest and 24 being the smallest). The top five SIC number categories are:

- SIC 2819 - Industrial Inorganic Chemicals, Not Elsewhere Classified;
- SIC 3312 - Blast Furnaces (including Coke Ovens), Steel Works, and Rolling Mills;
- SIC 3334 - Primary Smelting and Refining of Aluminum;
- SIC 2812 - Alkalies and Chlorine; and
- SIC 3339 - Primary Smelting and Refining of Nonferrous Metals, Not Elsewhere Classified.

EXHIBIT 2-6

SUMMARY OF SIC CODES SEARCHED IN THE 1991 BRS

SIC Code	INDUSTRIAL COMMODITY SECTOR	REPORTED IN 1991 BRS	RANK IN BRS
1011	Iron Ores	Yes	8
1021	Copper Ores	Yes	7
1031	Lead and Zinc Ores	Yes	19
1041	Gold Ores	Yes	9
1044	Silver Ores	Yes	17
1051	Bauxite and Other Aluminum Ores	No	-
1061	Ferroalloy Ores, Except Vanadium	Yes	22
1092	Mercury Ores	No	-
1094	Uranium-Radium-Vanadium Ores	Yes	21
1099	Metal Ores Not Elsewhere Classified	Yes	16
1446	Industrial Sand	Yes	20
1452	Bentonite	No	-
1453	Fire Clay	No	-
1455	Kaolin and Ball Clay	No	-
1459	Clay, Ceramic, and Refractory Minerals, Not Elsewhere Classified	No	-
1472	Barite	Yes	15
1473	Fluorspar	No	-
1474	Potash, Soda, and Borate Minerals	Yes	23
1475	Phosphate Rock	Yes	14
1477	Sulfur	No	-
1479	Chemical and Fertilizer Mineral Mining, Not Elsewhere Classified	Yes	24
1499	Miscellaneous Nonmetallic Minerals, Not Elsewhere Classified	Yes	10
2812	Alkalies and Chlorine	Yes	4
2819	Industrial Inorganic Chemicals, Not Elsewhere Classified	Yes	1
2874	Phosphatic Fertilizers	Yes	12
3274	Lime	Yes	18
3295	Minerals and Earths, Ground or Otherwise Treated	Yes	13
3312	Blast Furnaces (Including Coke Ovens), Steel Works, and Rolling Mills	Yes	2

EXHIBIT 2-6 (Continued)

SUMMARY OF SIC CODES SEARCHED IN THE 1991 BRS

SIC Code	INDUSTRIAL COMMODITY SECTOR	REPORTED IN 1991 BRS	RANK IN BRS
3313	Electrometallurgical Products	Yes	6
3331	Primary Smelting and Refining of Copper	Yes	11
3332	Primary Smelting and Refining of Lead	No	-
3333	Primary Smelting and Refining of Zinc	No	-
3334	Primary Smelting and Refining of Aluminum	Yes	3
3339	Primary Smelting and Refining of Nonferrous Metals, Not Elsewhere Classified	Yes	5

It is not surprising that the above SIC number categories comprise the top five because these industries are (1) known to generate listed hazardous wastes such as K061, K062, K064, K065, K066, K071, K088, K090, K091, and K106, and (2) are SICs that encompass a wide variety of mineral/inorganic chemical products. The lack of information for the other mineral processing related wastes may be explained by the age of the data evaluated. Specifically, the most recent data available at the time of the original analysis were from the 1991 Biennial Reports. Thus, at that time many of the respondents (and potential respondents) might not yet have been required to manage their mineral processing-derived wastes as if they were no longer considered "high volume, low toxicity wastes."

Although EPA did not perform an exhaustive review and analysis of the BRS reports, it appears as though the bulk of the records contained in the BRS appear to be related to non-mineral processing activities (e.g., painting wastes, laboratory wastes, used oil, discarded chemicals, and cleaning/degreasing wastes). The BRS does, however, contain limited information on production-derived wastes, product filtering wastes, spent process liquids, routine cleaning wastes, and wastes from rinsing operations (flushing, dipping, and spraying). The typical types of wastes include:

- Halogenated and non-halogenated solvents;
- Thinners and petroleum distillates;
- Other halogenated and non-halogenated organic solids;
- Asbestos solids and debris;
- Caustics with inorganics and cyanide;
- Caustics with inorganics;
- Reactive sulfide and salts;
- Other inorganic sludges;
- Air pollution control wastes;
- Solvent extraction wastes; and
- Spent acids.

Much of the information reported is for listed hazardous wastes. For example, within the SIC 3312 classification, the following EPA Hazardous Waste Identification Numbers were used at least once (but not at every facility):

D001	D028	F008	P119
D002	D029	F012	U002
D003	D030	K060	U012
D004	D032	K061	U019
D005	D034	K062	U044
D006	D035	K087	U080
D007	D036	P010	U144
D008	D038	P012	U154

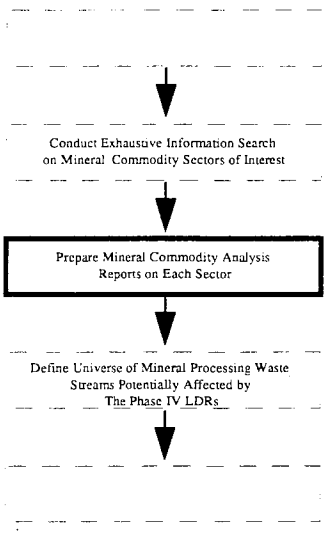
D009	D039	P022	U159
D010	D040	P029	U161
D011	F001	P030	U196
D018	F002	P039	U201
D019	F003	P048	U210
D021	F004	P098	U211
D022	F005	P104	U218
D026	F006	P105	U220
D027	F007	P106	U239

Lastly, although we did not perform a rigorous analysis, it seems that most of the reported wastes were managed off-site. Treatment/disposal options for wastes that were reportedly managed on-site included wastewater treatment, discharge to a publicly owned treatment works (POTW), incineration, deep-well injection, stabilization and land disposal, and materials (e.g., metals) recovery.

After an exhaustive search through both the publicly available and Agency-held information sources, EPA assembled and organized all of the collected information by mineral commodity sector.

C. Prepare Mineral Commodity Analysis Reports

Step Three



As discussed above, EPA embarked on its information collection program to collect current information on relevant mineral processes, salient statistics, waste characteristics, waste generation rates, and waste management information. All of the publicly available information was collected, evaluated for relevance (both applicability and age), and compiled to prepare 49 analyses covering 62 mineral commodities. Each mineral commodity analysis report consists of three major sections:

- A commodity summary describing the uses and salient statistics of the particular mineral commodity or commodities.
- A process description section with detailed, current process information and process flow diagram(s).
- A process waste stream section that identifies -- to the maximum extent practicable -- individual waste streams, sorted by the nature of the operation (i.e., extraction/beneficiation or mineral processing).[2] Within this section, EPA also identified:

  - waste stream sources and form (i.e., wastewater (<1 percent solids and total organic content), 1-10 percent solids, and >10% solids);
  - Bevill Exclusion status of the waste stream (i.e., extraction/beneficiation waste stream, mineral processing waste stream, or non-uniquely associated waste stream);
  - waste stream characteristics (total constituent concentration data, and statements on whether the waste stream does or is likely to exhibit one of the RCRA hazardous waste characteristics of toxicity, ignitability, corrosivity, or reactivity);
  - annual generation rates (reported or estimated);

[2] EPA strongly cautions that the process information and identified waste streams presented in the commodity sector reports should not be construed to be an authoritative list of processes and waste streams. These reports represent a best effort, and may not include every potential process and waste stream. Furthermore, the omission of an actual waste stream (and thus its not being classified as either an extraction/beneficiation or mineral processing waste in this report) does not relieve the generator from its responsibility of correctly determining whether the particular waste is covered by the Mining Waste Exclusion.

- management practices (e.g., tank treatment and subsequent NPDES discharge, land disposal, or in-process recycling); and

- whether the waste stream was being (or could potentially be) recycled, and thus be classified as either as a sludge, by-product, or spent material.

The collection and documentation of the commodity summary and process description sections of the mineral commodity analysis reports was relatively straightforward and involved little interpretation on the part of EPA. However, the preparation of the process waste stream sections of the mineral commodity analysis reports required extensive analysis and substantive interpretation of the publicly available information by the Agency. The process used by EPA to develop descriptions of waste stream sources, form, characteristics, management, and recyclability is described below.

C.1 Bevill-Exclusion Status

Determining the Special Waste Status of Mineral Industry Wastes

EPA used the Agency's established definitions and techniques for determining which operations and waste streams might be subject to LDR standards. EPA decisions concerning whether individual wastes are within the scope of the RCRA Mining Waste Exclusion are based upon a number of different factors. The Agency examines these factors in sequence, in such a way as to yield unambiguous and consistent decisions from site to site and across all regions of the country. The basic thought process is illustrated conceptually in the flow diagram presented on the next page (Exhibit 2-7).

By resolving the basic questions posed in this diagram in step-wise fashion, persons should be able to generally understand the special waste status of any individual mineral production waste. The steps in this process are outlined below. The sequence of these steps is very important, as the need for proceeding to the next step is determined by the answer to the question posed in the current step. Of particular importance is determining the point at which mineral processing first occurs; all wastes generated after that initial processing step are considered processing wastes or downstream manufacturing wastes.

EPA's evaluation sequence proceeds as follows:

- Ascertain whether the material is considered a solid waste under RCRA.

- Determine whether the waste is generated by a primary mineral production step, and, more generally, whether or not primary production occurs in the sector/within a process type.

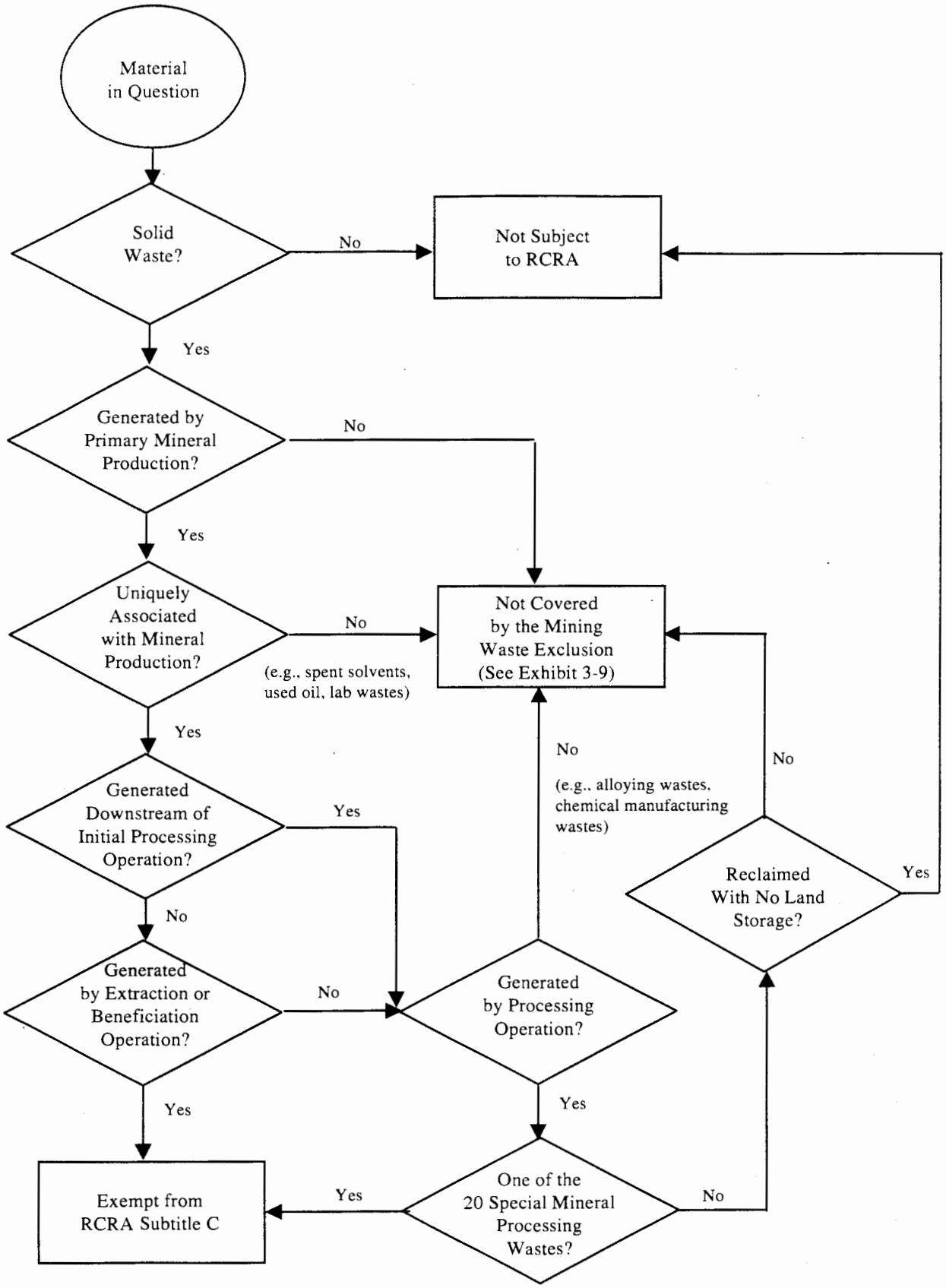
- Establish whether the waste and the operation that generates it are uniquely associated with mineral production.

- Determine whether the waste is generated by a mineral extraction, beneficiation, or processing step.

- Check to see whether the waste, if it is a processing waste, is one of the 20 special wastes from mineral processing. This analytical sequence results in one of three outcomes:

(1) the material is not a solid waste and hence, not subject to RCRA;

EXHIBIT 2-7
Process Summary for Mining Waste Exclusion Determinations



(2) the material is a solid waste but is exempt from RCRA Subtitle C because of the Mining Waste Exclusion; or

(3) the material is a solid waste that is not exempt from RCRA Subtitle C and is subject to regulation as a hazardous waste if it is listed as a hazardous waste or it exhibits any of the characteristics of hazardous waste.[3]

General Considerations

The first step in evaluating whether or not wastes produced by a facility are excluded from RCRA Subtitle C regulation is to establish whether primary mineral production takes place at the facility. The Mining Waste Exclusion does not apply to secondary production of mineral commodities; wastes from scrap recycling, metals recovery from flue dust, and similar activities have always been subject to Subtitle C regulation if these wastes exhibit hazardous characteristics or are listed hazardous wastes (as some are).

Primary mineral production operations are defined as those using at least 50 percent ores, minerals, or beneficiated ores or minerals as the feedstock(s) providing the mineral value. In addition, the Exclusion is limited in scope to wastes from the *extraction, beneficiation, and processing* of ores and minerals; it does not extend to alloying or to downstream chemical manufacturing, metal casting or fabrication, or other activities that use a saleable commodity (e.g., carbon steel, cathode copper, titanium tetrachloride, merchant grade phosphoric acid) as the primary raw material.

It may, therefore, be possible to establish easily and quickly that a particular facility and its wastes are not eligible for special waste status. If primary mineral production does not occur at the facility, then, by definition, the Mining Waste Exclusion does not apply to any of the wastes that the facility generates. The key questions that arise here are, "What does this facility produce?" and "From what?" If the facility does not produce intermediate or final mineral commodities from a raw material mix containing at least 50 percent ores, minerals, or beneficiated ores or minerals, then no wastes generated at the site are eligible for the Exclusion, and the facility (and its wastes) has the same RCRA status as that of any other industrial plant.

If (and only if) it has been determined by EPA that primary mineral production occurs at a particular facility, then the analytical focus can shift to specific operations, materials, and waste streams.[4] In that instance, the next logical question is whether or not the material in question is a solid waste. If the material is not a solid waste, then the question of whether the Mining Waste Exclusion applies will be irrelevant, because RCRA requirements will not apply to that material. In general, EPA's position has always been that materials that are discarded or are managed in a waste-like manner (e.g., placed on the ground) are solid wastes and subject to RCRA. This policy is amplified and tailored to the particular circumstances found in the minerals industry in today's final rule. EPA is today establishing a conditional exclusion from the definition of solid waste for secondary materials from mineral processing that are recycled; the conditions for the exclusion are no land placement of the materials[5], legitimate recovery of metals, water, acid, and/or cyanide values, and no speculative accumulation of secondary materials. A one-time notification also is required. EPA recognizes that establishing whether a material is a solid waste may be difficult, but believes that this determination needs to be made so that the regulatory status of the material in question can be ascertained.

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[3] RCRA Subtitle C regulations define toxicity as one of the four characteristics of a hazardous waste. EPA uses the Toxicity Characteristic Leaching Procedure (TCLP) to assess whether a solid waste is a hazardous waste due to toxicity. In today's final rule, EPA is reinstating the application of the TCLP to mineral processing wastes in response to a Court remand. For further discussion, see the preamble to today's final rule.

[4] Because of the confusion regarding the scope of the Mining Waste Exclusion that has occurred in the past, EPA believes that it is important to clarify its long-standing position that the Exclusion applies to wastes, not to facilities. Therefore, it must be understood that claims that a particular facility is "exempt" from regulation under Subtitle C because of the Bevill Amendment are inaccurate; the applicability of the Exclusion is judged "one waste at a time."

[5] Site-specific waivers of the land placement prohibition may be obtained from delegated state agencies for storage of solid (i.e., no free liquids) materials on concrete or asphalt pads, provided that run-on/run-off controls are installed, fugitive dust is controlled, and all of these constituent release controls are maintained properly.

Once it has been determined that a material is a solid waste generated by a facility engaged in primary mineral production, the more difficult questions concerning whether the waste is excluded from Subtitle C requirements may be tackled. In evaluating whether a particular solid waste is or is not covered by the Mining Waste Exclusion, EPA starts at the beginning of the production sequence, i.e., where the ores or minerals are in their most impure form, and focuses on the operations in the production sequence that are directly involved in producing the mineral commodity. It is very important to follow the sequence of production operations carefully. The same activities, occurring at different points in the production sequence, may generate wastes that are classified very differently under the Mining Waste Exclusion.

It is worth emphasizing that only wastes that are "uniquely associated" with primary mineral production operations are eligible for special waste status. All other types of wastes are not eligible for special waste status, even if they are generated and/or managed at a mineral production site, and even if that site generates some wastes that are defined as special wastes. This "uniquely associated" concept is discussed in greater detail in the next section.

It is also worthy of note that spills of certain materials require prescribed actions on the part of the facility operator. If the spilled substance has a Reportable Quantity (RQ) limit and that limit is exceeded, then the facility operator must report the incident to the appropriate regulatory authority.[6] This requirement has been established by EPA pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); accordingly, it is not affected by the Mining Waste Exclusion to RCRA. That is, exempt status (or even the question of whether a material is a solid waste) has no bearing on whether or not the spill reporting requirements must be met.

The Uniquely Associated Concept - "Indigenous" to Mineral Production or Not?

As mentioned earlier, in order for a waste generated at a mineral production site to be eligible for special waste status, it must be "uniquely associated" with the extraction or beneficiation of ores and minerals and with certain processing wastes. The Agency believes that the following summary of the uniquely associated concept can enable persons to understand the required site-specific decisions unambiguously:

(1) Uniquely associated mineral production wastes originate from, and obtain all or substantially all of their chemical composition through direct contact with, ores, minerals, or beneficiated ores or minerals;

(2) Operations that generate uniquely associated wastes are restricted to those that serve to remove mineral values from the ground, concentrate or otherwise enhance their characteristics, remove impurities, or are part of a sequence leading to the production of a saleable mineral product; and

(3) Wastes from all ancillary operations (e.g., vehical maintenance shop) taking place at mineral extraction, beneficiation, and processing sites are not uniquely associated.

This concept has been a central part of EPA's interpretation of the Bevill Amendment since the Agency's first response to Congressional directives was published in 1980 and is illustrated in the example provided in Highlight 1. In this notice, EPA stated that

[6] Reportable quantity substances, limits, and requirements may be found at 40 CFR Part 301.

> [T]his exclusion does not, however, apply to solid wastes, such as spent solvents, pesticide wastes, and discarded commercial chemical products, that are not uniquely associated with these mining and allied processing operations, or cement kiln operations. Therefore, should either industry generate any of these non-indigenous wastes and the waste is identified or listed as hazardous under Part 261 of the regulations, the waste is hazardous and must be managed in conformance with the Subtitle C regulations. (45 FR 76619, November 19, 1980)

Highlight 1. Lubrication Wastes and Chemical Spills

EPA reviewed the claims of a company in the minerals industry in 1992, regarding the regulatory status of several wastes generated at its lanthanide production facility. Among the wastes discussed were pinion gear grease and residues from cleanup of spills of clean solvents that are used in solvent extraction operations. EPA concluded that these wastes were not uniquely associated with mineral extraction, beneficiation, or processing operations, and thus, were not excluded wastes. EPA based this conclusion on the fact that these wastes do not originate from, and do not obtain their chemical composition primarily through direct contact with, ores, minerals, or beneficiated ores or minerals.

The Agency further stated at 54 FR 36616 (September 1, 1998) that:

> "Congress intended to put within the regulatory exclusion only wastes generated as a consequence of exploiting a natural resource, not wastes from other industrial activities, even if both occur at the same facility".

EPA reiterated the "non uniquely associated" standard in the 1989 Final Bevill Rule:

> [T]he Agency finds no compelling reason to provide exemptions for particular small volume wastes that may be associated with mineral processing operations, such as cleaning wastes. Many other industrial operations also generate such wastes, and EPA does not believe that the fact that current management involving co-management justifies continued regulatory exclusion...

The Agency has repeatedly applied the uniquely associated concept to delineate the boundaries of the Mining Waste Exclusion since that time, and it remains a key determinant of whether or not a particular waste should be afforded exclusion from RCRA Subtitle C. In fact, EPA addressed this issue at length in the preambles to its final rules establishing the boundaries of the Mining Waste Exclusion for mineral processing wastes.

Mineral extraction, beneficiation, and processing facilities usually generate some wastes that are not unique to mineral production, some of which may exhibit characteristics of hazardous waste. It is critical to understand that such wastes are not and have never been exempt from regulation as hazardous wastes under RCRA Subtitle C. To the extent that any such materials are solid wastes and are listed or exhibit characteristics of hazardous wastes, they must be managed as hazardous wastes, i.e., in accordance with the standards found at 40 CFR Parts 261-264 or analogous state requirements.

The Agency believes that it is appropriate to evaluate whether a particular waste is uniquely associated with mining and mineral processing as follows:

(1) Any waste from ancillary operations are not "uniquely associated" because they are not properly viewed as being "from" mining or mineral processing;

(2) In evaluating wastes from non-ancillary operations, one must consider the extent to which the waste originates or derives from processes that serve to remove mineral values from the ground, concentrated or otherwise enhance their characteristics or remove impurities; and

(3) The extent to which the mineral recovery process imparts its chemical characteristics to the waste. Under this test, the greater the extent to which the waste results from the mineral recovery process itself, and the more the process imparts to the waste its chemical characteristics, the more likely the waste is "uniquely associated."

The Agency believes that this approach provides a reasonable basis to determine whether a waste is "uniquely associated."

The Agency believes that these factors touch on the full range of facts that are likely to be relevant in any particular case. As is evident from the criteria summarized above, judgment must be exercised where the question is whether a waste from a non-ancillary operation is uniquely associated. EPA believes that this is appropriate because of the fact-specific nature of this determination and the myriad circumstances that can arise. However, as noted above, the Agency believes that wastes generated from ancillary operations (such as truck maintenance shops at a mine and not from the mining or mineral recovery process itself), are not uniquely associated. Such circumstances would likely present the most readily identifiable cases of non-uniquely associated wastes.

The approach noted above reflects the longstanding principle, based on the clear language in Section 3001 of RCRA, that uniquely associated wastes must result from mining and mineral processes themselves. This approach also is generally consistent with industry's underlying contention that the uniquely associated concept should exempt wastes that are "indigenous" to mining. EPA disagrees, however, with industry's contention that uniquely associated wastes are any wastes that are unavoidably generated by mining operations.

Examples of non-exempt wastes that may be found at mineral extraction, beneficiation, and/or processing sites, and that may be subject to regulation if they are listed as hazardous wastes or exhibit characteristics of hazardous waste, include (<u>but are not limited to</u>) the following:

- Cleaning wastes (e.g., spent solvents);
- Used oil and antifreeze from motor vehicles and equipment;
- Wastes from automotive and equipment maintenance shops;
- Pesticide, painting, and other chemical product wastes;
- Off-specification products;
- Spills (including contaminated soil) of any material outside of the primary mineral commodity production process, including unused beneficiation or processing reagents (e.g., sodium cyanide);
- Laboratory wastes (e.g., cupels, spent or contaminated reagents);
- Certain types of wastewater treatment sludges.[7]

Evaluating whether or not a particular waste is uniquely associated with primary mineral production operations should be straightforward in most cases. The key concept to bear in mind is that the composition and chemical characteristics of uniquely associated wastes are determined, or at least heavily influenced, by whether they are generated from resources that serve to remove or concentrate mineral values. Accordingly, wastes generated by generic industrial activities (e.g., vehicle or machinery operation, maintenance, or cleaning), laboratory operations, painting, pesticide application, and plant trash incineration, among others, are not uniquely associated and therefore, are not eligible for the Mining Waste Exclusion. In addition, discarded, spilled, or off-specification chemicals are ineligible for the same reason. (See Highlight 2.)

Finally, as a practical matter, the uniquely associated question is critical only in determining the exempt status of wastes from extraction and beneficiation operations. All mineral processing wastes except for the 20 specific wastes listed at 40 CFR Part 261.4(b)(7) have been removed from the scope of the Exclusion through formal rulemaking procedures. Therefore, <u>all</u> solid wastes produced by mineral processing operations (except the 20

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[7] Only sludges resulting from mineral extraction and beneficiation operations plus the 20 exempt mineral processing wastes are covered by the exclusion; all other treatment sludges are not exempt under the Mining Waste Exclusion.

specific wastes) are either not uniquely associated or were removed from the Exclusion through rulemaking. In either case, such wastes are not covered by the Mining Waste Exclusion.

Highlight 2. Off-Specification Products

In response to an inquiry related to the special waste status of several materials generated at a facility that produces boron and related products from brines, in 1992 EPA stated, "The Bevill Exclusion does not apply to solid wastes such as discarded commercial chemicals; they are not uniquely associated with mineral extraction, beneficiation, or processing. Discarded commercial chemicals include finished mineral-derived products that are generated at these plants but found to be off-specification and, thus, are discarded. Other wastes not uniquely associated with mineral extraction, beneficiation, or processing include many cleaning wastes (such as spent commercial solvent that was used in cleaning production vessels) and used lubricating oils."

Consequently, the need to determine whether a waste is or is not uniquely associated is limited to operations in the upstream end of the production sequence, which is generally simpler and easier to understand from a conceptual standpoint than downstream processing and/or manufacturing operations. The issue of where the "line" between beneficiation and processing lies and how this line is applied to individual mineral production facilities is discussed below.

Definitions of Beneficiation and Processing - Finding the Line

Once it has been established that extraction, beneficiation, and/or processing occurs at a particular facility and that the facility generates wastes that are uniquely associated with minerals production, the next question is whether mineral processing activities (as distinct from extraction or beneficiation) occur on site, and if so, whether these activities generate solid wastes that are subject to RCRA Subtitle C. The distinction between extraction/ beneficiation and processing is critical because all wastes that are uniquely associated with extraction and beneficiation operations are excluded from Subtitle C, while only 20 specific mineral processing wastes are exempt from Subtitle C requirements under the Mining Waste Exclusion.

In response to a 1988 Federal Appeals Court decision, EPA has developed explicit regulatory definitions of mineral beneficiation and processing, which are articulated in two final rules published in 1989 and 1990. As a consequence, when considering the regulatory status of wastes generated by a particular facility, EPA no longer relies upon pre-September, 1989 EPA notices, correspondence, or other guidance. (See Highlight 3) As delineated in the final rule published on January 23, 1990 (55 FR 2322),[8] beneficiation of ores and minerals includes and is restricted to a set of discrete activities that are generally performed in a predictable sequence, while processing of ores, minerals, and beneficiated ores and minerals is defined by a set of attributes rather than by

Highlight 3. Decisions on Regulatory Status Made Prior to September 1, 1989 Must be Reevaluated and Should not be Relied Upon

In 1985, EPA was asked to clarify the special waste status of leachate derived from certain smelter wastes. Because at that time smelter wastes were considered to be special wastes (and thus, excluded from Subtitle C regulation under the Mining Waste Exclusion) and because wastes derived from special wastes were also deemed special wastes, EPA concluded that leachate from smelter slag and pyritic cinders (the smelter wastes in question) were covered by the Mining Waste Exclusion and, accordingly, were exempt from regulation under RCRA Subtitle C. Subsequently, however, the scope of the Exclusion for mineral processing wastes (such as those from smelting) was narrowed considerably, to a list of 20 specific high volume, low hazard solid wastes. Wastes derived from these 20 wastes (or any other processing wastes, for that matter) were explicitly removed from the scope of the Exclusion in 1989 and 1990 (54 FR 36623). That is, EPA's earlier findings notwithstanding, leachates and other wastes derived from any mineral processing wastes are not excluded from RCRA Subtitle C regulation under the Mining Waste Exclusion, unless they are one of the 20 wastes listed in Figure 1-1, above.

[8] The final rule establishing the definition of beneficiation was first published on September 1, 1989 (54 FR 36592). The January 23, 1990 publication includes a technical correction to the definition originally promulgated in September.

specific activities.[9] Moreover, processing wastes were evaluated using specific quantitative criteria to determine whether they were of high volume and low hazard, and thus, eligible for special waste status.

Residues arising from treatment of extraction or beneficiation wastes (e.g., sludge from treatment of acid mine drainage) are also excluded from regulation. In contrast, treatment residues of mineral processing wastes are not eligible for the Exclusion unless they are one of the 20 wastes identified during the rulemaking process, because no such additional treatment residues were found to meet the special waste criteria (high volume and low hazard) during the rulemaking process. One important additional point concerns the mixing of excluded and hazardous, non-excluded wastes; this practice is generally subject to Subtitle C regulation and is addressed below.

EPA has emphasized that operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation. Therefore, solid wastes arising from such operations are considered mineral processing wastes, rather than beneficiation wastes. For that reason, a clear understanding of the mineral production sequence is vital to sound decision-making; the sequence considered extends to the operations preceding entry of the mineral value into a particular facility or portion thereof. (See Highlight 4).

Highlight 4. When "Beneficiation" Follows Processing

The primary copper industry provides an interesting illustration of the distinctions that exist between mineral beneficiation and processing. At a number of active primary copper facilities, copper is recovered from ores in two different ways: dump leaching is used to solubilize copper values in mined and stockpiled low grade ores, and conventional mining, milling, flotation, smelting, and refining are used to process higher grade ores. Metal-bearing solution from the dump leaching operation is, in many cases, sent to electrowinning (a type of beneficiation operation), which yields purified metallic copper. In contrast, after smelting, conventional copper production yields partially purified copper, in the form of "anodes," which is then further purified in an electrolytic refining process that is functionally very similar to that used to recover copper values from the dump leaching solution. Because, however, the anode copper is produced by operations that are defined as mineral processing, wastes generated by this electrolytic refining operation are mineral processing wastes, while wastes generated by the electrowinning of copper from the dump leach solution are defined as beneficiation wastes and are excluded from Subtitle C regulation. Because wastes from refining of anode copper are not among the 20 special mineral processing wastes, they are not exempt from Subtitle C regulation. Thus, in this case and in others, waste streams from similar operations may be subject to different regulatory requirements, even if they are generated at the same facility, depending upon the points in the production sequence from which they arise.

Defining which operations are beneficiation and which (if any) are processing can be a complex undertaking, and is best approached in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To perform this type of analysis, the level and depth of information needed on facility operations increases dramatically over that required to resolve the issues discussed above. **A detailed process flow diagram, as well as information on ore type(s), the functional importance of each step in the production sequence, waste generation points and quantities, and waste management practices are the minimum data needs for locating the beneficiation/processing "line" at a given facility**. Typically, EPA must obtain this information directly from the facility operator. Because mineral production operations are almost always non-linear (i.e., include internal cycling of materials), at least to some degree, the process flow diagram is probably the single piece of information that is most critical to establishing which activities are defined as beneficiation operations.

The meaning of some mineral production terms may not be readily apparent. Furthermore, minerals industry terminology is not highly standardized. Therefore, it is important to focus on the nature of individual operations in a mineral production sequence, rather than simply relying on the names or descriptions that may be applied to portions of the facility by the owner or operator.

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[9] It is worthy of note that, as stated in the September 1, 1989 (54 FR 36592) rulemaking notice, no new special mineral processing wastes will be recognized by EPA in the future, even if particular newly generated wastes should happen to comply with the established criteria. That is, the list of 20 excluded processing wastes will not be expanded under any circumstances.

Once the necessary information has been obtained from the facility operator, the Agency can begin an analysis to determine at what point beneficiation activities end and processing begins. As a first step, the Agency applies it's definitions of beneficiation activities. Using these definitions as a reference point, the decision-maker may then evaluate information that he/she has gathered concerning specific operations to determine whether those operations comport with Agency definitions. In EPA's experience, the following activities are generally easy to identify as beneficiation using this simple analytical process:

crushing	grinding	briquetting
sorting	sizing	flotation
sintering	pelletizing	gravity concentration
calcining	drying	magnetic separation
washing	filtration	electrostatic separation
		roasting, autoclaving, and/or chlorination[10]

It is useful to note that these operations share certain qualities that make them easily identifiable as beneficiation activities. Many of these operations do not generate <u>any</u> waste streams or effluents under typical operating conditions. To the extent that others on the list do generate wastes (e.g., flotation), such wastes generally share certain common attributes. First, the wastes typically fall into one of three general categories: 1) waste rock; 2) mill tailings; or 3) mine water. Second, the volumes of waste generated by beneficiation activities tend to be very large. Where there is doubt concerning whether a particular waste is generated by beneficiation or processing operations, the Agency finds it useful to consider whether or not the waste shares these identifying attributes.

Other mineral industry activities are more difficult to classify unambiguously as beneficiation operations. Certain beneficiation activities may bear a close resemblance to certain mineral processing operations. The lack of standard industry terminology means that beneficiation activities may be described using a mineral processing term and vice versa. Beneficiation activities that may easily be confused with processing activities are listed below. The mineral processing operations which these beneficiation operations resemble are included in parentheses.

- Amalgamation (similar to smelting)
- Crystallization (similar to chemical conversion)
- Dissolution (similar to digestion)
- Leaching (similar to digestion)
- Ion Exchange (similar to chemical conversion)
- Solvent Extraction (similar to chemical conversion)
- Electrowinning (similar to electrolytic refining)
- Precipitation (similar to chemical conversion)

As a result of the similarity of these activities to certain mineral processing operations, it is critical that the decision-maker have complete and detailed information concerning the unit operations in question in order to adequately evaluate whether they qualify as beneficiation activities. In most cases, the amount of information and the level of detail required will exceed that required for evaluating the simpler activities discussed above. In addition, the potentially complex nature of some of these operations means that more in-depth study of unit operations may be necessary before a determination can be made. Once the decision-maker has all of the relevant information needed and fully understands the unit operations involved, analysis can proceed. The decision-maker first consults Agency definitions, and then evaluates unit operations using the definitions as a reference point.

It is likely that, when evaluating facility information that includes references to these more complex operations, the state or regional decision-maker will be required to make judgment calls as to the nature of the operation. This may be particularly true in cases in which a production sequence involves the use of heat or acid

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[10] Only in preparation for a leaching operation that does <u>not</u> produce a final or intermediate product that does not undergo further beneficiation or processing.

(see discussion at 54 FR 36618). For example, there may be disagreement regarding whether a particular operation is "leaching" or "dissolution" (beneficiation) or is "acid attack" or "digestion" (processing). When faced with operations that cannot be classified unambiguously as beneficiation or processing activities, EPA decision-makers sometimes find that considering the following information can help them in making these difficult determinations.

- Beneficiation operations typically serve to separate the mineral value(s) from waste material, i.e., remove impurities, or otherwise improve the characteristics of the material for further refinement. Beneficiation activities do not change the mineral values themselves and typically include reducing (e.g., by crushing or grinding) or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. Where heat or chemicals, such as acid, are applied in a beneficiation operation, it is generally to drive off impurities (e.g., water), dissolve mineral values in a solution as a means of separation (leaching), or to retrieve dissolved values from a solution (e.g., crystallization or solvent extraction). A chemical change in the mineral value does not typically occur.

- Processing operations, in contrast, generally follow beneficiation and serve to change the value(s) into a more useful chemical form, often by use of vigorous, even destructive, thermal or chemical reactions of the value(s) and/or waste material with fluxes or reagents. In contrast to beneficiation operations, processing activities often destroy the physical structure of the incoming ore or mineral feedstock(s), such that the materials leaving the operations do not closely resemble those that entered the operation. Examples of the differences between beneficiation and processing operations are provided in Highlights 5 and 6.

Highlight 5. "Acid Treatment" of Clay is Beneficiation

A facility produces desiccant and adsorbent products from calcium montmorillonite clay using a sequence of steps that includes crushing, drying, acid treatment, washing and filtration, drying, and sizing. In response to an inquiry from the relevant state agency in 1989, EPA reviewed the available information regarding the acid treatment operation and concluded that it is a beneficiation operation, for the following reasons: (1) it uses a beneficiated ore as the primary feedstock; and (2) the acid treatment process (which substitutes protons for some aluminum, magnesium, and iron ions in the clay) does not "appear to destroy or substantially change the physical structure of the clay particles entering the operation." Consequently, the aqueous waste that results from the acid treatment operation (as well as the wastes generated by the other operations listed above) is a beneficiation waste that is exempt from hazardous waste regulation under the Mining Waste Exclusion.

Highlight 6. Bauxite Refining is Mineral Processing

Bauxite refining in the U.S. is accomplished through the use of the Bayer process, in which bauxite ore (impure hydrated aluminum oxide) is digested with a concentrated caustic (sodium hydroxide) solution under elevated temperature and pressure conditions. This yields soluble sodium aluminate, which is cooled, diluted, and hydrolyzed to form insoluble aluminum hydroxide, which can then be filtered out and calcined to produce alumina (aluminum oxide). Because in the Bayer process the bauxite ore is vigorously attacked by a strong chemical agent, thereby destroying the physical structure of the mineral, and because a large percentage of the solid material entering the process is chemically altered, EPA concluded in its rulemaking activities in 1989 that this operation constitutes mineral processing, rather than beneficiation. Even though strong acids and extreme temperatures are not employed in the Bayer process, the combination of the strongly alkaline (rather than acidic) reagent and the high pressures (several times atmospheric) applied to the ore slurry are sufficient to change the chemical form of the mineral value and the physical form of the feed material stream.

- Typically, beneficiation wastes are earthen in character and comprise a relatively high proportion of the material entering the operation. Processing wastes, on the other hand, are often very different in character from the material(s) entering the operation (i.e., are typically not earthen in character), and comprise a comparatively small proportion of the feedstock. This

distinction is illustrated in Highlight 6. Waste streams that differ substantially in character or volume from the input materials are in most cases either processing wastes or wastes from downstream operations (e.g., chemical manufacturing) that are completely outside the scope of the Mining Waste Exclusion. Indeed, the generation rates and accumulated quantities of extraction and beneficiation wastes typically dwarf those of downstream, on-site processing and manufacturing operations.

If it is determined that a material is a processing waste, the EPA decision-maker checks to determine if the waste is on the list of 20 excluded wastes. If the processing waste is on that list, it is unambiguously exempt from RCRA Subtitle C hazardous waste regulations under the Mining Waste Exclusion. Any processing wastes that are not listed under the 20 excluded wastes are not covered by the Exclusion, and therefore are subject to regulations under Subtitle C, if the wastes are listed hazardous wastes or exhibit a characteristic of hazardous waste.

Active Management - Disturbing Old Wastes Can Influence Regulatory Status

EPA believes that among the positive effects of this proposal would be to encourage the "re-mining" of previously generated mineral processing wastes--that is, the excavation of such wastes from disposal sites (including remediation sites) for purposes of mineral recovery. Many of the 60 or more mine and mineral processing sites on the National Priorities List could reduce costs of remediation by remining. Such recovery would promote the statutory goals of less land disposal, increased material recovery, and also proper waste treatment (since the treatment standards for most mineral processing wastes are based on performance of High Temperature Metal Recovery processes such as smelting). The reason re-mining could be encouraged is that the previously disposed mineral processing materials would not be solid wastes once they are excavated for purposes of legitimate recovery by mineral processing or beneficiation processes, provided they satisfy the same conditions that a newly-generated secondary material from mineral processing would satisfy. See also 261.1(c)(8) (stating that a material that is speculatively accumulated need not be considered a solid waste any longer "once they are removed from accumulation for recycling").

EPA notes further that excavation of wastes would not render the historic disposal unit subject to RCRA requirements. See 53 FR at 51444 (Dec. 21, 1988) (movement of waste from one unit to another does not subject the initial unit to land disposal restriction requirements); 55 FR at 8758 (same); Letter from Lisa K. Friedman, Associate General Counsel Solid Waste and Emergency Response Division to Richard Stoll (Sept. 5, 1990) (indicating that under the same reasoning movement of waste from one unit to another, by itself, does not trigger RCRA permitting requirements for the initial unit). EPA notes that some questions have been raised about the scope of EPA's discussion of ``active management" in the preamble to the Sept. 1, 1989 rule. In that discussion, EPA described some activities that could subject existing waste management units containing non-Bevill wastes to Subtitle C. 55 FR at 8755; 54 FR at 36597. The 1989 preamble did not specifically address the question of whether removal of some waste from an existing unit subjects the waste remaining in the unit to Subtitle C regulation. EPA is clarifying that the Agency's position, as discussed above, is that removal of waste from such a unit does not constitute "disposal" for purposes of triggering Subtitle C regulation, and the language of the 1989 preamble, although somewhat unclear, should be read to be consistent with EPA's statements in the NCP preamble on this point.

Mixture Rule

Under today's rule, the Agency has decided that if subtitle C hazardous waste exhibiting a characteristic is mixed with Bevill-exempt waste exhibiting the same characteristic and the mixture continues to exhibit that common characteristic, then the entire mixture should be considered to be non-exempt hazardous waste. This result is consistent with normal rules on when wastes are hazardous, which state that if a waste exhibits a hazardous waste characteristic, it remains a hazardous waste unless and until it no longer exhibits a characteristic. 261.3(d)(1). In addition, such a principle will make this rule easier to administer (should this situation actually occur), since enforcement officials will not have to parse out which portion of the waste mixture is imparting the characteristic property. Finally, the result is consistent with the overall object of today's rule: not to let Bevill wastes be used as a means of allowing unregulated management of normal subtitle C hazardous wastes.

The Agency reiterates that the rule does not alter in any way the current Agency mixture rule. The purpose of this rulemaking is to eliminate the current Bevill mixture rule and place the mixing of hazardous wastes that may occur at mineral processing plants on the same status as all other hazardous waste management.

Illustrations of how today's rule operates

Although the regulatory parlance for today's rule has always been the 'Bevill mixture rule', the greatest practical consequence of the rule is probably on the units where mixing occurs. This is because units (i.e. tanks, impoundments, piles, landfills, etc.) where hazardous wastes are placed will (absent some exemption or exclusion other than that provided by the Bevill amendment) be regulated units, i.e. units subject to subtitle C standards for treatment, storage, and/or disposal. This point is illustrated by the following examples, which also illustrate the effect of the rule on the resulting mixtures;

Example 1. Facility A generates F 001 listed spent solvents which it mixes with a solid waste that has Bevill exempt-status. The mixing occurs in a landfill. The landfill is a regulated unit because hazardous waste --F 001 --is being disposed in it. (Among other things, this means that the F 001 wastes could not be placed in the landfill until the LDR treatment standard is satisfied.) In addition, all of the wastes with which the F 001 wastes are mixed are hazardous wastes carrying the F 001 waste code by application of the mixture rule.

Example 1a. Same facts as in example 1, except that the waste being mixed is F 003 spent solvent, a waste listed only because it exhibits a characteristic of hazardous waste. The landfill becomes a regulated unit for the same reason as in example 1. (See Chemical Waste Management v. EPA, 976 F.2d at 20 n.4 and 24 n. 10 (placement of waste which is hazardous for any amount of time in a unit subject that unit to subtitle C regulation); 61 FR at 2352 (same). However, the status of the resulting waste mixture is determined by the principles for characteristic hazardous wastes, illustrated below.

Example 2. Facility B generates a characteristic ignitable solvent which it adds to a surface impoundment containing a Bevill-exempt waste that would exhibit the TC for lead. The resulting mixture exhibits TC for lead but is no longer ignitable. The surface impoundment is a regulated unit, since it is engaged in treatment (elimination of the ignitability characteristic) and disposal (the placement of the ignitable waste). The remaining wastes in the unit retain their Bevill-exempt status because they do not exhibit the characteristic property of the non-Bevill hazardous waste. Thus, if the waste were to be removed from the impoundment and disposed elsewhere, disposal need not occur in a regulated unit.

Example 3. Facility C generates a characteristic hazardous waste exhibiting TC for lead which it mixes in a tank with Bevill-exempt wastes which also would exhibit the TC for lead. The resulting mixture continues to be TC for lead. The tank is engaged at least in storage of hazardous waste, and possibly treatment (depending on how the D008 hazardous waste is affected by the mixing). If waste is removed from the tank, it remains subject to subtitle C because it continues to exhibit the characteristic of the non-exempt hazardous waste.

C.2 Waste Stream Sources and Form

EPA reviewed process descriptions and process flow diagrams obtained from numerous sources including, Kirk-Othmer, EPA's Effluent Guideline Documents, EPA survey instruments, and the literature. As one would expect, the available process descriptions and process flow diagrams varied considerably in both quality and detail, both by commodity and source of information. Therefore, EPA often needed to interpret the information to identify specific waste streams. For example, process descriptions and process flow charts found through the Agency's electronic literature search process often focused on the production process of the mineral product and omitted any description or identification of waste streams (including their point of generation). In such cases, the Agency used professional judgment to determine how and where wastes were generated.

C.3 Waste Stream Characteristics

EPA used waste stream characterization data obtained from numerous sources to document whether a particular waste stream exhibited one (or more) of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity). In cases in which actual data indicated that a waste did exhibit one of the characteristics of a hazardous waste, the specific characteristic was designated with a **Y**. Despite, however, more than ten years of Agency research on mineral processing operations, EPA was unable to find waste characterization data for many waste streams. To present mineral commodity profiles that were as complete as possible, EPA used a

step-wise methodology for estimating waste characteristics for individual waste streams when documented waste generation rates and analytical data were not available. Specifically, due to the paucity of waste characterization data (particularly, TCLP data), EPA used total constituent data (if available) or professional judgment to determine whether a particular waste exhibits one of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, or reactivity).

To determine whether a waste might exhibit the characteristic of toxicity, EPA first compared 1/20th of the total constituent concentration of each TC metal to its respective TC level.[11] In cases in which total constituent data were not available, EPA then used professional judgment to evaluate whether the waste stream could potentially exhibit the toxicity characteristic for any of the TC metals. For example, if a particular waste stream resulted through the leaching of a desired metal from an incoming concentrated feed, the Agency assumed that the precipitated leach stream contained high total constituent (and therefore, high leachable) concentrations of non-desirable metals, such as arsenic. Continuing through the step-wise methodology, EPA relied on professional judgment to determine, based on its understanding of the nature of a particular processing step that generated the waste in question, whether the waste could possibly exhibit one (or more) of the characteristics of ignitability, corrosivity, or reactivity. Waste streams that EPA determined could potentially exhibit one or more of the characteristics of a RCRA hazardous waste were designated by **Y?**. The Agency acknowledges the inherent limitations of this conservative, step-wise methodology and notes that it is possible that EPA may have incorrectly assumed that a particular waste does (or does not) exhibit one or more of the RCRA hazardous waste characteristics.

The Agency stresses that the results and information presented in the individual commodity analysis reports are based on the review of publicly available information. The accuracy and representativeness of the collected information are only as good as the source documents. As a result of this limited data quality review, EPA notes that in some instances, Extraction Procedure (EP) leachate data reported by various sources are greater than 1/20th of the total constituent concentration. Generally one would expect, based on the design of the EP testing procedure, the total constituent concentrations to be at least 20-times the EP concentrations. This apparent discrepancy, however, can potentially be explained if the EP results were obtained from total constituent analyses of liquid wastes (i.e., EP tests conducted on wastes that contain less than one-half of one percent solids content are actually total constituent analyses).

C.4 Waste Stream Generation Rates

As data were available, EPA used actual waste generation rates reported by facilities in various Agency survey instruments and background documents. Due, however, to the general lack of data for many of the mineral commodity sectors and waste streams, the Agency needed to develop a step-wise method for estimating mineral processing waste stream generation rates when actual data were unavailable.

Specifically, EPA developed an "expected value" estimate for each waste generation rate using draft industry profiles, supporting information, process flow diagrams, and professional judgment. From the "expected value" estimate, EPA developed upper and lower bound estimates, which reflect the degree of uncertainty in our data and understanding of a particular sector, process, and/or waste in question. For example, EPA obtained average or typical commodity production rates from published sources (e.g., BOM Mineral Commodity Summaries) and determined input material quantities or concentration ratios from published market specifications. In parallel with this activity, EPA reviewed process flow diagrams for information on flow rates, waste-to-product ratios, or material quantities. The Agency then calculated any additional waste generation rates and subtracted out known material flows, leaving a defined material flow, which was allocated among waste streams using professional judgment. Finally, EPA assigned a maximum, expected, and minimum volume estimate to each waste stream.

A key element in developing waste generation rates was the fact that by definition, average facility level generation rates of solids and sludges are less that 45,000 metric tons/year, and generation rates of wastewaters are less than 1,000,000 metric tons/year. Using this fact, in the absence of any supporting information, maximum values

[11] Based on the assumption of a theoretical worst-case leaching of 100 percent and the design of the TCLP extraction test, where 100 grams of sample is diluted with two liters of extractant, the maximum possible TCLP concentration of any TC metal would be 1/20th of the total constituent concentration.

for solids and sludges were set at the highest waste generation rate found in the sector in question or 45,000 metric tons/year/ facility, whichever is lower.

The precise methodology for determining waste generation rates varied depending on the quantity and quality of available information. The waste streams for which EPA had no published annual generation rate were divided into five groups and a methodology for each group was assigned as follows.

1. **Actual generation rates for the waste in question from one or more facilities were available.** EPA extrapolated from the available data to the sector on the basis of waste-to-product ratios to develop the expected value, and used a value of +/- 20% of the expected value to define the upper and lower bounds.

2. **A typical waste-to-product ratio for the waste in question was available.** EPA multiplied the waste-to-product ratio by sector production (actual or estimated) to yield a sector wide waste generation expected value, and used one-half and twice this value for the lower and upper bounds, respectively.

3. **No data on the waste in question were available, but generation rates for other generally comparable wastes in the sector were available.** EPA used the maximum and minimum waste generation rates as the upper and lower bounds, respectively, and defined the expected value as the midpoint between the two ends of the range. Adjustments were made using professional judgment if unreasonable estimates resulted from this approach.

4. **No data were available for any analogous waste streams in the sector, or information for the sector generally was very limited.** EPA drew from information on other sectors using analogous waste types and adjusting for differences in production rates/material throughput. The Agency used upper and lower bound estimates of one order of magnitude above and below the expected value derived using this approach. Results were modified using professional judgment if the results seemed unreasonable.

5. **All EPA knew (or suspected) was the name of the waste.** The Agency used the high value threshold (45,000 metric tons/year/facility or 1,000,000 metric tons/year/facility) as the maximum value, 0 or 100 metric tons per year as the minimum, and the midpoint as the expected value.

Appendix A provides detailed descriptions of the methodology used to estimate waste generation rates for individual waste streams.

C.5 Waste Stream Management Practices

EPA reviewed process descriptions and process flow diagrams obtained from numerous sources including, Kirk-Othmer, EPA's Effluent Guideline Documents, EPA survey instruments, and the literature. As noted earlier, the available process descriptions and process flow diagrams varied considerably in both quality and detail, both by commodity and source of information. Therefore, EPA often needed to interpret the information to determine how specific waste streams were managed. For example, process descriptions and process flow charts found through the Agency's electronic literature search process often focused on the production process of the mineral product and omitted any description or identification of how or where waste streams were managed. In such cases, the Agency used professional judgment to determine how and where specific waste streams were managed. For example, EPA considered (1) how similar waste streams were managed at mineral processing facilities for which the Agency had management information, (2) the waste form and whether it was amenable to tank treatment, (3) generation rates, and (4) proximity of the point of waste generation to the incoming raw materials, intermediates, and finished products to predict the most likely waste management practice.

C.6 Waste Stream Recyclability and Classification

As was the case for the other types of waste stream-specific information discussed above, EPA was unable to locate published information showing that many of the identified mineral processing waste streams were being

recycled. In cases in which the Agency found information showing that a particular waste stream was being either fully or partially recycled, the recyclability of the waste stream is designated by **Y** and **YS**, respectively.

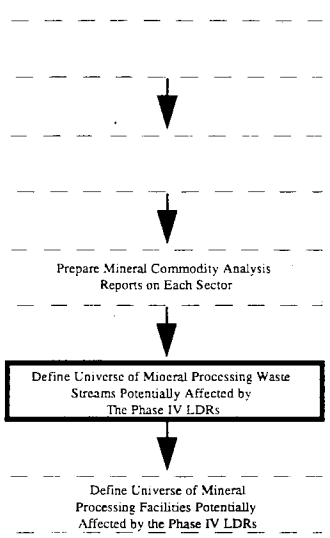
However, due to the paucity of data for many of the mineral commodity sectors and waste streams, the Agency needed to develop a method for determining whether a particular mineral processing waste stream was expected to be either fully or partially recycled, designated by **Y?** and **YS?**, respectively. The Agency developed a work sheet to assist EPA staff in making consistent determinations of whether the mineral processing waste streams could potentially be recycled, reused, or recovered. This work sheet, shown in Appendix B, was designed to capture the various types of information that could allow one, when using professional judgment, to determine whether a particular waste stream could be recycled or if it contained material of value.

If EPA determined that the waste stream was or could be fully/partially recycled, it used the definitions provided in 40 CFR §§ 260.10 and 261.1 to categorize the waste streams as either by-products, sludges, or spent materials. Appendix C presents the RCRA definitions and examples of by-products, sludges, and spent materials. Work sheets developed for individual waste streams are presented in Appendix D.

EPA, through the process of researching and preparing mineral commodity analysis reports for the mineral commodities listed in Exhibit 2-2, identified a total of 553 waste streams that are believed to be generated at facilities involved in mineral production operations. These extraction/beneficiation and mineral processing waste streams are listed in Appendix E.

D. Identify Mineral Processing Waste Streams Potentially Affected by the Phase IV LDRs

Step Four



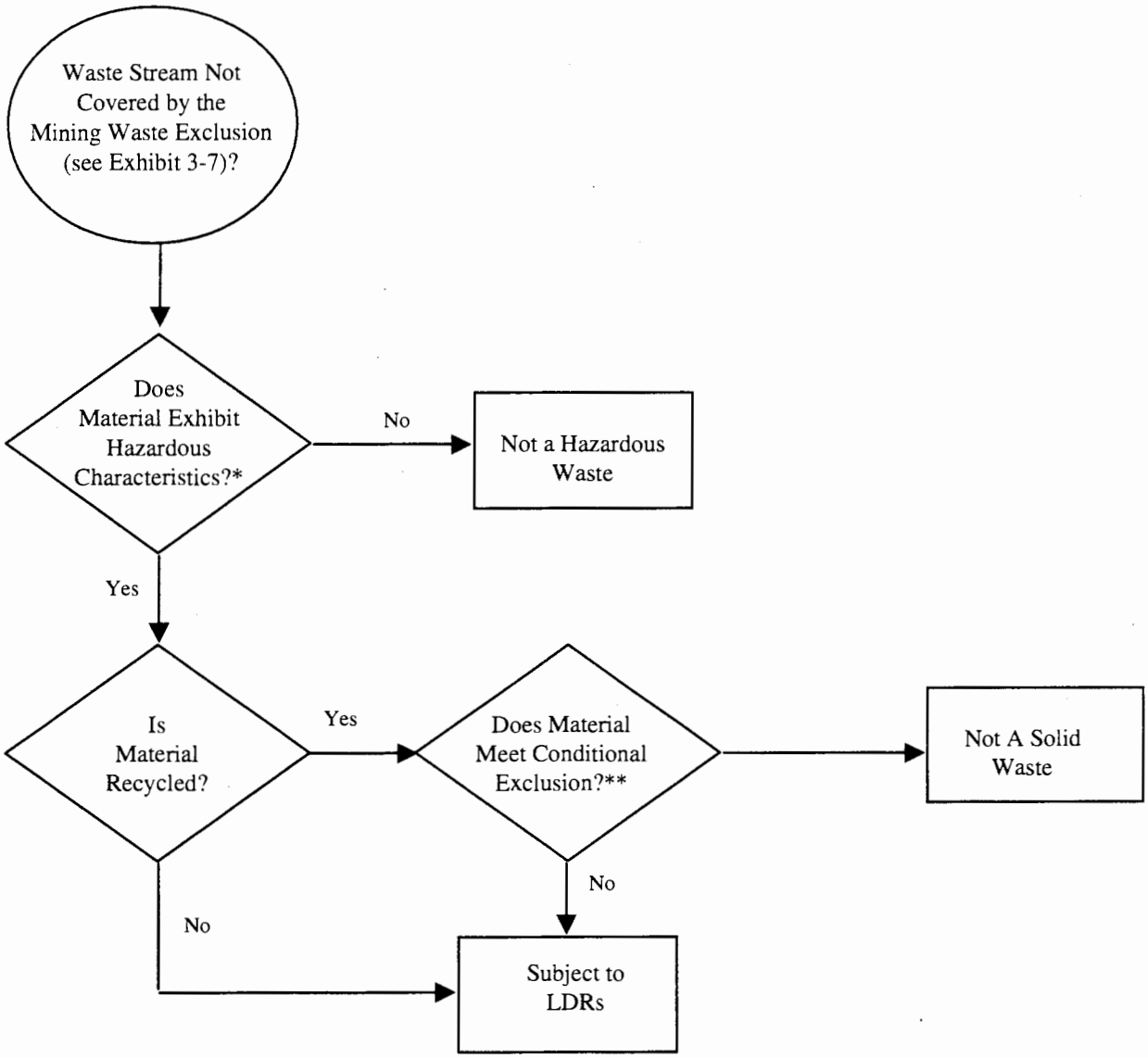
The Agency then evaluated each of the waste streams listed in Appendix E using the process outlined in Exhibit 2-9, to remove waste streams that would not be affected by the Phase IV LDRs. Specifically, EPA removed:

- All of the extraction and beneficiation waste streams;
- The "Special 20" Bevill-Exempt mineral processing waste streams;
- Waste streams that were known to be fully recycled in process; and
- All of the mineral processing waste streams that did not exhibit one or more of the RCRA characteristics of a hazardous waste (based on either actual analytical data or professional judgment).

As a result of this evaluation process, EPA narrowed the potential universe of waste streams that could potentially be affected by the proposed Phase IV LDRs to the 120 hazardous mineral processing waste streams presented below in Exhibit 2-10.

EXHIBIT 2-9

Waste Streams Potentially Affected by the Phase IV LDRs



* Listed hazardous waste are excluded from further analysis because they are already subject to all relevant Subtitle C requirements.

** To meet the conditional exclusion, materials must be stored in tanks, containers, of buildings for less than one year, or have a site specific determination that sold material may be stored on a concrete or asphalt pad. (Other requirements can be found in 261.4(a)(15))

EXHIBIT 2-10

POTENTIALLY HAZARDOUS MINERAL PROCESSING WASTE STREAMS BY COMMODITY SECTOR

Alumina and Aluminum
- Cast house dust
- Electrolysis waste

Antimony
- Autoclave filtrate
- Slag and furnace residue
- Stripped anolyte Solids

Beryllium
- Chip treatment wastewater
- Filtration discard
- Spent Barren Filtrate

Bismuth
- Alloy residues
- Spent caustic soda
- Electrolytic slimes
- Lead and zinc chlorides
- Metal chloride residues
- Slag
- Spent electrolyte
- Spent soda solution
- Waste acid solutions
- Waste acids

Cadmium
- Caustic washwater
- Copper and lead sulfate filter cakes
- Copper removal filter cake
- Iron containing impurities
- Spent leach solution
- Lead sulfate waste
- Post-leach filter cake
- Spent purification solution
- Scrubber wastewater
- Spent electrolyte
- Zinc precipitates

Calcium
- Dust with quick lime

Chromium and Ferrochromium
- ESP Dust
- GCT Sludge

Coal Gas
- Multiple effects evaporator concentrate

Copper
- Acid plant blowdown
- APC dust/sludge
- Process wastewaters
- Spent bleed electrolyte
- Tankhouse slimes
- Waste contact cooling water
- Spent furnace brick
- WWTP sludge

Elemental Phosphorus
- Andersen Filter Media
- Precipitator slurry
- NOSAP slurry
- Phossy Water
- Furnace building washdown
- Furnace scrubber blowdown

Fluorspar and Hydrofluoric Acid
- Off-spec fluosilicic acid

Germanium
- Waste acid wash and rinse water
- Chlorinator wet air pollution control sludge
- Hydrolysis filtrate
- Leach residues
- Spent acid/leachate
- Waste still liquor

Gold and Silver
- Slag
- Spent furnace dust

Lead
- Acid plant sludge
- Baghouse incinerator ash
- Slurried APC dust
- Solid residues
- Spent furnace brick
- Stockpiled miscellaneous plant waste
- Wastewater treatment plant solids/sludges
- Wastewater treatment plant liquid effluent

Magnesium and Magnesia from Brines
- Cast house dust
- Smut

Mercury
- Dust
- Furnace residue
- Quench water

EXHIBIT 2-10 (Continued)

Molybdenum, Ferromolybdenum, and Ammonium Molybdate
- Flue dust/gases
- Liquid residues

Platinum Group Metals
- Slag
- Spent acids
- Spent solvents

Rare Earths
- Spent ammonium nitrate processing solution
- Electrolytic cell caustic wet APC sludge
- Process wastewater
- Spent scrubber liquor
- Solvent extraction crud
- Spent lead filter cake
- Waste solvent
- Wastewater from caustic wet APC

Rhenium
- Spent barren scrubber liquor
- Spent rhenium raffinate

Scandium
- Spent acids
- Spent solvents from solvent extraction

Selenium
- Spent filter cake
- Plant process wastewater
- Slag
- Tellurium slime wastes
- Waste solids

Synthetic Rutile
- Spent iron oxide slurry
- APC dust/sludges
- Spent acid solution

Tantalum, Columbium, and Ferrocolumbium
- Digester sludge
- Process wastewater
- Spent raffinate solids

Tellurium
- Slag
- Solid waste residues
- Waste electrolyte
- Wastewater

Titanium and Titanium Dioxide
- Pickle liquor and wash water
- Scrap milling scrubber water
- Smut from Mg recovery
- Leach liquor and sponge wash water
- Spent surface impoundment liquids
- Spent surface impoundments solids
- Waste acids (Sulfate process)
- Waste acids (Chloride process)
- WWTP sludge/solids

Tungsten
- Spent acid and rinse water
- Process wastewater

Uranium
- Waste nitric acid from UO_2 production
- Vaporizer condensate
- Superheater condensate
- Slag
- Uranium chips from ingot production

Zinc
- Acid plant blowdown
- Waste ferrosilicon
- Process wastewater
- Spent refractory brick
- Spent cloths, bags, and filters
- Spent goethite and leach cake residues
- Spent surface impoundment liquids
- Spent synthetic gypsum
- TCA tower blowdown
- Wastewater treatment plant liquid effluent
- WWTP solids

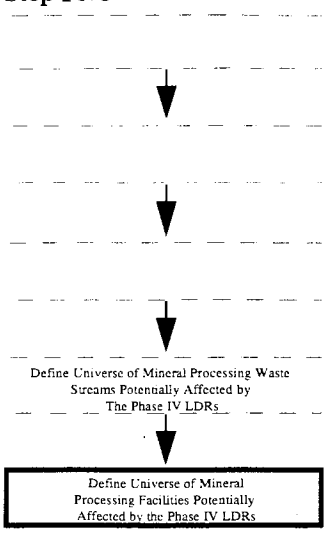
Zirconium and Hafnium
- Spent acid leachate from zirconium alloy production
- Spent acid leachate from zirconium metal production
- Leaching rinse water from zirconium alloy production
- Leaching rinse water from zirconium metal production

Note: EPA was unable to collect sufficient information to determine whether the production of Bromine, Gemstones, Iodine, Lithium and Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium produce mineral processing wastes.

Note: This is not necessarily a complete list of hazardous mineral processing waste. This is only a list of wastestream the Agency believes could be hazardous based on best available information.

E. Identify Mineral Processing Facilities Potentially Affected by the Phase IV LDRs

Step Five



EPA then used the information contained in the individual sector analysis reports to identify the number of facilities, by commodity, that potentially generate the hazardous mineral processing wastes listed in Exhibit 2-10. As discussed earlier, the individual sector analysis reports listed the facilities involved in the production of a particular mineral commodity. In addition, as the available information allowed, the Agency also (1) identified which facilities used which processes and (2) which processes generated which waste streams. In cases in which the Agency had insufficient information to determine which of the individual facilities generated a particular waste stream, EPA assumed that the waste stream was generated at all of the reported facilities known to be using the same process.

The Agency then used the individual sector analysis reports, various U.S. Bureau of Mines documents, the Randol Mining Directory, and the Mine Safety and Health Administration (MSHA) address/employment database to determine which of the mineral processing facilities were collocated with mining (extraction) and/or extraction/beneficiation facilities.

Lastly, the Agency used the 1990 Report to Congress and the individual commodity sector analysis reports to identify the mineral processing facilities that also generate one (or more) of the special 20 Bevill-Exempt mineral processing wastes.

Exhibit 2-11 presents the final mineral processing database developed using our methodology as discussed above. Appendix F presents a summary of the mineral processing facilities by mineral commodity sector that EPA believes generate hazardous mineral processing wastes. Appendix F also indicates whether the mineral processing facilities are collocated and/or generate one (or more) of the "Special 20" waste streams. Appendix G, presents the same information (as shown in Appendix F) for the mineral processing sectors that do not generate hazardous mineral processing wastes.

F. Caveats and Limitations

The results and information presented in this report are based on extensive review of publicly available information, supplemented by information provided in public comment. The accuracy and representativeness of the collected information are only as good as the source documents. As a result of this limited data quality review, EPA notes that in some instances, Extraction Procedure (EP) leachate data reported by various sources are greater than 1/20th of the total constituent concentration. Generally, one would expect, based on the design of the EP testing procedure, the total constituent concentrations to be at least 20-times the EP concentrations. This apparent discrepancy, however, can potentially be explained if the EP results were obtained from total constituent analyses of liquid wastes (i.e., EP tests conducted on wastes that contain less than one-half of one percent solids content are actually total constituent analyses).

In addition, to present mineral commodity profiles that are as complete as possible, EPA used a step-wise methodology for estimating both annual waste generation rates and waste characteristics for individual waste streams when documented waste generation rates and analytical data were not available. EPA's application of this methodology to estimate waste generation rates resulted in the development of low, medium, and high annual waste generation rates for non-wastewaters and wastewaters that were bounded by zero and 45,000 metric tons/yr/facility and by zero and 1,000,000 metric tons/yr/facility, respectively (the thresholds for determining whether a waste stream is a high volume, Bevill-exempt waste). Due to the paucity of waste characterization data (particularly, TCLP data), EPA used total constituent data (if available) or best engineering judgment to determine whether a particular waste exhibited one of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity).

To determine whether a waste might exhibit the characteristic of toxicity, EPA first compared 1/20th of the total constituent concentration of each TC metal to its respective TC level[12]. In cases in which total constituent data were not available, EPA then used best engineering judgment to evaluate whether the waste stream could potentially exhibit the toxicity characteristic for any of the TC metals. For example, if a particular waste stream resulted through the leaching of a desired metal from an incoming concentrated feed, we assumed that the precipitated leach stream contained high total constituent (and therefore, high leachable) concentrations of non-desirable metals, such as arsenic. Continuing through the step-wise methodology, we relied on EPA's best engineering judgment to determine, based on our understanding of the nature of a particular processing step that generated the waste in question, whether the waste could possibly exhibit one (or more) of the characteristics of ignitability, corrosivity, or reactivity. The Agency acknowledges the inherent limitations of this conservative, step-wise methodology and notes that it is possible that EPA may have incorrectly assumed that a particular waste does (or does not) exhibit one or more of the RCRA hazardous waste characteristics.

[12] Based on the assumption of a theoretical worst-case leaching of 100 percent and the design of the TCLP extraction test, where 100 grams of sample is diluted with two liters of extractant, the maximum possible TCLP concentration of any TC metal would be 1/20th of the total constituent concentration.

EXHIBIT 2-11
Final Mineral Processing Waste Stream Database

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
Alumina and Aluminum	Cast house dust	19	19	19	19	23	830	830	830
	Electrolysis waste	58	58	58	58	23	2,500	2,500	2,500
Antimony	Autoclave filtrate	NA	0.32	27	54	6	53	4,500	9,000
	Stripped anolyte solids	0.19	0.19	0.19	0.19	2	95	95	95
	Slag and furnace residue	21	21	21	21	6	3,500	3,500	3,500
Beryllium	Chip treatment wastewater	NA	0.2	100	2000	2	100	50,000	1,000,000
	Spent barren filtrate	55	55	55	55	1	55,000	55,000	55,000
	Filtration discard	NA	0.2	45	90	2	100	23,000	45,000
Bismuth	Alloy residues	NA	0.1	3	6	1	100	3,000	6,000
	Spent caustic soda	NA	0.1	6.1	12	1	100	6,100	12,000
	Electrolytic slimes	NA	0	0.02	0.2	1	0	20	200
	Lead and zinc chlorides	NA	0.1	3	6	1	100	3,000	6,000
	Metal chloride residues	3	3	3	3	1	3,000	3,000	3,000
	Slag	NA	0.1	1	10	1	100	1,000	10,000
	Spent electrolyte	NA	0.1	6.1	12	1	100	6,100	12,000
	Spent soda solution	NA	0.1	6.1	12	1	100	6,100	12,000
	Waste acid solutions	NA	0.1	6.1	12	1	100	6,100	12,000
	Waste acids	NA	0	0.1	0.2	1	0	100	200
Cadmium	Caustic washwater	NA	0.19	1.9	19	2	95	950	9,500
	Copper and lead sulfate filter cakes	NA	0.19	1.9	19	2	95	950	9,500
	Copper removal filter cake	NA	0.19	1.9	19	2	95	950	9,500
	Iron containing impurities	NA	0.19	1.9	19	2	95	950	9,500
	Spent leach solution	NA	0.19	1.9	19	2	95	950	9,500
	Lead sulfate waste	NA	0.19	1.9	19	2	95	950	9,500
	Post-leach filter cake	NA	0.19	1.9	19	2	95	950	9,500
	Spent purification solution	NA	0.19	1.9	19	2	95	950	9,500
	Scrubber wastewater	NA	0.19	1.9	19	2	95	950	9,500
	Spent electrolyte	NA	0.19	1.9	19	2	95	950	9,500
	Zinc precipitates	NA	0.19	1.9	19	2	95	950	9,500
Calcium	Dust with quicklime	0.04	0.04	0.04	0.04	1	40	40	40
Chromium and Ferrochromium	ESP dust	3	3	3	3	1	3,000	3,000	3,000
	GCT sludge	NA	0.03	0.3	3	1	30	300	3,000
Coal Gas	Multiple effects evaporator concentrate	NA	0	0	65	1	0	0	65,000

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
Copper	Acid plant blowdown	5300	5300	5300	5300	10	530,000	530,000	530,000
	Spent furnace brick	3	3	3	3	10	300	300	300
	WWTP sludge	6	6	6	6	10	600	600	600
Elemental Phosphorus	Andersen Filter Media	0.46	0.46	0.46	0.46	2	230	230	230
	Precipitator slurry	160	160	160	160	2	80,000	80,000	80,000
	NOSAP slurry	160	160	160	160	2	80,000	80,000	80,000
	Phossy Water	670	670	670	670	2	340,000	340,000	340,000
	Furnace scrubber blowdown	410	410	410	410	2	210,000	210,000	210,000
	Furnace Building Washdown	700	700	700	700	2	350,000	350,000	350,000
Fluorspar and Hydrofluoric Acid	Off-spec fluosilicic acid	NA	0	15	44	3	0	5,000	15,000
Germanium	Waste acid wash and rinse water	NA	0.4	2.2	4	4	100	550	1,000
	Chlorinator wet air pollution control sludge	NA	0.01	0.21	0.4	4	3	53	100
	Hydrolysis filtrate	NA	0.01	0.21	0.4	4	3	53	100
	Leach residues	0.01	0.01	0.01	0.01	3	3	3	3
	Spent acid/leachate	NA	0.4	2.2	4	4	100	550	1,000
	Waste still liquor	NA	0.01	0.21	0.4	4	3	53	100
Lead	Acid plant sludge	14	14	14	14	3	4,700	4,700	4,700
	Baghouse incinerator ash	NA	0.3	3	30	3	100	1,000	10,000
	Slurried APC Dust	7	7	7	7	3	2,300	2,300	2,300
	Solid residues	0.4	0.4	0.4	0.4	3	130	130	130
	Spent furnace brick	1	1	1	1	3	330	330	330
	Stockpiled miscellaneous plant waste	NA	0.3	67	130	3	100	22,000	43,000
	WWTP liquid effluent	2600	2600	2600	2600	3	870,000	870,000	870,000
Magnesium and Magnesia from Brines	Cast house dust	NA	0.076	0.76	7.6	1	76	760	7,600
	Smut	26	26	26	26	2	13,000	13,000	13,000
Mercury	Dust	0.007	0.007	0.007	0.007	7	1	1	1
	Quench water	NA	63	77	420	7	9,000	11,000	60,000
	Furnace residue	0.077	0.077	0.077	0.077	7	11	11	11
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	Flue dust/gases	NA	1.1	250	500	11	100	23,000	45,000
	Liquid residues	1	1	1	1	2	500	500	500
Platinum Group Metals	Slag	NA	0.0046	0.046	0.46	3	2	15	150
	Spent acids	NA	0.3	1.7	3	3	100	570	1,000
	Spent solvents	NA	0.3	1.7	3	3	100	570	1,000

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
Rare Earths	Spent ammonium nitrate processing solution	14	14	14	14	1	14,000	14,000	14,000
	Electrolytic cell caustic wet APC sludge	NA	0.07	0.7	7	1	70	700	7,000
	Process wastewater	7	7	7	7	1	7,000	7,000	7,000
	Spent scrubber liquor	NA	0.1	500	1000	1	100	500,000	1,000,000
	Solvent extraction crud	NA	0.1	2.3	4.5	1	100	2,300	4,500
	Wastewater from caustic wet APC	NA	0.1	500	1000	1	100	500,000	1,000,000
Rhenium	Spent barren scrubber liquor	NA	0	0.1	0.2	2	0	50	100
	Spent rhenium raffinate	88	88	88	88	2	44,000	44,000	44,000
Scandium	Spent acids	NA	0.7	3.9	7	7	100	560	1,000
	Spent solvents from solvent extraction	NA	0.7	3.9	7	7	100	560	1,000
Selenium	Spent filter cake	NA	0.05	0.5	5	3	17	170	1,700
	Plant process wastewater	66	66	66	66	2	33,000	33,000	33,000
	Slag	NA	0.05	0.5	5	3	17	170	1,700
	Tellurium slime wastes	NA	0.05	0.5	5	3	17	170	1,700
	Waste solids	NA	0.05	0.5	5	3	17	170	1,700
Synthetic Rutile	Spent iron oxide slurry	45	45	45	45	1	45,000	45,000	45,000
	APC dust/sludges	30	30	30	30	1	30,000	30,000	30,000
	Spent acid solution	30	30	30	30	1	30,000	30,000	30,000
Tantalum, Columbium, and Ferrocolumbium	Digester sludge	1	1	1	1	2	500	500	500
	Process wastewater	150	150	150	150	2	75,000	75,000	75,000
	Spent raffinate solids	2	2	2	2	2	1,000	1,000	1,000
Tellurium	Slag	NA	0.2	2	9	2	100	1,000	4,500
	Solid waste residues	NA	0.2	2	9	2	100	1,000	4,500
	Waste electrolyte	NA	0.2	2	20	2	100	1,000	10,000
	Wastewater	NA	0.2	20	40	2	100	10,000	20,000
Titanium and Titanium Dioxide	Pickle liquor and wash water	NA	2.2	2.7	3.2	3	730	900	1,100
	Scrap milling scrubber water	NA	4	5	6	1	4,000	5,000	6,000
	Smut from Mg recovery	NA	0.1	22	45	2	50	11,000	23,000
	Leach liquor and sponge wash water	NA	380	480	580	2	190,000	240,000	290,000
	Spent surface impoundment liquids	NA	0.63	3.4	6.7	7	90	490	960
	Spent surface impoundments solids	36	36	36	36	7	5,100	5,100	5,100
	Waste acids (Sulfate process)	NA	0.2	39	77	2	100	20,000	39,000
	WWTP sludge/solids	420	420	420	420	7	60,000	60,000	60,000
Tungsten	Spent acid and rinse water	NA	0	0	21	6	0	0	3,500

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
	Process wastewater	NA	2.2	4.4	9	6	370	730	1,500
Uranium	Waste nitric acid from UO2 production	NA	1.7	2.5	3.4	17	100	150	200
	Vaporizer condensate	NA	1.7	9.3	17	17	100	550	1,000
	Superheater condensate	NA	1.7	9.3	17	17	100	550	1,000
	Slag	NA	0	8.5	17	17	0	500	1,000
	Uranium chips from ingot production	NA	1.7	2.5	3.4	17	100	150	200
Zinc	Acid plant blowdown	130	130	130	130	1	130,000	130,000	130,000
	Waste ferrosilicon	17	17	17	17	1	17,000	17,000	17,000
	Process wastewater	5000	5000	5000	5000	3	1,700,000	1,700,000	1,700,000
	Discarded refractory brick	1	1	1	1	1	1,000	1,000	1,000
	Spent cloths, bags, and filters	0.15	0.15	0.15	0.15	3	50	50	50
	Spent goethite and leach cake residues	15	15	15	15	3	5,000	5,000	5,000
	Spent surface impoundment liquids	1900	1900	1900	1900	3	630,000	630,000	630,000
	WWTP Solids	0.75	0.75	0.75	0.75	3	250	250	250
	Spent synthetic gypsum	16	16	16	16	3	5,300	5,300	5,300
	TCA tower blowdown	0.25	0.25	0.25	0.25	1	250	250	250
	Wastewater treatment plant liquid effluent	2600	2600	2600	2600	3	870,000	870,000	870,000
Zirconium and Hafnium	Spent acid leachate from Zr alloy prod.	NA	0	0	850	2	0	0	430,000
	Spent acid leachate from Zr metal prod.	NA	0	0	1600	2	0	0	800,000
	Leaching rinse water from Zr alloy prod.	NA	34	42	51	2	17,000	21,000	26,000
	Leaching rinse water from Zr metal prod.	NA	0.2	1000	2000	2	100	500,000	1,000,000

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Haz ?	Cur-rent Re-cycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag						By-Prod	Spent Mat'l	Sludge	Waste Water	1-10% Solids	Solid
Alumina and Aluminum	Cast house dust			Y			Y			N?	N?	N?	1	Y?			1	0	0	1
	Electrolysis waste					Y?				N?	N?	N?	0.5	Y?			1	0	0	1
Antimony	Autoclave filtrate	Y?		Y?		Y?	Y?			Y?	N?	N?	0.5	YS?		1		1	0	0
	Stripped anolyte solids	Y?								N?	N?	N?	0.5	Y	1			0	0	1
	Slag and furnace residue					Y?				N?	N?	N?	0.5	N				0	0	1
Beryllium	Chip treatment wastewater				Y?					N?	N?	N?	0.5	YS?		1		1	0	0
	Spent barren filtrate							Y		N?	N?	N?	1	YS		1		1	0	0
	Filtration discard					Y?				N?	N?	N?	0.5	N				0	0	1
Bismuth	Alloy residues					Y?				N?	N?	N?	0.5	N				0	0	1
	Spent caustic soda					Y?				N?	N?	N?	0.5	Y?		1		0	1	0
	Electrolytic slimes					Y?				N?	N?	N?	0.5	Y?	1			0	0	1
	Lead and zinc chlorides					Y?				N?	N?	N?	0.5	N				0	0	1
	Metal chloride residues					Y?				N?	N?	N?	0.5	N				0	0	1
	Slag					Y?				N?	N?	N?	0.5	N				0	0	1
	Spent electrolyte					Y?				N?	N?	N?	0.5	N				0	1	0
	Spent soda solution					Y?				Y?	N?	N?	0.5	Y?		1		1	0	0
	Waste acid solutions									Y?	N?	N?	0.5	N				1	0	0
	Waste acids									Y?	N?	N?	0.5	YS?		1		1	0	0
Cadmium	Caustic washwater			Y?						Y?	N?	N?	0.5	Y?		1		1	0	0
	Copper and lead sulfate filter cakes			Y?		Y?				N?	N?	N?	0.5	Y?	1			0	0	1
	Copper removal filter cake			Y?						N?	N?	N?	0.5	Y?	1			0	0	1
	Iron containing impurities			Y?						N?	N?	N?	0.5	N				0	0	1
	Spent leach solution	Y?		Y?		Y?				Y?	N?	N?	0.5	Y?		1		0	1	0
	Lead sulfate waste			Y?		Y?				N?	N?	N?	0.5	Y?	1			0	0	1
	Post-leach filter cake			Y?						N?	N?	N?	0.5	N				0	0	1
	Spent purification solution			Y?						Y?	N?	N?	0.5	N				1	0	0
	Scrubber wastewater			Y?						Y?	N?	N?	0.5	Y?			1	1	0	0
	Spent electrolyte			Y?						Y?	N?	N?	0.5	N				0	1	0
	Zinc precipitates			Y?						N?	N?	N?	0.5	Y?	1			0	0	1
Calcium	Dust with quicklime									Y?	N?	N?	0.5	Y			1	0	0	1
Chromium and Ferrochromium	ESP dust				Y			Y		N?	N?	N?	1	YS			1	0	0	1
	GCT sludge				Y?					N?	N?	N?	0.5	Y			1	0	0	1

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Haz ?	Cur-rent Re-cycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag						By-Prod	Spent Mat'l	Sludge	Waste Water	1-10% Solids	Solid
Coal Gas	Multiple effects evaporator concentrate	Y						Y		N?	N?	N?	1	YS	1			0	1	0
Copper	Acid plant blowdown	Y		Y	Y	Y	Y	Y	Y	Y	N?	N?	1	YS			1	0	1	0
	Spent furnace brick				Y?					N?	N?	N?	0.5	Y?		1		0	0	1
	WWTP sludge			Y?		Y?				N?	N?	N?	0.5	YS			1	0	0	1
Elemental Phosphorus	Andersen Filter Media			Y						N?	N?	N?	1	N				0	0	1
	Precipitator slurry			Y?						N?	Y	Y	1	YS			1	0	1	0
	NOSAP slurry									N?	N?	Y	1	N				0	1	0
	Phossy Water			Y?						N?	Y	Y	1	YS		1		0	1	0
	Furnace scrubber blowdown			Y						Y	N?	N?	1	Y			1	1	0	0
	Furnace Building Washdown			Y						N?	N?	N?	1	Y		1		1	0	0
Fluorspar and Hydrofluoric Acid	Off-spec fluosilicic acid									Y?	N?	N?	0.5	YS	1			1	0	0
Germanium	Waste acid wash and rinse water	Y?		Y?	Y?	Y?		Y?	Y?	Y?	N?	N?	0.5	YS?		1		1	0	0
	Chlorinator wet air pollution control sludge	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?	0.5	YS?			1	0	0	1
	Hydrolysis filtrate	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?	0.5	N				0	0	1
	Leach residues			Y?		Y?				N?	N?	N?	0.5	N				0	0	1
	Spent acid/leachate	Y?				Y?				Y?	N?	N?	0.5	YS?		1		1	0	0
	Waste still liquor	Y?		Y?	Y?	Y?		Y?	Y?	N?	Y?	N?	0.5	N				0	0	1
Lead	Acid plant sludge									Y?	N?	N?	0.5	Y?			1	0	0	1
	Baghouse incinerator ash			Y		Y				N?	N?	N?	1	N				0	0	1
	Slurried APC Dust			Y		Y				N?	N?	N?	1	Y			1	0	0	1
	Solid residues					Y?				N?	N?	N?	0.5	Y?	1			0	0	1
	Spent furnace brick					Y				N?	N?	N?	1	Y		1		0	0	1
	Stockpiled miscellaneous plant waste			Y		Y				N?	N?	N?	1	YS?		1		0	0	1
	WWTP liquid effluent					Y?				Y?	N?	N?	0.5	Y		1		1	0	0
Magnesium and Magnesia from Brines	Cast house dust		Y?							N?	N?	N?	0.5	Y?			1	0	0	1
	Smut		Y							N?	N?	N?	1	N				0	0	1
Mercury	Dust						Y?			N?	N?	N?	0.5	N				0	0	1
	Quench water					Y?	Y?			N?	N?	N?	0.5	Y?		1		1	0	0
	Furnace residue						Y?			N?	N?	N?	0.5	N				0	0	1

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Haz ?	Cur-rent Re-cycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag						By-Prod	Spent Mat'l	Sludge	Waste Water	1-10% Solids	Solid
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	Flue dust/gases					Y?				N?	N?	N?	0.5	N				0	0	1
	Liquid residues	Y?		Y?		Y?		Y?		N?	N?	N?	0.5	N				1	0	0
Platinum Group Metals	Slag					Y?		Y?		N?	N?	N?	0.5	Y?	1			0	0	1
	Spent acids					Y?			Y?	Y?	N?	N?	0.5	N				1	0	0
	Spent solvents					Y?			Y?	N?	Y?	N?	0.5	N				1	0	0
Rare Earths	Spent ammonium nitrate processing solution									Y	N?	N?	1	0				1	0	0
	Electrolytic cell caustic wet APC sludge									Y?	N?	N?	0.5	Y			1	0	0	1
	Process wastewater					Y				Y?	N?	N?	1	YS?		1		1	0	0
	Spent scrubber liquor									Y?	N?	N?	0.5	YS?			1	1	0	0
	Solvent extraction crud									N?	Y?	N?	0.5	N				0	0	1
	Wastewater from caustic wet APC				Y?	Y?				Y?	N?	N?	0.5	YS?			1	1	0	0
Rhenium	Spent barren scrubber liquor							Y?		N?	N	N	0.5	Y?			1	1	0	0
	Spent rhenium raffinate					Y?				N?	N?	N?	0.5	N				0	0	1
Scandium	Spent acids									Y?	N?	N?	0.5	N				1	0	0
	Spent solvents from solvent extraction									N?	Y?	N?	0.5	Y?		1		1	0	0
Selenium	Spent filter cake							Y?		N?	N?	N?	0.5	Y?	1			0	0	1
	Plant process wastewater					Y				Y	N?	N?	1	YS?		1		1	0	0
	Slag							Y?		N?	N?	N?	0.5	YS?	1			0	0	1
	Tellurium slime wastes							Y?		N	N?	N?	0.5	Y?	1			0	0	1
	Waste solids							Y?		N?	N?	N?	0.5	N				0	0	1
Synthetic Rutile	Spent iron oxide slurry			Y?	Y?					N?	N?	N?	0.5	YS?	1			0	0	1
	APC dust/sludges			Y?	Y?					N?	N?	N?	0.5	Y			1	0	0	1
	Spent acid solution			Y?	Y?					Y?	N?	N?	0.5	Y		1		1	0	0
Tantalum, Columbium, and Ferrocolumbium	Digester sludge									Y?	N?	N?	0.5	N				0	0	1
	Process wastewater	Y?		Y?	Y?	Y?		Y?		Y	N?	N?	1	Y?		1		0	1	0
	Spent raffinate solids									Y?	N?	N?	0.5	N				0	0	1
Tellurium	Slag							Y?		N?	N?	N?	0.5	YS?	1			0	0	1
	Solid waste residues							Y?		N?	N?	N?	0.5	N				0	0	1
	Waste electrolyte					Y?		Y?		N?	N?	N?	0.5	N				1	0	0

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Haz ?	Current Re-cycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag						By-Prod	Spent Mat'l	Sludge	Waste Water	1-10% Solids	Solid
	Wastewater							Y?		Y?	N?	N?	0.5	Y		1		1	0	0
Titanium and Titanium Dioxide	Pickle liquor and wash water			Y?	Y?	Y?				Y?	N?	N?	0.5	YS?		1		1	0	0
	Scrap milling scrubber water			Y?	Y?	Y?		Y?		N?	N?	N?	0.5	YS?			1	1	0	0
	Smut from Mg recovery									N?	N?	Y	1	Y?	1			0	0	1
	Leach liquor and sponge wash water				Y?	Y?				Y	N?	N?	1	YS?		1		1	0	0
	Spent surface impoundment liquids				Y?	Y?				N?	N?	N?	0.5	Y?		1		1	0	0
	Spent surface impoundments solids				Y?	Y?				N?	N?	N?	0.5	N				0	0	1
	Waste acids (Sulfate process)	Y			Y			Y	Y	Y	N	N	1	N				1	0	0
	WWTP sludge/solids				Y?					N	N	N	0.5	N				0	0	1
Tungsten	Spent acid and rinse water									Y?	N?	N?	0.5	YS?		1		1	0	0
	Process wastewater									Y?	N?	N?	0.5	YS?		1		1	0	0
Uranium	Waste nitric acid from UO2 production									Y?	N?	N?	0.5	YS?		1		1	0	0
	Vaporizer condensate									Y?	N?	N?	0.5	N				1	0	0
	Superheater condensate									Y?	N?	N?	0.5	N				1	0	0
	Slag									N?	Y?	N?	0.5	Y	1			0	0	1
	Uranium chips from ingot production									N?	Y?	N?	0.5	Y?	1			0	0	1
Zinc	Acid plant blowdown	Y		Y	Y	Y?	Y?	Y	Y	Y	N	N	1	Y			1	1	0	0
	Waste ferrosilicon					Y?				N?	N?	N?	0.5	Y?	1			0	0	1
	Process wastewater	Y		Y	Y	Y		Y	Y	Y	N?	N?	1	Y?		1		1	0	0
	Discarded refractory brick	Y?		Y?	Y?	Y?				N?	N?	N?	0.5	N				0	0	1
	Spent cloths, bags, and filters			Y?		Y?	Y?	Y?	Y?	N?	N?	N?	0.5	Y		1		0	0	1
	Spent goethite and leach cake residues	Y		Y	Y	Y?	Y?	Y	Y	N?	N?	N?	1	Y				0	0	1
	Spent surface impoundment liquids			Y?						Y	N?	N?	1	YS?		1		1	0	0
	WWTP Solids	Y?		Y?		Y?	Y?	Y?	Y?	N?	N?	N?	0.5	YS			1	0	0	1
	Spent synthetic gypsum	Y?		Y		Y?				N?	N?	N?	1	N				0	0	1
	TCA tower blowdown			Y?		Y?	Y?	Y?		Y?	N?	N?	0.5	YS		1		1	0	0
	Wastewater treatment plant liquid effluent			Y?						N?	N?	N?	0.5	YS?		1		1	0	0

EXHIBIT 2-11 (Continued)

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Haz ?	Cur-rent Re-cycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag						By-Prod	Spent Mat'l	Sludge	Waste Water	1-10% Solids	Solid
Zirconium and Hafnium	Spent acid leachate from Zr alloy prod.									Y?	N?	N?	0.5	N				1	0	0
	Spent acid leachate from Zr metal prod.									Y?	N?	N?	0.5	N				1	0	0
	Leaching rinse water from Zr alloy prod.									Y?	N?	N?	0.5	YS?		1		1	0	0
	Leaching rinse water from Zr metal prod.									Y?	N?	N?	0.5	YS?		1		1	0	0

III. MINERAL COMMODITIES

A. INDIVIDUAL MINERAL COMMODITY REVIEWS

ALUMINA & ALUMINUM

A. Commodity Summary

Aluminum, the third most abundant element in the earth's crust, is usually combined with silicon and oxygen in rock. Rock that contains high concentrations of aluminum hydroxide minerals is called bauxite. Although bauxite, with rare exceptions, is the starting material for the production of aluminum, the industry generally refers to metallurgical grade alumina extracted from bauxite by the Bayer Process, as the ore. Aluminum is obtained by electrolysis of this purified ore.[1]

The United States is entirely dependent on foreign sources for metallurgical grade bauxite. Bauxite imports are shipped to domestic alumina plants, which produce smelter grade alumina for the primary metal industry. These alumina refineries are in Louisiana, Texas, and the U.S. Virgin Islands.[2] The United States must also import alumina to supplement this domestic production. Approximately 95 percent of the total bauxite consumed in the United States during 1994 was for the production of alumina. Primary aluminum smelters received 88 percent of the alumina supply. Fifteen companies operate 23 primary aluminum reduction plants. In 1994, Montana, Oregon, and Washington accounted for 35 percent of the production; Kentucky, North Carolina, South Carolina, and Tennessee combined to account for 20 percent; other states accounted for the remaining 45 percent. The United States is the world's leading producer and the leading consumer of primary aluminum metal. Domestic consumption in 1994 was as follows: packaging, 30 percent; transportation, 26 percent; building, 17 percent; electrical, 9 percent; consumer durables, 8 percent; and other miscellaneous uses, 10 percent. The 1994 production of aluminum was 3,300,000 metric tons while the production capacity was 4,163,000 metric tons per year.[3] Exhibits 1 and 2 list the names and locations of the domestic alumina and aluminum production plants. In addition, 1992 production capacities have been provided in Exhibit 2 for some of the aluminum producers.

EXHIBIT 1

SUMMARY OF ALUMINA PROCESSING FACILITIES

Facility Name	Location	Process Methods
ALCOA	Point Comfort, TX	Bayer
Kaiser (1992 alumina prod. was 1.06 mt[4])	Gramercy, LA	Bayer
Martin	St. Croix, VI	Bayer
Ormet	Burnside, LA	Bayer
Reynolds	Corpus Christi, TX	Bayer

[1] "Aluminum and Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. II, 1991, pp. 190-212.

[2] Patricia A. Plunkert and Errol D. Sehnke, "Aluminum, Bauxite, and Alumina," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 183-203.

[3] Patricia Plunkert, "Aluminum," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 16-17.

[4] Patricia Plunkert, 1992, Op. Cit., pp. 183-203.

EXHIBIT 2

SUMMARY OF ALUMINUM PROCESSING FACILITIES

Facility Name	Location	Type of Operations	1992 Production Capacity[5] (1000 metric tons)
ALCOA	Warrick, IN Massena, NY Badin, NC Alcoa, TN Rockdale, TX Wenatchee, WA	Hall-Heroult Hall-Heroult Hall-Heroult Hall-Heroult Hall-Heroult Hall-Heroult	Unknown Unknown Unknown Unknown Unknown Unknown
ALUMAX	Mt. Holly, SC	Hall-Heroult	275
Alcan Aluminum Corp.	Henderson, KY	Hall-Heroult	Unknown
Columbia Aluminum Corp.	Goldendale, WA	Hall-Heroult	Unknown
Eastico	Frederick, MD	Hall-Heroult	Unknown
Intalco	Ferndale, WA	Hall-Heroult	Unknown
Kaiser Aluminum Corp.	Spokane, WA Tocoma, WA	Hall-Heroult Hall-Heroult	Unknown Unknown
Columbia Falls Aluminum Corp.	Columbia Falls, MT	Hall-Heroult	Unknown
National South Wire	Hawesville, KY	Hall-Heroult	Unknown
Noranda	New Madrid, MO	Hall-Heroult	215
Northwest	The Dalles, OR	Hall-Heroult	82
Ormet	Hannibal, OR	Hall-Heroult	Unknown
Ravenswood	Ravenswood, WV	Hall-Heroult	Unknown
Reynolds	Massena, NY Troutdale, OR Longview, WA	Hall-Heroult Hall-Heroult Hall-Heroult	123 121 204
Venalco	Vancouver, WA	Hall-Heroult	Unknown

[5] Ibid.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Free moisture in crude bauxite, as mined, may range from five to 30 percent. To produce dry bauxite, most of the free moisture is removed by heating crude bauxite in rotary drying kilns. Calcined bauxite is produced by heating bauxite to reduce total volatile matter, including chemically combined water, to less than one percent. Approximately two tons of crude ore is required to produce one ton of calcined bauxite.

Alumina tri-hydrate is used for the production of the pure aluminum chemicals, high quality refractories, and other high aluminum products, while aluminum is used for the preparation of the purest aluminum chemicals. Alumina and bauxite are the principal raw materials for the production of aluminum chemicals such as aluminum sulfate, aluminum chloride, aluminum fluoride, sodium aluminate, and aluminum acetate.[6]

Metallurgical grade alumina (i.e., 30 to 60 percent aluminum oxide)[7] is extracted from bauxite by the Bayer process and aluminum is obtained from this purified ore by electrolysis via the Hall-Heroult process. These processes are described below. Exhibits 3 and 4 present process flow diagrams for the Bayer process and the Hall-Heroult process.

2. Generalized Process Flow Diagram

Bayer Process

A process flow diagram of the Bayer process is shown in Exhibit 3. The primary purpose of a Bayer plant is to process bauxite to provide pure alumina for the production of aluminum. All bauxite refineries share five common process steps: (1) ore preparation; (2) bauxite digestion; (3) clarification; (4) aluminum hydroxide precipitation; and (5) calcination to anhydrous alumina. Additional operations include steam and power generation, heat recovery to minimize energy consumption, process liquor evaporation to maintain a water balance, impurity removal from process liquor streams, classification and washing of trihydrate, lime causticization of sodium carbonate to sodium hydroxide, repair and maintenance of equipment, rehabilitation of residue disposal sites, and quality and process control. Each step in the process can be carried out in a variety of ways depending upon bauxite properties and optimum economic tradeoffs. Each of these steps is discussed in further detail below.[8]

Ore Preparation

Bauxite mining processes depend largely on the nature of the ore body. If the ore is not uniform, contains an excessive amount of kaolin, or is difficult to handle due to the moisture content, blending operations, physical beneficiation, and bauxite drying are used. Grinding is designed to produce feed material small enough to ensure easy alumina extraction, yet coarse enough to avoid clarification problems with bauxite residue. Uniform, consistent, easily digested bauxite slurry is formed by blending properly ground bauxite slurry in slurry storage "surge" tanks prior to digestion.[9]

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[6] V.J. Hill, "Bauxite," from Industrial Minerals and Rocks, 6th ed., Society for Mining, Metallurgy, and Exploration, 1994, pp. 135-147.

[7] Aluminum Company of America. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[8] "Aluminum Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. II, 1991, pp. 254-261.

[9] Ibid.

Bauxite Digestion

Digestion extracts and solubilizes the available aluminum mineral from the bauxite. In digestion, which is performed in steel vessels, autoclaves, or tubular reactors, hot spent liquor reacts with the aluminum minerals in the bauxite to form soluble sodium aluminate ($NaAlO_3$)[10]. Virtually all other constituents are rejected as undissolved solids. Other important reactions that occur in digestion are desilication, causticization of liquor, and precipitation of impurities. The reactive silica in bauxite, such as that in kaolin, reacts with the caustic solution to form soluble sodium silicate, which then reacts at digester temperature to form an insoluble sodium aluminum silicate known as "desilication product." Causticization, the reaction of hydrated lime with sodium carbonate to regenerate sodium hydroxide and precipitate calcium carbonate, is an important part of the Bayer process chemistry. Na_2CO_3 is formed in Bayer liquors by caustic degradation of the organics in bauxite and by absorption of carbon dioxide during exposure of process liquors to the atmosphere. Although poor lime efficiency and alumina losses during digestion as calcium aluminates have led to the practice of "outside" causticization of dilute pregnant liquors in the residue washing area of the plant, digestion lime additions are still made to control impurities such as phosphorus pentoxide.[11]

Clarification

Clarification is necessary to separate bauxite residue solids from the supersaturated pregnant liquor near its boiling point. Coarse particles, called sand because of their high silica content, are usually removed by cycloning followed by washing on sand classifiers prior to disposal. Iron oxide, silica, and other undigested portions of the ore are also removed in settling, thickening, and filtration units, and sent to treatment and disposal units. These wastes are commonly called red and brown muds; these two wastes are RCRA special wastes and therefore are not subject to LDR regulations.[12] In most plants, the fine fraction of residue is settled in raking thickeners with the addition of flocculants to improve the clarity of thickener overflow. The concentrated thickener underflow is washed before disposal in countercurrent decantation washers, on vacuum drum-type filters, or a combination of both. Thickener overflow is filtered to remove the final traces of solids and ensure product purity. Kelly-type pressure filters are most widely used, but some plants use sand filters in which the liquor is filtered by gravity through a bed of properly sized sand. Filtered solids are removed from filter press cloth by hosing and are elutriated from the sand by backwashing.[13]

Aluminum Hydroxide Precipitation

Precipitation is the heart of the Bayer process where recovery of the $Al(OH)_3$ from process liquors occurs in high yield and product quality is controlled. In 1988, practically all of the hydroxide was obtained by Bayer processing and 90 percent of it was calcined to metallurgical grade alumina (Al_2O_3). The liquor is usually seeded with fine gibbsite seed from previous cycles to initiate precipitation. Precipitation can be continuous or batch. Modern plants use the continuous system. Slurry leaving precipitation is classified into a coarse fraction and one or more fine fractions, usually by elutriation in hydroclassifiers. In smelting grade alumina plants, the coarse fraction, called primary product, is sent to calcination; the fine fractions, called secondary and tertiary seed, are recycled to be grown to product size.[14]

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[10] Aluminum Company of America. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[11] Ibid.

[12] U.S. Environmental Protection Agency, "Aluminum Production," from Report to Congress on Special Wastes from Mineral Processing, Vol. II, Office of Solid Waste, July 1990, pp. 3-1 - 3-15.

[13] "Aluminum Compounds," Op.Cit., pp. 254-261.

[14] Ibid.

Calcination to Anhydrous Alumina

Calcination, the final operation in the Bayer process for production of metallurgical grade alumina, is performed either in rotary kilns or fluid bed stationary calciners. Prior to calcination, the process liquor is washed from the $Al(OH)_3$ using storage tanks and horizontal vacuum filters. During heating, the trihydroxide undergoes a series of changes in composition and crystal structure but essentially no change in particle shape. The product is a white powder and consists of aggregates of differing sizes.[15]

Evaporation and Impurity Removal

Evaporation over and above that obtained in the cooling areas from flashed steam is usually required to maintain a water balance by accounting for the dilution arising from residue and $Al(OH)_3$ washing, free moisture in the ore, injected steam, purge water, and uncontrolled dilutions. Evaporation also serves to concentrate impurities in the liquor stream such as sodium oxalate (a product of organics degradation), facilitating the removal of these impurities.[16]

Hall-Heroult Process

Reduction

Since the development of the Hall-Heroult process, nearly all aluminum has been produced by electrolysis of alumina dissolved in a molten cryolite based bath. Molten aluminum is deposited on a carbon cathode, which serves also as the melt container. Simultaneously, oxygen is deposited on and consumes the cell's carbon anodes. The overall all reaction is[17]:

$$2Al_2O_3 + 3C - 4Al + 3\ CO_2$$

Cryolite is the primary constituent of the Hall-Heroult cell electrolyte. Because of its rarity and cost, synthetic cryolite is substituted. Synthetic cryolite is manufactured by reacting hydrofluoric acid with sodium aluminate from the Bayer process. Once the smelting process is in operation, no cryolite is needed because cryolite is produced in the reduction cells by neutralizing the Na_2O brought into the cell as an impurity in the alumina using aluminum fluoride. Thus, the operating cells require inputs of aluminum fluoride. Aluminum fluoride is produced in a fluidized bed by the reaction of hydrofluoric acid gas and activated alumina made by partially calcining the alumina hydrate from the Bayer process. Alumina fluoride is also made by the reaction of fluosilicic acid, a by-product of phosphoric acid production, and aluminum hydroxide from the Bayer process. The aluminum fluoride solution is filtered, and AlF_3 is precipitated by heating, then is flash dried and calcined.

The equivalent of 3-4 kg of fluoride per metric ton of aluminum produced is absorbed from the bath into the cell lining over the lining's 3 to 10 year life. The most common method of recovery treats the crushed lining using dilute NaOH to dissolve the cryolite and other fluorides. The solution is filtered and Na_3AlF_6 is precipitated by neutralizing the NaOH using carbon dioxide. The aluminum industry in the United States uses about 15 kg of fluoride ion per metric ton aluminum, 10-25 percent of which is lost. The remainder, consisting of cryolite generated in reduction cells and of bath in scrap cell linings, is stored for future use. New fluoride for the aluminum industry comes largely from fluorspar and phosphate rock.

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[15] Ibid.

[16] Ibid.

[17] Ibid.

EXHIBIT 3

THE BAYER PROCESS

(Adapted from: Development Document for Effluent Limitations, 1989.)

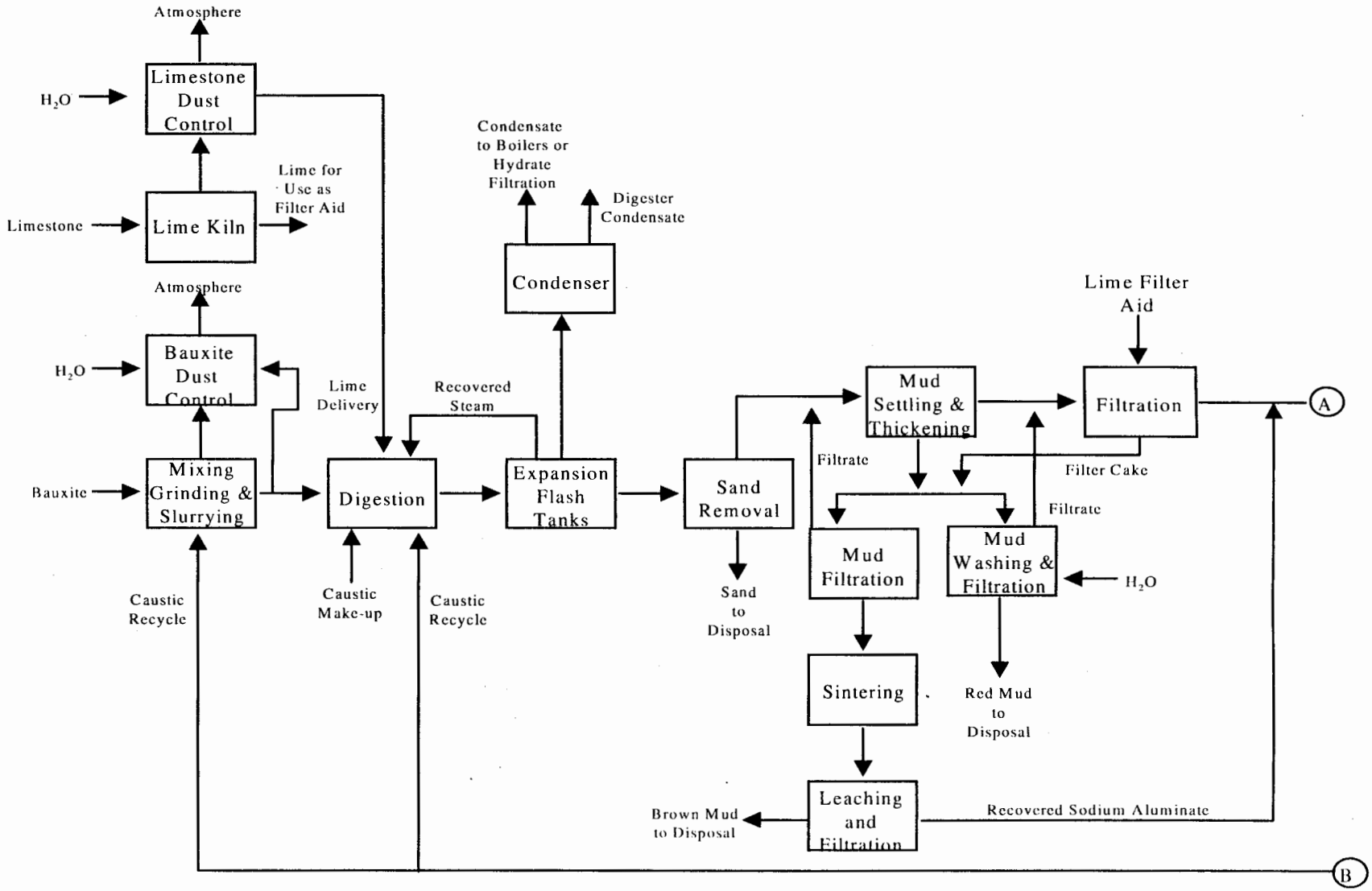


EXHIBIT 3 (Continued)

THE BAYER PROCESS

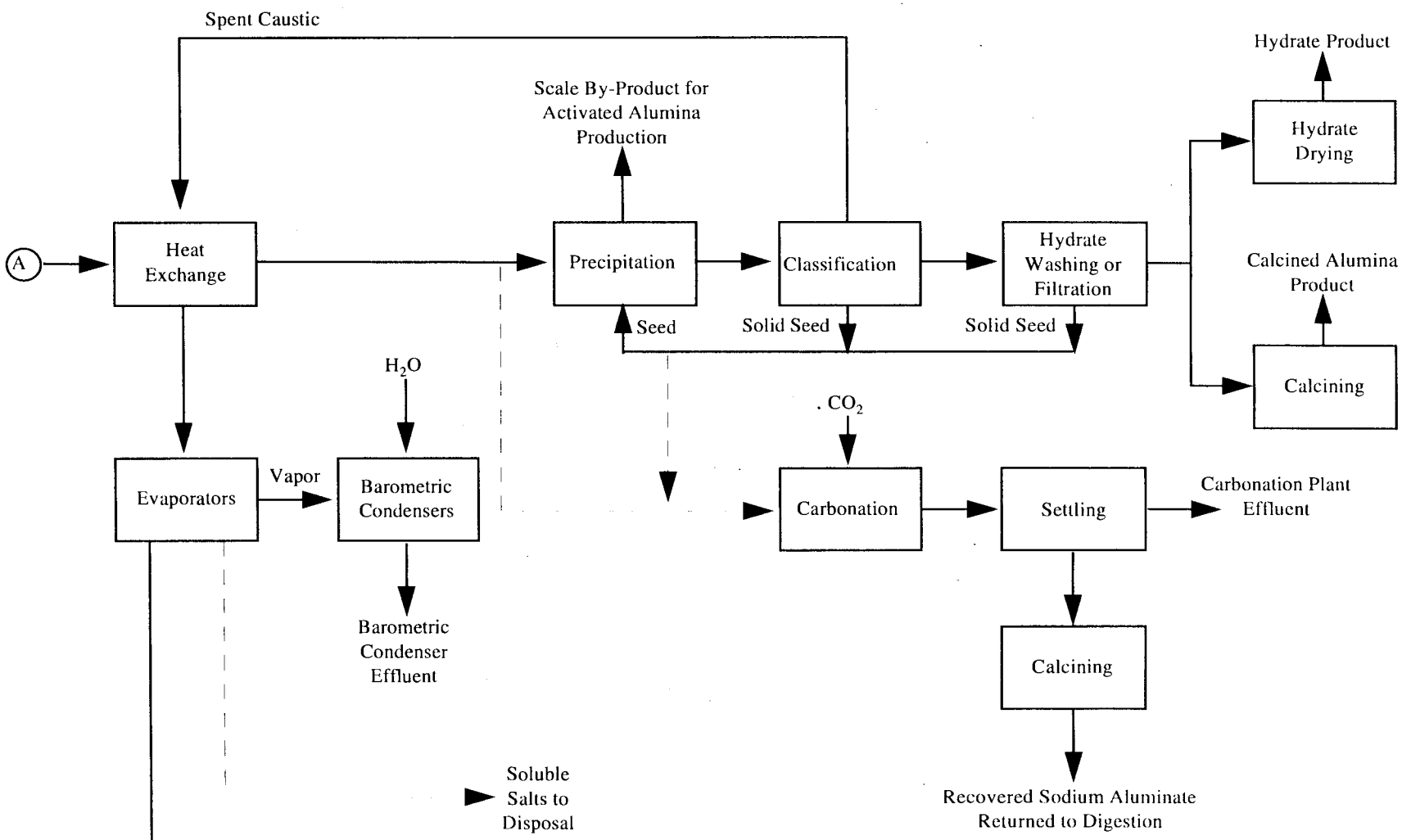
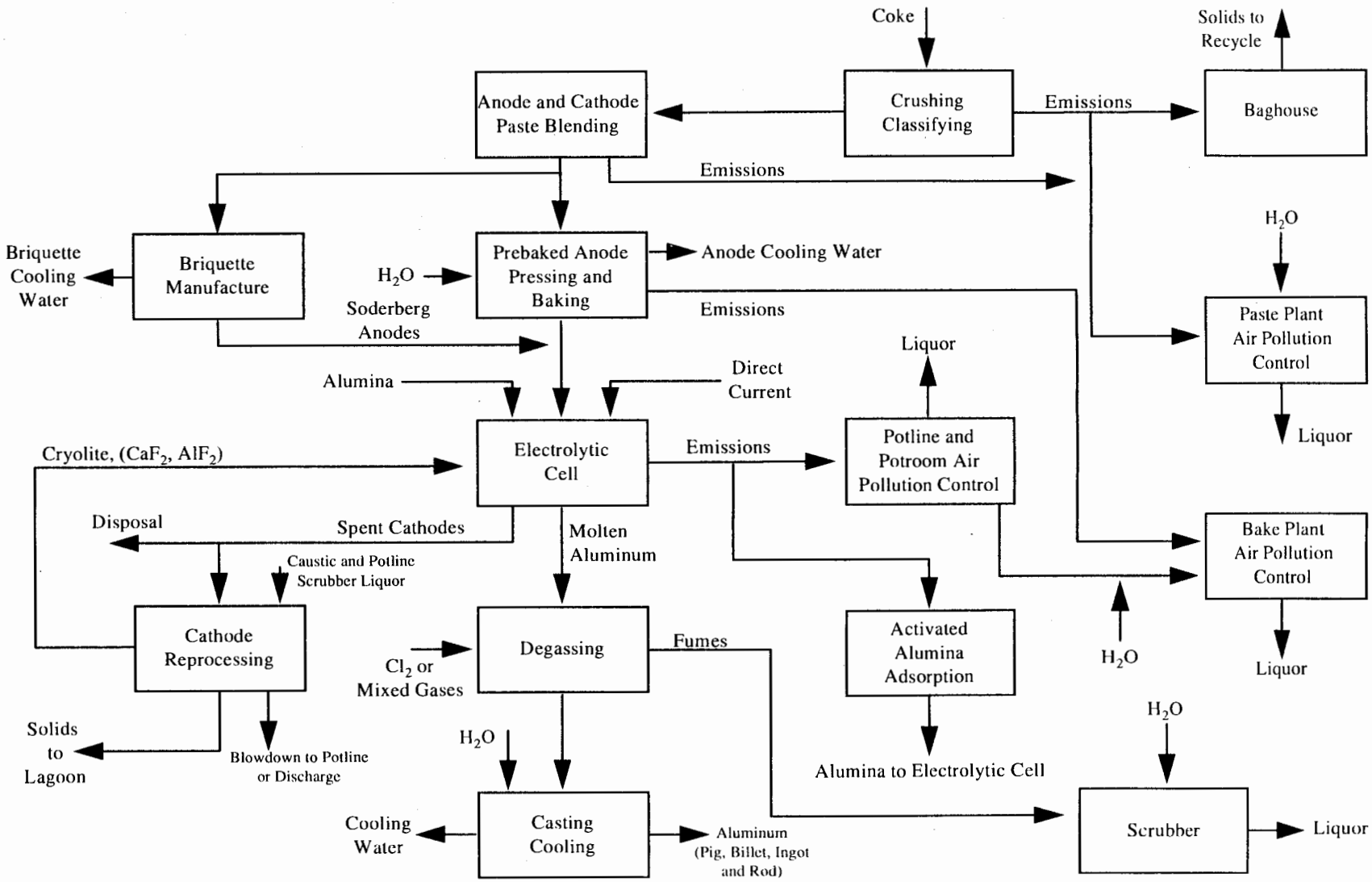


EXHIBIT 4

THE HALL-HEROULT PROCESS

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989.)



Fluxing and Degassing

The molten aluminum collected in the bottom of the electrolytic pots is tapped and conveyed to holding furnaces for subsequent refining and alloying. Refining consists of fluxing to remove impurities and degassing to reduce entrapped hydrogen gas in the molten aluminum. These two operations are often performed prior to casting. Degassing is performed by injecting chlorine, nitrogen, argon, helium, and mixtures of chlorine and inert gases into the molten aluminum. Hydrogen desorbs into the chlorine bubble due to the partial pressure difference between the elements. The addition of a gas to the melt also mixes the aluminum to assure that all materials added concurrently for alloying are distributed evenly in the molten aluminum. Chlorine gas reacts with trace element impurities to form insoluble salt particles. These salt particles and the metal oxide impurities rise to the surface of the molten bath through specific gravity differences and flotation, respectively. The impurities collect at the surface of the molten metal and are skimmed and removed from the furnace.[18]

Casting

Casting is generally the final step at most aluminum reduction plants. The most common methods for casting include: pig and sow casting, direct chill casting, continuous rod casting, and shot casting.

Stationary casting is used to cast *pigs and sows* (ingots). In this method of casting, the molds are stationary and the contact cooling water (if used) generally evaporates.[19]

There are two methods of *direct chill casting*, vertical and horizontal. Vertical direct chill casting is characterized by continuous solidification of the metal while it is being poured. The length of the ingot or billet cast using this method is determined by the vertical distance it is allowed to drop rather than by mold dimensions. Molten aluminum is tapped from the smelting furnace and flows through a distributor channel into a shallow mold. Noncontact cooling water circulates within this mold, causing solidification of the aluminum. As the solidified aluminum leaves the mold, it is sprayed with contact cooling water to reduce the temperature of the forming ingot or billet. The cylinder descends into a tank of water, causing further cooling of aluminum as it is immersed. When the cylinder reaches its lowest position, pouring stops, the ingot is removed, and the process is repeated to create another ingot. Horizontal chill casting is performed in much the same manner as vertical chill casting. The main difference is that the cast aluminum is conveyed from the mold in the horizontal direction rather than vertically.[20]

In *continuous rod casting*, a ring mold is fitted into the edge of a rotating casting wheel. Molten aluminum is then poured into the mold and cools as the mold assembly rotates. After the wheel has rotated about 160 degrees, the pliable aluminum bar is released. Immediately following release from casting, the rod is transported on conveyers to a rolling mill where the diameter of the rod is reduced.[21]

In *shot casting*, aluminum shot is used as a deoxidant. Molten metal is poured into a vibrating feeder, where droplets of molten metal are formed through perforated openings. The droplets are cooled in a quench tank.[22]

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[18] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Vol II, Office of Water Regulations Standards, May 1989.

[19] Ibid.

[20] Ibid.

[21] Ibid.

[22] Ibid.

Anode Paste Plant

Fabrication of anodes takes place in the anode paste plant where coal tar pitch and ground petroleum coke are blended together to form paste. During electrolysis, the prebaked anode is gradually consumed and becomes too short to be effective. The resulting anode "butts" are recycled for use in the paste plant. Operations in the paste plant include crushing, screening, calcining, grinding, and mixing. The paste is then formed into briquettes or into green prebaked anodes. In this stage, briquettes and green anodes are essentially the same, differing only in size. Briquettes are formed through an extrusion process in which the paste is forced through a die and then chopped into small pieces using a dicer. Green anodes, which are much larger than briquettes, are formed by pressing paste into a mold. Vibration may also be used. After forming, cooling water is used to quench the briquette or anodes to facilitate handling.

Anode Bake Plant

Anodes used in prebaked potline cells are baked prior to their use in the potline. Two basic furnace types are used to bake anodes, ring furnaces and tunnel kilns. In the ring furnace, green anodes are packed into pits with a blanket of coke or anthracite filling the space between the anode blocks and the walls of the pits. A blanket of calcined petroleum coke also fills the top of each pit above the top layer of anodes to help prevent oxidation of the carbon anodes.

Each pit is baked for a period of about 40-48 hours. The flue system of the furnace is arranged so that hot gas from the pits being baked is drawn through the next section of pits to gradually preheat the next batch of anodes before they are baked. Air for combustion is drawn through the sections previously baked, cooling them. The baked anodes are then stripped from the furnace pits.

In the tunnel kiln, a controlled atmosphere is maintained to prevent oxidation of the carbon anodes. Green anode blocks are loaded on transporter units that enter the kiln through an air lock, pass successively through a preheating zone, a baking zone, and a cooling zone, and leave the kiln through a second air lock. The refractory beds of the cars are sealed mechanically to the kiln walls to form the muffle chamber and permit movement of the units through the kiln. The muffle chamber is externally heated by combustion gases and the products of combustion are discharged through an independent stack system. Effluent gases from the baking anodes may be introduced into the fire box so as to recover the fuel value of hydrocarbons and reduce the quantity of unburned hydrocarbons. Baked anodes are delivered to air blast cleaning machines using fine coke as blasting grit. Fins, scrafs, and adherent packing are removed by this treatment, and the baked anodes are then transferred to the rod shop where the electrodes are attached.[23]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Several diverse research initiatives have been carried out to reduce the quantity and/or toxicity of the numerous production wastes generated in the alumina/aluminum industry. Spent potliner wastes (SPL) from aluminum reduction (Hazardous Waste Number K088) have become one of the aluminum industry's biggest environmental concerns. Reynolds Metals Company (Reynolds) developed a process for detoxifying SPL in which the SPL was blended with limestone and an antiagglomeration agent and thermally treated in a rotary kiln. The process is successful in destroying cyanides and reducing the concentration of soluble fluorides in the kiln residue. The cyanides are destroyed by oxidation and the majority of soluble fluoride salts are converted to stable, insoluble calcium fluoride by reaction with limestone. The process was developed and utilized for more than 2 years on an industrial scale at Reynolds' idled Hurricane Creek Alumina Plant in Bauxite, AR. More than 300,000 tons of SPL reportedly were treated successfully during this period.[24] In fact, Reynolds received a RCRA delisting variance for this waste stream.

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[23] Ibid.

[24] Patricia Plunkert, 1992, Op. Cit., pp. 183-203.

On April 8, 1996, EPA finalized land disposal restrictions for K088 and established treatment standards based on the Reynolds process described above. While the Agency determined at that time that adequate treatment capacity was available, for several logistical and other reasons, the Agency decided to grant a nine-month capacity variance for K088, until January 8, 1997. Some of the logistical barriers to complying with the LDRs included pretreament requirements, such as grinding or crushing, that generators of waste would need to meet prior to sending the wastes to the treatment facility. Also, some facilities generating K088 needed time to work out such logistical issues as transportation, pretreatment capacity, and contracting for treatment capacity. Shortly following the Agency's decision to grant the extension, several aluminum producers petitioned for a full two-year capacity variance and modification of the treatment standards. The petition cited problems that had been identified with the Reynolds process. In response to the petition, the Agency extended the capacity variance for an additional six months, to July 8, 1997. A further extension was granted to October 8, 1997. No further action was taken by the Agency when that variance expired; LDRs and the the treatment standards promulgated in April 1996 therefore became effective on October 8, 1997.

An alternative treatment known as the COMTOR process was developed at Comalco's Research Center in Melbourne, Australia. The process has three stages--feed preparation, calcination, and fluoride recovery. Crushing the SPL before treatment reportedly improved the rate and quality of the detoxification process. The COMTOR process utilized a new type of calciner, known as a Torbed. Calcination reportedly was the most effective method for reducing the leachable cyanide content of the SPL. Ash treatment recovered the fluoride values for recycling directly to the electrolytic cell. Once the cyanide was destroyed and the fluorides either recovered or stabilized, the residue reportedly passed the standard leach tests and was no longer considered toxic.[25]

The Florida Institute of Phosphate Research (FIPR) reportedly has developed a dewatering process that may achieve promising results on red mud waste streams from the Bayer process operations. The FIPR process consists of adding pulp fibers with a polyacrylamide flocculant. The fibers assist in the formation of large flocs that have the physical stability to withstand normal industrial dewatering techniques.[26]

Biological methods of converting sodium oxalate, generated from the Bayer process production of alumina, have been tested. The use of micro-organisms to dispose of sodium oxalate was said to be far simpler and cheaper than the currently employed burning and landfilling methods of disposal.[27]

Manganese dioxide treatment has been found to cause a beneficial decrease in the soda content of the alumina and that a small reduction in the total organic carbon levels with this treatment also may be significant in improving the viscosity of the liquor.[28]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

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[25] Ibid.

[26] Ibid.

[27] Ibid.

[28] Ibid.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between bauxite ore preparation and bauxite digestion because the bauxite ore is vigorously attacked (digested) by a strong chemical agent, thereby destroying the physical structure of the mineral, to produce sodium aluminate. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated downstream of the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Water softener sludge. The 1991 total waste volume generation rate for this waste stream was 2,000 metric tons per year.[29] Because this waste is not a mineral processing waste, the Agency did not evaluate it further.

2. Mineral Processing Wastes

Alumina Production

Existing data and engineering judgment suggest that the materials listed below from alumina production do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

Evaporator Salt Waste. The 1991 total waste volume generation rate for this waste stream was 2,000 metric tons per year.[30]

Bauxite Residue. The 1991 total waste volume generation rate for this waste stream was 137,000 metric tons per year.[31] Placement in impoundments behind retaining dikes built around clay-lined ground is commonly used for disposal of bauxite residue. Leaks into aquifers have motivated the installation of underdrains between the residue and a clay-sealed, plastic-lined lake bottom. Another method of disposal is called semidry disposal, dry-stacking, or the drying field method. This method takes advantage of the thixotropic nature of the residue. The

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[29] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Wastes Characterization Data Set, Vol. I, Office of Solid Waste, August 1992, pp. I-2 - I-8.

[30] Ibid.

[31] Ibid.

residue is concentrated by vacuum filtration or other means to 35-50 percent solids. Using agitation and/or additives, the viscosity of the concentrated slurry is reduced so it can be pumped to the disposal area where it flows like lava. The slurry is called nonsegregating because neither water nor sand separate from it. As viscosity increases, the flow stops. There is no free water on the surface of the impoundment, so the deposited residue dries and cracks whenever it is not raining. When the percent solids approaches 70-75 percent, bulldozers can work on the deposit.[32]

Waste Alumina. The 1991 total waste volume generation rate for this waste stream was 7,000 metric tons per year.[33]

Spent Cleaning Residue. The 1991 total waste volume generation rate for this waste stream was 3,000 metric tons per year.[34]

Pisolites. Kaiser, in Gramercy, LA reported generating 72,920 metric tons of this waste in 1988. Reportedly, this waste was either sold for construction of farm roads or sent to a pisolite storage pile which is lined with an in-situ clay barrier.[35]

Wastewater. There are four sources of wastewater from bauxite production--(1) digester condensate, (2) barometric condenser effluent, (3) carbonation plant effluent, and (4) mud impoundment effluent. Digester condensate may be recycled to product wash or boiler water. Barometric condensate is a good quality, somewhat alkaline water. Mud impoundment effluent is recycled or discharged. These wastewaters are not expected to be hazardous. Waste characterization data are presented in Attachment 1.

Red and brown muds result from the clarification step of the Bayer process and are RCRA exempt special wastes. The 1991 total waste generation rate for this waste stream was 2,800,000 metric tons per year.[36] The red and brown muds are routed to large on-site surface impoundments known as red and brown mud lakes. In these lakes, the red and brown muds settle to the bottom and the water is removed, treated, and either discharged or reused. The muds are not removed, but are accumulated and disposed in place. The muds dry to a solid with a very fine particle size. The impoundments that receive the muds typically have a surface area of between 44.6 and 105.3 hectares. The depth of the impoundments ranges from 1 to 16 meters and averages 7 meters. As of 1988, the quantity of muds accumulated on-site ranged from 500,000 to 22 million metric tons per facility, with an average of 9.7 million metric tons per facility.[37]

Red and brown muds contain significant amounts of iron, aluminum, silicon, calcium, and sodium. Red muds may also contain trace amounts of elements such as barium, boron, cadmium, chromium, cobalt, gallium, vanadium, scandium, and lead, as well as radionuclides. The types and concentrations of minerals present in the muds depend on the composition of the ore and the operating conditions in the digesters.

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[32] "Aluminum Compounds," Op. Cit., pp. 254-261.

[33] U.S. Environmental Protection Agency, 1992, Op. Cit., pp. I-2 - I-8.

[34] U.S. Environmental Protection Agency, Op. Cit., 1992, pp. I-2 - I-8.

[35] RTI Survey, Kaiser, Gramercy, LA, 1988, ID# 100339.

[36] Ibid.

[37] U.S. Environmental Protection Agency, Op. Cit., 1990, 3-1 - 3-15.

Aluminum Production

APC dust/sludge is a possible waste stream from aluminum production operations, including electrolysis, fluxing, degassing, and anode production. Emissions may consist of unreacted chlorine and aluminum chloride gas, aluminum oxide, sulfur, fluoride, hydrocarbons, and organics.[38] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Flue Dust. The 1991 waste generation rate was 39,000 metric tons per year.[39] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Sweepings. The 1991 waste generation rate was 23,000 metric tons per year.[40] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Electrolysis Waste. Electrolysis wastes include fluoride emissions and hydrocarbon fumes. Both sodium tetrafluoroaluminate gas and entrained liquid solidify to form fluoride particulates. Treatment consists of dry scrubbers that catch particulates and sorb HF on alumina that is subsequently fed to the cells. Nearly all the fluoride evolved is fed back into the cell.[41] Hydrocarbon fumes are generally disposed of by burning. This waste is generated at a rate of 58,000 metric tons per year (adjusted from a 1991 reported value to reflect recent changes in the sector) and may be toxic for lead.[42] This waste was formerly classified as a sludge.

Baghouse Bags and Spent Plant Filters. The 1991 waste generation rate was 19,000 metric tons per year.[43] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Skims and Discarded Drosses.[44] The Aluminum Association has provided the Agency with information about skims and drosses. They stated these materials are byproducts, generated as part of the aluminum melting process. Specifically, when exposed to the atmosphere, a thin layer of aluminum oxide forms on the molten aluminum's surface (i.e., scrap aluminum being melted is coated with aluminum oxide). This oxide material is the starting point for byproducts derived from melting aluminum. The oxide layer increases during stirring, transferring, fluxing, and pouring operations, and floats to the surface of the molten aluminum. It builds up in troughs, furnaces, and crucibles during the casting process, and free aluminum becomes mixed and entrapped with the oxide. Dross is the solidified material, generally consisting of oxides of aluminum and other alloying materials, formed when molten aluminum reacts with the atmosphere or moisture. Skim are accumulations of oxide with entrapped metal, formed on the metal surface after melting from oxide films introduced as surface oxides on all charge components. Skims and drosses were formerly categorized by EPA as characteristic byproducts.

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[38] U.S. Environmental Protection Agency, 1989. Op. Cit., Vol. II.

[39] Ibid.

[40] Ibid.

[41] "Aluminum Alloys," 1992, Op. Cit., pp. 190-212.

[42] U.S. Environmental Protection Agency, 1992, Op. Cit., pp. I-2 - I-8.

[43] Ibid.

[44] The Aluminum Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

In 1994, the U.S. aluminum industry generated approximately 439,000 metric tons of skims and drosses. Approximately 80,000 metric tons were reclaimed on-site, while an estimated 350,000 metric tons went off-site for reclamation. On a facility-specific basis, one company processed 76,900 metric tons of aluminum byproducts which it generated, sending other volumes off-site for further processing to companies which specialize in aluminum byproduct recovery. Recycling of aluminum skims and drosses is very common, and economically feasible with metal contents as low as eight percent. Depending on the material and processes employed, recovery rates may exceed 60 percent. For example, in 1994, one recovery facility processed 90,500 metric tons of byproducts at an average recovery rate of 60 percent. The facility then returned the recovered metal to its customers. The U.S. exports approximately 4,700 metric tons of aluminum byproducts annually, while aluminum companies import 13,600 metric tons of aluminum byproducts per year.

Anode Prep Waste. The 1991 waste generation rate was 20,000 metric tons per year.[45] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Scrap Furnace Brick. The 1991 waste generation rate was 77,000 metric tons per year.[46] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Cryolite Recovery Residue. The 1991 waste generation rate was 30,000 metric tons per year.[47] Historical management of this waste has included disposal in an unlined surface impoundment.[48] This waste may contain high levels of lead. Existing data and engineering judgment suggest, however, that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Cast House Dust. This waste is generated at a rate of 19,000 metric tons per year (adjusted from a 1991 reported value to reflect recent changes in the sector) and may contain toxic levels of cadmium and mercury.[49] This waste may be recycled and was formerly classified as a sludge. Attachment 1 presents waste characterization data for casthouse dust.

Spent Potliners. This waste is a listed hazardous waste (K088). The 1991 waste generation rate was 118,000 metric tons per year.[50] This waste stream may contain toxic levels of arsenic, cyanide, and selenium as well as detectable levels of cadmium, chromium, barium, lead, mercury, silver, and sulfates. This waste is generally managed through landfilling, indefinite "storage," or cathode reprocessing. Cathode reprocessing serves a hazardous waste treatment function by reducing waste volume, and incidentally recovering cryolite. Cathode reprocessing consists of grinding the spent potliners in a ball mill and then leaching with caustic to solubilize fluoride. Undigested cathode material is separated from the leachate using sedimentation and then sent to lagoons. Sodium aluminate is then added to the leachate to initiate the precipitation of cryolite and a second solid-liquid separation is performed to recover cryolite, which can be reused in the electrolytic cell. Lime is added to the supernatant to precipitate calcium fluoride and a third solid-liquid separation is performed. The resulting supernatant is then routed

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[45] Ibid.

[46] Ibid.

[47] Ibid.

[48] U.S. Environmental Protection Agency, Technical Background Document, Development of Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, August 1989, pp. 3-4--3-6.

[49] U.S. Environmental Protection Agency, 1992, Op.Cit., pp. I-2 - I-8.

[50] Ibid.

back to the front of the process and used for leaching. Blowdown from the system varies from plant to plant but it is universally used as potline scrubber liquor make-up when wet potline scrubbers are used. It is also common to route potline scrubber liquor through the cathode reprocessing circuit. In this way, fluoride concentrations of the scrubber liquor are controlled and recycling is possible. Spent potliners are listed wastes, KO88.

Sludge. This waste is generated at a rate of 80,000 metric tons per year (adjusted from a 1991 reported value to reflect recent changes in the sector). Management of this waste includes disposal in an unlined surface impoundment.[51] Attachment 1 presents waste characterization data for this waste stream. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Treatment plant Effluent. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further. Waste characterization data are presented in Attachment 1.

Miscellaneous Wastewater. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further. Waste characterization data are presented in Attachment 1.

D. Non-uniquely Associated Hazardous Wastes

Cooling tower blowdown was generated at a rate of 8,000 metric tons per year in 1991.[52] Because this waste stream is non-uniquely associated, the Agency did not evaluate it further. Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous), and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

Two commenters provided new information on the processes used in the alumina/aluminum sector (COMM65, COMM77). This new information has been incorporated into the Agency's sector report, as appropriate.

Sector-specific Issues

None.

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[51] U.S. Environmental Protection Agency, Technical Background Document, Development of Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, August 1989, pp. 3-4--3-6.

[52] Patricia Plunkert, 1992, Op. Cit.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER - ALUMUMINA/ALUMINUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.0005	0.298	1.5	20/20	-	-	-	0/0	-	-
Arsenic	0.001	0.333	1.5	20/20	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.0001	0.033	0.4	20/20	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.001	0.057	0.2	20/20	-	-	-	0/0	1.0	0
Chromium	0.004	0.074	0.6	20/20	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.01	0.285	1.6	20/20	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.008	0.491	5	20/20	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0001	0.001	0.0062	19/19	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.004	0.682	4	20/20	-	-	-	0/0	-	-
Selenium	0.0005	2.488	44	20/20	-	-	-	0/0	1.0	0
Silver	0.0005	0.075	0.36	20/20	-	-	-	0/0	5.0	0
Thallium	0.0005	0.191	0.69	20/20	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.01	0.168	1	20/20	-	-	-	0/0	-	-
Cyanide	0.002	39.44	180	22/22	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - CASTHOUSE DUST - ALUMINA/ALUMINUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	7.5	7.5	7.5	1/1	0.42	0.42	0.42	1/1	-	-
Arsenic	32	32	32	1/1	0.001	0.001	0.001	0/1	5.0	0
Barium	10	10	10	1/1	0.28	0.28	0.28	1/1	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	7.2	7.2	7.2	1/1	3.5	3.5	3.5	1/1	1.0	1
Chromium	110	110	110	1/1	0.086	0.086	0.086	1/1	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	510	510	510	1/1	0.25	0.25	0.25	1/1	-	-
Iron	93000	93000	93000	1/1	0.47	0.47	0.47	1/1	-	-
Lead	17	17	17	1/1	0.024	0.024	0.024	1/1	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	1100	1100	1100	1/1	19	19	19	1/1	-	-
Mercury	0.0001	0.0001	0.0001	0/1	0.84	0.84	0.84	1/1	0.2	1
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	260	260	260	1/1	0.74	0.74	0.74	1/1	-	-
Selenium	0.92	0.92	0.92	1/1	0.001	0.001	0.001	0/0	1.0	0
Silver	1.9	1.9	1.9	1/1	0.15	0.15	0.15	1/1	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	120	120	120	1/1	0.58	0.58	0.58	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	18	18	18	1/1	-	-
Fluoride	-	-	-	0/0	61	61	61	1/1	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	27000	27000	27000	1/1	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - TREATMENT PLANT EFFLUENT - ALUMINA/ALUMINUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.0005	0.3438	1.1	15/15	-	-	-	0/0	-	-
Arsenic	0.002	0.3326	1.9	15/15	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.001	0.0191	0.06	15/15	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.002	0.0690	0.2	15/15	-	-	-	0/0	1.0	0
Chromium	0.004	0.0434	0.24	15/15	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.006	0.0975	0.744	15/15	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.02	0.2222	0.6	15/15	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0001	0.0019	0.0213	14/14	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.005	0.1985	0.56	15/15	-	-	-	0/0	-	-
Selenium	0.001	0.3743	3	15/15	-	-	-	0/0	1.0	0
Silver	0.002	0.1416	0.7	15/15	-	-	-	0/0	5.0	0
Thallium	0.001	0.2288	0.69	15/15	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.056	0.2561	2	15/15	-	-	-	0/0	-	-
Cyanide	0.004	37.0253	200	17/17	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - MISCELLANEOUS WASTEWATERS - ALUMINA/ALUMINUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.0005	0.377	2	11/11	-	-	-	0/0	-	-
Arsenic	0.01	0.512	2.3	11/11	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.0005	0.019	0.08	11/11	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.001	0.037	0.1	11/11	-	-	-	0/0	1.0	0
Chromium	0.004	0.029	0.2	11/11	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.008	0.299	1.3	11/11	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.01	0.438	3	11/11	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0001	0.001	0.003	11/11	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.005	0.326	1	11/11	-	-	-	0/0	-	-
Selenium	0.001	3.964	40	11/11	-	-	-	0/0	1.0	0
Silver	0.002	0.129	0.5	11/11	-	-	-	0/0	5.0	0
Thallium	0.0005	0.189	0.73	11/11	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.02	0.108	0.6	11/11	-	-	-	0/0	-	-
Cyanide	0.004	95.24	180	11/11	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SLUDGE - ALUMINA/ALUMINUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.64	1.68	3	3/5	0.032	0.032	0.032	1/1	-	-
Arsenic	0.72	7.18	16	5/5	0.001	0.014	0.026	1/2	5.0	0
Barium	4	31.2	78	5/5	0.01	0.024	0.037	2/2	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.0465	1.04	2	3/5	0.001	0.013	0.025	1/2	1.0	0
Chromium	1.3	13.7	33	5/5	0.002	0.005	0.008	2/2	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.38	95.40	380	5/5	0.001	0.011	0.021	2/2	-	-
Iron	730	2386	5300	5/5	0.27	0.300	0.33	2/2	-	-
Lead	5	30.98	63	5/5	0.001	0.002	0.003	1/2	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	0.41	24.96	60	5/5	0.12	0.235	0.35	2/2	-	-
Mercury	0.0001	0.06	0.32	3/5	0.0001	0.0002	0.0002	1/2	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	15	224	520	5/5	0.045	0.045	0.045	1/1	-	-
Selenium	0.05	0.32	0.78	4/5	0.001	0.004	0.006	1/2	1.0	0
Silver	0.04	1.02	2	3/5	0.001	0.002	0.002	1/2	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	1.4	82.48	320	5/5	0.011	0.056	0.1	2/2	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	2	436	870	2/2	-	-
Fluoride	-	-	-	0/0	0.48	48.74	97	2/2	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	2.2	12.60	23	2/2	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-
	-	-	-	0						

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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ANTIMONY

A. Commodity Summary

According to the U.S. Bureau of Mines, antimony metal and oxide are produced by seven companies domestically. Additionally, a small amount of antimony is recovered domestically as a byproduct of smelting lead and silver-copper ores. Exhibit 1 presents the names, locations, and type of processes used by the facilities involved in the primary production of antimony metals and oxides. Estimated apparent domestic consumption was 45,000 metric tons during 1994. Antimony is used mainly in flame retardants, transportation (including batteries), chemicals, ceramics, and glass.[1]

Antimony is generally found in association with other elements in complex ores as the sulfide mineral stibnite. Antimony is made available commercially as antimony trioxide. Most of the antimony trioxide produced is derived from imported original sources.

EXHIBIT 1

SUMMARY OF ANTIMONY FACILITIES

Facility Name	Location	Type of Operations
Amspec Chemical Corp	Gloucester, NJ	Pyrometallurgical
Ant. Process (inactive)	Moscow, TN	Pyrometallurgical
Anzon, Inc.	Laredo, TX	Pyrometallurgical
ASARCO Incorporated	Omaha, NE	Pyrometallurgical
ASARCO (inactive)	El Paso, TX	Electrowinning
Chemet (inactive)	Moscow, TN	Pyrometallurgical
Laurel Ind.	LaPorte, TX	Pyrometallurgical
M&T Chemical (inactive)	Baltimore, MD	Pyrometallurgical
McGean Chemical	Cleveland OH	Pyrometallurgical
Sunshine Mining Company	Kellogg, ID	Electrowinning
US Antimony Corp.	Thompson Falls, MT	Pyrometallurgical

[1] Antimony Specialist, "Antimony," from Mineral Commodity Summaries, U.S. Bureau of Mines, 1995, p. 18.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Primary antimony production usually arises as a byproduct or coproduct of mining, smelting, and refining other antimony-containing ores such as tetrahedrite (a complex silver-copper-antimony-sulfide ore) or lead ore.[2]

2. Generalized Process Flow Diagram

Antimony can be produced using either pyrometallurgical processes or a hydrometallurgical process. As shown in Exhibits 2 through 7, for the pyrometallurgical processes, the method of recovery depends on the antimony content of the sulfide ore. For example, the lowest grades of sulfide ores, containing 5-25% antimony, are volatilized as oxides; ores containing 25-40% antimony are smelted in a blast furnace; and 40-60% antimony ores are either liquated or treated by iron precipitation. As shown in Exhibit 6, the rich oxide ores that result from either volatilization, smelting, or liquation can be reduced directly in a reverberatory furnace. Exhibit 7 outlines the process used to refine the antimony metal resulting from pyrometallurgical process.

Alternatively, antimony can be recovered hydrometallurgically by leaching and electrowinning as shown in Exhibit 8.[3] Currently, the Sunshine Mining Company in Kellogg, Idaho is the only domestic mine that employs the hydrometallurgical process.

Pyrometallurgical Recovery

Oxide Volatilization. As indicated in Exhibit 2, low grade ore is recovered through oxide volatilization. The ore is roasted with coke or charcoal in a rotary kiln or shaft furnace. As a result of the roasting step, sulfur is burned away and removed in the waste gases and antimony trioxide, which condenses, can be recovered in flues, condensing pipes, or a Cotrell precipitator. The resultant oxide is briquetted and reduced to metal.[4] The largest producer of antimony metal from roasting is Anzon in Laredo, Texas.

Blast Furnace Smelting. As shown in Exhibit 3, the blast furnace smelting process used to recover antimony from intermediate (25-40%) grades of oxide and sulfide ores, flue dust, liquation residues, mattes, briquetted fines, and rich slags is similar to the blast furnace method used to process lead. A low pressure, high smelting column, water-jacketed blast furnace is used. The slag is separated from the antimony metal and sent to waste or reprocessing.[5]

Sulfur Liquation. As indicated in Exhibit 4, liquation is used to recover antimony from high grade ores. The ores can be heated either in batch mode in a perforated pot, or in continuous mode using a reverberatory furnace. This process separates the antimony sulfide from the gangue. The liquated product is known as crude or needle antimony, which can either be distributed as antimony sulfide or converted to recover antimony metal. Either iron precipitation or oxide reduction can be used to recover metallic antimony from the sulfide.[6]

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[2] Thomas O. Llewelyn, "Antimony," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, p. 225.

[3] "Antimony," Kirk-Othmer Encyclopedia of Chemical Technology, 1992, 4th ed., Vol. III, p. 370.

[4] Ibid.

[5] Ibid., p. 371.

[6] Ibid.

EXHIBIT 2

ANTIMONY OXIDE VOLATILIZATION PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, pp. 3-31 - 3-45)

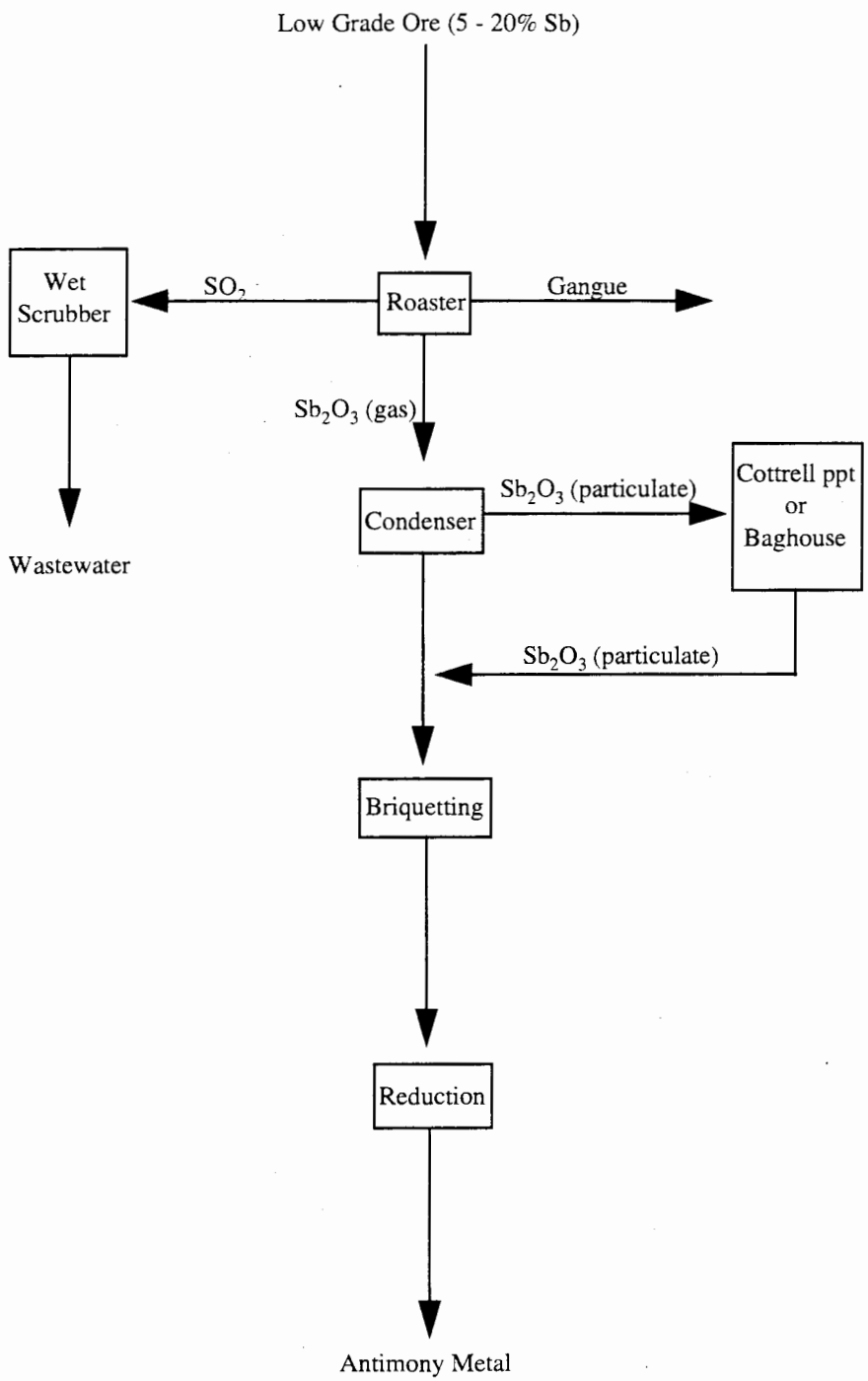


EXHIBIT 3

ANTIMONY SMELTING

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, pp. 3-31 - 3-45.)

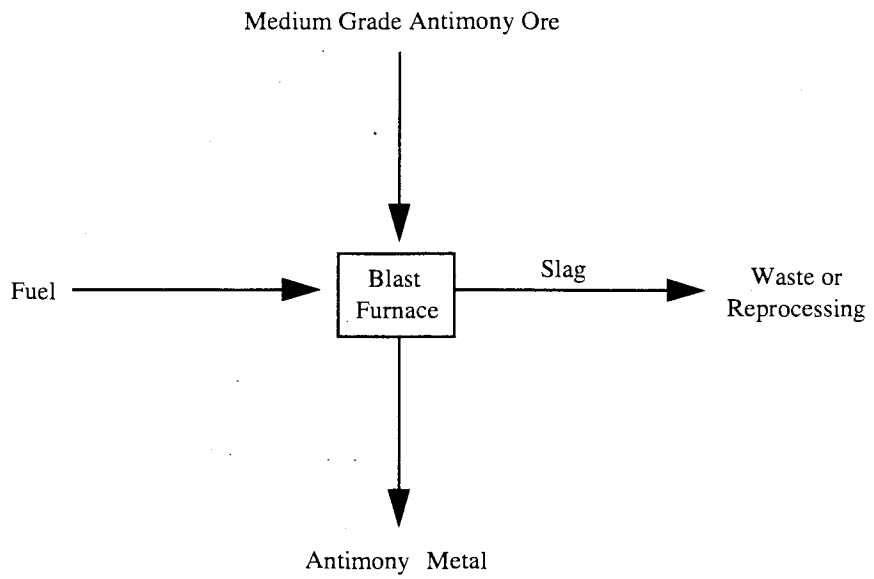


EXHIBIT 4

ANTIMONY LIQUATION PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, pp. 3-31 - 3-45.)

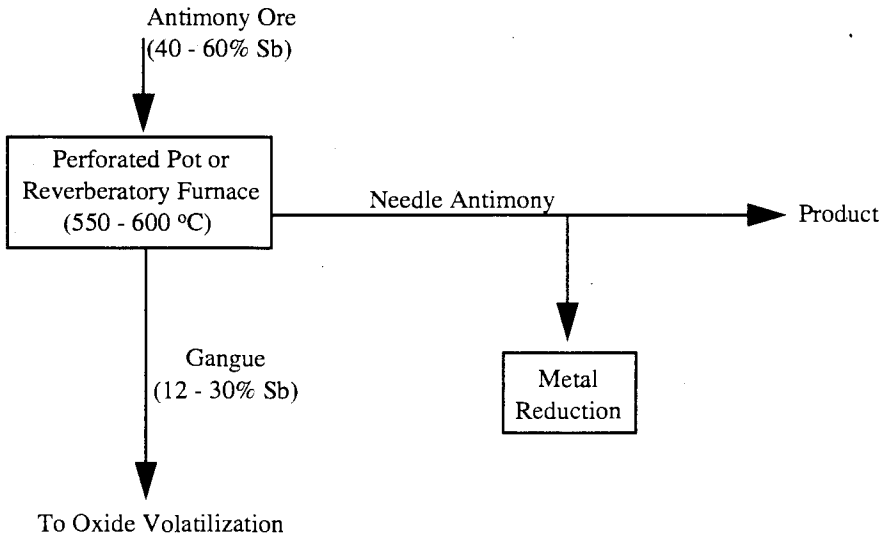


EXHIBIT 5

ANTIMONY IRON PRECIPITATION REDUCTION PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, pp. 3-31 - 3-45.)

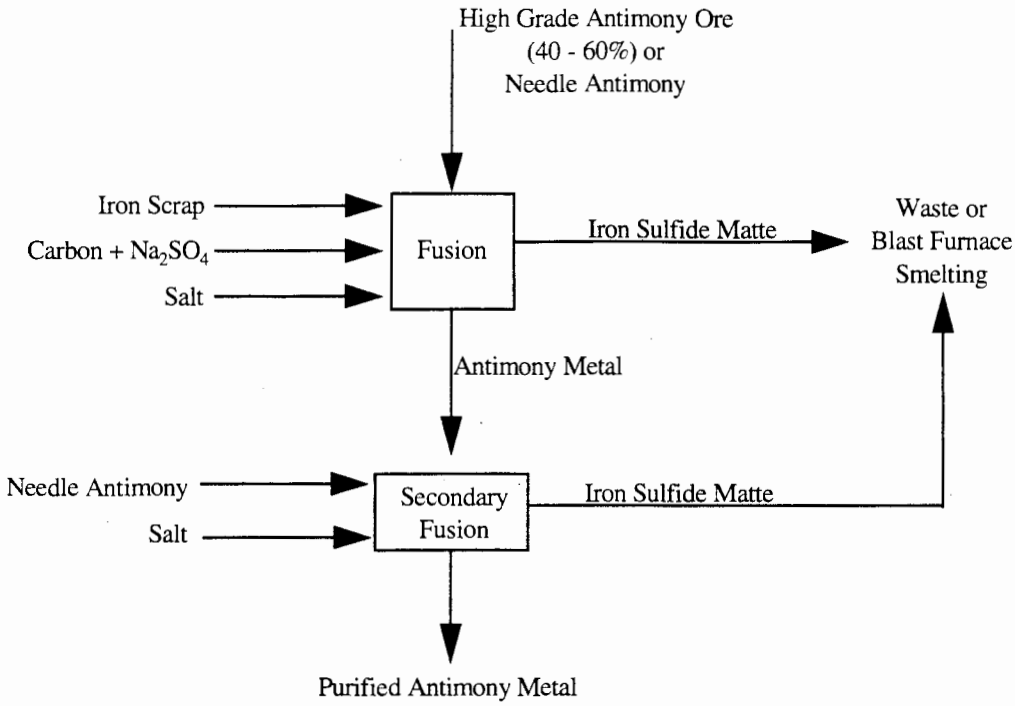
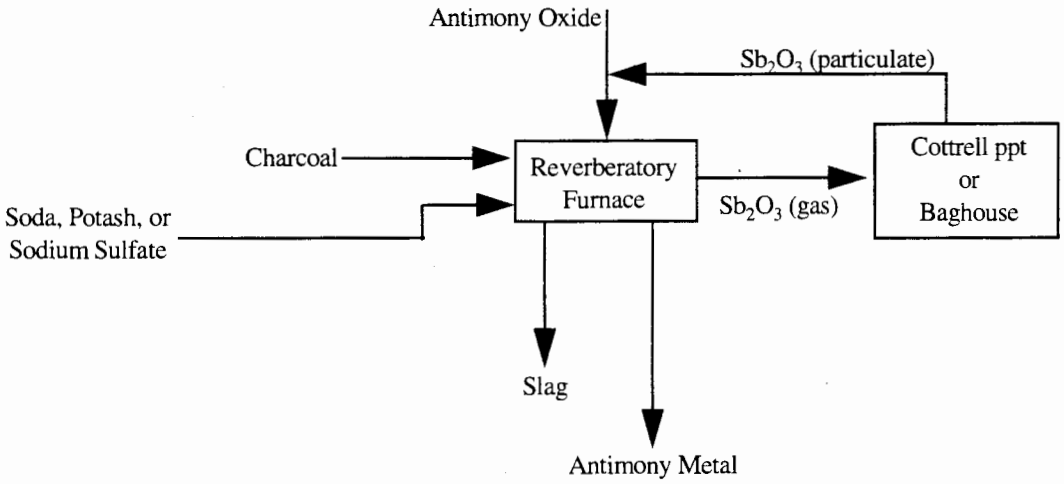


EXHIBIT 6

ANTIMONY OXIDE REDUCTION PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, pp. 3-31 - 3-45.)



Iron Precipitation. Iron precipitation is used to convert crude antimony sulfide to metallic antimony. As Exhibit 5 illustrates, the molten antimony sulfide is heated in combination with iron scrap, carbon, and Na_2SO_4. The process uses iron as the reductant to replace antimony in the molten antimony sulfide. Sodium sulfate and carbon are added to produce sodium sulfide. Alternatively, salt is added to form a fusible light matte with iron sulfide and facilitate the separation of the metal. Because the resultant metal contains high concentrations of iron and sulfur, a second fusion with liquate antimony and salt is used to produce a purified antimony metal.[7]

Oxide Reduction. Antimony trioxide or other antimony oxides are reduced with charcoal in reverberatory furnaces as shown in Exhibit 6. The addition of an alkaline flux of soda, potash, and sodium sulfate dissolves residual sulfides and gangue and also minimizes volatilization. During this process, the loss of antimony due to volatilization necessitates the use of Cotrell precipitators or baghouses to recover the antimony trioxide for reprocessing. During this process, a slag is produced and separated from the antimony metal.[8]

Refining. Metal resulting from pyrometallurgical reduction requires refining to remove arsenic, sulfur, iron, and copper impurities. Exhibit 7 presents a typical flow process diagram for the refining process. The iron and copper concentrations can be reduced by adding stibnite or a mixture of sodium sulfate and charcoal to form an iron-bearing matte. The matte is skimmed from the surface of the molten metal, after which the metal is treated with an oxidizing flux of caustic soda or sodium carbonate and niter (sodium nitrate) to remove arsenic and sulfur. Although lead is not readily removed from antimony, material containing lead may be used for lead based alloy applications.[9]

Hydrometallurgical Recovery

Antimony can also be recovered using the hydrometallurgical process outlined in Exhibit 8, which involves leaching followed by electrowinning and autoclaving. The hydrometallurgical process is based on the knowledge that: (1) an alkaline sodium sulfide solution acts as an effective solvent for most antimony compounds and (2) most other metals are insoluble in such a solution (excluding arsenic, tin, and mercury).[10][10] The Sunshine Mining Company is the only domestic antimony facility that uses this hydrometallurgical technique. The Sunshine facilities are a complete mine-to market operation. In addition to their antimony plant, their operations include a mill, a silver-copper refinery, and a functional mint. Their antinomy facility produces both antimony metal and sodium antimonate. The process at this facility involves: (1) leaching and filtration, (2) electrowinning, and (3) autoclaving and tails treatment.

Leaching and Filtration. The ore concentrates from the mill are leached in a batch process in a heated, pressurized vat. Some of the concentrates are blended, prior to leaching, with coke, sodium sulfate, and sodium carbonate and then melted in a furnace. The resultant material is then leached with a sodium hydroxide solution. Other concentrates are combined with sodium sulfide and sulfur and leached with a sodium hydroxide solution without prior melting. This leach solution is created by combining the barren catholyte (depleted electrolyte from downstream electrowinning), elemental sulfur, sodium sulfide, and sodium hydroxide. The solution matrix then solubolizes the antimony and any arsenic present that is not in the form of arsenopyrite, producing soluble thio compounds including $NaSbS_2$, Na_3SbS_3, Na_3SbS_4, and Na_3AsS_3. The solids can then be separated from the leaching

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[7] Ibid.

[8] Ibid.

[9] Ibid., pp. 372-373.

[10] Corby G. Anderson, Suzzann M. Nordwick, and L. Ernest Kyrs, "Processing of Antimony at the Sunshine Mine," from Residues and Effluents - Processing and Environmental Considerations, The Minerals, Metals, & Materials Society, 1991, p. 349-366.

EXHIBIT 7

ANTIMONY REFINING

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, pp. 3-31 - 3-45.)

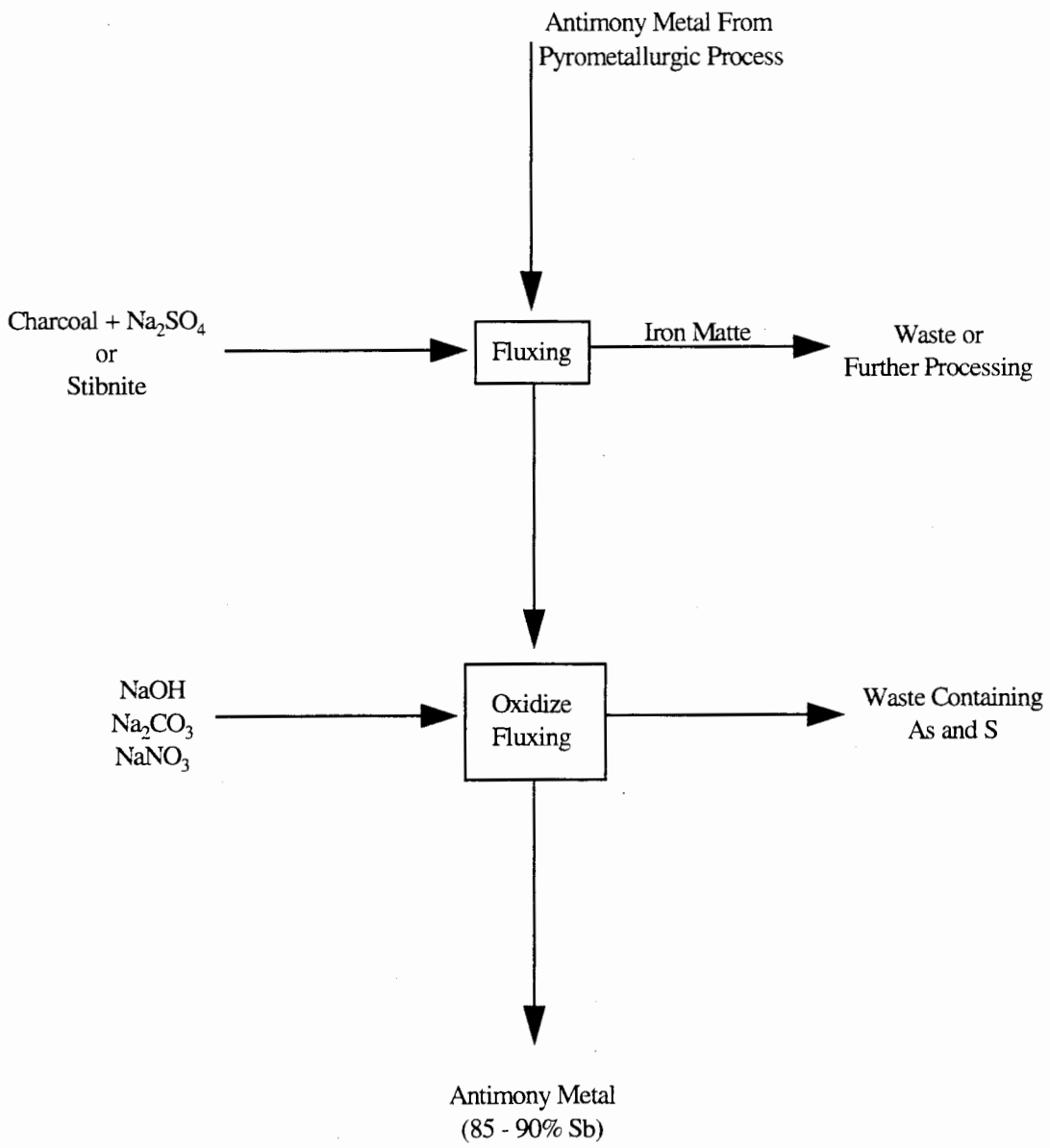
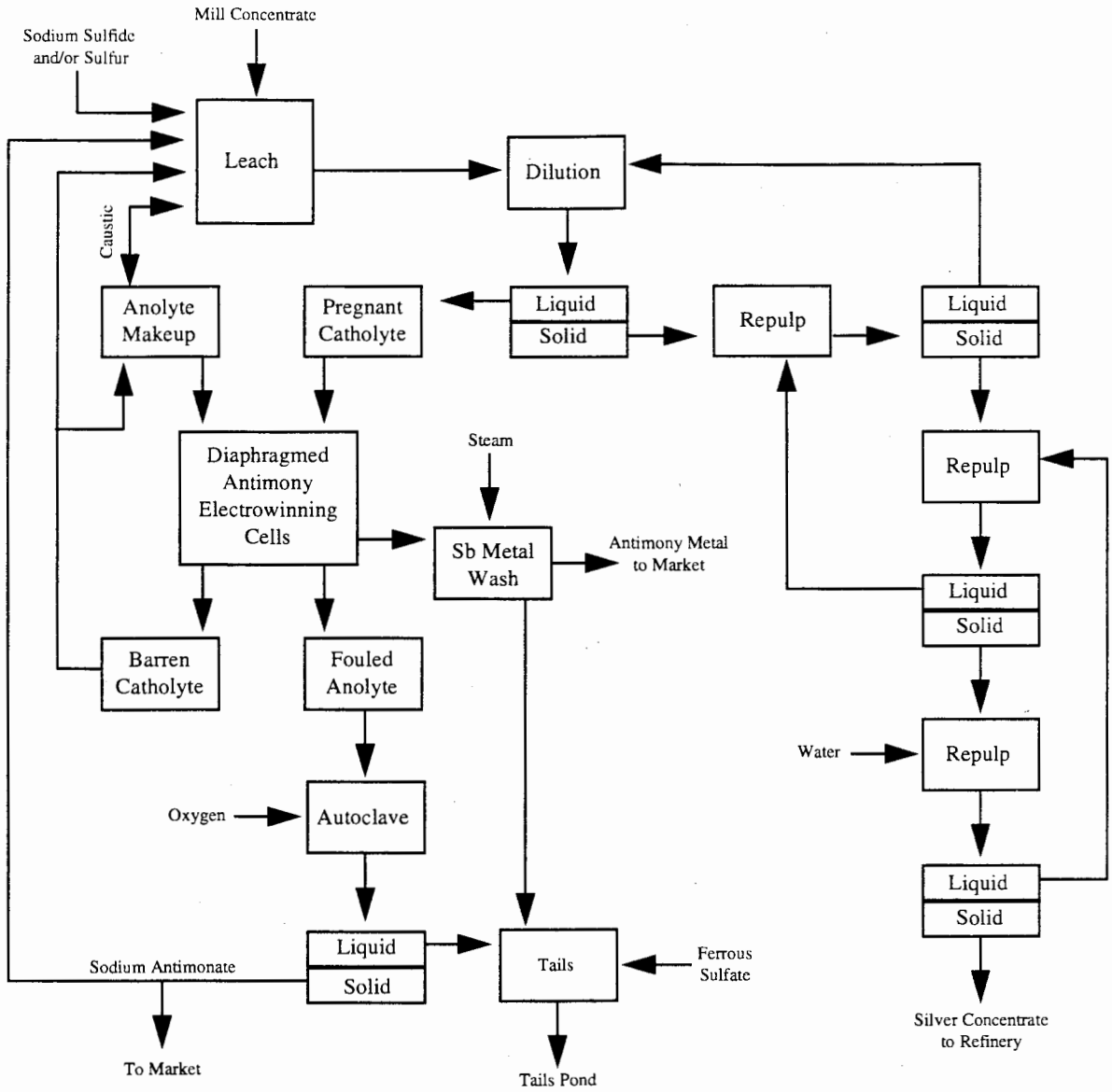


EXHIBIT 8

HYDROMETALLURGICAL ANTIMONY PRODUCTION PROCESS

(Adapted from: Residues and Effluents - Processing and Environmental Considerations, 1991, pp. 349 - 366.)



solution by thickening and filtration. The leached residue is either disposed of or processed further to recover other metals.[11]

As shown in Exhibit 7, when the leaching is complete, the resultant slurry is diluted to enhance solid separation from the alkaline solution. Dilution involves the use of water recovered from downstream repulping. After dilution the slurry consists of an antimony bearing pregnant catholyte solution and a high grade silver-copper residue. The solid-liquid separation takes place by conventional settling and thickening. Both primary and secondary thickeners are used with a repulp stage occurring in between. Including this first repulping step, there three total repulping steps involved in the Sunshine Mine recovery process. Residue from the secondary thickener is repulped a second time and then recovered with a disc filter. The mixture is then sent through a third and final repulping stage during which fresh water enters the process. The final filtration step involves a drum filter. The wash water flows from the drum filter back through to the second repulping stage. From the second repulping step, the wash water flows through the disc filter and back to the first repulp step and from there the water is sent back to the leach stage for use in the dilution step. The three repulping steps allow for maximum recovery of the leached antimony and provide a copper-silver residue that is free from alkaline sulfur compounds that might interfere with acid pressure leaches downstream when the resultant solid filter cake is sent to the Sunshine silver refinery.[12]

Electrowinning. As shown in Exhibit 8, the pregnant solution from the leaching process is used as feed for the electrowinning circuit. Antimony metal is deposited on the cathode as a brittle, non-adherent layer which is periodically stripped and washed. The resultant product is either sold or sent for further processed to antimony trioxide.

Because the products of oxidation at the anode interfere with the deposition of antimony at the cathode, two different and physically separated solutions are used. The catholyte, in this case the pregnant solution from the leaching process, surrounds the cathode and the anolyte, a combination of barren catholyte and sodium hydroxide solution, surrounds the anode. Mixing of the two solutions is minimized by the use of a canvas barrier or diaphragm. The canvas barrier has small pores that allow the solutions to come into contact, maintaining the integrity of the electrical circuit.

The recovered metal is washed by blowing steam into a tank containing hot water and the metallic antimony. This step removes any solutions or soluble solids that have adhered to the metal during the plating process. This wash water is sent to tails treatment and can be autoclaved to recover sodium antimonate. After drying, the antimony metal product is packaged and sold to secondary smelters for use as a lead hardener or for antimony oxide production.[13]

After the antimony has been removed, the barren catholyte can be recycled to the process through one of two methods. In the process where the ore is melted prior to leaching, the spent electrolyte is spray dried and the dried salts are captured in a baghouse for reuse during the blending step. In the other process where the concentrates are leached without melting them first, the barren catholyte solution is recycled directly into the leaching process. Site-specific information indicates that the fouled anolyte is removed and treated by autoclaving to recover sodium antimonate, which is then recycled to the leaching process. The resultant antimony metal can be converted to antimony trioxide in a fuming furnace.[14]

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[11] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Vol. IV, Office of Water Regulations Standards, 1989, p. 2062.

[12] Corby G. Anderson, 1991, Op. Cit., p. 355.

[13] Corby G. Anderson, 1991, Op. Cit., p. 360.

[14] U.S. Environmental Protection Agency, 1989. Op. Cit., p. 2063.

Autoclaving. Sodium antimonate ($NaSbO_3$) is produced by autoclaving the antimony-bearing fouled anolyte solution from the electrowinning process. Residual caustic sodas are also present in the fouled anolyte and can be recovered. Oxygen autoclaving, heating the solution under pressure in the presence of oxygen, is used to produce the sodium antimonate. The elevated temperature and pressure drive the oxidation reaction and result in the formation of insoluble sodium antimonate which is separated from the remaining liquid by sedimentation and decanting. The resultant sodium antimonate either recycled back to the leaching step or sold depending on market conditions.[15]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

Since antimony is generally recovered as a co-product or a by-product of other metals, all of the wastes generated during antimony recovery are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, please see the report for lead presented elsewhere in this background document.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Because antimony is recovered as a co-product or a by-product of other metals, mining wastes are addressed in the descriptions of the initial ore/mineral. For a further description of these wastes see the report for lead presented elsewhere in this background document.

2. Mineral Processing Wastes

The following wastes have been identified as generated during the oxide volatilization process.

Gangue. Gangue generated from roasting during the oxide volatilization process may contain traces of antimony and other heavy metals. Gangue generated from either smelting or other higher grade recovery processes may be sent to oxide volatilization for further antimony recovery, since that process is designed for lower grade ores. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater. The wastewater generated from the wet scrubber process following oxide volatilization may contain sulfur and some heavy metals. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

The following wastes have been identified as generated during the smelting and refining portions of the antimony recovery process. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate low, medium, and high waste generation rates.

APC Dust/Sludge. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Sludge from Treating Process Waste Water. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[15] Corby G. Anderson, 1991, Op. Cit., p. 361.

Refining Dross. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Slag and Furnace Residue. The slag generated during the oxide reduction process may contain residual soda, potash, or sodium sulfate. The waste generation rate for this waste stream is reported to be 32,000 mt/yr. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

Waste Solids. Wastes produced from fluxing during the refining process contain arsenic (As) and sulfur (S). Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Hydrometallurgical Recovery

Leach Residue. The leach residue contains antimony, sulfur, sodium, pyrite, silica, and stibnite.[16] In the antimony plant in Kellogg, Idaho, a hot alkaline sulfide solution is used to dissolve antimony and most arsenic species from the ore concentrate, leaving a leach residue containing less than one percent antimony.[17] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Gangue (Filter Cake). At the Kellogg plant, slurry from the leach tanks is diluted and then thickened and filtered in a series of repulp-filtration steps. The resulting filter cake, containing 18-20 percent moisture, becomes feed material at the silver refinery. Filtered leach solution containing antimony (primarily as sodium thioantimonate) is fed to the antimony electrowinning circuit.[18] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Stripped Anolyte Solids. Electrowinning "tails" consist of fouled anolyte and cathode wash water. The fouled anolyte is heated and pressurized with oxygen in a 1,500 gallon autoclave to recover sodium antimonate before being sent to the tailings pond.[19] The waste generation rate for this waste stream is reported to be 190 metric tons/yr. This waste stream is fully recycled and is classified as a by-product. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for arsenic.

Spent Barren Solution. Barren catholyte solution is recycled back to the leach step and to the anolyte make up water added prior to the electrowinning step. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Autoclave Filtrate. The liquid phase from the autoclave, which contains sodium arsenate and residual antimony is treated with solid ferrous sulfate to precipitate arsenic as $Fe_3(AsO_4)$ and antimony as Sb_2S_3 at a pH of 8 to 8.5. Quicklime is then added to precipitate residual iron in the solution. The resulting anolyte slurry is then commingled with mill tailings and pumped to an unlined on-site surface impoundment. Natural sedimentation removes solids under the liquid outflow which is discharged under an NPDES permit.[20] The low, medium, and high annual waste generation rates were estimated as 380 metric tons/yr, 32,000 metric tons/yr, and 64,000 metric tons/yr,

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[16] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 2062.

[17] Gary Light, ICF, Incorporated, "Report on July 1993 Mineral Processing and Incinerator Site Visits," Draft memorandum to Bengie Carroll, August 10, 1993, p. 2-1.

[18] Ibid., p. 2-2.

[19] Ibid.

[20] Ibid.

respectively. We used best engineering judgment to determine that this waste stream may be partially recycled and may exhibit the characteristics of toxicity (arsenic, cadmium, lead, and mercury) and corrosivity. This waste stream is classified as a spent material. Waste characterization sampling data for this waste stream is included as Attachment 1.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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U.S. Environmental Protection Agency. Development Document for Effluent Limitation Guidelines and Standards for Nonferrous Metals Manufacturing Point Source Category. Vol V. Office of Water Regulations Standards. May 1989. p. 2079

U.S. Environmental Protection Agency. "Antimony." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. Office of Solid Waste. p. 3-31 - 3-45.

ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - AUTOCLAVE FILTRATE - ANTIMONY

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	3.7	40.59	120	8/8	-	-	-	0/0	-	-
Arsenic	260	1977.75	3700	8/8	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.002	0.069	0.3	8/8	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.2	0.391	0.8	8/8	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.01	0.458	3.05	8/8	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.015	5.30	12.6	7/7	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.01	0.110	0.27	8/8	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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ARSENIC

A. Commodity Summary

The most common source of arsenic is as a byproduct from the smelting of copper and lead concentrates as arsenic trioxide (As_2O_3). Arsenic trioxide is commonly converted to arsenic acid for use in producing arsenical wood preservatives, which accounted for 75% of the U.S. demand for arsenic in 1992.[1] Other uses include agricultural chemicals (16% of demand), glass manufacturing (4%), and other uses (2%). In addition, arsenic metal is produced by the reduction of arsenic trioxide and is used in nonferrous alloys and electronics, which accounted for 3% of demand in 1992.

China and Chile are the world's largest producers of arsenic trioxide, followed by Mexico and the Philippines. The United States imported over 13,000 metric tons of arsenic trioxide and over 500 metric tons of arsenic metal from China in 1992.[2] U.S. production of arsenic ceased in 1985 when ASARCO closed indefinitely its copper smelter and associated arsenic recovery plant in Tacoma, Washington, largely due to the increasing costs of complying with air quality standards.[3] Arsenic is no longer produced in the U.S., but three facilities, Hickson Corp. of Conley, GA, CSI of Harrisburg, NC, and Osmose Corp. of Memphis, TN, convert arsenic trioxide to arsenic acid for use in producing wood preservatives.[4]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Arsenic trioxide (As_2O_3) is volatilized during smelting, concentrated in flue dusts, and extracted through distillation or roasting of the flue dusts to produce crude arsenic trioxide of minimum 95% purity.[5] This product can be refined through resublimation in a reverberatory furnace or through hydrometallurgical leaching methods to produce commercial-grade arsenic trioxide, known as white arsenic.[6]

2. Generalized Process Flow Diagram

Exhibit 1 presents a typical process flow diagram for the production and/or recovery of arsenic trioxide. As shown in the exhibit, vapor and gases laden with dust containing arsenic trioxide are liberated during smelting of copper (and lead) concentrates. Flue dust containing up to 30% arsenic trioxide is then roasted after a small amount of pyrite or galena is added to prevent the formation of arsenites and to promote formation of low-arsenic residue that can be recycled. The resulting high-arsenic fumes are passed through a series of brick chambers called kitchens (not shown in the diagram) that operate at progressively decreasing temperatures, from 220°C to 100°C or less, to condense the arsenic trioxide vapor to concentrations of 90-95%. This crude trioxide is either pyrometallurgically

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[1] U.S. Bureau of Mines, Mineral Industry Surveys: Arsenic in 1992, Branch of Metals and the Branch of Data Collection and Coordination, June 1993, p. 4.

[2] Ibid.

[3] Loebenstein, J., The Materials Flow of Arsenic in the United States, U.S. Bureau of Mines Information Circular 9382, 1994, p. 2.

[4] U.S. Bureau of Mines, 1993, Op. Cit., p. 1.

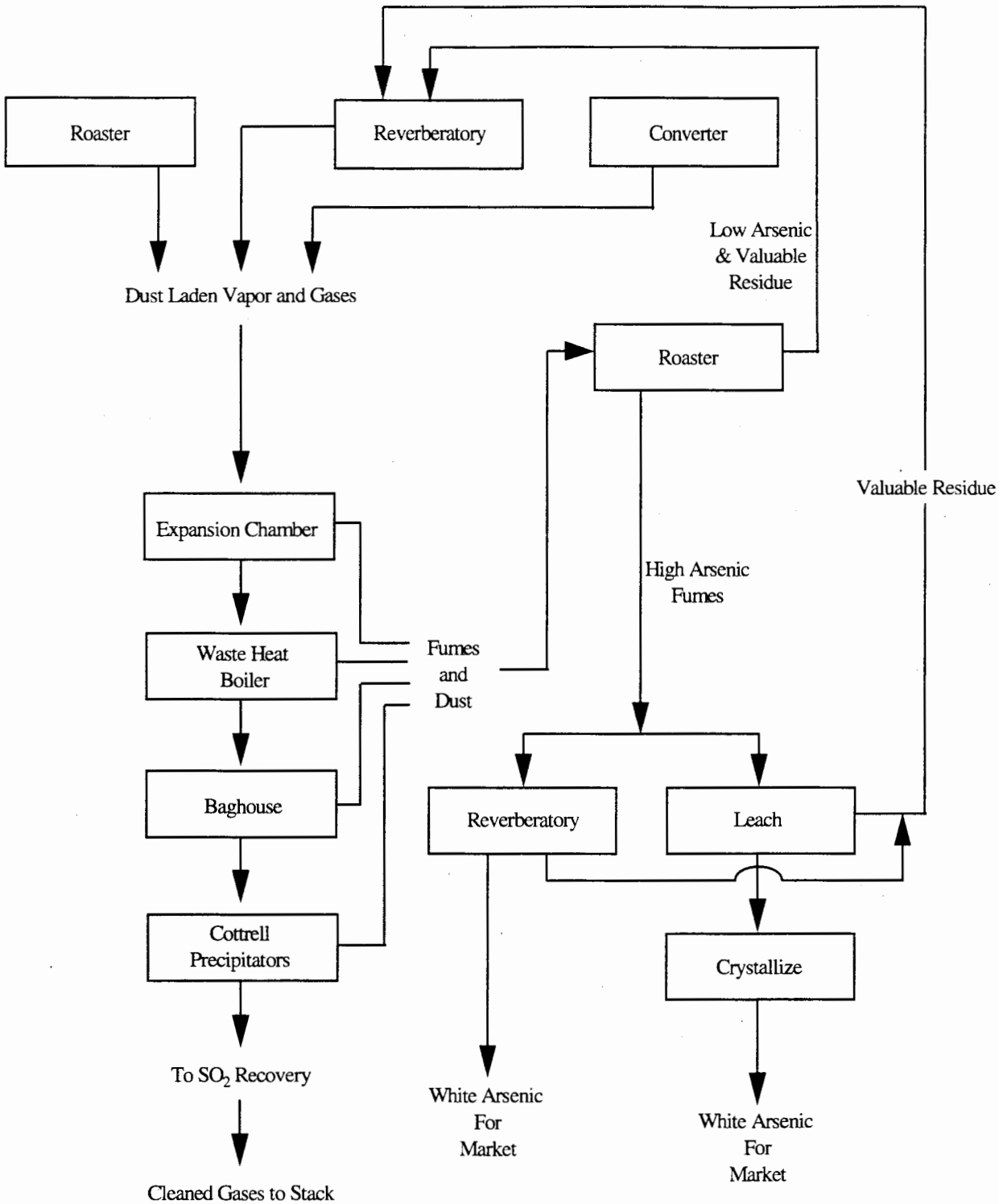
[5] "Arsenic and Arsenic Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. III, 1992, pp. 626-628.

[6] U.S. Bureau of Mines, Mineral Facts and Problems, Bulletin 675, 1985, p. 45.

EXHIBIT 1

ARSENIC TRIOXIDE PRODUCTION PROCESS

(Adapted from: "Arsenic and Arsenic Alloys," 1992, Op. Cit., p. 627.)



refined through resublimation in a reverberatory furnace or hydrometallurgically refined through leaching. In the former method, the trioxide vapors pass through a settling chamber and then through about 40 additional kitchens to promote additional condensation, yielding white arsenic of 99-99.9% purity. Dust from the kitchens having 90% arsenic trioxide collects in baghouses and is reprocessed. In the latter method, arsenic trioxide fumes are pressure-leached in an autoclave using water or mother liquor. Arsenic trioxide dissolves and the resulting residue is reprocessed. The arsenic trioxide is recovered through vacuum-cooling to promote crystallization; arsenic trioxide is removed through centrifuging to yield white arsenic of 99% purity.[7]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

The Bureau of Mines has investigated the recovery of arsenic from flue dusts from copper processing using an alternative method to distillation or roasting. Flue dusts were first leached with sulfuric acid and refinery-bleed solution to solubilize arsenic and copper. Arsenic was recovered as arsenic trioxide from the resulting leach liquor through reduction and precipitation using sulfur dioxide.[8] In 1981, Equity Silver Mines Limited in Houston, British Columbia began operating a leach plant to reduce arsenic levels in silver-gold-copper flotation concentrate. The concentrate was leached with caustic sulfide, producing a leach liquor containing most of the arsenic in the concentrate. The leached arsenic was originally recovered as calcium arsenate through oxidation and lime precipitation but was found to be not marketable. Full-scale plant tests were conducted in 1983 to produce a heavy metal arsenate thought to be marketable; however, the circuit was shut down in 1984 due to economic factors.[9]

4. Beneficiation/Processing Boundary

Since arsenic trioxide is recovered as a by-product of copper and lead smelting, please see the reports for lead and copper presented elsewhere in this background document for a description of where the beneficiation/processing boundary occurs for this mineral commodity.

C. Process Waste Streams

The recovery of arsenic trioxide as a byproduct from copper and lead smelting constitutes primary mineral processing in the context of the Mining Waste Exclusion. In contrast, the manufacture of arsenic acid and arsenic metal from arsenic trioxide is considered to be chemical manufacturing and clearly has always been outside the scope of the Mining Waste Exclusion. Therefore, as there currently is no primary production of arsenic in the United States, there are no newly identified "mineral processing" wastes subject to the RCRA LDR program.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[7] "Arsenic and Arsenic Alloys," 1992, Op. Cit., pp. 626-628.

[8] Gritton, K., D. Steele, and J. Gebhardt, "Metal Recovery from Copper Processing Wastes," presented at the Second International Symposium, Recycling of Metals and Engineered Materials, Williamsburg, Virginia, October 28-31, 1990, sponsored by the Minerals, Metals, & Materials Society, Warrendale, PA.

[9] Edwards, C., "The Recovery of Metal Values from Process Residues," Journal of Mines, June 1991, p. 32.

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BERYLLIUM

A. Commodity Summary

Beryllium (Be) is used as an alloy, oxide, or metal in electronic components, electrical components, aerospace applications, defense applications, and other applications.[1] Beryllium is processed into three forms -- beryllium alloys (principally beryllium-copper); beryllium oxide or beryllia ceramic; and metallic beryllium.[2] Beryllium-copper alloys account for about 75 percent of the United States annual consumption of beryllium on a metal equivalent basis. These alloys, most of which contain about two percent beryllium, are used because of their high electrical and thermal conductivity, high strength and hardness, good fatigue and corrosion resistance, and non-magnetic properties.[3] Beryllia ceramic is specified for its electrical insulating properties and its unusual ability to conduct heat. Metallic beryllium offers light weight, strength, stiffness, specialized nuclear properties, and the ability to dissipate heat rapidly.[4]

Beryllium is a recognized constituent in some 40 minerals. However, only two minerals -- beryl, an aluminosilicate ($3BeO \bullet Al_2O_3 \bullet 6SiO_2$) containing 5 to 13 percent beryllium oxide (BeO), and bertrandite ($Be_4Si_2O_7(OH)_2$), which occurs as tiny silicate granules containing less than one percent BeO -- are commercially available as beryllium ores.[5] A BeO content of 10 percent is considered necessary for the economic extraction of beryllium from beryl and bertrandite ores. Bertrandite ores are considered a commercially viable source of beryllium because of the large reserves present, the ability to mine it in an open pit, and the fact that beryllium may be extracted by leaching with sulfuric acid. In fact, the majority of beryllium produced is now obtained from bertrandite.[6]

The major deposits of beryllium in the United States are bertrandite deposits in the Spor Mountains of Utah. Brush Wellman, Inc. bought the mineral rights to these deposits and began mining in the 1960's.[7] Its plant near Delta, Utah, is the only commercial beryllium extraction and production plant operating in the Western world.[8] The Delta plant uses both beryl and bertrandite ores as inputs for the production of beryllium hydroxide. Although bertrandite ore is mined on-site using open-pit methods, the beryl ore is imported primarily from Brazil. However, beryl deposits also occur in China, Argentina, India, Russia, and some African countries. Beryl is usually obtained as a by-product from mining zoned pegmatite deposits to recover feldspar, spodumene, or mica.[9] Two other facilities process the beryllium hydroxide to produce beryllium metal, alloy or oxide. Exhibit 1 presents the name,

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[1] Deborah A. Kramer, "Beryllium," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 28.

[2] Brush Wellman, Inc. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[3] U.S. Bureau of Mines, "Beryllium in 1992," Mineral Industry Surveys, April 1993, p. 3.

[4] Brush Wellman, Inc. Op. Cit.

[5] Brush Wellman, Comments of Brush Wellman Inc. on EPA's Proposed Reinterpretation of the Mining Waste Exclusion, December 30, 1985, p. 1.

[6] "Beryllium and Beryllium Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. IV, 1992, p. 126.

[7] "From Mining to Recycling," Metal Bulletin Monthly — MBM Copper Supplement, 270, 1993, p. 27.

[8] Deborah A. Kramer, January 1995, Op. Cit., p. 28.

[9] "Beryllium and Beryllium Alloys," 1992, Op. Cit., p. 126.

location, the type of processing, input material and product for each of the beryllium processing facilities. Exhibit 2 presents general site information on the Delta, UT facility.

EXHIBIT 1

SUMMARY OF PRIMARY AND SECONDARY BERYLLIUM ORE PROCESSORS[a]

Facility Name	Location	Type of Process	Input Material	Products
Brush Wellman	Delta, UT	Primary	Ores	$Be(OH)_2$
Brush Wellman	Elmore, OH	Secondary	$Be(OH)_2$	Be Metal and Alloys
NGK Metals	Revere, PA	Secondary	$Be(OH)_2$	Be Metal

[a] - Personal Communication between ICF Incorporated and Deborah Kramer, U.S. Bureau of Mines, October 1994.

EXHIBIT 2

SITE INFORMATION

Facility Name	Facility Location	Potential Factors Related to Sensitive Environment
Brush Wellman, Inc.	Delta, Utah	• Brush Wellman mill located 10 miles north of Delta, Utah; mine located 50 miles west of the mill. • Nearest resident lives 5 miles from Brush Wellman facility • Brush Wellman facility is not located in: a 100-year floodplain, an area designated as wetland, Karst terrain, fault area, or an endangered species habitat • No public drinking water wells are located within 5 miles of the Brush Wellman facility • Private drinking water wells are located within 1 mile of the Brush Wellman facility

B. Generalized Process Description

1. Discussion of Typical Production Processes

Brush Wellman extracts bertrandite ore at a mine site located approximately 50 miles northwest of Delta, Utah. The ore is transported to a mill located 10 miles north of Delta and is treated using a counter-current extraction process to produce beryllium sulfate, $BeSO_4$. A second route, using the Kjellgren-Sawyer process, treats the beryl ore and provides the same beryllium sulfate intermediate. The intermediates from the two ore extraction processes are combined and fed to another extraction process. This extraction process removes impurities solubilized during the processing of the bertrandite and beryl ores and converts the beryllium sulfate to beryllium hydroxide, $Be(OH)_2$. The beryllium hydroxide is either sold, or sent off-site to either be converted to beryllium fluoride, BeF_2, which is then catalytically reduced to form metallic beryllium, converted to beryllium oxide, or converted to beryllium alloys.

2. Generalized Process Flow Diagram

Exhibit 3 (Parts 1-3) presents a generalized process flow diagram for the production of metallic beryllium. Each part of the process is described in greater detail below.

Part 1: Extraction of Beryllium as Beryllium Sulfate

Processing of bertrandite and imported beryl ores takes place at the Brush Wellman plant in Delta, Utah. Even though beryllium is extracted from both ores as beryllium sulfate, there are significant differences in the two extraction procedures. For example, the beryl extraction procedure requires five 15-foot diameter thickeners, while the bertrandite process uses eight 90-foot diameter thickeners.[10]

Bertrandite Ore. The bertrandite ore is crushed, sized, and wet milled to provide a pumpable slurry of particles below 840 μm.[11] The slurry is leached with sulfuric acid, H_2SO_4, at moderate temperatures (about 95°C) to solubilize the beryllium. The resulting beryllium sulfate solution is separated from unreacted solids using thickeners and counter-current decantation (CCD). The solids from the thickener underflow are discarded to a tailings pond.[12]

Beryl Ore. In contrast to bertrandite, beryl ore contains beryllium in a tightly bound crystalline structure. Therefore, in order to effectively leach the beryllium with sulfuric acid, it is first necessary to destroy the crystalline structure. The Kjellgren-Sawyer process is used commercially to extract beryllium from beryl. In this process, the ore is crushed, melted at 1650°C, and quenched by pouring the molten ore into water. The resulting noncrystalline glass (frit) is heat treated at 900-950°C to further increase the reactivity of the beryllium component. After grinding to <74 μm, a slurry of the frit powder is reacted with concentrated sulfuric acid at 250-300°C to produce soluble beryllium sulfate and aluminum sulfate, $Al_2(SO_4)_3$.[13] The spent solid fraction is separated from the beryllium sulfate solution using thickeners and CCD and discarded to a tailings pond.

Beryllium sulfate leach solutions from the bertrandite and beryl CCD thickeners are combined in a surge tank and pumped to another tank where sulfuric acid is added. The solution is then pumped to a filter which is pre-coated with diatomaceous earth. The clarified filtrate solution from the filter (called extraction feed) is pumped to another surge tank before being introduced into the next step of the process, the production of beryllium hydroxide. The filter cake from the filter is continuously scraped off, repulped with fresh water, and pumped to the leach output where it is recycled to the CCD thickeners for beryllium recovery.[14]

In the past, the beryllium sulfate solution produced from the extraction of beryl ore was neutralized with ammonia in order to separate the bulk of the aluminum as ammonium alum. The ammonium alum crystals were then removed by centrifugation. Organic chelating agents, such as the sodium salt of ethylenediaminetetraacetic acid (EDTA) and triethanolamine, were added to the alum-free solution in the presence of sodium hydroxide to form a

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[10] U.S. Environmental Protection Agency, "Beryllium," 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, 1988, p. 3-47.

[11] Crushing, sizing, and wet milling are shown as physical processing in Exhibit 1.

[12] Brush Wellman, Comments of Brush Wellman Inc. on EPA's Proposed Reinterpretation of the Mining Waste Exclusion, Revised November 21, 1988, p. 8.

[13] Crushing, melting, quenching, heat treating, and grinding are shown as physical treatment in Exhibit 1.

[14] Brush Wellman, Inc. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

solution of sodium beryllate. Heating the solution to just below its boiling point precipitated a granular beryllium hydroxide that was recovered by continuous centrifugation.[15]

Part 2: Production of Beryllium Hydroxide from Beryllium Sulfate

During the extraction processes performed on the bertrandite and beryl ores, elements other than beryllium (e.g., aluminum, iron, and magnesium) are solubilized and must be removed in order to prevent product contamination. Therefore, extraction feed solution is pumped from the surge tank to the solvent extraction circuit. Solvent extraction is a closed-loop circuit consisting of three steps: loading, stripping, and acid conversion. The loading step consists of ten pairs of mixer and settler tanks. To liberate the beryllium from the extraction feed, the extraction feed is mixed with kerosene containing di(2-ethylhexyl)phosphate in each mixer tank and allowed to separate by gravity in each settler tank, where beryllium-laden organic liquid floats to the top. This is done sequentially through all ten mixer/settler pairs with aqueous liquid moving downcurrent from the first extraction mixer tank to the last settling tank, while the organic liquid moves upcurrent from the last mixer tank to the first settling tank. The aqueous liquid that leaves the end of the loading step of the solvent extraction circuit is known as raffinate, and it contains all of the magnesium (Mg) and most of the aluminum (Al) found in the beryllium sulfate extraction feed solution. The raffinate is pumped to a surge tank where any residual organic liquid is allowed to separate. The raffinate is then pumped to a water collection tank where it is combined with other wastewater streams and pumped to the tailings disposal tank, and then to the tailings pond. None of the raffinate is recycled.

The beryllium-laden organic liquid that comes out of the loading step of the solvent extraction circuit is called loaded organic. It is pumped to a surge tank and then to two pairs of mixer/settler tanks which comprise the stripping step of the solvent extraction circuit. The loaded organic is contacted with a small volume of aqueous ammonium carbonate in the mixer tanks, and allowed to separate in the settler tanks. The ammonium carbonate solution strips the beryllium, any remaining aluminum, iron, and uranium from the loaded organic, and results in an ammonium-beryllium carbonate solution with a ten-fold higher beryllium concentration than the loaded organic. The ammonium-beryllium carbonate solution is pumped to a surge tank before being introduced into the iron hydrolysis step. The remaining organic liquid from the stripping step is termed stripped organic.

The stripped organic has a basic pH from the stripping step and is converted to an acid pH for reuse in the loading step of the solvent extraction circuit. This is done in the acid conversion step of the solvent extraction circuit. In this step, the stripped organic is treated in two pairs of mixer/settler tanks by contacting it with aqueous sulfuric acid solution. The acidified, or converted, organic is pumped to two surge tanks prior to being recycled to the loading step of the solvent extraction circuit. The aqueous liquid from the acid conversion step is a wastewater called converted aqueous feed (CAF) and is pumped to the raffinate surge tank for discard. None of the CAF is recycled.[16]

Heating the ammonium beryllium carbonate solution to 95°C liberates part of the ammonia (NH_4) and carbon dioxide (CO_2) and causes the precipitation of beryllium carbonate, $BeCO_3$. The beryllium carbonate is separated on a rotary drum filter and may be drummed as an intermediate product. However, the beryllium carbonate may also be reslurried in deionized water and processed to beryllium hydroxide. Heating the beryllium carbonate slurry to 165°C in a pressure vessel liberates the remaining carbon dioxide and the resulting beryllium hydroxide is recovered by filtration.[17]

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[15] "Beryllium and Beryllium Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. IV, 1978, p. 808.

[16] Brush Wellman, Inc. January, 26, 1996. Op. Cit.

[17] Ibid.

EXHIBIT 3

Process Flow Diagram for Production of Metallic Beryllium (Part 1 of 3)

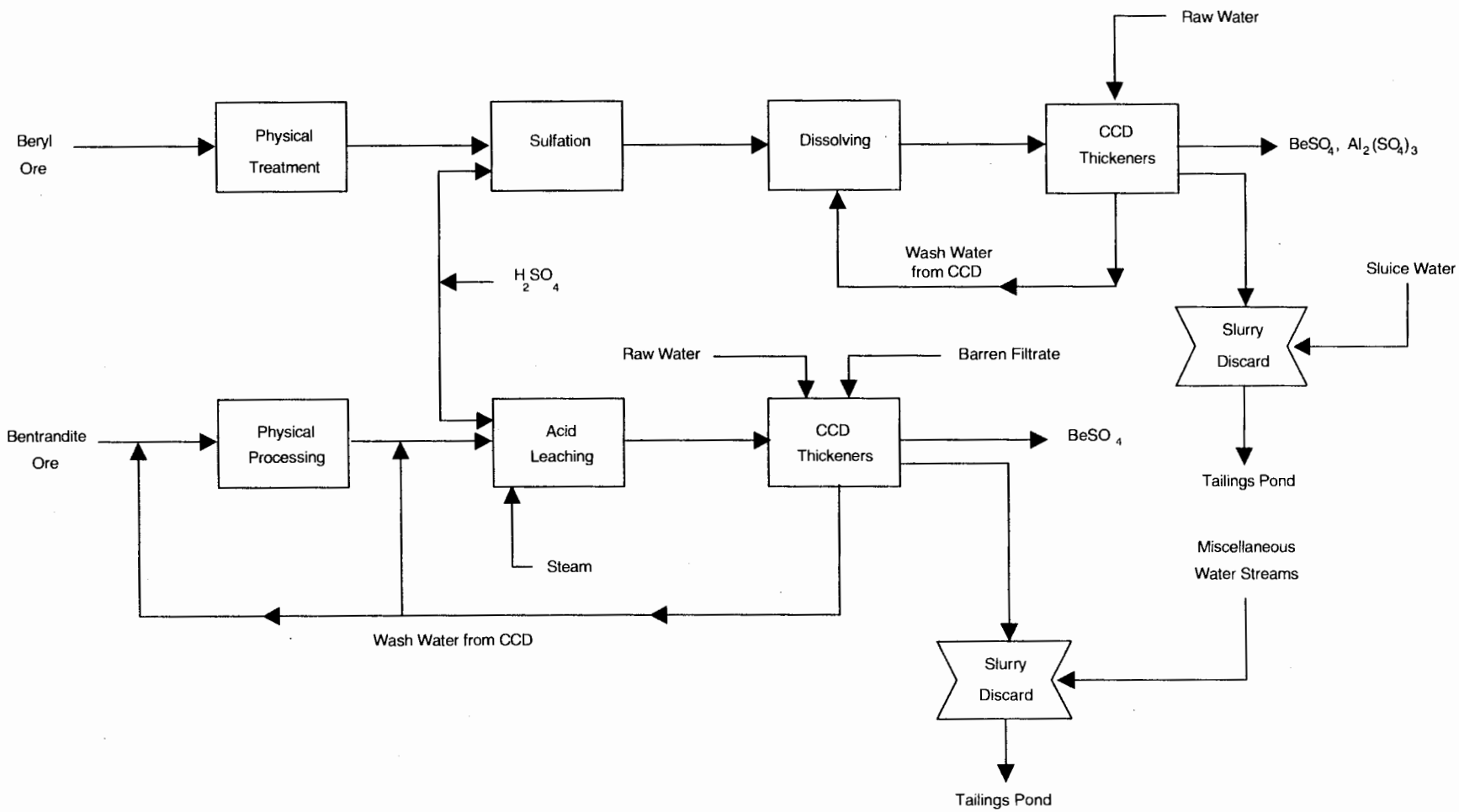
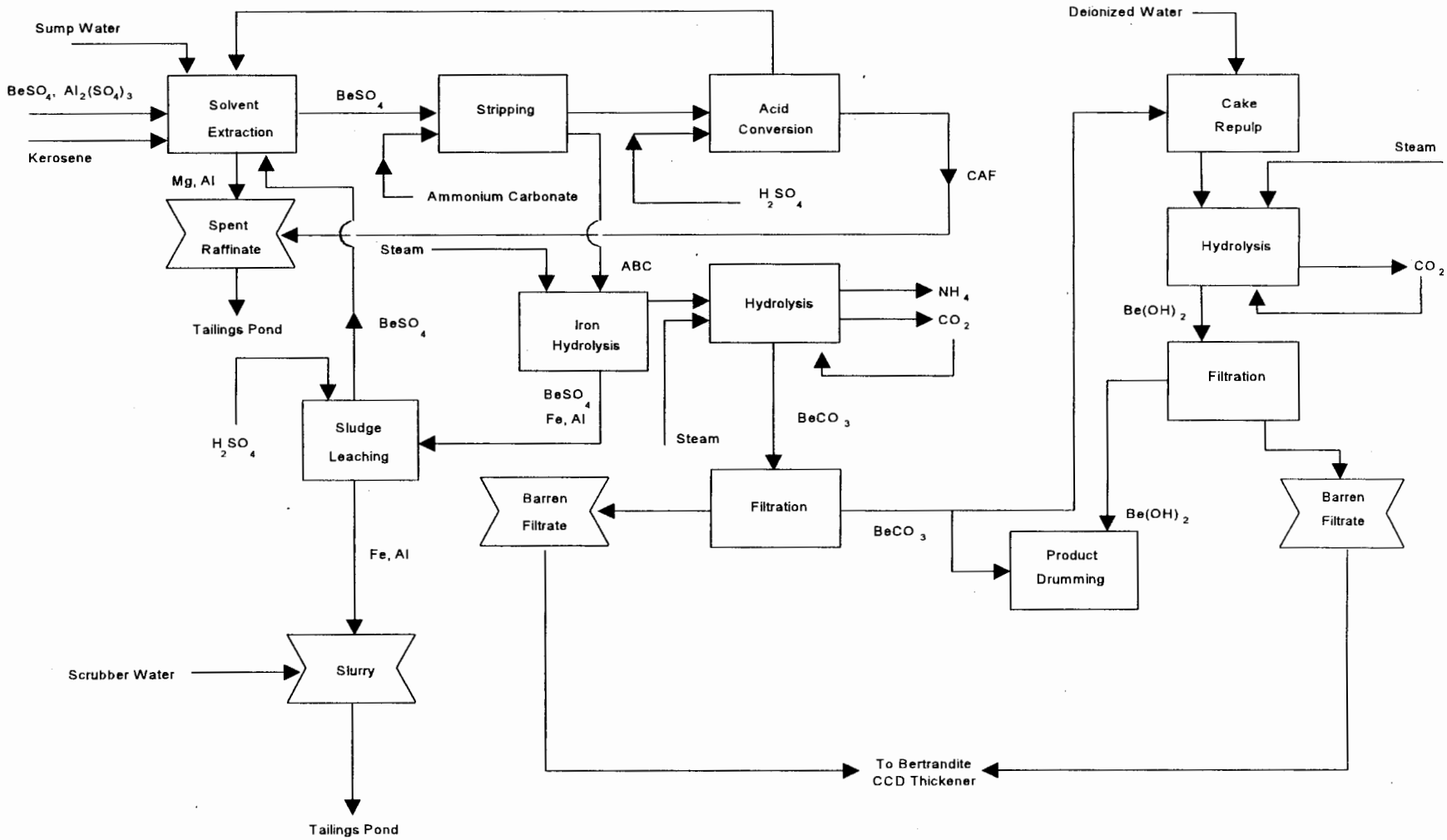


EXHIBIT 3

Process Flow Diagram for Production of Metallic Beryllium (Part 2 of 3)

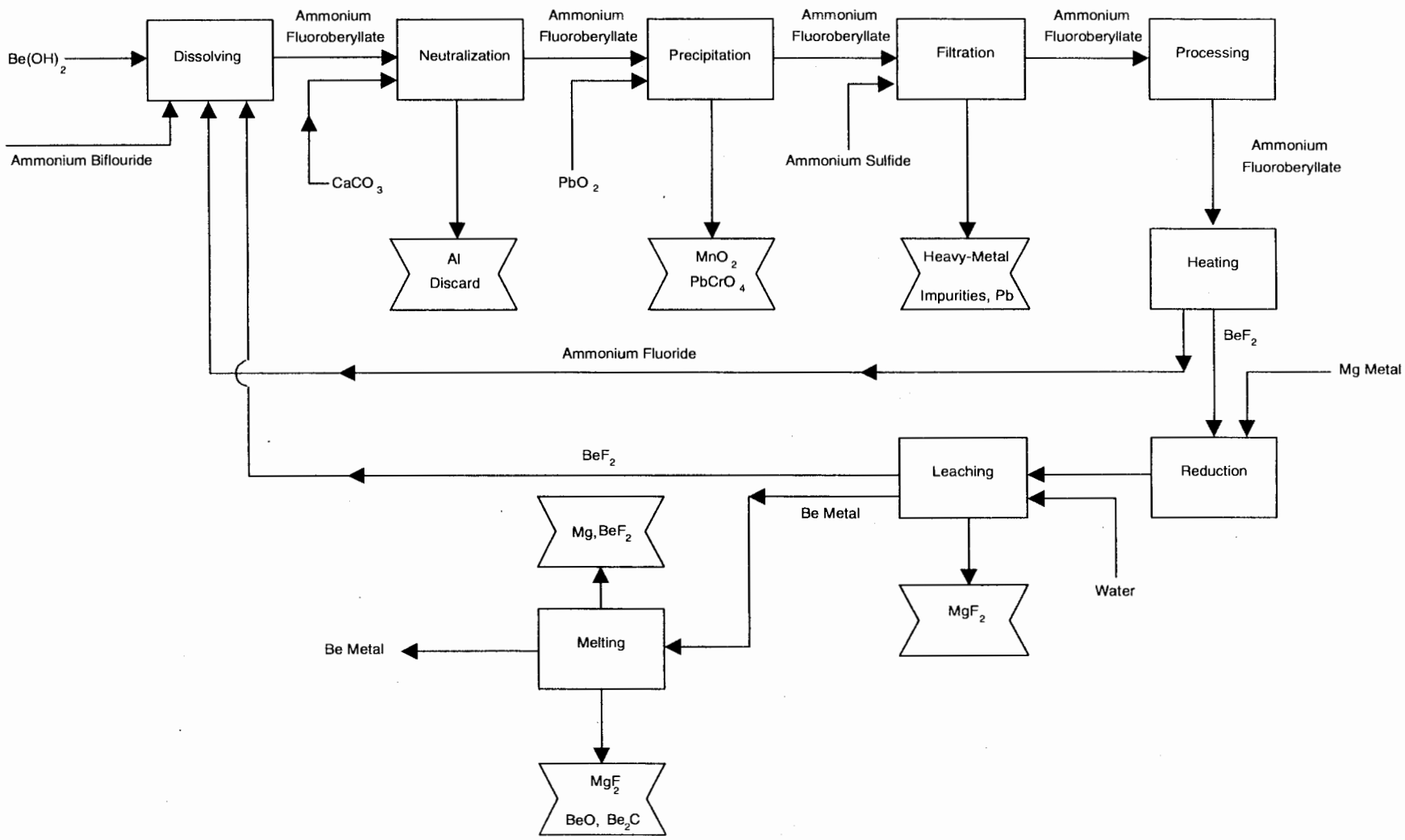


ABC = Ammonium Beryllium Carbonate

CAF = Converted Aqueous Feed

EXHIBIT 3

Process Flow Diagram for Production of Metallic Beryllium (Part 3 of 3)



Beryllium hydroxide production is the starting point for all further beryllium processing. Following hydroxide extraction, separate production processes are involved in producing the three basic beryllium lines (i.e., metallic beryllium, beryllium alloys, and beryllia).

Part 3: Production of Beryllium Metal, Oxide, and Alloys

Production of Metallic Beryllium. Brush Wellman uses the Schwenzfeier process to prepare a purified, anhydrous beryllium fluoride for reduction to beryllium metal. The first step of this process involves dissolving beryllium hydroxide in ammonium bifluoride to yield a solution of ammonium fluoroberyllate at pH 5.5. The solution is neutralized by adding aquaammonia. Then, solid calcium carbonate, $CaCO_3$, is added and the solution is heated to 60°C to remove aluminum before filtering. After filtration, ammonium sulfide is added to the filtrate to remove any heavy-metal impurities. Following the filtration step, ammonium fluoroberyllate is crystallized by co-current evaporation under vacuum. The crystals are continuously removed by centrifugation and washed lightly, while the mother liquor and washings are returned to the evaporator.[18] The ammonium fluoroberyllate is charged into inductively heated, graphite-lined furnaces where it is thermally decomposed to beryllium fluoride and ammonium fluoride. The ammonium fluoride is vaporized into fume collectors for recycle to the dissolution operation, whereas the molten beryllium fluoride is removed from the bottom of the furnace and solidified as a glassy product on water-cooled casting wheels.[19]

The beryllium fluoride is then reduced by magnesium metal (Mg) at a stoichiometric ratio of 1 BeF_2 : 0.7 Mg. In this process, magnesium metal and beryllium fluoride are charged into a graphite crucible at a temperature of about 900°C. The excess beryllium fluoride produces a slag of magnesium and beryllium fluorides having a melting point substantially below that of beryllium metal. The excess BeF_2 prevents the formation of an oxide film on the beryllium particles and assists in the coalescence of the metal.[20]

When the exothermic reaction is completed, the reaction products are heated to about 1300°C to allow molten beryllium to separate and float on top of the slag. The molten beryllium and slag are then poured into a graphite receiving pot where both solidify. The reaction product is then crushed and water-leached in a ball mill. The excess beryllium fluoride quickly dissolves, causing disintegration of the reaction mass and liberation of the beryllium metal as spherical pebbles. The leach liquor in this step is continuously passed through the ball mill in order to remove the fine, insoluble magnesium fluoride (MgF_2) particles formed during the reduction reaction. The magnesium fluoride is ultimately separated from the leach liquor and discarded. The leach liquor, which includes the excess beryllium fluoride, is then recycled as part of the input for making ammonium fluoroberyllate. The beryllium metal pebbles contain 98 percent beryllium along with entrapped reduction slag and unreacted magnesium. To remove these impurities, the metal is melted in induction furnaces under a vacuum. The excess magnesium and beryllium fluoride from the slag vaporize and are collected in suitable filters. Nonvolatiles, such as beryllium carbide (Be_2C), beryllium oxide, and magnesium fluoride, separate from the molten metal as a dross that adheres to the bottom of the crucibles. The purified beryllium metal is poured and cast into ingots of 150-200 kilograms.[21]

Production of Beryllium Oxide. Exhibit 4 illustrates the production of beryllium oxide. Beryllium hydroxide is dissolved in water and sulfuric acid. The resulting beryllium sulfate solution is filtered to remove impurities. The solution flows to one of two evaporators followed by two crystallizers in parallel where beryllium sulfate crystals are formed. The crystals are separated from the mother liquor in a centrifuge, and the mother liquor is recycled to the beryllium hydroxide dissolver.

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[18] Evaporation, centrifugation, and washing are shown as processing in Exhibit 1.

[19] "Beryllium and Beryllium Alloys", 1992, Op. Cit., pp. 129-130.

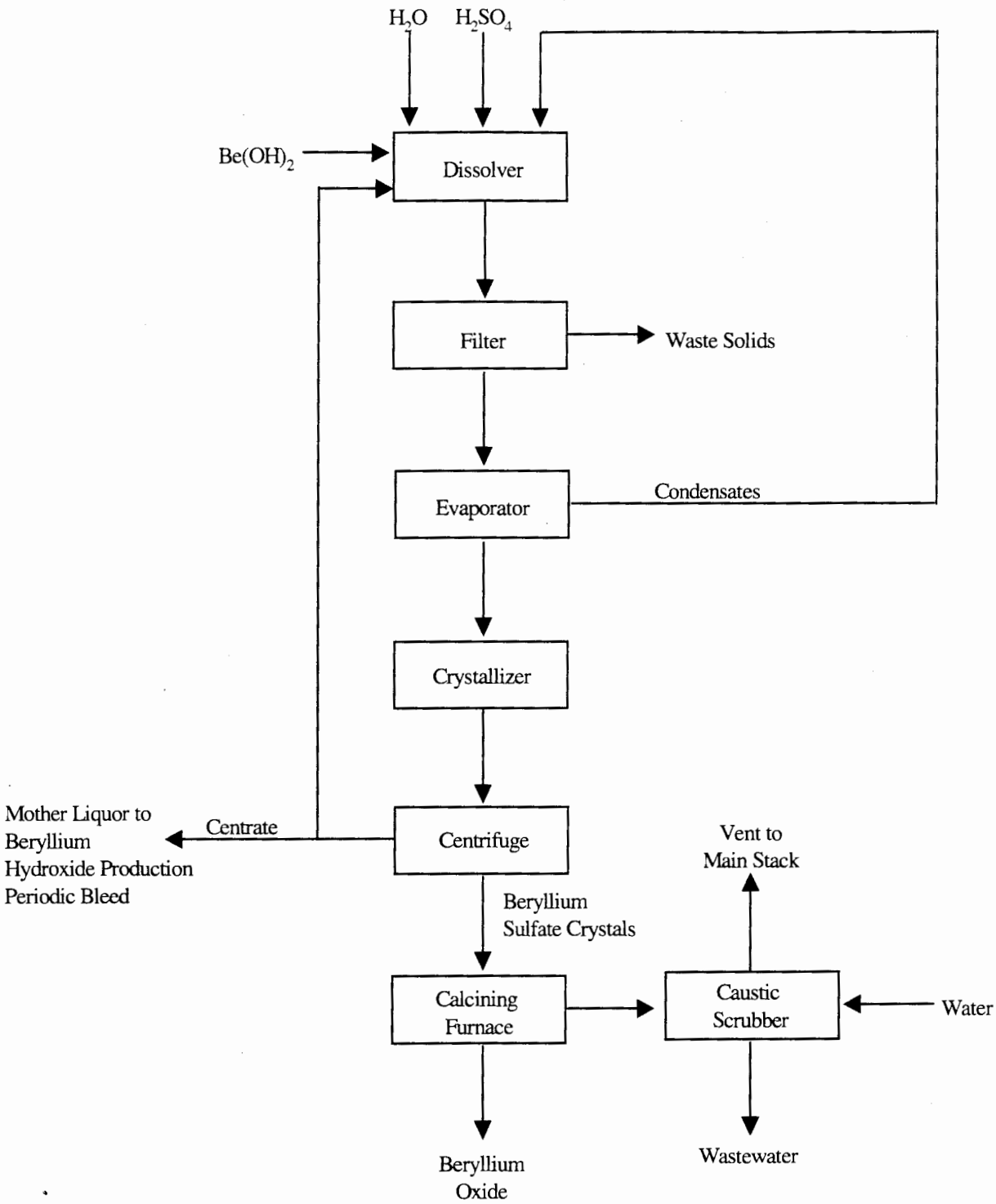
[20] Ibid., p. 130.

[21] "Beryllium and Beryllium Alloys," 1978, Op. Cit., p. 810.

EXHIBIT 4

PROCESS FLOW DIAGRAM FOR PRODUCTION OF BERYLLIUM OXIDE

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989, p. 3647.)



The beryllium sulfate is calcined in gas fired furnaces at about 1100°C to beryllium oxide. The exhaust gas from the calcining furnace is scrubbed in caustic scrubbers to remove sulfur dioxide. The scrubber water is sent to treatment.[22]

Production of Beryllium-copper Alloys. Beryllium hydroxide, electrolytic copper, and carbon are combined in an electric arc furnace to make beryllium-copper master alloy. The resultant melt, containing about four percent beryllium is cast into ingots. Remelting master alloy ingots with additional copper and other alloying elements yields the desired beryllium-copper alloy, which is then cast into slabs or billets. Slabs of beryllium copper alloys are processed further into strip or plate, and billets are extruded into tube, rod, bar, and wire products.[23]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

The Fluoride process, an alternative to the Kjellgren-Sawyer process, converts the beryllium oxide found in beryl ore to a water-soluble form by roasting with fluxes. In this process, pulverized beryl ore is roasted with sodium fluorosilicate at approximately 750°C to form slightly soluble sodium fluoroberyllate. The reaction products are extruded as wet briquettes and ground in a wet pebble mill. The sodium fluoroberyllate is then leached with water at room temperature. The filtered solution is treated with sodium hydroxide to form sodium beryllate, from which a filterable beryllium hydroxide is precipitated by boiling. The beryllium hydroxide can then be processed to metallic beryllium using the process discussed in Part 3.[24]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

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[22] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Vol. VII, Office of Water Regulation Standards, May 1989, p. 3643.

[23] Deborah A. Kramer, "Beryllium Minerals," from Industrial Rocks and Minerals, 6th Ed., Society for Mining, Metallurgy, and Exploration, 1994, p. 152.

[24] "Beryllium and Beryllium Alloys," 1978, Op. Cit., pp. 808-809.

Bertrandite and Beryl Ore Processes

EPA determined that for the production of beryllium via the bertrandite and beryl ore processes, mineral processing occurs between solvent extraction and iron hydrolysis, due to the change in chemical composition that occurs during hydrolysis.[25] Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Other Beryllium Processing

Because other beryllium products are produced after either bertrandite ore processing or beryl ore processing, all of the wastes generated during these operations are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, please see the bertrandite ore and beryl ore process sections above.

C. Process Waste Streams

During the production of metallic beryllium from beryl and bertrandite ores, several waste streams are generated. Each waste stream is identified below, along with the portion of the process in which it is created. For each waste stream, any specific information regarding its physical and chemical characteristics is provided, as well as generation rates and management practices.

1. Extraction/Beneficiation Wastes

Part 1: Extraction of Beryllium as Beryllium Sulfate

Physical Processing/Treatment wastes. These wastes are generated by the physical processing or treatment of ore, and may include **tailings**, **gangue**, and **wastewater**. No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

Bertrandite thickener slurry. Approximately 370,000 metric tons of bertrandite thickener slurry were discarded to a tailings pond in 1992.[26] The pH of the bertrandite thickener slurry has been reported between 2.5 and 3.5.[27] The attached data in Attachment 1 indicate that the pH of bertrandite thickener slurry ranges from 2 to 3. Therefore, this waste may sometimes exhibit the hazardous characteristic of corrosivity. We used best engineering judgment to determine that this waste stream may be recycled to extraction/beneficiation units. Bertrandite thickener slurry was formerly classified as a by-product. This waste stream is combined with approximately 250,000 metric tons of miscellaneous water streams prior to disposal.[28] The miscellaneous water streams are generated during the bertrandite ore extraction process, but the origin of these streams is unknown. See Attachment 1 for waste characterization data.

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[25] U.S. Environmental Protection Agency, Letter from Mr. Robert Tonetti, Acting Deputy Director, Waste Management Division, Office of Solid Waste to Mr. Richard Davis, Brush Wellman, Inc., March 15, 1990.

[26] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, Volume I, August, 1992, p. I-2.

[27] Brush Wellman, 1988, Op. Cit., p. 8.

[28] RTI Survey 101006, National Survey of Solid Wastes From Mineral Processing Facilities, Brush Wellman Co., Delta, UT, 1989, p. 2-4.

Beryl thickener slurry. In 1992, beryl thickener slurry was discarded to a tailings pond at a rate of 3,000 metric tons/yr.[29] The beryl thickener slurry has a pH of 2.[30] Therefore, this waste exhibits the hazardous characteristic of corrosivity. We used best engineering judgment to determine that this waste stream may be recycled to extraction beneficiation units. Beryl thickener slurry was formerly classified as a by-product. This waste stream is combined with about 21,000 metric tons of sluice water prior to disposal.[31] The sluice water is used to transport the beryl ore to the start of the ore extraction processes. See Attachment 1 for waste characterization data.

Part 2: Production of Beryllium Hydroxide from Beryllium Sulfate

Spent raffinate. Approximately 380,000 metric tons of spent raffinate were discarded to a tailings pond in 1992. This waste exhibits the hazardous characteristics of toxicity (for selenium) and corrosivity.[32] The raffinate has a pH of 1.4.[33] This aqueous waste stream also contains magnesium and aluminum,[34] and may contain treatable concentrations of metal impurities, total suspended solids, and low levels of organics.[35] This waste stream is discarded to a tailings pond.[36] Spent raffinate was formerly classified as a spent material. This waste stream is combined with approximately roughly 33,000 metric tons of an **acid conversion stream** prior to disposal.[37] See Attachment 1 for waste characterization data.

Sump water. This waste is generated during the solvent extraction process that removes metal impurities from the beryllium sulfate solution. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Acid conversion stream. This waste is the resultant aqueous liquid of the stripping step of the solvent extraction process and is referred to as converted aqueous feed. This waste stream is combined with spent raffinate and discarded to a tailings pond.[38] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[29] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-2.

[30] Ibid., p. 6-61.

[31] RTI Survey 101006, 1989, Op. Cit., p. 2-4.

[32] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-2.

[33] Brush Wellman, 1988, Op. Cit., p. 11.

[34] "Beryllium and Beryllium Alloys", 1992, Op. Cit., p. 129.

[35] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3569.

[36] Brush Wellman, Inc. January 25, 1996. Op. Cit.

[37] RTI Survey 101006, 1989, Op. Cit., p. 2-4.

[38] Brush Wellman, Inc. January 25, 1996. Op. Cit.

2. Mineral Processing Wastes

Part 2: Production of Beryllium Hydroxide from Beryllium Sulfate

Separation slurry. In 1992, the separation slurry was discarded to a tailings pond at a rate of 2,000 metric tons/yr.[39] The separation slurry has a pH of 3.[40] The slurry contains iron and aluminum which have been precipitated as hydroxides and carbonates from the aqueous ammonium beryllium carbonate stream.[41] This waste stream is combined with about 39,000 metric tons of scrubber water prior to disposal.[42] The scrubber water is probably basic because it is used to scrub the ammonia and carbon dioxide stream released during the heating of the ammonium beryllium carbonate. See Attachment 1 for waste characterization data.

Spent barren filtrate streams. The barren filtrate streams are produced during the filtration of beryllium carbonate and beryllium hydroxide. Approximately 88,000 metric tons of barren filtrate were discarded to a tailings pond in 1992. This waste exhibits the hazardous characteristic of toxicity for selenium.[43] The barren filtrate streams have a pH of 9.8.[44] EPA received conflicting data about whether this waste stream is recycled to the bertrandite CCD thickeners or is disposed, so we used best engineering judgment to determine that this waste stream is partially recycled. The streams were formerly classified as spent material. The barren filtrate stream from the filtration of beryllium carbonate operation contains uranium that was solubilized in the ore extraction processes. See Attachment 1 for waste characterization data.

Beryllium hydroxide supernatant. When beryllium is recovered from recycled customer material, internally generated residues, scrap, and recycled mother liquor from the beryllium oxide crystallization operations, the raw material is dissolved in sulfuric acid and beryllium and then precipitated with caustic as beryllium hydroxide. After gravity separation, the supernatant is discharged as a wastewater stream.[45] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further. See Attachment 1 for waste characterization data.

Part 3: Production of Beryllium Metal, Oxide, and Alloys

Production of Metallic Beryllium

The following waste streams are generated during the conversion of beryllium hydroxide to beryllium metal.

Neutralization discard. This waste stream contains precipitated aluminum. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[39] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-2.

[40] Brush Wellman, 1988, Op. Cit., p. 9.

[41] "Beryllium and Beryllium Alloys," 1978, Op. Cit., p. 807.

[42] RTI Survey 101006, 1989, Op. Cit., p. 2-4.

[43] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-2.

[44] Brush Wellman, 1988, Op. Cit., p. 10.

[45] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3660.

Precipitation discard. This waste stream contains precipitated manganese dioxide and lead chromate. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Filtration discard. This waste stream contains lead and other heavy-metal impurities. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 23,000 metric tons/yr, and 45,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity for lead. This waste stream is not recycled.

Leaching discard. This waste stream contains insoluble magnesium fluoride. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Dross discard. This waste stream contains nonvolatiles, such as beryllium oxide, magnesium fluoride, and beryllium carbide which separate from the molten beryllium metal during the final melting process. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Melting emissions. This gaseous waste stream contains magnesium and beryllium fluoride which vaporized during the final melting process and collected on suitable filters. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Process wastewater. Process condensates are generated from the ammonium beryllium fluoride crystallizer and the ammonium fluoride sludge filtrate evaporator. The condensed water is used as makeup for the fluoride furnace scrubbing system, for the beryllium pebble plant scrubbing system, for sludge washing, and general plant water usage such as floor washing. Periodic discharge from the process water pit is necessary to prevent dissolved solids build-up. The process wastewater has a neutral pH, and treatable concentrations of beryllium and fluoride. Ammonia and cyanide are also reported as present above treatable concentrations.[46]

Pebble plant area vent scrubber water. The beryllium pebble plant contains a ventilation system for air circulation. A wet scrubber is employed to clean the used air prior to venting to the atmosphere. Although the scrubber is recycled extensively, a blowdown stream is periodically discharged to the process water pit. Makeup water for the scrubber is obtained from the process water pit. This scrubber water has a slightly acidic pH, and treatable concentrations of beryllium and fluoride.[47] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further. See Attachment 1 for waste characterization data.

Chip treatment wastewater. Pure beryllium metal scrap in the form of chips is treated with nitric acid and rinsed prior to being vacuum cast along with beryllium pebbles into a beryllium metal billet. The spent acid and rinse water are discharged. This operation combines refining beryllium from secondary as well as primary sources.[48] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 50,000 metric tons/yr, and 1,000,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity for chromium. See Attachment 1 for

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[46] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3661.

[47] Ibid., p. 3662.

[48] Ibid., p. 3661.

waste characterization data. We also used best engineering judgment to determine that this waste stream may be partially recycled. This waste stream was formerly classified as a spent material.

Production of Beryllium Oxide

Scrubber liquor. This waste contains the sulfur dioxide removed from the furnace exhaust gas and sent to treatment. While over 90 percent of this stream is recycled, the rest is discharged as a wastewater stream. Scrubber liquor has a neutral pH, very high concentrations of dissolved solids (primarily sodium sulfate), and treatable concentrations of beryllium, fluoride and suspended solids.[49] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Waste solids. This waste stream contains the impurities filtered from beryllium sulfate solution. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Production of Beryllium-copper alloys

No other information on waste characteristics, waste generation, or waste management of wastes generated during production of beryllium-copper alloys was available in the sources listed in the bibliography.

D. Non-uniquely Associated Wastes

Non-uniquely associated hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

Four commenters provided new factual information on beryllium sector processes and waste streams. (COMM58, COMM59, COMM60, COMM64). This information has been incorporated into the commodity summary, process description, and waste stream description sections of this sector report.

Sector-Specific Issues

Three commenters indicated that the Agency had incorrectly placed the beneficiation/processing line in the beryllium sector. (COMM58, COMM60, COMM64) The commenters indicated that the Agency's placement of the beneficiation/processing line was inconsistent with prior Agency determinations. The Agency agrees that the beneficiation/processing line was incorrectly located in the initial draft of the sector report, and has revised the discussion of the beneficiation/processing boundary to reflect the decision made in the March 15, 1990 letter from Robert Tonetti, Acting Deputy Director, Waste Management Division, to Richard Davis of Brush Wellman, Inc.[50]

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[49] Ibid., p. 3660.

[50] In the process of incorporating this change into two supporting documents of this Rulemaking (Regulatory Impact Analysis and Characterization of Mineral Processing Wastes and Materials), EPA inadvertently removed spent barren filtrate from cost and risk modeling analyses as a beneficiation waste. This waste is a processing waste because it is generated downstream of the initial mineral processing step of beryllium production, iron hydrolysis. EPA has corrected this error in the supporting documents.

EPA received conflicting information about the disposition of spent barren filtrate. One commenter indicated that spent barren filtrate is recycled to the bertrandite CCD thickeners (COMM59). However, in comments on the Regulatory Impact Analysis, the same commenter indicated that spent barren filtrate is not recycled (COMM60). In the May 12, 1997 Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, this same commenter indicated that a waste stream known as "finc barren filtrate" is recycled (Brush Wellman, Inc., 2P4P-00052). It is unclear whether "fine barren filtrate" and spent barren filtrate are the same waste stream because the commenter provided differing generation quantities for "fine barren filtrate" and "barren filtrate." Furthermore, a process flowsheet provided in the comment did not indicate direct recycling of barren filtrate to the CCD thickeners. In light of this conflicting information, EPA is assuming that this material is partially recycled as described in the spent barren filtrate waste stream description.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - BETRANDITE THICKENER SLURRY - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	200.00	454.50	709.00	2/2	6.80	6.80	6.80	1/1	-	-
Antimony	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Arsenic	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	5.0	0
Barium	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	100.0	0
Beryllium	9.70	3,209.90	9,320.00	3/3	0.84	0.84	0.84	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	0.50	0.50	0.50	0/1	0.01	0.01	0.01	0/1	1.0	0
Chromium	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	5.0	0
Cobalt	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Copper	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Iron	7.00	186.00	365.00	2/2	0.12	0.12	0.12	1/1	-	-
Lead	17.20	17.20	17.20	1/1	0.03	0.03	0.03	0/1	5.0	0
Magnesium	300.00	340.00	380.00	2/2	16.00	16.00	16.00	1/1	-	-
Manganese	308.00	308.00	308.00	1/1	0.49	0.49	0.49	1/1	-	-
Mercury	0.0500	0.0500	0.0500	0/1	0.0001	0.0001	0.0001	0/1	0.2	0
Molybdenum	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Nickel	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Selenium	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	1.0	0
Silver	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	5.0	0
Thallium	25.00	25.00	25.00	0/1	0.25	0.25	0.25	0/1	-	-
Vanadium	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Zinc	65.30	65.30	65.30	1/1	1.19	1.19	1.19	1/1	-	-
Sulfate	1,900.00	2,450.00	3,000.00	2/2					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	18.20	18.20	18.20	1/1					-	-
pH *	2.00	2.50	3.00	2/2				2/2	2<pH>12	1
Organics (TOC)	385.00	385.00	385.00	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - BERYL PLANT SLURRY DISCHARGE - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detected	Minimum	Average	Maximum	# Detected	Level	In Excess
Aluminum	0.62	0.62	0.62	1/1	0.22	0.22	0.22	1/1	-	-
Antimony	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	-	-
Arsenic	0.30	0.30	0.30	1/1	0.13	0.13	0.13	1/1	5.0	0
Barium	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	100.0	0
Beryllium	0.05	4,660.02	9,320.00	2/2	0.19	0.19	0.19	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.005	0.005	0.005	0/1	0.005	0.005	0.005	0/1	1.0	0
Chromium	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	5.0	0
Cobalt	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	-	-
Copper	0.05	0.05	0.05	0/1	0.15	0.15	0.15	1/1	-	-
Iron	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	-	-
Lead	0.03	0.03	0.03	0/1	0.03	0.03	0.03	0/1	5.0	0
Magnesium	5.29	5.29	5.29	1/1	4.13	4.13	4.13	1/1	-	-
Manganese	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	-	-
Mercury	0.0003	0.0003	0.0003	0/1	0.0001	0.0001	0.0001	0/1	0.2	0
Molybdenum	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	-	-
Nickel	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	-	-
Selenium	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	1.0	0
Silver	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	5.0	0
Thallium	0.25	0.25	0.25	0/1	0.25	0.25	0.25	0/1	-	-
Vanadium	0.05	0.05	0.05	0/1	0.05	0.05	0.05	0/1	-	-
Zinc	0.05	0.05	0.05	0/1	2.32	2.32	2.32	1/1	-	-
Sulfate	8,740.00	8,740.00	8,740.00	1/1					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	155.00	155.00	155.00	1/1					-	-
pH*	2.00	2.00	2.00	1/1					2<pH>12	1
Organics (TOC)	579.00	579.00	579.00	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT RAFFINATE - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	1570	1610	1650	2/2	3050	3050	3050	1/1	-	-
Antimony	0.10	0.10	0.10	0/1	1.00	1.00	1.00	1/1	-	-
Arsenic	3.05	3.05	3.05	1/1	1.19	1.19	1.19	1/1	5.0	0
Barium	0.10	0.10	0.10	0/1	1.00	1.00	1.00	1/1	100.0	0
Beryllium	2.62	5.52	8.00	5/5	2.83	2.83	2.83	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.01	0.01	0.01	0/1	0.10	0.10	0.10	1/1	1.0	0
Chromium	0.81	0.81	0.81	1/1	1.00	1.00	1.00	1/1	5.0	0
Cobalt	0.10	0.10	0.10	0/1	1.00	1.00	1.00	1/1	-	-
Copper	0.10	0.10	0.10	0/1	1.00	1.00	1.00	1/1	-	-
Iron	2.88	2.88	2.88	1/1	3.16	3.16	3.16	1/1	-	-
Lead	0.05	0.05	0.05	0/1	0.69	0.69	0.69	1/1	5.0	0
Magnesium	1690	1690	1690	1/1	1640	1640	1640	1/1	-	-
Manganese	60.70	60.70	60.70	1/1	61.10	61.10	61.10	1/1	-	-
Mercury	0.0001	0.0001	0.0001	0/1	0.0002	0.0002	0.0002	1/1	0.2	0
Molybdenum	0.10	0.10	0.10	0/1	1.00	1.00	1.00	1/1	-	-
Nickel	0.46	0.46	0.46	1/1	1.00	1.00	1.00	1/1	-	-
Selenium	0.41	0.41	0.41	1/1	1.00	1.00	1.00	1/1	1.0	1
Silver	0.10	0.10	0.10	0/1	1.00	1.00	1.00	1/1	5.0	0
Thallium	0.50	0.50	0.50	0/1	5.00	5.00	5.00	1/1	-	-
Vanadium	0.10	0.10	0.10	0/1	1.00	1.00	1.00	1/1	-	-
Zinc	141.00	141.00	141.00	1/1	125	125	125	1/1	-	-
Sulfate	55900	55900	55900	1/1					-	-
Fluoride	7000	7000	7000	1/1					-	-
Chloride	298.00	298.00	298.00	1/1					-	-
pH*	0.90	0.95	1.00	2/2					2<pH>12	2
Organics (TOC)	-	-	-	0					-	-

*Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SEPARATION SLURRY - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	1110	1110	1110	1/1	54.10	54.10	54.10	1/1	-	-
Antimony	64.60	64.60	64.60	1/1	0.12	0.12	0.12	1/1	-	-
Arsenic	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	5.0	0
Barium	5.00	5.00	5.00	0/1	0.10	0.10	0.10	1/1	100.0	0
Beryllium	180.00	262.80	320.00	5/5	34.80	34.80	34.80	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	0.50	0.50	0.50	0/1	0.02	0.02	0.02	1/1	1.0	0
Chromium	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	5.0	0
Cobalt	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Copper	5.00	5.00	5.00	0/1	0.11	0.11	0.11	1/1	-	-
Iron	28000	47300	66600	2/2	3.21	3.21	3.21	1/1	-	-
Lead	26.50	26.50	26.50	1/1	0.03	0.03	0.03	1/2	5.0	0
Magnesium	15.80	15.80	15.80	1/1	3.21	3.21	3.21	2/2	-	-
Manganese	5.00	5.00	5.00	0/1	0.13	0.13	0.13	1/1	-	-
Mercury	0.1300	0.1300	0.1300	1/1	0.0001	0.0001	0.0001	0/1	0.2	0
Molybdenum	10.70	10.70	10.70	1/1	0.05	0.05	0.05	0/1	-	-
Nickel	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	-
Selenium	12.80	12.80	12.80	1/1	0.05	0.05	0.05	0/1	1.0	0
Silver	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	5.0	0
Thallium	25.00	25.00	25.00	0/1	0.25	0.25	0.25	0/1	-	0
Vanadium	5.00	5.00	5.00	0/1	0.05	0.05	0.05	0/1	-	0
Zinc	28.30	28.30	28.30	1/1	1.60	1.60	1.60	1/1	-	-
Sulfate	8030	8030	8030	1/1					-	-
Fluoride	7.00	7.00	7.00	1/1					-	-
Chloride	-	-	-	0/0					-	-
pH*	3.00	3.08	3.15	2/2					2<pH>12	0
Organics (TOC)	475.00	475.00	475.00	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - BARREN FILTRATE - BERYLLIUM

Constituents	Total Constituent Analysis - PPM Minimum	Average	Maximum	# Detects	EP Toxicity Analysis - PPM Minimum	Average	Maximum	# Detects	TC Level	# Values In Excess
Aluminum	0.30	579.88	2,290.00	4/4	14.70	293.85	573.00	2/2	-	-
Antimony	1.35	3.18	5.00	1/2	0.79	0.90	1.00	2/2	-	-
Arsenic	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	5.0	0
Barium	0.05	2.53	5.00	0/2	0.15	0.58	1.00	2/2	100.0	0
Beryllium	7.90	48.04	76.30	5/5	2.66	15.03	27.40	2/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.03	0.26	0.50	1/2	0.02	0.06	0.10	2/2	1.0	0
Chromium	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	5.0	0
Cobalt	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Copper	0.10	2.55	5.00	1/2	0.05	0.53	1.00	1/2	-	-
Iron	0.20	222.13	886.00	4/4	0.34	108.67	217.00	2/2	-	-
Lead	0.03	7.56	15.10	1/2	0.03	0.27	0.52	1/2	5.0	0
Magnesium	2.72	516.36	1,030.00	2/2	2.48	147.74	293.00	2/2	-	-
Manganese	0.05	101.03	202.00	1/1	0.05	6.63	13.20	1/2	-	-
Mercury	0.0001	0.0251	0.0500	0/2	0.0001	0.0002	0.0002	1/2	0.2	0
Molybdenum	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Nickel	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Selenium	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	1.0	1
Silver	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	5.0	0
Thallium	0.25	12.63	25.00	0/2	0.25	2.63	5.00	1/2	-	-
Vanadium	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Zinc	0.76	57.38	114.00	2/2	0.78	13.29	25.80	2/2	-	-
Sulfate	710.00	14,705.00	28,700.00	2/2					-	-
Fluoride	81.00	121.00	161.00	2/2					-	-
Chloride	175.00	178.50	182.00	2/2					-	-
pH*	9.00	9.38	9.60	4/4					2<pH>12	0
Organics (TOC)	370.00	1,405.00	2,440.00	2/2					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - BERYLLIUM HYDROXIDE SUPERNATANT RAW WASTEWATER - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.003	0.003	0.003	1/1	-	-	-	0/0	-	-
Arsenic	0.003	0.003	0.003	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	12	12	12	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.004	0.004	0.004	1/1	-	-	-	0/0	1.0	0
Chromium	0.11	0.11	0.11	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	1.4	1.4	1.4	1/1	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.168	0.168	0.168	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0002	0.0002	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.12	0.12	0.12	1/1	-	-	-	0/0	-	-
Selenium	0.003	0.003	0.003	1/1	-	-	-	0/0	1.0	0
Silver	0.32	0.32	0.32	1/1	-	-	-	0/0	5.0	0
Thallium	0.002	0.002	0.002	1/1	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.19	0.19	0.19	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PROCESS WASTEWATER - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.30	579.88	2,290.00	4/4	14.70	293.85	573.00	2/2	-	-
Antimony	1.35	3.18	5.00	1/2	0.79	0.90	1.00	2/2	-	-
Arsenic	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	5.0	0
Barium	0.05	2.53	5.00	0/2	0.15	0.58	1.00	2/2	100.0	0
Beryllium	7.90	48.04	76.30	5/5	2.66	15.03	27.40	2/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.03	0.26	0.50	1/2	0.02	0.06	0.10	2/2	1.0	0
Chromium	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	5.0	0
Cobalt	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Copper	0.10	2.55	5.00	1/2	0.05	0.53	1.00	1/2	-	-
Iron	0.20	222.13	886.00	4/4	0.34	108.67	217.00	2/2	-	-
Lead	0.03	7.56	15.10	1/2	0.03	0.27	0.52	1/2	5.0	0
Magnesium	2.72	516.36	1,030.00	2/2	2.48	147.74	293.00	2/2	-	-
Manganese	0.05	101.03	202.00	1/1	0.05	6.63	13.20	1/2	-	-
Mercury	0.0001	0.0251	0.0500	0/2	0.0001	0.0002	0.0002	1/2	0.2	0
Molybdenum	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Nickel	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Selenium	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	1.0	1
Silver	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	5.0	0
Thallium	0.25	12.63	25.00	0/2	0.25	2.63	5.00	1/2	-	-
Vanadium	0.05	2.53	5.00	0/2	0.05	0.53	1.00	1/2	-	-
Zinc	0.76	57.38	114.00	2/2	0.78	13.29	25.80	2/2	-	-
Sulfate	710.00	14,705.00	28,700.00	2/2					-	-
Fluoride	81.00	121.00	161.00	2/2					-	-
Chloride	175.00	178.50	182.00	2/2					-	-
pH*	9.00	9.38	9.60	4/4					2<pH>12	0
Organics (TOC)	370.00	1,405.00	2,440.00	2/2					-	-

*Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PEBBLE PLANT AREA VENT SCRUBBER WATER - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.003	0.0030	0.003	2/2	-	-	-	0/0	-	-
Arsenic	0.042	0.0510	0.06	2/2	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	210	210	210	2/2	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.033	0.0335	0.034	2/2	-	-	-	0/0	1.0	0
Chromium	0.093	0.1165	0.14	2/2	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.5	0.5400	0.58	2/2	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.168	0.1680	0.168	2/2	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0003	0.0004	0.0004	2/2	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.064	0.0640	0.064	2/2	-	-	-	0/0	-	-
Selenium	0.003	0.0030	0.003	2/2	-	-	-	0/0	1.0	0
Silver	0.0005	0.0043	0.008	2/2	-	-	-	0/0	5.0	0
Thallium	0.002	0.0020	0.002	2/2	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.096	0.1130	0.13	2/2	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - CHIP TREATMENT WASTEWATER - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.003	0.003	0.003	1/1	-	-	-	0/0	-	-
Arsenic	0.003	0.003	0.003	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	3300	3300	3300	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.063	0.063	0.063	1/1	-	-	-	0/0	1.0	0
Chromium	7.4	7.4	7.4	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	1.4	1.4	1.4	1/1	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.2	0.2	0.2	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0002	0.0002	1/1	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.78	0.78	0.78	1/1	-	-	-	0/0	-	-
Selenium	0.003	0.003	0.003	1/1	-	-	-	0/0	1.0	0
Silver	0.04	0.04	0.04	1/1	-	-	-	0/0	5.0	0
Thallium	0.002	0.002	0.002	1/1	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	7.2	7.2	7.2	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SCRUBBER LIQUOR - BERYLLIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	0
Antimony	0.003	0.0067	0.015	6/6	-	-	-	0/0	-	-
Arsenic	0.003	0.0030	0.003	6/6	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.49	1.0733	2	6/6	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.004	0.0073	0.015	6/6	-	-	-	0/0	1.0	0
Chromium	0.042	0.0675	0.13	6/6	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.12	0.4100	1.5	6/6	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.16	0.1667	0.168	6/6	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0002	0.0002	6/6	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.019	0.0297	0.043	6/6	-	-	-	0/0	-	-
Selenium	0.003	0.0030	0.003	6/6	-	-	-	0/0	1.0	0
Silver	0.024	0.0655	0.1	6/6	-	-	-	0/0	5.0	0
Thallium	0.002	0.0020	0.002	6/6	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.039	0.0553	0.087	6/6	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

BISMUTH

A. Commodity Summary

According to the Bureau of Mines, bismuth is produced, as a byproduct of lead refining, at only one facility (ASARCO - Omaha, NE). Reported consumption of bismuth was estimated at 1,500 metric tons during 1994 and 40 companies in the East were responsible for 98 percent of the total bismuth consumption. Bismuth is used primarily in the following industries: pharmaceuticals and chemicals (including cosmetics), metallurgical additives, and fusible alloys and solder.[1]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Bismuth is recovered mainly during the smelting of copper and lead ores. Exhibit 1 shows the extraction of bismuth-containing dust from copper-based sources. Bismuth-containing dust from copper smelting operations is transferred to lead smelting operations for recovery. At lead smelting operations, bismuth is recovered by one of two processes: the Betterton-Kroll Process (shown in Exhibit 2) and the Betts Electrolytic Process (shown in Exhibit 3).[2] Bismuth can also be recovered from other bismuth -bearing materials by the process shown in Exhibit 4. Exhibit 5 presents the flow diagram for the process used to refine the bismuth-lead alloy produced during either the Betterton-Kroll or the Betts Electrolytic Process.

2. Generalized Process Flow Diagram

Betterton-Kroll Process

As shown in Exhibit 2, the Betterton-Kroll process is based on the formation of high-melting compounds such as Ca_2Bi_2 and Mg_3Bi_2 that separate from the molten lead bullion bath and can be skimmed off as dross. During this process, magnesium and calcium are mixed with the molten lead to form ternary compounds (e.g., $CaMg_2Bi_2$). The ternary compounds rise to the surface when the lead is cooled to just above its melting point, forming a dross containing bismuth, calcium, magnesium, and lead, which is skimmed. Bismuth is recovered by melting the dross in a furnace, treating the dross with chlorine or lead chloride to remove the calcium, magnesium, and lead.[3] The resulting chlorides are skimmed off the molten bismuth as a slag. The addition of air and caustic soda to oxidize any remaining impurities forms additional slag which can be disposed in conjunction with the slag from the blast furnace.[4]

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[1] Stephen M. Jasinski, "Bismuth," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 30.

[2] "Bismuth," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. IV, 1992, p. 238.

[3] Laurence G. Stevens and C.E.T. White, "Indium and Bismuth," from Metals Handbook Volume 2. Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, Tenth ed., 1990, p. 753-754.

[4] U.S. Environmental Protection Agency, Industrial Process Profiles for Environmental Use: Chapter 27. Primary Lead Industry, Office of Research and Development, July 1980.

EXHIBIT 1

BISMUTH COPPER SOURCES

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-70 - 2-76.)

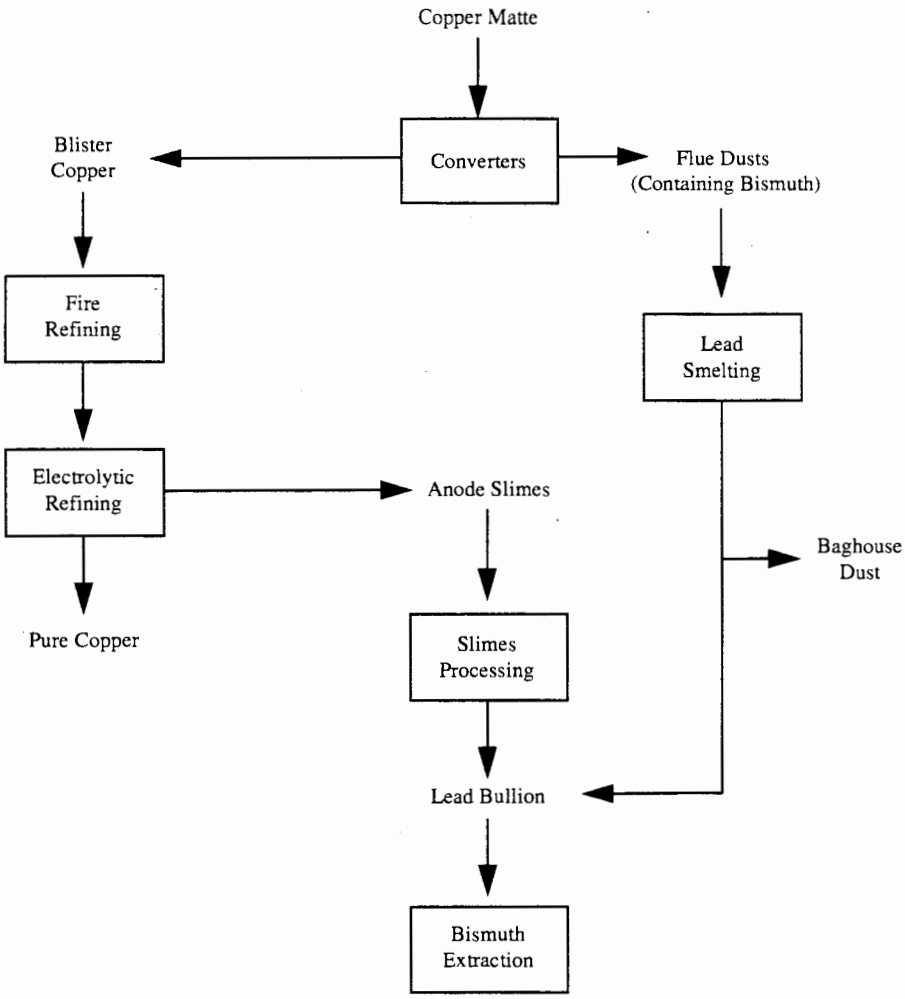
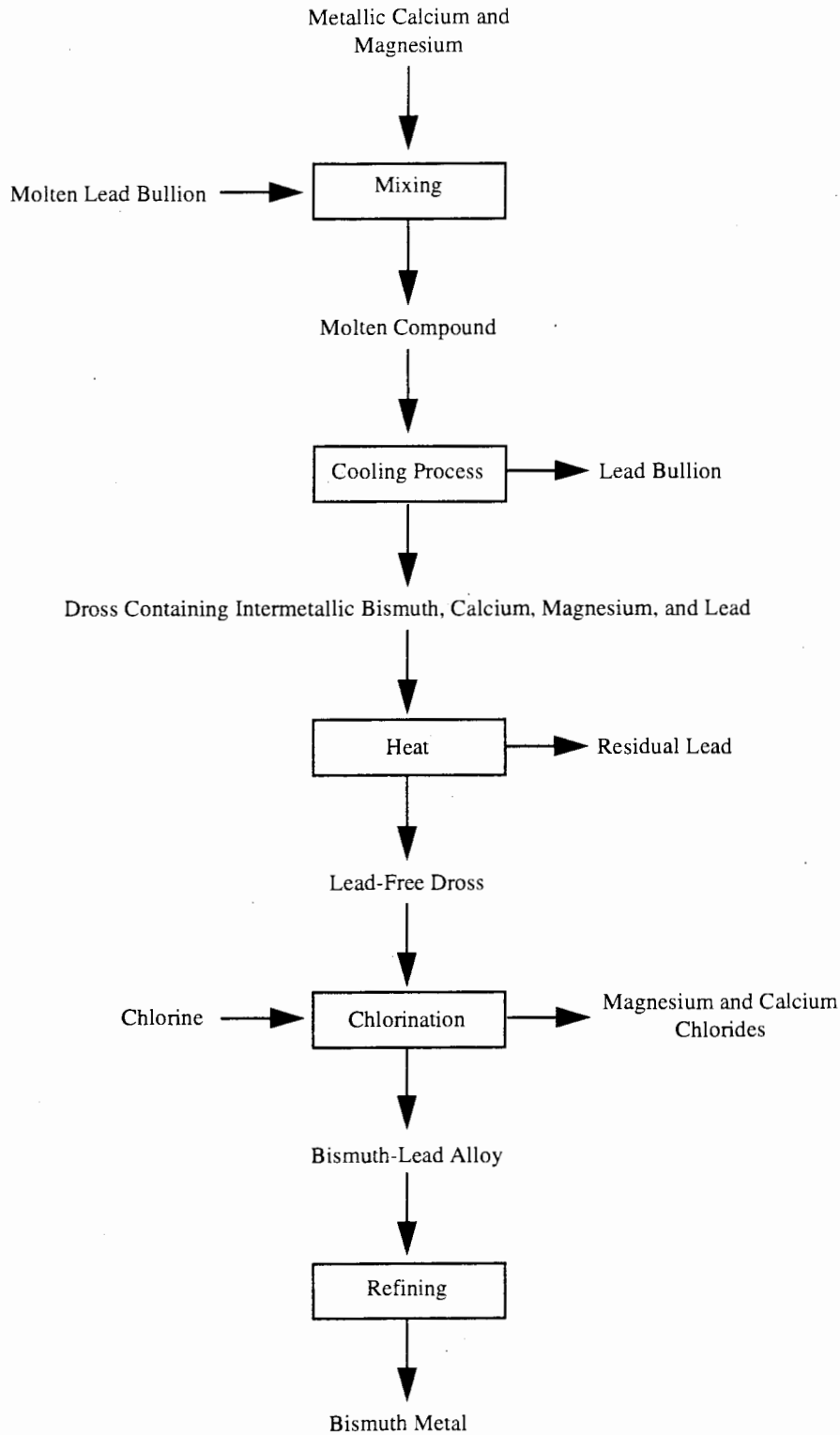


EXHIBIT 2

BISMUTH BETTERTON-KROLL PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-7- - 2-76.)



Betts Electrolytic Process

As shown in Exhibit 3, in the Betts Electrolytic Process the lead bullion with impurities is electrolyzed in a solution of fluosilicate and free fluosilicic acid with pure lead cathodes. The impurities, including bismuth, are retained in the form of a black anode slime. This slime is then scraped from the anode, washed, and partially dried prior to processing for bismuth. The recovery of bismuth is only one of several process end-product objectives in the treatment of the process residue. The primary objective is the fusion of the dried residues to produce a slag containing lead, arsenic, and antimony.[5] The slimes are smelted and the resulting metal is cupelled, yielding a slag containing bismuth. The cupel slag is reduced and refined.[6] One important difference between the Betts process and the Betterton-Kroll process is that in the Betterton-Kroll process, the lead bullion is purified prior to mixing with calcium and magnesium, while in the Betts process, the impurities are left in the lead bullion.[7]

Extraction From Bismuth Bearing Materials

As shown in Exhibit 4, bismuth also can be extracted from roasted tin concentrates and other bismuth-bearing materials by leaching with hydrochloric acid. After dilution of the acid leach, bismuth is precipitated as bismuth oxychloride. Further purification is achieved by redissolving the bismuth oxychloride in hydrochloric acid. The bismuth oxychloride is reprecipitated, dried, and reduced with carbon using soda ash flux to produce crude bismuth bullion.[8]

Refining

Exhibit 5 presents one method of bismuth refining in which the bismuth-lead alloy is mixed with caustic soda to form a purified metal mix. Zinc is added to the metal mix, which then undergoes Parkes Desilverization, a process used to recover gold and silver from softened lead bullion. The zinc combines with the molten bullion to form a skim with the gold and copper, which is then removed. More zinc is then added to form a silver skim layer which also is removed. Once the silver and gold are separated, they are sent for further processing and the recovered zinc can be recycled. More detailed description of Parkes Desilvering can be found in the description of lead processing found elsewhere in this report.

Following the desilverization process, chlorine is added to the resultant bismuth-bearing material which is then heated to 500° C. After heating, the impure bismuth is oxidized with air and caustic soda, producing 99.999 percent pure bismuth metal.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

The bismuth recovery process starts with materials obtained from the smelting of lead which is a minerals processing operation. Therefore, all of the wastes generated in the recovery process are categorized as mineral processing wastes. For example, even though leaching is typically considered to be a beneficiation operation, in this particular situation where it follows a minerals processing operation, waste from this step is categorized as mineral

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[5] Funsho K. Ojebuoboh, "Bismuth-production, properties, and applications," JOM, 44, No. 4, April 1992, p. 47.

[6] Laurence G. Stevens and C.E.T. White, 1990, Op. Cit., pp. 753-754.

[7] Funsho K. Ojebuoboh, 1992, Op. Cit., p. 47.

[8] Ibid.

EXHIBIT 3

BETTS ELECTROLYTIC EXTRACTION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-70 - 2-76.)

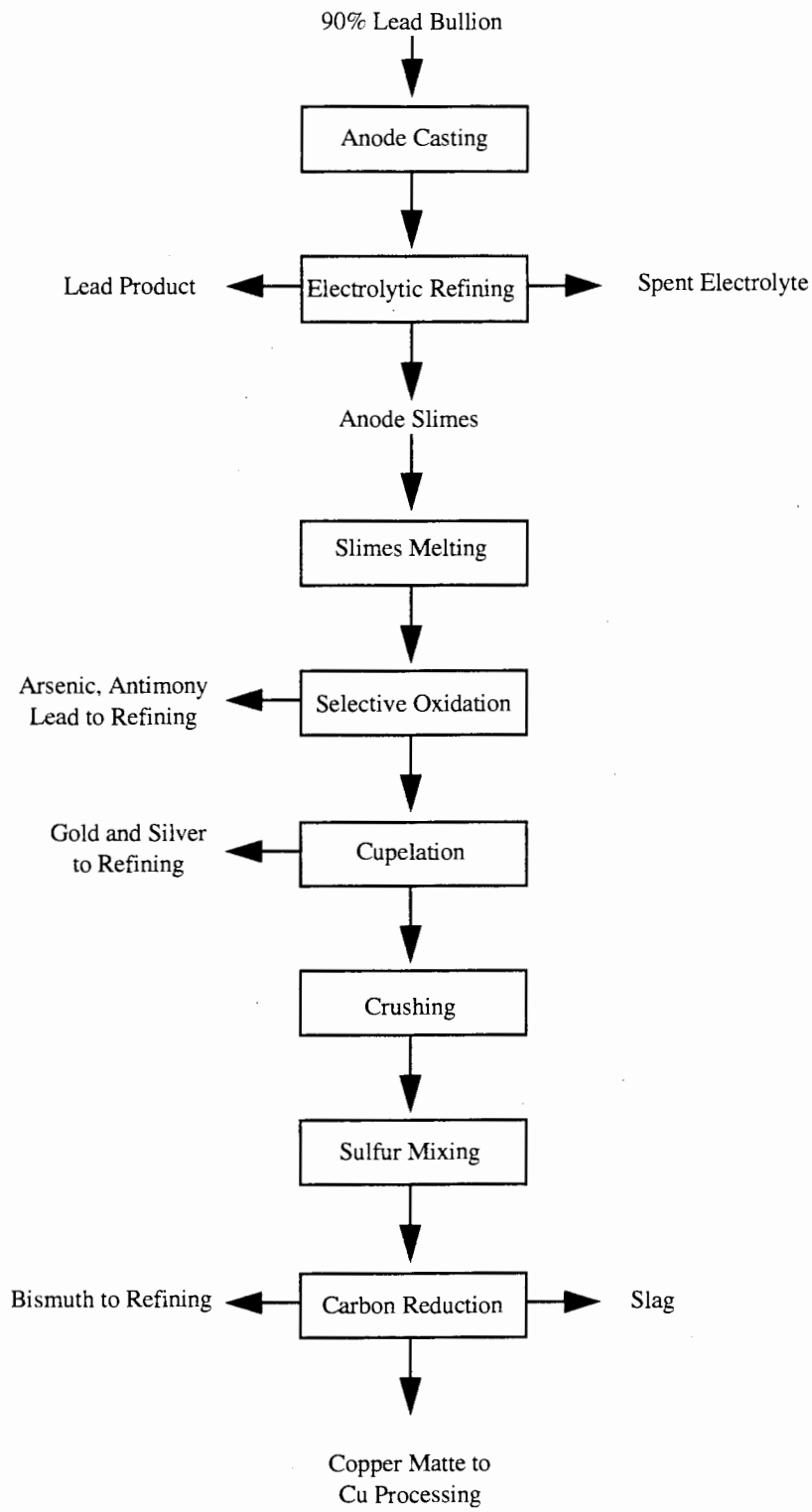


EXHIBIT 4

RECOVERY FROM BISMUTH BEARING MATERIALS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-70 - 2-76.)

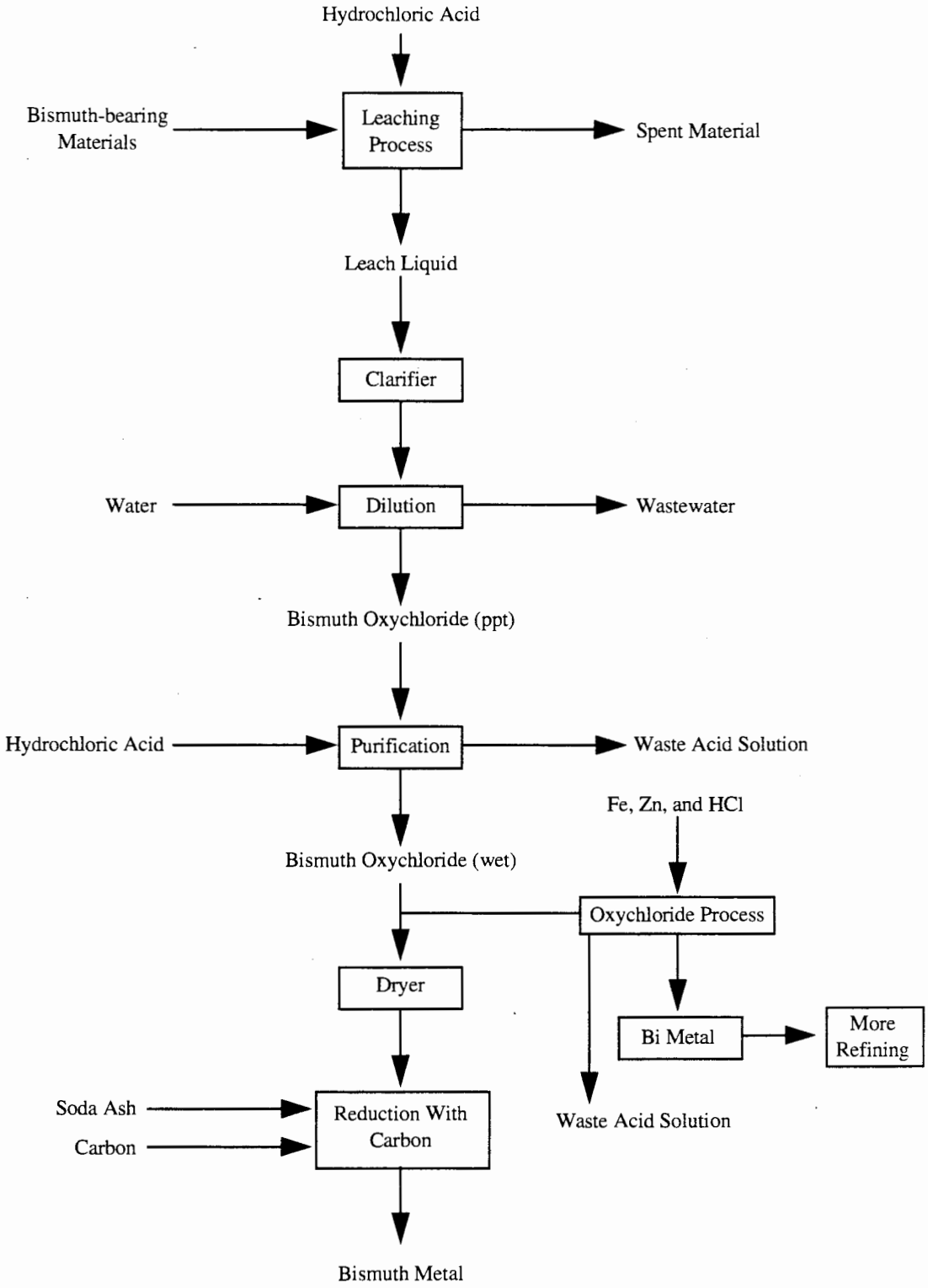
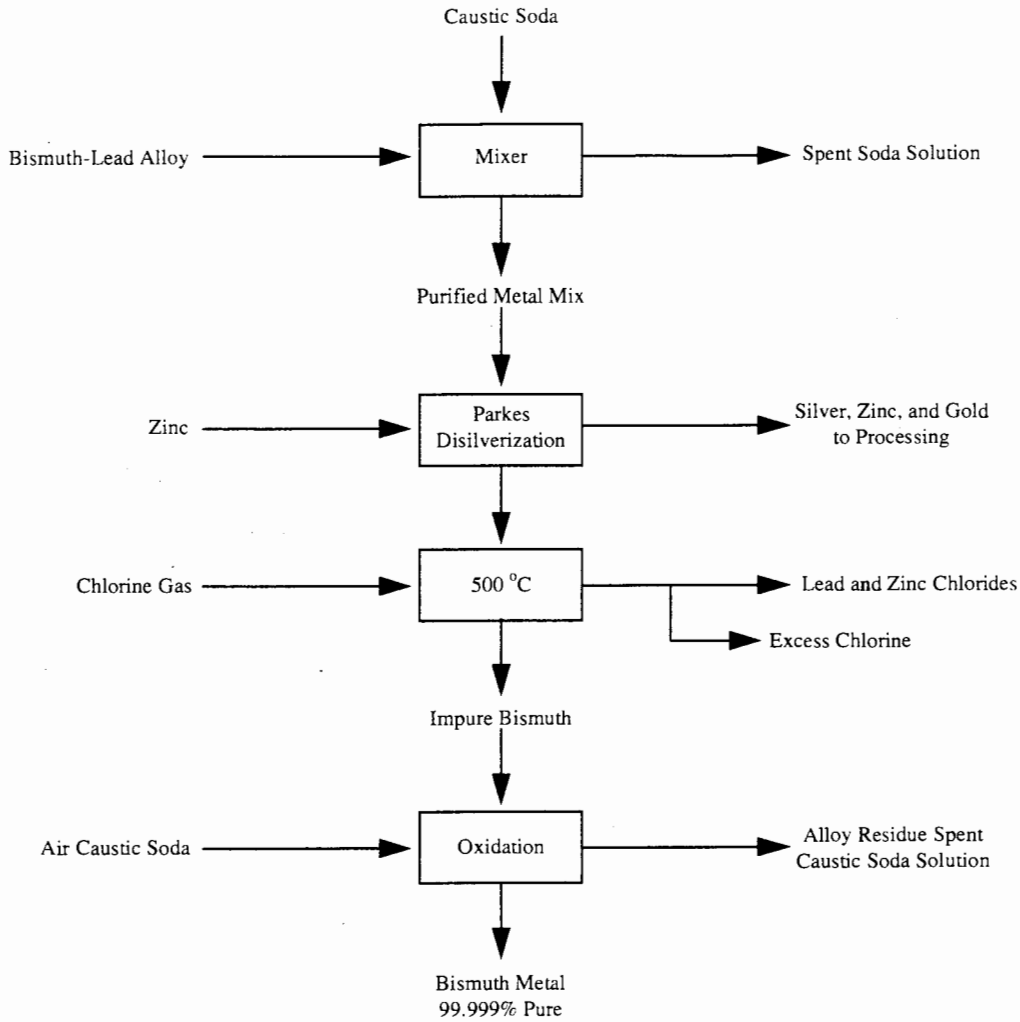


EXHIBIT 5

BISMUTH REFINING

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-70 - 2-76.)



processing waste. For a description of where the beneficiation/processing boundary occurs for this mineral comodity, please see the report for lead presented elsewhere in this background document.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Because bismuth is recovered as a byproduct of lead and copper ore production, mining wastes are addressed in the descriptions of the initial ore/mineral. For a further description of these wastes see the reports for copper and lead presented elsewhere in this background document.

2. Mineral Processing Wastes

The extraction methods used to recover bismuth (e.g., leaching, electrolysis) generate wastes including waste caustic sodas, electrolytic slimes, and waste acids. In addition, the following wastes are also generated during the processes described above. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate low, medium, and high annual waste generation rates.

Extraction

Spent Caustic Soda. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 6,100 metric tons/yr, and 12,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste stream may be recycled and may exhibit the characteristic of toxicity for lead. This waste is classified as a spent material.

Electrolytic Slimes. The slimes generated during this process are likely to be reprocessed. Low, medium, and high annual waste generation rates were estimated as 0 metric tons/yr, 20 metric tons/yr, and 200 metric tons/yr, respectively. We used best engineering judgment to determine that this waste stream may be recycled and may exhibit the characteristic of toxicity for lead. This waste is classified as a by-product.

Waste Acids. The waste acids generated are likely to be neutralized and discharged with waste water from the process. Low, medium, and high annual waste generation rates were estimated as 0 metric tons/yr, 100 metric tons/yr, and 200 metric tons/yr, respectively. We used best engineering judgment to determine that this waste stream may be partially recycled and may exhibit the characteristic of corrosivity. This waste is classified as a spent material.

Betterton-Kroll Process

Metal Chloride Residues. Chlorination generates magnesium and calcium chlorides. This waste stream has a reported annual waste generation rate of 3,000 metric tons/yr. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

Slag. The slag produced during this process contains magnesium, lead, and calcium. It is disposed with the blast furnace slag. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 1,000 metric tons/yr, and 10,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

Betts Electrolytic Process

Spent Electrolyte. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 6,100 metric tons/yr, and 12,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

Slag. Slag is generated from carbon reduction as shown in Exhibit 3.

Extraction From Bismuth-Bearing Materials

Spent Material. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Waste acid solutions. As shown in Exhibit 4, these wastes are generated when the bismuth oxychloride is dissolved in hydrochloric acid. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 6,100 metric tons/yr, and 12,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of corrosivity.

Bismuth Refining

As shown in Exhibit 5, the following wastes are associated with the bismuth refining process.

Spent soda solution. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 6,100 metric tons/yr, and 12,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste stream may be recycled and may exhibit the characteristics of toxicity (lead) and corrosivity. This waste is classified as a spent material.

Excess chlorine. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 150 metric tons/yr, and 200 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (lead) and reactivity.

Alloy residues. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 3000 metric tons/yr, and 6000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

Lead and Zinc chlorides. Low, medium, and high annual waste generation rates were estimated as 100 metric tons/yr, 3000 metric tons/yr, and 6000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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BORON

A. Commodity Summary

Borates are defined by industry as any compound that contains or supplies boric oxide. A large number of materials contain boric oxide, but the three most common boron containing minerals are borax, ulexite, and colemanite.[1] Kernite is a metamorphic phase of borax and is an important borax mineral. Borate production in the United States in centered mainly in the Mojave Desert in southern California. Borax and kernite are mined by U.S. Borax (located in Boron, California) and borate is also recovered from brines pumped from Searles Lake.[2] Kernite comprises more than one-third of the boron deposit in Boron, California.

Borax is the most important boron mineral for the borate industry. It crushes freely, and dissolves readily in water, and its solubility and rate of solution increase with water temperature. Kernite has a higher B_2O_3 content than borax, but its excellent cleavage causes it to form fibers that mat and clog handling equipment. Being slowly soluble in water, kernite requires autoclaving or pre-refinery hydration for efficient conversion into refined products. It is currently used primarily as feed for the boric acid plant located in Boron, California.[3] Colemanite is the preferred calcium-bearing borate used by the non-sodium fiberglass industry. Although it has low solubility in water, it readily dissolves in acid.[4]

The major uses of borates include: fiberglass insulation, textile or continuous-filament glass fibers, glass, detergents and bleaches, enamels and frits, fertilizers, and fire retardants.[5] According to the U.S. Bureau of Mines, apparent domestic consumption of boric oxide in 1994 was estimated at 362 thousand metric tons.[6]

B. Generalized Process Description

1. Discussion of Typical Production Processes

There are two companies that operate borate recovery plants domestically, each using a distinctly different borate-containing source. The first plant near Searles Lake recovers borax from natural mineral-rich lake brines. The process at Searles Lake involves fractional distillation followed by evaporation. Borax is only one of the products recovered there; other products include sodium sulfate, lithium compounds, potash, and other salts. The second company, U.S. Borax, mines and processes crude and refined sodium borates, their anhydrous derivatives, and anhydrous boric acid at a plant in Boron, California.[7]

2. Generalized Process Flow Diagram

Exhibits 1 through 4 present the process flow diagrams for borate brine extraction and boric acid recovery. Exhibit 1 illustrates the processes used to prepare boric acid from ore in Boron, California. Exhibits 2, 3 and 4

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[1] Robert B. Kistler and Cahit Helvaci, "Boron and Borates," from Industrial Minerals And Rocks, 1994, p. 171.

[2] Ibid.

[3] Ibid.

[4] Ibid.

[5] Ibid., p. 183.

[6] Phyllis A. Lyday, "Boron," from Mineral Commodity Summaries, U.S. Bureau of Mines, 1995, pp. 32-33.

[7] Phyllis A. Lyday, "Boron," from Minerals Yearbook Volume 1. Metals and Minerals, 1992, p. 249.

present the methods used at two of the plants involved in the Searles Lake operations to recover borates from the brines deposits in California.

Borate Ore Processing

At the U.S. Borax facility in Boron, California, the ores are selectively mined, crushed, and stockpiled for production at two distinct facilities producing sodium borate and boric acid, respectively.

Sodium Borate Production. The principal ore used in the process, tincal, is soluble in water. After the ore is crushed, the tincal is dissolved in water. The resulting insolubles are then separated from the solution and the clarified liquor is fed to the crystallizers. Next, the crystals of sodium borate are separated from the weak solution which then can be recycled back to the dissolution step. The crystals are dried and can either be sold as borax or treated further to produce other borate materials.[8] One of the products prepared when the crystals are cooled is sodium borate decahydrate. If sodium borate pentahydrate is the desired product, the sodium borate decahydrate can be sent to further recrystallization. Anhydrous sodium borate can be produced by thermally dehydrating either the sodium borate decahydrate or sodium borate pentahydrate.[9] U.S. Borax also produces boric acid from ores, discussed below.

Boric Acid Production. Some of the solid sodium borate ore from the stockpile at the U.S. Borax facility is reacted with sulfuric acid and used as feed in the production of boric acid.[10] Exhibit 1 presents the process used to produce boric acid from the ore stockpile. Clays, sands and other impurities are also present in the ore. After the ore is crushed and ground, it is acid digested using sulfuric acid to produce two new compounds, sodium sulfate and boric acid. The clay and other insolubles are then removed from the aqueous stream. Rake classifiers separate out the larger material, while settling tanks and thickeners are used to remove the finer materials. The stream is then filtered further to remove any remaining insoluble materials. After filtration, the solution is pumped to crystallizers. In the crystallizers, the solution is cooled, forming a slurry containing solid boric acid crystals and a boric acid solution. Further filtration and centrifugation separate the solid boric acid, which can be dried and packaged for sale.[11] The remaining liquor can be further evaporated to recover a sodium sulfate co-product.

Brine Extraction

Operations at Searles Dry Lake in California involve the recovery of boron from brine deposits at three separate facilities: Trona, Argus, and Westend. Not all of these facilities are directly involved with the extraction of boron from brines. The Argus facility, for example, only produces soda ash, however, the carbonated liquid from this plant is used at the Westend plant. Borates can be recovered from concentrated brines prepared by either of two methods: carbonation or evaporation. Exhibit 2 presents the process flow diagrams for the method used at the Westend plant. Exhibit 3 presents the liquid-liquid extraction steps used at the Trona plant to process brine prepared by evaporation.

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[8] U.S. Environmental Protection Agency, "Boron," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-77-2-84.

[9] Versar, Inc., "Boron Derivatives," Multi-media Assessment of the Inorganic Chemicals Industry, Prepared for U.S. Environmental Protection Agency, August 1980, p. 2-5.

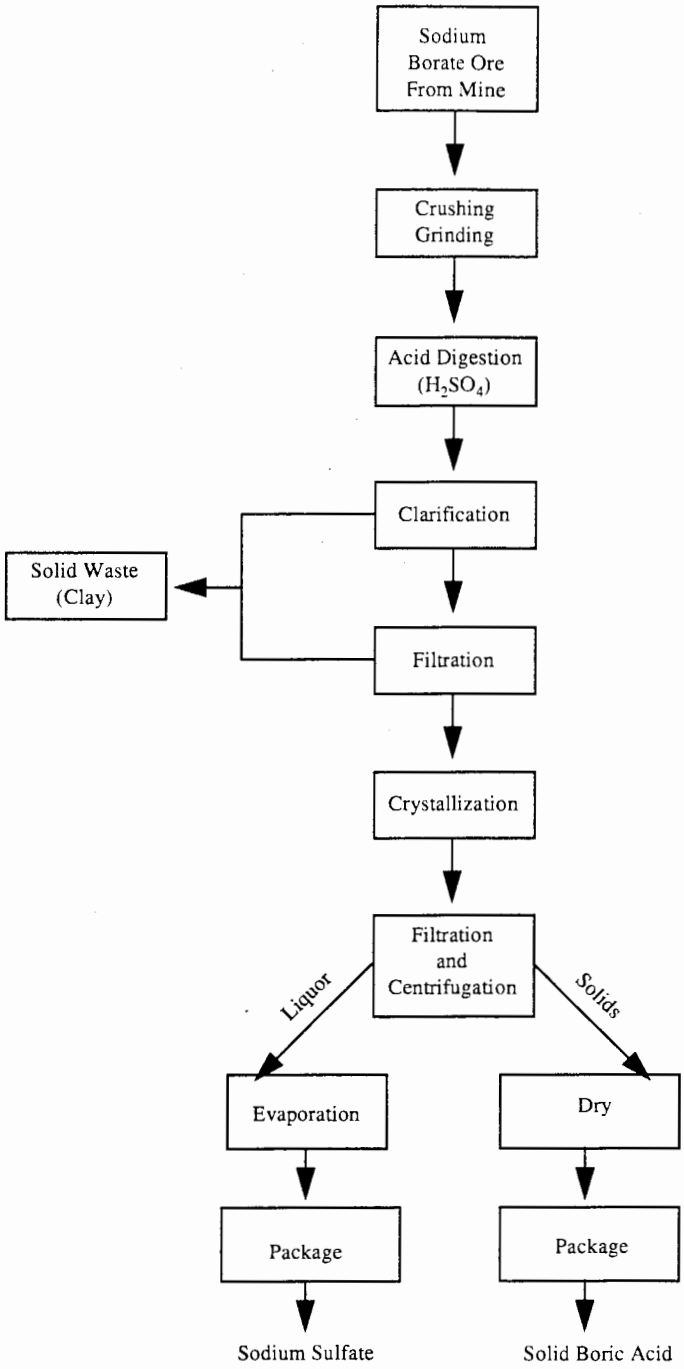
[10] Ibid.

[11] "Comments Regarding Classification of the Boric Acid Production Line at Boron Operation of United States Borax & Chemical Corporation," Memorandum and Enclosures from W.W. Cooper, Ph.D., Senior Environmental Scientist, U.S. Borax to Mr. Lynn E. Johnson, R.E.H.S., Toxic Substances Control Program. October 3 and 11, 1991.

EXHIBIT 1

BORIC ACID PRODUCTION AT BORON, CALIFORNIA

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-77 - 2-84.)



Westend Plant (Carbonated Liquor). Carbonation is used at the Argus facility to supersaturate the brine solution with sodium bicarbonate. As shown in Exhibit 2, the carbonated liquor from this facility is used in combination with the brine solution at the Westend facility. The Westend facility produces anhydrous sodium borate, sodium borate pentahydrate, sodium borate decahydrate, boric acid, sodium sulfate, and sodium bicarbonate. At the Westend plant, after the sodium bicarbonate has precipitated out, the brine and carbonated liquor mixture is cooled to crystallize sodium borate decahydrate. The crude sodium decahydrate is filtered out from the liquor, which can be sent for further processing to the sulfate plant. The crude sodium borate decahydrate is then either heated to its melting point to remove hydrated water, thus producing anhydrous sodium borate, which can either be packaged and sold or sent to further processing or, acid digested using sulfuric acid to produce boric acid. Although not shown in the Exhibit 2, the sodium borate decahydrate can be redissolved and hydrated and then cooled to form either sodium borate decahydrate or sodium borate pentahydrate. If the anhydrous sodium borate is reacted with sulfuric acid instead, the resulting product is boric acid.[12]

Trona Plant (Evaporated Brine). Evaporation processes are used in the Searles Lake operations to remove sodium chloride from the brine and to concentrate other desired constituents of the brine prior to further processing. The brine is pumped initially to solar evaporation ponds and concentrated. As the brine is evaporated, the sodium chloride concentration increases until the NaCl crystallizes out of solution. In addition, during the evaporation process, a rapid, controlled cooling selectively crystallizes various other salts including sodium bicarbonate and sodium sulfate. The concentrated brine from the evaporation ponds is then sent to the Trona plant for use as brine feedstock.[13]

Liquid-Liquid Extraction. The Trona facility uses a proprietary liquid-liquid extraction process to remove borate compounds from the brine (Exhibit 3). Specifically, during the process the brine is mixed with a chelating agent in a kerosene solution to remove the borates from the brine. Brine is pumped to the plant and emulsified. The emulsion is sent to a settling tank and through an API separator to break the emulsion and the extractant from the brine. The spent brine is returned to Searles Lake. The extractant is then combined with dilute sulfuric acid to convert the sodium borate to boric acid. This step produces a strip liquor containing boric acid, sodium sulfate, potassium sulfate, and sodium chloride. The strip liquor is then sent to a carbon filtration column to remove any remaining organic fractions. The filtered liquor is vacuum cooled in a boric acid crystallizer. The resulting boric acid crystals are centrifuged to separate them from the liquor, washed, dried, and packaged for sale. The resulting "mother liquor" is vacuum cooled further to crystallize the mixed sulfates, which are centrifuged to form a sulfate cake and sent to a potash production line.[14]

Potash/Borax Line. The potash/borax line is part of the Trona plant that produces pentahydrate borax, anhydrous borax, potassium chloride (potash), and potassium sulfates. As shown in Exhibit 4, brine is pumped to the plant from the evaporation ponds and sent to further evaporation. Following the evaporation, some of the concentrated brine is fed to tanks and vacuum cooled. Following this, the resultant halite is slurried, filtered, washed, and sent back to Searles Lake with the spent liquor. After the drying step, the solution is cooled and the potassium chloride that precipitates out can be sold as a product. The remaining brine is mixed with the sulfate cake from the liquid-liquid extraction process and potassium sulfate is precipitated. Following the precipitation of potassium chloride, the residual solution can be cooled to allow sodium borate pentahydrate to precipitate out from the remaining solution. This is then redissolved, hydrated, and filtered, producing dehydrated borax products (i.e., sodium borate decahydrate or sodium borate pentahydrate). The decahydrate borax can be further processed by heating to remove hydrated water, thus producing anhydrous sodium borate.[15] At Searles Lake the same processes

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[12] California Department of Toxic Substances Control, "Searles Lake Mining Operation," Memorandum from William Soo Hoo, Chief Counsel to Van Housman, Office of Solid Waste, U.S. Environmental Protection Agency, August 1, 1991.

[13] Ibid.

[14] Ibid.

[15] Ibid.

EXHIBIT 2

BORATE BRINE PROCESSING AT SEARLES LAKE, CALIFORNIA
WESTEND PLANT (CARBONATED LIQUOR FEEDSTOCK)

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-77 - 2-84.)

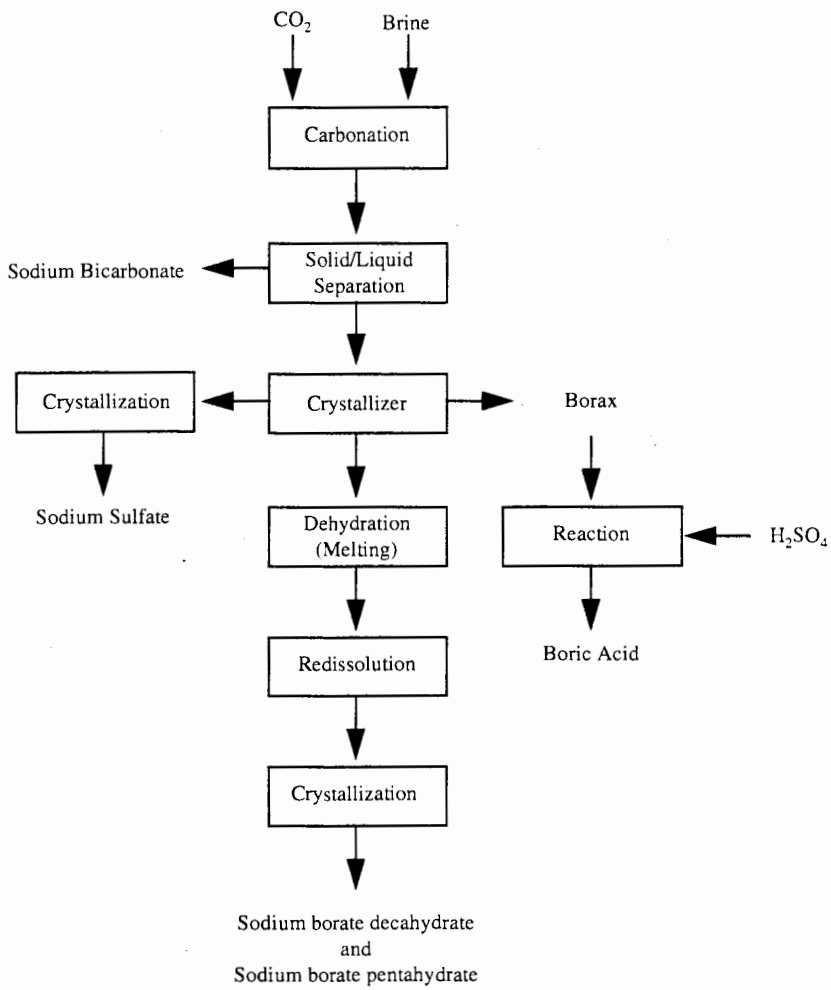


EXHIBIT 3

BORATE BRINE PROCESSING AT SEARLES LAKE, CALIFORNIA TRONA PLANT (LIQUID-LIQUID EXTRACTION)

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-77 - 2-84.)

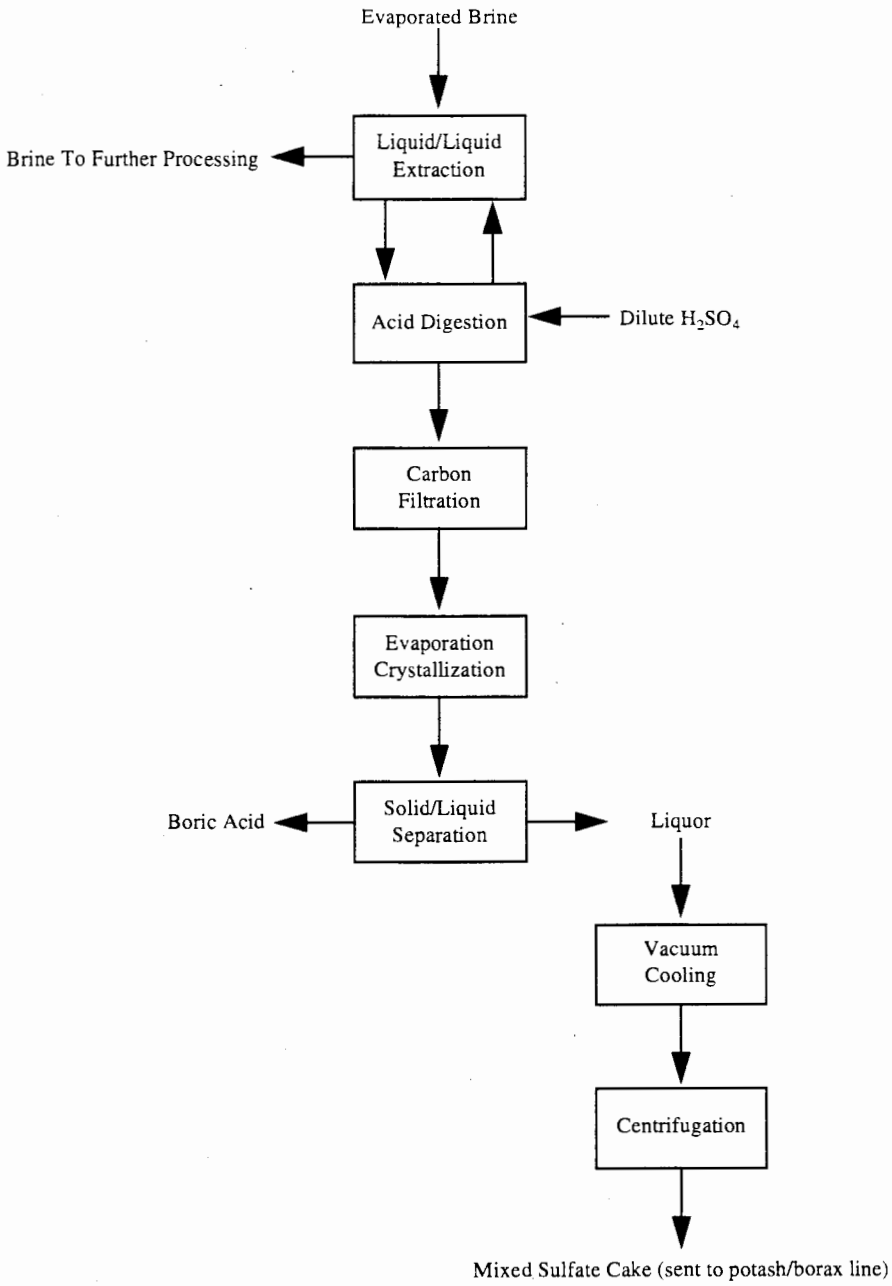
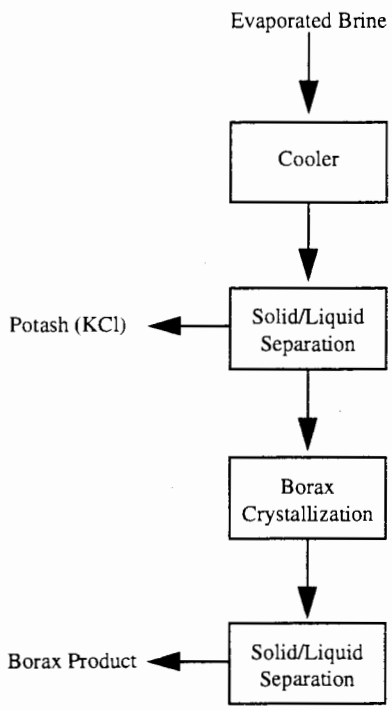


EXHIBIT 4

PRODUCTION OF POTASH AND BORAX AT SEARLES LAKE, CALIFORNIA TRONA PLANT

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-77 - 2-84.)



are also used to produce chemicals including sodium chloride, soda ash, and potassium chloride. These solids are precipitated from the brine solution as the solution evaporates.[16]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA reviewed the processes used to produce sodium borate and boric acid from borate ores (at U.S. Borax) and from brines (at Searles Lake) and determined that the beneficiation/mineral processing line is crossed when sodium borate is digested using sulfuric acid to produce boric acid and sodium sulfate. Specifically, at the U.S. Borax facility, the beneficiation/mineral processing line occurs between the crushing and grinding of the solid sodium borate ore and acid digestion with sulfuric acid. At the Searles Lake, Westend Plant, the beneficiation/mineral processing line occurs when borax is removed from the crystallizer and reacted with sulfuric acid to produce boric acid. At the Searles Lake, Trona Plant, the beneficiation/mineral processing line occurs between the liquid/liquid extraction and acidification step. EPA identified these points in the processes as where beneficiation ends and mineral processing begins because it is here where a significant chemical change to the sodium borate occurs (sodium borate reacts with the sulfuric acid to produce two new chemicals - boric acid and sodium sulfate). Therefore, because EPA has determined that all operations following the initial "mineral processing" step in the production sequences are also considered mineral processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/ processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

With regard to the production of potash and borax at the Searles Lake, Trona Plant, EPA determined that all of the processes may be classified as extraction or beneficiation activities. As a result, all of the wastes associated

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[16] Versar Inc., 1980, Op. Cit., p. 2-7.

with the production of borates are considered to be extraction or beneficiation wastes and, thus, eligible for the Bevill Mining Waste Exclusion.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Borate Ore Processing

Gangue. Gangue solids are generated from the initial dissolution step during the production of sodium borate decahydrate. In 1980, these waste were reported as generally inert insolubles, although they contained 0.08 percent natural arsenic mineral realgar. The solid wastes from ore residues and evaporation wastes were sent to on-site lined evaporation ponds.[17]

Wastewater. Process wastewater from washing contains dissolved borax and other salts may be sent to lined evaporation ponds.[18]

From Brines

Spent Solvents, Crud, and Waste Brine. The brine extraction process generates waste brine and spent solvents. The plant extract or crud generated during the recovery of boron from brines at the Trona plant contains arsenic and halogens and is ignitable.[19]

Particulate Emissions. Particulates generated from drying operations are collected in dry bags and recycled. In 1980, the wastes were generated at approximately 14 kg per kkg of product.[20]

Boric Acid Production

Spent Sodium Sulfate. Crystallization produces sodium sulfate. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

2. Mineral Processing Wastes

Boric Acid Production

Spent Clay and Other Insolubles. No information is available.

Waste Liquor and Underflow Mud. Some of the liquor remaining after the boric acid is filtered off contains arsenic. In 1980, one site reported that the arsenic was present as a natural impurity in the ore used to make the sodium pentahydrate. Another site reported returning the arsenic-containing wastes to the original subterranean brine source. One commenter reported a combined generation rate for waste liquor and mud of 150,000 tons/yr and

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[17] Ibid.

[18] Versar, Inc., 1980, Op. Cit., p. 2-7.

[19] California Department of Toxic Substances Control, Memorandum from William Soo Hoo, Director, to Sylvia K. Lowrance, Office of Solid Waste, U.S. Environmental Protection Agency, May 8, 1992.

[20] Versar, Inc., 1980, p. 2-5.

indicated that the TCLP analysis performed for arsenic is consistently well below 5 ppm.[21] Low, medium, and high annual waste generation rates were estimated as 300 metric tons/yr, 150,000 metric tons/yr, and 300,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for arsenic. This waste is recycled and formerly was classified as a spent material. Existing data and engineering judgment suggest that waste liquor and underflow mud material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent Sodium Sulfate. Crystallization following acid digestion produces sodium sulfate. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Wastes

There are no non-uniquely associated wastes in this specific sector. However, standard ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

One commenter addressed the boron sector report (COMM 86). The commenter provided some technical corrections and some specific line edits for the report. These comments have been included, as appropriate, in the revised boron sector report.

Sector-specific Issues

None.

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[21] U.S. Borax. Comments submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

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BROMINE (from brines)

A. Commodity Summary

Bromine is a member of the halogen family of elements. Elemental bromine is highly reactive and occurs in nature only as bromide compounds. Sources of bromide include sea water, subterranean brines, saline lakes, oil and gas well brines, and evaporate chloride minerals including halite (NaCl), sylvite (KCl), and carnallite.[1] Bromide compounds are used in fire retardants, agriculture, petroleum additives (ethylene dibromide is an antiknock additive in leaded gasoline), and well drilling fluids. Domestic consumption of bromide was estimated to be 287 million kilograms in 1994.[2]

According to the U.S. Bureau of Mines, companies in Arkansas and Michigan were responsible for all elemental bromine production in 1993. Exhibit 1 presents the names, locations, and types of operations employed by the facilities involved in the production of bromine. The Dow Chemical Company (Dow) in Ludington, Michigan is not directly involved in the purification of bromine; however, Dow removes bromine from its magnesium brines because it is an impurity in their magnesium operation. Dow ships the recovered bromine to the Ethyl Corporation in Arkansas to be purified and prepared for sale.

EXHIBIT 1

SUMMARY OF BROMINE FACILITIES

Facility Name	Locations	Type of Operations
Dow Chemical Company	Ludington, MI	Brine extraction prior to production of magnesium chloride. Sent to Ethyl Corporation for purification.[a]
Ethyl Corp.	Magnolia, AR	Brine Extraction
Great Lakes Chemical Corp.	El Dorado, AR (3 plants)	Brine Extraction

[a] Personal communication between Jocelyn Spielman, ICF Incorporated and Phyllis Lyday, U.S. Bureau of Mines. October 5, 1994.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Commercial bromine production processes involve the oxidation of bromide to bromine, using chlorine as the oxidant. Most of the liberated bromine remains dissolved in the brine. The brine is then stripped of bromine and the bromine is then recovered from the stripping agent. Further purification by distillation is often a final step in the process.[3] Exhibits 2 and 3 present the generalized process flow diagrams for the production of bromine and each of the steps is described in further detail below.

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[1] M.J. Wilhelm and K.C. Williams, "Bromine Resources," from Industrial Minerals and Rocks, 1994, 6th ed. p. 187.

[2] Phyllis Lyday, "Bromine," Mineral Commodity Summaries, 1995, U.S. Bureau of Mines, p. 34.

[3] "Chemicals from Brines," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. IV, 1992, p. 823.

2. Generalized Process Flow Diagram

As shown in Exhibits 2 and 3, there are three principal steps involved in the production of bromine from brines: (1) skimming and acid stripping; (2) bromine extraction from the aqueous solution; and (3) condensation and purification of the bromine. Variations on this production process generally differ in the extraction step.[4]

Skimming and Acid Stripping

Skimming and Hydrocarbon Removal. The first step in bromine recovery is skimming the oil from the well brines and removing hydrocarbons. Following the skimming process, the brine solution undergoes acidification and stripping with the addition of sulfuric acid. Spent hydrogen sulfate (H_2S) is stripped from the solution and sent to sodium sulfate (Na_2S) recovery.

Acidification and Chlorination. Although bromine occurs in the form of bromide in sea water and in natural brine deposits containing chloride, additional chlorine may be added to oxidize bromide to bromine. Chlorine is used because it has a higher reduction potential than bromine.[5] As shown in Exhibit 3, acidification with H_2SO_4 can be part of the recovery process.

Extraction of Bromine

Bromine is extracted or stripped from the chlorinated solution using either steam (steaming out) or air (blowing out process). Steam is used when the concentration of bromine in the brine is greater than 1,000 ppm. The advantage of this method is that bromine can be condensed directly from the steam. Air is used when the bromine source is sea water because large volumes of stripping gas would be required, thereby making the use of steam too expensive. However, when air is used, bromine must be trapped in an alkaline or reducing solution to concentrate it.[6]

Steaming Out. As shown in Exhibit 3, brine is pumped to the top of a granite absorption tower filled with ceramic packing material. Steam and chlorine are pumped in from the bottom of the tower. The bromine is oxidized by the chlorine as it falls through the ceramic material. The chlorine replaces the bromine in the brine and the gaseous bromine rises to the top of the tower with the steam, where it is condensed to a liquid.[7]

Blowing Out. Generally, sea water contains bromine as either magnesium bromide or sodium bromide. When the source of the bromine is sea water, the blowing out method is used to strip the bromine from the brine. In the blowing out method, prior to reaching the tower, raw sea water is acidified with sulfuric acid followed by the addition of chlorine. Air is drawn into the base of the tower and rises as the bromine descends. Air containing bromine passes to the absorption tower, where the bromine reacts with sulfur dioxide to form hydrogen bromide.[8]

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[4] "Bromine," Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed., Vol. IV, 1992, p. 548.

[5] Ibid., pp. 548-549.

[6] Ibid.

[7] Phyllis Lyday, "Bromine," from Minerals Yearbook Volume 1. Metals and Minerals, 1992, p. 259.

[8] Ibid., pp. 259-260.

EXHIBIT 2

BROMINE EXTRACTION FROM WELLS

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1992, pp. 547 - 550.)

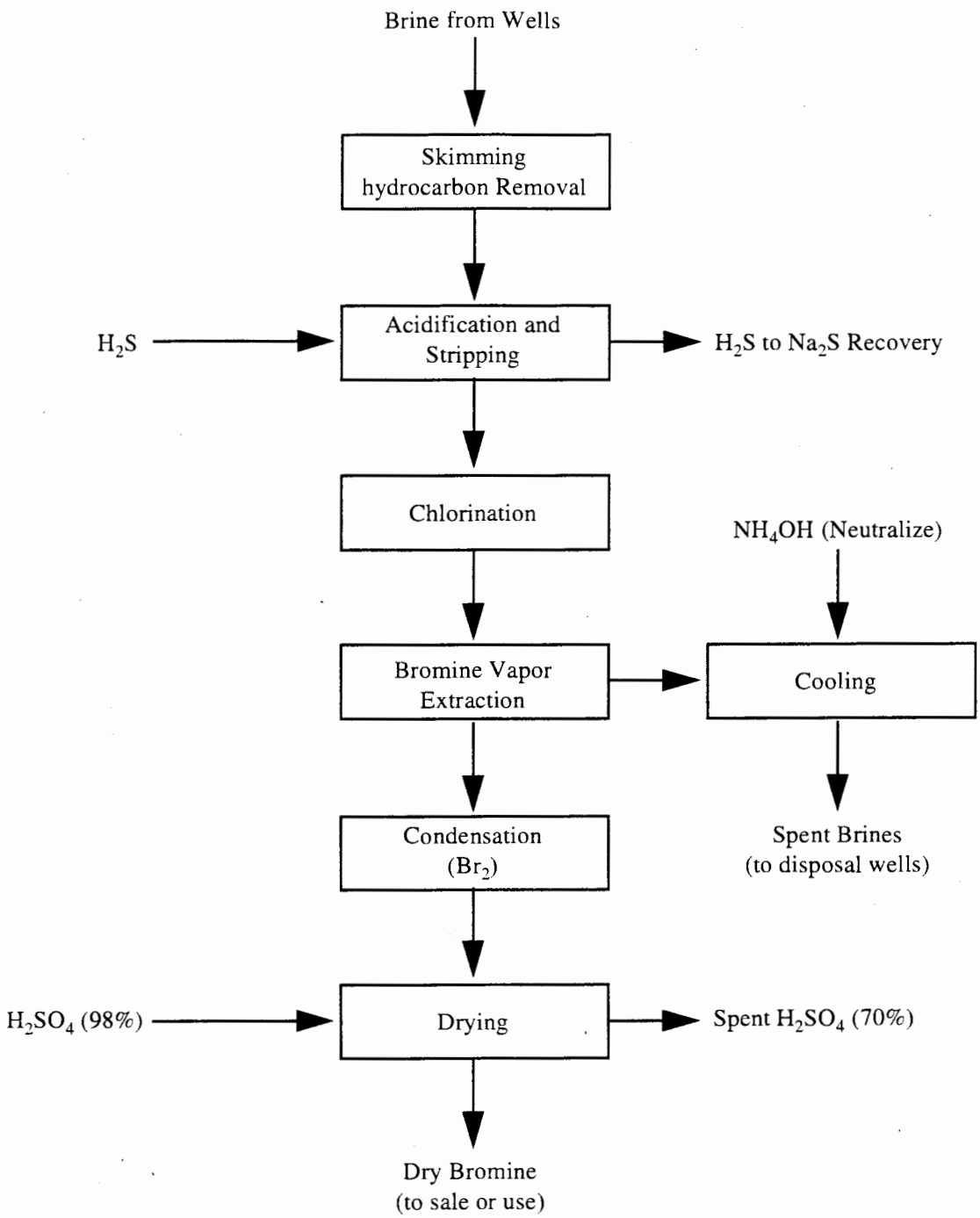
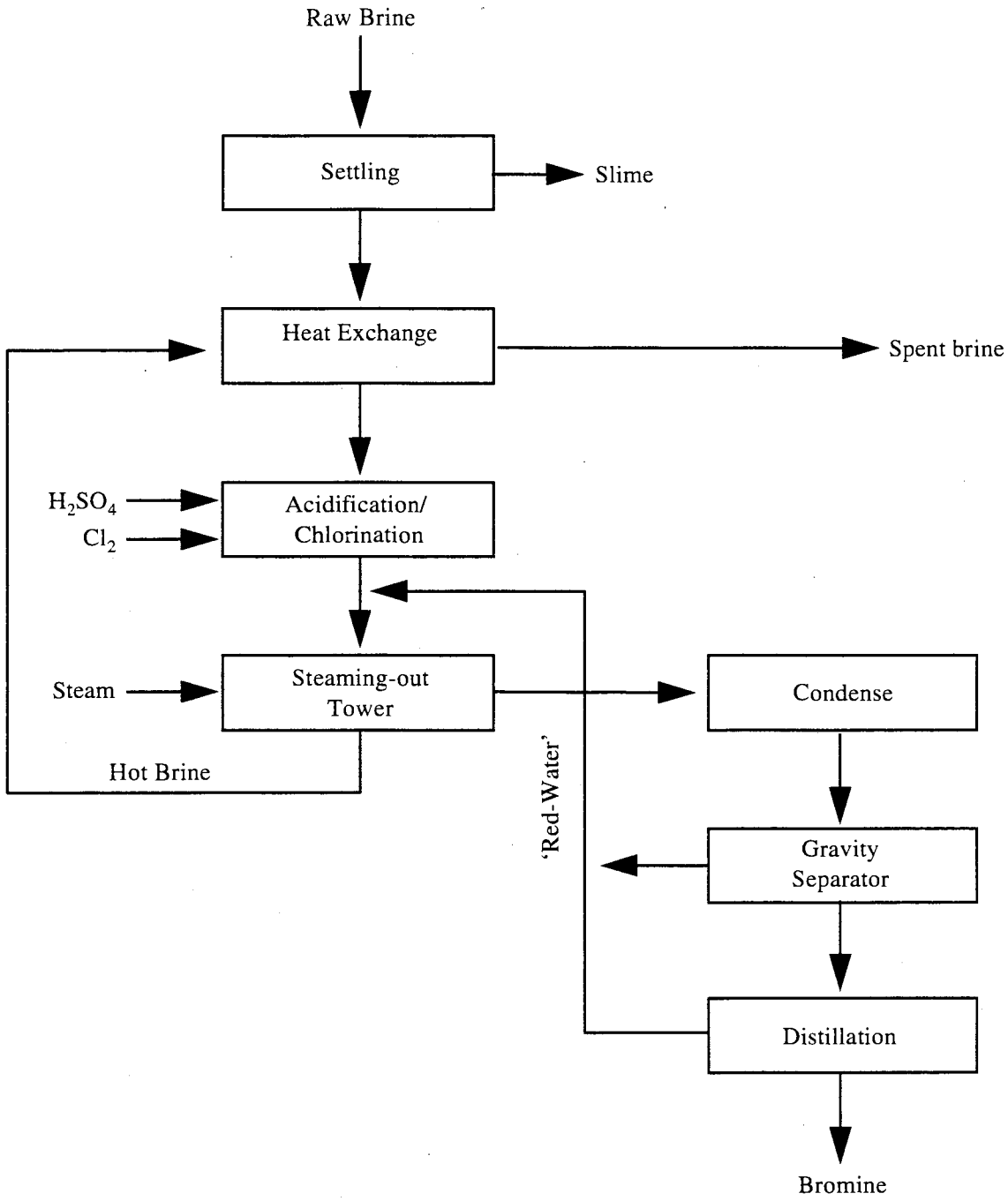


EXHIBIT 3

STEAMING OUT PROCESS FOR RECOVERY OF BROMINE FROM HIGH BROMIDE BRINES

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1992, pp. 547 - 550.)



Condensation and Purification of Bromine

Following either method of extraction, the brine stream can be separated from the emerging gas stream containing free bromine. The gas is then cooled to condense water and bromine. The spent brine from the vapor extraction process can be neutralized with the addition of NH_4OH and cooled. After removing the ammonia, spent brine can either be used in other processes, sent to disposal wells, or returned to the source.

Condensation. The condensation process varies depending on the extraction process used. After the steaming out method, the bromine is condensed directly from the steam. Following the blowing out method, the bromine can be separated by adding acid to the extracted solution and distilling with steam. The gaseous stream containing bromine can be condensed and purified.[9] The liquid resulting from the condensation step is separated and the recovered water is recycled back to the absorption tower.

Purification. Typically, following condensation the bromine is dried with sulfuric acid and then purified by distillation. As shown in Exhibit 2, a 98 percent H_2SO_4 can be added, resulting in the generation of a spent solution containing 70 percent H_2SO_4. The resultant dry bromine is sent to sale or use.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Recent patents describe a single-stage vacuum and a double-stage vacuum process for bromine recovery which modify existing recovery procedures. The single-stage vacuum is similar to the steaming out process, except that it is carried out under subatmospheric pressure. The double-stage vacuum re-strips the tail brines from the first stripping under greater vacuum. The use of a vacuum in these modified process eliminates the need to heat the brine with steam by matching the vapor pressure of the brines. Additional benefits of the vacuum modification include increased tower capacity, reduction in chlorine use, and reduction in the amount of lime needed to treat the spent brine.[10]

4. Beneficiation/Processing Boundary

EPA does not have enough information on this mineral commodity sector to determine where in the production sequence mineral processing begins.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Waste Brine. Waste liquids are generated during the vapor extraction and once these are neutralized and cooled they can either be sent to disposal wells or returned to the brine deposit. These spent brines may contain ammonia from the neutralizing step. Alternatively, waste brine can also be generated during the steaming out process in the form of a hot bromine-free liquor that emerges from the bottom of the tower. This liquor is neutralized with lime and discharged to a waste pond.[11]

Slimes. Slimes are generated from the settling step in the steaming out process.

Water Vapor. Some chlorine and water vapor are captured at the top of the tower during steaming out.

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[9] Ibid., p. 260.

[10] "Bromine," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. IV, 1992, p. 550.

[11] Phyllis Lyday, 1992, Op. Cit., p. 260.

2. Mineral Processing Wastes

Bromine is used to make several organic chemical compounds in operations in close proximity to the brine extraction process. EPA does not have enough information to determine where in the production sequence mineral processing begins.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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Personal Communication with Phyllis Lyday, Bromine Specialist, U.S. Bureau of Mines. October 5, 1994.

U.S. Environmental Protection Agency. "Bromine." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. 1988. Office of Solid Waste, pp. 2-85 - 2-88.

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CADMIUM

A. Commodity Summary

Four companies are responsible for producing all of the domestic primary cadmium. According to the U.S. Bureau of Mines, cadmium is used in batteries, 71%; pigments, 10%; coating and plating, 8%; stabilizers for engineering plastics and similar synthetic products, 5%; and alloys and other miscellaneous uses, 6%.[1]

Cadmium is produced mainly as a byproduct of refining zinc metal from sulfide ore concentrates. It is also produced as a byproduct of beneficiating and refining lead ores or complex copper-zinc ores. Cadmium minerals are not found alone in commercially viable deposits. Greenockite (CdS) is the only cadmium mineral of importance. It is not found in any isolated deposits, but is nearly always associated with sphalerite (ZnS).[2]

Exhibit 1 shows the names and locations of the four primary cadmium producers. Three of the four companies (Big River Zinc Corporation, ZCA, and Jersey Miniere Zinc Company) recover cadmium as a byproduct of smelting domestic and imported zinc concentrates. The fourth company (ASARCO) recovered cadmium from other sources such as lead smelter baghouse dust.[3]

EXHIBIT 1

SUMMARY OF CADMIUM PRODUCING FACILITIES

Facility Name	Location
ASARCO	Denver, CO
Big River Zinc Corporation	Sauget, IL
Jersey Miniere Zinc Company	Clarksville, TN
ZCA	Bartlesville, OK

B. Generalized Process Description

1. Discussion of Typical Production Processes

Cadmium is mainly a byproduct of the production of zinc metal from sulfide ore concentrates. The mined zinc ores are crushed and ground to liberate the zinc sulfide particles from the waste host rock. The ground ore is usually treated by a differential flotation process to separate the zinc-bearing particles from the waste rock, yielding a high-grade zinc concentrate and waste tailings. About 90% to 98% of the cadmium present in zinc ores is recovered in the mining and beneficiating stages of the extraction process. Zinc concentrate is converted from zinc sulfide to zinc oxide by roasting, and at the same time most of the sulfur is removed as sulfur dioxide. The sulfur dioxide

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[1] Peter Kuck, "Cadmium," from Mineral Commodity Summaries, U.S. Bureau of Mines, 1995, pp. 36-37.

[2] Thomas O. Llewellyn, "Cadmium," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 271-276.

[3] Ibid.

offgas is stripped of all entrapped dust and other impurities and then converted to sulfuric acid in an acid plant.[4] Cadmium is recovered from zinc and zinc lead concentrates as precipitates from solution (hydrometallurgical process) or as cadmium-lead fume (pyrometallurgical process), respectively, as shown in Exhibit 2. Cadmium may also be recovered as a byproduct of beneficiating and refining lead ores or complex copper-zinc ores.

2. Generalized Process Flow

Cadmium from Zinc

Hydrometallurgical Process

The hydrometallurgical process is used to recover cadmium as a precipitate. In this process, cadmium, copper, and zinc are dissolved in the sulfuric acid leach of the roasted zinc ore. Copper and cadmium are among the most common interfering impurities that are removed before the purified solution is subjected to electrolysis for zinc recovery. Most of the cadmium is precipitated using a zinc dust addition. The purified zinc sulfate solution is sent to the cellroom, and metallic zinc is recovered from the solution by electrowinning. The cadmium precipitate is sent to the cadmium plant where it is filtered and pressed into a cake containing cadmium, zinc, and minor amounts of copper and lead. Impurities are separated and a sufficiently pure cadmium sponge is dissolved in sulfuric acid. Metallic cadmium is recovered by electrolysis of this solution where cadmium is deposited on cathodes. After deposition, the cathodes are removed from the cells and stripped and the cadmium metal is melted and cast into shapes. Exhibit 3 presents a process flow diagram of the production of cadmium from zinc.[5]

Pyrometallurgical Process

During the pyrometallurgical extraction of zinc, calcine from a roaster can be sintered with coke in a sintering machine to give a dense desulfurized product. The sintering operation results in considerable volatilization of cadmium and lead compounds, enhanced by the presence of chloride, leading to a 90-99% recovery of cadmium. The fume and dust from the sintering machine are collected in a baghouse. Cadmium not removed during sintering and subsequent operations follows the zinc metal and often is recovered during zinc metal purification by distillation.[6]

The cadmium content in the feed to lead and copper smelters is lower than that generally encountered in zinc plants, and this necessitates upgrading the initial cadmium level in the fume by one or more refuming steps in a kiln or reverberatory furnace. The final fume may contain as much as 45% cadmium. Fumes usually require more processing and purification steps for cadmium recovery than do purification residues from electrolytic zinc plants. Galvanic precipitation is the most frequently adopted method for the final recovery of cadmium in pyrometallurgical plants, but electrolysis may also be used.[7]

Exhibit 4 presents a process flow diagram of cadmium recovery from cadmium bearing fumes. Depending on composition, the fume may have to be roasted with or without sulfuric acid or oxidized using sodium chlorate or chlorine in order to convert cadmium into a water- or acid-soluble form and to eliminate volatile constituents.

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[4] U.S. Environmental Protection Agency, "Cadmium," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-64 - 3-71.

[5] Ibid.

[6] "Cadmium and Cadmium Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. IV, 1993, pp. 749- 754.

[7] Ibid.

EXHIBIT 2

PRELIMINARY CADMIUM ROASTING PROCESSES

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1992, pp. 749 - 754.)

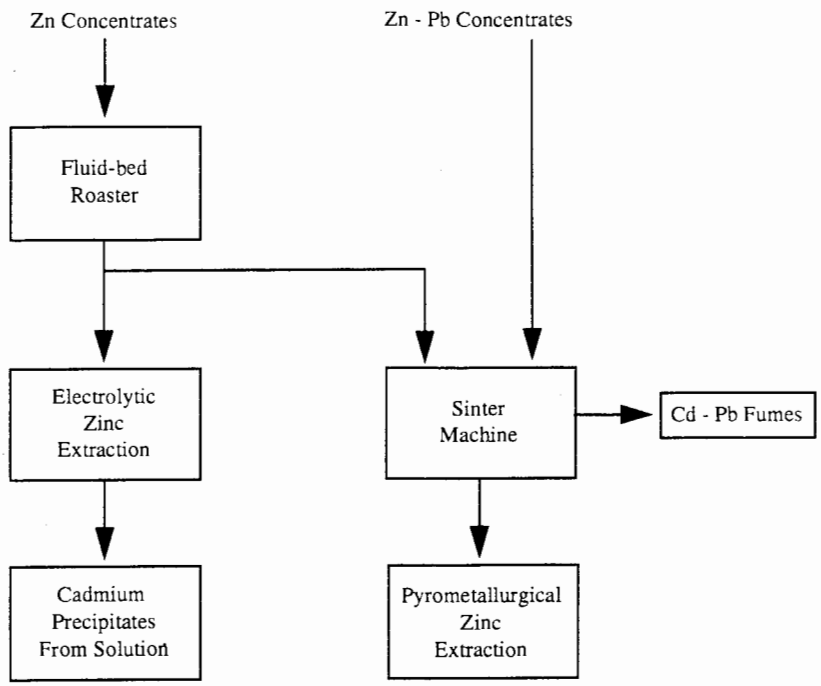


EXHIBIT 3

HYDROMETALLURGICAL PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-64 - 3-71.)

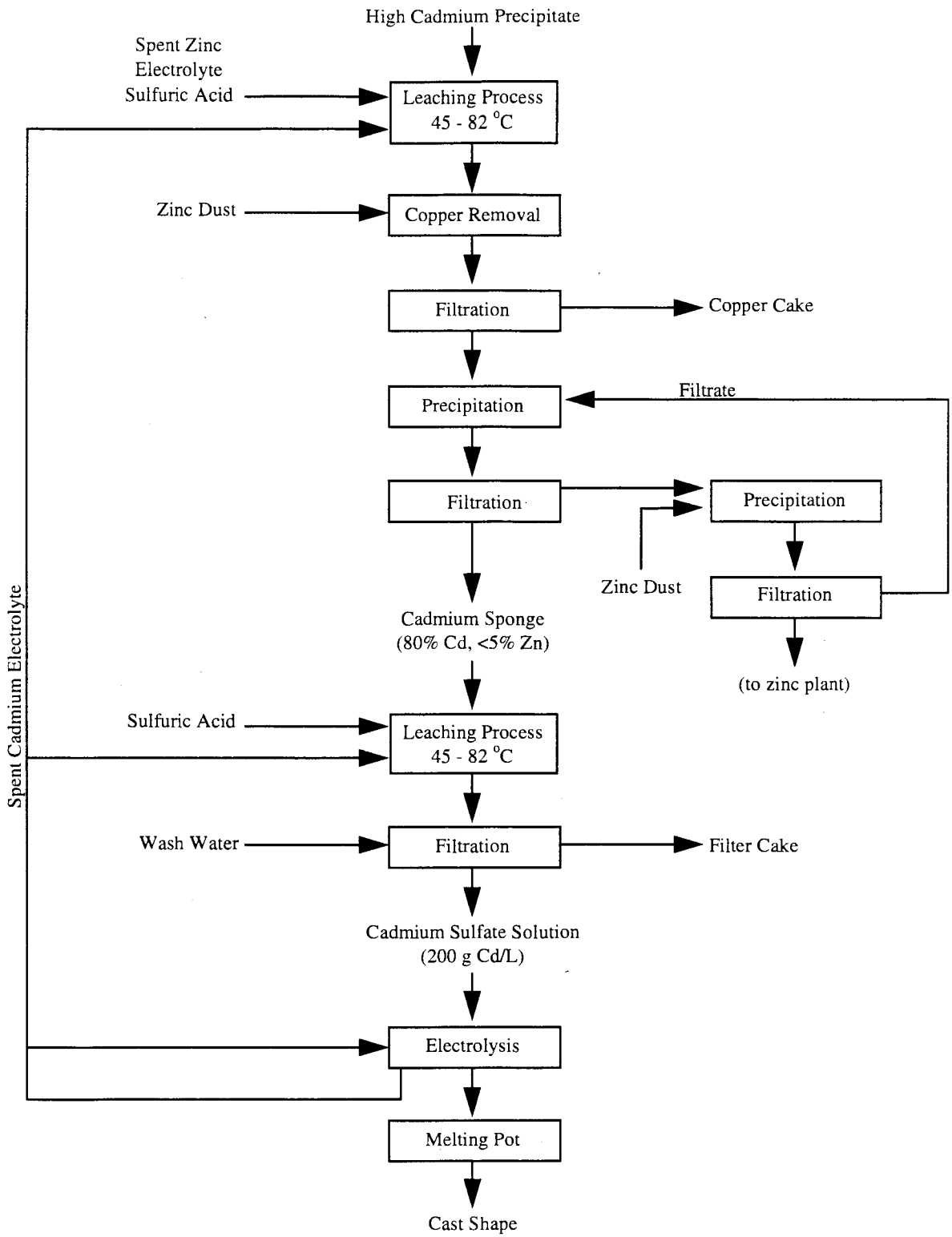
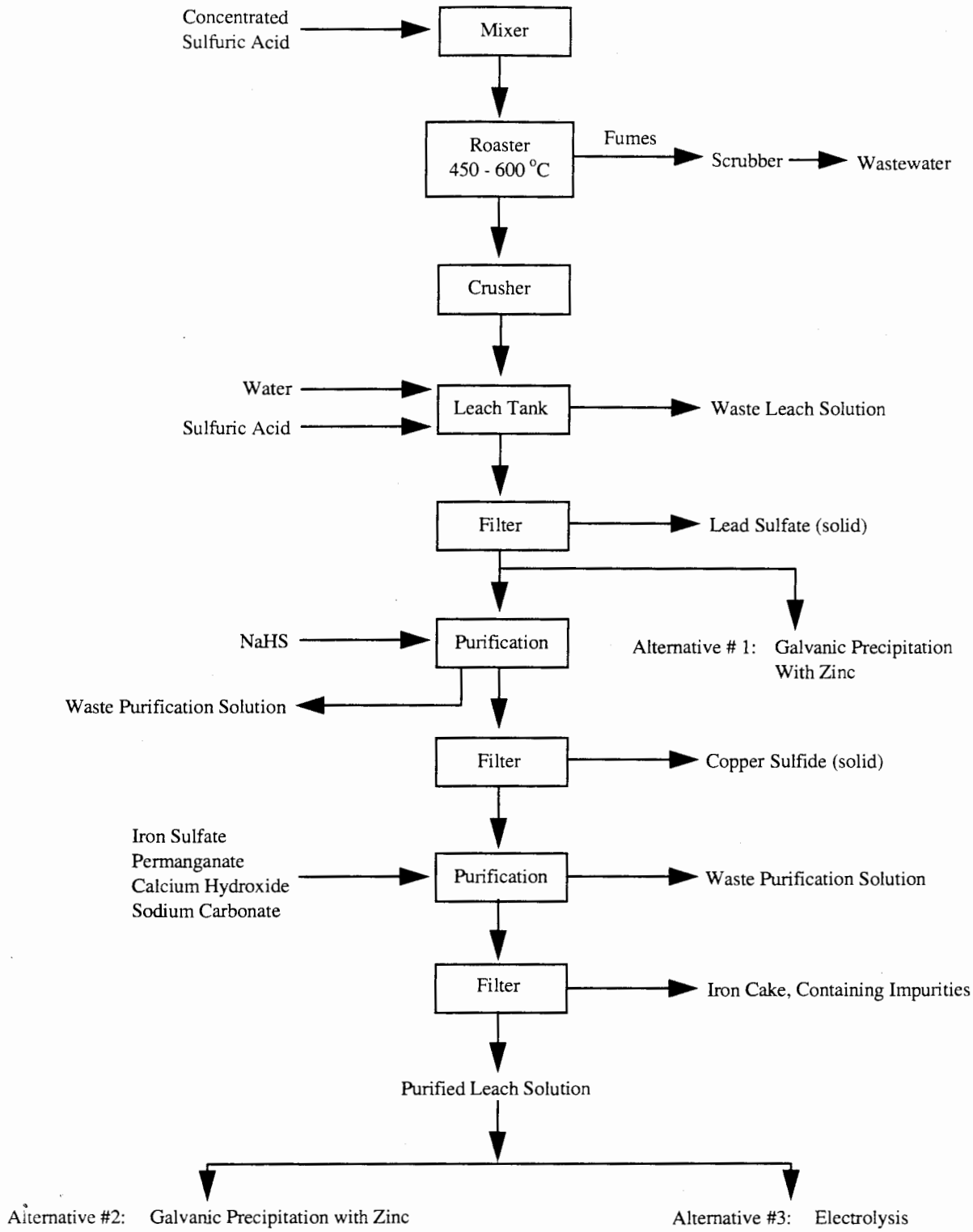


EXHIBIT 4

PYROMETALLURGICAL PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-64 - 3-71.)



However the leach solution is obtained, it must generally be purified to remove arsenic, iron, copper, thallium, and lead. The cadmium may also be galvanically precipitated from the leach solution and then redissolved (see Exhibit 5).[8]

Alternative 2 in Exhibit 5 indicates the most common method for the recovery of cadmium from purified leach solution by galvanic displacement with zinc in the form of dust, sheets, or even rods or rectangular anodes. The final processing depends on the grade of zinc. In most cases, the pH for galvanic precipitation is below 2, although one plant operates at pH 6.2. In most plants, the final cadmium sponge is washed to remove soluble impurities, and then compacted by briquetting. The briquettes may be melted under a flux of sodium hydroxide or ammonium chloride or be distilled for final purification.[9]

Electrolysis is the third alternative for cadmium recovery. Exhibit 6 presents a process flow diagram of this operation. The electrolysis may be operated on a semi-continuous basis with the cadmium eventually being stripped completely from the electrolyte, which is then discarded after suitable treatment. Instead of the usual silver-lead anodes, high silicon-iron anodes, such as Duriron, are commonly used.[10]

Cadmium from Lead

Cadmium may also be obtained from flue dust collected at lead or copper smelters. Concentrates of copper, and especially lead, contain considerable amounts of cadmium. In copper smelters, the flue dusts are collected and recycled through the smelter system to upgrade the cadmium content. At the lead smelters the cadmium is fumed off and collected in the blast furnace baghouses. The baghouse dust is recycled to upgrade the cadmium content and is later used as feed material for the cadmium refinery plant.[11]

The cadmium upgraded dusts are charged into a tank and dissolved with sulfuric acid. The resultant solution is filtered to remove impurities and to obtain a purified cadmium sulfate solution. Next, metallic cadmium, called sponge because of its appearance, is precipitated from the solution using zinc dust. The sponge is usually briquetted, remelted, and cast into ingots.

Some plants produce cadmium oxide and/or metallic cadmium powder. Cadmium oxide is produced by melting the ingots and keeping a controlled oxidizing atmosphere in the retort. To produce metal powder, the melted ingots in the retort are kept under an inert atmosphere while cadmium is distilled into a condenser as metallic powder.[12]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

Since cadmium is recovered as a by-product of other metals, all of the wastes generated during cadmium recovery are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, see the reports for zinc and lead presented elsewhere in this document.

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[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] Thomas Llewellyn, 1992, Op. Cit., pp. 271-276.

[12] Ibid.

EXHIBIT 5

ALTERNATIVES 1 AND 2
GALVANIC PRECIPITATION WITH ZINC

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-64 - 3-71.)

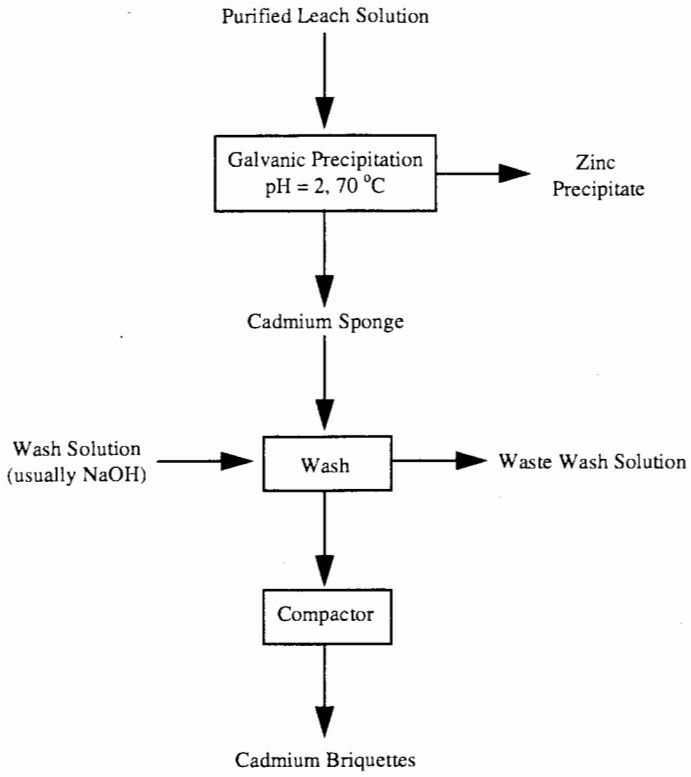
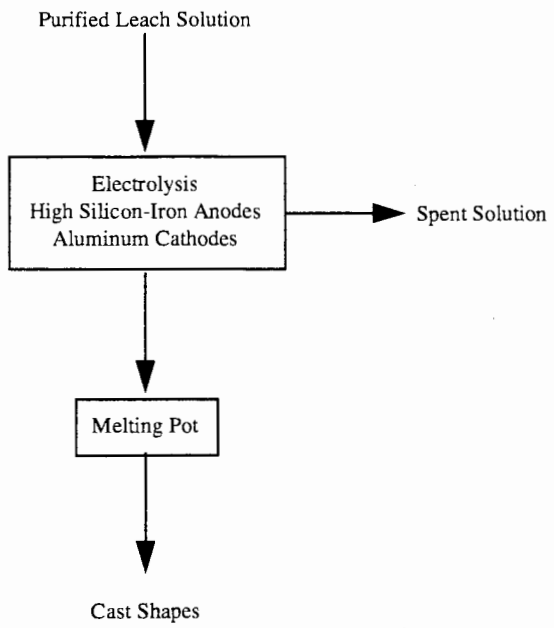


EXHIBIT 6

ALTERNATIVE 3
ELECTROLYSIS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-64 - 3-71.)



C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Waste tailings.

2. Mineral Processing Wastes

Since cadmium is toxic to humans and certain other living organisms, care must be taken during the production, use, and disposal of cadmium and its compounds to avoid the dispersal of cadmium fumes and dusts or the release of cadmium-bearing effluents into the environment so that exposure is minimized.[13] Listed below are possible waste streams from cadmium production. Generally, all wastes are recycled or treated with other refinery wastes.

Hydrometallurgical Process

Copper removal filter cake. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium. This waste may be recycled and is classified as a byproduct.

Post-leach filter cake. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium. This waste may be recycled to extraction/beneficiation units and is classified as a byproduct.

Spent electrolyte may contain thallic sulfate. Information regarding thallium removal from the spent electrolyte remains unclear. However, according to the U.S. Bureau of Mines, there was no domestic production of thallium metal in 1993; suggesting that thallium is not recovered domestically from cadmium production operations. However, sludges from cadmium processing which are used for recovery of metals such as germanium may contain thallium. Since there is no domestic production of germanium, the thallium contained in these sludges may be recovered in other countries.[14] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for cadmium and corrosivity.

Pyrometallurgical Process

Copper sulfide and lead sulfate filter cakes. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium and lead. This waste may be recycled and is classified as a byproduct.

Iron containing impurities. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr,

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[13] Patricia A. Plunkert, "Cadmium," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, pp. 111-119.

[14] Personal communication between Peter Kuck, U.S. Bureau of Mines and ICF Incorporated, October 12, 1994.

respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium.

Lead sulfate waste (solid). Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium and lead. This waste may be recycled and is classified as a byproduct.

Spent leach solution. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for arsenic, cadmium, and lead and corrosivity. This waste may be recycled and is classified as a spent material.

Spent purification solution. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for cadmium and corrosivity.

Scrubber wastewater. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for cadmium and corrosivity. This waste may be recycled and is classified as a spent material.

Galvanic Precipitation

Caustic washwater solution. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for cadmium and corrosivity. This waste may be recycled and is classified as a spent material.

Zinc precipitate. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 190 metric tons/yr, 1,900 metric tons/yr, and 19,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium. This waste may be recycled and is classified as a byproduct.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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CALCIUM METAL

A. Commodity Summary

Pure calcium is a bright silvery-white metal. Under normal atmospheric conditions, however, freshly exposed surfaces of calcium rapidly become covered with an oxide layer. The metal is extremely soft and ductile, having a hardness between that of sodium and aluminum.[1] Calcium is very reactive and reacts vigorously with water, liberating hydrogen and forming calcium hydroxide, $Ca(OH)_2$. Calcium does not readily oxidize in dry air at room temperature, but is quickly oxidized in moist or dry oxygen at about 300° C.[2]

Calcium is an excellent reducing agent, and at elevated temperatures it reacts with oxides or halides of almost all metallic elements to form the corresponding metal. Calcium is used in lead refining (for removal of bismuth), steel refining (as a desulfurizer and deoxidizer), and as an alloying agent for aluminum, silicon, and lead. Calcium is also used in the recovery of refractory metals (e.g., chromium, rare earth metals, and thorium) from their oxides and in the reduction of uranium dioxide.[3]

Pfizer Chem (Quigley Company), located in Canaan, Connecticut is the only domestic producer of calcium metal. Pfizer Chem uses the retort process. Calcium alloys, however, are produced by several companies, including Elkem in Pittsburgh, Pennsylvania.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Calcium metal is produced by the aluminothermic method involving the high temperature vacuum reduction of calcium oxide. The raw materials for this process are limestone and aluminum. In this process, aluminum metal acts as the reducing agent. Exhibits 1 and 2 present flow diagrams for the typical process for producing calcium metal.

2. Generalized Process Flow Diagram

Aluminothermic Process

As shown in Exhibit 1, high calcium limestone, $CaCO_3$, is quarried and calcined to form calcium oxide. As shown in Exhibit 2, the calcium oxide is then ground to a small particle size and dry blended with the desired amount of finely divided aluminum. This mixture is then compacted into briquettes to ensure good contacts for reactants. The briquettes are then placed in horizontal tubes, i.e., retorts, made of heat resistant steel and heated to 1100-1200°C. The open ends of the retort protrude from the furnace and are cooled by water jackets to condense the calcium vapor. The retorts are then sealed and evacuated to a pressure less than 13 Pa. After the reaction has been allowed to proceed for approximately 24 hours, the vacuum is broken with argon and the condensed blocks of about 99% pure calcium metal, known as crowns, and calcium aluminate residue are removed.[4]

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[1] "Calcium," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. IV, 1992, p. 777.

[2] Ibid., p. 778.

[3] Ibid., p. 777.

[4] Ibid., pp. 779-780.

EXHIBIT 1

LIME AND LIMESTONE PRODUCTION

(Adapted from: Industrial Minerals and Rocks, 1994, p. 592.)

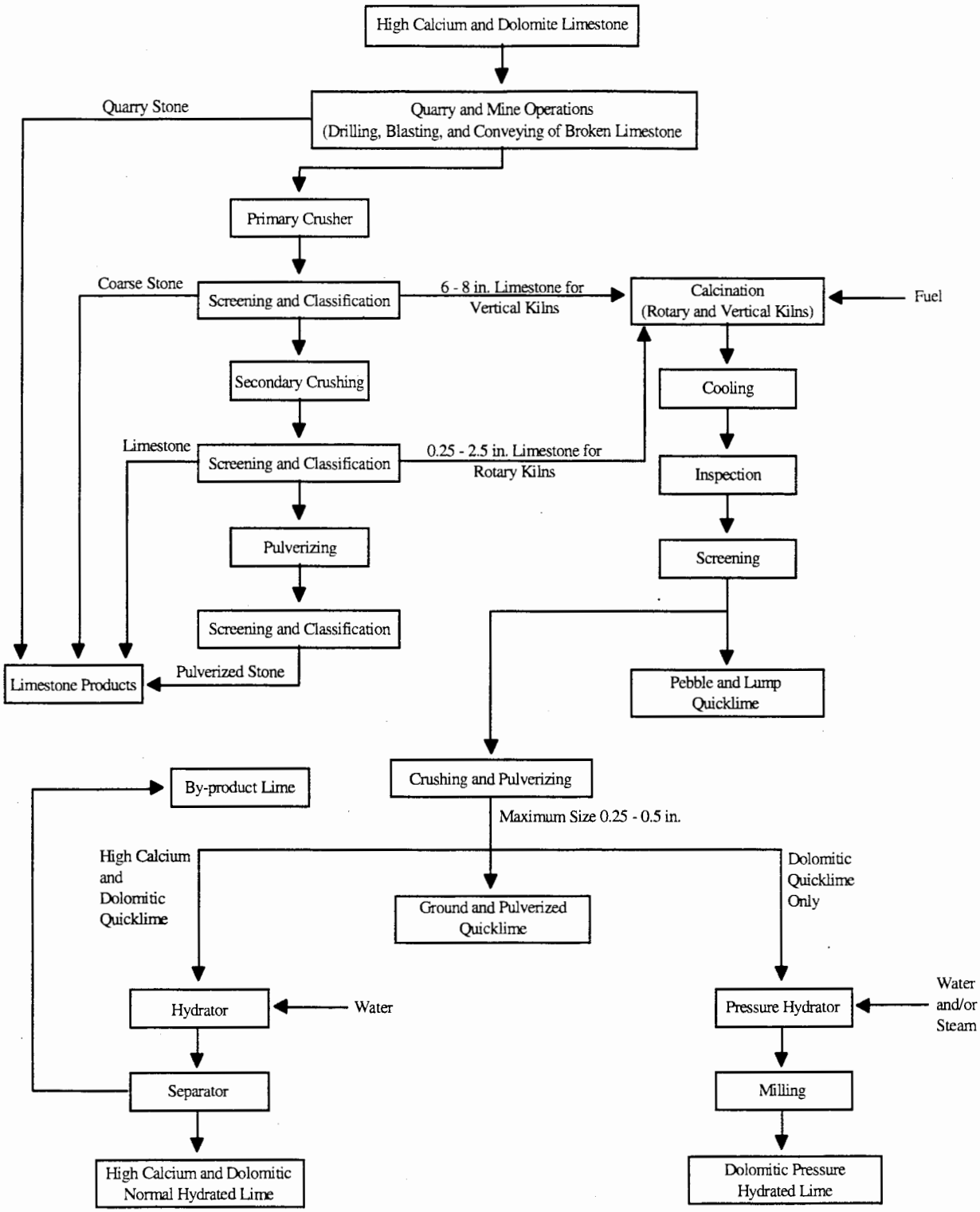
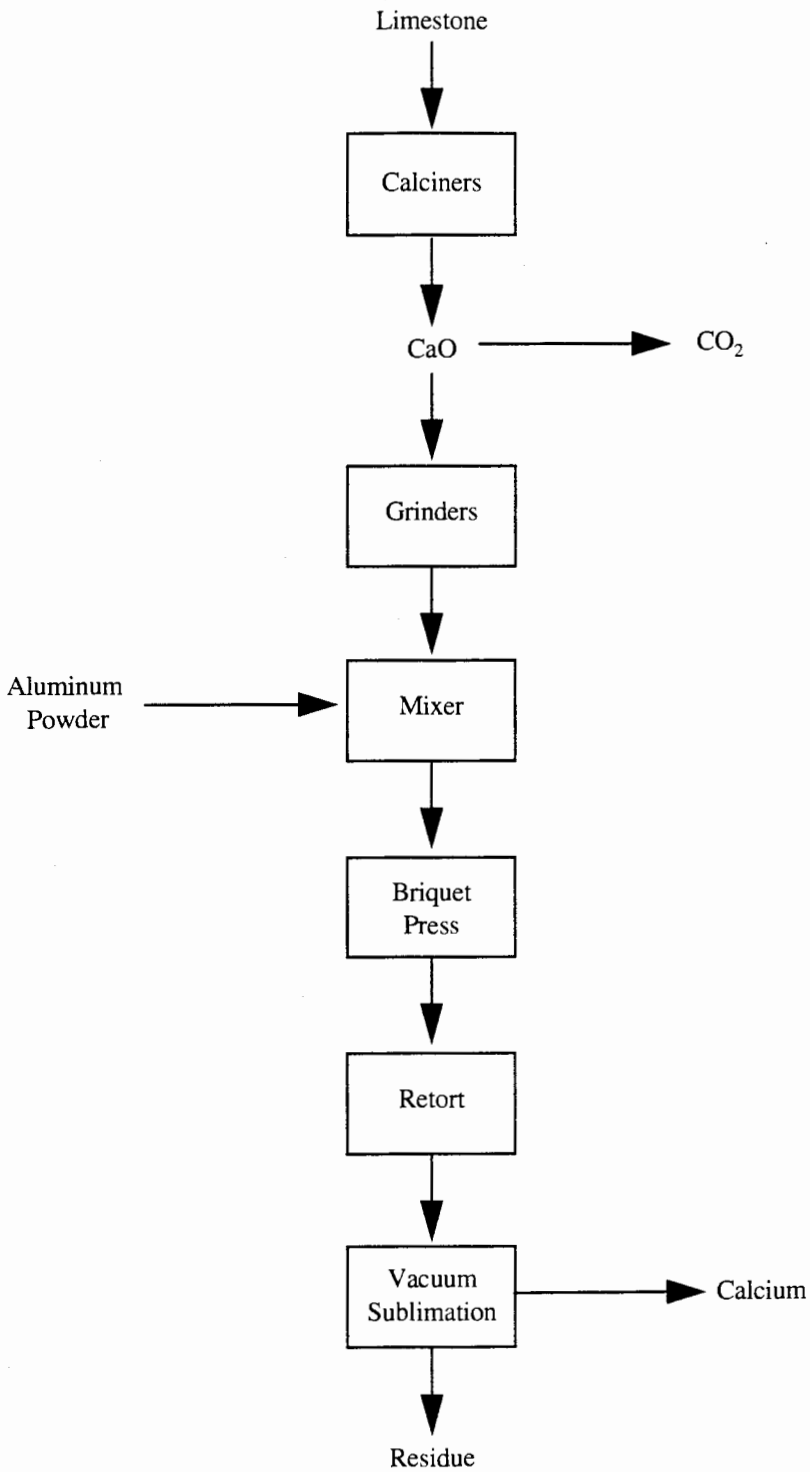


EXHIBIT 2

ALUMINUM REDUCTION PROPCESS

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. IV, 1992, pp. 777 - 782)



Redistillation

In applications involving the reduction of other metal compounds, a purity greater than 99% calcium is required. The necessary higher purities can be achieved through redistillation. For one method of redistillation, crude calcium is placed at the bottom of a large vertical retort made of heat-resistant steel equipped with a water cooler condenser at the top. The retort is sealed and evacuated to a pressure of less than 6.6 Pa while the bottom is heated to 900-925°C. Under these conditions calcium quickly distills to the condensing section leaving behind the bulk of the less volatile impurities. Any processing that takes place after this point must be in the absence of moisture to avoid oxidation.[5] Redistillation does not reduce those impurities that result from volatile materials, such as magnesium. Volatile alkali metals can be separated from calcium by passing the vapors over refractory oxides such as TiO_2, ZrO_2, CrO_3 to form nonvolatile Na_2O and K_2O.[6]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between briquet pressing of calcium oxide and retorting. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where calcium oxide undergoes a chemical change to produce calcium metal. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2,

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[5] Ibid., pp. 780-781.

[6] Ibid.

along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Overburden. No waste characterization data or generation rates are available for overburden resulting from the mining operations. However, the overburden is likely left at the mining site.

Off-gases. The gases that result from the calciner operation are generally vented to the atmosphere, and consist primarily of CO_2 and water vapor.

2. Mineral Processing Wastes

The aluminothermic process employed at the Pfizer plant in Connecticut generates two main sources of mineral processing wastes. It is not clear whether the land surface is on or off site. The description of the wastes does not specify whether the terms reactive and non-combustible refer to RCRA definitions.

Calcium Aluminate Wastes. The calcium aluminate is a non-reactive waste and is generally disposed of in a land surface storage area. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Dust with Quicklime. While dust collected from the system is recycled, some fugitive dust is accumulated due to contamination concerns. The dust is reactive, non-combustible, and disposed of on the land surface. This waste stream has a reported waste generation rate of 40 mt/yr. We used best engineering judgment to determine that this waste stream may exhibit the characteristic of corrosivity. This waste stream is fully recycled and is classified as a sludge.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

BIBLIOGRAPHY

"Calcium." Kirk-Othmer Encyclopedia of Chemical Technology. 4th ed. Vol. IV. 1992. pp. 777-782.

CESIUM/RUBIDIUM

A. Commodity Summary

The properties of cesium and its compounds are similar to those of rubidium and its compounds. As a result, cesium and rubidium compounds are often used interchangeably. Although neither cesium nor rubidium is recovered domestically from mined ores, according to the U.S. Bureau of Mines each is manufactured by primarily one company domestically (Cabot Corp. - Revere, PA). Cesium products are manufactured from imported pollucite ore and used commercially in electronics, photoelectric, and medical applications. Rubidium products are manufactured from imported lepidolite ore and also used commercially in the electronic and medical industries. Both cesium and rubidium were used in the form of chemical compounds in research and development endeavors.[1] Exhibit 1 presents the names and locations of the facilities once involved in the production of cesium/rubidium.

EXHIBIT 1

SUMMARY OF CESIUM/RUBIDIUM FACILITIES

Facility Name	Location	Type of Operations
Cabot Corp	Revere, PA	Recovery of both cesium and rubidium
Callery Chem	Pittsburgh. PA	Uncertain
Carus Corp	La Salle, IL	Acid Digestion
Corning Glass	Corning, NY	Uncertain

B. Generalized Process Description

1. Discussion of Typical Production Processes

Cesium. The production of cesium metal from pollucite can be achieved through three basic methods: direct reduction with metals, decomposition with bases, and acid digestion. Acid digestion is the primary commercial process for cesium production and is described in further detail below.[2] Exhibit 2 presents the generalized process flow diagram for the production of cesium.

Rubidium. Rubidium is found widely dispersed in potassium minerals and salt brines. Lepidolite, a lithium mica, is the principal source of rubidium. Because pollucite ore also contains some rubidium dioxide (RbO_2), some rubidium is processed as a by-product of cesium manufacture from this ore. The traditional methods for recovering rubidium involve extraction of mixed alkali alums from the ore and are described in further detail below.[3] Exhibits 3 through 6 present generalized process flow diagrams for the production of rubidium.

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[1] Robert G. Reese, Jr., "Cesium" and "Rubidium," from Mineral Commodity Summaries, 1995, pp. 40-41 and pp. 138-139.

[2] "Cesium," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol V, 1993, p. 753.

[3] "Rubidium," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol XX, 1982, p. 493.

2. Generalized Process Flow Diagram

Cesium

As shown in Exhibit 2, the recovery of cesium from pollucite requires that the raw ore be crushed and ground, and mixed with water to form a slurry.[4] Some sources indicate that no further concentration is necessary at this point and the pollucite can be digested with an acid.[5] Other sources indicate that following the production of the pollucite slurry, froth flotation can be used to yield a pollucite concentrate that is acidified through the addition of sulfuric acid. Waste gangue is discarded and the acidified concentrate is treated with hydrofluoric acid, aluminum sulfate, and a cationic reagent (e.g., cocoamine acetate) for conditioning. This conditioned pulp is then sent through froth flotation for a second time and the resultant product is a relatively pure pollucite which is prepared for acid digestion. Any non-pollucite minerals are separated through the froth filtration and discarded.[6]

Either hydrochloric, hydrobromic, hydrofluoric, or sulfuric acid can be used for the acid digestion step to produce the cesium salt that can be evaporated to yield a dried cesium salt.[7] Other sources suggest that hydrobionic acid could be used as well.[8]

Rubidium

As shown in Exhibit 3, the recovery of rubidium from either pollucite or lepidolite ore requires that the ore be leached for a prolonged period of time in sulfuric acid to form alkali alums. The alum solution is filtered from the residue, which is washed with water. Calcination of the ore prior to leaching increases the yield. The other alkali metals are separated from the rubidium solution by fractional recrystallization. The purified rubidium alum is converted to rubidium hydroxide, by neutralization to precipitate the aluminum. The addition of barium hydroxide precipitates the sulfate.

As shown in Exhibit 4, the chlorostannate method requires a partial separation of rubidium from the potassium-bearing ore. The dissolved carbonates are converted to chlorides, and the solution is treated with enough stannic chloride to precipitate cesium chlorostannate, which is less soluble than its rubidium counterpart. The cesium-free chloride solution is treated with an excess of stannic chloride to precipitate rubidium chlorostannate which may be decomposed to separate the rubidium and tin chlorides by pyrolytic, electrolytic, or chemical methods. As shown in Exhibit 5, solvent extraction and ion exchange can also be used to separate rubidium from other alkali-metal compounds.[9]

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[4] U.S. Environmental Protection Agency, "Cesium," from 1988 Final Draft Summary Report on Mineral Industry Processing Wastes, Office of Solid Waste, 1988, p. 3-72.

[5] "Cesium," 1993, Op. Cit., p. 753.

[6] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-72.

[7] "Cesium," 1993, Op. Cit., p. 753.

[8] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-73.

[9] "Rubidium," 1982, Op. Cit., p. 493.

EXHIBIT 2

CESIUM RECOVERY FROM POLLUCITE ORE

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-179 - 3-186.)

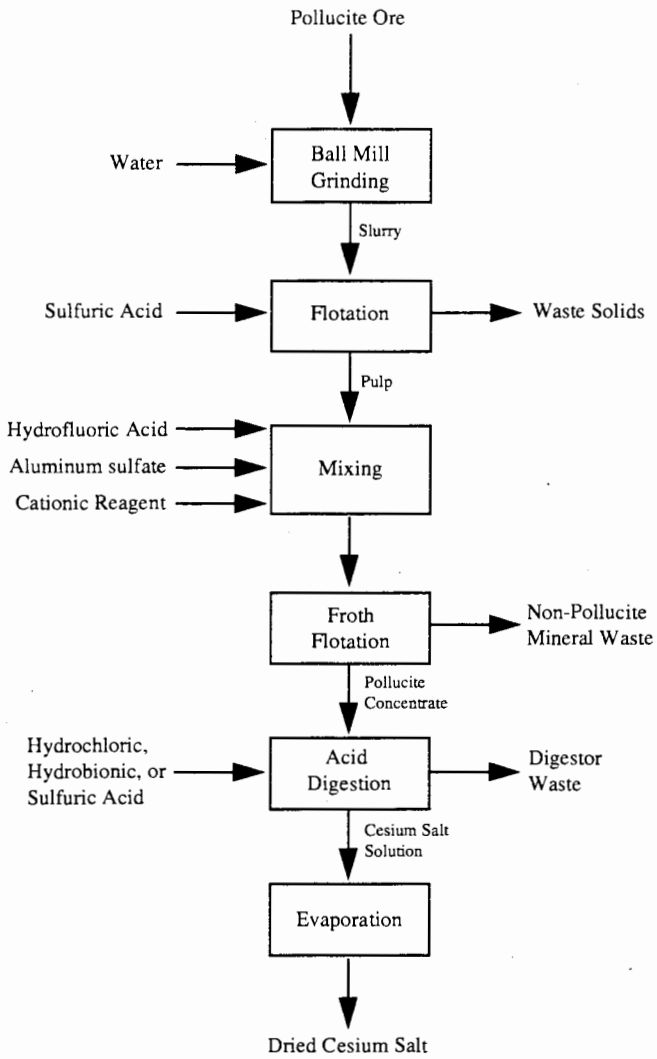
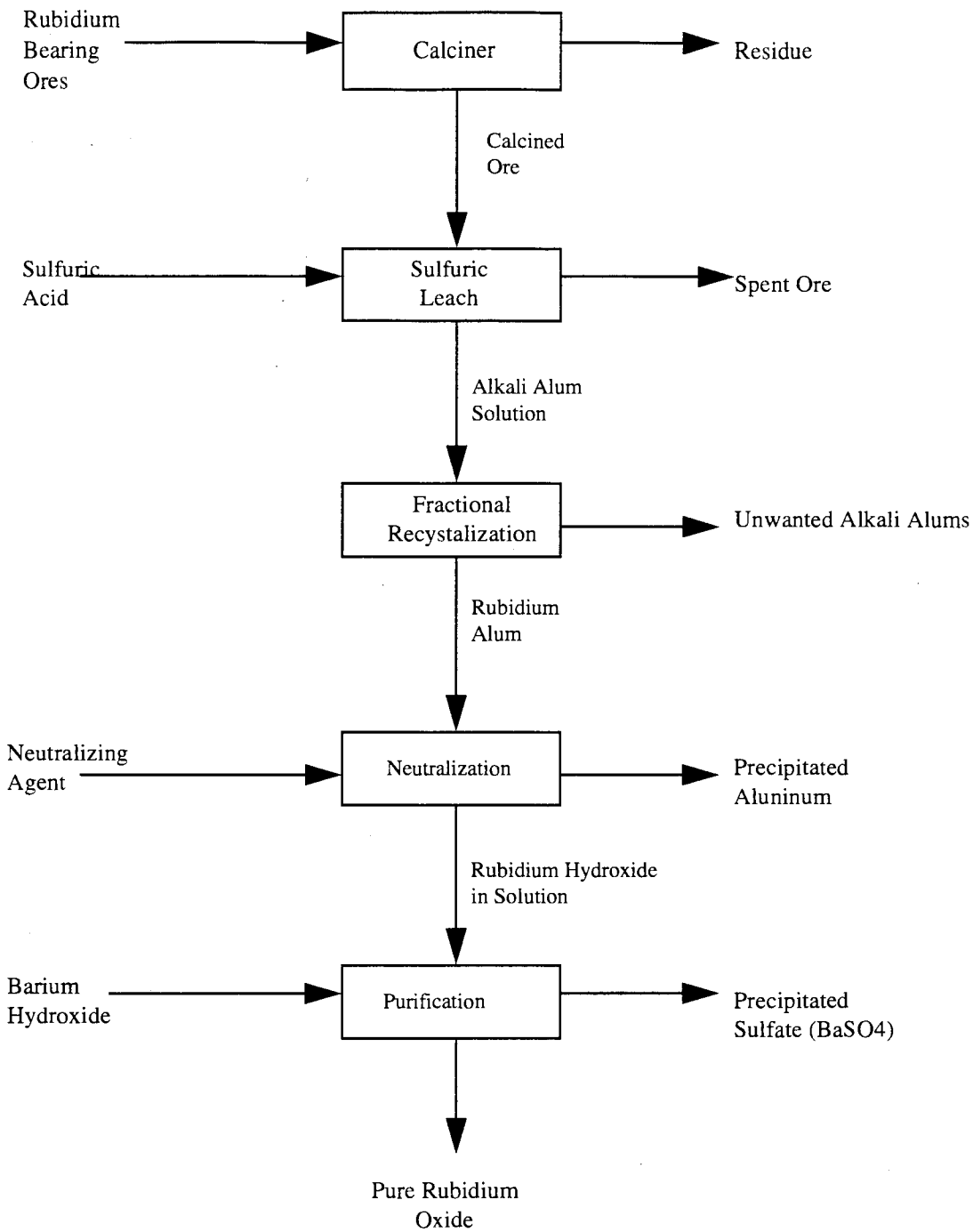


EXHIBIT 3
Rubidium Alums, Extraction

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes 1988, pp.3-179 - 3-186)



Source: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-179-3-186.

EXHIBIT 4

RUBIDIUM STANNIC CHLORIDE PRECIPITATION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-179 - 3-186.)

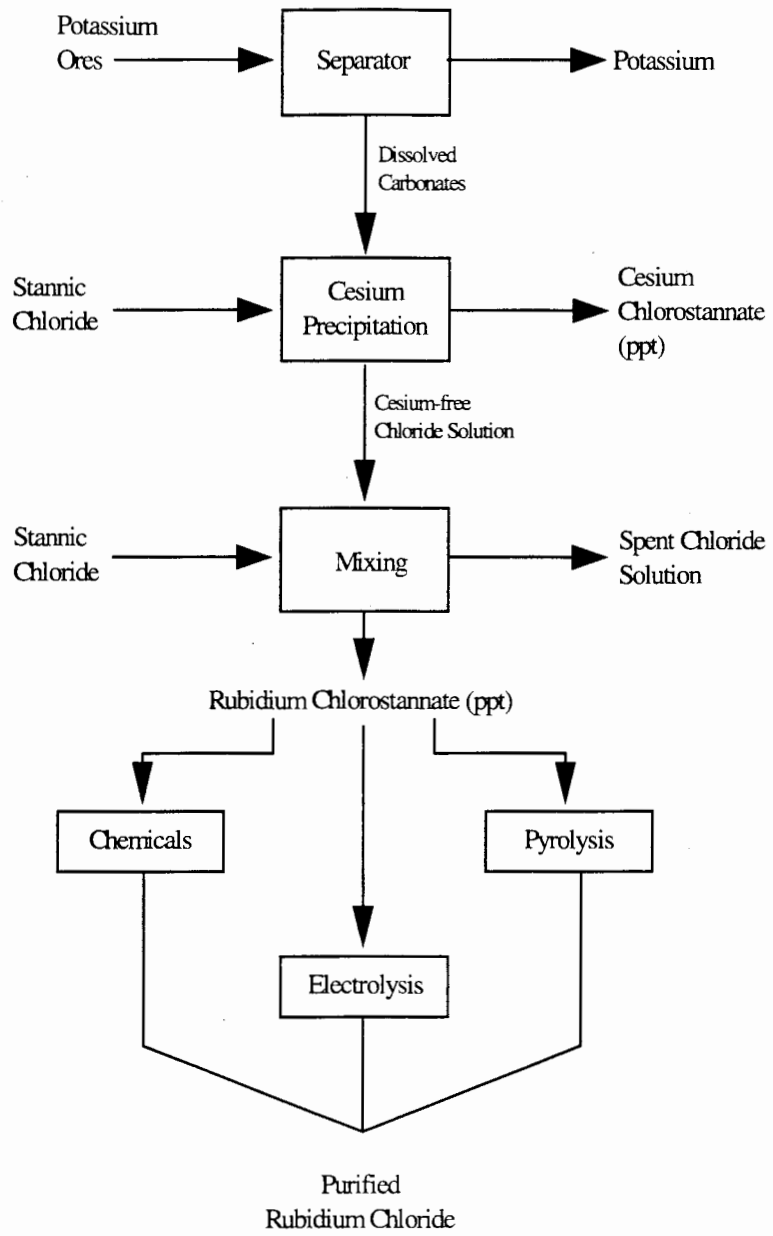


EXHIBIT 5

RUBIDIUM FROM ALKALI METALS

(Adapted from: 1988 Final Draft Summary of Mineral Industry Processing Wastes, 1988, pp. 3-179 - 3-186.)

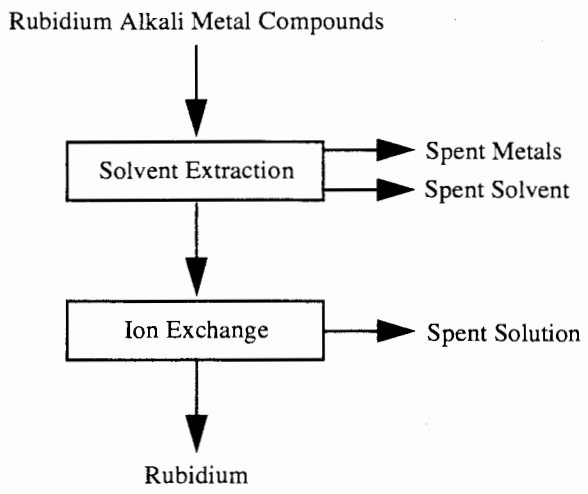
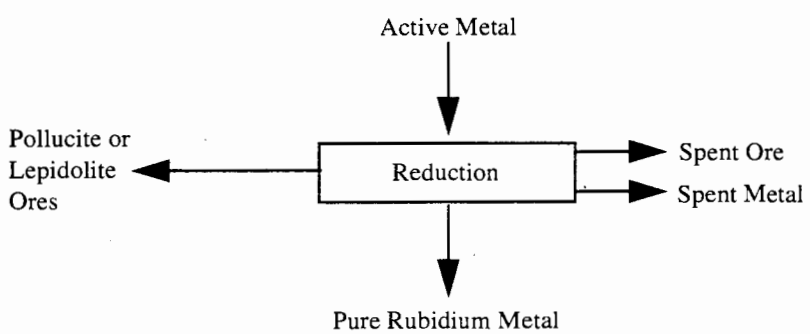


EXHIBIT 6

RUBIDIUM REDUCTION

(Adapted from: 1988 Final Draft Summary of Mineral Industry Processing Wastes, 1988, pp. 3-179 - 3-186.)



3. Identification/Discussion of Novel (or otherwise distinct) Processes

Cesium

In the process used by Carus Corp, the pollucite is digested with sulfuric acid to produce cesium alum that is dissolved in an aqueous hydroxide solution to form cesium alum hydroxide and potassium sulfate. Cesium permanganate can then be directly precipitated by the addition of potassium permanganate.[10]

Alternatively, if hydrochloric acid is used in the acid digestion, permangante can be added to the resulting cesium chloride after the removal of excess iron and alumina as hydroxides. The resultant cesium permanganate can be converted to the carbonate or chloride by reduction with methanol.[11]

Rubidium

As shown in Exhibit 6, pure rubidium metal can be obtained by reducing either pollucite or lepidolite ores with an active metal. Alternatively, pure rubidium compounds can be reduced thermochemically to yield pure rubidium metal.[12]

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for the cesium recovery process within this specific mineral commodity sector, the beneficiation/processing line occurs between froth flotation and acid digestion. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where the pollucite ore undergoes a significant chemical change. For the stannic chloride precipitation process, EPA determined that the beneficiation/processing line occurs between the production of rubidium chlorostannate and pyrolysis, electrolysis,

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[10] "Cesium," 1993, Op. Cit., p. 753.

[11] Ibid., p. 754.

[12] "Rubidium," 1982, Op. Cit., p. 493.

or chemical addition. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where rubidium chlorostannate undergoes a significant chemical change to produce rubidium chloride. EPA also determined that rubidium alum extraction and rubidium recovery from alkali metals do not generate any mineral processing wastes. Also, all wastes generated during the rubidium reduction process are mineral processing wastes. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

The wastes generated during the recovery of cesium and rubidium are listed below. Waste characterization data, including information on generation rates and waste management are not available.

Cesium

Waste Gangue. Waste gangue is generated from froth flotation.
Non-Pollucite Mineral Waste

Rubidium

Alum Extraction

Calciner Residues
Spent Ore
Alkali Alums
Precipitated Aluminum
Precipitated Barium Sulfate

Stannic Chloride Precipitation

Cesium Chlorosonnate
Spent Chlorine Solution

Solvent Extraction

Spent Metal
Spent Solvent
Spent Ion-exchange solution

2. Mineral Processing Wastes

Existing data and engineering judgment suggest that the following materials do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

Acid Digestion

Digester waste

Stannic Chloride Precipitation

Pyrolytic Residue
Electrolytic Slimes
Chemical Residues

Reduction

Slag

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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U.S. Environmental Protection Agency. "Rubidium." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. Office of Solid Waste. 1988. pp. 3-179-3-186.

ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT SURFACE IMPOUNDMENT LIQUIDS - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	0.008	0.008	0.008	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.03	0.03	0.03	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT SURFACE IMPOUNDMENT SOLIDS - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	20000	20000	20000	1/1	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	20000	20000	20000	1/1	-	-	-	0/0	-	-
Lead	7500	7500	7500	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	2000	2000	2000	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	110000	110000	110000	1/1	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	33	33	33	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT AMMONIUM NITRATE PROCESSING SOLUTION - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.046	0.38	0.97	3/3	-	-	-	0/0	-	-
Antimony	0.229	10.11	20	2/2	-	-	-	0/0	-	-
Arsenic	0.0025	0.01	0.025	4/5	0.002	0.049	0.132	3/3	5.0	0
Barium	0.038	0.07	0.11	5/5	0.006	6.99	20	3/3	100.0	0
Beryllium	0.009	0.01	0.009	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.0025	0.03	0.095	4/5	0.003	0.013	0.03	3/3	1.0	0
Chromium	0.009	0.06	0.24	3/5	0.027	0.048	0.079	3/3	5.0	0
Cobalt	0.054	4.93	9.8	2/2	0.0005	0.065	0.15	2/3	-	-
Copper	0.005	0.04	0.085	2/3	-	-	-	0/0	-	-
Iron	0.053	0.05	0.053	1/1	-	-	-	0/0	-	-
Lead	0.001	0.02	0.03	4/4	0.005	0.014	0.02	2/3	5.0	0
Magnesium	0.005	56.08	221	6/6	-	-	-	0/0	-	-
Manganese	0.005	0.02	0.045	3/4	-	-	-	0/0	-	-
Mercury	0.0001	0.00	0.0005	2/3	0.0065	0.06	0.094	2/3	0.2	0
Molybdenum	-	-	-	0/0	0.009	0.07	0.124	3/3	-	-
Nickel	-	-	-	0/0	0.004	3.28	9.8	3/3	-	-
Selenium	0.0025	0.01	0.016	1/3	0.023	0.05	0.095	3/3	1.0	0
Silver	0.005	0.04	0.097	3/5	0.009	0.02	0.038	3/3	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.001	0.02	0.046	3/4	-	-	-	0/0	-	-
Cyanide	0.005	0.09	0.25	0/3	-	-	-	0/0	-	-
Sulfide	0.025	0.34	0.5	0/3	-	-	-	0/0	-	-
Sulfate	69	595	1,494	3/3	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	1,126	11,108	21,300	3/3	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	0.1	7.07	9.59	9/9					2<pH>12	1
Organics (TOC)	107.13	109.17	111.2	2/2					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PROCESS WASTEWATER - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	27.9	35.7	43.5	2/2	23.2	25.6	28	2/2	-	-
Antimony	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Arsenic	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	5.0	0
Barium	0.50	0.50	0.50	0/2	0.50	0.85	1.20	1/2	100.0	0
Beryllium	0.05	0.05	0.05	0/2	0.05	0.05	0.05	0/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.00050	0.039	0.054	1/4	0.05	0.05	0.05	0/2	1.0	0
Chromium	0.00050	0.26	0.50	1/4	0.50	0.50	0.50	0/2	5.0	0
Cobalt	0.5	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Copper	0.5	1.08	1.65	1/2	0.50	1.56	2.62	1/2	-	-
Iron	8.57	10.19	11.80	2/2	7.55	7.76	7.97	2/2	-	-
Lead	0.0005	2.50	8.45	3/4	0.63	5.31	10.0	2/2	5.0	1
Magnesium	154	2,117	4,080	2/2	1,020	4,955	8,890	2/2	-	-
Manganese	3.68	104	204	2/2	2.52	10.4	18.3	2/2	-	-
Mercury	0.00010	0.00010	0.00010	0/2	0.0001	0.0001	0.0001	0/2	0.2	0
Molybdenum	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Nickel	0.008	1.25	4.00	2/4	0.50	0.50	0.50	0/2	-	-
Selenium	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	1.0	0
Silver	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	5.0	0
Thallium	2.50	2.50	2.50	0/2	2.50	2.50	2.50	0/2	-	-
Vanadium	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Zinc	1.98	8.09	14.20	2/2	1.98	7.24	12.5	2/2	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	152	786	1,420	2/2	-	-	-	0/0	-	-
Fluoride	0.20	15.10	30.0	2/2	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	0.034	1,675	6,490	4/4	-	-	-	0/0	-	-
TSS	0.030	4,740	9,480	2/2	-	-	-	0/0	-	-
pH *	0.4	0.7475	1.1	4/4					2<pH>12	4
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT ELECTROLYTIC CELL QUENCH WATER - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.005	0.0067	0.01	3/3	-	-	-	0/0	-	-
Arsenic	0.006	0.0177	0.025	3/3	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.001	0.0010	0.001	3/3	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.001	0.0073	0.02	3/3	-	-	-	0/0	1.0	0
Chromium	0.001	0.0173	0.033	3/3	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.01	0.0230	0.033	3/3	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.14	0.2733	0.4	3/3	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0008	0.002	3/3	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.013	0.0380	0.051	3/3	-	-	-	0/0	-	-
Selenium	0.005	0.0110	0.023	3/3	-	-	-	0/0	1.0	0
Silver	0.001	0.0010	0.001	3/3	-	-	-	0/0	5.0	0
Thallium	0.001	0.0057	0.015	3/3	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.06	0.1167	0.19	3/3	-	-	-	0/0	-	-
Cyanide	0.0003	0.0075	0.022	3/3	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

CHROMIUM, FERROCHROMIUM, AND FERROCHROMIUM-SILICON

A. Commodity Summary

Chromite ore, the starting material for chromium metal, alloys, and other chromium products, is not mined in the United States.[1] The metallurgical and chemical industry consumed 93 percent of the imported chromite ore used domestically in 1994; the refractory industry consumed the remainder. The major end uses of chromium metal and ferroalloys were stainless and heat-resisting steel (78 percent), full-alloy steel (8 percent), superalloys (2 percent) and other miscellaneous uses (12 percent).[2] Exhibit 1 summarizes the producers of chromium products in 1992. Only a small amount of the chromite is processed to produce ductile chromium; the rest is used in an intermediate form.[3]

EXHIBIT 1

SUMMARY OF PRODUCERS OF CHROMIUM PRODUCTS (IN 1992)[a]

Facility Name	Location	Industry
American Chrome & Chemicals Inc.	Corpus Christi, TX	Chemical
Elkem AS, Elkem Metals Co.	Marietta, OH	Metallurgical
Elkem AS, Elkem Metals Co.	Alloy, WV	Metallurgical
General Refractories Co.	Lehi, UT	Refractory
Harbison-Walker Refractories[b]	Hammond, IN	Refractory
Macalloy Corp.	Charleston, SC	Metallurgical
National Refractories and Mining Corp.	Moss Landing, CA	Refractory
National Refractories and Mining Corp.	Columbiana, OH	Refractory
North American Refractories Co. Ltd.	Womelsdorf, PA	Refractory
Occidental Chemicals Corp.	Castle Hayne, NC	Chemical
Satra Concentrates Inc.	Steubenville, OH	Metallurgical

[a] - Papp, John. "Chromium," Minerals Yearbook Volume 1. Metals and Minerals 1992. United States Bureau of Mines. 1992. p. 355.
[b] - a division of Dresser Industries Inc.

Ferrochromium, an alloy of iron and chromium, is used as an additive in steel making. There are three major grades of ferrochromium: low carbon, high carbon, and charge grade. In the past, low carbon ferrochromium was required by steel makers to keep the carbon content of steel low. However, improved ladle refining techniques

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[1] John Papp, "Chromium," from Mineral Commodity Summaries, U.S. Bureau of Mines, 1995, p. 43.

[2] Ibid, p. 42.

[3] "Chromium and Chromium Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. VI, 1993, p. 230.

such as argon oxygen decarburization, have allowed the steel industry to use high carbon ferrochromium, which is less expensive.[4]

Ferrochromium-silicon is used in the metallurgical industry to produce stainless, alloy, and tool steels and cast irons.[5] Ferrochromium-silicon is a smelted product of chromite ore; silicon is added during the smelting process. Although a high silicon ferrochromium is sometimes produced as an intermediate in the production of low carbon ferrochromium, no ferrochromium-silicon is being produced in the United States, and it is unlikely to be produced domestically again.[6,7] Ferrochromium-silicon typically contains 34 to 42 percent chromium, 38 to 45 percent silicon and 0.05 to 0.06 percent carbon.[8]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Chromite ore is prepared for processing using several methods, depending on the ore source and the end use requirements. Course clean ore is hand sorted, while fine clean ore is gravity separated. Lumpy ore mixed with host rock may require heavy-media separation. If the chromite mineral occurs in fine grains intermixed with host rock, crushing, gravity separation and magnetic separation may be used.[9] Chromite ore is typically beneficiated before it is sold, hence many of these operations may not be conducted in the United States.[10] Exhibit 2 is a conceptual diagram of chromite ore processing. Either ferrochromium or sodium chromate is produced, and may be sold or further processed to manufacture other chromium compounds, as well as chromium metal.

2. Generalized Process Flow Diagram

Ferrochromium

Ferrochromium is made by smelting chromite ore in an electric arc furnace with flux materials (quartz, dolomite, limestone, and aluminosilicates) and a carbonaceous reductant (wood chips, coke, or charcoal.) Lumpy ore may be fed directly to the furnace, while finer ore must be agglomerated before it is added to the furnace. In efficiently operated smelters, furnace dust is collected and resmelted, and slag is crushed and processed to recover chromium. The chromium content of the ferrochromium is determined by the chromite ore's chromium to iron ratio.[11] The production of low carbon ferrochromium requires top blowing with oxygen. Aluminum, or more frequently, silicon is used as the reducing agent. Extremely low carbon ferrochromium is made by the simplex process, in which high carbon ferrochromium and oxidized ferrochromium are heated under high vacuum. The

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[4] John Papp, "Chromium," Minerals Yearbook Volume 1. Metals and Minerals 1992, U.S. Bureau of Mines, 1992, p. 325.

[5] John Papp, "Chromium," Mineral Facts and Problems, U.S. Bureau of Mines, 1985, p. 141.

[6] Personal Communication between ICF Incorporated and John Papp, U.S. Bureau of Mines, March 1994.

[7] "Chromium and Chromium Alloys," 1993, Op. Cit., p. 232.

[8] Ibid, p. 234.

[9] John Papp, 1992, Op. Cit., p. 327.

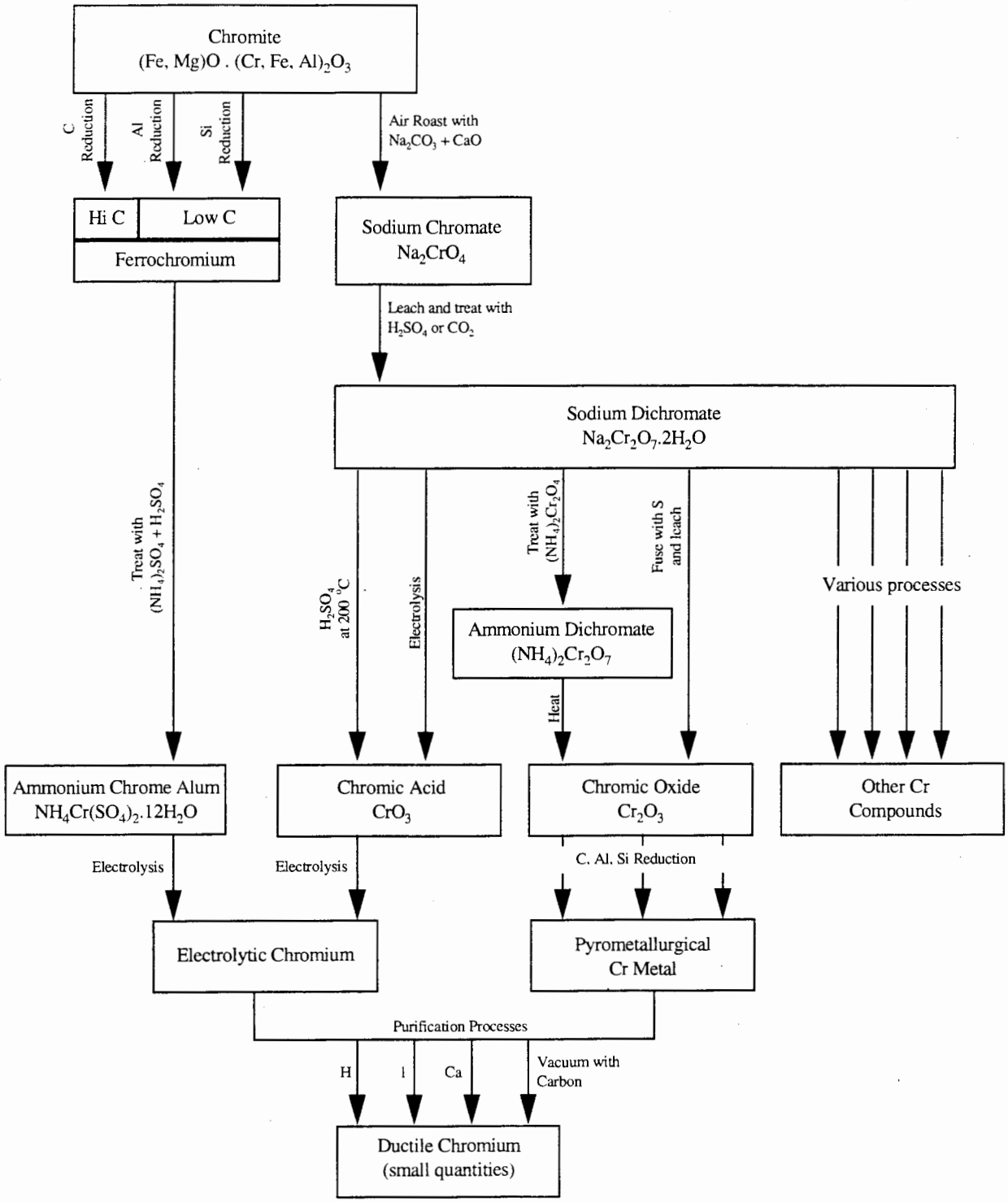
[10] John Papp, "Chromite," Industrial Minerals and Rocks, 6th Ed., Society for Mining, Metallurgy, and Exploration, 1994, p. 210.

[11] John Papp, 1992, Op. Cit., p. 328.

EXHIBIT 2

CONCEPTUAL DIAGRAM OF CHROMITE ORE PROCESSING

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1993, p. 275.)



carbon and oxygen form carbon monoxide, leaving a pure ferrochromium with a carbon content of about 0.01 weight percent.[12]

Sodium Chromate and Dichromate

Sodium chromate and dichromate are produced at two facilities by a hydrometallurgical process during which ground chrome ore and soda ash are mixed (lime and/or leached calcine are sometimes added as well), roasted in an oxidizing atmosphere, and leached with weak chromate liquor or water, as shown in Exhibit 3.[13] The resulting leach liquor is separated from the remaining leach residue. At the American Chrome and Chemicals facility, the roasting/leaching sequence is repeated, that is, two complete chromium extraction cycles are performed prior to removal of the residue. The leach residue is then treated, as discussed below. The treatment residue from this operation is classified as a RCRA special waste; it is disposed on-site at both facilities.[14] The leach solution contains unrefined sodium chromate; this liquor is neutralized and then filtered (not shown) to remove metal precipitates (primarily alumina hydrate).[15] The alumina-free sodium chromate may be marketed, but the predominant practice is to convert the chromate to the dichromate form. Occidental Chemicals Corp. uses a continuous process that involves treatment with sulfuric acid, evaporation of sodium dichromate, and precipitation of sodium sulfate (see left output stream from leaching and precipitation operation in Exhibit 3.) Sodium sulfate may be sold as a byproduct or disposed. American Chrome and Chemicals uses carbon dioxide (CO_2) to convert the chromate to dichromate (see right output stream from leaching and precipitation operation in Exhibit 3.) This process confers the advantage of not generating a sludge. The dichromate liquor may be sold as 69 percent sodium dichromate solution or returned to the evaporators, crystallized, and sold as a solid.[16]

Chromium Oxide

Sodium dichromate can be converted into both anhydrous chromic oxide and hydrated chromic oxide.[17] To produce anhydrous chromic oxide (not shown), sodium dichromate, sulfur and wheat flour are blended with water, and the resultant slurry is heated in a kiln. The material recovered from the kiln is slurried with water, filtered, washed, dried, ground to size, screened and packaged. To produce hydrated chromic oxide (not shown), sodium dichromate solution and boric acid are blended and heated in a kiln. The reacted material is slurried with water and washed. Most of the washwater from the process is treated with sulfuric acid to recover boric acid. A waste stream containing boric acid and sodium sulfate leave the boric acid recovery unit. The product with some of the final washwater is filtered, rewashed, dried, ground, screened and packaged.[18]

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[12] "Chromium and Chromium Alloys," 1993, Op. Cit., p. 232.

[13] Ibid., p. 275.

[14] American Chrome and Chemicals and Occidental Chemical, 1989. Company Responses to the "National Survey of Solid Wastes from Mineral Processing Facilities", U.S. EPA, 1989.

[15] Marks, et al., editors, Encyclopedia of Chemical Technology, Wiley Interscience, New York, NY, 1978, pp. 93-94.

[16] U.S. Environmental Protection Agency, Report to Congress on Special Wastes from Mineral Processing, Volume II, Office of Solid Waste, July 1990, p. 4-2.

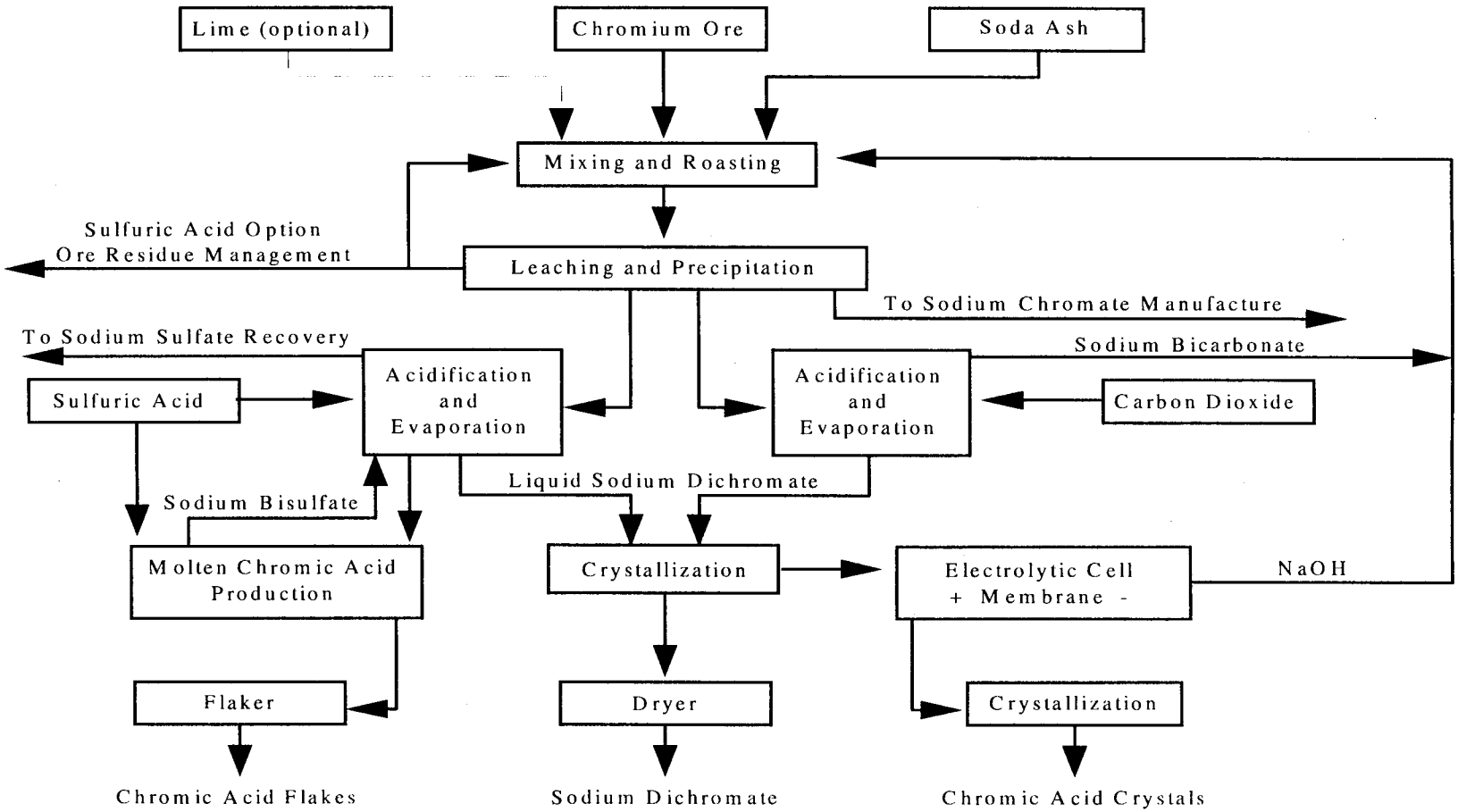
[17] Processing of either form of chromic oxide, as well as chromium metal are not primary mineral processing, and are therefore outside the scope of this report. Brief descriptions of these processes have been included for completeness.

[18] Versar, Inc., Multi-Media Assessment of the Inorganic Chemicals Industry, Vol. II, Prepared for U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, August 1980, pp. 3-13 - 3-16.

EXHIBIT 3

SODIUM CHROMATE AND SODIUM DICHROMATE PRODUCTION

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1993, p. 275.)



Chromium Metal

Chromium metal can be made either pyrometallurgically or electrolytically. In the pyrometallurgical method (not shown), chromium oxide (Cr_2O_3) reacts with aluminum powder in a refractory lined vessel after being ignited with barium peroxide and magnesium powder. Chromium metal may also be made from the oxide by reduction with silicon in an electric arc furnace. The chromium from this process is similar to that obtained by the aluminothermic process, except the aluminum content is lower and the silicon content may approach 0.8 percent. Chromium may also be made by reducing chromium oxide briquets with carbon at low pressure and temperatures of 1,275 to 1,400°C.[19]

Exhibit 4 shows the production of electrolytic chromium by the chrome alum process conducted at the Elkem Metals Company's Marietta Plant. High carbon ferrochromium is ground and leached with a hot solution of reduced anolyte, chrome alum mother liquor, and makeup sulfuric acid. Cold mother liquor is added, and the slurry is filtered to remove the undissolved solids, which are mostly silica. The filtrate is conditioned at elevated temperature for several hours to convert the chromium to the non-alum form. The filtrate is then cooled to 5°C, allowing a crude ammonium sulfate to crystallize. This iron salt is further treated to form technical ferrous ammonium sulfate, which can be sold as fertilizer and other purposes. The filtrate is clarified and aged, allowing ammonium chrome alum to precipitate. The slurry is filtered, and the chrome alum is dissolved in hot water. The chrome alum solution is clarified and fed to the electrolysis cell. After the electrolysis is complete, the cathodes are removed, washed, and the metal is removed by air hammers. The metal is crushed, washed, and dehydrogenated.[20]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Research is being conducted to investigate the feasibility of using plasma smelting both worldwide, as a more efficient way of processing ferrochromium, and in the United States, to utilize low quality chromium bearing ores.[21]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value typically does not occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

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[19] "Chromium and Chromium Alloys," 1993, Op. Cit., pp. 232-234.

[20] Ibid., pp. 234-236.

[21] J.E. Goodwill, "Developing Plasma Applications for Metal Production in the USA," Iron and Steelmaking, 17, No. 5, 1990, p. 352.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in Section B.

Ferrochromium and Ferrochromium-Silicon

EPA determined that for ferrochromium and ferrochromium-silicon, mineral processing first occurs when the chromite ore undergoes smelting in an electric arc furnace and the physical/chemical structure of the chromite ore is significantly altered. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Sodium Chromate/Dichromate

EPA determined that for sodium chromate/dichromate, mineral processing occurs at the "leaching" sequence of the process because the ore is vigorously attacked (digested) with a concentrated acid to significantly change the physical structure of the ore. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Chromium Oxide

Since chromium oxide is produced from sodium dichromate, all of the wastes generated during chromium oxide production are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, please see the sodium chromate/dichromate section above.

Chromium Metal

Since chromium metal is produced from either ferrochromium or chromium oxide, all of the wastes generated during chromium oxide production are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, please see the ferrochromium and chromium oxide sections above.

C. Process Waste Streams

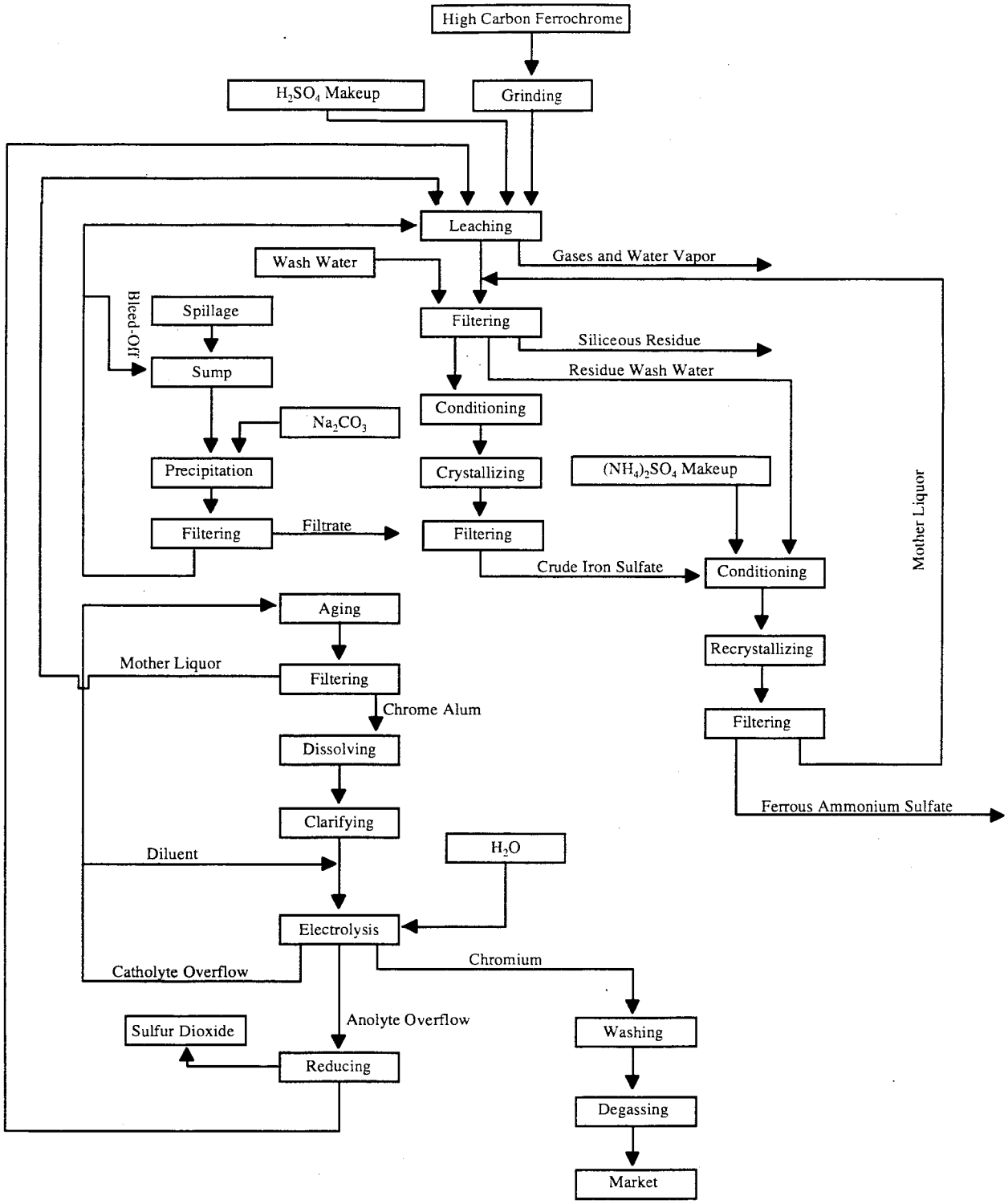
1. Extraction and Beneficiation Wastes

Wastes from the extraction and beneficiation of chromite may include gangue, and tailings. No information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

EXHIBIT 4

ELECTROLYTIC CHROMIUM METAL PRODUCTION

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1993, p. 235.)



2. Mineral Processing Wastes

The following waste streams have been associated with the production of sodium dichromate, ferrochromium, and ferrochromium-silicon.

Ferrochromium

Dust or Sludge was a listed hazardous waste (K091) that has been remanded. EPA has decided not to "re-list" this waste. Data from the Newly Identified Mineral Processing Waste Characterization Data Set indicate the presence of chromium and selenium above toxicity characteristic levels for the remanded electrostatic precipitator (ESP) dust. This waste is thus considered to be a characteristic hazardous waste under RCRA Subtitle C. At the present time, there is only one generator of this characteristic D007 waste.[22] The generator treats the material by adding ferrous sulfate to reduce the leachable level of chromium to below regulatory levels. The non-hazardous ESP dust is either disposed of in an off-site sanitary landfill or is used as a binding agent in Macalloy's briquetting process. This facility reported producing approximately 3,000 metric tons of ESP dust annually. [23]

This facility also produces gas conditioning tower sludge (or GCT sludge) that it recycles back to the electric arc furnace. The commenter stated that this sludge usually does not exhibit the toxicity characteristic for chromium. Although no information was available on the generation rate of this waste, EPA estimated a low, medium, and high annual waste generation rate of 30, 300, and 3,000 metric tons/yr, respectively. The GCT sludge is fully recycled. This material formerly was classified as a sludge.

Slag and Residues. According to the Newly Identified Mineral Processing Waste Characterization Data Set, approximately 47,000 metric tons of slag and residue are produced annually in the United States, and the available data do not indicate that the waste is hazardous.[24]

Sodium Dichromate Production

Treated roast/leach residue is classified as a RCRA special waste. We note, however, that prior to treatment, the roast/leach residue is not a RCRA special waste. Treatment of the leach residue consists of treating the residue slurry with either a ferrous or sulfide ion to reduce hexavalent chromium followed by treatment with sulfuric acid to lower the pH level. American Chrome and Chemicals pumps the leach residue directly to a dedicated treatment unit, in which sulfuric acid and sodium sulfide are used to induce the desired chemical changes in the residue, while at Occidental Chemicals Corp., the untreated residue is pumped to a wastewater treatment plant which receives, and apparently combines, several other influent streams prior to treatment with several different chemical agents. At both plants, the treated residue is pumped in slurry form to disposal surface impoundments.[25]

The treated residue from roasting/leaching of chrome ore, is a solid material, though it typically is generated as a slurry containing particles between 2 mm and about 0.08 meters (3 inches) in diameter. The treated roast/leach

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[22] The Ferroalloys Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[23] Nexsen, Pruet, Jacobs & Pollard, LLP (Counsel to Macalloy Corporation). Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. May 12, 1997.

[24] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Vol. I, Office of Solid Waste, August 1992, p. I-3.

[25] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 4-2.

residue is composed primarily of metallic oxides, such as those of iron, aluminum, silicon, magnesium, and chromium, as well as sulfates.[26] Using the available data on the composition of treated roast/leach residue, EPA evaluated whether the residue exhibited any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. The limited available data indicated that the waste did not exhibit any of the four hazardous waste characteristics.

According to the Newly Identified Mineral Processing Waste Characterization Data Set, approximately 102,000 metric tons of treated leach residue are produced annually in the United States.[27]

Ferrochromium-silicon

Dust or Sludge was a listed hazardous waste that has been remanded.[28] EPA has decided not to re-list this waste. According to the Newly Identified Mineral Processing Waste Characterization Data Set, there is presently no domestic production of ferrochromium-silicon. Additional data is provided in Attachment 1.

D. Non-uniquely Associated Wastes

There are no non-uniquely associated wastes in this specific sector. However, standard ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

Two commenters provided new factual information that has been included in the sector report (COMM 3, COMM 48). Macalloy Corporation also provided comments on the May 1997 Second Supplemental Proposed Rule. These comments also have been captured in the sector report.

Sector-specific Issues

One commenter indicated that it was encouraged to learn that the effort to obtain a chromium listing as K091 would be eliminated. However, the commented believes that EPA's Proposed Rule circumvents the remanding by Federal Court by calling the waste a so-called "newly identified" mineral processing waste, subject to the even more stringent UTS criteria. The commenter believes that EPA has ignored the wishes of the courts and has yielded to groups that desire only tougher regulations, apparently just for the sake of more regulation.[29] EPA does not agree that it is yielding to any influences and reaffirms that any solid waste that possesses one or more of the TCLP characteristics is indeed a hazardous waste that must be regulated under Subtitle C of RCRA.

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[26] Occidental Chemical Corp., Company Responses to the "National Survey of Solid Wastes from Mineral Processing Facilities", U.S. EPA, 1989.

[27] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Vol. I, Office of Solid Waste, August 1992, p. I-3.

[28] Ibid.

[29] Macalloy Corporation. Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. May 12, 1997.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - DUST OR SLUDGE - FERROCHROME - SILICON

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	12,100	12,100	12,100	1/1	1.39	1.39	1.39	1/1	-	-
Antimony	0.60	0.60	0.60	0/1	0.023	0.023	0.023	1/1	-	-
Arsenic	50.00	50.00	50.00	0/1	0.40	0.40	0.40	0/1	5.0	0
Barium	138	138	138	1/1	0.60	0.60	0.60	1/1	100.0	0
Beryllium	0.52	0.52	0.52	1/1	0.00050	0.00050	0.00050	0/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.15	0.15	0.15	0/1	0.0015	0.0015	0.0015	0/1	1.0	0
Chromium	41.00	801	1,560	2/2	2.07	12.69	27.00	3/3	5.0	2
Cobalt	1.00	1.00	1.00	1/1	0.0015	0.0015	0.0015	0/1	-	-
Copper	3.50	3.50	3.50	1/1	0.0015	0.0015	0.0015	0/1	-	-
Iron	1,270	1,270	1,270	1/1	0.0020	0.0020	0.0020	0/1	-	-
Lead	273	273	273	1/1	0.0010	0.02	0.03	2/2	5.0	0
Magnesium	121,000	121,000	121,000	1/1	954	954	954	1/1	-	-
Manganese	1,510	1,510	1,510	1/1	5.08	5.08	5.08	1/1	-	-
Mercury	0.049	0.049	0.049	0/1	0.00010	0.00010	0.00010	0/1	0.2	0
Molybdenum	0.145	0.145	0.145	0/1	0.0082	0.0082	0.0082	1/1	-	-
Nickel	16.20	16.20	16.20	1/1	0.033	0.033	0.033	1/1	-	-
Selenium	5.50	5.50	5.50	1/1	0.069	0.069	0.069	1/1	1.0	0
Silver	0.15	0.15	0.15	0/1	0.0015	0.0015	0.0015	0/1	5.0	0
Thallium	23.90	23.90	23.90	1/1	0.029	0.029	0.029	0/1	-	-
Vanadium	1.50	1.50	1.50	1/1	0.011	0.011	0.011	1/1	-	-
Zinc	3,270	3,270	3,270	1/1	1.63	1.63	1.63	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - DUST OR SLUDGE - FERROCHROME

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	28,100	29,200	30,300	2/2	0.017	0.068	0.12	2/2	-	-
Antimony	3.85	11.43	19.00	1/2	0.039	0.047	0.055	2/2	-	-
Arsenic	2.65	2.85	3.05	0/2	0.006	0.014	0.040	1/4	5.0	0
Barium	75.60	76.00	76.40	2/2	0.083	0.575	1.60	4/4	100.0	0
Beryllium	0.66	1.33	2.00	2/2	0.00050	0.00050	0.00050	0/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.70	0.78	0.85	0/2	0.0015	0.0027	0.0050	0/3	1.0	0
Chromium	3,390	5,360	6,470	3/3	0.010	17.99	63.20	18/21	5.0	12
Cobalt	9.20	9.20	9.20	1/1	0.00150	0.00150	0.00150	0/2	-	-
Copper	9.20	24.35	39.50	2/2	0.0020	0.0020	0.0020	0/2	-	-
Iron	6,240	15,170	24,100	2/2	0.0020	0.0020	0.0020	0/2	-	-
Lead	300	1,290	1,860	3/3	0.0050	0.57	4.73	10/17	5.0	0
Magnesium	188,000	188,500	189,000	2/2	409	880	1,350	2/2	-	-
Manganese	5,750	5,770	5,790	2/2	0.013	0.72	1.43	2/2	-	-
Mercury	0.26	0.32	0.38	1/2	0.00010	0.00053	0.00100	0/3	0.2	0
Molybdenum	3.20	3.75	4.30	2/2	0.022	0.037	0.052	2/2	-	-
Nickel	128	130	131	2/2	0.003	0.006	0.009	1/2	-	-
Selenium	37.00	42.90	48.80	2/2	0.02	22.79	68.20	2/3	1.0	1
Silver	5.60	5.95	6.30	2/2	0.0020	0.0050	0.010	2/4	5.0	0
Thallium	27.10	130	232	2/2	0.066	0.077	0.088	2/2	-	-
Vanadium	17.70	19.35	21.00	2/2	0.0015	0.0025	0.0035	1/2	-	-
Zinc	13,600	14,300	15,000	2/2	0.0010	0.0015	0.0020	1/2	-	-
Cyanide	0.59	0.59	0.59	1/1	-	-	-	0/0	-	-
Sulfide	5.05	5.05	5.05	0/1	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	485	485	485	1/1	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

COAL GAS

A. Commodity Summary

In 1992, more than 997,545,000 short tons of coal were produced by 2,746 mines located in the United States.[1] Coal is classified into four general categories: bituminous, subbituminous, lignite, and anthracite coal. Nearly all coal is used in combustion or coking. At least 80 percent is burned directly in boilers for generation of electricity or steam. Small amounts are used for transportation, space heating, and firing of ceramic products. The rest is essentially pyrolyzed to produce coke, coal gas, ammonia, coal tar, and light oil products from which many chemicals are produced. Combustible gases and chemical intermediates are also produced by the gasification of coal, and different carbon products are produced by various heat treatments. A small amount of coal is used in miscellaneous applications such as fillers, pigments, foundry material, and water filtration.[2]

Coal gasification produces a synthetic gas that is either further processed and sold as synthetic natural gas or used to fire a gas turbine, generating electricity in an integrated gasification combined cycle (IGCC) system. As shown in Exhibit 1, there is only one commercial scale synthetic gas producer, and two commercial scale IGCC plants.[3] The Tennessee Eastman facility is used in the production of acetic anhydride. There are also several demonstration scale projects funded, at least in part, by the U.S. Department of Energy's Clean Coal Technology (CCT) program, including two coal preparation technologies, one mild gasification project, and one indirect liquefaction project, as well as six IGCC systems.[4] Exhibit 2 lists the Clean Coal Projects, their sponsors, locations, types of technology, and status. In addition to the CCT demonstration projects, there may be other planned or operating private demonstration scale projects. The profitability of existing facilities and the potential for the opening of new plants will be affected by the prices of traditional fuel sources such as oil and gas.

EXHIBIT 1

SUMMARY OF COMMERCIAL COAL GASIFICATION FACILITIES

Facility Name	Location	Type of Process
Great Plains Coal Gasification Plant, Dakota Gasification Co.[a]	Beulah, ND	Synthetic Gas
Louisiana Gasification Technology, Inc.[a]	Placamine, LA	IGCC
Tennessee Eastman[b]	NA	IGCC

[a] - U.S. EPA, Report to Congress on Special Wastes from Mineral Processing, July 1990, p. 5-1.
[b] - "Coal Conversion Processes (Gasification)," Kirk-Othmer Encyclopedia of Chemical Technology, Vol 6. 4th. ed. 1993. pp. 543.

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[1] U.S. Department of Energy, Coal Production 1992, Energy Information Administration, October 1993, p. 18.

[2] "Coal," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol VI, 1993, p. 424.

[3] A fourth subsidized commercial scale facility (Cool Water) operated from 1982 to 1988 in Daggett, California. This facility shut down after the Department of Energy funding ended.

[4] U.S. Department of Energy, Clean Coal Technology Demonstration Program: Program Update 1993," December 31, 1993, pp. 7-2 - 7-3.

EXHIBIT 2

SUMMARY OF CLEAN COAL TECHNOLOGY DEMONSTRATION PROJECTS[a]

Project Name	Sponsor	Location	Technology	Project Stage
Self-Scrubbing Coal: An Integrated Approach to Clean Air	Custom Coals International	Central City, PA	Coal Preparation	Design/ Permitting
Advanced Coal Conversion Process Demonstration	Rosebud SynCoal Partnership	Colstrip, MT	Coal Preparation	Operating
ENCOAL Mild Coal Gasification Project	ENCOAL Corporation	Near Gillette, WY	Mild gasification	Operating
Commercial Scale Demonstration of the Liquid-Phase Methanol (LPMEOH) Process	Air Products and Chemicals, Inc.	Kingsport, TN	Indirect Liquefaction	Project Definition
Combustion Engineering IGCC Repowering Project	ABB Combustion Engineering, Inc.	Springfield, IL	IGCC	Assessing Project Options
Camden Clean Energy Demonstration Project	Duke Energy Corp.	Camden, NJ	IGCC	Negotiating Cooperative Agreement
Pinon Pine IGCC Power Project	Sierra Pacific Power Company	Reno, NV	IGCC	Design
Toms Creek IGCC Demonstration Project	TAMCO Power Partners	Coeburn, VA	IGCC	Project Definition
Tampa Electric Integrated Gasification Combined Cycle Project	Tampa Electric Company	Lakeland, FL	IGCC	Design/ Permitting
Wabash River Coal Gasification Repowering Project	Wabash River Coal Gasification Repowering Project Joint Venture	West Terre Haute, IN	IGCC	Construction

[a] - U.S. Department of Energy, "Clean Coal Technology Demonstration Program: Program Update 1993," December 31, 1993, pp. 6-22, 6-23, & 6-27.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Coal gasification is essentially incomplete combustion of coal, producing a product gas and heat instead of carbon dioxide and heat. In combustion, oxygen in stoichiometric excess reacts with the combustible matter in coal, mostly carbon and hydrogen, to produce heat, the primary product of interest, as well as carbon dioxide and water. Gasification involves the incomplete combustion of coal in the presence of steam. Only 20-30 percent of the oxygen theoretically required for complete combustion to carbon dioxide and water is used; therefore, only a fraction of the carbon in the coal is oxidized completely to carbon dioxide, the rest forms a mixture of gases including carbon

monoxide, methane, hydrogen and hydrogen sulfide. The heat released by the partial combustion provides the bulk of the energy necessary to drive the gasification reactions.[5,6] When synthetic gas is produced as a product, lignite coal is sized, and gasified with steam and oxygen producing raw gas, ash, and gasifier liquor. The gas is cooled, purified in several steps, and sold. This process is described in greater detail below.

2. Generalized Process Flow Diagram

There is currently one facility, the Great Plains Coal Gasification Plant, which produces synthetic natural gas on a commercial scale. Exhibit 3 illustrates the production of synthetic natural gas at this facility. The facility employs 12 Lurgi Mark IV high pressure coal gasifiers, with two gasifiers on standby for spare capacity. Exhibit 4 is a schematic diagram of a Lurgi Mark IV Gasifier. Lignite coal, which is taken from four mines that are co-located with the facility, is crushed and fed to the top of individual gasifiers through a lock-hopper system; steam and compressed oxygen are introduced at the bottom of each gasifier.[7] The steam and oxygen travel up through the coal/ash bed. As steam and oxygen contact the coal in the gasifier, the resulting combustion reactions produce two major gases, carbon dioxide and carbon monoxide. The further reaction of these gases with carbon and steam results in "gasification," the formation of carbon oxides, methane, and hydrogen.[8]

After gasification occurs, excess carbon remains in the form of "char." The char is combusted in a high-temperature exothermic (heat releasing) reaction to provide energy for a series of reactions, including drying, devolatization, and gasification, most, but not all, of which are endothermic (heat using) reactions. The char is then converted to energy in the "combustion zone," roughly the middle of the gasifier. The residue of this combustion is the gasifier ash. The gases formed in these reactions rise to the top of the unit, where their heat dries and drives off volatiles liberated from the coal that has just entered the gasifier.[9] Because not all of the flue gas constituents are converted in the gasification process, the exiting gas stream contains both flue gas and product gas. These two gaseous streams are separated downstream of the gasifiers and the product gas is converted to salable methane.[10]

The ash remaining in the bed after the reaction is removed by a rotating grate at the bottom of the gasifier and is discharged through a gas lock. The ash is discharged into an enclosed ash sluiceway, where recirculating ash sluice water is introduced to cool the ash and transport it to the ash handling and disposal area. The hot crude product gas leaving the gasifiers goes through several operations, including quenching (to cool and clean), shift conversion (to alter the ratio of hydrogen to carbon monoxide), further cooling of the gas, and processing through the Rectisol unit (to remove sulfur compounds and carbon dioxide). The desulfurized crude gas is sent to the methanation unit; the product gas is then compressed and dried for delivery to a pipeline for distribution.[11]

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[5] "Coal Conversion Processes (Gasification)," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. VI, 1993, p. 551.

[6] "Steam," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXI, 1983, pp. 543-544.

[7] CDM Federal Programs Corporation, Draft Report American Natural Gas Special Study, Prepared for U.S. Environmental Protection Agency, Office of Waste Programs Enforcement, March 19, 1987, pp. 14-27.

[8] Dakota Gasification Company, "Letter to Mr. Robert Tonetti and Mr. Bob Hall, Office of Solid Waste, U.S. EPA", August 12, 1991, p. 5.

[9] Ibid.

[10] Dakota Gasification Company, "Lurgi Gasification and Flue Gas Scrubbing Simplified," Memorandum to D. W. Peightal from T. G. Towers, July 29, 1991.

[11] CDM Federal Programs Corporation, 1987, Op. Cit., pp. 14-27.

EXHIBIT 3

PROCESS FLOW DIAGRAM OF SYNTHETIC GAS PRODUCTION

(Adapted from: RTI Survey 100065, 1989)

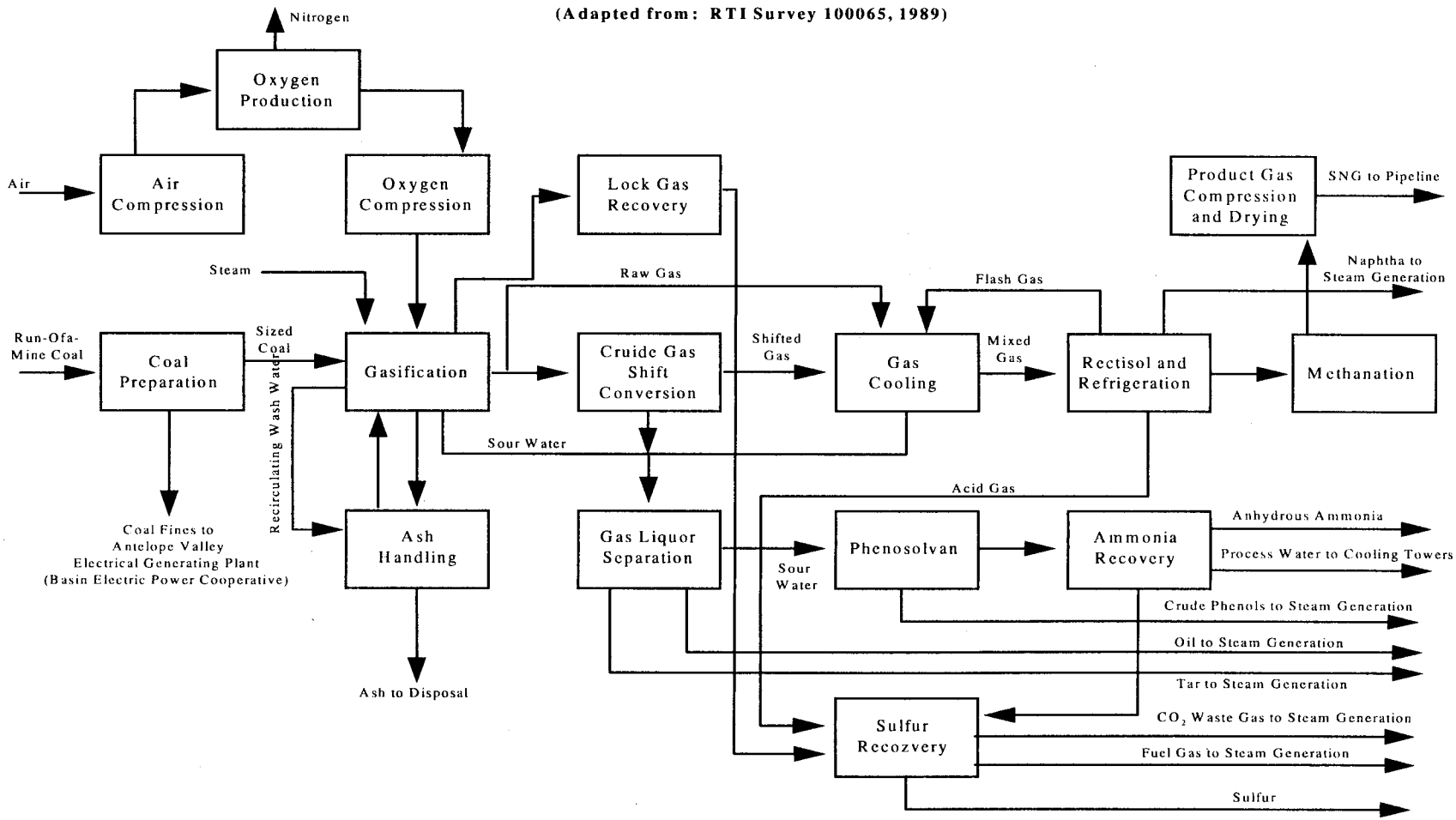
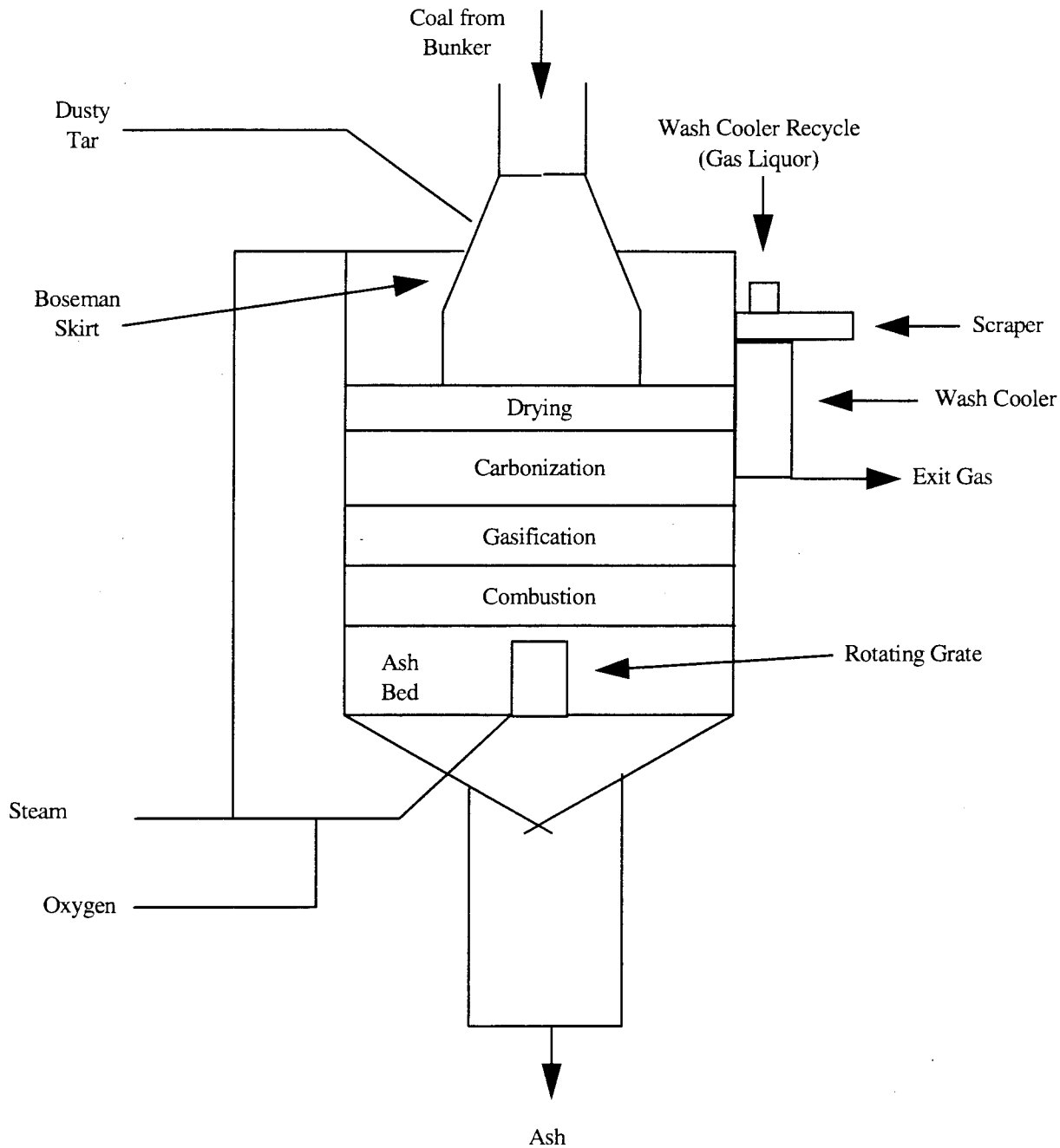


EXHIBIT 4

SCHEMATIC DIAGRAM OF LURGI MARK IV GASIFIER

(Adapted from: Dakota Gasification Company, July 29, 1991.)



The quenching operation described above, in addition to cooling the raw gas, serves to remove entrained particles from the gas and to condense and remove unreacted steam, organic compounds, and soluble gases. This cooling operation generates an aqueous stream known as quench liquor (labelled "sourwater" in Exhibit 3). This quench liquor, along with similar streams from the shift conversion, gas cooling, and rectisol units, are sent to the gas liquor separation unit (for removal of tar and oil), to a phenosolvan unit (for phenol recovery), and to a phosam-W ammonia recovery unit (for ammonia recovery). The process water leaving the phosam-W unit, known as stripped gas liquor, is classified as a RCRA special waste.

This process wastewater is used as makeup water for a water cooling system that is needed to cool the gasifiers during operation. The hot water is routed to a cooling tower used to remove heat from the system. Evaporation from the cooling tower exceeds the quantity of stripped gas liquor generated on an annual basis; hence, all stripped gas liquor is used as makeup water. The stripped gas liquor passes through the cooling tower (not shown) where it is concentrated, reducing the volume by a factor of ten, and through the Multiple Effects Evaporator (not shown) where it is concentrated again, further reducing the volume by a factor of ten. This concentrate then goes to the Liquid Waste Incinerator (LWI) for incineration. The blowdown water from the LWI is used as makeup water to the ash sluice system.[12,13]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

In an IGCC unit, oxygen, pulverized coal, and sometimes steam are gasified, and the syngas is cooled, cleaned and combusted to power a gas turbine, to generate electricity. Excess heat is also recovered to generate electricity using a steam turbine. IGCC, coking, and pyrolysis are considered to be energy producing operations rather than mineral processing, and are therefore outside the scope of this report.

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

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[12] North Dakota State Department of Health, Letter to Robert L. Duprey, Director, Waste Management Division, EPA, June 10, 1986. p. 1.

[13] CDM Federal Programs Corporation, 1987, Op. Cit., pp. 41-42.

EPA determined that for the production of coal gas, the beneficiation/processing line occurs between coal preparation and coal gasification due to the chemical reaction that occurs between oxygen, steam, and coal within the gasification unit that significantly changes the physical/chemical structure of coal. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction and Beneficiation Wastes

Wastes from the extraction and beneficiation of coal may include gangue, fines, baghouse coal dust, and coal pile runoff. Run-of-mine lignite from neighboring mines is crushed to less than 2 inches. Fines are removed by screening and are sent to an adjacent power plant. Baghouses collect the dust from crushing, conveying, sizing, and storage operations. Coal dust collected in the baghouses is returned to the process. Coal pile runoff is handled by the plant's storm drainage system, which includes a coal pile runoff retention pond. This pond provides sufficient retention time to permit coal particles, soil sediments, and dust suspended in the stormwater to settle out. The clarified water from the pond is discharged to the stormwater pond through an overflow weir.[14]

2. Mineral Processing Wastes

Gasifier Ash is classified as a RCRA special waste. This ash is removed from the bottom of the gasifier, quenched, passed through crushers to reduce the maximum size to eight centimeters, and sluiced into ash sumps for settling and dewatering. The dewatered ash is trucked to an on-site clay-lined landfill, where it is disposed of along with ash from boilers, superheaters, and incinerators, and settled solids from process water management units (e.g., impoundments, API separators.)[15] The North Dakota Department of Health reported that the Beulah facility had considerable problems with their dewatering system which resulted in the disposal of large quantities of very wet ash.[16] According to the Newly Identified Mineral Processing Waste Characterization Data Set, approximately 301,000 metric tons of gasifier ash are produced annually in the United States.[17]

Process Wastewater is classified as a RCRA special waste.[18] According to the Newly Identified Mineral Processing Waste Characterization Data Set, approximately 5,143,000 metric tons of process wastewater are produced annually in the United States.[19] The management of the process wastewater (i.e., stripped gas liquor) is reuse; the water is used as make-up water for the water-cooling system that cools the gasifiers. Specifically, the process wastewater is routed from the cooling tower to the multiple effect evaporators, to the liquid waste incinerator, and finally to the gasifier ash handling system.

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[14] Ibid., pp. 63-64.

[15] U.S. Environmental Protection Agency, Report to Congress on Special Wastes from Mineral Processing, Volume II, Office of Solid Waste, July 1990, p. 5-3.

[16] North Dakota State Department of Health, 1986, Op. Cit., pp. 1-2.

[17] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Vol. I, Office of Solid Waste, August 1992, p. I-3.

[18] U.S. Environmental Protection Agency, 1990, Op.Cit., p. 5-3.

[19] U.S. Environmental Protection Agency, 1992, Op.Cit., p. I-3.

Surface Impoundment Solids (Cooling Tower Pond Sludge). When the supply of process wastewater generated on a daily basis exceeds the need for cooling system make-up water, the process wastewater is stored in an impoundment until it is needed. No long-term accumulation of waste occurs in this unit; the water is pumped to the cooling tower and any settled solids are dredged (approximately 13 metric tons in 1988) and sent to the solid waste disposal landfill.[20] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Zeolite Softening PWW. Available data do not indicate that the waste exhibits hazardous characteristics.[21] Therefore, the Agency did not evaluate this material further.

Cooling Tower Blowdown. Evaporation of water inside the cooling water system increases the concentration of any impurities in the make-up water remaining in the cooling system; these impurities can lead to scaling or other operational problems in the system. Therefore, the cooling water in the system is bled off at a rate of 360-500 gpm to prevent concentrations of impurities from reaching unacceptable levels. This concentrated bleed, known as cooling tower blowdown, was generated at a rate of approximately 766,000 metric tons in 1988. The cooling tower blowdown is treated in a multiple effects evaporator (MEE) unit.[22]

According to the Newly Identified Mineral Processing Waste Characterization Data Set, approximately 646,000 metric tons of cooling tower blowdown are produced annually in the United States.[23] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Multiple Effects Evaporator Concentrate. Cooling tower blowdown is treated in a multiple effects evaporator (MEE) unit. Distillate from this treatment is returned to the cooling system or used as other facility utility water. The remaining residual, MEE concentrate, is returned as feed to the gasifier or is sent to an on-site liquid waste incinerator (LWI). Separate surge ponds are used for storage of MEE distillate and concentrate.[24] MEE concentrate has been found to exhibit the characteristic of EP toxicity for arsenic and selenium. The arsenic levels range from 3-29 ppm and the selenium levels from 15-44 ppm.[25] This waste stream is partially recycled and classified as a by-product. Although no published information regarding the waste generation rate was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 0 metric tons/yr, and 65,000 metric tons/yr, respectively.

Multiple Effects Evaporator Pond Sludge. Approximately 100 cubic yards of MEE pond sludge are generated annually in the United States.[26] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Liquid Waste Incinerator Blowdown. Spent cooling water from the LWI unit, referred to as LWI blowdown, is sent to the coal ash sluice area to be included as make-up water for ash handling. Any incinerator

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[20] U.S. Environmental Protection Agency, 1990, Op.Cit., p. 5-3.

[21] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[22] U.S. Environmental Protection Agency, 1990, Op.Cit., p. 5-4.

[23] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[24] U.S. Environmental Protection Agency, 1990. Op. Cit., p. 5-4.

[25] North Dakota State Department of Health, 1986, Op. Cit., p. 1.

[26] Versar, Inc. Draft Site Visit Report on Dakota Gasification Company, Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, August 4, 1989. p. 3.

ash/solids in the blowdown are, therefore, combined with the gasifier ash and managed as such.[27] LWI blowdown was found to exhibit the characteristic of EP toxicity for arsenic and selenium. The arsenic levels range from 6-16 ppm and the selenium levels from 7-54 ppm.[28] Although no published information regarding the waste generation rate was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 0 metric tons/yr, and 45,000 metric tons/yr, respectively. LWI blowdown is recycled in process, therefore, it is not included in the analysis.

Liquid Waste Incinerator Pond Sludge. Approximately 300 cubic yards of liquid waste incinerator pond sludge are generated annually in the United States.[29] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent Methanol Catalyst. The methanation unit uses a nickel catalyst to upgrade the synthetic gas to methane. The spent catalyst is recycled.[30] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 5,000 metric tons/yr, and 45,000 metric tons/yr, respectively. This waste stream is not hazardous, therefore, it is not included in the analysis.

Stretford Solution Purge Stream. The Stretford process uses a dilute solution of sodium carbonate, sodium bicarbonate, sodium metavanadate, and anthraquinone disulfonic acid (ADA) to remove hydrogen sulfide from a number of gas streams and convert it to elemental sulfur. After hydrogen sulfide removal, the treated gas stream is incinerated in the boilers for its fuel value. The Stretford solution purge stream contains vanadium salts, thiosulfate, thiocyanate, and ADA. The purge stream is collected in a wastewater tank, concentrated in a crystallizer, and subsequently disposed of as a liquid. This liquid crystallizes into a solid during cooling after it is transported to a secure disposal site. The liquid removed during concentration is used as cooling tower makeup water.[31] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 5,000 metric tons/yr, 17,000 metric tons/yr, and 45,000 metric tons/yr, respectively. This waste stream is not hazardous, therefore, it is not included in the analysis.

Flue Dust Residues. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Oily Water Treatment System

Oily water from all paved process areas drain to the oily water sewer. In addition, contaminated stormwater and other contaminated waters may be diverted to the oily water sewer, which drains into the oily water treatment system. This treatment system is intended to process contaminated water streams from the plant by reducing the oil content from between 10 and 100 ppm free oils to less then 5 ppm free oils. The system consists of American Petroleum Institute (API) separators, dissolved air flotation units, vacuum filtration of sludges and froths, and pressure media filtration. Effluent from this system is discharged to the cooling tower.

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[27] As reported by Dakota Gasification Company, approximately 32,000 metric tons of LWI blowdown was generated in 1988 with a solids content of 5 percent; these approximately 1,600 metric tons of solids are assumed to be included in the total volume of gasifier ash reported by the company.

[28] North Dakota State Department of Health, 1986, Op. Cit., p. 1.

[29] Versar, Inc., 1989, Op. Cit., p. 3.

[30] CDM Federal Programs Corporation, 1987, Op. Cit., p. 6.

[31] Ibid., pp. 52-58.

The oily water is pumped to two API separators in parallel. Oils are skimmed off and sent to the slop oil decanting tanks, while sludge is scraped off the bottom and transferred to the froth sump. The slop oil is used as fuel for the boilers. Effluent from the API separators is transferred to the dissolved air flotation units where air, coagulant aid, and caustic or acid are added to assist in removing any remaining oils. Under some plant operating conditions, this API separator effluent is routed to cooling tower surge ponds following treatment.

Oils from the top and sludges from the bottom of the DAF unit are transferred to the froth sump. DAF effluent is passed through sand filters before it is used as cooling tower makeup water. The API/DAF sludge in the froth sump is sent to the vacuum precoat drum filter. This equipment is operated only when sufficient quantities of sludge have accumulated. The filter cake is collected in hoppers for off-site disposal and the filtrate is returned to the oily water sewer.[32]

API Water. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

API Oil/Water Separator Sludge. Approximately 1,500 cubic yards of API oil/water separator sludge are generated annually in the United States.[33] These sludges are disposed of off-site.[34] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Dissolved Air Flotation Sludge. Approximately 2,688 cubic yards of dissolved air flotation sludge are generated annually in the United States.[35] The DAF sludges are disposed of with the gasifier ash.[36] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Sludge and Filter Cake. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Vacuum Filter Sludge. The vacuum filter sludge is generated intermittently. This stream is disposed of with the ash in the plant's ash handling system.[37] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated by cleaning operations that generate up to 3,350 gallons of spent solvents each year; laboratory services that may generate 1,800 gallons of hazardous waste (F002, F003, F004, and D002) each year; and container storage, which could generate hazardous wastes from spills, and the associated clean up activities. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil (which has been analyzed and found to be non-hazardous).[38]

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[32] Ibid., pp. 36-37.

[33] Versar, Inc, 1989, Op. Cit., p. 3.

[34] CDM Federal Programs Corporation, 1987, Op. Cit., p. 7.

[35] Versar, Inc., 1989, Op. Cit., p. 3.

[36] CDM Federal Programs Corporation, 1987, Op. Cit., p. 7.

[37] Ibid., p. 39.

[38] Ibid., pp. 73-76.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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COPPER

A. Commodity Summary

The physical properties of copper, including malleability and workability, corrosion resistance and durability, high electrical and thermal conductivity, and ability to alloy with other metals, have made it an important metal and production input to a number of diverse industries.[1,2] Copper deposits are found in a variety of geological environments, which are affected by the rock-forming processes that occurred at a particular location. These deposits can be grouped in the following broad classes: porphyry and related deposits, sediment-hosted copper deposits, volcanic-hosted massive sulfide deposits, veins and replacement bodies associated with metamorphic rocks, and deposits associated with ultramafic, mafic, ultrabasic, and carbonatite rocks. The most commonly mined type of copper deposit, porphyry copper, is found predominantly in areas along the western continental edges of North and South America, as well as in the southwestern United States, associated with large granite intrusions.[3,4]

Copper occurs in about 250 minerals, only a few of these, however, are commercially important.[5] Deposits considered to be economically recoverable at current market prices may contain as little as 0.5 percent of copper or less, depending on the mining method, total reserves, and the geologic setting of the deposit.[6] Most copper ores contain some amount of sulfur-bearing minerals. The weathering environment affecting the ore body following deposition is determined mainly by the availability of oxygen. Ores exposed to air tend to be oxidized, while those in oxygen poor environments remain as sulfides.[7]

The United States is the second largest copper producer in the world. Next to Chile, the United States had the largest reserves (45 million metric tons) and reserve base (90 million metric tons) of contained copper. In 1994, domestic mine production rose to slightly more than 1.8 million metric tons and was valued at about $4.4 billion. The principal mining states, in descending order, Arizona, Utah, New Mexico, Michigan, and Montana, accounted for 98 percent of domestic production; copper also was recovered at mines in seven other states. Eight primary and five secondary smelters, nine electrolytic and six fire refineries, and 15 solvent extraction-electrowinning plants were operating at the end of 1994. Refined copper and direct melt scrap were consumed at about 35 brass mills; 15 wire rod mills; and 750 foundries, chemical plants, and miscellaneous consumers.[8] Exhibit 1 presents the names and locations of the mining, smelting, refining, and electrowinning facilities located in the United States. As available, Exhibit 1 also presents information on potential site factors indicating whether the facility is located in a sensitive environment.

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[1] "Copper," Kirk-Othmer Encyclopedia of Chemical Technology, 4th Ed., Vol. VII, 1993, p. 381.

[2] U.S. Environmental Protection Agency, Technical Resources Document-Extraction and Beneficiation of Ores and Minerals: Volume 4 Copper, Office of Solid Waste, 1993d, p. 3.

[3] "Copper," 1993, Op. Cit., p. 384.

[4] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 7.

[5] Ibid., p. 9.

[6] Ibid., p. 7.

[7] Ibid., p. 9.

[8] Edelstein, Daniel L, from Minerals Commodities Summaries, U.S. Bureau of Mines, January 1995, pp. 50-51.

EXHIBIT 1

Summary of Copper Mining, Smelting, Refining, and Electrowinning Facilities[9]

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
ASARCO	El Paso, TX	Smelting	
ASARCO	Amarillo, TX	Electrolytic Refining	
ASARCO	Ray, AZ	Electrowinning	
ASARCO	Hayden, AZ	Smelting and Electrowinning	
Burro Chief Copper Mine	Tyrone, NM	Extraction and Electrowinning	
Chino Mines Company	Hurley, NM	Smelting/Fire Refining	100 year floodplain, karst terrain 1,000 feet below surface, private wells within 1 mile[10]
Copper Range	White Pine, MI	Open Pit Mining, Smelting and Refining	fault area
Cyprus Pinos Altos Mine	Silver City, NM	Extraction	
Cyprus	Claypool, AZ	Smelting, Refining, and Electrowinning	
Cyprus Casa Grande Mine	Casa Grande, AZ	In-situ Extraction and Roasting	
Cyprus Miami Mining Corp.	Claypool, AZ	Heap Leaching	fault area, private wells within 1 mile
Cyprus Mineral Park Corp.	Kingman, AZ	Dump Leaching	
Cyprus Sierrita/Twin Buttes	Green Valley, AZ	Heap Leaching	
Cyprus Mining	Bagdad, AZ	Electrowinning	
Cyprus Bagdad Copper Mine	Bagdad, AZ	Heap Leaching and Milling	

[9] ICF Incorporated, Mining and Mineral Processing Facilities Database, August 1992.

[10] Phelps Dodge Corporation. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, January 25, 1996.

EXHIBIT 1 (Continued)

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
Flambeau Copper Mine	Wisconsin[11]	Extraction	
Gibson Mine	Mesa, AZ	Strip and In-situ Extraction	
Johnson Camp Mine	Tucson, AZ	Heap Leaching	
Kennecott	Garfield, UT	Mining	low pH and metals contamination of ground water found hydraulically down-gradient from mine operations[12]
Kennecott[13]	Magma, UT	Smelting and Refining	
Magma Mine (BHP Copper)	Superior, AZ	Undercutting and Filling (Mining)	
Magma (BHP Copper)	San Manuel, AZ	Smelting, Refining, and Electrowinning	public and private wells within 1 mile
Mineral Park Mine	Kingman, AZ	Extraction	
Mission Unit	Sahuarita, AZ	Extraction	
Montanore Mine	Libby, MT	Extraction	
Morenci Mine	Morenci, AZ	Heap Leaching	
Noranda	Casa Grande, AZ	Electrowinning	
Oracle Ridge Mine	San Manuel, AZ	Extraction	
Phelps Dodge	Morenci, AZ	Electrowinning	
Phelps Dodge	Playas, NM	Smelting	

[11] Ibid.

[12] Ibid.

[13] Ibid.

EXHIBIT 1 (Continued)

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
Phelps Dodge	El Paso, TX	Refining	fault area, public and private wells within 1 mile
Phelps Dodge	Hurley, NM	Smelting and Electrowinning	
Pinos Altos Mine	Silver City, NM	Extraction	
Pinto Valley Operations	Miami, AZ	Extraction and Electrowinning	
Pinto Valley	Pinto Valley, AZ	Electrowinning	
Ray Complex	Hayden, AZ	Extraction	
San Manuel Div. Mine	San Manuel, AZ	Extraction	
San Pedro Mine	Truth or Consequence, NM	Extraction	
Silver Butte Mine	Riddle, OR	Extraction	
Silver Bell Unit	Marana, AZ	Extraction	
St. Cloud Mining Co.	Truth or Consequence, NM	Extraction	
Sunshine Mine	Kellog, ID	Extraction	
Tennessee Chemical	Copperhill, TN	Closed	
Tyrone Branch Mine	Tyrone, NM	Dump Leaching and Electrowinning	
Western World Copper Mine	Marysville, CA	Extraction	
Yerington Mine	Tucson, AZ	Extraction	

The majority of the copper produced in the United States is used in the electrical industry; it is used for a wide range of wiring applications (from power transmission lines to printed circuit boards), in microwave and electrical tubes, motors and generators, and many other specialized applications where its high electrical and thermal conductivity can be employed. While copper has been replaced in some applications by aluminum (e.g., for overhead power lines) and fiber optics (e.g., in telecommunications), its durability, strength, and resistance to fatigue assure its continued use in the electrical industry. These latter three characteristics also make copper and copper alloys a valued material in construction and containment (e.g., pipes and tanks), and in other activities where endurance and resistance to corrosion are required.[14]

Primary production of copper in the United States steadily increased in the early 1990s. Total apparent consumption rose from 2,170,000 metric tons in 1990 to 2,800,000 metric tons in 1994. Approximately 42 percent of the 1994 domestic consumption of copper went to building and construction industries, while 24 percent was used by the electrical and electronic products industries. Industrial machinery and equipment consumed 13 percent, transportation equipment consumed 12 percent, and consumer and general products consumed the remaining 9 percent.[15] Clearly, the development of new infrastructure in the United States and abroad would increase the worldwide demand for copper, but consumption per unit of new gross product would be less than that in the past because substitutes for copper are often used in a number of industries. For example, new telephone infrastructure is largely based on fiber optics technology rather than copper. Continued re-opening of mothballed facilities, expansion of existing facilities, and development of new mines could lead to copper supplies increasing faster than demand.[16,17]

B. General Process Description

1. Discussion of the Typical Production Process

The two major processes employed in the United States to recover copper from ores are classified as either (1) pyrometallurgical methods, or (2) hydrometallurgical methods. Pyrometallurgical methods consist of conventional smelting technology, and are widely used. Hydrometallurgical methods involve leaching and recovery by precipitation or electrowinning, and are gaining in popularity. For example, in 1984 100,180 tons of copper were produced by solvent extraction and electrowinning (SX/EW), while in 1992 439,043 tons were produced by SX/EW.[18] Some within the industry believe that hydrometallurgical operations are only economically attractive for producing 30,000 metric tons of copper product per year or less.[19,20]

2. Generalized Flow Diagram

Exhibit 2 presents a flow diagram of the typical pyrometallurgical operations involved in the production of copper from ore. Exhibit 3 presents a flow diagram of the typical hydrometallurgical operations involved in the production of copper from ore.

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[14] Edelstein, Daniel L, 1995, Op. Cit.

[15] Ibid.

[16] Ibid.

[17] U.S. Environmental Protection Agency, "Primary Copper Processing," Report to Congress on Special Wastes from Mineral Processing, Vol. II, Office of Solid Waste, July 1990, p. 6-2.

[18] "Copper," 1993, Op. Cit., p. 412.

[19] Ibid., p. 408.

[20] Keith R. Suttill, "Pyromet or Hydromet?" Engineering and Mining Journal, 191, May 1990, p. 31.

EXHIBIT 2

Process Flow Diagram for the Production of Copper

Pyrometallurgical Process

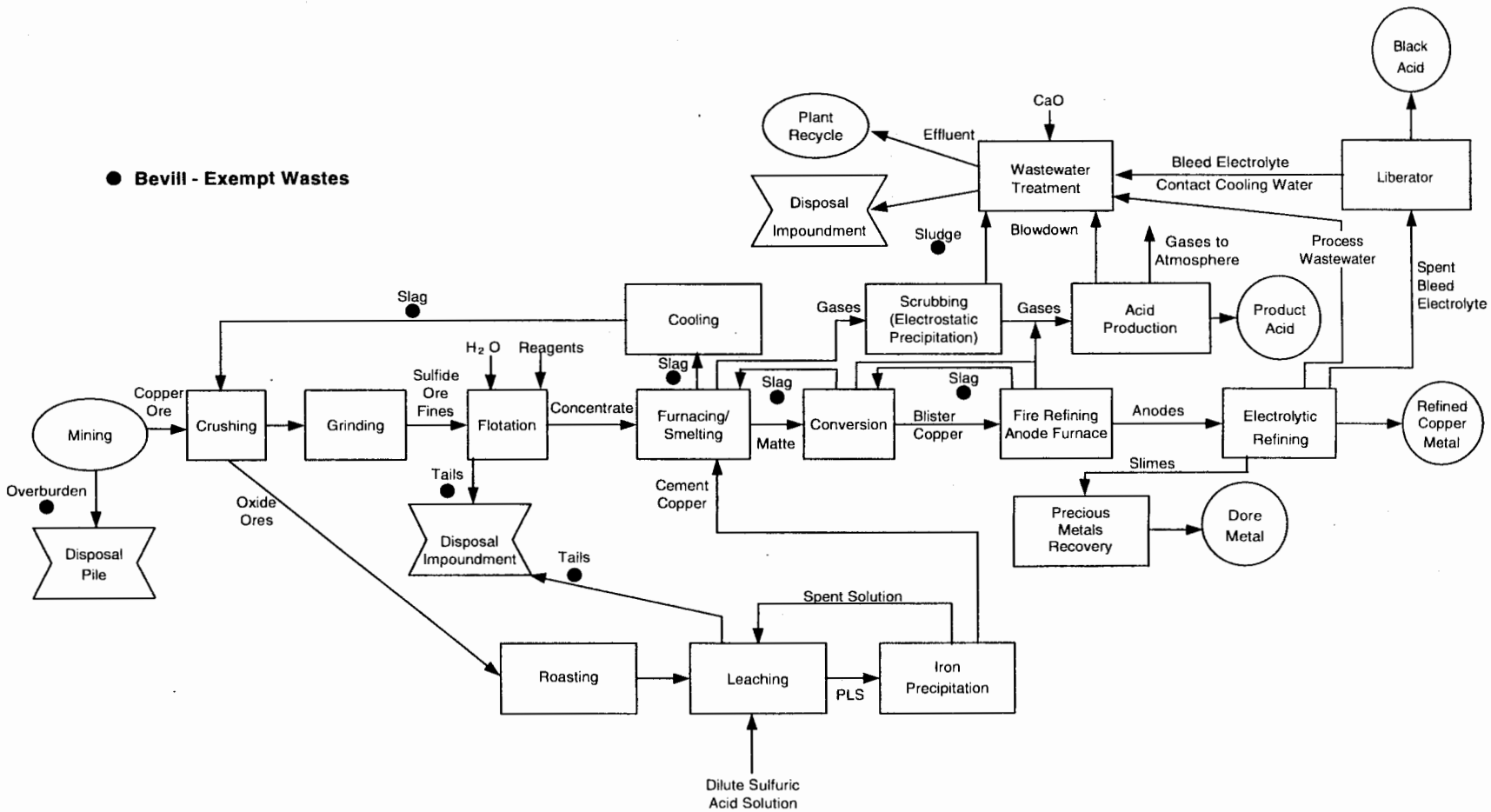
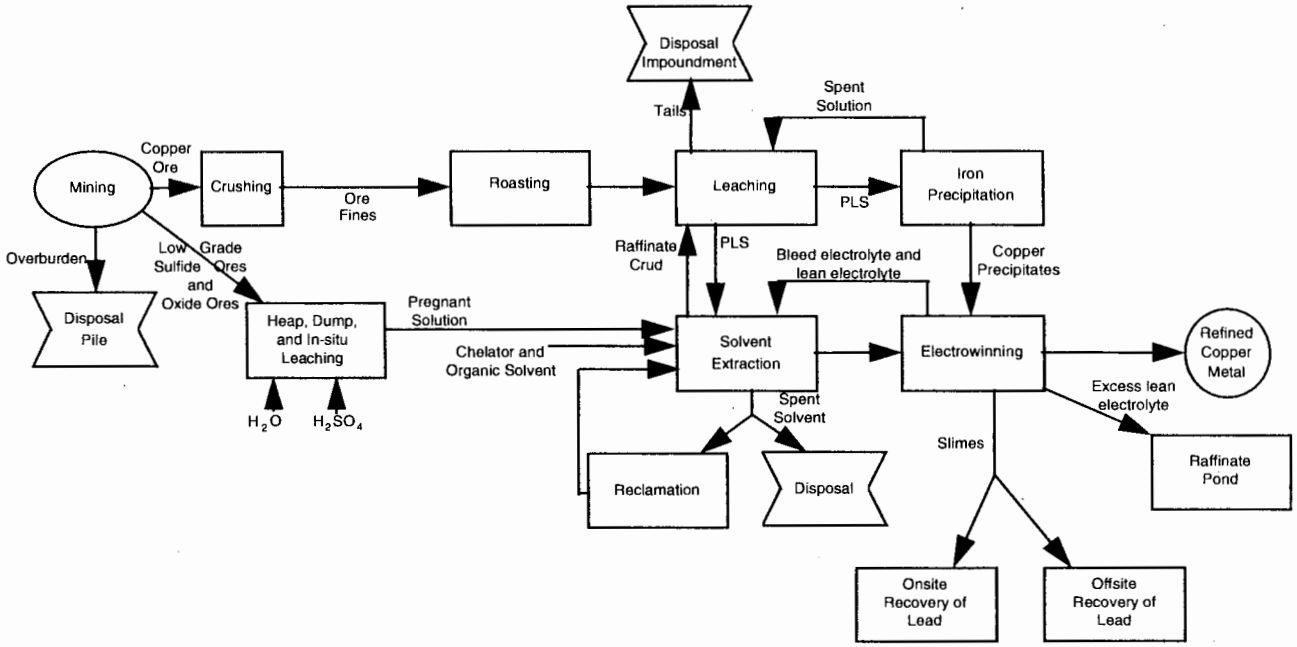


EXHIBIT 3

Process Flow Diagram for the Production of Copper

Hydrometallurgical Process



Extraction and Beneficiation Operations

Prior to pyrometallurgical operations, sulfide ore (which often contains less than one percent copper) is crushed and ground with water and placed in a concentrator.[21] The rock/water slurry is subjected to physical and chemical actions (i.e., air sparging and hydrophobic chemical reagents) inside a flotation tank. The chemical reagents assist the flotation process by acting as frothing and collector agents. Methylisobutyl carbonal (MIBC) is a typical frothing agent, and sodium xanthate, fuel oil, and VS M8 (a proprietary formulation) are typical collector agents. As a result of the physical and chemical actions, the copper value rises to the surface of the flotation unit as a froth.[22]

The material remaining on the bottom of the flotation tank (spent ore or "gangue"), is partially dewatered and then discharged to tailing ponds for disposal.[23] In cases in which the copper ore contains a large amount of clay minerals, "slime" (a mixture of clay minerals and copper values) often forms and is separated from the gangue for further copper recovery. The slime is reground and subjected to flotation to remove the copper value. Once the copper value is removed, the slime is ultimately managed/disposed with the gangue.[24,25]

The concentrate resulting from the flotation circuit contains approximately 30 percent copper and, in some instances, may also contain significant recoverable concentrations of molybdenum. If molybdenum is readily recoverable, as it is at Magma Copper (Arizona), the concentrate is sent to the molybdenum plant for recovery; otherwise, the concentrate is ready for subsequent pyrometallurgical operations.[26,27] Alternatively, the concentrate can be dewatered and the dry product may either be stored for further processing or shipped to another facility for processing. The collected water is usually recycled in the milling circuit.

All oxide ore and some low grade sulfide ores destined for hydrometallurgical beneficiation are not crushed, floated, or sent to a concentrator. These ores are instead leached with copper values recovered by solvent extraction and electrowinning operations.[28,29]

At a molybdenum recovery plant, such as the one at Magma Copper (Arizona), the copper concentrate contains approximately one percent molybdenum disulfide (which in itself is a saleable co-product). To isolate the molybdenum from the copper concentrate, the concentrate undergoes additional flotation steps. The copper concentrate is added to a rougher flotation cell where sodium cyanide is added to suppress the copper, thus causing the molybdenum to float to the surface. Some operations, however, including the Chino Mines facility, do not recover molybdenum disulfide using sodium cyanide. They instead use, sodium disulfide to suppress the copper and

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[21] Phelps Dodge Corporation. Op. Cit.

[22] U.S. Environmental Protection Agency, Trip Report -- Site Visit to Magma Copper and Cyprus Miami Copper Mines," Draft Memorandum, Office of Solid Waste, April 1994b, p. 6.

[23] Ibid., p. 6.

[24] "Copper," 1993, Op. Cit., pp. 388-92.

[25] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 53.

[26] "Copper," 1993, Op. Cit., pp. 388-92.

[27] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 53.

[28] BHP Copper. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, January 25, 1996.

[29] Phelps Dodge Corporation. Op. Cit.

float the molybdenum.[30] The copper concentrate falls to the bottom and the underflow is sent for drying and thickening prior to smelting. The molybdenum-containing overflow is sent to additional cleaner and recleaner circuits. At the last recleaner circuit, 70 percent of the overflow is filtered and dried, and the remaining 30 percent is returned to the filter at the beginning of the recleaner circuit. The filtered, dry molybdenum disulfide product (95 percent) is packed into 55-gallon drums and sold as molybdenite.[31]

Pyrometallurgical Processing

Pyrometallurgical processes employ high-temperature chemical reactions to extract copper from its ores and concentrates. These processes generally are used with copper sulfides and in some cases high-grade oxides.[32] Depending on the copper mineral and the type of equipment, pyrometallurgical recovery may take as many as five steps: roasting, smelting, converting, fire refining, and electrorefining. The products from smelting, converting, fire refining in an anode furnace, and electrolytic refining are copper matte, blister copper, copper anodes, and refined copper, respectively.[33] Roasting dries, heats, and partially removes the sulfur and volatile contaminants from the concentrated ore to produce a calcine suitable for smelting.[34] Modern copper smelters generally have abandoned roasting as a separate step, and have combined this function with the smelting furnace. However, in older systems using multiple brick hearths, the copper concentrate moves from the top of the hearth towards the base, while air is injected counter-current to the concentrate. The roasted ore leaves through the bottom brick hearth and sulfur dioxide (2-6 percent) exits through the top.[35]

Smelting involves the application of heat to a charge of copper ore concentrate, scrap, and flux, to fuse the ore and allow the separation of copper from iron and other impurities. The smelter furnace produces two separate molten streams: copper-iron-sulfide matte, and slag, as well as sulfur dioxide gas.[36] The smelter slag, essentially a mixture of flux material, iron, and other impurities, is a RCRA special waste. The slags from some smelting furnaces are higher in copper content than the original ores taken from the mines, and may therefore be sent to a concentrator for copper recovery.[37,38] Tailings from flotation of copper slag are a second RCRA special waste. Reverberatory furnaces are being replaced by electric or flash furnaces because reverberatory furnaces are not as energy efficient, and they produce large volumes of low concentration SO_2 gas, which is difficult to use in sulfur recovery.[39]

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[30] Phelps Dodge Corporation. Op. Cit.

[31] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 7.

[32] Office of Technology Assessment, Copper: Technology and Competitiveness, OTA-E-67, Washington, DC: U.S. Government Printing Office, September 1988, p. 133.

[33] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-2.

[34] Office of Technology Assessment, 1988, Op. Cit., p. 134.

[35] "Copper," 1993, Op. Cit., p. 394-95.

[36] Process upsets sometimes require the copper concentrate to be stored temporarily until the smelter is operational. In many cases, this temporary storage takes place in the pipeline. In other cases, such as at the Hidalgo Smelter, concentrate is shipped by rail car, then stored in an enclosed building prior to being fed by a conveyor belt to the smelter. (Phelps Dodge Corporation. Op. Cit.)

[37] "Copper," 1993, Op. Cit., p. 393.

[38] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-3.

[39] K. Yoshiki-Gravelsins, J. M. Toguri, and R. T. Choo, "Metals Production, Energy, and the Environment. Part II: Environmental Impact," Journal of Mines, 45, No. 8, August 1993, p. 23.

Moreover, the gases produced by electric furnace smelting are smaller in volume, lower in dust (less than 1 percent), and have a higher SO_2 concentration, which allows better sulfur recovery in an acid plant.[40] Gases from smelting operations contain dust and sulfur dioxide. The gases are cleaned using a variety of particulate control technologies, including baghouses, scrubbers, settling chambers, and electrostatic precipitators.[41] The gases are then sent to the acid plant, which converts the sulfur dioxide-rich gases to sulfuric acid (a useable and/or saleable product).[42]

In the converter (the most common being the Peirce-Smith converter, followed by the Hoboken converter and the Mitsubishi continuous converter), a high silica flux and compressed air or oxygen are introduced into the molten copper matte. Most of the remaining iron combines with the silica to form converter slag, a RCRA special waste. After removing the slag, additional air or oxygen is blown in to oxidize the sulfur and convert the copper sulfide to blister copper that contains about 99 percent copper; the sulfur is removed in the form of SO_2 gas, which reports to an acid plant where it is converted to high grade sulfuric acid. Depending on the efficiency of the acid plant, differing amounts of SO_2 are emitted to the atmosphere. Some facilities have combined the smelting furnace and converter into one operation, such as the one used by Kennecott (i.e., the Kennecott-Outokumpo flash converting process).[43,44] In the interest of conserving energy and improving efficiency, many companies are now employing flash smelting (such as the Outokumpo, Inco, Mitsubishi, or Noranda processes) to produce matte feed.[45]

Oxygen and other impurities in blister copper must be removed before the copper can be fabricated or cast into anodes for electrolytic refining. Blister copper is fire refined in reverberatory or rotary furnaces known as anode furnaces. When co-located with a smelter or converter, the furnace may receive the blister copper in molten form so remelting is unnecessary. Air is blown in to oxidize some impurities; flux may be added to remove others. The residual sulfur is removed as sulfur dioxide. A slag is generated during anode furnace operation. This slag is also a component of the RCRA special waste. The final step in fire refining is the reduction of the copper and oxygen removal by feeding a reducing gas such as ammonia, reformed gas, or natural gas into the copper while it is still in the anode furnace. The molten copper then is cast into either anodes for further electrolytic refining or wire-rod forms.[46,47] Smelted copper typically retains metallic impurities at concentrations that can interfere with electrical uses. Anode copper may be suitable for non-electric uses such as decorative copper or cooking utensils, but wire bar is made specifically for electrical wire manufacturing and requires high grade electrowon or electrolytically refined copper.[48]

At the Cyprus Amax Minerals Company, during the addition of oxygen into the converter furnace while slag is present (slag blow), secondary copper materials may be added to recover copper and to cool the furnace charge. Once the iron has been removed, the converter furnace switches to "copper blow" (the addition of oxygen without the presence of slag), and at this point, very high copper content materials can be added to the furnace. For example, reverts (a mixture of converter slag and matte which is frozen to the walls and bottom of a transfer ladle)

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[40] Ibid., p. 27.

[41] Phelps Dodge Corporation. Op. Cit.

[42] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 8.

[43] "Copper," 1993, Op. Cit., p. 396.

[44] U.S. Environmental Protection Agency, 1990, Op. Cit., pp. 6-3 - 6-4.

[45] "Copper," 1993, Op. Cit., p. 396.

[46] Ibid., p. 399-400.

[47] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-4.

[48] BHP Copper. Op. Cit.

may be introduced at this point. Reverts are knocked loose and stored until they have cooled sufficiently to allow equipment to move them to the crushing and sizing area. The material is chipped and then fed back into the furnace for melting and then to the converters and eventually anode casting in order to continue copper production during times when the Isamelt furnace is down. Reverts are accumulated in more than one area and are surveyed for inventory control purposes and left undisturbed until ready to be reused in the furnaces. The matte is accumulated in a slag accumulation area located on the ground.[49]

Electrolytic refining (or electrorefining) purifies the copper anodes by virtually eliminating the oxygen, sulfur, and base metals that limit copper's useful properties. In electrorefining, the copper anodes produced from fire-refining are taken to a "tank house" where they are dissolved electrolytically in acidic copper sulfate solution (the electrolyte). The copper is electrolytically deposited on "starter" sheets of purified copper to ultimately produce copper cathodes (relatively pure copper with only trace contaminants -- less than a few parts per million) for sale and/or direct use. The concentration of copper and impurities in the electrolyte are monitored and controlled. As necessary, the electrolyte is purified and the resulting impurities (left on the bottom of the electrolytic cells -- often referred to as "anode slimes") are processed for recovery of precious metals (gold, silver, platinum, palladium), bismuth, selenium, and tellurium.[50] Electrorefining also produces aqueous waste streams (e.g., process wastewater, bleed electrolyte) that must be treated and discharged, reused, or disposed of in some manner. Many of the facilities use a wastewater treatment operation to treat these wastes. The solid residual from these treatment operations is a calcium sulfate sludge, which is yet another RCRA special waste generated by the primary copper sector.[51] The exemption from RCRA regulation for calcium sulfate sludge, which has a variable water content, does not depend on its water content.[52]

Hydrometallurgical Beneficiation

Hydrometallurgical copper recovery is the extraction and recovery of copper from oxide ore and some low grade sulfide ores using aqueous solutions. Hydrometallurgical operations include the following: (1) acid extraction of copper from oxide ores; (2) oxidation and dissolution of sulfides in spent ore from mining, concentrator tailings, or *in situ* ore bodies (e.g., low grade oxide and sulfide mine wastes); and (3) dissolution of copper from concentrates to avoid conventional smelting.[53] In summary, the copper-bearing ore (and in some cases, the overburden) is leached, then the copper is recovered from the pregnant leachate through precipitation, or solvent extraction and electrowinning (SX/EW).[54]

The simplest form of hydrometallurgical beneficiation of low grade ore, practiced at large, open-pit copper mines is dump leaching. In dump leaching, the raw material is leached using a dilute sulfuric acid solution. At Phelps Dodge facilities, leaching is accomplished by applying raffinate (a weak aqueous acid solution) to the leach ore stockpiles by standard sprinkler irrigation spray heads or drip emitters.[55] There are several other types of leaching operations (progressing from least capital intensive and inefficient -- using the rock "as is" -- to most capital

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[49] Cyprus Amax Minerals Company. Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, October 10, 1997.

[50] "Copper," 1993, Op. Cit., pp. 401-404.

[51] U.S. Environmental Protection Agency, 1990, Op. Cit., p. 6-4.

[52] Phelps Dodge Corporation. Op. Cit.

[53] "Copper," 1993, Op. Cit., p. 408.

[54] Office of Technology Assessment, 1988, Op. Cit., p. 140.

[55] U.S. Environmental Protection Agency Telephone Questionnaire. August 22, 1997. Facility Contact: Richard N. Mohr, Phelps Dodge Morenci, Inc.

intensive and efficient -- using ground ore): *in situ*, heap or pile, dump, vat, and heat or agitation leaching. In some cases, roasting is employed prior to leaching in order to enhance the leachability of the material. In roasting, heat is applied to the ore, which enhances its amenability to leaching without destroying the physical structure of the ore particles. The roasted material is then subjected to leaching (as described above). The copper-rich leachate (referred to as "pregnant leachate solution") is subjected to further beneficiation while the waste material is either left in place (in the case of dump, *in situ*, heap, or pile leaching) or managed in tailing ponds (in the case of vat, heat, or agitation leaching).

Copper is removed from the pregnant leachate solution (PLS) through either iron precipitation (or cementation) or solvent extraction and electrowinning. In cementation, which was once the most popular method for recovering copper from the PLS, the leachate is combined with detinned iron in a scrap iron cone (such as the Kennecott-Precipitation Cone) or vibrating cementation mill, where the detinned iron replaces the copper in the solution. The copper precipitates are removed for subsequent hydrometallurgical refining (electrowinning) or pyrometallurgical processing.[56,57]

In solvent extraction (now, the most popular process), an organic chemical (chelator) that binds copper but not impurity metals is dissolved in an organic solvent (often kerosene[58]) and is mixed with the pregnant leachate solution. The copper-laden organic solution is separated from the leachate in a settling tank. A weak sulfuric acid (or lean) electrolyte[59] is then added to the pregnant organic mixture, which strips the copper into an electrolytic solution ready for electrowinning. The barren leachate (or raffinate) is sent back to the leaching system. Electrowinning is the recovery of copper from the loaded electrolyte solution produced by solvent extraction, yielding wire-grade[60] copper metal. When the iron concentration in the electrolyte stream[61] becomes too high, some solution is bled off and sent to the SX unit for further copper recovery. The copper-poor (or lean) electrolyte from electrowinning is returned to the SX plant. Excess lean electrolyte from the SX unit is returned to the raffinate pond to later be recycled into the leaching circuit. Filter clay is used to filter the electrolyte.[62] Impurities left on the bottom of the electrowinning cells are referred to as "muds or slimes." BHP Copper refers to the impurities left on the bottom of the electrowinning cell as "anode sludge." Both this anode sludge and lead anodes that are no longer usable are periodically removed from the cells and send to lead smelting facilities for resource recovery.[63] Electrowinning is functionally equivalent to electrolytic refining.[64,65]

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[56] "Copper," 1993, Op. Cit., p. 410.

[57] Office of Technology Assessment, 1988, Op. Cit., pp. 140-142.

[58] Phelps Dodge uses a petroleum distillate manufactured specifically for use in the solvent extraction process. This petroleum distillate consists of longer chain hydrocarbons with a lower volatile organic content than kerosene. (Phelps Dodge Corporation. Op. Cit.)

[59] Phelps Dodge Corporation. Op. Cit.

[60] Ibid.

[61] Ibid.

[62] Ibid.

[63] BHP Copper. Op. Cit.

[64] "Copper," 1993, Op. Cit., pp. 412-13.

[65] Office of Technology Assessment, 1988, Op. Cit., p. 142.

We note that at Magma Copper (Arizona), the pregnant leach solution (PLS) is collected in the PLS feed pond, where other inputs to the PLS feed pond include liquids from *in-situ* leaching, Gould Solution, and TNT filter cake. Gould Solution is produced from the electrolytic refining of copper foil at one facility in Chandler, AZ. The spent electrolyte solution (containing 100 g/L sulfuric acid and 60 g/L copper) is trucked to Magma Copper, where it is added directly to the PLS feed pond. Magma Copper has proposed to accept filter cakes consisting of copper oxide mud from copper chloride etching solution generated during the production of circuit boards. This material (TNT filter cake) would be mixed with the PLS feed to the SX unit.[66] At the Phelps Dodge Morenci site, PLS which has been stripped of copper (acidic solution) from the SX process, copper-bearing bleed electrolyte and washdown water from the EW process, and fresh water are transferred by pipeline to lined impoundments for reuse in the leaching process. This "raffinate" is piped to the top of the leach stockpiles for reuse. In addition, water collected behind dams in Rocky Gulch and Gold Gulch is piped for reuse in the leaching process. All reagents used in the SX and EW processes are stored in above ground tanks.[67]

The Kennecott Corporation's new hydrometallurgical plant combines acid plant blowdown, refinery bleed solutions, and electrostatic precipitator (ESP) dusts in a series of chemical reactions to produce a metal concentrate, a sulfide cake, and non-hazardous tailings. The valued metals are returned to the smelter for recovery. Impurities such as bismuth, that would have otherwise compromised the quality of the copper product, can thereby be removed while extracting the maximum economic benefit in resource recovery from valuable metals contained in the dust.[68]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Additional pyrometallurgical technologies still under development include the solid matte oxygen converting (SMOC) process and continuous total pressure oxidation process. The SMOC process developed by Kennecott is a one-step smelting process designed to eliminate the hot matte and slag transfers between smelting and converting, thereby reducing their attendant fugitive emissions. In the total pressure oxidation process, chalcopyrite ($CuFeS_2$) can be hydrothermally oxidized directly to digenite (CuS) inside a single, continuous, autoclave reactor. The enriched solid residue (super concentrate) is separated from the liquor, containing ferrous sulfate and sulfuric acid, and the upgraded concentrate can proceed directly to smelting. The acid solution can be used in heap or dump leaching.[69] Total pressure oxidization is especially well-suited for concentrates with a high copper to sulfur ratio.[70]

Magma has constructed a new flue dust leaching (FDL) facility to recover copper from several smelter by-product streams. Feedstocks to the FDL facility were to include flash furnace dust (20-25 percent copper, 1.3 percent arsenic), converter flue dust (80 percent copper, 0.01 percent arsenic), acidic bleed solution from the Lurgi scrubbers (3.6 g/L copper, 0.4 g/L arsenic, 3.5 g/L acid pH 1.6). (Lurgi scrubbers are pollution control devices for smelter converter offgas.) These feedstocks were to be stored in bins or slurry tanks prior to entering a series of agitator leach vessels. Sulfuric acid (93 percent concentration) would be added to dissolve the copper into solution. The copper rich leachate was to be purified in a dedicated solvent extraction unit, where an extremely concentrated copper sulfate solution (one that could easily be crystallized into commercial grade copper sulfate crystals) would be

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[66] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 16.

[67] U.S. Environmental Protection Agency Telephone Questionnaire. Op. Cit.

[68] Kennecott Corporation. Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, May 12, 1997.

[69] Robert W. Bartlet, "Copper Super-Concentrates--Processing, Economics, and Smelting," EPD Congress, 1992, pp. 652-653.

[70] J. A. King, D. A. Knight, and D. B. Dreisinger, "The Total Pressure Oxidation of Copper Concentrates," The Minerals, Metals and Materials Society, 1993, p. 735.

generated. The crystals could be either sold "as is" or sent to the main solvent extraction circuit.[71] The remaining solids would be thickened, washed, and filtered. The resulting filter cake was to be sent back to the flash furnace for smelting. In a comment, Magma Copper wrote that this facility was originally designed to utilize BHP's existing SX plant, not the dedicated plant described above. After evaluating the high operating costs of the dedicated SX as well as the treatment plant, BHP determined that it could not economically operate the FDLP, and the plant has never been operated.[72] Kennecott Utah Copper's modernized smelter includes a pneumatic conveying system that allows mineral-rich boiler and electrostatic precipitator (ESP) dusts to be re-introduced directly into the flash smelting and flash converting furnaces without any additional handling. This dust on average contains approximately 35% copper, as compared to less than 1% copper in mined ore and less than 30% in virgin copper concentrate. Additionally, this dust contains significant amounts of valuable precious metals.[73]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this mineral commodity sector, depending on the specific process, the beneficiation/processing line occurs between flotation and furnacing or between iron precipitation and furnacing because furnacing (or smelting) significantly alters the physical/chemical structure of the beneficiated ore. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence also are considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below information about process waste streams associated with both extraction/beneficiation and mineral processing activities, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

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[71] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 9.

[72] BHP Copper. Op. Cit.

[73] U.S. Environmental Protection Agency, "Verbatim Comment Excerpts, Summary and Response Form, for Kennecott Utah Copper Corporation." Excerpt number COMM1054-8-1.

C. Process Waste Streams

As discussed above (and shown in Exhibits 2 and 3), the extraction, beneficiation, and processing of copper leads to the generation of numerous solid, liquid and gaseous wastes, which depending on the material, may be recycled or purified prior to disposal. The generation, treatment, and management of each of these wastes is discussed below.

1. Extraction/Beneficiation Wastes

Wastes generated from the extraction and beneficiation of copper from copper-bearing ores are exempt from RCRA Subtitle C and the scope of BDAT determinations. Wastes from the extraction/beneficiation of copper-bearing ores are discussed below.

Spent ore. This waste from mining operations, along with overburden, is generated from the actual removal of copper ore from the ground and contains little or no recoverable copper values. Overburden and spent ore may be stockpiled for reclamation upon closure of the facility or to achieve contemporaneous reclamation of leach piles and rock piles.[74] These materials are typically hauled from the mine site and are disposed of in on-site spent ore dumps. At Magma Copper (Arizona), spent ore is left in place; at other facilities, however, the spent ore may be hauled to the surface and disposed.[75] In 1980, more than 282 million tons of spent ore were disposed.[76]

Tailings (or gangue). This waste results from the flotation of ground ore/water slurry. The composition of tailings varies according to the characteristics of the ore; this waste is comprised of very fine host rock and nonmetallic minerals. Tailings are sent to tailings impoundments for disposal, but may first be dewatered in thickeners. For example, at Magma Copper (Arizona) tailings from the copper and molybdenum flotation processes are sent to a hydroseparator for dewatering. The hydroseparator underflow is sent to a repulper and the slurry is discharged to the tailings ponds for disposal. The hydroseparator overflow is sent to a thickener, where the solids (underflow) are sent to the repulper and the liquid stream (water overflow) is reused in the flotation circuit. Tailings generated during the flotation processes are excluded from RCRA Subtitle C regulation under the Bevill Amendment.[77] In 1985, the industry disposed of more than 189 million tons of gangue.[78]

Slime. A clay/copper material called slime is often generated during the flotation of copper ore containing a large amount of clay minerals. Slime is separated from the gangue and is reground and refloated to remove additional copper value. The slime is ultimately disposed of along with the tailings. There is no information on the quantity of slime generated annually.[79] The term also has another meaning in the industry, usually referring to the clay and silt fraction of the tailing that is separated from the coarser tailing materials by size classifiers (usually cyclones) at the tailing disposal site. This separation, which can be accomplished by gravity separation as the tailing slurry is deposited and flows toward the water decant area at the tailing ponds is encouraged in order to deposit the sandier materials near the tailing embankment to provide higher embankment stability than the finer materials would have created. The finer materials (slimes) are then deposited in the interior of the tailing impoundment.[80] We note

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[74] Phelps Dodge Corporation. Op. Cit.

[75] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 10.

[76] U.S. Environmental Protection Agency, 1993d, Op. Cit., pp. 50-51.

[77] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 10.

[78] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 53-54.

[79] "Copper," 1993, Op. Cit., p. 388-92.

[80] Phelps Dodge Corporation. Op. Cit.

that this "slime" is much different in composition than the "slimes or muds" generated by electrolytic refining (see below).

Process wastewaters. Various processing wastewaters result from conveyance, flotation, mixing, and dissolution operations. Process wastewaters may either be treated on site at wastewater treatment facilities or discharged to tailings ponds, surface impoundments, or to receiving streams. Process wastewaters are believed not to be land stored and are fully recycled.[81]

Solvent extraction/electrowinning. These operations result in the generation of several liquid and semi-liquid wastes. Often these materials are still either useful or rich in values and can be reused or recycled. The following waste streams are uniquely associated with copper beneficiation activities and, therefore, are subject to the Bevill Mining Waste Exclusion:

> **Slimes or "muds"**. These materials result from the deposition of sediment in electrowinning cells. These materials often contain recoverable quantities of lead and are either processed on-site or are drummed and sent off-site for recovery.[82] Approximately 3,000 metric tons of slimes are generated annually.[83]
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> **Crud (often referred to as "gunk," "grungies," or "grumos")**. This waste is generated during solvent extraction. Crud is solid particles associated with oil/water dispersions of varied complexity and typically forms stable multi-phase emulsions. Crud is periodically removed from the system. The crud is centrifuged or otherwise treated to remove the organics, which are returned to the solvent extraction circuit for reuse. Site-specific management information is available for several companies. At the Chino Mines Company (Santa Rita, NM), the recovered organic is filtered using Filtrol No.1 montmorillonite clay[84] and then solids, mainly fine rock materials from the leach rock and particles of the clay used as a filter for the organic solution, are returned to the leach system. Any aqueous solution is drained off and returned to the raffinate pond and the leach circuit.[85] In some cases, the resulting solids contain sufficient quantities of precious metals to warrant recovery (off-site).[86] We note that at both the Magma Copper Company's San Manuel, AZ facility and the Cyprus Mines' Miami, AZ facility, crud is recycled into the raffinate pond which is linked to, and forms, an integral part of the SX/EW processing circuit.[87,88] Phelps Dodge Morenci generates 1,650 tons/year of copper bearing gunk. This gunk is smelted for flux values and to recover copper.[89] Entire sector production rates for crud are currently not available.

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[81] Exhibit 1. Draft Technical Background Document Characterization of Mineral Processing Wastes and Materials, March 18, 1997.

[82] "Copper," 1993, Op. Cit., pp. 401-404.

[83] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Volume I, Office of Solid Waste, August 1992, p. I-3.

[84] Tom Burniston, James N. Greenshield, and Peter E. Tetlow, "Crud Control in Copper SX Plants," Engineering and Mining Journal, 193, No. 1, January 1992, pp. 32-33.

[85] Phelps Dodge Corporation. Op. Cit.

[86] U.S. Environmental Protection Agency, 1993d, Op. Cit., p. 54.

[87] RTI Survey 100750, National Survey of Solid Wastes from Mineral Processing Facilities, Magma Copper Co., San Manuel, AZ, 1989.

[88] Tom Burniston, James N. Greenshield, and Peter E. Tetlow, 1992, Op. Cit., p. 34.

[89] U.S. Environmental Protection Agency Telephone Questionnaire. Op. Cit.

Raffinate or barren leachate. This waste is generated when the pregnant leachate is stripped and is recycled back to the leaching circuit. Approximately 70,036,000 metric tons of raffinate is generated annually.[90,91] At the Phelps Dodge Corporation raffinate is recycled for its copper content and is reused in the leach system because of its acidity.[92]

Spent kerosene. Commonly used as the organic material in solvent extraction, spent kerosene is purified using filter clay. The resulting impurities or "grungies" are sent to the dump-leaching area, sent off-site for precious metals recovery, sent to the raffinate pond, or are disposed of with tailings.[93] The Phelps Dodge Corporation recycles the spent kerosene for reuse in the solvent extraction operation.[94]

2. Mineral Processing Wastes

Smelting and Refining operations generate numerous solid, liquid, and gaseous wastes, several of which are Bevill Exempt wastes including **furnace slags**, **anode casting slags**, and **wastewater treatment sludges**. Other wastes are described below.

Spent bleed electrolyte. Spent electrolyte results from electrolytic refining in electrolytic cells. Normally, spent electrolyte is purified in liberator cells. Liberator cells are similar to normal electrolytic cells, but they have lead anodes instead of copper anodes. The electrolyte is cascaded through the liberator cells, and an electric current is applied to strip the electrolyte of copper. Copper in the solution is deposited on copper starting sheets (cathodes). As the copper in the solution is depleted, the quality of the copper deposited is lowered. Copper liberator cathodes, which contain impurities, are returned to the smelter to be melted and cast into anodes. Purified electrolyte is recycled to the electrolytic cells. Any bleed electrolyte can be neutralized with mill tailings and disposed of intailing ponds or pumped to a raffinate pond, from which it is pumped to on-site copper leaching dumps. Sludge that settles to the floor of the liberator cell is returned to the smelter or sold.[95,96]

Site-specific management information is available for several companies. Cyprus Miami Mining Corp. in Claypool, AZ recycles the bleed electrolyte to the solvent extraction plant.[97] Magma Copper Company's San Manuel facility recycled the bleed electrolyte to the solvent extraction/electrowinning plant for copper recovery.[98] At one

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[90] The 1992 NIMPW Characterization Data Set indicates that 70,036,000 metric tons of raffinate are generated annually. We are currently trying to verify this number and will revise it in the near future (if appropriate).

[91] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[92] Phelps Dodge Corporation. Op. Cit.

[93] U.S. Environmental Protection Agency, 1993d, Op. Cit., pp. 114-115.

[94] Phelps Dodge Corporation. Op. Cit.

[95] U.S. Environmental Protection Agency, Revised Draft Wastes from Primary Copper Processing Characterization Report for Cyprus Miami Mining Corporation, Claypool, AZ, Office of Solid Waste, May 1991, p. 5.

[96] U.S. Environmental Protection Agency, Draft Overview of Solid Waste Generation, Management, and Chemical Characteristics in the Primary Copper Smelting and Refining Industry, Industrial Environmental Research Laboratory, Office of Research and Development, October 1984, p. 3-12.

[97] RTI Survey 100156, National Survey of Solid Wastes from Mineral Processing Facilities, Cyprus Miami Mining Corp., Clay Pool, AZ, 1989.

[98] RTI Survey 100750, 1989, Op. Cit.

time Kennecott Utah Copper's Bingham Canyon, UT facility treated the bleed electrolyte in its wastewater treatment plant.[99] It is now routed to the hydrometallurgical plant where it is used as reagent/raw material for metal recovery.[100]

At the Phelps Dodge Refinery in El Paso, electrolyte is withdrawn from tankhouse circulation and sent to the nickel sulfate plant for copper and nickel recovery. The process Phelps Dodge uses is similar to the above description except for the following steps. Liberator sludge is sent to the smelter for metal recovery and the copper-free solution is evaporated to concentrate the nickel salts. The precipitated nickel sulfate is separated from the concentrated sulfuric acid solution by centrifuging. While the nickel sulfate crystals are marketed, the concentrated spent sulfuric acid is disposed off site at a permitted deep-well injection facility.[101]

Approximately 307,000 metric tons of bleed electrolyte are generated annually. Bleed electrolyte exhibits the hazardous characteristics of toxicity (for arsenic, cadmium, chromium, lead, selenium, and silver) and corrosivity.[102] This partially recycled waste stream was formerly classified as a spent material. Additional data are included in Attachment 1. Spent bleed electrolyte is believed not to be land stored.[103]

Tankhouse slimes. Often referred to as "anode slimes", tankhouse slimes are the result of material deposition in electrolytic cells. Slimes contain the constituents in a copper anode that remain insoluble during the electrorefining process and ultimately settle to the bottom of the cells.[104] Generally, slimes generated from copper refining of various ores have the same values and impurities, including gold, silver, platinum group metals, copper, selenium, arsenic, tin, lead, and tellurium. However, their metals concentrations may vary widely, depending on the ore from which the copper anodes have been obtained. The raw slimes always have high copper contents, and the selenium content is also usually high. Therefore, normal slime treatment includes initial decopperization of the slimes, followed usually by deselenization. Traditionally, these slimes are then sent to smelting in a doré furnace, followed by refining.[105] A new method of metals recovery gaining popularity is wet chlorination, which uses chlorination and solvent extraction to recover these values.[106] These materials often contain valuable quantities of precious metals and are either processed on-site or are drummed and sent off-site for recovery. Approximately 4,000 metric tons of tankhouse slimes are generated annually.[107] Although EPA found no published information regarding waste characteristics, we used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for selenium, silver, arsenic and lead. This partially recycled waste stream was formerly classified as a by-product.

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[99] RTI Survey 100834, National Survey of Solid Wastes from Mineral Processing Facilities, Kennecott Utah Copper, Bingham Canyon, UT, 1989.

[100] Kennecott Corporation. Op. Cit.

[101] Phelps Dodge Corporation. Op. Cit.

[102] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[103] Exhibit 1. Op. Cit.

[104] James E. Hoffmann, "Advances in the Extractive Metal Metallurgy of Selected Rate and Precious Metals," Journal of Mines, 43, No. 4, 1991, pp. 22-23.

[105] M. Devia and A. Luraschi, "A Study of the Smelting and Refining of Anode Slimes to Doré Metal," Copper 91 (Cobre 91), Ottawa, Ontario, Canada, 18-21 Aug. 1991, Pergamon Press, Inc., New York, 1992 p. 210.

[106] James E. Hoffmann, 1991, Op. Cit., p. 23.

[107] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

The Phelps Dodge Corporation's refinery in El Paso processes tankhouse slimes in its slimes treatment plant. Treatment includes the removal of copper and tellurium, followed by deselenization through roasting. The selenium-free calcine residue from the roasters is transferred to the precious metals plant, where it undergoes a wet chlorination leach and solvent extraction for precious metals recovery. Recovery of precious metals involves leaching with calcium nitrate to dissolve the contained silver, and electrowinning of the filtered silver nitrate solution to produce high purity silver crystals. These crystals are melted in a silver-induction furnace and cast into silver ingots. The silver-free calcine residue is leached. The residue is sent to the smelter for recycling and the liquor containing dissolved gold is delivered to the solvent extraction process. The resulting high purity gold sand, which is washed with dilute hydrochloric acid and alcohol, is melted in a gold induction furnace and cast into gold bars. A platinum-palladium cake is produced from the raffinate, and the residual precious metals (gold, platinum and palladium), rhodium, selenium and tellurium are removed by reduction with hydrazine. The hydrazine cake is returned to the autoclave at the slimes plant for recycling until the concentrations of platinum and palladium give the cake a red color, at which time it can be sold as platinum-palladium sponge.[108] Tankhouse slimes are believed not to be land stored.[109]

Acid plant blowdown. This waste originates in the gas cleaning section of the acid plant. It is generated from the water spraying of smelter converter gases and consists largely of smelter feed carryover solids. Blowdown has been reported to contain 14 percent sulfate, 15 percent total dissolved solids, 1 percent copper, 1 percent iron and 70 percent water.[110] Acid plant blowdown also may contain significant concentrations (i.e., >1,000 mg/L) of arsenic, cadmium, lead, molybdenum, and selenium (additional data are included in Attachment 1).[111] Approximately 4,847,000 metric tons of acid plant blowdown are generated annually. This waste exhibits the characteristics of toxicity (for arsenic, cadmium, chromium, lead, mercury, selenium, and silver) and corrosivity.[112] This partially recycled waste was formerly classified as a by-product.

Site-specific management information is available for several facilities. Four of the seven primary copper facilities generating acid plant blowdown (ASARCO Inc.'s Hayden, AZ and El Paso, TX plants; Cyprus Miami in Claypool, AZ; and Phelps Dodge Corporation in Hurley, NM) beneficially recycle all of the acid plant material for metals recovery, and thus do not generate K064. A fifth facility (Kennecott in Garfield, UT), currently generates calcium sulfate wastewater treatment plant sludge, a special mineral processing waste excluded from RCRA Subtitle C regulation under the Bevill Amendment, but is planning process changes that will result in the elimination of that waste stream in favor of metals recovery from acid plant blowdown. The two remaining primary copper facilities generating acid plant blowdown (Phelps Dodge in Hidalgo, NM; and BHP Copper (formerly Magma Copper) in San Manuel, AZ) do not generate a sludge that meets the K064 listing description. Phelps Dodge treats its acid plant blowdown with lime in a series of tanks, and discharges the resulting calcium sulfate wastewater treatment sludge to double-lined surface impoundments equipped with monitoring wells, subject to the requirements of a state discharge plan. [113]

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[108] Phelps Dodge Corporation. Op. Cit.

[109] Exhibit 1. Op. Cit.

[110] U.S. Environmental Protection Agency, 1991, Op. Cit., pp. 5-7.

[111] U.S. Environmental Protection Agency, Study of Remanded Mineral Processing Wastes Draft Report, Office of Solid Waste, April 1994c, p. 19.

[112] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-3.

[113] National Mining Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, January 25, 1996.

Cyprus Miami Mining Corp. in Claypool, AZ recycles the solid fraction to the smelter and the liquid portion to the solvent extraction plant.[114] At the Phelps Dodge Hidalgo Smelter, radial flow scrubbers have been installed to minimize the volume of APB prior to neutralization of the APB with lime to create calcium sulfate sludge. The calcium sulfate sludge is sent to a series of double-lined ponds where the liquid phase is decanted and reused pursuant to New Mexico regulations.[115] Chino Mining Company in Hurley, NM neutralizes the blowdown with magnesium hydroxide in a settler. The solids are recycled to the smelter and the fluids are recycled to the concentrator.[116] At the Magma Copper Company's San Manuel, AZ facility, the blowdown is neutralized with alkaline tailings,[117] and the resulting mixture is sent to tailings dams.[118] Kennecott Utah Copper in Bingham Canyon, UT sends the blowdown to the hydrometallurgical plant where it is used as reagents/raw materials for metal recovery. [119]

Acid plant thickener sludge. This sludge results from the treatment of weak acid plant blowdown (see above). In the past, this waste stream generally was discharged to either a tailings pond or an evaporation pond. Recent site-specific information, addressing all Phelps Dodge facilities[120] and several others, however, indicates that this waste stream is no longer generated. Specifically, two facilities filter solids from the blowdown and blend the recovered solids with incoming copper ore for beneficiation/processing. The filtered blowdown is routed to an on-site electrowinning circuit for recovery of copper (and other metals). At a third facility, the blowdown is neutralized with ammonia, then filtered, and the resulting solids are blended with incoming ore. The majority of the filtrate is returned to the sulfuric acid plant for reuse as scrubber water, and the remaining portion of the filtrate is evaporated to recover ammonium sulfate product. At a fourth facility, the blowdown is neutralized with magnesium hydroxide, then filtered, and the resulting solids are blended with incoming ore. The filtrate is reused as make-up water in the flotation circuit. At a fifth facility, the blowdown is first neutralized with alkaline tailings and then discharged to a tailings pond (analysis of the neutralized blowdown indicates that it is not TC characteristic). At a sixth facility, the blowdown is neutralized with lime and then sent to a double-lined, Subtitle C evaporation pond. At a seventh facility, the blowdown is neutralized with lime, combined with other plant wastewaters, and then sent to an unlined evaporation pond (analysis of the combined wastewater indicates that it exhibits the TC characteristic for arsenic, lead, and selenium).[121] Additional data are included in Attachment 1.

Waste contact cooling water. This waste results from heat exchanging operations, such as those taking place at the smelter. The water used for anode cooling is reported to contain dissolved arsenic, copper, and zinc, and also to pick up aluminum and chlorides, probably from mold dressing compounds.[122] Site-specific management information is available for several companies. The Magma Copper Company's San Manuel, AZ facility recycles the

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[114] RTI Survey 100156, 1989, Op. Cit.

[115] Phelps Dodge Corporation. Op. Cit.

[116] RTI Survey 100495, National Survey of Solid Wastes from Mineral Processing Facilities, Chino Mining Co. Hurley, NM, 1989.

[117] BHP Copper. Op. Cit.

[118] RTI Survey 100750, 1989, Op. Cit.

[119] Kennecott Corporation. Op. Cit.

[120] Phelps Dodge Corporation. Op. Cit.

[121] U.S. Environmental Protection Agency, 1994c, Op. Cit., pp. 3-4.

[122] U.S. Department of Commerce, Industrial Process Profiles for Environmental Use: Chapter 29 Primary Copper Industry, Industrial Environmental Research Lab, July 1980. p. 89.

copper anode cooling water to the concentrator.[123] At Kennecott's facilities, waste contact cooling water is routed to the KUCC process water system. The water is used for process water, and ultimately discharged to the tailings impoundment, where it is pumped back into the process water system.[124] At Cyprus Miami Mining Corp., Claypool, AZ, contact cooling water is returned to the Industrial Water System.[125] According to the Phelps Dodge Corporation, waste contact cooling water may be clarified or distilled in a brine concentrator prior to reuse in the production process or as on-site irrigation water.[126] Approximately 13,000 metric tons of contact cooling water is generated annually.[127] Although EPA found no published information regarding waste characteristics, we used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for arsenic. This recycled waste stream was formerly classified as a spent material.

WWTP liquid effluent. Treated effluent from the wastewater treatment plant is either disposed of in the tailings surface impoundments or discharged through a NPDES permitted outflow, and therefore it is not included in the analysis. The Phelps Dodge Corporation reportedly recycles WWTP liquid effluent back into its operations.[128] Approximately 4,590,000 metric tons of WWTP liquid effluent is generated annually.[129] We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for lead. Additional data are included in Attachment 1.

Process wastewaters. Various processing wastewaters result from cooling and electrorefining operations. Water is used for many things, including seal water in crushers and pumps, and for dust suppression in low grade heat extraction from furnace cooling elements and acid plant coolers, sulfuric acid production, anode cooling, steam production, electricity production, potable drinking water, and conveyance of sanitary sewage.[130] Process wastewaters may either be treated on site at wastewater treatment facilities or discharged to tailings ponds, surface impoundments, or to receiving streams. At Claypool, process wastewater is limited to anode casting cooling water. It is mixed with cooling tower effluent and stored for later recycling back to the process.[131] At Magma Copper Company's San Manuel site, process wastewater from both the electrolytic refinery and the flash furnace is sent to an on-site tailings pond.[132] At Copper Range Co.'s White Pine facility, process wastewater consists of contact and non-contact cooling water. It is commingled with mill tailings and pumped to a tailings basin where the solids settle out. The water is then discharged through permitted outfalls.[133] Approximately 4,891,000 metric tons of process

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[123] RTI Survey 100750, 1989, Op. Cit.

[124] Kennecott Corporation. Op. Cit.

[125] U.S. Environmental Protection Agency, 1991, Op. Cit., p. 3.

[126] Phelps Dodge Corporation. Op. Cit.

[127] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[128] Phelps Dodge Corporation. Op. Cit.

[129] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[130] Christine P. Viecelli, "Comprehensive Water Management Program For a Primary Copper Smelter," Residues and Effluents - Processing and Environmental Considerations," The Minerals, Metals and Materials Society, 1991, p. 82.

[131] U.S. Environmental Protection Agency, 1991, Op. Cit., p. 5.

[132] RTI Survey 100750, 1989, Op. Cit.

[133] RTI Survey 101782, National Survey of Solid Wastes from Mineral Processing Facilities, Copper Range Co., White Pine, MI, 1989.

wastewaters are generated annually. This waste exhibits the hazardous characteristic of toxicity (for arsenic, cadmium, lead and mercury) and corrosivity.[134] We used best engineering judgement to determine that this waste may also exhibit the characteristics of toxicity for selenium. This recycled waste stream was formerly classified as a spent material. Additional data are included in Attachment 1. Hazardous process wastewaters are believed not to be land stored prior to reclamation.[135]

Scrubber blowdown. This waste results when low volumes of high total dissolved solids (TDS) materials are removed from the gas scrubbing system. At the Phelps Dodge Hidalgo smelter, electric furnace gases are cleaned in a scrubber. The resulting effluent is either neutralized and recycled, or utilized as acid plant scrubber liquor, and then neutralized with lime.[136] Chino Mining Company in Hurley, NM neutralizes the blowdown with magnesium hydroxide in a settler. The solids are recycled to the smelter and the fluids are recycled to the concentrator.[137] At Magma Copper company's San Manuel, AZ facility, Lurgi scrubber blowdown is usually recycled back through the concentrator. Only during mechanical failure, or insufficient mill capacity does the solution become mixed with acid plant blowdown and tailings for deposition on the tailings impoundments.[138] At Cyprus Mining Corporation, Casa Grande, AZ, scrubber blowdown resulting from tail gas cleaning operations using a double-contact alkali scrubber generates a slurry that is discharged to a 40-mil lined lagoon.[139] This waste exhibits the characteristic of toxicity for arsenic, cadmium, and selenium, and may also be toxic for mercury.[140] This partially recycled waste stream was formerly classified as a sludge. Although no published information regarding the waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 49,000 metric tons/yr, 490,000 metric tons/yr, and 4,900,000 metric tons/yr, respectively. Additional data are included in Attachment 1. Scrubber blowdown is believed not to be land stored.[141]

Discarded furnace and converter brick. This maintenance waste is periodically generated during rebuilding of the furnace and converters. At one facility, bricks are crushed and stockpiled for recycling to the sulfide mill where the copper is recovered through beneficiation. Furnace brick, at one location, was reported to contain 7 percent iron, 6 percent copper, 2 percent magnesium, and 1 percent phosphorus.[142] Approximately 3,000 metric tons of furnace brick is generated annually.[143] Revert (molten matte that is spilled during its transfer in the smelting process) also contains significant concentrations of copper and is returned to the crushing/grinding

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[134] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[135] Exhibit 1. Op. Cit.

[136] Phelps Dodge Corporation. Op. Cit.

[137] RTI Survey 100495, 1989, Op. Cit.

[138] RTI Survey 100750, 1989, Op. Cit.

[139] ICF Incorporated, Mineral Processing Waste Sampling Survey Trip Reports, Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, August 1989, p. 2.

[140] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

[141] Exhibit 1. Op. Cit.

[142] U.S. Environmental Protection Agency, 1991, Op. Cit., p. 7.

[143] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4.

circuit.[144] At one facility, the converter bricks are re-processed through the smelter while the furnace bricks are discarded. Some bricks may contain chromium above hazardous characteristic levels.[145]

APC dusts/sludges. Generated during smelting operations, these materials may contain significant concentrations of copper. These dusts/sludges are typically fed back to the smelter.[146] Site-specific management information is available for several companies. At Kennecott Utah Copper, Bingham Canyon, UT, previously only some of the copper-containing flue dust was returned to the smelting vessel; the majority of the flue dust was stockpiled for future recycling.[147] KUCC no longer stockpiles flue dust for future recycling. Formerly, stockpiled material which could not be processed in the hydrometallurgical plant was disposed of at a properly permitted disposal facility. Flue dust that is generated in the current process is automatically reprocessed for recovery of mineral values in the hydrometallurgical plant.[148] All APC dusts generated at Phelps Dodge have recoverable values, and are recycled.[149]

Alternatively, bismuth can be recovered from air pollution control solids. Specifically, in copper smelting, a portion of the bismuth is volatilized in the copper converter and captured along with such elements as lead, arsenic, and antimony as a dust in a baghouse or cottrell system. The dust is then transferred to a lead smelting operation. A major portion of the bismuth, however, also remains with the metallic copper. Therefore, during electrolytic refining of the copper, the bismuth accumulates in the anode slime and can be reclaimed during recovery operations.[150,151] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 222,000 metric tons/yr, and 450,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for arsenic. This fully recycled waste stream was formerly classified as a sludge. APC dusts/sludges are believed not to be land stored and are fully recycled.[152]

Surface impoundment waste liquids. The liquids sent to surface impoundments frequently contain mixtures of tailings and process wastewater (such as slag concentrate filtrate), which may have been treated in a wastewater treatment plant. Often the solids are allowed to settle out, and the liquids are discharged through permitted outfalls. Approximately 615,000 metric tons of surface impoundment liquids are generated annually. This

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[144] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 11.

[145] U.S. Environmental Protection Agency, Trip Report -- Site Visit to Magma Copper and Cyprus Miami Copper Mines," Draft Memorandum, Office of Solid Waste, April 1994b.

[146] Gavin, P. Swayn, Ken R. Robilliard, and John M. Floyd, "Applying Ausmelt Processing to Complex Copper Smelter Dusts," Journal of Mines, 45, No. 8, 1993, p. 35.

[147] ICF Incorporated, 1989, Op. Cit., p. 2.

[148] Kennecott Corporation. Op. Cit.

[149] Phelps Dodge Corporation. Op. Cit.

[150] "Indium and Bismuth," ASM International Materials Handbook, Tenth Edition, Vol. 2: Properties and Selection: Non-ferrous Alloys and Special-Purpose Materials, 1990, p. 753.

[151] Funsho K. Ohebuoboh, "Bismuth-Production, Properties, and Applications," Journal of Mines, 44, No. 4, 1992. pp. 46-49.

[152] Exhibit 1. Op. Cit.

waste exhibits the hazardous characteristic of corrosivity.[153] We used best engineering judgement to determine that this waste may also exhibit the hazardous characteristic of toxicity for arsenic, lead, and selenium. Also, we used best engineering judgement to determine that this waste stream is partially recycled. This waste was formerly classified as a spent material. Additional data are included in Attachment 1.

Chamber solids/scrubber sludge. Approximately 31,000 metric tons of chamber solids and scrubber sludges are generated annually from smelting on refining processes.[154] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent black sulfuric acid sludge. This material is obtained from the vacuum evaporation of decopperized electrolyte. The black acid liquor may also be used in leaching operations or be sold to fertilizer manufactures.[155] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

WWTP sludge. This sludge results from the neutralization of process waters using magnesium hydroxide or lime. This material is generated by the Phelps Dodge Hurley facility, which uses magnesium hydroxide, and the Phelps Dodge Hidalgo smelter, which uses lime.[156,157] Approximately 6,000 metric tons of solids and sludges are generated annually.[158] Although no published information regarding waste characteristics was found, we used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium and lead. This partially recycled waste stream was formerly classified as a sludge. Additional data are included in Attachment 1.

Attachment 2 contains a summary of the operational history and environmental contamination documented at several former copper production sites that are now on the Superfund National Priority List.

D. Non-uniquely Associated Wastes

Non-uniquely associated hazardous wastes may be generated at on-site laboratories and include chemicals, liquid samples, and ceramics/crucibles which are disposed of off-site at commercial hazardous waste facilities. Other hazardous wastes may include spent paints and solvents (non-chlorinated solvents such as "140 Stoddard" and petroleum naphtha, and "Safety Kleen" solvents) generated from facility maintenance operations, and spent batteries. Waste oil also may be generated, and might be hazardous. Non-hazardous wastes are likely to include sanitary wastewater, power plant wastes (such as run-off from coal piles and ash), and refuse.

Finally, spent catalysts (vanadium pentoxide) are generated in the acid plant. Acid plants at copper smelters are ancillary operations that produce sulfuric acid from sulfur-rich smelter emissions. The spent vanadium pentoxide

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[153] Funsho K. Ohebuoboh, 1992, Op. Cit.

[154] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-4

[155] U.S. Environmental Protection Agency, 1984, Op. Cit., p. 3-12.

[156] U.S. Environmental Protection Agency, 1992, Op. Cit., p. 13-74.

[157] Phelps Dodge Corporation. Op. Cit.

[158] U.S. Environmental Protection Agency, 1992, Op. Cit.

catalyst is not unique to copper smelter acid plants, and is either sent off-site for recycling for the silica values,[159] or disposed of either on- or off-site.[160]

E. Summary of Comments Received by EPA

The Agency received information from nine public commenters on the MPSR's description of the copper sector. (COMM36, COMM38, COMM40, COMM46, COMM58, COMM67, COMM73, COMM1085, COMM1090) The Agency appreciates this information and has used it to update the summary of facilities, the general process description, and the process waste streams description as included in sections B, C and D above.

New Factual Information

Three commenters provided new factual information that has been incorporated into sections B, C and D above. One commenter identified the following materials as being recycled back into their processing operations: raffinate, spent kerosene and WWTP effluent. (COMM38) One commenter stated that electrowinning produces lead containing slimes and not precious metals laden slimes. (COMM67) One commenter stated that the process wastewaters listed in the mineral processing section are actually beneficiation wastewaters. (COMM58) Seven commenters provided new process description information. (COMM38, COMM40, COMM58, COMM67, COMM46 ,COMM67, COMM40) One commenter provided a correction for the classification of scrubber blowdown. (COMM67) Two commenters provided information on their sites' locations. (COMM38, COMM40) One commenter corrected a description of the disposal of crud (COPMM38) Three commenters made the distinction between sulfide ores which are pyrometallurgically processed versus oxide and low-grade sulfide ores which are hydrometallurgically processed. (COMM38, COMM58, COMM67) One commenter clarified that calcium sulfate sludge has a variable water content. (COMM38) One commenter included an alternate definition of slime. (COMM38) One commenter stated that asbestos and PCBs are not hazardous wastes under RCRA. (COMM38) Two commenters made corrections to the process flow diagram. (COMM58, COMM67) One commenter added to the description of anode copper. (COMM67)

Sector-specific Issues

Seven commenters asserted that slimes, muds, crud, raffinate, barren leachate solution and spent kerosene are uniquely associated. (COMM36, COMM38, COMM40, COMM46, COMM58, COMM67, COMM73) The Agency agrees with these commenters and has changed the MPSR accordingly. One commenter criticizes the generic nature of the process waste descriptions. The Agency acknowledges this fact and will modify the MPSR as necessary. (COMM67)

The Agency received comments on numerous issues on which the Agency decided no action was required. These issues include: the interpretation of the beneficiation/processing line (COMM40, COMM46); classifying wastes on a site specific basis (COMM67); the reinterpretation of existing regulatory interpretations (COMM67); report text about primary and secondary smelting that could be interpreted incorrectly (COMM67); the basis for determining beneficiation/processing line (COMM67); the Agency's use of best engineering judgment in making toxicity determination of waste streams (COMM38, COMM58, COMM67); the validity that WWTP effluent is toxic for lead (COMM38); surface impoundment wastes are not wastes since they are reused (COMM38); the aggregation of process wastewater streams in determining hazardous characteristics (COMM67); the classification of converter and anode slags (COMM38); relevance and basis for text in report regarding copper supply and demand (COMM38); the classification of tankhouse slimes as wastes since they contain valuable mineral resources (COMM38); the classification of waste contact cooling water as a waste discourages recycling (COMM38); the classification of APC dusts as wastes, since they are reclaimed in smelters (COMM38); the recycling of process related residues and sludges (COMM46); the classification of waste contact cooling water as a spent material (COMM67); the classification of reused sulfuric acid as a spent material (COMM67); the classification of APC

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[159] Phelps Dodge Corporation. Op. Cit.

[160] U.S. Environmental Protection Agency, 1994b, Op. Cit., p. 12.

sludge should be as a by-product (COMM67); the "Surface Impoundment Waste Liquids" section duplicates information in other sections (COMM67); the lack of identification of a waste referred to as "surface impoundment waste liquid" on page 940 in Appendix D of the MPSR (COMM67); the multiple grinding and flotation of the clay portion of ore is not recycling (COMM67); the Agency's distinction between tailings and slimes (COMM67); the term "ancillary" as applied to vanadium pentoxide catalyst (COMM67); the case histories presented in attachment 2 (COMM67); the inadequate description of materials under the chamber solids/scrubber sludge heading (COMM67); the importance of recycling water in the flotation circuit (COMM38);classification of converter and anode slag as wastes (COMM38); the term waste rock (COMM38); the environmental impacts of leaching (COMM67); converter slag, furnace brick, refinery bleed solution, wastewater sludge being reused within 48 hours of generation is unpractical or impossible (COMM36, COMM67, COMM1085, COMM1090); containers are use to transport slag but not for storage (COMM67); slags are not susceptible to weathering, blowing or erosion (COMM67, COMM40); continuous closed loop recycling of spent electrolyte (COMM46); the alternative feedstock restriction ignores the operation needs of copper smelters (COMM38); spent kerosene should not a waste (COMM67).

One commenter questioned how the generation rate of waste was used in determining the beneficiation/ processing line. (COMM67) The generation rate was applied to determine high volume/low toxicity wastes only after primary mineral processing was determined to occur.

One commenter stated that slimes be reclassified as co-products and furnace and converter bricks be reclassified as in-process materials. (COMM67) Because slimes require significant processing to recover the precious metal values, they are not co-products. Bricks clearly are spent materials.

One commenter stated that the reuse of acid solution from the SMOC process might be a use constituting disposal. (COMM67) This is not a use constituting disposal if the reuse is a legitimate operation and meets the condition of recovering one or more of the following: metals, acid, water or cyanide.

One commenter cautions the Agency that ore should not be classified as having "high" or "low" value. (COMM67) The Agency disagrees with this commenter because many facilities have written to state that they use hydrometallurgical processes specifically on *low* grade sulfide ores. Without this terminology, it would be impossible to make this distinction.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT BLEED ELECTROLYTE - COPPER

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	6.20	145.04	356.00	5/5	10.00	139.73	361.00	3/3	-	-
Antimony	23.20	203.50	565.00	9/9	20.50	67.37	98.50	3/3	-	-
Arsenic	0.02	2,218.50	11,500.00	10/10	10.00	347.00	1,100.00	4/4	5.0	4
Barium	0.25	7.19	18.00	3/4	0.40	5.23	10.00	3/4	100.0	0
Beryllium	0.03	0.36	1.00	2/3	0.05	0.68	1.00	2/3	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.03	0.52	1.00	3/4	0.02	1.27	3.07	4/4	1.0	3
Chromium	0.84	12.59	38.00	4/4	0.80	5.55	10.00	4/4	5.0	2
Cobalt	1.90	39.15	124.00	4/4	1.69	55.56	126.00	3/3	-	-
Copper	10.00	26,787	120,380	14/14	485.00	10,991.25	22,200.00	4/4	-	-
Iron	54.30	386.54	1,360.00	8/8	89.40	443.85	1,390.00	4/4	-	0
Lead	0.25	19.68	90.60	6/6	0.25	3.20	5.00	3/4	5.0	2
Magnesium	9.13	196.76	503.00	4/4	14.40	195.53	505.00	3/3	-	-
Manganese	0.62	9.04	32.60	4/4	0.79	11.43	33.00	4/4	-	-
Mercury	0.0001	0.0050	0.0100	3/4	0.0001	0.0019	0.0062	2/4	0.2	0
Molybdenum	0.25	62.58	187.00	2/3	0.50	67.83	193.00	2/3	-	-
Nickel	10.00	6,357.30	33,050.00	10/10	10.00	200.67	365.00	3/3	-	-
Selenium	0.01	4.25	10.60	5/5	0.01	7.18	10.00	4/4	1.0	3
Silver	0.23	2.75	10.00	3/4	0.19	5.17	10.00	3/4	5.0	2
Thallium	1.25	17.92	50.00	2/3	2.50	34.17	50.00	2/3	-	-
Vanadium	0.25	3.58	10.00	2/3	0.50	6.83	10.00	2/3	-	-
Zinc	2.73	25.84	62.40	5/6	2.73	28.48	63.00	4/4	-	-
Sulfate	18,301	218,273	786,653	11/11					-	-
Fluoride	1.00	1.00	1.00	1/1					-	-
Chloride	32.50	121.63	285.00	6/6					-	-
TSS	95,650	224,330	308,000	5/5					-	-
pH *	1.00	1.93	2.72	4/4					2<pH>12	3
Organics (TOC)	7.29	153.63	382.00	3/3					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - ACID PLANT BLOWDOWN - COPPER

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	1.16	870.32	5,200.00	8/8	0.78	750.39	1,500.00	2/2	-	-
Antimony	0.26	36.44	140.00	2/4	0.17	2.58	5.00	1/2	-	-
Arsenic	0.05	855.76	5,800.00	10/15	0.04	884.35	12,800	12/15	5.0	10
Barium	0.05	1.38	5.90	7/12	0.05	2.54	10.90	8/15	100.0	0
Beryllium	0.005	0.07	0.13	1/2	0.01	0.25	0.50	0/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.20	62.93	620.00	16/16	0.05	4.28	24.50	14/15	1.0	9
Chromium	0.10	3.62	21.00	14/14	0.00	0.41	5.00	11/15	5.0	1
Cobalt	0.02	3.35	9.00	4/5	0.05	5.03	10.00	1/2	-	-
Copper	1.80	3,151.86	40,000	20/20	1.89	144.53	1,190.00	9/9	-	-
Iron	7.90	2,402.62	10,000	12/12	0.22	103.82	1,010.00	10/10	-	-
Lead	0.20	1,061.28	17,900	19/19	0.04	2.83	6.74	13/15	5.0	3
Magnesium	2.10	638.49	2,070.00	10/10	60.60	1,015.30	1,970.00	2/2	-	-
Manganese	0.05	40.61	140.00	8/9	0.02	10.20	100.00	7/10	-	-
Mercury	0.00	0.32	1.50	6/11	0.0001	0.0426	0.3100	8/15	0.2	2
Molybdenum	0.50	70.68	390.00	5/6	5.91	15.86	25.80	2/2	-	-
Nickel	0.01	221.33	1,450.00	10/11	0.02	1.83	5.00	2/3	-	-
Selenium	0.00	78.97	1,000.00	6/13	0.01	1.21	7.63	11/15	1.0	3
Silver	0.00	11.52	124.00	6/11	0.01	0.41	5.00	6/15	5.0	1
Thallium	0.25	1.38	2.50	0/2	0.25	8.50	25.00	0/3	-	-
Vanadium	0.05	1.39	2.72	1/2	0.05	2.53	5.00	0/2	-	-
Zinc	5.10	1,737.16	10,000	13/13	3.16	100.70	467.00	10/10	-	-
Sulfate	766.00	23,198	135,570	12/12					-	-
Fluoride	20.60	761.02	1,780.00	6/6					-	-
Chloride	0.10	793.01	2,740.00	6/7					-	-
TSS	170.00	13,593.70	58,600.00	5/5					-	-
pH *	0.99	2.21	5.00	17/17					2<pH>12	10
Organics (TOC)	1.39	436.30	1,300.00	3/3					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - ACID PLANT THICKENER SLUDGE - COPPER

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	200.00	1,600.00	3,000.00	2/2	-	-	-	0/0	-	-
Arsenic	90.00	2,795.00	5,500.00	2/2	0.18	52.44	193.00	7/7	5.0	5
Barium	400.00	2,700.00	5,000.00	2/2	0.04	3.69	10.90	5/7	100.0	0
Beryllium	-	-	-	0/0	45.00	45.00	45.00	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	250.00	1,875.00	3,500.00	2/2	0.16	7.97	24.50	6/6	1.0	4
Chromium	50.00	760.00	1,470.00	1/2	0.00	0.03	0.17	7/7	5.0	0
Cobalt	20.00	210.00	400.00	2/2	-	-	-	0/0	-	-
Copper	21,000	89,500	158,000	2/2	-	-	-	0/0	-	-
Iron	39,000	163,000	287,000	2/2	0.22	23.50	150.00	7/7	-	-
Lead	56,000	275,500	495,000	2/2	0.04	1.94	3.80	7/7	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	0.03	0.36	1.03	4/5	-	-
Mercury	-	-	-	0/0	0.0003	0.1038	0.3100	4/6	0.2	2
Molybdenum	50.00	625.00	1,200.00	2/2	-	-	-	0/0	-	-
Nickel	40.00	1,355.00	2,670.00	2/2	-	-	-	0/0	-	-
Selenium	5.00	307.50	610.00	1/2	0.03	0.24	0.61	7/7	1.0	0
Silver	67.30	217.00	366.70	2/2	0.02	0.04	0.10	2/5	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	2,230	13,315	24,400	2/2	3.16	193.64	500.00	7/7	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	10.00	740.00	1,470.00	2/2					-	-
Chloride	620.00	9,310	18,000	2/2					-	-
TSS	-	-	-	0/0					-	-
pH *	1.81	1.81	1.81	1/1					2<pH>12	1
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT LIQUID EFFLUENT - COPPER

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.798	0.798	0.798	1/1	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	0.002	0.151	0.300	2/2	-	-	-	0/0	1.0	0
Chromium	0.023	0.023	0.023	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	130.00	130.00	130.00	1/1	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.050	3.53	7.00	2/2	-	-	-	0/0	5.0	0
Magnesium	0.354	25.18	50.00	2/2	-	-	-	0/0	-	-
Manganese	0.060	0.060	0.060	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	0.011	0.011	0.011	1/1	-	-	-	0/0	-	-
Nickel	0.014	0.207	0.400	2/2	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.600	0.600	0.600	1/1	-	-	-	0/0	-	-
Sulfate	1889.00	2744.50	3600.00	2/2					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	740.00	1794.00	2848.00	2/2					-	-
pH *	3.10	7.48	11.80	5/5					2<pH>12	-
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PROCESS WASTEWATER - COPPER

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.050	1.23	7.71	7/7	0.05	1.02	4.91	5/5	-	-
Antimony	0.050	0.73	1.51	6/6	0.05	0.38	0.95	5/5	-	-
Arsenic	0.005	14.90	191.00	14/15	0.0003	4.75	23.20	11/12	5.0	3
Barium	0.005	27.57	318.60	12/12	0.0027	0.26	1.20	12/12	100.0	0
Beryllium	0.005	0.02	0.05	5/5	0.0050	0.01	0.01	5/5	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.0003	1.26	10.00	15/15	0.0050	7.31	32.00	12/12	1.0	5
Chromium	0.005	1.86	22.02	15/16	0.0001	0.12	0.53	12/12	5.0	0
Cobalt	0.010	0.15	0.50	6/6	0.0500	0.05	0.05	5/5	-	-
Copper	0.050	227.31	1,410.00	12/12	0.0500	159.88	664.00	7/7	-	-
Iron	0.090	957.33	8,466.00	8/9	0.0001	33.69	139.00	9/10	-	-
Lead	0.003	36.39	402.50	16/16	0.0020	1.39	7.30	12/12	5.0	1
Magnesium	0.221	485.67	3,643.00	8/8	3.3600	24.39	59.00	5/5	-	-
Manganese	0.050	8.03	63.07	8/8	0.0250	1.22	8.00	10/10	-	-
Mercury	0.0001	0.0010	0.0050	11/12	8.00E-07	0.1910	1.0600	5/11	0.2	2
Molybdenum	0.005	14.77	100.30	7/7	0.0500	0.51	2.33	1/5	-	-
Nickel	0.050	1.15	5.30	9/9	0.0500	0.15	0.40	3/6	-	-
Selenium	0.0005	0.55	7.00	15/15	0.0002	0.03	0.05	5/12	1.0	0
Silver	0.004	0.10	0.50	12/12	1.50E-05	0.03	0.05	11/12	5.0	0
Thallium	0.250	1.13	4.00	6/7	0.1000	0.32	0.81	6/6	-	-
Vanadium	0.050	0.18	0.50	5/5	0.0500	0.05	0.05	5/5	-	-
Zinc	0.01	8.72	42.00	11/11	0.0170	43.50	202.00	12/12	-	-
Sulfate	216.00	2,152.63	7,519.00	8/8					-	-
Fluoride	5.40	8.20	11.00	2/2					-	-
Chloride	28.40	363.39	1,862.00	7/7					-	-
TSS	1.50	55,080	270,800	13/13					-	-
pH *	1.35	6.37	8.50	28/28					2<pH>12	3
Organics (TOC)	0.60	257.13	1,280.00	5/5					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SCRUBBER BLOWDOWN - COPPER

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	1.84	1.84	1.84	1/1	1.63	1.63	1.63	1/1	-	-
Antimony	0.73	0.73	0.73	1/1	0.65	0.65	0.65	1/1	-	-
Arsenic	0.05	13.98	27.90	2/2	27.40	27.40	27.40	1/1	5.0	1
Barium	0.05	0.73	1.40	2/2	0.05	0.05	0.05	1/1	100.0	0
Beryllium	0.01	0.01	0.01	1/1	0.01	0.01	0.01	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	2.10	3.75	5.40	2/2	1.93	1.93	1.93	1/1	1.0	1
Chromium	0.17	0.28	0.40	2/2	0.17	0.17	0.17	1/1	5.0	0
Cobalt	0.05	0.05	0.05	1/1	0.05	0.05	0.05	1/1	-	-
Copper	4.90	4.90	4.90	1/1	3.05	3.05	3.05	1/1	-	-
Iron	11.50	11.50	11.50	1/1	9.50	9.50	9.50	1/1	-	-
Lead	4.90	11.60	18.30	2/2	4.88	4.88	4.88	1/1	5.0	0
Magnesium	15.80	15.80	15.80	1/1	14.80	14.80	14.80	1/1	-	-
Manganese	0.05	0.05	0.05	1/1	0.05	0.05	0.05	1/1	-	-
Mercury	0.01	0.49	0.98	2/2	0.022	0.022	0.022	1/1	0.2	0
Molybdenum	0.90	0.90	0.90	1/1	0.85	0.85	0.85	1/1	-	-
Nickel	0.47	0.47	0.47	1/1	0.44	0.44	0.44	1/1	-	-
Selenium	0.01	7.20	14.40	2/2	7.71	7.71	7.71	1/1	1.0	1
Silver	0.02	0.04	0.05	2/2	0.05	0.05	0.05	1/1	5.0	0
Thallium	0.25	0.25	0.25	1/1	0.25	0.25	0.25	1/1	-	-
Vanadium	0.05	0.05	0.05	1/1	0.05	0.05	0.05	1/1	-	-
Zinc	6.24	6.24	6.24	1/1	6.28	6.28	6.28	1/1	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	-	-	-	0/0					-	-
pH *	-	-	-	0/0					2<pH>12	-
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT LIQUIDS - COPPER

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	2.20	2.45	2.70	2/2	-	-	-	0/0	-	-
Arsenic	0.06	33.23	150.00	5/5	0.25	0.25	0.25	2/2	5.0	0
Barium	0.001	0.001	0.001	1/1	5.00	5.00	5.00	2/2	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	0.01	0.15	0.30	2/2	0.05	0.05	0.05	2/2	1.0	0
Chromium	0.02	1.61	4.00	3/3	0.25	0.25	0.25	2/2	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.01	25.41	90.00	7/7	-	-	-	0/0	-	-
Iron	0.63	48.21	88.00	3/3	-	-	-	0/0	-	-
Lead	0.03	2.11	7.00	4/4	0.25	0.25	0.25	2/2	5.0	0
Magnesium	0.10	2.77	4.20	3/3	-	-	-	0/0	-	-
Manganese	0.02	0.04	0.06	2/2	-	-	-	0/0	-	-
Mercury	0.0001	0.0001	0.0001	1/1	0.10	0.10	0.10	2/2	0.2	0
Molybdenum	0.72	1.76	2.80	2/2	-	-	-	0/0	-	-
Nickel	0.10	0.97	3.00	4/4	-	-	-	0/0	-	-
Selenium	0.02	3.08	9.00	3/3	0.05	0.05	0.05	2/2	1.0	0
Silver	0.02	0.02	0.02	1/1	0.25	0.25	0.25	2/2	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.11	0.57	1.00	3/3	-	-	-	0/0	-	-
Sulfate	1,250.00	6,908.25	18,842.00	4/4					-	-
Fluoride	17.00	17.00	17.00	1/1					-	-
Chloride	129.00	1,573.50	2,230.00	4/4					-	-
TSS	2,230.00	11,742.50	25,470.00	4/4					-	-
pH *	1.30	6.36	10.00	9/9					2<pH>12	2
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT SLUDGE - COPPER

Constituents	Total Constituent Analysis - PPM Minimum	Average	Maximum	# Detects	EP Toxicity Analysis - PPM Minimum	Average	Maximum	# Detects	TC Level	# Values In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	50,000	225,000	400,000	2/2	-	-	-	0/0	-	-
Iron	150,000	150,000	150,000	1/1	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	0	0	0	2/2					-	-
pH *	3.10	6.05	9.00	2/2					2<pH>12	-
Organics (TOC)	-	-	-	0/0					-	0

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

ATTACHMENT 2

MINING SITES ON THE NATIONAL PRIORITY LIST

Mining Sites on the National Priority List

Name of Site: Anaconda Smelter

Owner of Site: Anaconda Copper Mining Company (merged with ARCO in 1977)

Location of Site: Mill Creek, Montana (26 miles west of Butte)

Climate Data: To be determined

Commodity Mined: Copper

Facility History: The Anaconda Copper Mining Company first began copper smelting operations in 1884 at the "Upper Works" smelter. The Upper Works consisted of a concentrator and smelter buildings, which housed roasters and reverberatory furnaces, all connected to masonry flues and two smokestacks. By 1887, the company had expanded and built an additional smelter 1 mile east of the Upper Works. The new smelter was known as the "Lower Works". By 1889, an electrolytic copper refinery had been built as well, and was located between the two smelters. Due to shortage of smelting capacity, a larger, more efficient copper smelter was completed in 1902, and known as "Smelter Hill" or "Washoe Smelter". The Upper and Lower Works were subsequently demolished in 1903. The Washoe Smelter operated from 1902 to 1980.

Waste(s) at Issue: Copper ore processing has produced wastes that cover over 6,000 acres and contain elevated levels of arsenic, cadmium, copper, lead, and zinc. Wastes include 185 million cubic yards of tailings (pond); 27 million cubic yards of granulated slag (pile); and 0.25 million cubic yards of flue dust. Stack emissions have contaminated the soils near the smelter. Ongoing fugitive flue dust emissions (from piles) and fugitive dust emissions (from soil) have contaminated the community for over 100 years.

Disposal Sites: This site has 12 Operable Units, but only two have been investigated:
Mill Creek Operable Unit — Mill Creek is an unincorporated community located approximately 25 miles west-northwest of Butte, Montana. It covers 160 acres of land and consists of 37 household with less than 100 people. The contaminants of concern in this Operable Unit are arsenic, lead, and cadmium. Arsenic dust in the air, and arsenic, lead, and cadmium in the soil and drinking water present public health risks.
Flue Dust Operable Unit — flue dust is a fine grained waste material which was formed in the smelter flue. The dust contains high concentrations of arsenic, cadmium, copper, lead, and other metals. The amount of flue dust stored onsite, as of December 1989, was estimated to exceed 316,000 tons.

The other 10 Operable Units are as follows: Smelter Hill — former ore processing area. This Operable Unit has soil and ground water contamination by metals. Old Works — Wastes (tailings) are located in a 100-year floodplain along a 2.75 mile stretch of Warm Springs Creek. This area is the focus of a removal operation. In addition, waste piles and soils at the smelter site and surface water near the site will be sampled. Arbiter — a copper refining plant that produced cathode copper from sulfide ores using an ammonia leach process. Slurry wastes from this inactive plant contain arsenic, cadmium, lead, zinc, and are located in a pond near the plant. Beryllium Disposal Areas — a beryllium flake-metal pilot plant and a beryllium oxide pilot plant were operated on Smelter Hill between 1964 and 1968. Following closure, waste containing beryllium was disposed of in the Opportunity tailings pond. Community soils — nearby community soils contaminated by smelter emissions. Slag — slag is the material separated from the metal during refining process; it consists of 85% silica dioxide (sand) and 15% iron oxide. Tailings/Alluvium

— tailings make up the largest volume of waste at this site and are deposited in both the Anaconda and Opportunity ponds. The Opportunity ponds stretch 3 miles across from east to west. Regional Soils — contaminated agricultural lands surrounding the site. Regional Ground Water — ground water which have been contaminated from sources such as the Opportunity ponds, slag piles, tailings, and contaminated soils. Surface water and sediment — tailings have migrated into streams near the site.

Soil Pathway: It was discovered that the soil contamination (by arsenic, cadmium, and lead) in Mill Creek was widespread. The geometric mean concentration of arsenic in Mill Creek surface soils is 638 mg/kg; for cadmium it is 25 mg/kg; and for lead it is 508 mg/kg. At a depth of 18 inches, concentrations of arsenic are below 100 mg/kg and approach background levels at 42 inches below the surface. High concentrations of cadmium and lead are also found in the first 6 inches of the soil profile. However, lead and cadmium concentrations decrease more rapidly with depth than arsenic concentrations. Cadmium levels were found to be less than detection limits at a depth of 9 inches, and lead levels reached background levels below 6 inches.

Ground Water Pathway: The water table underlying Mill Creek is 20 feet or deeper below the surface. Domestic well water is drawn from this aquifer. In 1986, sampling showed that seven household water supplies had detectable arsenic levels. Cadmium and lead levels were mostly at or below detection limits.

Surface Water Pathway: Mill Creek is the major drainage system is the area of the Anaconda Smelter and The Mill Creek community. Mill Creek was sampled four times and results showed that arsenic was present in the creek. Total arsenic concentrations ranged form 12 to 32.2 ug/l. Zinc was also detected in the waters of Mill Creek. Until transport of contaminated soil into Mill Creek is controlled or remedied, it is estimated that recontamination of Mill Creek will occur at a rate of 1.5 mg/kg of soil per year.

Air Pathway: In 1984, samples of airborne particulate matter were collected at four different locations near the smelter and tested for total suspended particulates, respirable particulates, and trace-metal content. Arsenic concentrations were found to be 0.1 mg/m^3. The highest arsenic concentration found at the Mill Creek station was 0.681 mg/m^3. Elevated levels of cadmium, lead, and arsenic were found in household dust samples as well. Residential dust showed an average concentration of 264 mg/kg arsenic, and indoor respirable arsenic concentrations were 0.019 ug/m^3.

Environmental Issues: The Anaconda Smelter site is located in the Upper Clark Fork Basin above Warm Springs Creek and the main stem of the Clark Fork River to the Bitterroot River below Missoula, Montana. In addition, the community of Mill Creek is immediately adjacent to this site. Therefore, contaminants from the Anaconda Smelter site (e.g., arsenic, lead) pose a potential risk to human health and the environment (e.g, aquatic life, drinking water).

Mining Sites on the National Priority List

Name of Site: Tex Tin Corporation

Owner of Site: Tex Tin Corporation

Location of Site: Texas City, TX (situated on 175 acres in an area of mixed land use)

Climate Data: Not given

Commodity Processed: Secondary copper smelting

Facility History: Originally operated by the U.S. Government during World Ward II as its primary tin smelting operation, the site was then acquired by the Associated Metals and Minerals Corporation from the Wah Chang Corporation in 1970 and became know as the Gulf Chemical and Metallurgical Company (GC&M). Since 1985, the company has been known as the Tex Tin Corporation. At one time, the facility was operated as an iron recovery facility, but it is currently engaged in the secondary smelting of copper. The Tex Tin site was added to the NPL in August 1990.

Waste(s) at Issue: Heavy metals (arsenic, tin, lead and nickel) found in onsite surface and ground water, and in ambient air sampled on and off the site.

Disposal Site: In 1977, the Tex Tin had three metals reclamation circuits: nickel sulfate, ferric chloride, and tin. Nickel sludge circuit - The nickel sludge was stored in drums in the north end of the smelter building. After smelting, waste sludge was sold for other metals recovery. A small quantity removed during vessel cleaning was dumped with the slag from the tin process. Ferric chloride circuit - The company was sold iron sludge contaminated with the herbicide Amiben. The material was stored in two areas (not specified). Runoff would flow through the plant to the pond system. A small quantity removed from the settling tank was disposed of in Acid Pond B. Tin ingots circuit - The product was received in the form of ore sacks (imported from Bolivia) which were stored on pallets by Ponds A and B, tin residues in 55-gallon drums which were stored in the ore storage building, and tin ore which were piled along Highway 519. After primary smelting, rich slag was stored onsite. End slag was produced after the electrolyte process and GC&M planned to install a new rotary furnace for secondary tin smelting. In 1979, the nickel circuit had been discontinued. Ferric chloride production had also decreased which caused GC&M to cease buying Amiben-contaminated iron sludge for use in this circuit. GC&M also stopped disposing of the settling-tank sludge in the acid pond. A rotary furnace was added to the tin circuit which resulted in material dumped north of the acid pond. Waste areas identified at the site have included wastewater treatment ponds, a gypsum slurry pond, an acid pond which once contained ferric chloride and hydrochloric acid, several drained acid ponds, slag, sludge, and ore piles. One of the slag piles is contaminated with the herbicide Amiben. The facility also stored approximately 4,000 drums containing radioactive material. At one time, the facility stored piles of spent catalyst in the anticipation of building a plant to extract metals such as tungsten. An inactive, licensed, low-level radioactive landfill, containing uranium/antimony slag, is also located onsite. The slag is from a pilot study on the extraction of bismuth from a bismuth-uranium catalyst. One other area of possible contamination, an abandoned oil-processing facility, has been identified on the Tex Tin property. The Morchem Resources facility was located on the northwestern portion of the site (then owned by GC&M) from 1982 to 1983. Morchem processed Luwa bottoms (high boiling-point glycols with 1% molybdenum) and waste oil from chemical and refining companies. The facility was abandoned in 1984. No other information is known about this facility.

Soil Pathway: Possible soil contamination is not well characterized. In 1980, EPA conducted a Potential Hazardous Waste Site Inspection. Piles of tin slag, iron ore, and crushed empty barrels were noted in the rear of the plant. A reddish material (possibly iron) was noted in the drainage ditch located close to the area of the material piles. One soil sample was collected by the Texas Department of Health's Bureau of Radiation Control near the low-level radioactive landfill in December 1984. The four metals detected were found to be at significantly elevated concentrations and considered a health concern. They include: antimony (2,590 ppm), arsenic (720 ppm), copper (130 ppm), and lead (980 ppm). The level of copper in the soil was not sufficiently elevated to represent a health concern.

Ground Water Pathway: The Chicot Aquifer underlies the site and extends from 60 feet to approximately 1,000 feet below the land surface. The flow is generally in a southeasterly direction towards Galveston Bay. Ground water in the vicinity of the acid pond was monitored from 1975 to 1980. The monitoring wells were screened at 37 to 47 feet below the ground surface. The contaminant concentrations detected were much higher from the downgradient wells' samples as compared to the upgradient well. Twelve metals were detected and determined to exceed drinking-water standards and long-term health advisories. The metals of concern and their maximum concentrations detected include: arsenic (0.198 ppm), barium (6.5 ppm), cadmium (7 ppm), chromium (0.25 ppm), copper (390 ppm), lead (200 ppm), manganese (357 ppm), mercury (0.011 ppm), nickel (7 ppm), silver (1.02 ppm), tin (100 ppm), zinc (140 ppm).

Surface Water Pathway: Inspections by the Texas Water Quality Board concluded that dikes designed to prevent discharges from two old outfalls and the acid pond were seeping, allowing contaminated water to enter Wah Chang Ditch. The ditch is currently pumped into the Texas City Industrial Channel, which enters Galveston Bay. Twelve surface water samples were collected from various locations at the facility between 1975 to 1988. The constituent of concern and their maximum detected levels include: arsenic (0.94 ppm), chromium (81 ppm), copper (60 ppm), mercury (0.02 ppm), nickel (535 ppm), zinc (42.7 ppm).

Air Pathway: In January 1986, air-quality monitoring samples were obtained along the site perimeter using high-volume particulate samplers. The conclusion reached after the sampling was that heavy metals and arsenic were being carried offsite by the wind. The maximum values of the detected contaminants were: arsenic (2.34 ug/m^3), cadmium (0.64 ug/m^3), chromium (0.40 ug/m^3), lead (4.42 ug/m^3), nickel (0.21 ug/m^3), and tin (103.6 ug/m^3).

Environmental Issues: Commercial businesses, residential areas, and petrochemical complexes are all located within 0.25 miles of the site. The saline Swan Lake is located approximately 2 miles from the site and is used primarily for recreational fishing and crabbing. A principal concern is the potential environmental contamination of surface waters through the transport of heavy metals into Chicot Aquifer, and drainage of contaminated water into Galveston Bay. Most drinking water is supplied municipally, however, a 1985 survey identified a small beach house community located approximately one mile southwest of the Tex Tin facility that uses private water wells. The community, consisting of approximately 60 homes, is supplied by 25 wells. While most of the wells are more than 200 feet deep, at least three of the wells are less than 105 feet deep and are in the Chicot Aquifer. Possible human routes of exposure were noted as ingestion, inhalation, and dermal contact with contaminated media. Inhalation and incidental ingestion of airborne particles of Tex Tin emissions or entrained dust have also been cited as potential pathways of concern. In addition, low levels of radioactivity have been detected onsite in association with the tin, copper, and antimony slags and with the company roads that have been graded with tin slag. According to the Bureau of Radiation Control, the radiation levels are well below Federal occupational exposure limits, but are approaching the upper limits of the range of levels generally considered safe for the general public.

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Mining Sites on the National Priority List

Name of Site: Torch Lake

Owner of Site: Not applicable

Location of Site: Keweenaw Peninsula of Upper Michigan (14 miles from Lake Superior)

Climate Data: Not given

Commodity Mined: Copper

Facility History: For over 100 years, the area surrounding Torch Lake was the center of Michigan's copper mining, smelting, and milling activities. Over 10.5 billion pounds of copper were processed in the area between 1868 and 1968. An estimated 5 million tons of copper were produced in the Keweenaw Copper District of Michigan from the 1960's to 1968. More than half of this was processed along the shores of Torch Lake. Mining activities in the lake area peaked between the early 1900's and 1920. By 1986, only one small copper recovery plant was still operating. Torch Lake was listed on the NPL in June 1988.

Waste(s) at Issue: At the mills, copper was processed and the recovered copper was sent to a smelter, while tailings were disposed of with process wastewaters into or on land around Torch Lake. In 1916, copper was recovered from previously discarded tailings in Torch Lake through an ammonia leaching process. Further technological advances initiated a flotation process using reagents consisting of 50 percent coal tar, 15 percent pyridine oil, 20 percent coal tar creosote, and 15 percent wood creosote. In 1926, xanthates were added to the reagents. Between 1868 and 1968, an estimated 200 million tons of tailings were pumped into the lake, reducing its volume by approximately 20 percent.

Disposal Site: The Torch Lake site has three operable units (OUs). OU1 includes surface tailings, contents of buried and submerged drums along the western shore of the lake, and industrial chemicals. OU2 includes potentially contaminated media in and around the lake. OU3 includes other tailings sources in the mid-Keweenaw Peninsula, including the North Entry, the northern portion of Portage Lake, and tributary areas.

Tailings: Mine tailings are divided into two categories. The first involves tailings resulting from crushing and gravitational separation processes. The resulting contaminants of concern are: arsenic, copper, lead, and zinc. The second category of tailings is a result of flotation reprocessing. The contaminants of concern associated with this category include: arsenic, copper, lead, zinc, and industrial chemicals (lime, pyridine oil, coal tar creosotes, wood creosote, pine oil, and xanthates). Surface and subsurface tailings samples were collected and analyzed. Fifty eight surface samples were collected from a 0- to 6-inch depth and density of 1 sample per 10 acres. Twelve subsurface samples were collected from a depth of 0 to 3 feet and at a density of 1 sample per 20 acres. The sampling analysis indicated that the concentration and distribution of metals appeared to be similar in both surface and subsurface samples. Copper concentrations were elevated above background soil concentrations (3,020 mg/kg surface and 5,540 mg/kg subsurface as compared to 100 mg/kg in native soils). In summary, however, neither organic or inorganic compound levels in tailings from OU1 were found to be dramatically higher than background soils. In 1989, the U.S. Bureau of Mines determined that leachate from Torch Lake mine tailings was extremely low in comparison to leachate from 30 other sites and they concluded that very little metal is being released from the tailings.

Drums: In 1989, buried and submerged drums in tailings piles were discovered and determined to have very low hazardous constituent concentrations as measured by EP Toxicity tests. PCBs and pesticides were not found above the detection limits in the samples. The eighth drum contained 4,000 ppm of trichloroethylene; and it is suspected that the contents of the drum are related to illegal dumping.

Soil Pathway: A limited soil investigation found that traces of tailings and slag were evident. The contaminants of potential concern and their maximum values detected include: aluminum (7,600 mg/kg), arsenic (7 mg/kg), barium (101 mg/kg), chromium (20.1 mg/kg), copper (459 mg/kg), lead (329 mg/kg), manganese (357 mg/kg), mercury (0.47 mg/kg), nickel (33.7 mg/kg), and vanadium (26.30 mg/kg). Soil samples from residential locations generally had concentrations of inorganic compounds an order of magnitude higher than background concentrations. The EPA Technical Assistance Team (TAT) also collected samples from the east side of Torch Lake and determined that the metals detected in the samples were all within typical soil background concentrations and below maximum concentrations for EP Toxicity.

Ground Water Pathway: The U.S. Geological Survey sampled well water in 1968 and 1977. Analysis of the 35 wells in Houghton County indicated that only 3 had specific conductance greater than 500 micromhos per centimeter. These results indicated Torch Lake as a high quality water source for general use. Many Torch Lake communities and seasonal residents get their water from municipal systems or from an independent supplier. In July 1989, EPA's TAT sampled seven private wells and two municipal wells. Only one location sampled had a concentration of either organic or inorganic compounds in excess of the Maximum Contaminant Levels (MCLs). The sample collected from the Lake Linden municipal well had an iron concentration of 0.33 ppm which is slightly greater than the Secondary MCL of 0.3 ppm for iron. Ground water contamination is to be discussed further in the ROD for OU2.

Surface Water Pathway: Water enters Torch Lake from the Trap Rock River, and Hammell, Dover, McCallum, and Sawmill Creeks. The Trap Rock River is the largest discharger into Torch Lake, and the Trap Rock River Watershed covers approximately 58 percent of the Torch Lake Drainage Basin. An estimated 2,000 kilograms per year of dissolved copper is transported through Trap Rock River and its tributaries into Torch Lake. Contamination of the surface water is to be addressed in the ROD for OU2.

Air Pathway: The Michigan Department of Resources (MDNR) collected air samples from four sampling locations (based on wind and population profiles) to monitor likely exposure points, emissions sources, and background conditions. Total Suspended Particulates (TSP) samples were collected for one month, for 24-hour periods every other day in 1989. Further analysis of the two samples indicating the highest concentration of TSP were further analyzed for arsenic, chromium, copper, nickel, lead, and zinc. The analysis indicated that mean ambient-air concentrations at the two sample stations exceeded background ambient-air concentrations for aluminum, arsenic, barium, copper, magnesium, iron, manganese, and TSP.

Environmental Issues: A century of mining waste deposition into Torch Lake created environmental concerns in the 1970's. In 1971, a discharge of cupric ammonium carbonate leaching liquor from the Lake Linden Leaching Plant occurred and MDNR reported discoloration of several acres of lake bottom. Further investigations found 15 water quality parameters with acceptable background ranges. Heavy metal concentrations in lake sediments were within background ranges, except for arsenic, chromium, zinc, and copper, which were all at elevated levels. Plant and benthic invertebrate analysis did not indicate any water quality changes. Three months later, the spill was cited as the cause of temporary depletion of oxygen, elevated copper levels, increased pH, and increased carbon alkalinity in the lake

and bioassays indicated toxicity to some macroinvertebrates. Changes in the dominant predator fish species and observance of abnormalities in certain fish species prompted a fish consumption advisory in 1983 for Sauger and Walleye caught in the lake. In the same year, the lake was designated as a Great Lakes Area of Concern (AOC). In 1988, the Agency for Toxic Substances and Disease Registry (ATSCR) concluded that the site is a potential public health concern because of possible exposure to unknown etiological agents that may create adverse health effects over time. The mine tailings contaminating Torch Lake have not been determined to cause known health effects, and there is no indication that human exposure is currently occurring or has occurred in the past.

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ELEMENTAL PHOSPHORUS

A. Commodity Summary

Phosphorus is the twelfth most abundant element, almost all of which occurs as salts of phosphoric acid. Phosphate rock deposits occur as marine phosphorites, apatite-rich igneous rock, and modern and ancient guano. Apatite minerals comprise the majority of phosphate constituents in phosphate rock. All domestic production is from marine phosphorites. According to the U.S. Bureau of Mines, nearly 93 percent of the phosphate rock sold or used by U.S. producers in 1991 was for the manufacture of wet-process phosphoric acid, single superphosphate, and triple superphosphate; the balance (approximately 7 percent) was used to produce elemental phosphorus.[1]

Solid elemental phosphorus exists in several allotropic forms -- white, red, and black. The most commercially important is white (elemental) phosphorus. Red phosphorus is also important commercially. Black phosphorus has been prepared only in a few laboratories.[2]

Phosphorus-based materials are used mostly in fertilizers, detergents, foods and beverages, and metal treatment coating. Elemental phosphorus is used as a process input to produce a wide array of phosphorus chemicals. Most phosphorus is converted to derivatives, including phosphorus sulfides and halides, phosphorus pentoxide, and phosphoric acid. Elemental phosphorus is used in the deoxidation and alloying of copper; and elemental phosphorus is used with ferrophosphorus in ferrous metallurgy. White phosphorus is also used in roach and rodent poisons, chemical warfare, and other military purposes. Generally, red phosphorus is made from white phosphorus. Red phosphorus is used for wooden and paper safety matches and in the manufacture of fireworks.[3]

According to the largest U.S. producer of phosphorus, there are four domestic producers of elemental phosphorus. FMC operates a facility in Pocatello, ID and Monsanto operates a facility in Soda Springs, ID. The remaining two facilities are owned and operated by the Rhone Poulenc Basic Chemical Company and the Occidental Chemical Company.[4] These are located Silver Bow, MT and Columbia, TN, respectively.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Phosphate rock is mined using both surface and underground mining techniques. A modern electric furnace process for the production of phosphorus consists of a sequence of four operations: preparing the furnace burden, charging and operating the furnace, collecting the liquid products, and collecting the gaseous products.[5]

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[1] David Morse, "Phosphate Rock," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 977-980.

[2] "Phosphorus and the Phosphides," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XVII, 1982, pp. 473-490.

[3] Ibid.

[4] FMC Corporation. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[5] Kirk-Othmer Encyclopedia of Chemical Technology. Op. Cit.

2. Generalized Process Flow Diagram

White Phosphorus

Exhibit 2 presents a process flow diagram for the production of white elemental phosphorus. The furnace burden must be porous enough to allow gases to escape from the reaction zone near the bottom of the furnace. Several agglomeration methods must be employed to prepare phosphate rock fines for the electric furnace. The fines must be sintered and then crushed to size and screened. Another agglomeration method is nodulizing. In this process, phosphate fines are heated in a rotary kiln to incipient fusion. The tumbling in the kiln causes the material to cohere and form spheroidal agglomerates. A final method of agglomeration is formation of pellets by tumbling. The pellets can then be calcined in a rotary kiln.[6]

The agglomerated phosphate rock is charged to an electric arc furnace with coke as a reductant and silica as a flux. The reduction generates a calcium silicate slag and ferrophosphorus, which are tapped, and carbon monoxide offgases that contain volatilized phosphorus. Dusts are removed from the offgases using dry separation techniques such as electrostatic precipitation, and phosphorus is removed by condensation in the presence of recirculation water above the melting point of phosphorus. The carbon monoxide gases are subsequently burned, and phosphorus is decanted from the water and stored for sale. The recirculating water is neutralized, and a purge of mud and soluble impurities is removed and disposed.[7]

Red Phosphorus

Although red phosphorus is usually manufactured by a batch process, continuous methods are now being used. In the batch process, white phosphorous is converted to red phosphorus in a steel or cast-iron vessel. The liquid phosphorus, which is protected by a layer of water, passes into the vessel, which then is closed. The vessel is heated gradually so that unconverted liquid phosphorus does not boil violently and erupt. A reflux condenser is used to retain the phosphorus. The mass remains fluid until almost half of the phosphorus has turned into red phosphorus. As the process continues, the mass thickens and solidifies. The mass is cooled and red phosphorus is removed. The material is then wet-ground and boiled with sodium carbonate solution to remove any traces of white phosphorus, which is flammable in air. The red phosphorus is sieved, washed on a rotary filter, vacuum dried, and stabilized by one of two methods. In the first method, red phosphorus is suspended in a sodium aluminate solution and then aerated. In the second method, magnesium oxide is precipitated onto the red phosphorus.[8]

FMC Facility Process[9]

FMC Corporation is the world's largest producer of elemental phosphorus, producing about 240 million pounds of elemental phosphorus per year. Under normal operating conditions, this process operates 24 hours per day, 365 days per year.[10] Because of the large quantities of elemental phosphorus produced here and the importance of this facility in the market, FMC's process is described below and a process flow sheet is presented in Exhibit 3. This information was provided by FMC. The Agency may not necessarily agree with FMC's characterization of its waste streams.

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[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] The processes discussed in this technical background document pertain to production at the FMC Pocatello, ID plant, and may not be fully representative of industry practices employed by the other three domestic phosphorous producers.

[10] FMC Corporation. Op. Cit. January 25, 1996.

Storage and Preparation of Raw Materials

Storage and preparation of raw materials consists of stockpiling; screening and crushing; briquetting; calcining; and proportioning of the shale ore, coke, and silica. Shale ore arrives at the plant by railcar and is unloaded by a rotary car dumper. The ore is conveyed to the stacker for distribution on one of two storage piles. Ore is then collected from the piles by a reclaimer which deposits it on a conveyer belt. The conveyor belt carries the ore to crushing and screening. Ore is first screened to remove oversized material and then crushed to a uniform size and sent to the briquetting process. Fugitive dust from screening and crushing is collected by three baghouses. The briquetting process presses the crushed material into briquettes similar to the size and shape of charcoal briquettes, which are fed to the calcining process. FMC Pocatello's calciners are sintering operations in which the briquetted shale is heated to form a coherent mass without melting. The calcining operation is therefore principally an agglomeration method. The process occurs in grate calciners in which the briquettes are carried on moving grates or pallets through the calcining zone where hot gases are pulled through the feed bed (the briquettes) and grate. Because the briquettes ride on the moving pallets they undergo little or no tumbling or other motion during this process. Water and carbon dioxide are given off during this process, but the temperatures are carefully controlled below the fusion point of the phosphate shale. Temperatures above the fusion point result in a phenomenon known as "fusing the bed" in which the briquettes on the pallets fuse into a single, rigid mass that cannot be handled in FMC's downstream material handling equipment. FMC calcines the ore for two reasons: (1) to harden the briquettes, thereby limiting briquette breakage; and (2) to drive off moisture content and carboniferous matter. (The carbon is driven off as carbon dioxide.) Calcining does not chemically alter the phosphate shale.

It is important to harden the briquettes during calcining to reduce breakage and allow proper flow of gaseous reaction products in the furnaces. Hardened (calcined) phosphate shale briquettes (nodules) are choke-fed into the furnace following mechanical conveyance and mixing with coke and silica. Significant breakage can occur to improperly hardened nodules during drops from one conveyor to the next and as the nodules are forced into the tops of the furnaces. Phosphate in the shale nodules, which is unchanged chemically during calcination from phosphate in the as-received mined shale, is reduced in the furnaces with coke to form elemental phosphorus and carbon monoxide. This occurs near the bottom of the furnaces in the plasma arcs at the tips of the carbon electrodes. Gas-phase reaction products, primarily elemental phosphorus and carbon monoxide, percolate up from the reaction zones through gas channels in the incoming bed of phosphate nodules, coke, and silica. Nodule fragments, formed by breakage from broken or improperly calcined briquettes, can plug these gas channels, interfering with proper, steady-state furnace operation.

It is also important to drive off water during calcining of the briquettes to prevent volatilization of steam in the high temperature furnaces and to prevent an unwanted side reaction involving water and elemental carbon. In the calciners, water content is reduced from about 11 percent in the incoming phosphate shale to less than 1 percent in the hardened briquettes or nodules. The dried and hardened nodules are conveyed and fed to the phosphorus furnaces, which operate at very high temperature. At the top, where the nodules, coke, and silica are being choke-fed, the temperature is about 400°C, while near the bottom, temperatures can reach 1500°C in the plasma-arc zones. If wet briquettes were allowed to enter the furnaces, steam would be uncontrollably and possibly explosively volatilized. At these temperatures, and in the reducing conditions found inside the furnaces, water and elemental carbon can undergo the watergas reaction to form hydrogen and carbon monoxide. This is a very destructive side reaction that can consume both coke, a reagent necessary for the reduction of phosphorus shale to elemental phosphorus, and the furnace electrodes and sidewall refractory bricks (both of which are solid carbon). Finally, water generated in the furnaces can cause increased corrosion in downstream process equipment.

Although less important than water removal, it is also necessary to drive off carboniferous material during calcination. Volatilization of these materials in the furnaces can create severe furnace pressure excursions. During calcining of phosphorus shale, quantities of low boiling point metals may be volatilized.[11]

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[11] FMC Corporation. Op. Cit. January 25, 1996.

EXHIBIT 2

ELEMENTAL PHOSPHORUS PRODUCTION

(Adapted from: Phosphorus, A Mineral Processing Waste Generation Profile.)

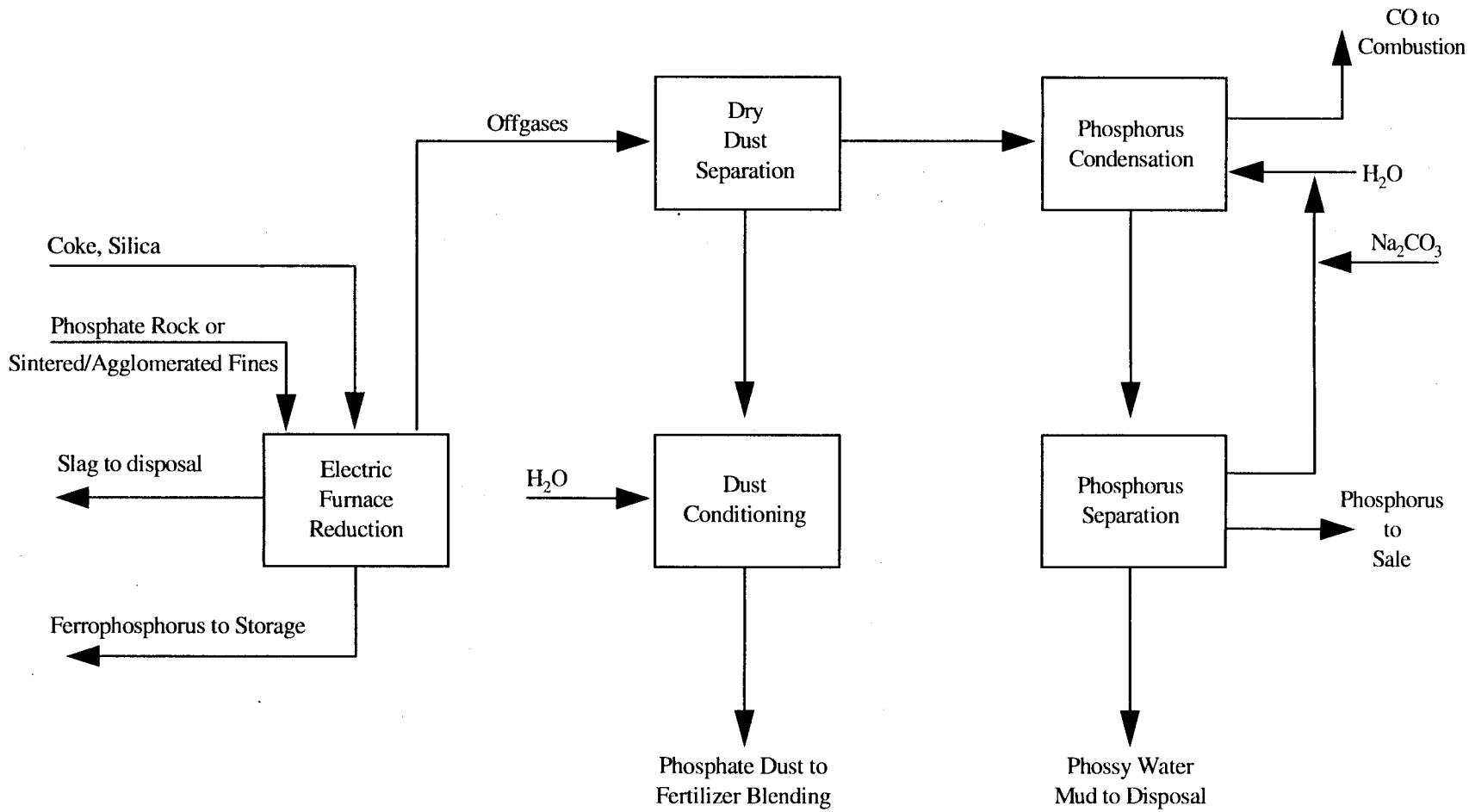
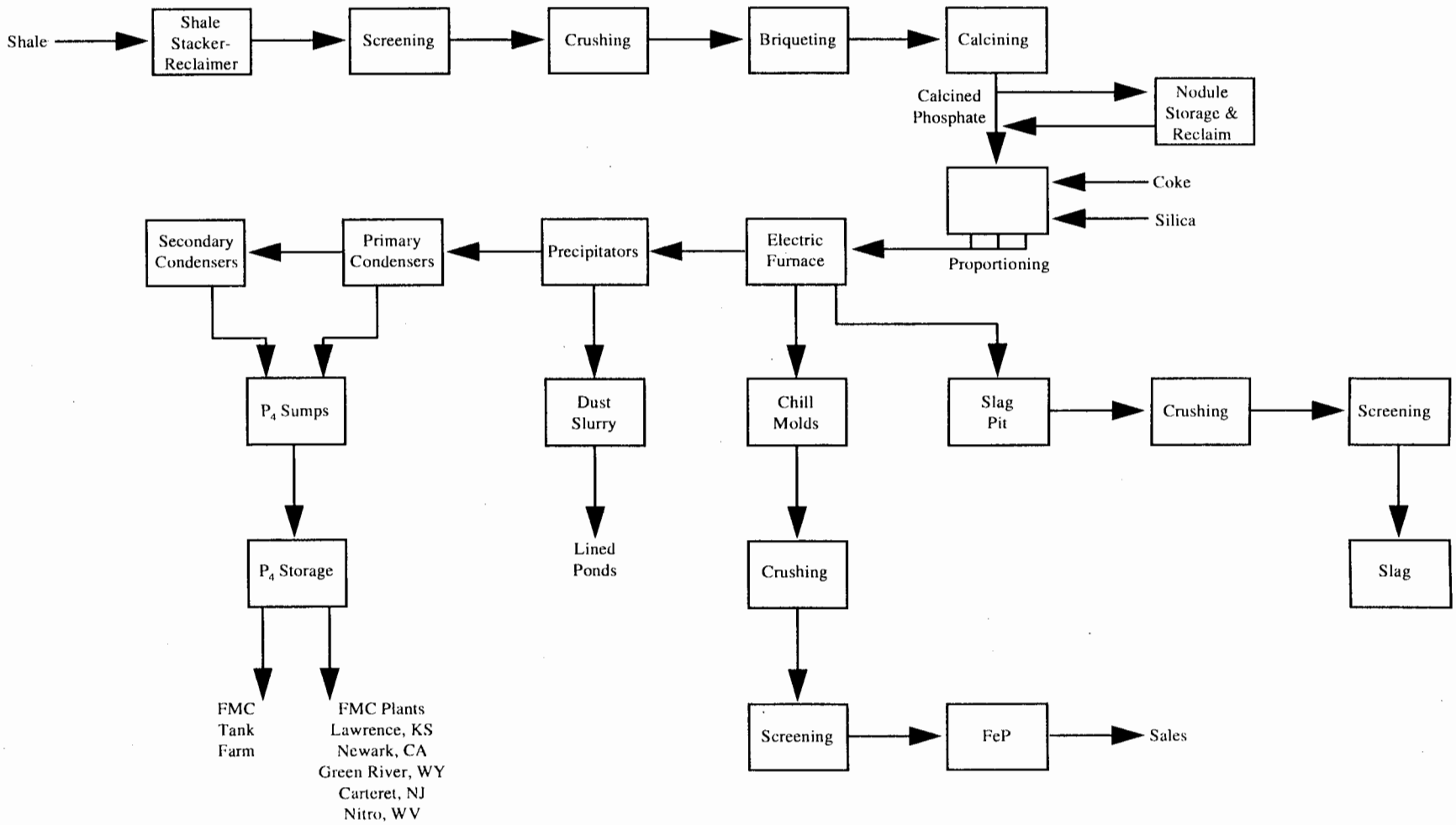


EXHIBIT 3

PROCESS AT FMC FACILITY

(Adapted from: Elemental Phosphorus Processing Waste Characterization Report For FMC Corporation, 1991, pp. 1-4.)



Electrothermal Processing

The burden is then fed to one of four electric arc furnaces through feed chutes located on top of the furnaces. There are 10 feed chutes per furnace to distribute burden uniformly about the electrodes. Each furnace is equipped with three electrodes that heat the furnaces to reduce the phosphate to gaseous elemental phosphorus. Silica is used as a fluxing agent to bind with the calcium present in the phosphate ore and form slag. The coke reacts with the phosphate ore to form carbon monoxide and ferrophosphorus. The furnace offgas, which contains elemental phosphorus, carbon monoxide and particulates, passes through an electrostatic precipitator (ESP) for particulate removal. The gas is then passed through a primary condenser where the phosphorus is cooled by water sprays and condensed to a liquid. Each furnace is equipped with a precipitator and primary condenser. The majority of the phosphorus is condensed in the primary condenser. The gas stream leaving the primary condenser is combined with the gas streams from the other primary condensers at the carbon monoxide header. The combined gas stream, which is primarily carbon monoxide, flows to a second condenser for additional phosphorus removal. The carbon monoxide stream from the secondary condenser is used as fuel for the calciners. Excess carbon monoxide goes to the roof flare and to the flare pit.

Elemental phosphorus is gravity fed from the condenser to sumps in the furnace building. Phosphorus in the sumps is kept under water to prevent contact with air. Phosphorus is transferred from the sumps to one of seven storage tanks at the phosphorus loading dock by pumping water into the top of the sumps to displace the phosphorus and forced it out the bottom of the sump and into the bottom of the storage tanks. The phosphorus displaces water from the top of the storage tank, and this water flows back to the sumps to form a closed-loop system. The combined capacity of the seven storage tanks is 3,131,000 pounds of phosphorus. Phosphorus is pumped from the storage tanks into railcars for off-site shipment. FMC also has 12 underground storage tanks for long term storage of phosphorus. The phosphorus dock also processes sludge generated at the furnace building sumps, storage tanks, and in the returning railcars. The sludge is dried in a centrifuge and stored before being pumped back to the furnaces for phosphorus recovery.[12]

Air emissions from furnace operations result from normal furnace operation, furnace venting, and slag tapping. The electrothermal process generates carbon monoxide which is used as fuel at the calciners or vented to the flare pit. Furnace venting occurs during furnace maintenance/repair or process upsets. During maintenance/ repair, the furnace is vented to the roof flare. Emissions to the flare bypass the carbon monoxide header. These emissions consist primarily of phosphorus pentoxide. Emissions from process upsets, such as furnace overpressurization, are vented to a pressure relief valve. These emissions are also primarily phosphorus pentoxide. Emissions from slag tapping are vented to the atmosphere through a Medusa scrubber followed by an Anderson scrubber.[13]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

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[12] National Enforcement Investigations Center (NEIC), Multi-Media Compliance Investigation, FMC Corporation - Phosphorus Chemicals Division, Pocatello, Idaho, January 1994.

[13] Ibid.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for the production of elemental phosphorus, the beneficiation/processing line occurs between agglomeration and electric arc furnace reduction because the agglomerated phosphate rock undergoes a significant thermal reaction inside the electric arc furnace to yield gaseous phosphorus. Calcining is recognized as a beneficiation activity in the production of phosphorous. It is one of the final activities performed prior to the chemical change of phosphate ore into the elemental phosphoro\us product.[14] Because EPA has determined that all operations following the initial "processing" step (in this case, the introduction of proportioned ore into the electric furnace) in the production sequence also are considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated downstream of the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Fugitive dust is generated from screening and crushing. FMC collects this dust in baghouses.[15]

Calcining offgas solids. FMC sends air emissions from the calciners to scrubbers for removal of particulates and radionuclides.[16] It should be ruled that if calcining at FMC drivers off more than water and carbon dioxide, it is not a beneficiation activity (See 40 CFR 261.4(b)(7).

2. Mineral Processing Wastes

Surface impoundment waste solids are generated at a rate of 373 kg per kkg product.[17] Existing data and engineering judgment indicate that this waste does not exhibit characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further. Waste characterization data are presented in Attachment 1.

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[14] FMC Corporation. Op. Cit. January 25, 1996.

[15] NEIC. Op. Cit. 1994.

[16] Ibid.

[17] U.S. Environmental Protection Agency, Multi-Media Assessment of the Inorganic Chemicals Industry, Volume II, Chapter 8, 1980.

Slag, a RCRA special waste, contains trace amounts of radioactive materials in a stable, calcium silicate matrix. For every pound of white phosphorus produced, eight to ten pounds of slag are generated. In 1988, this waste was generated at a rate of 2.6 million metric tons per year.[18] At FMC, slag is tapped into the slag pit which is located next to the furnace building. The slag is allowed to cool before it is loaded and hauled to the slag storage piles. Some slag is screened and crushed for use in berm and road maintenance.[19]

Dust. Phosphatic dusts may contain slightly elevated levels of radioactivity as well as volatilized, reduced heavy metals. Phosphatic dusts are normally sold for blending with fertilizer materials[20] and formerly were classified as byproducts. Past management practices have included storage in a waste pile and offsite landfill disposal.[21] Dust is generated at a rate of 4,400 metric tons per year (adjusted from a reported value to reflect changes in the sector). Dusts may exhibit the characteristics of toxicity (for cadmium), ignitability, and reactivity.

Furnace offgas solids. This waste may contain cyanide. The generation rate for furnace offgas solids is 24,000 metric tons per year[22] (adjusted from a reported value to reflect recent changes in the sector). Waste characterization data are presented in Attachment 1. This waste may be recycled and formerly was classified as a sludge.

Sludge is generated in the sumps and consists of a phosphorus/water emulsion and particulates not removed by the ESPs. Generally, sludge is distilled in iron retorts of steam heated vessels to recover phosphorus. Recovered phosphorus is added to the product and phosphorus free residues from the retorts are landfilled. Sludge is generated at a rate of 25 kg per kkg product.[23] At FMC, the sludge is sent to the phosphorus dock where it is processed with sludge generated from furnace building sumps, storage tanks, and returning railcars. The sludge is dried in a centrifuge and stored before being pumped back to the furnace for phosphorus recovery.[24] Existing data and engineering judgment suggest that this waste does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate it further.

Precipitator slurry scrubber water. FMC treats the scrubber water with lime and discharges it to calciner ponds for settling. The water is recycled back to the scrubbers from the calciner ponds.[25] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further. Waste characterization data are presented in Attachment 1.

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[18] U.S. Environmental Protection Agency, Report to Congress on Special Wastes from Mineral Processing, Volume II: Methods and Analysis, Office of Solid Waste, July 1990, p. 7-3.

[19] NEIC, 1994, Op. Cit.

[20] .S. Environmental Protection Agency. "Phosphate Rock," from 1988 Final Draft Summary Report of Mineral Industry Processing Waste, 1988, pp. 2-120 - 2-127.

[21] U.S. Environmental Protection Agency, Technical Background Document, Development of Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, August 1989, pp. 3-4--3-6.

[22] Ibid.

[23] U.S. Environmental Protection Agency, Op. Cit., Volume II, Chapter 8, 1980.

[24] NEIC, 1994, Op. Cit.

[25] Ibid.

Cooling water is generated from cooling of furnace domes by direct water spray. At FMC, this water is discharged via a permitted outfall.[26] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Furnace scrubber blowdown. FMC generates this waste at the rate of 43.4 million gallons per year.[27] Management for this waste may include treating in a tank and sending the sludge to disposal impoundments.[28] This waste may exhibit the characteristics of toxicity for cadmium and corrosivity prior to treatment. Waste characterization data for raw furnace scrubber blowdown are presented in Attachment 1.

Furnace building washdown. This waste is generated from numerous sources in the furnace building. The term "furnace building washdown" is a generic term used at the FMC facility to designate water collected in the V-3600 tank from numerous sources throughout the furnace building. The water is eventually discharged into a RCRA Interim Status MTR pond. Water is used in condensing elemental phosphorus from the furnace off-gas stream, water seals on pressure relief devices and overfill protection systems, electrical transformer and furnace cooling, furnace tapping fume scrubber systems, conveying and storage operations to keep phosphorus under water cover, slurrying and transporting electrostatic precipitator solids, cleaning (rinsing) of process equipment to ensure maximum performance, and other miscellaneous uses such as pump packings and steam condensate. The V-3600 tank is the back-up water collection point for some of these streams, which do not normally report to this tank. The discharge from the V-3600 tank collectively has been known as "furnace building washdown" because waters from numerous sources in the furnace building are the primary components of this stream. This stream is generated continuously during process operations. Contaminants in this stream originate from the mineral feedstocks (phosphate shale, silica, and coke) used at Pocatello to produce elemental phosphorus. This stream does not contain outside contaminants such as solvents or acidic or caustic cleaning agents. The furnace building washdown occasionally exhibits the Toxicity Characteristic for cadmium (D006). The TSS average is .08 percent, and it is also considered a wastewater for LDR purposes. Furnace Building Washdown contains elemental phosphorus and NORM. The FMC facility generates approximately 79 million gallons of this waste a year.[29]

WWTP sludge/solids. This waste is not expected to be hazardous. Waste characterization data are presented in Attachment 1.

Surface impoundment waste liquids. This waste is not expected to be hazardous. Waste characterization data are presented in Attachment 1. This waste is completely recycled at FMC.

Spent furnace brick. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Waste ferrophosphorus is tapped from the furnaces. It is tapped into chill molds inside the furnace building and allowed to cool. After cooling, the ferrophosphorus is crushed and screened before being sold as a raw material to the steel industry.[30] Based on existing data and engineering judgment, this waste is not expected to exhibit characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further.

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[26] Ibid.

[27] FMC Corporation. Op. Cit. January 25, 1996.

[28] U.S. Environmental Protection Agency, Technical Background Document, Development of Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, August 1989, pp. 3-4 to 3-6.

[29] FMC Corporation. Op. Cit. January 25, 1996.

[30] Ibid.

WWTP liquid effluent is not expected to be hazardous. This waste may be discharged under NPDES. The generation rate for this waste stream is 1,520,000 metric tons per year[31] (adjusted from a reported value to reflect recent changes in the sector). Waste characterization data are presented in Attachment 1.

Andersen Filter Media (AFM). Andersen Filter Media (AFM) is a felt-like material that is used in the Andersen scrubbers to filter fine particulate. Andersen Cleanable Media High Efficiency Air Filter (CHEAF) scrubbers are used in series with the Medusa Scrubbers to further clean fumes from furnace tapping and phosphorus dock loading and operations. Andersen Filter Media is used in these scrubbers to filter fine particulates. The AFM is generated at a rate of 420 cubic yards per year. The material fails the TCLP for cadmium and sometimes arsenic, chromium, lead and selenium and is a RCRA hazardous waste.[32]

AFM rinsate. This waste stream has been eliminated by FMC as a waste reduction process modification.

FMC generates three additional waste streams, as described below, which may or may not be typical of other phosphorus producers.[33]

Precipitator slurry. The elemental phosphorus product exits the furnaces as a gas along with the carbon monoxide produced in the furnace reaction. The furnace off-gas also includes entrained solids and solids that have volatilized in the furnace and condensed as the off-gas cools. Electrostatic precipitators are used to remove these furnace off-gas solids prior to the water spray condensers that remove the elemental phosphorus as a liquid. At FMC, these solids collect in a vessel at the bottom of the precipitator, known as the slurry pot, where water is added with a mixer to form what is termed precipitator slurry. The slurry pot acts as a gas seal on the precipitators to prevent in-leakage of air. Some elemental phosphorus condenses in the slurry pot and the solids contain low volatile metals such as cadmium and zinc in elevated levels. Historically, precipitator slurry has been sent to ponds where the solids settle out and the water is recycled. FMC produces 43 million gallons of precipitator slurry (may be combined with NOSAP slurry as discussed below) each year. Although there are elevated levels of metals in the precipitator slurry, the solids typically do not fail a Toxicity Characteristic Leaching Procedure (TCLP) test, unless there are extenuating circumstances, in which case it will fail for cadmium (D006).

Based on preliminary data, EPA has indicated that precipitator slurry is ignitable (D001) and reactive (D003). The slurry also contains NORM and elemental phosphorus and should be managed accordingly. The TSS in the precipitator slurry typically exceed 1 percent, and the TOC concentration present in the precipitator slurry does not exceed 1 percent. Therefore, the slurry is considered an LDR non-wastewater.

NOSAP Slurry. In 1994 and 1995 as part of its waste minimization efforts, FMC developed and installed the NOSAP, which is a modification to the electrostatic precipitator and the slurry pot. Lime slurry is added to the slurry pot to control the pH of the slurry to a set point of pH 12. The lime reacts with the phosphorus to form phosphites and phosphine gas, thus reducing the concentration of phosphorus to below 1000 ppm. The lime also prevents the metals from becoming leachable and ensures the slurry will not fail the TCLP test. The resulting slurry that has gone through this process is known as NOSAP slurry. Based on preliminary data, EPA has indicated that NOSAP slurry is reactive (D003). If all precipitator slurry went through the NOSAP process, FMC would produce only 22 million gallons per year since the NOSAP slurry has a higher solids content. The solids in NOSAP slurry are the same as precipitator slurry with the exception of the effect of the lime. The NORM content is the same and there is still some residual phosphorus content. NOSAP slurry that does not meet specifications is a component of precipitator slurry. The TSS in the NOSAP slurry typically exceed 1 percent, and the TOC in the NOSAP slurry does not exceed 1 percent. Therefore, the NOSAP slurry is a non-wastewater for LDR purposes.

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[31] U.S. Environmental Protection Agency, Op. Cit., Vol. II, pp. 14-45 - 14-59.

[32] FMC Corporation. Op. Cit. January 25, 1996.

[33] FMC Corporation. Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. May 12, 1997.

The maximum volume of precipitator slurry and NOSAP slurry that would be generated in one year would be 43 million gallons.

Phossy water. This water waste stream is called phossy water by FMC. Phossy water may carry the D003 RCRA waste code for reactivity. It is possible that phossy water could exhibit the TC for cadmium (D006) upon process upset. As a result of its contact with phosphorus, phossy water contains suspended phosphorus and other dissolved solids. In addition, the phossy water contains NORM. The majority of phossy water is recovered for reuse, but excess phossy water is generated from two locations within the facility. Due to the presence of elemental phosphorus, the solids in phossy water may spontaneously oxidize and ignite if dewatered. The TSS in the phossy water typically exceed 1 percent, and the TOC in the phossy water does not exceed 1 percent. Therefore, the phossy water is a non-wastewater for LDR purposes. FMC generates 89 million gallons total of the phossy water per year. Solids in phossy water settle out, and are considered to be mineral processing wastes, because the 1984 rule states that a waste of a mineral process waste is a mineral process wastes. Based on available data, solids from phossy water may be a hazardous waste.

Although other phosphorous manufacturers may generate the following waste streams, FMC does not do so at its facility: phosphatic dust, condenser water discard, precipitator slurry scrubber water, WWTP liquid effluent, and WWTP sludge/solids.

D. Non-uniquely Associated Wastes

Non-contact cooling water is generated by cooling of the ore calciner grates that transport the briquettes. At FMC, the noncontact cooling water is discharged via a permitted outfall.[34] This waste is a non-uniquely associated waste. Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous), and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

Three commenters provided additional factual information about the elemental phosphorous production process (COMM 42, 70, 78)). This information, where appropriate, has been included in sector report.

Sector-specific Issues

Two commenters disagreed with the Agency's assertion that certain wastes generated during elemental phosphorous production are RCRA ignitable and reactive (COMM 42, COMM 70). One of these commenters has since agreed to treat certain wastes as ignitable and reactive (COMM 70).

One commenter stated that water recycled from ponds on-site should not be considered a hazardous waste, because it does not fit any one criteria that would make it a hazardous waste under the RCRA statute definitions (COMM 70).

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[34] NEIC, 1994, Op. Cit.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT SOLIDS - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	10,000	10,000	10,000	1/1	-	-	-	0/0	-	-
Phosphate	200,000	386,667	480,000	3/3	-	-	-	0/0	-	-
Silica	50,000	50,000	50,000	2/2	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	5.00	5.53	5.80	3/3					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SLAG QUENCHWATER - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	11.60	11.60	11.60	1/1	11.50	11.50	11.50	1/1	-	-
Antimony	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	-	-
Arsenic	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	5.0	0
Barium	0.05	0.05	0.05	0/1	0.050	0.050	0.050	0/1	100.0	0
Beryllium	0.005	0.005	0.005	0/1	0.0050	0.0050	0.0050	0/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.012	0.012	0.012	1/1	0.011	0.011	0.011	1/1	1.0	0
Chromium	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	5.0	0
Cobalt	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	-	-
Copper	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	-	-
Iron	3.60	3.60	3.60	1/1	3.34	3.34	3.34	1/1	-	-
Lead	0.35	0.35	0.35	1/1	0.17	0.17	0.17	1/1	5.0	0
Magnesium	5.72	5.72	5.72	1/1	5.72	5.72	5.72	1/1	-	-
Manganese	1.54	1.54	1.54	1/1	1.52	1.52	1.52	1/1	-	-
Mercury	0.00010	0.00010	0.00010	0/1	0.00020	0.00020	0.00020	1/1	0.2	0
Molybdenum	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	-	-
Nickel	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	-	-
Selenium	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	1.0	0
Silver	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	5.0	0
Thallium	0.250	0.250	0.250	0/1	0.25	0.25	0.25	0/1	-	-
Vanadium	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	-	-
Zinc	3.13	3.13	3.13	1/1	2.94	2.94	2.94	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	5.00	5.00	5.00	1/1	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	41.30	41.30	41.30	1/1	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	5.78	8.29	10.80	2/2					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - CONDENSER PHOSSY WATER DISCARD - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.424	64.39	220	5/5	5.70	11.90	16.10	3/3	-	-
Antimony	0.016	1.76	4	3/5	0.050	0.71	1.30	3/4	-	-
Arsenic	0.0024	1.27	3	3/5	0.031	0.12	0.25	3/5	5.0	0
Barium	0.120	16.09	90	5/6	0.15	0.86	3.20	5/6	100.0	0
Beryllium	0.005	0.026	0.05	2/4	0.005	0.014	0.025	1/3	-	-
Boron	14	14.000	14	1/1	9.400	9.400	9.400	1/1	-	-
Cadmium	0.002	324	3200	11/11	0.067	0.17	0.40	6/6	1.0	0
Chromium	0.014	33.15	250	8/8	0.049	0.23	0.40	5/6	5.0	0
Cobalt	0.013	0.15	0.5	2/4	0.050	0.15	0.25	0/2	-	-
Copper	0.017	20.98	100	5/5	0.005	0.08	0.25	1/4	-	-
Iron	1.2	20.26	53	4/4	0.87	4.02	6.49	3/3	-	-
Lead	0.024	13.49	48	7/7	0.125	0.64	1.80	2/4	5.0	0
Magnesium	6.83	32.22	64	6/6	6.4	13.23	17.00	3/3	-	-
Manganese	0.23	1.77	3.8	4/4	0.25	0.95	1.85	2/4	-	-
Mercury	0.00010	0.1506	1	3/7	0.00010	0.000175	0.0002	1/4	0.2	0
Molybdenum	0.035	0.17	0.5	2/4	0.05	0.15	0.25	0/2	-	-
Nickel	0.046	6.93	45	5/7	0.02	0.09	0.25	2/5	-	-
Selenium	0.002	2.58	13.9	3/6	0.002	0.10	0.25	0/3	1.0	0
Silver	0.02	1.36	4.47	3/5	0.01	0.08	0.25	0/4	5.0	0
Thallium	0.0455	24.88	120	2/5	0.25	0.75	1.25	0/2	-	-
Vanadium	0.05	2.27	10	4/6	0.05	0.17	0.25	1/3	-	-
Zinc	0.6	5,794	53,000	10/10	6.47	71.49	167	5/5	-	-
Cyanide	36.00	36.00	36.00	1/1	-	-	-	0/0	-	-
Sulfide	1.20	1.20	1.20	1/1	-	-	-	0/0	-	-
Sulfate	2.50	363	964	6/7	41.00	74.00	107	2/2	-	-
Fluoride	80.00	3,934	25,900	7/7	155	304	453	2/2	-	-
Phosphate	25.00	1,833	9,070	6/6	591	662	732	2/2	-	-
Silica	63.00	63.00	63.00	1/1	-	-	-	0/0	-	-
Chloride	38.00	364	1,250	9/9	69	152	234	2/2	-	-
TSS	0.78	12652	50000	4/4	-	-	-	0/0	-	-
pH *	3.00	5.09	7.10	7/7					2<pH>12	0
Organics (TOC)	20.00	39.67	76.20	3/3					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - FURNACE OFFGAS SOLIDS - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	98.20	4,290	11,500	4/4	4.60	11.22	24.10	3/3	-	-
Antimony	0.43	9.68	25.50	2/3	0.050	0.76	1.32	2/3	-	-
Arsenic	0.050	12.78	25.50	0/2	0.020	0.56	1.30	5/7	5.0	0
Barium	0.84	34.18	96.70	3/3	0.050	0.14	0.25	2/4	100.0	0
Beryllium	0.022	1.29	2.55	1/2	0.005	0.015	0.025	0/2	-	-
Boron	39.000	185.50	332.00	2/2	24.000	24.000	24.000	1/1	-	-
Cadmium	0.45	60.74	200	4/4	0.011	8.05	27.00	7/7	1.0	4
Chromium	1.61	14.04	25.50	2/3	0.050	0.33	0.90	6/8	5.0	0
Cobalt	0.05	12.78	25.50	0/2	0.050	0.15	0.25	0/2	-	-
Copper	0.05	37.64	116	2/4	0.050	0.15	0.25	0/2	-	-
Iron	16.80	7,744	20,000	5/5	1.81	6.67	13.00	3/3	-	-
Lead	2.57	136	368	3/3	0.45	0.90	1.40	4/4	5.0	0
Magnesium	84.00	687	1,373	4/4	3.39	5.84	7.10	3/3	-	-
Manganese	2.79	337	1,170	4/4	0.25	0.74	1.55	2/3	-	-
Mercury	0.00010	0.00010	0.00010	0/1	0.00010	0.00010	0.00010	0/1	0.2	0
Molybdenum	0.050	12.78	25.50	0/2	0.05	0.15	0.25	0/2	-	-
Nickel	0.050	14.14	29.00	2/4	0.10	0.17	0.25	2/3	-	-
Selenium	0.050	12.78	25.50	0/2	0.010	0.07	0.25	3/5	1.0	0
Silver	0.050	12.78	25.50	0/2	0.020	0.12	0.25	4/6	5.0	0
Thallium	0.25	43.65	128	1/3	0.25	0.75	1.25	0/2	-	-
Vanadium	0.64	12.71	25.50	2/3	0.05	0.30	0.60	1/3	-	-
Zinc	5.70	13,489	61,665	5/5	6.07	116	267	3/3	-	-
Cyanide	52.00	52.00	52.00	1/1	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	173	8,802	17,616	4/4	-	-	-	0/0	-	-
Fluoride	941	1,221	1,500	2/2	-	-	-	0/0	-	-
Phosphate	13.38	240,007	480,000	2/2	-	-	-	0/0	-	-
Silica	50,000	125,000	200,000	2/2	-	-	-	0/0	-	-
Chloride	510	38,564	150,000	4/4	-	-	-	0/0	-	-
TSS	988,200	988,200	988,200	1/1	-	-	-	0/0	-	-
pH *	5.00	5.40	5.80	2/2					2<pH>12	0
Organics (TOC)	20.00	384,940	1,140,000	3/3					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PRECIPITATOR SLURRY - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	28	28	28	1/1	0.31	0.31	0.31	1/1	-	-
Arsenic	5	5	5	1/1	0.1	0.1	0.1	1/1	5.0	0
Barium	18	18	18	1/1	1	1	1	1/1	100.0	0
Beryllium	0.2	0.2	0.2	1/1	0.01	0.01	0.01	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	1300	1300	1300	1/1	0.022	0.022	0.022	1/1	1.0	0
Chromium	60	60	60	1/1	0.237	0.237	0.237	1/1	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	130	130	130	1/1	0.11	0.11	0.11	1/1	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	1	1	1	1/1	0.0005	0.0005	0.0005	1/1	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	11	11	11	1/1	0.08	0.08	0.08	1/1	-	-
Selenium	8	8	8	1/1	0.2	0.2	0.2	1/1	1.0	0
Silver	1	1	1	1/1	0.02	0.02	0.02	1/1	5.0	0
Thallium	650	650	650	1/1	0.2	0.2	0.2	1/1	-	-
Vanadium	60	60	60	1/1	0.3	0.3	0.3	1/1	-	-
Zinc	11000	11000	11000	1/1	69.9	69.9	69.9	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	200000	200000	200000	1/1	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - FURNACE SCRUBBER BLOWDOWN - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	3.70	2,360	18,000	8/8	0.25	4.23	11.40	5/6	-	-
Antimony	0.016	1.31	4.80	2/8	0.05	0.53	1.60	3/7	-	-
Arsenic	0.016	1.46	8.70	4/8	0.00125	0.14	0.54	3/6	5.0	0
Barium	0.050	41.94	280.00	4/7	0.050	0.43	1.20	4/7	100.0	0
Beryllium	0.0020	0.17	0.93	3/7	0.0025	0.01	0.03	1/6	-	-
Boron	25.00	25.00	25.00	1/1	19	19.00	19.00	1/1	-	-
Cadmium	0.0010	2.37	9.60	10/13	0.0050	0.40	2.07	4/7	1.0	2
Chromium	0.0005	110	940	7/10	0.005	0.34	0.90	4/7	5.0	0
Cobalt	0.0030	38.81	260	3/7	0.03	0.08	0.25	0/5	-	-
Copper	0.0005	46.66	310	3/7	0.005	0.07	0.25	1/5	-	-
Iron	0.030	10,382	63,000	8/8	0.0375	3.88	6.86	5/6	-	-
Lead	0.004	25.69	150	8/8	0.125	0.31	0.42	2/6	5.0	0
Magnesium	5.40	174	1,300	10/10	0.17	6.10	10.70	5/6	-	-
Manganese	0.50	3,464	26,000	7/8	0.25	2.03	6.50	5/6	-	-
Mercury	0.00010	0.019	0.10	2/8	0.0001	0.0001	0.0002	1/6	0.2	0
Molybdenum	0.029	11.06	71.00	4/7	0.010	0.074	0.25	0/5	-	-
Nickel	0.009	68.89	530	5/8	0.015	0.079	0.25	2/6	-	-
Selenium	0.003	0.12	0.50	3/7	0.0025	0.071	0.25	1/6	1.0	0
Silver	0.0010	0.48	1.60	1/7	0.01	0.074	0.25	1/6	5.0	0
Thallium	0.040	1.52	4.50	1/8	0.25	0.53	1.25	1/6	-	-
Vanadium	0.015	83.25	710	7/9	0.015	0.25	0.79	3/7	-	-
Zinc	0.023	79.11	211	12/12	0.55	44.38	130	7/7	-	-
Cyanide	0.900	0.90	0.90	1/1	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	18.10	3,167	18,600	8/8	6.00	7.00	8.00	2/2	-	-
Fluoride	51.60	2,481	20,200	9/9	2.41	5.66	8.91	2/2	-	-
Phosphate	6.40	959	3,700	7/7	2.17	4.02	5.87	2/2	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	0.38	177	420	10/11	0.27	0.47	0.67	2/2	-	-
TSS	0.49	2,667	8,000	4/4	-	-	-	0/0	-	-
pH *	1.10	4.38	6.61	10/10					2<pH>12	1
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT SLUDGE/SOLIDS - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	54500	54,500	54,500	1/1	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	233	233	233	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	1143	1,143	1,143	1/1	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	17400	17,400	17,400	1/1	-	-	-	0/0	-	-
Lead	188	188	188	1/1	-	-	-	0/0	5.0	0
Magnesium	2775	2,775	2,775	1/1	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	10625	10,625	10,625	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	1507	1,507	1,507	1/1	-	-	-	0/0	-	-
Fluoride	150	2,575	5,000	2/2	-	-	-	0/0	-	-
Phosphate	200	200	200	1/1	-	-	-	0/0	-	-
Silica	50000	162,200	274,400	2/2	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	4	7.1	11.3	3/3					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT LIQUIDS - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.424	0.42	0.42	1/1	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	0.643	0.64	0.64	1/1	-	-	-	0/0	-	-
Cadmium	2.86	2.86	2.86	1/1	-	-	-	0/0	1.0	0
Chromium	0.014	0.04	0.07	2/2	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	54.5	54.50	54.50	1/1	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.00012	0.00012	0.00012	1/1	-	-	-	0/0	0.2	0
Molybdenum	0.084	0.084	0.084	1/1	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	0.045	0.045	0.045	1/1	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	0.21	0.37	0.53	2/2	-	-	-	0/0	-	-
Zinc	0.29	2.11	3.94	2/2	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	118	118	118	1/1	-	-	-	0/0	-	-
Fluoride	122	122	122	1/1	-	-	-	0/0	-	-
Phosphate	100	490	1,000	3/3	-	-	-	0/0	-	-
Silica	47.70	47.70	47.70	1/1	-	-	-	0/0	-	-
Chloride	38.00	111	183	2/2	-	-	-	0/0	-	-
TSS	240	240	240	1/1	-	-	-	0/0	-	-
pH *	4.00	5.33	6.80	4/4					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT LIQUID EFFLUENT - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	1.00	1.00	1.00	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	177	177	177	1/1	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	190	190	190	1/1	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	536	536	536	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	1,533	1,533	1,533	1/1	-	-	-	0/0	-	-
Fluoride	22.80	22.80	22.80	1/1	-	-	-	0/0	-	-
Phosphate	100	100	100	1/1	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	2,308	2,308	2,308	1/1	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	4.00	4.85	5.70	2/2					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - AFM RINSATE - ELEMENTAL PHOSPHOROUS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	0.2	0.2	0.2	1/1	-	-
Arsenic	1	1	1	1/1	0.14	0.14	0.14	1/1	5.0	0
Barium	-	-	-	0/0	1	1	1	1/1	100.0	0
Beryllium	-	-	-	0/0	0.01	0.01	0.01	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	4	4	4	1/1	4.12	4.12	4.12	1/1	1.0	1
Chromium	1	1	1	1/1	0.278	0.278	0.278	1/1	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	0.19	0.19	0.19	1/1	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	0.0005	0.0005	0.0005	1/1	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	0.08	0.08	0.08	1/1	-	-
Selenium	1	1	1	1/1	1.03	1.03	1.03	1/1	1.0	1
Silver	-	-	-	0/0	0.02	0.02	0.02	1/1	5.0	0
Thallium	-	-	-	0/0	0.03	0.03	0.03	1/1	-	-
Vanadium	-	-	-	0/0	0.19	0.19	0.19	1/1	-	-
Zinc	-	-	-	0/0	37.2	37.2	37.2	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	20000	20000	20000	1/1	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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FLUORSPAR AND HYDROFLUORIC ACID

A. Commodity Summary

In 1994, approximately 73 percent of the reported fluorspar (CaF_2) consumed in the United States was used in the production of hydrofluoric acid. About 10 percent of the fluorspar was used as a fluxing agent in steelmaking, and in iron and steel foundries. The remaining 17 percent was consumed in aluminum fluoride manufacture, primary aluminum production, glass manufacture, enamels, welding-rod coatings, and other miscellaneous end uses or products.[1] Fluorspar is sold in three grades: metallurgical (minimum 85 percent CaF_2), ceramic (85-96 percent CaF_2), and acid (minimum 97 percent CaF_2).[2] While there are seven active domestic fluorspar mines, the majority of fluorspar used in the U.S. is imported.[3]

Hydrofluoric acid is an aqueous solution of hydrogen fluoride produced by a reaction of fluorspar and sulfuric acid. Hydrofluoric acid is the feedstock used to produce almost all of the organic and inorganic fluorine-bearing chemicals. Hydrofluoric acid also is used in aluminum and uranium processing.[4] As of 1989, three facilities actively produced hydrofluoric acid. Although several other facilities produce hydrofluoric acid as an intermediate product during the formulation of commercial chemicals or compounds, these facilities are not included as part of the primary hydrofluoric acid industry. The names and locations of the three hydrofluoric acid production facilities are shown in Exhibit 1.

EXHIBIT 1

SUMMARY OF HYDROFLUORIC ACID PRODUCERS (IN 1989)

Facility Name	Location
Allied Signal	Geismar, LA
E.I. duPont	La Porte, TX
Attochemical, N.A.	Calvert City, KY

B. General Process Description

1. Discussion of the Typical Production Processes

Hydrofluoric acid is produced by reacting acid-grade fluorspar and sulfuric acid in a kiln, and cooling and purifying the product. This process is described in detail below.

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[1] M.M. Miller, "Fluorspar," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 58.

[2] M.M. Miller, "Fluorspar," from Minerals Yearbook. Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, p. 487.

[3] U.S. Bureau of Mines, Randol Mining Directory 1994/1995, Randol International Ltd., Golden, CO, 1994, p. 165.

[4] M.M. Miller, 1994, Op. Cit., p. 58.

2. Generalized Flow Diagram

Before fluorspar can be used to make hydrofluoric acid, the raw ore must be physically concentrated and purified. Ceramic and acid grades of fluorspar are concentrated (not shown) by crushing and grinding fluorspar, and purified by froth flotation. First the fluorspar is crushed and ground. Then lead and zinc sulfides are preferentially floated away from the fluorspar. The easily floating fluorspar is removed and sent to the cleaner circuit. The tailings are discarded and the middling product is reground and passed through a cleaner circuit. The flotation process yields acid grade concentrate, and sometimes lower grade concentrates, which are sold either as ceramic or metallurgical grade fluorspar. Metallurgical grade fluorspar is produced by hand sorting, crushing and screening, and gravity concentration.[5]

Hydrofluoric acid is produced from acid-grade fluorspar (CaF_2) which reacts with sulfuric acid in a heated retort kiln to produce hydrogen fluoride gas, as shown in Exhibit 2. The acid grade fluorspar typically contains at least 97 percent calcium fluoride, as well as silica, calcium carbonate, carbon, sulfur, phosphorus pentoxide, chloride, mixed metal oxides, and a trace amount of arsenic. The sulfuric acid generally is between 93 and 99 percent pure. Both sulfuric acid and oleum (SO_3) are commonly used.[6] The residue remaining after retorting is calcium sulfate anhydrite, commonly known as fluorogypsum, which is a RCRA special waste. This solid is slurried in process water as it exits the kiln and is transported either to the waste management units[7] or, at the duPont plant, to a production operation for further processing for sale as a byproduct.[8] The process wastewater, the second RCRA special waste generated by this sector, is stored/treated in on-site surface impoundments and then either reused in the process operations or discharged.

The crude product gas is handled differently by the various manufacturers, but cooling and scrubbing are always involved. Exhibit 2 shows the gas being cooled, purified by scrubbing, and condensed. The crude product may be diluted and sold as an approximately 70 percent hydrofluoric acid solution, or distilled to remove any remaining water and impurities, and sold as anhydrous hydrogen fluoride, a colorless fuming liquid. The wastes from the refrigerated condenser go to an acid scrubber. The sulfuric acid used in this process unit is then sent to the acid feed, to react with the fresh fluorspar. The waste stream from the acid scrubber is sent to a water scrubber which generates fluorosilicic acid and gases. The fluorosilicic acid may be recovered or disposed.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

No new novel processes have been utilized, however, a possible process under investigation involves extracting fluorine as fluorosilicic acid from phosphate rock during the production of phosphoric acid. Also under investigation is the production of calcium fluoride from calcium silicon hexafluoride ($CaSiF_6$) produced by the reaction of fluorosilicic acid and phosphate rock.[9]

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[5] M.M. Miller, 1992, Op. Cit., pp. 488-89.

[6] "Fluorspar," from Kirk Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. XI, 1994, p. 364.

[7] Allied Signal, Inc., 1989, Public comments from Allied Signal, Inc. addressing the 1989 Proposed Reinterpretation of the Mining Waste Exclusion (Docket No. MW2P00020); November 8, 1989; pg. 1.

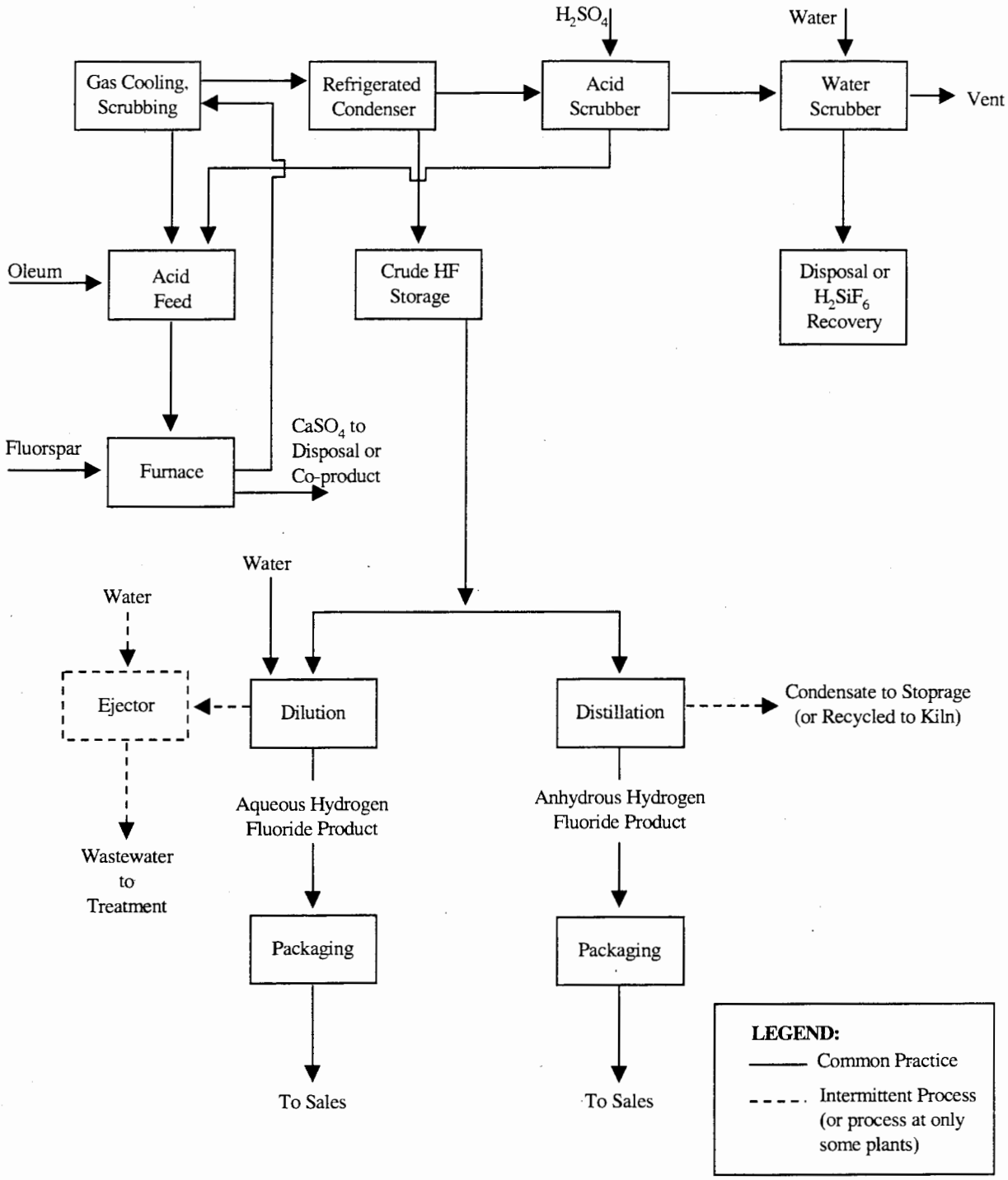
[8] At the duPont facility, lime is added when the fluorogypsum is quenched in order to enhance the chemical characteristics of the material for construction applications.

[9] "Fluorspar," 1994, Op. Cit., pp. 367-68.

EXHIBIT 2

HYDROFLUORIC ACID PRODUCTION

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1994, p. 367 and Development Document, Section 12, Hydrofluoric Acid Industry.)



4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs when the beneficiated fluorspar is mixed with concentrated acid in the furnace/kiln where an intense exothermic chemical reaction occurs and signficantly alters the chemical structure of the fluorspar. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction and Beneficiation Wastes

Gangue, lead and zinc sulfides, spent flotation reagents, and tailings are likely to be generated by the beneficiation of fluorspar. The lead and zinc sulfides may be processed further to recover the lead and zinc. No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

2. Mineral Processing Wastes

The hydrofluoric acid production process generates several waste streams. Two of these waste streams, fluorogypsum and process wastewater, were classified as RCRA special wastes, and were studied in the July 1990 Report to Congress on Special Wastes from Mineral Processing.

Fluorogypsum. This waste is a solid material consisting primarily of fine particles of calcium sulfate, usually less than 0.02 mm in diameter, that is slurried for transport from the kilns to waste management units. Using available data on the composition of fluorogypsum, EPA evaluated whether the waste exhibits any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. Based on analyses of four samples from two facilities (Geismar and Calvert City) and professional judgment, the Agency

does not believe the fluorogypsum exhibits any of these characteristics. All eight of the inorganic constituents with EP toxicity regulatory levels were measured in concentrations (using the EP leach test) that were at least two orders of magnitude below the regulatory levels.[10] According to the Newly Identified Mineral Processing Waste Characterization Data Set, approximately 894,000 metric tons of fluorogypsum are produced annually in the United States.[11] The La Porte, TX plant sells its fluorogypsum for use as a filler for a road base, railroad subbase, and paving material.[12]

Process wastewater. This waste is an aqueous liquid, the chemical constituents of which include fluoride, calcium, and sulfate, with smaller amounts of iron and silicon, as well as many trace metals. Using available data on the composition of hydrofluoric acid process wastewater, EPA evaluated whether the wastewater exhibits any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. Based on available information and professional judgment, the Agency does not believe the wastewater is reactive, ignitable, or EP toxic. All eight of the inorganic constituents with EP toxicity regulatory levels were measured in concentrations (using the EP leach test) that were at most 0.6 times the regulatory levels. Some wastewater samples, however, exhibit the characteristic of corrosivity. Analyses of the pH of hydrofluoric acid process wastewater at the Geismar and Calvert City facilities indicate that the wastewater is corrosive in all of the nine samples analyzed, sometimes with pH values as extreme as 1.00 (for comparison, pH levels below 2.0 are operationally defined as corrosive wastes).[13] According to the Newly Identified Mineral Processing Waste Characterization Data Set, approximately 13.6 million metric tons of process wastewater are produced annually in the United States.[14]

Sludges. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Off-Spec Fluorosilicic acid (H_2SiF_6). This waste is recovered from the water scrubber, and can be used in water fluoridation after it is recovered. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 15,000 metric tons/yr, and 44,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of corrosivity. This waste stream is partially recycled and classified as a by-product.

APC Dusts. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely AssociatedWastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

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[10] From the response of Allied Signal, Inc. and Pennwalt Corp. to EPA's "National Survey of Solid Wastes from Mineral Processing Facilities", conducted in 1989.

[11] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, August 1992, p. I-5.

[12] From the response of E.I. duPont to EPA's "National Survey of Solid Wastes from Mineral Processing Facilities," conducted in 1989.

[13] From the response of Allied Signal, Inc. and Pennwalt Corp. to EPA's "National Survey of Solid Wastes from Mineral Processing Facilities", conducted in 1989.

[14] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-5.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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GEM STONES

A. Commodity Summary

The gem stone industry in the United States is extremely small and relies on foreign trade to meet most of its source requirements. The United States has no known large resources of precious gem stones (i.e., diamonds, rubies, sapphires, and emeralds) and reserves are generally limited to semiprecious stones. Several semiprecious gem stone deposits are mined in the United States. In 1992, 91% of the total U.S. gem stone production (by value) was made up by the following states: Arizona, Nevada, Oregon, Maine, California, and Montana. In 1994, domestic natural gem stone production was approximately $51.6 million.[1]

Most gem stone mining appears to be done by hobbyists and amateurs in Mitchell County, NC; Judith Basin County, MT; San Diego County, CA; Oxford County, ME; and Gila County, AZ where gems such as turquoise, tourmaline, kunzite, emerald, and sapphire are found.

Gem stones are formed in nature in one of three ways: (1) from metamorphic processes, (2) by precipitating from aqueous solutions, and (3) by crystallizing from magmas. There are three major compositional groups of gem stones: silicate minerals comprise one-third; alumino-silicates comprise one-fifth; and oxides comprise one-seventh of gem minerals. The remaining groups are sulfides, phosphates, borosilicates, and carbonates.

Some semi-precious stones are produced as by-products of other mining operations. For example, beryl, tourmaline, spodumene, and gem quartz may be coproducts of mica, feldspar, quartz, or other pegmatite minerals. Diamonds may be recovered from gold dredges, turquoise from copper mines, agate and petrified wood from gravel pits, and gem garnet from abrasive garnet mines and mills.

Gem stones are used primarily for decoration. There are, however, some industrial applications for gem stone material. For instance, industrial processes requiring clean homogeneous stones use low-quality diamond. Tourmaline is used in laboratories to demonstrate the polarization of light, to measure the compressibility of fluids, and to measure high pressures. Agate is made into mortar and pestle sets, knife edges for balances, textile rollers, and spatulas. Gem stones are used as jewel bearings in timing devices, gauges, meters, and other applications requiring precision elements.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Gem stone production includes three steps, (1) mining, (2) processing, and (2) enhancement. These steps are discussed in greater detail below.

2. General Process Flow

Mining

Gem stone mining operations vary according to size and complexity. Small shallow deposits are generally mined by a few people with prybars, picks, shovels, and buckets. Drilling, blasting, and timbering may or may not be employed. Mechanized hauling and hoisting are done only at the largest mines.

Processing

In small operations, gem stone ores are broken, crushed, and concentrated by hand picking, washing, screening, or jigging. In larger operations, mechanized processes are employed. For instance, diamond processing

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[1] Gordon Austin, "Gemstones," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 64-65.

involves standard gravity methods, grease belts, electrostatic separation, skin-flotation, magnetic separation, separation by x-ray luminescence, and separation by optical sorting.

Enhancement

Gem materials are cut in four main operations: sawing, grinding, sanding, and polishing. An initial cut is made with a diamond saw or blade to obtain a slice of desired thickness. Grinding of the stone may be done with impregnated-diamond, silicon carbide, aluminum oxide wheels, or coated abrasive disks. Multiple grinding steps ranging from 80 mesh through 600 mesh abrasives are used. Disk and belt sanders use abrasives bonded to cloth or waterproof reinforced paper. Leather laps or hard felt are used with a polishing agent to obtain the final polish.

Polishing agents such as fine diamond compound, tin oxide, tripoli, chromium oxide, cerium oxide, alumina, and rouge are typically used. These polished irregular shapes can then be further polished by tumbling them in a rubber lined drum and using a grinding and polishing medium with or without water.

Finally, many gem stones are further treated to enhance their appearance. Several different chemical and physical processes may be used, including bleaching, oiling, waxing, staining, dyeing, plastic and color impregnation by diffusion or dyeing, surface modification with color coating, lasering, glossing, heat treatment to change color, and irradiation by electromagnetic spectrum and by energetic particles to change color. Interference filters, foil backings, surface decoration, and inscribing are used to alter the surface of gems. The most common method of gem enhancement is heat treatment which can change color, structure, and clarity. A newer method of gem enhancement is diffusion treatment. This involves a chemical heat treatment in a bath of chemicals containing iron and titanium.[2]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Synthesis of materials that can replace rare crystalline materials has been encouraged by industry. Synthetic gem stones may be used in electronics and semiconductors or as frequency controllers, polarizers, transducers, radiation detectors, infrared optics, bearings, strain gages, amplifiers, lasers, lenses, crucibles, and more.[3]

4. Beneficiation/Processing Boundaries

Based on a review of the process, there are no mineral processing operations involved in the production of gem stones.

C. Process Waste Streams

Existing data and engineering judgement suggest that the wastes listed below from gem stone production do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

1. Extraction/Beneficiation Wastes

The extraction of gem bearing material in mines creates **overburden**. However, land disturbance due to gem stone extraction is minimal since the number of underground mines in operation is minimal.[4] Additional miscellaneous wastes include **spent chemical agents** used to color the gem stones, **spent polishing media**, and **waste minerals**.

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[2] Gordon T. Austin, "Gemstones," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 501-519.

[3] Jean W. Pressler, "Gemstones," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, pp. 305-315.

[4] Ibid.

2. Mineral Processing Wastes

No wastes are identified.

D. Non-uniquely AssociatedWastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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Austin, Gordon. "Gemstones." From Minerals Yearbook Volume 1. Metals and Minerals. U.S. Bureau of Mines. 1992. pp. 501-519.

Pressler, Jean. "Gemstones." From Mineral Facts and Problems. U.S. Bureau of Mines. 1985. pp. 305- 315.

GERMANIUM

A. Commodity Summary

Germanium is recovered either as a minor byproduct of the refining of base metal ores, or as a constituent of coal deposits.[1] Germanium has a metallic grayish appearance and is hard and brittle. It is a semiconductor with electrical properties between those of metal and an insulator.[2] The Bureau of Mines estimated domestic consumption at 25,000 kilograms during 1994.[3] The domestic germanium industry is composed of three germanium refineries, one each in New York, Pennsylvania, and Oklahoma and a mining operation located in Tennessee.[4] Additional information is provided on a recovery operation in Utah. Exhibit 1 presents the names and locations of the facilities involved in the production of germanium.

EXHIBIT 1

SUMMARY OF GERMANIUM PROCESSING FACILITIES

Facility Name	Location	Type of Operations
Atomergic Chem	Plainview, NY	Refining
Cabot	Revere, PA	Refining
Eagle-Picher	Quapaw, OK	Refining
Jersey Miniere	Clarksville, TN	Mining
Musto Exploration	St. George, UT	Mining and Refining

Germanium is available commercially as a tetrachloride and a high purity oxide, and is commonly found in the form of zone-refined ingots, single crystal bars, castings, doped semiconductors, and optical materials.[5] Some of the major end uses for germanium include infrared optics, fiber-optics systems, detectors, and semiconductors.[6]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Germanium is recovered as a by-product of other metals, mostly copper, zinc, and lead. The process described in detail below refers to the recovery of germanium from residues at zinc ore processing facilities. Exhibits 2 through 4 present process flow diagrams for the production of germanium.

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[1] Thomas O. Llewellyn, "Germanium," from Minerals Yearbook Volume 1. Metals and Minerals, 1992, p. 531.

[2] Ibid., p. 531.

[3] Thomas O. Llewllyn, "Germanium," from Minerals Commodity Summaries, U.S. Bureau of Mines, 1995, p. 66.

[4] Ibid.

[5] Thomas O. Llewellyn, 1992, Op. Cit. p. 531.

[6] Thomas O. Llewellyn, 1994, Op. Cit., p. 70.

EXHIBIT 2

RECOVERY OF GERMANIUM DURING ZINC ORE PROCESSING

(Adapted from: 1988 Final Draft Summary Report on Mineral Industry Processing Wastes, 1988, pp. 3-93 - 3-99.)

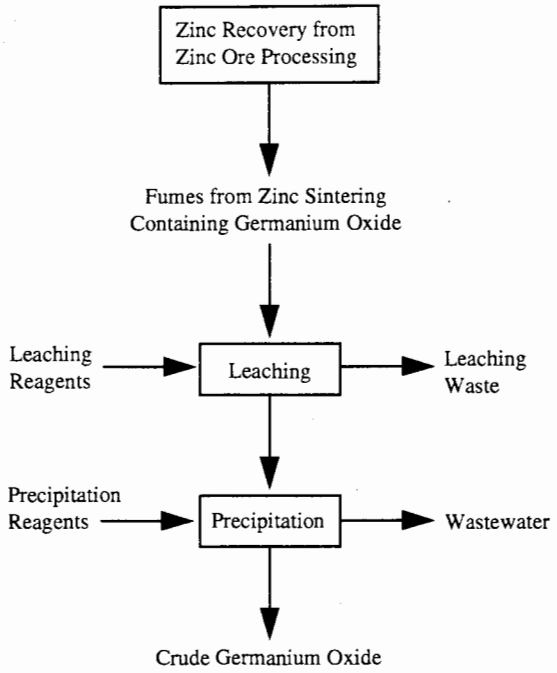


EXHIBIT 3

PRIMARY AND SECONDARY GERMANIUM PRODUCTION PROCESS

(Adapted from: Development Document for Effluent Limitations Guidelines and Standards for Nonferrous Metals Manufacturing Point Source Category, 1989, pp. 5231 - 5352.)

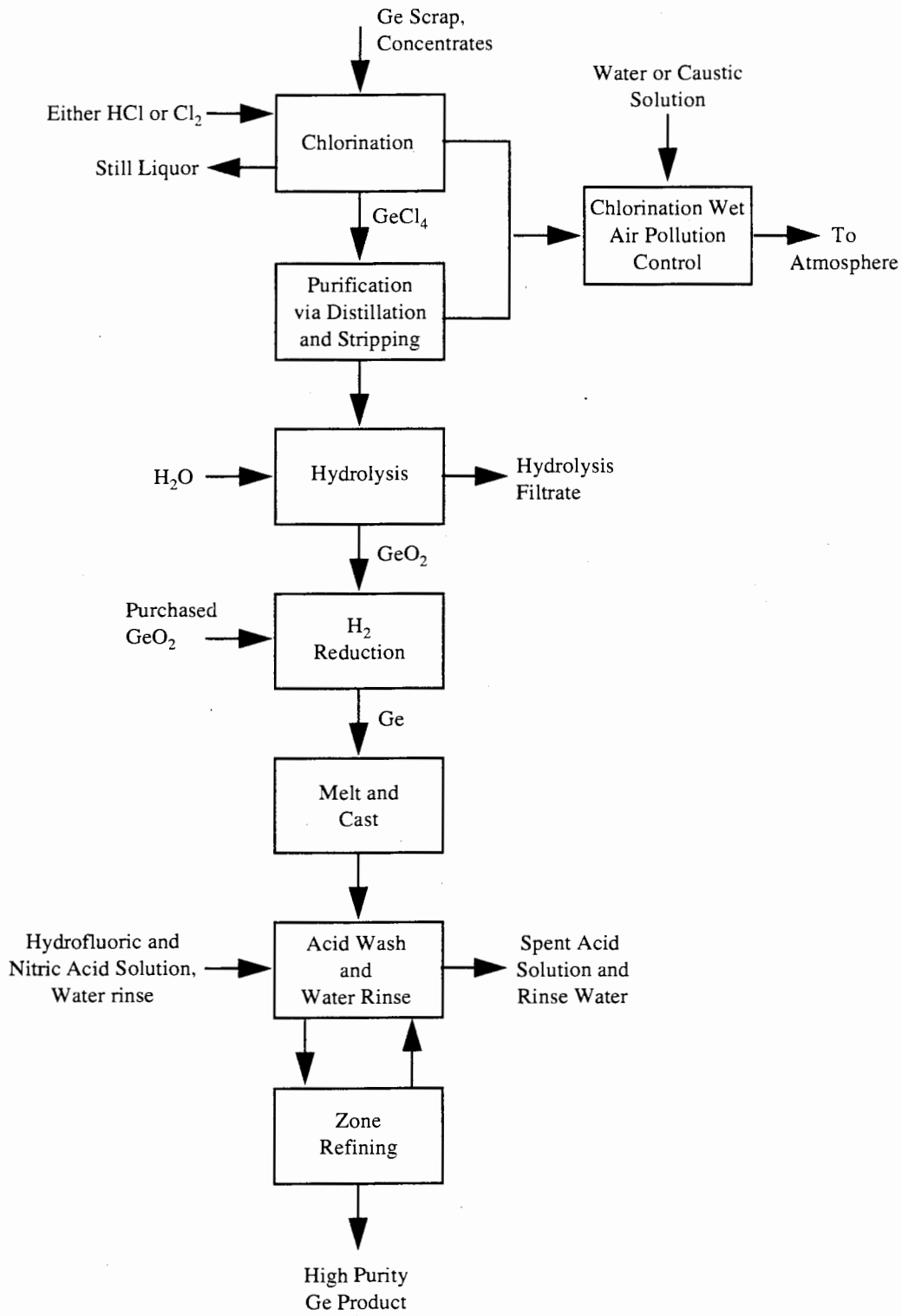
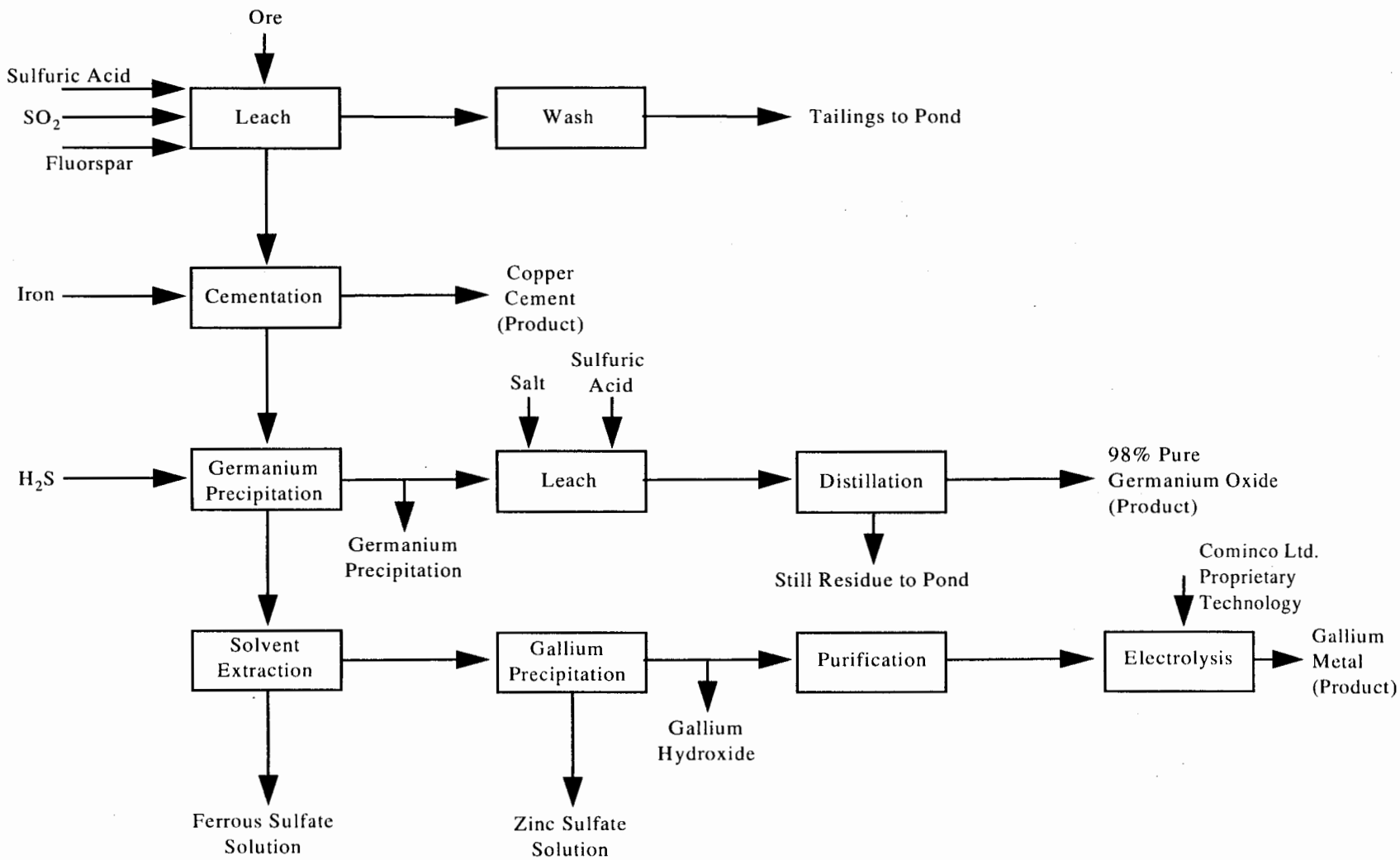


EXHIBIT 4

PROCESS FLOW SHEET FOR GALLIUM AND GERMANIUM PRODUCTION

(Adapted from: 1988 Final Draft Summary Report on Mineral Industry Processing Wastes, 1988, pp. 3-93 - 3-99.)



2. Generalized Process Flow Diagram

As shown in Exhibit 2, germanium-bearing residues from zinc ore processing facilities are a main source for germanium metal. In general, the ore is roasted and sintered. The sintering fumes, which contain oxidized germanium are then collected and leached with sulfuric acid, yielding a solution that contains germanium. Germanium can then be selectively precipitated from the solution through the addition of zinc dust. The remaining solids can be recycled to maximize the recovery of germanium.[7]

Most germanium, regardless of the process by which it was recovered from ore, is refined using chlorination. As shown in Exhibit 3, germanium concentrates are chlorinated with concentrated hydrochloric acid or chlorine gas to produce germanium tetrachloride ($GeCl_4$) in solution.[8] Chlorine is usually added to the primary distillation or subsequent fractionation, or both, to suppress the volatility of arsenic.[9] Solid impurities and still liquor are separated and discarded as waste or processed further, while the filtrates and other wash water are sent for further germanium recovery.[10]

The resultant purified germanium tetrachloride is then hydrolyzed with deionized water to produce a solid germanium dioxide (GeO_2). The germanium dioxide is removed by filtration, dried, and reduced to germanium metal with hydrogen at approximately 760 °C. The metal can then be melted and cast into first reduction or as-reduced bars.[11]

An alternative process, shown in Exhibit 4, is used at the Musto Exploration site in Utah to recover germanium. Fluorspar and ore are leached with sulfuric acid and sulfur dioxide. The fluorspar forms hydrofluoric acid which then helps leach both germanium and gallium. Copper can be removed from the leachate by cementation on iron and can then be sold as a byproduct. Hydrogen sulfide is used to precipitate the germanium. Following this precipitation, the remaining liquid is sent for further gallium recovery. The recovered germanium is refined via leaching and distillation. Any still residues are discarded.[12]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

Since germanium is recovered as a by-product of other metals, all of the wastes generated during germanium recovery are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, please see the reports for copper, zinc, and lead presented elsewhere in this background document.

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[7] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for Nonferrous Metals Manufacturing Point Source Category, Vol. X, Office of Water Regulations Standard, May 1989, p. 5256.

[8] Ibid., p. 5256.

[9] "Germanium," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed, Vol XI, 1994, p. 796.

[10] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 5256.

[11] "Germanium," 1994, Op. Cit. p. 796.

[12] U.S. Environmental Protection Agency, "Germanium," from 1988 Final Draft Summary Report on Mineral Industry Processing Wastes, Office of Solid Waste, 1988, p. 3-96.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Not applicable.

2. Mineral Processing Wastes

Exhibit 3 identifies the following wastes from the recovery of primary and secondary germanium and gallium recovery. Although no published information regarding waste generation rate or characteristics was found. we used the methodology outlined in Appendix A of this report to estimate low, medium, and high annual waste generation rates.

Waste Still Liquor. As shown in Exhibit 3, plants which chlorinate germanium raw materials generate an acidic still liquor containing arsenic, nickel, zinc and germanium, and suspended solids.[13] Low, medium, and high annual waste generation rates were estimated as 10 metric tons/yr, 210 metric tons/yr, and 400 metric tons/yr. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (arsenic, cadmium, chromium, lead, selenium, and silver) and ignitability. Waste characterization sampling data for this waste stream is included as Attachment 1.

Chlorinator Wet Air Pollution Control Sludge. Plants chlorinating germanium use a wet scrubbing system to control HCl and H_2 fumes. Waste from the scrubbing system contains cadmium, lead, nickel, germanium, suspended solids, and an alkaline pH.[14] Low, medium, and high annual waste generation rates were estimated as 10 metric tons/yr, 210 metric tons/yr, and 400 metric tons/yr. We used best engineering judgment to determine that this waste stream may be partially recycled and may exhibit the characteristic of toxicity (arsenic, cadmium, chromium, lead, selenium, and silver). This waste is classified as a sludge. Waste characterization sampling data for this waste stream is included as Attachment 1.

Hydrolysis Filtrate. As shown in Exhibit 3, germanium tetrachloride is hydrolyzed to germanium dioxide by adding deionized water. Germanium dioxide solids are separated from the liquid phase by filtration, and the filtrate may be discharged. The filtrate contains nickel and germanium.[15] Low, medium, and high annual waste generation rates were estimated as 10 metric tons/yr, 210 metric tons/yr, and 400 metric tons/yr. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity (arsenic, cadmium, chromium, lead, selenium, and silver). Waste characterization sampling data for this waste stream is included as Attachment 1.

Waste Acid Wash and Rinse Water. Germanium ingots or bars are washed with a HF-HNO_3 mixture and then rinsed with water to remove residual acid from the bar. The discharged spent acid and rinse water contain treatable concentrations of lead, germanium, and fluoride.[16] Low, medium, and high annual waste generation rates were estimated as 400 metric tons/yr, 2,200 metric tons/yr, and 4,000 metric tons/yr. We used best engineering judgment to determine that this waste stream may be partially recycled and may exhibit the characteristics of toxicity (arsenic, cadmium, chromium, lead, selenium, and silver) and corrosivity. This waste is classified as a spent material. Waste characterization sampling data for this waste stream is included as Attachment 1.

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[13] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 5273.

[14] Ibid., p. 5273.

[15] Ibid.

[16] Ibid.

Exhibits 2 through 4 also identify the following mineral processing wastes associated with the production of germanium. No information on waste generation or management is available for these wastestreams.

Roaster off-gases. Off-gases containing sulfur dioxide are generated during roasting and sent to an acid plant for treatment.

Leach Residues. Ferrous residues are removed and sent to disposal. Residues containing copper and cadmium are sent to further treatment and distribution. This waste stream has a reported annual waste generation rate of 10 metric tons/yr. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity (cadmium and lead).

Germanium-Oxides Fumes. As shown in Exhibit 2, fumes containing germanium oxide are generated during sintering. From these fumes, scrubbing water or solids as well as air pollution control dusts may also be generated.

Spent Acid/Leachate. Spent acid is generated by leaching the germanium oxide fumes from the zinc sintering. The spent acid likely contains arsenic and other heavy metals, including lead and zinc. Low, medium, and high annual waste generation rates were estimated as 400 metric tons/yr, 2,200 metric tons/yr, and 4,000 metric tons/yr. We used best engineering judgment to determine that this waste stream may be partially recycled and may exhibit the characteristics of toxicity (arsenic and lead) and corrosivity. This waste is classified as a spent material.

Wastewater. Some wastewater will result from the precipitation step. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

As shown in Exhibit 4, tailings are generated as a result of the initial leaching at the Musto Exploration process. Still residues are generated as a result of further refining operations at Musto Exploration and sent to ponds for further treatment.[17]

D. Non-uniquely AssociatedWastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[17] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-96.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTE ACID WASH AND RINSE WATER - GERMANIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Min.	Avg.	Max.	# Detects	Level	In Excess
Aluminum	350	350	350	1/1	-	-	-	0/0	-	-
Antimony	0.04	0.04	0.04	1/1	-	-	-	0/0	-	-
Arsenic	0.39	0.39	0.39	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.05	0.05	0.05	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.05	0.05	0.05	1/1	-	-	-	0/0	1.0	0
Chromium	0.50	0.50	0.50	1/1	-	-	-	0/0	5.0	0
Cobalt	0.50	0.50	0.50	1/1	-	-	-	0/0	-	-
Copper	0.10	0.10	0.10	1/1	-	-	-	0/0	-	-
Iron	2.90	2.9	2.9	1/1	-	-	-	0/0	-	-
Lead	0.78	0.78	0.78	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	0.09	0.09	0.09	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	0.50	0.50	0.50	1/1	-	-	-	0/0	-	-
Nickel	0.20	0.20	0.20	1/1	-	-	-	0/0	-	-
Selenium	0.01	0.01	0.01	1/1	-	-	-	0/0	1.0	0
Silver	0.07	0.07	0.07	1/1	-	-	-	0/0	5.0	0
Thallium	0.01	0.01	0.01	1/1	-	-	-	0/0	-	-
Vanadium	1.00	1.00	1.00	1/1	-	-	-	0/0	-	-
Zinc	0.06	0.06	0.06	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - HYDROLYSIS FILTRATE - GERMANIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Min.	Avg.	Max.	# Detects	Level	In Excess
Aluminum	0.78	0.78	0.78	1/1	-	-	-	0/0	-	-
Antimony	0.01	0.01	0.01	1/1	-	-	-	0/0	-	-
Arsenic	0.20	0.20	0.20	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.05	0.05	0.05	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.05	0.05	0.05	1/1	-	-	-	0/0	1.0	0
Chromium	0.50	0.50	0.50	1/1	-	-	-	0/0	5.0	0
Cobalt	0.50	0.50	0.50	1/1	-	-	-	0/0	-	-
Copper	0.10	0.10	0.10	1/1	-	-	-	0/0	-	-
Iron	0.37	0.4	0.4	1/1	-	-	-	0/0	-	-
Lead	0.20	0.20	0.20	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	0.05	0.05	0.05	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	0.52	0.52	0.52	1/1	-	-	-	0/0	-	-
Nickel	1.00	1.00	1.00	1/1	-	-	-	0/0	-	-
Selenium	0.12	0.12	0.12	1/1	-	-	-	0/0	1.0	0
Silver	0.00	0.00	0.00	1/1	-	-	-	0/0	5.0	0
Thallium	0.02	0.02	0.02	1/1	-	-	-	0/0	-	-
Vanadium	1.00	1.00	1.00	1/1	-	-	-	0/0	-	-
Zinc	0.05	0.05	0.05	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTE STILL LIQOUR - GERMANIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Min.	Avg.	Max.	# Detects	Level	In Excess
Aluminum	1.50	1.50	1.50	1/1	-	-	-	0/0	-	-
Antimony	0.03	0.03	0.03	1/1	-	-	-	0/0	-	-
Arsenic	1.70	1.70	1.70	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.05	0.05	0.05	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.23	0.23	0.23	1/1	-	-	-	0/0	1.0	0
Chromium	0.50	0.50	0.50	1/1	-	-	-	0/0	5.0	0
Cobalt	0.50	0.50	0.50	1/1	-	-	-	0/0	-	-
Copper	0.16	0.16	0.16	1/1	-	-	-	0/0	-	-
Iron	1.80	1.8	1.8	1/1	-	-	-	0/0	-	-
Lead	0.20	0.20	0.20	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	2.20	2.20	2.20	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	0.50	0.50	0.50	1/1	-	-	-	0/0	-	-
Nickel	2.00	2.00	2.00	1/1	-	-	-	0/0	-	-
Selenium	0.09	0.09	0.09	1/1	-	-	-	0/0	1.0	0
Silver	0.00	0.00	0.00	1/1	-	-	-	0/0	5.0	0
Thallium	0.01	0.01	0.01	1/1	-	-	-	0/0	-	-
Vanadium	1.00	1.00	1.00	1/1	-	-	-	0/0	-	-
Zinc	150.00	150.00	150.00	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - CHLORINATOR WET APC - GERMANIUM

Constituents	Total Constituent Analysis - PPM Minimum	Average	Maximum	# Detects	EP Toxicity Analysis - PPM Min.	Avg.	Max.	# Detects	TC Level	# Values In Excess
Aluminum	4.10	4.10	4.10	1/1	-	-	-	0/0	-	-
Antimony	0.02	0.02	0.02	1/1	-	-	-	0/0	-	-
Arsenic	0.10	0.10	0.10	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.05	0.05	0.05	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.46	0.46	0.46	1/1	-	-	-	0/0	1.0	0
Chromium	0.50	0.50	0.50	1/1	-	-	-	0/0	5.0	0
Cobalt	0.50	0.50	0.50	1/1	-	-	-	0/0	-	-
Copper	0.20	0.20	0.20	1/1	-	-	-	0/0	-	-
Iron	11.00	11.0	11.0	1/1	-	-	-	0/0	-	-
Lead	0.45	0.45	0.45	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	0.25	0.25	0.25	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	0.50	0.50	0.50	1/1	-	-	-	0/0	-	-
Nickel	1.80	1.80	1.80	1/1	-	-	-	0/0	-	-
Selenium	0.04	0.04	0.04	1/1	-	-	-	0/0	1.0	0
Silver	0.00	0.00	0.00	1/1	-	-	-	0/0	5.0	0
Thallium	0.02	0.02	0.02	1/1	-	-	-	0/0	-	-
Vanadium	1.00	1.00	1.00	1/1	-	-	-	0/0	-	-
Zinc	0.17	0.17	0.17	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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GOLD AND SILVER

A. Commodity Summary

Gold and silver are discussed together in this report since most of the processes used to recover one will also recover the other. In addition, both metals are often found together in nature. A mine is generally classified as a gold or silver mine based on which metal recovered yields the greatest economic value to the operator. Exhibit 1 presents the names and locations of known gold and silver smelters and refineries. Exhibit 2 presents the names and locations of the 25 leading gold-producing mines in the United States.

EXHIBIT 1

SUMMARY OF KNOWN GOLD AND SILVER SMELTERS AND REFINERIES

Facility Name	Facility Location
ASARCO, Inc.	Amarillo, TX Omaha, NE
AURIC-CHLOR, Inc.	Rapid City, SD
David Fell & Company, Inc.	City of Commerce, CA
Drew Resources Corp.	Berkeley, CA
Eastern Smelting & Refining Corp.	Lynn, MA
Englehard Industries West, Inc.	Anaheim, CA
GD Resources, Inc.	Sparks, NV
Handy & Harman	Attleboro, MA South Windsor, CT
Johnson Matthey	Salt Lake City, UT
Metalor USA Refining Corp.	North Attleboro, MA
Multimetco, Inc.	Anniston, AL
Nevada Gold Refining Corp.	Reno, NV
Sunshine Mining Co.	Kellogg, ID
Williams Advanced Materials	Buffalo, NY

Source: Randol Mining Directory, 1994, pp. 741-743.

EXHIBIT 2

TWENTY-FIVE LEADING GOLD-PRODUCING MINES IN THE UNITED STATES (IN ORDER OF OUTPUT)

Mine	Location	Source of Gold
Nevada Mines Operations, Newmont Gold Company	Elko and Eureka, NV	Gold ore
Gold Strike, Barrick Mercur Gold Mines, Inc.	Eureka, NV	Gold ore
Bingham Canyon, Kennecott-Utah Copper Corp.	Salt Lake, UT	Copper ore
Jerritt Canyon (Enfield Bell), Freeport-McMoran Gold Company	Elko, NV	Gold ore
Smoky Valley Common Operation, Round Mountain Gold Corp.	Nye, NV	Gold ore
Homestake, Homestake Mining Company	Lawrence, SD	Gold ore
McCoy and Cove, Echo Bay Mining Company	Lander, NV	Gold ore
McLaughlin, Homestake Mining Company	Napa, CA	Gold ore
Chimney Creek, Gold Fields Mining Company	Humboldt, NV	Gold ore
Fortitude and Surprise, Battle Mountain Gold Company	Lander, NV	Gold ore
Bulldog, Bond Gold, Bullfrog, Inc.	Nye, NV	Gold ore
Mesquite, Goldfields Mining Company	Imperial, CA	Gold ore
Getchell, FMG, Inc.	Humboldt, NV	Gold ore
Sleeper, Amax Gold, Inc.	Humboldt, NV	Gold ore
Cannon, Asamera Minerals (U.S.), Inc.	Chelan, WA	Gold ore
Ridgeway, Ridgeway Mining Company	Fairfield, SC	Gold ore
Jamestown, Sonora Mining Corp.	Tuolumne, CA	Gold ore
Paradise Peak, FMC Gold Company	Nye, NV	Gold ore
Rabbit Creek, Rabbit Creek Mining, Inc.	Humboldt, NV	Gold ore
Barney's Canyon, Kennecott Corp.	Salt Lake City, UT	Copper ore
Continental, Montana Resources	Silver Bow, MT	Gold ore
Zortman-Landusky, Pegasus Gold, Inc.	Phillips, MT	Gold ore
Golden Sunlight, Golden Sunlight Mines, Inc.	Jefferson, MT	Gold ore
Wind Mountain, Amax Gold, Inc.	Washoe, NV	Gold ore
Foley Ridge & Amie Creek, Wharf Resources	Lawrence, SD	Gold ore

Source: Mining Industry Profile Gold, 1993, pp. 5.

The United States is the second largest gold producing nation in the world. Gold lode and placer mines are located mostly in western states and Alaska while production in Nevada and California accounts for 70 percent of domestic production. The 1994 mine production value was over $4.1 billion. Uses of gold include jewelry and arts, 71 percent; industrial (electronic), 22 percent; and dental, 7 percent.[1] The 1994 silver production was valued at $240 million. Nearly three-fourths of the 1994 silver mine production was in Nevada, Idaho, Arizona, and Montana. Approximately 50 percent of the refined silver consumed domestically during 1993 was used in the manufacture of photographic products; 20 percent in electrical and electronic products; 10 percent in electroplated ware, sterlingware, and jewelry; and 20 percent in other uses.[2]

Silver occurs as native metal, but is usually found in sulfur-bearing minerals. About two-thirds of the world silver reserves and resources are contained in copper, lead, and zinc deposits. Ores in which silver or gold is the main component account for the remaining one-third of total world reserves and resources. The chief silver minerals found in domestic reserves are native silver, argentite, ceragyrite, polybasite, proustite, pyrargyrite, and tetrahedrite. Other ore minerals of silver are the tellurides, stromeyerite, and pearceite. Gold occurs mainly as native metal, alloyed with silver and/or other metals, and as tellurides. A naturally occurring alloy of gold and silver is known as electrum. Other gold minerals are rare. Gold is commonly associated with the sulfides of antimony, arsenic, copper, iron, and silver.[3]

B. Generalized Process Description

Precious metals may be recovered from the ore or from refining processes of base metals such as copper and lead. Because these are distinct and separate recovery methods, they are discussed separately in this report. Section 1 describes precious metal recovery from ore, and Section 2 describes precious metal recovery from refinery slimes. Section 3 is a discussion of precious metal refining operations.

SECTION 1: PRECIOUS METAL RECOVERY FROM ORES

1. Discussion of Typical Production Processes

Most domestic gold comes from surface lode mines. Silver is mined using open pit and underground methods. Several processes may be used to recover gold and silver from their ores. These include gravity separation, amalgamation, froth flotation, and cyanidation. Several processes may be combined at any given plant. These processes are discussed in more detail below.

2. Generalized Process Flow Diagram

Gravity Separation

Gravity separation relies on density differences to separate desired materials from host rock. Devices used include gold pans, sluices, shaking tables, and jigs. Gravity separation is used at most placer mines and at some lode or vein deposits.[4]

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[1] John Lucas, "Gold," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1994, pp. 72-73.

[2] Robert Reese, "Silver," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 154-155.

[3] John M. Lucas, "Gold," from Minerals Yearbook Volume 1 Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 535-561.

[4] U.S. Environmental Protection Agency, "Gold and Silver," from, 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, Office of Solid Waste, 1988, pp. 3-100- 3-115.

Amalgamation

Fine gold in placer deposits is often not separable from the ore minerals by density alone. The fine concentrate stream from a gravity separator, called "black sand" because of its color, often contains several dense minerals as well as fine gold. This fine gold may be recovered by amalgamation which involves the dissolution of gold or silver in mercury. The resulting alloy, amalgam, is relatively soft and will adhere readily to other pieces of amalgam or to mercury.[5]

Historically, amalgamation was widely used in the United States for recovery of gold and silver from their ores. Although this method is still practiced in other parts of the world, amalgamation most likely occurs domestically on a very limited scale.

Ore Preparation

Extracted ore must be milled to prepare it for further recovery activities. Uniformly sized particles may be obtained by crushing, grinding, and wet or dry classification. The degree of milling performed on the ore depends on the gold concentration of the ore, mineralogy and hardness of the ore, the mill's capacity, and the next planned step for recovery. Milled ore is pumped to the next operation unit in the form of a slurry. Fugitive dust generated during crushing and grinding activities is usually collected by air pollution control devices and recirculated into the beneficiation circuit. Most mills use water sprays to control dust from milling activities.[6]

After milling, sulfide ores may be subjected to oxidation by chlorination, bio-oxidation, roasting, or autoclaving. Chlorination is not commonly used to oxidize sulfide ores because of high equipment maintenance costs caused by the corrosive nature of the oxidizing agent. Bio-oxidation of sulfide ores employs bacteria to oxidize the sulfur-bearing minerals. Roasting of sulfide ores involves heating the ores in air to convert them to oxide ores and break up their physical structure, allowing leaching solutions to penetrate and dissolve the gold. Roasting oxidizes the sulfur in the ore, generating sulfur dioxide that can be captured and converted to sulfuric acid. Roasting temperatures are dependent on the mineralogy of the ore, but range as high as several hundred degrees Celsius. Roasting of carbonaceous ores oxidizes the carbon to prevent interference with leaching, which, in time, improves gold recovery efficiency. Autoclaving (pressure oxidation) is a relatively new technique that operates at lower temperatures than roasting. Autoclaving uses pressurized steam to start the reaction and oxygen to oxidize sulfur-bearing minerals. Heat released from the oxidation of sulfur sustains the reaction. The Getchell and Barrick Goldstrike Mines in Nevada, the McLaughlin Mine in California, and the Barrick Mercur Mine in Utah are currently using pressure oxidation (autoclave) technology, totally or in part, to beneficiate sulfide or carbonaceous gold ores.[7]

Agglomeration

Because ores with a high proportion of small particles may retard the percolation of the lixiviate, agglomeration is used to increase particle size. This operation includes mixing the crushed ore with portland cement and/or lime, wetting the ore evenly with cyanide solution to start leaching before the heap is built, and mechanically tumbling the ore mixture so fine particles adhere to larger particles.

Cyanidation - Leaching

Cyanidation leaching is the primary means of recovery of fine gold and silver. In this process, solutions of sodium or potassium cyanide are brought into contact with an ore which may or may not require extensive preparation prior to leaching. Gold and silver are dissolved by cyanide in high pH solutions in the presence of

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[5] Ibid.

[6] U.S. Environmental Protection Agency, Technical Resource Document, Extraction and Beneficiation of Ores and Minerals, Vol. II, July 1994.

[7] Ibid.

oxygen. There are three general methods of contacting ores with leach solutions: (1) heap leaching, (2) vat leaching, and (3) agitation leaching. Cyanidation heap leaching and agitation leaching account for most gold and silver recovery.[8,9] These leaching methods are discussed in detail below.

(1) Cyanidation - Heap Leaching

Heap leaching, shown in Exhibit 3, is the least expensive process and is used most often to treat low value ores. In 1993, heap leaching accounted for 39 percent of gold production.[10] In many cases, heaps are constructed on lined pads and ore is sent directly from the mine with little or no preparation. However, at about half of the heap leaching operations, ore is crushed and agglomerated prior to placement on the heap to increase permeability of the heap and maintain the high pH (optimally 10.5) needed for leaching to occur.

Two types of pads used in gold heap leaching are permanent heap construction on a pad from which the leached ore is not removed, and on-off pads, which allow the spent ore to be removed from the pad following the leach cycle and fresh ore to be placed on the pad. Permanent heaps are typically built in lifts. Each lift typically is composed of a 5- to 30-foot layer of ore, though lifts may be higher at times.[11] On-off pads are not commonly used in the industry.

After the ore is piled on a leaching pad, the leaching solution is applied to the top of the pile by sprinklers. The solution generally has a concentration of 0.5 to 1 pound of sodium cyanide per ton of solution, though one major gold producer reports that the leaching solution is generally in the range of 0.25 pounds of sodium cyanide per ton of solution.[12,13] The precious metals are dissolved as the solution trickles through the pile, and the metal bearing solution is collected on the impervious pad and pumped to the recovery circuit. Following rejuvenation, which involves removing the metals, the solution is returned for reuse. The leaching process continues until no more precious metal is extracted. Typical operations will involve leaching for several months on each heap. The process is relatively inexpensive and can be operated for less than two dollars per ton of ore. However, as much as half of the gold and silver may not be extracted either because the leach liquor never contacts the precious metal or because the metal bearing solution is trapped in blind channels. At one facility, at least 60 percent (and often much higher[14] percentages) of the gold contained in leach-grade ore is recovered through heap leaching.[15] Waste streams from this process include spent ore and leaching solutions as well as residual leach liquor in the pile.

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[8] Personal communication between ICF Incorporated and Robert G. Reese, U.S. Bureau of Mines, September 23, 1994.

[9] Newmont Gold Company. Comments submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[10] Personal communication between ICF Incorporated and John M. Lucas, U.S. Bureau of Mines, September 15, 1994.

[11] Newmont Gold Company. Op. Cit.

[12] U.S. Environmental Protection Agency, Technical Resource Document, Treatment of Cyanide Heap Leaches and Tailings, Office of Solid Waste Special Waste Branch, 1994, pp. 2-4.

[13] Newmont Gold Company. Op. Cit.

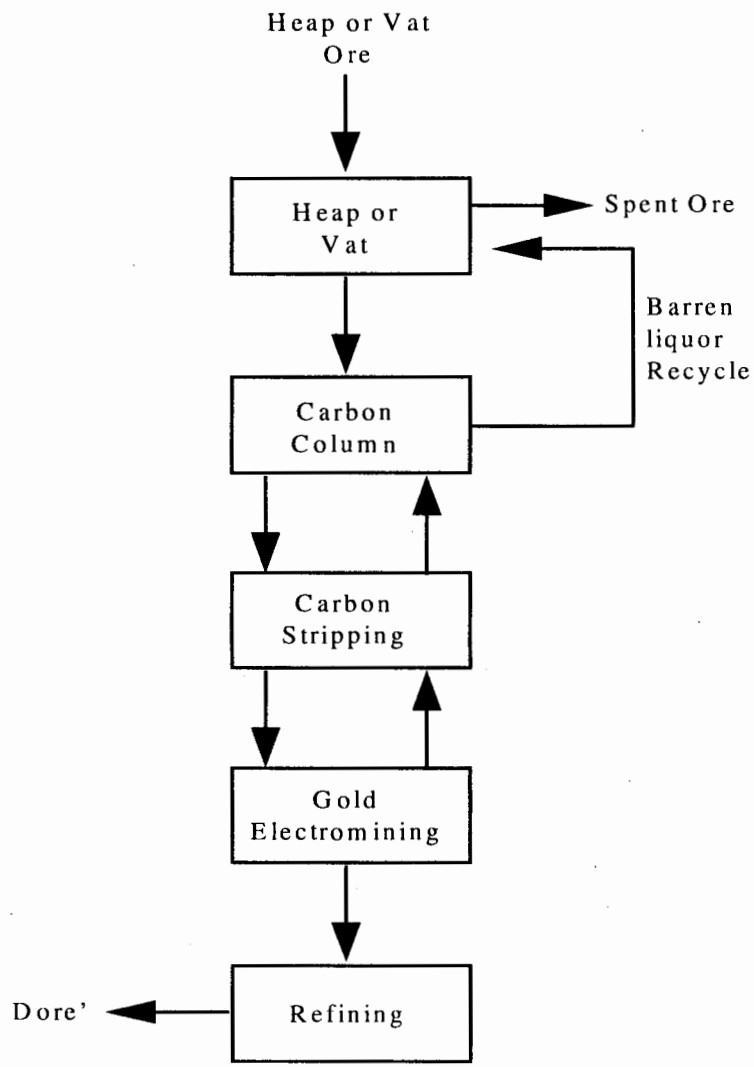
[14] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 3-100 - 30-115.

[15] Ibid.

EXHIBIT 3

GOLD-SILVER LEACHING

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-100 - 3-115.)



(2) Cyanidation - Vat Leaching

Vat leaching, shown in Exhibit 3, is used when greater solution control than that afforded by heap leaching is necessary. In this system, prepared ore is placed in a vat or tank and flooded with leach liquor. The solution is continuously cycled through, draining from the bottom of the vat, proceeding to gold recovery, rejuvenation, and returning to the top of the vat. The process is more expensive than heap leaching because the material must be removed from the vat at the end of the leaching process. While the primary advantage of vat leaching is better solution contact, channelization and stagnant pockets of solution still occur (almost as severely as in heap leaching) when solution is drained from the vat. However, some of the trapped solution is recovered when the solids are removed from the vat. Wastes from this process include spent ore and leaching solutions.[16]

(3) Cyanidation - Agitation Leaching

Agitation leaching is the most commonly used leaching process in gold beneficiation operations in the United States.[17] High value ores are treated by agitation leaching, shown in Exhibit 4, to maximize the recovery of metal values. The ore is crushed and ground in water to form a slurry. Cyanide is usually added at the grinding mill to begin the leaching process, and more cyanide may be added to the leaching tanks. Ores may be leached anywhere from 24 to 72 or more hours. Silver ores tend to require longer leaching times. The method of recovering the precious metal from solution determines how the solution is separated from the solids. If the Merrill-Crowe or carbon-in-column metal recovery process is used, the leach liquor will be washed out of the solids, usually by a combination of counter-current decantation and filtration washing with water. This produces a concentrated wash solution and recovers the maximum pregnant liquor from the solids. The resultant slurry will contain very little cyanide or gold and would not be expected to exhibit any hazardous characteristics. The carbon-in-leach and carbon-in-pulp beneficiation processes are the most commonly used metal recovery processes used in gold beneficiation operations.[18] If carbon-in-leach or carbon-in-pulp metal recovery is practiced, the slurry may be discarded without washing. The carbon should remove all of the precious metals, and the solution is recovered from the tailings treatment and recycled back to the process.[19]

Cyanidation - Metal Recovery

In leaching operations, after dissolving the metal, the leach solution is separated from the ore, and the gold and silver are removed from solution in one of two ways: (1) the Merrill-Crowe process, or (2) activated carbon loading followed by activated carbon stripping.[20] The primary difference between recovery methods is whether the metal is removed by precipitation with zinc or by adsorption on activated carbon. Zinc cyanide is more soluble than gold or silver cyanide and if pregnant liquor is contacted with metallic zinc the zinc will go into solution and the gold and silver will precipitate.[21] The two different recovery methods are described below.

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[16] U.S. Environmental Protection Agency, 1988, Op. Cit., 3-100 - 3-115.

[17] Newmont Gold Company and National Mining Association. Comments submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[18] Ibid.

[19] U.S. Environmental Protection Agency, 1988, Op. Cit., 3-100-3-115.

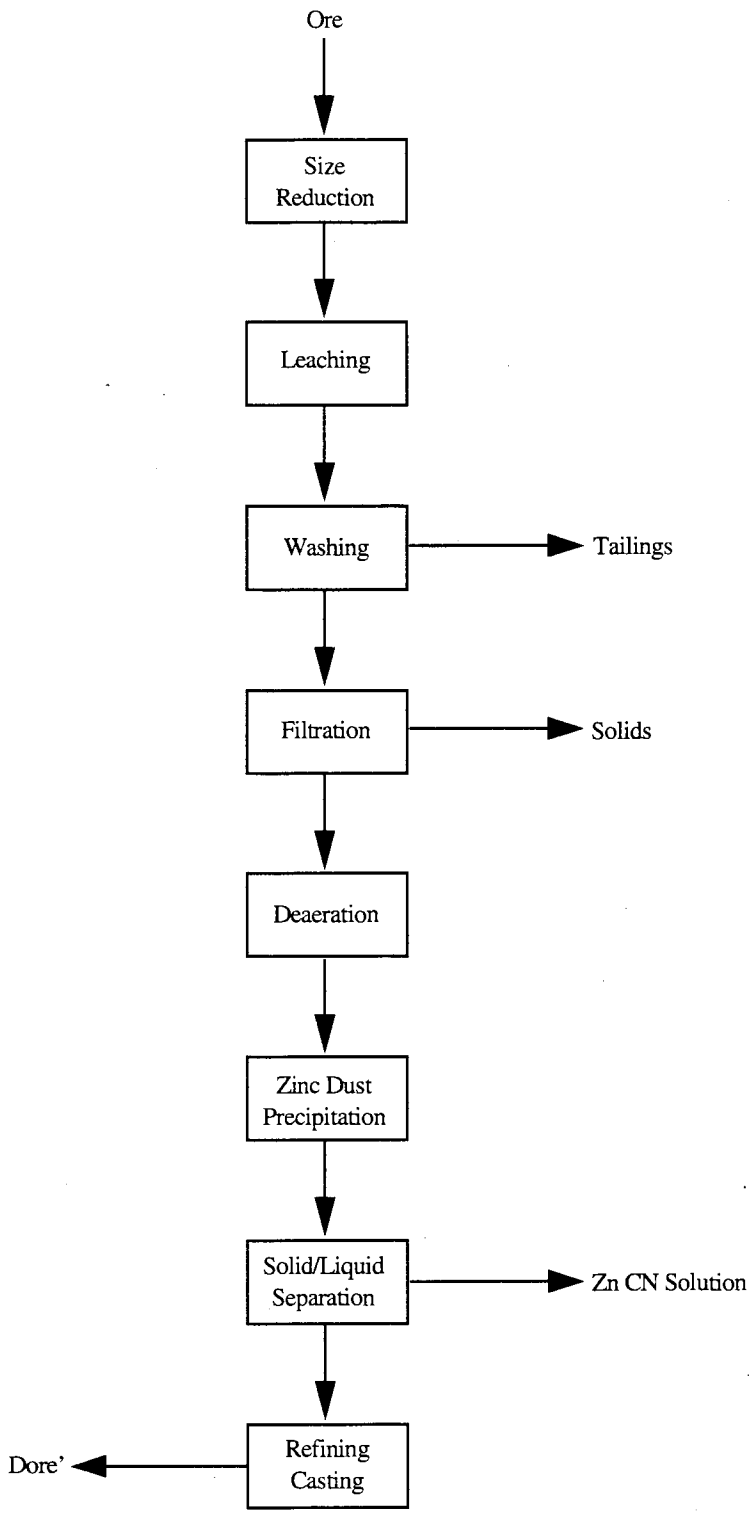
[20] Newmont Gold Company and National Mining Association. Op. Cit.

[21] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 3-100 - 3-115.

EXHIBIT 4

AGITATION LEACHING WITH MERRILL-CROWE RECOVERY

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-100 - 3-115.)



(1) Cyanidation - Metal Recovery - Merrill-Crowe

In the Merrill-Crowe process, the pregnant leaching solution is filtered for clarity, then vacuum deaerated to remove oxygen and decrease precious metal solubility. The deaerated solution is then mixed with fine zinc powder to precipitate the precious metals. The solids, including the precious metals, are removed from the solution by filtration, and the solution is sent back to the leaching circuit. The solids are melted and cast into bars. If silver and gold are present, the bars are called doré. In most cases, the metal is then sent to an off-site refinery. Most operations using zinc precipitation in the United States use some variation of the Merrill-Crowe process.[22]

(2) Cyanidation - Metal Recovery - Activated Carbon Loading/Activated Carbon Stripping

Precious metal leach solutions can be brought into contact with activated carbon by carbon-in-column, carbon-in-pulp, and carbon-in-leach processes.

Carbon-in-column systems are used at heap and vat leach operations and in other situations where the leaching solution is separated from the solids being leached prior to precious metal recovery. The leaching solution is passed through a series of columns containing beds of activated carbon. The gold and silver are adsorbed as cyanide complexes on the surface of the carbon. After passing through the columns, the solution is returned to the leaching circuit. When the carbon in a column is loaded with precious metals, the column is switched to a stripping circuit.[23]

In many agitation plants, the gold is recovered from the leached material before the solution is separated from the solids. In the *carbon-in-pulp* system, the leached pulp passes from the last stage of the leaching circuit into another series of agitation tanks. Each tank contains activated carbon granules. The slurry flows from tank to tank in series while the carbon is retained by screens. When the carbon in the first tank is fully loaded with precious metals, it is removed and sent to the stripping and reactivation circuit; the carbon in the other tanks is moved ahead one stage, and new carbon is added to the last stage. The carbon moves counter-current to the leached slurry and the leached slurry is finally sent to the tailings area for dewatering.[24] A process flow diagram of carbon-in-pulp metal recovery is shown in Exhibit 5.

Carbon-in-leach is similar to carbon-in-pulp except that the carbon is in the leaching tanks instead of in a separate recovery circuit. One advantage of carbon-in-leach over carbon-in-pulp is that some cyanide is released when gold adsorbs on carbon, making it available for more leaching. Another advantage is that fewer agitation tanks are necessary since the separate recovery circuit is eliminated. However, the agitation is more aggressive in the leach circuit causing more attrition of the carbon than in the carbon-in-pulp. Thus, the finely abraded carbon and its load of precious metals may be lost, reducing recovery and increasing costs due to increased carbon replacement.[25] A process flow diagram of carbon-in-leach metal recovery is presented in Exhibit 5.

Gold stripping from loaded activated carbon is usually done with a hot, concentrated alkaline cyanide solution, sometimes including alcohol. These conditions favor the desorbtion of the precious metals into the stripping solution. The solution then goes into an electrowinning cell where the precious metals are plated out, generally onto a steel wool cathode. The solution is recycled to the stripping stage and the cathode is sent on to

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[22] Ibid.

[23] Ibid.

[24] Ibid.

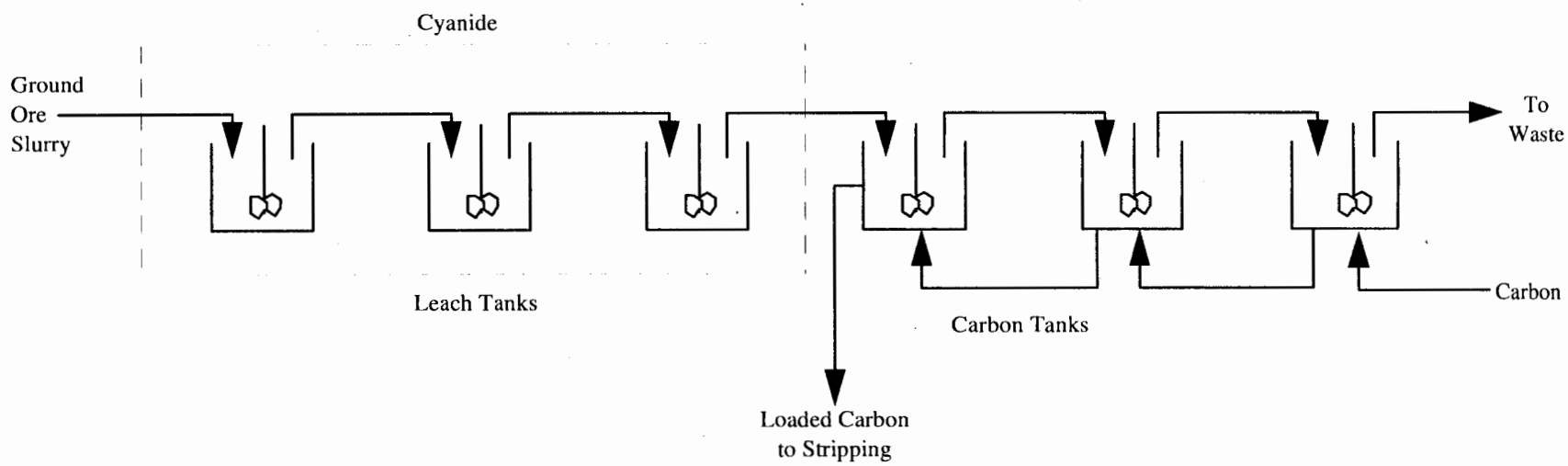
[25] Ibid.

EXHIBIT 5

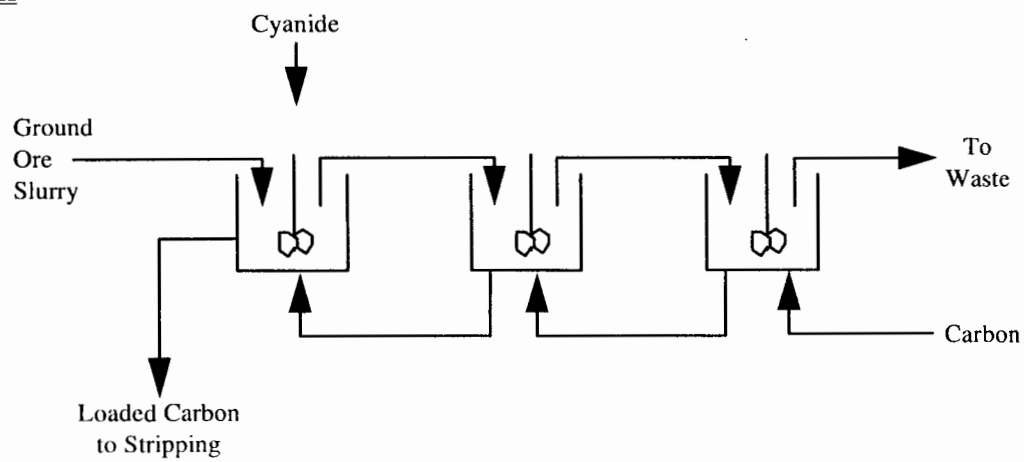
CARBON-IN-PULP AND CARBON-IN-LEACH METAL RECOVERY

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-100 - 3-115.)

CARBON-IN-PULP



CARBON-IN-LEACH



refining. Some operations refine the steel wool on site to make doré while others ship it directly to commercial refineries. The primary waste from carbon stripping is the spent stripping solution.[26]

The Anglo-American Research Laboratory (AARL) elution method is an alternative stripping process being used by at least one facility. In the first step of the AARL method, the loaded carbon is rinsed with a dilute (i.e., three percent) hydrochloric acid solution and then flushed with water to render the gold more amenable to separation from the carbon. The rinse waters resulting from this process are recycled by pipe to the carbon-in-leach circuit to recover any loaded carbon that is flushed out by the acid wash (loaded carbon typically contains 150 ounces of gold per ton). Following the acid wash/water rinse stage, desorption occurs. The loaded carbon is soaked in a concentrated solution composed of six percent sodium hydroxide and three percent sodium cyanide. This soaking loosens the bond between the carbon and gold. A fresh water rinse then picks up the gold. The resulting pregnant gold-bearing solution is pumped to the electrowinning circuit.[27]

Carbon Regeneration

After stripping, the carbon is reactivated on- or off-site and recirculated to the adsorption circuit. Carbon used in adsorption/desorbtion can be reactivated numerous times. The regeneration technique varies with mining operations, but generally involves an acid wash before or after extraction of the gold-cyanide complex, followed by reactivation in a kiln. The activated carbon is washed with dilute acid solution (pH of 1 or 2) to dissolve carbonate impurities and metal-cyanide complexes that adhere to the carbon along with the gold. This technique may be employed either immediately before or after the gold-cyanide complex is removed. Acid washing before the gold is removed enhances gold recovery. The Barrick Mercur Mine in Utah, the Barrick Goldstrike Mine in Nevada, and the Ridgeway Gold Mine in South Carolina are examples of facilities using acid prewash techniques. The Golden Sunlight Mine in Montana and the Battle Mountain Mine in Nevada use acid postwash techniques.[28]

The specific acid used for carbon washing is determined by the types of impurities need to be removed. Usually, a hydrochloric acid solution is circulated through 3.6 metric tons of carbon for approximately 16 to 20 hours. Nitric acid also is used in these types of operations, but is thought to be less efficient than hydrochloric acid in removing impurities. The resulting spent acid wash solutions may be neutralized with a high pH tailings slurry, dilute sodium hydroxide solution, or water rinse. When the spent acid wash solution reaches a stable pH of 10, it is sent to a tailing impoundment. Metallic elements may also be precipitated with sodium sulfide to remove them from the carbon.[29]

The carbon is screened to remove fines and thermally reactivated in a rotary kiln at about 730 °C for 20 minutes. The reactivated carbon is subsequently rescreened and reintroduced into the recovery system. Generally, less than 10 percent of the carbon is lost during the process because of particle abrasion.[30] Recirculating the carbon material gradually decreases performance in subsequent absorption and reactivation series. Carbon adsorption efficiency is closely monitored, and fresh carbon is added to maintain efficiency at design levels.[31]

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[26] Ibid.

[27] Newmont Gold Company. Op. Cit.

[28] U.S. Environmental Protection Agency, July 1994, Op. Cit., pp. 1-12.

[29] Ibid.

[30] Newmont Gold Company. Op. Cit.

[31] U.S. Environmental Protection Agency, July 1994, Op. Cit., pp. 1-12.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

EPA has determined that all of the activities discussed in Section 1 are classified as beneficiation activities.

SECTION 2: PRECIOUS METAL RECOVERY FROM REFINERY SLIMES

1. Discussion of Typical Production Processes

Gold and silver also are recovered from the refining processes for base metals, primarily lead and copper. Smelting operations remove iron, sulfur, and other impurities from the ore and produce copper anodes for electrolytic refining. In refining operations, the anodes produced from smelting are purified electrolytically to produce copper cathodes. The refinery slimes from these operations are processed for precious metals recovery, as portrayed in Exhibit 6. The recovery of precious metals in lead refineries is a normal part of the operation called "desilverizing."

2. Generalized Process Flow Diagram

A major source of precious metals from the copper industry is electrolytic cell slimes. The slimes are periodically removed from the cells in the refinery for treatment. The first stage of treatment removes the copper in the slimes by acid leaching, either as is or after roasting. The decopperized slimes are then placed in a furnace and melted with a soda-silica flux. The siliceous slag formed in this melting is removed, and air is blown through the molten material. Lime is added, and a high lead content slag is formed which is combined with the siliceous slag and returned to the copper anode casting furnace. Next, fused soda ash is added to the furnace and air is again blown through the melt, forming a soda slag which is removed and treated to recover selenium and tellurium. The remaining doré in the furnace is removed and sent to refining to recover the precious metals.[32] See the selenium and tellurium commodity reviews for a more detailed discussion of product recovery.

The desilverizing process takes advantage of the solubility of precious metals in molten zinc which is greater than their solubility in molten lead. Lead from previous stages of refining is brought in contact with a zinc bath, either in a continuous operation or in batches. The zinc absorbs the precious metals from the lead, and the lead is then passed onto a dezincing operation. The zinc bath is used until it contains 5,000 to 6,000 troy ounces of precious metal per ton of zinc. The zinc bath is then retorted to recover zinc by distillation. The zinc is returned to the desilverizing process, and the "retort metal" is treated by cupellation to produce doré bullion. In the cupellation,step, the base metals in the retort metal are oxidized with air and removed from the precious metals. The oxides are all treated for the recovery of their various precious metals. The doré is then sent to refining.[33]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

Because the slimes from which gold is recovered are mineral processing wastes generated in the recovery of other metals, all of the wastes generated during gold recovery from refinery slimes are, therefore, mineral processing wastes as well.

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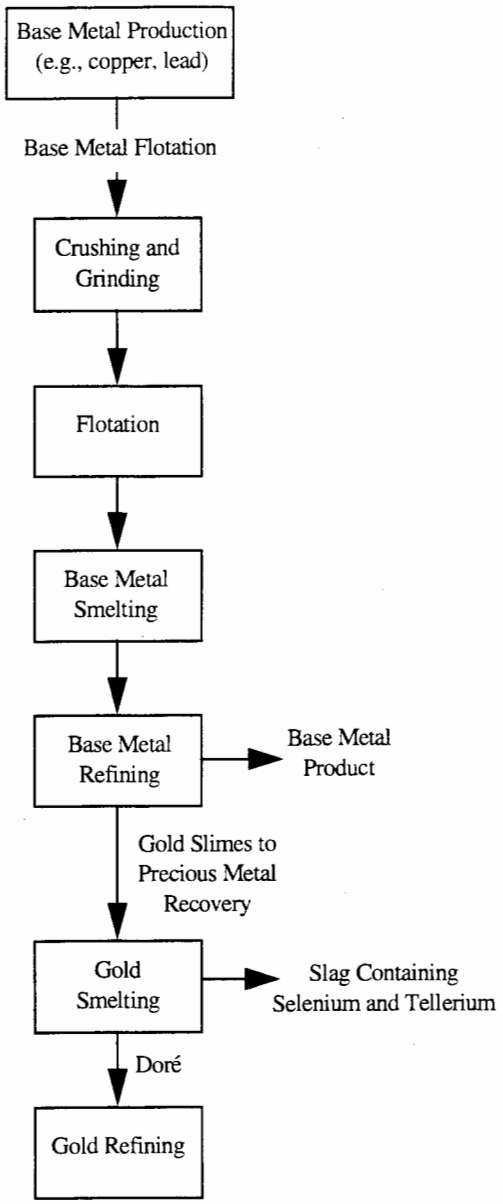
[32] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 3-100 - 3-115.

[33] Ibid.

EXHIBIT 6

OVERVIEW OF GOLD PRODUCTION FROM BASE METALS

(Adapted from: Technical Resource Document, Extraction and Beneficiation of Ores and Minerals, July 1994, pp. 1-12.)



SECTION 3: PRECIOUS METAL REFINING

1. Discussion of Typical Production Processes

The refining process used for gold and silver depends on the composition of the material in the feed. The most basic operation is "parting" which is the separation of gold and silver. Parting can be done electrolytically or by acid leaching. In either case, the silver is removed from the gold. Further treatments may be necessary to remove other contaminants. These treatments have the potential to produce wastes with hazardous characteristics, primarily corrosivity, since strong acids are used.[34]

2. Generalized Process Flow Diagram

Like several other gold refineries, the Newmont facility in Nevada electrowins its gold cyanide solution onto steel wool cathodes after carbon stripping. The barren cyanide solution is returned to the leach circuit for gold recovery. Sludge from the bottom of the electrowinning cell is filtered and sent to the retort for mercury recovery. The gold/steel wool cathode is placed in a vat containing a sulfuric acid solution. The solution dissolves the steel wool from the gold and silver, leaving a solid gold and silver residue. The waste sulfuric acid and steel wool solution is discharged to the tailings slurry. The gold and sislver solids are filtered under vacuum through diatomaceous earth. The gold and silver filter cake is then sent to the retort furnace where it is subjected to 1,200 °F for 14 hours. After retorting, a flux of silica and borax is added, and the gold and silver mixture is smelted in an induction furnace. It is from this induction furnace that gold doré bars are poured. Within days of generation, the slag generated from this smelting is sent to a ball mill for crushing and grinding and is then leached in tanks with sodium cyanide. The resulting gold rich slurry is conveyed to the cyanidation/leaching circuit where it is processed with primary gold-bearing slurries. In some cases, portions of the slag are recycled directly back into the induction furnaces for gold recovery. The gold slag may have between 3 and 4 ounces per ton of recoverable gold.[35] The slag from one facility reportedly averages 150 ounces of gold per ton.[36]

Silver Chloride Reduction

Silver metal is produced from silver chloride by a dissolution and cementation process. The silver chloride is dissolved in a dilute solution of ammonium hydroxide and recovered by cementation. The silver is replaced in solution, causing the silver ions to be reduced and precipitated from solution as silver metal.

Mercury Recovery

Many gold-bearing ores from the western United States contain small quantities of mercury. The presence of mercury decreases the gold-loading capacity of the activated carbon. During cyanidation of mercury-bearing gold-silver ores, significant amounts of mercury are extracted. Addition of calcium sulfide to the cyanide leach slurry precipitates the solubilized mercury and also some silver.[37] Primary mercury is also produced from gold-bearing ores by roasting or calcining. These processes are described in more detail in the chapter on mercury. Exhibit 7 presents an overall process flow sheet for gold production from ores.

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[34] Ibid.

[35] U.S. Environmental Protection Agency, Trip report for Newmont Gold Corporation, South Operations Facilities, Carlin Nevada, May 17, 1995.

[36] Newmont Gold Company. Op. Cit.

[37] Simpson, W.W., W.L. Staker, and R.G. Sandberg, Calcium Sulfide Precipitation of Mercury From Gold-Silver Cyanide-Leach Slurries, U.S. Department of Interior, 1986.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for recovering gold and silver from precious metal refining, the beneficiation/ processing line occurs between electrowinning and retorting because this is where a significant chemical change occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated during the production of gold and silver, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Mining

Mine water is a waste stream generated from gold and silver production. This waste consists of all water that collects in mine workings, both surface and underground, as a result of inflow from rain or surface water and ground water seepage. If necessary, the water is pumped to allow access to the ore body or to keep the mine dry. This water may be pumped from sumps within the mine pit or from interceptor wells. Mine water may be used and recycled to the beneficiation circuit, pumped to tailings ponds, or discharged to surface water. Quantity and chemical composition of mine water varies from site to site.[38]

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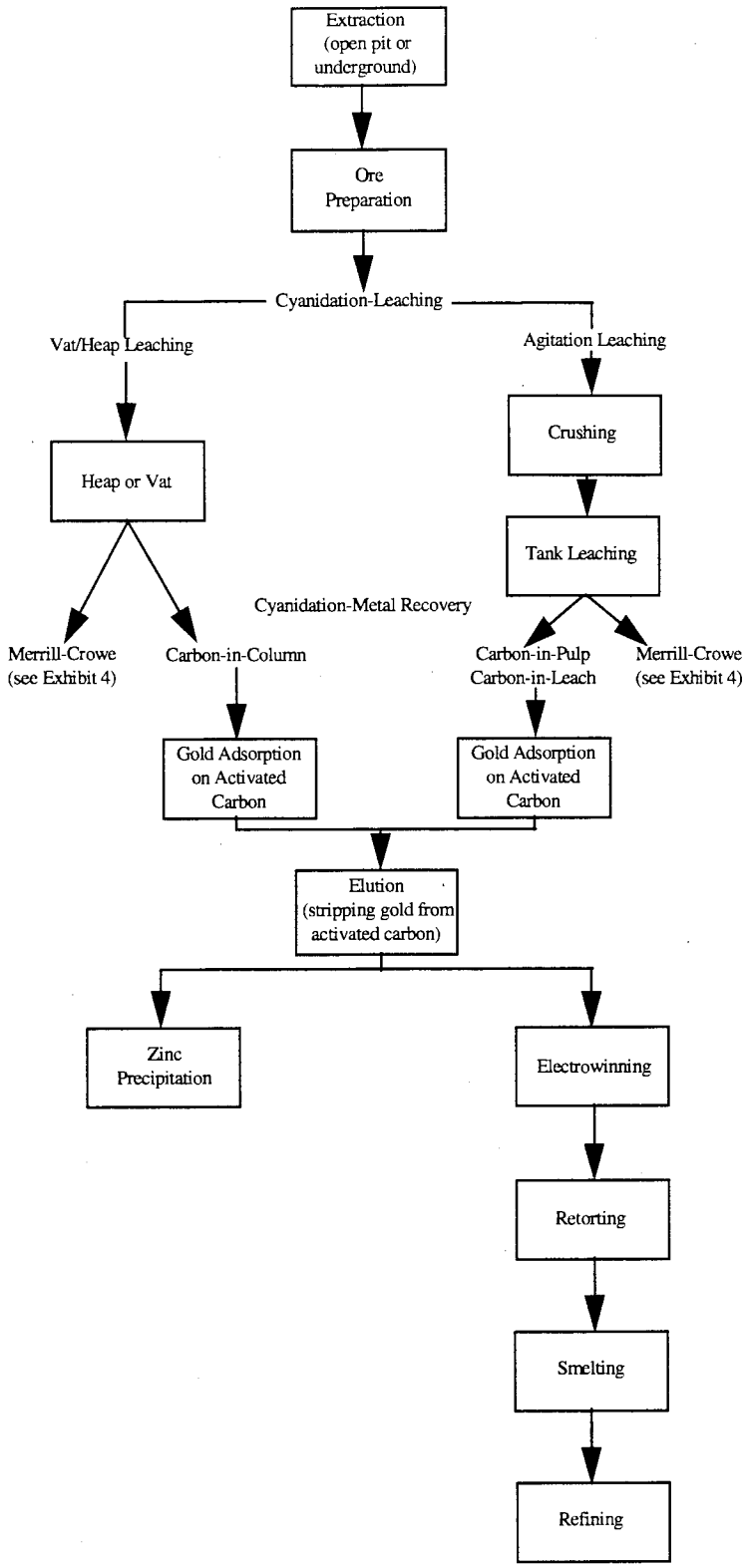
[38] U.S. Environmental Protection Agency, Mining Industry Profile, Gold, Office of Solid Waste, Special Waste Branch, 1993, pp. 41-45.

EXHIBIT 7

OVERVIEW OF GOLD PRODUCTION FROM ORES

(Adapted from: Technical Resource Document, Extraction and Beneficiation of Ores and Minerals, July 1994, pp. 1-12.)



Waste Rock. Overburden and mine development is referred to by the industry as waste rock. This waste is generally disposed of in waste rock piles or dumps. An estimated 25 million metric tons of overburden and mine development rock was generated in 1980 and 39 million metric tons in 1982. At surface mines, 71 percent of all material handled is discarded as waste. At underground mines, 20 percent is discarded as waste. The quantity and composition of the waste rock varies by site. Depending on the composition of the ore body, this waste may contain sulfides or oxides.

Amalgamation

Waste rock, clay, and sand may be disposed of in a tailings pond.

Black sand may contain residual mercury and be disposed of in a tailings pond.

Mercury bearing solution may be sent to mercury recovery or a tailings pond.

Ore Preparation

Sulfur dioxide may be routed to an acid plant and converted to sulfuric acid. This may be sold to other mines or used on-site for carbon washing and regeneration. At least one facility, Newmont's operation in Nevada, generates sulfuric acid,.[39]

Cyanidation

Spent Ore. The ore from leaching may contain residual cyanide. The ore in continuous or valley fill heaps is stacked in lifts and left in place for subsequent leaching, detoxification, and closure. Ore removed from on-off heap leaching pads is permanently disposed at waste or spent ore disposal sites. Typically, detoxification of the spent ore involves rinsing with water until the cyanide concentration in the effluent is below a specific standard set by the State regulatory agency. The heap may then be reclaimed with wastes in place. Spent ore from vat leaching exists in the form of a slurry composed of gangue and process water bearing cyanide and cyanide-metal complexes. The spent ore may be treated to neutralize cyanide prior to disposal. The slurry is typically disposed of in a tailings impoundment with some of the liquid component being recirculated to the tank leach as make-up water.[40]

Spent Leaching Solution. During the leaching operations, most of the barren cyanide solution is recycled to leaching activitie. On rare occasions, however, the build-up of metal impurities may interfere with the dissolution and precipitation of gold and, therefore, require a portion of the solution volume to be bled off and disposed. These solutions may contain free cyanide and metallo-cyanide complexes of copper, iron, nickel, and zinc, as well as other impurities, such as arsenic and antimony, mobilized during the leaching. Management practices for these solutions are unclear; however, they have been discharged to tailings impoundments.[41]

Merrill-Crowe

Filter cake resulting from zinc precipitation consists primarily of fine gangue material and may contain gold-cyanide complex, zinc, free cyanide, and lime. The filter may be washed with water, which is disposed of as part of the waste. The waste is typically sent to tailings impoundments or piles.

Spent leaching solution from zinc precipitation is often returned to the leaching process.

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[39] Newmont Gold Company. Op. Cit.

[40] U.S. Environmental Protection Agency, 1994, Op. Cit., pp. 1-12.

[41] Ibid.

Metal Recovery - Activated Carbon Stripping

Tailings in slurry form, composed of gangue (including sulfide materials and dissolved base metals) and process water bearing cyanide and cyanide-metal complexes, are generated from carbon-in-pulp and carbon-in-leach processes. The characteristics of this waste vary depending on the ore, cyanide concentration, and water source (fresh or recycled). The characteristics of the gangue are dependent on the ore source. The slurry is typically disposed of in a tailings impoundment with some of the liquid component being recirculated to the tank leach or other water consumptive system.[42]

Waste sulfuric acid from elution is exempt under the Bevill Amendment because it is generated in a beneficiation activity that is uniquely associated with mineral processing. This waste may be corrosive.

Waste steel wool solution may be corrosive.

Acid wash from carbon regeneration may be corrosive.

2. Mineral Processing Wastes

Smelting and Refining

Slag. Slag is typically generated at gold mining and milling operations.[43] At one facility, metal-bearing slag is broken off the molten dore and then placed into barrels inside the refinery building. The slag is then processed for gold recovery, normally within several days of its generation. Specifically, the slag is ground and then leached in tanks with sodium cyanide. The gold-rich slurry that results is then conveyed, by pipe, to the primary gold-bearing slurries in the mill for mixing. The facility also reports that in the past, slag also was processed by placing it directly back into the induction furnaces for gold recovery. Assays performed by Newmont Gold during 1995 and 1997 show that slag generated at its Nevada Mines Complex typically contains between 100 and 700 ounces of gold per ton. Tests also indicate that the slag may exhibit the characteristic of toxicity for cadmium.[44] No published information regarding waste generation rate or characteristics was found, though one facility reportedly generates approximately 38 to 57 tons of slag per year.[45, 46] This facility also indicated that it takes weeks to accumulate enough slag to constitute a large enough batch for cost effective metals recovery. The total industry generation rate for slag is thus probably less than 500 metric tons per year. One facility also indicated that slag may possess the characteristic of toxicity for cadmium.[47] The slag is not stored or processed on the land, nor does it enter the outside environment. Slag is believed to be fully recycled and was formerly classified as a byproduct.

WWTP Sludge. WWTP sludge is typically generated at gold refineries.[48] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 360,000 metric tons/yr, and 720,000 metric tons/yr, respectively. We used best engineering judgment to determine

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[42] Ibid.

[43] Precious Metals Producers. January 25, 1996. Op. Cit.

[44] Newmont Gold Company. May 12, 1997. Op. Cit.

[45] Newmont Gold Company. January 25, 1996. Op. Cit.

[46] Newmont Gold Company. May 12, 1997. Op. Cit.

[47] Ibid.

[48] Precious Metals Producers. Op. Cit.

that this waste may exhibit the characteristic of toxicity for silver. This waste may be recycled and was formerly classified as a sludge.

Spent Furnace Dust. Spent furnace dust is typically generated at gold mining and milling operations.[49] As part of the smelting process, gold-bearing dust is generated in the induction furnaces. This dust is conveyed by pipe to a baghouse located in the refinery building and collected in barrels. The barrels of baghouse dust are never stored outdoors. At the Nevada Mines Complex, sealed barrels of baghouse dust are accumulated for up to four months before being shipped off-site for smelting. At other facilities, smelting of baghouse dust may be done in the on-site induction furnace. Assays performed by Newmont Gold in 1995 and 1996 show that the baghouse dust from its Nevada Mines Complex contains approximately 2,200 ounces of gold per ton and that the dust may exhibit the characteristic of toxicity for cadmium and selenium. This facility generated approximately 1,550 ounces of gold in 1996 by smelting baghouse dust, generating revenues of over $600,000.[50] Thus, the facility generated less than one ton of baghouse dust in 1996, suggesting an industry-wide generation rate of less than 9 tons per year. The dust is entirely recycled and was formerly classified as a byproduct. At one facility, several months are required to accumulate sufficient baghouse dust to constitute a large enough batch to ship off-site for smelting.[51] We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for silver. At one facility, the dust exhibits the characteristic of toxicity for cadmium and selenium. The dust is not land stored and never enters the outside environment.[52,53] This waste is recycled and was formerly classified as a byproduct.

Retort Cooling Water. The retorting process at Newmont Gold's Nevada Mines Complex generates mercury-, silver- and gold-bearing gases. Water is used to cool and condense those gases. Through this process, the cooling water becomes contaminated with gold, silver, and mercury. This water is conveyed by pipe to the main beneficiation circuit to allow recovery of the metals and reuse of the water.[54]

Wastewater is typically generated at gold refineries and is generated from numerous sources, including the smelter air pollution control (APC), silver chloride reduction, electrolytic cell wet APC, and electrolyte preparation wet APC.[55] Wastewater from electrolyte preparation wet APC, electrolytic cell wet APC, and smelter wet APC may contain toxic metals, suspended solids, oil, and grease. This waste may be recycled.[56] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 440,000 metric tons/yr, 870,000 metric tons/yr, and 1,700,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for arsenic, silver, cadmium, chromium, and lead. This waste was formerly classified as a sludge.

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[49] Ibid.

[50] Newmont Gold Company. May 12, 1997. Op. Cit.

[51] Ibid.

[52] Newmont Gold Company. January 25, 1996. Op. Cit.

[53] Newmont Gold Company. May 12, 1997. Op. Cit.

[54] Ibid.

[55] Precious Metals Producers. Op. Cit.

[56] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Vol. V, 1989, pp. 2185-2186.

Refining Wastes. The most basic refining operation for the separation of gold and silver is "parting" which can be done electrolytically or by acid leaching. Further treatments are sometimes necessary to remove additional contaminants. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 360,000 metric tons/yr, and 720,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity for silver and corrosivity. This waste is recycled to extraction/beneficiation units.

D. Non-uniquely Associated Wastes

Ancilary hazardous wastes also may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), acidic tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous), and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

Three commenters submitted comments in response to the January 25, 1996 Supplemental Proposed Rule (COMM43, COMM57, COMM58), and one commenter submitted comments in response to the May 12, 1997 Second Supplemental Proposed Rule (Newmont Gold Company). All four commenters provided new factual information that has been incorporated into the gold and silver sector report.

Sector-specific Issues

Three commenters addressed sector-specific issues.

- Three commenters stated that the retorting step is, in fact, a beneficiation activity (COMM43, COMM57, COMM58). EPA has clarified in the report that the beneficiation/mineral processing boundary for gold recovery from ores is between electrowinning and retorting. Therefore, retorting is a mineral processing activity.

- One commenter stated that slag and spent furnace dust are not wastes because they are destined for reclamation (COMM57). EPA recognizes that these materials contain high concentrations of precious metals and that they are reclaimed. However, they are still considered to be wastes, and no change was made to the report.

- One commenter expressed confusion over the status of acid washing solution (COMM43), while another commenter stated that EPA incorrectly classified acid washing during the elution process as non-uniquely associated with mineral processing (COMM57). The Agency clarified in the report that the use of an acid solution to dissolve the steel wool from the gold/steel wool cathode is a beneficiation activity that is uniquely associated with mining or mineral processing. Acid wash solution from carbon regeneration activities after the gold is stripped, however, is not uniquely associated and, therefore, is not exempt under the Bevill Amendment.

- One commenter requested that EPA clarify the status of sulfuric acid (COMM43). The report was modified to indicate that waste sulfuric acid from elution is exempt under the Bevill Amendment because it is generated in a beneficiation activity that is uniquely associated with mining or mineral processing.

- One commenter noted an inconsistency in that spent carbon is identified as a beneficiation waste whereas carbon fines are not uniquely associated with mineral processing (COMM43). One commenter stated that spent carbon is routinely regenerated and reused and, therefore, is not a waste (COMM43).

Another commenter stated that carbon fines generated at on-site carbon regeneration kilns as well as other secondary materials generated during carbon regeneration are uniquely associated with mineral processing (COMM57). Spent carbon after the gold has been stripped is, in fact, a waste. The Agency clarified that spent carbon from cyanidation is a non-uniquely associated waste because spent carbon results from carbon regeneration which is a non-uniquely associated operation because many industries routinely regenerate carbon and generate wastes such as carbon fines. Therefore, carbon regeneration and the resulting wastes are non-uniquely associated with mining or mineral processing.

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IODINE

A. Commodity Summary

Iodine compounds are found in seawater, seaweed, marine organisms, and brines. Iodine and its compounds are generally marketed in the form of crude iodine, resublimed iodine, calcium iodate, calcium iodide, potassium iodide, sodium iodide, and numerous organic compounds.[1] Final uses of iodine include animal feed supplements, catalysts, inks and colorants, pharmaceuticals, photographic chemicals and film, sanitary and industrial disinfectants, and stabilizers.

Japan and Chile are the largest producers of iodine in the world and account for 99% of the U.S. iodine imports. All domestic iodine production is from iodine-rich natural brines in the deep subsurface of the Anadarko basin of northwestern Oklahoma. Oklahoma production began in 1977 and at present, three companies operate a total of four facilities (three major plants and one miniplant) for the recovery of iodine. The U.S. Bureau of Mines estimates that domestic production was 2,000,000 kilograms in 1994.[2] Exhibit 1 presents the names and locations of the facilities involved in the production of iodine.

EXHIBIT 1

SUMMARY OF IODINE PROCESSING FACILITIES

Facility Name	Location
Asahi Glass Company of Japan	Woodward, OK
Iochem Corporation of Japan	Vici, OK
North American Brine Resources (miniplant)	Dover, OK
North American Brine Resources (major plant)	Woodward, OK

B. Generalized Process Description

1. Discussion of Typical Production Processes

All three facilities (Asahi Glass Company of Japan, Iochem Corporation of Japan, and North America Brine Resources) obtain iodine-rich brines from the Morrowan sandstones. Asahi Glass Company operates 22 production wells and 10 injection wells ranging in depth from 2,130 to 2,290 meters. The Iochem facility has nine production wells and four injection wells ranging in depth from 3,000 to 3,183 meters. The North American Brine Resources facility operates two production wells and three injection wells drilled to about 1,800 meters.

North American Brine Resources also operates a mini facility near Dover, OK. At the Dover facility, North American Brine Resources recovers iodine from oil-field brines collected from a number of oil and gas wells in nearby parts of northwestern Oklahoma.

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[1] Kenneth S. Johnson, "Iodine," from Industrial Minerals and Rocks, 6th edition, Society for Mining, Metallurgy, and Exploration, 1994, pp. 583-587.

[2] Phyllis Lyday, "Iodine," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 82-83.

Brines are separated from hydrocarbons by using the blowing-out process. Iochem Corporation and North American's Woodward facility both use this process.[3] Exhibit 2 presents a typical process flow diagram for the production of iodine from brines by the blowing-out process.

2. Generalized Process Flow Diagram

Exhibit 2 displays the blowing-out process. In the first stage of this process, hydrogen sulfide gas (contained in the brine) is removed. This gas is reacted to form sulfur compounds which are sent to a hazardous waste disposal facility. The second stage of processing is chlorine oxidation to convert iodide to iodine. The iodine is then removed from the brine by air vapor stripping (air-blowout). The waste brine is treated with lime to adjust pH and is reinjected into Class IV disposal wells. The iodine vapor is absorbed by a solution of hydriodic and sulfuric acids. Sulfur dioxide is added to reduce the absorbed iodine to hydriodic acid. Most of the solution is recirculated to the absorption tower, but a bleed stream is sent to a reactor for iodine recovery. In the reactor, chlorine is added to oxidize and liberate the iodine which precipitates and settles out of solution. The settled iodine is filtered to remove waste liquor and melted under a layer of concentrated sulfuric acid. The melted iodine is then solidified either as flakes or ingots.[4]

Iodine is also recovered from oil well brines. In a settling tank, the iodine containing brine settles to the bottom and the oil rises to the top. The oil is skimmed off and processed with other oil from nearby wells. The brine is sent through a chlorinator which frees the iodine. It is then absorbed onto charcoal which is back-flushed with potassium or sodium hydroxide when full. This solution is treated with hydrochloric acid which results in a 90% crude iodine product. The spent brine is reinjected and the potassium/sodium hydroxide is recycled.[5]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

While domestic iodine production employs the chlorine-oxidation air-blowout method for recovery of iodine, three other brine clarification processes exist. In one process, silver iodide is precipitated by the addition of a silver nitrate solution. The silver iodide is filtered and treated with scrap iron to form metallic silver and a solution of ferrous iodide. The silver is redissolved in nitric acid and recycled, and the solution is treated with chlorine to liberate the iodine. In a second process, chlorine is added after clarification to liberate the iodine as a free element in solution. Passing the solution over bales of copper wire precipitates insoluble cuprous iodides. At intervals, the bales are agitated with water to separate the adhering iodide; the bales are then recycled. The cuprous iodide suspended in the water is filtered, dried, and sold. The third process uses ion-exchange resins on brines which have been oxidized to liberate iodine. The liberated iodine, which is in the form of polyiodide, is absorbed on an anion-exchange resin. When the ion-exchange resin is saturated, it is discharged from the bottom of the column and then transferred to the elutriation column. Iodine is elutriated with a caustic solution followed by sodium chloride. The regenerated resin is returned to the absorption column. The iodine-rich elutriant is acidified and oxidized to precipitate iodine. The crude iodine is then separated in a centrifuge and purified with hot sulfuric acid or refined by sublimation.[6]

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[3] Phyllis A. Lyday, "Iodine," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 609-612.

[4] U.S. Environmental Protection Agency, "Iodine," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-109 - 2-112.

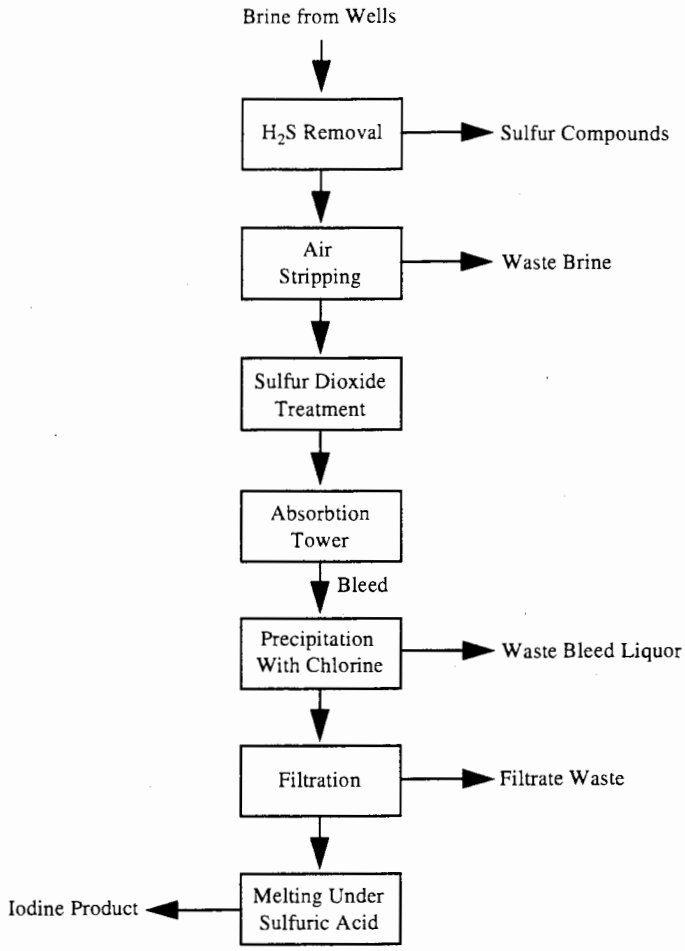
[5] Personal Communication between ICF Incorporated and Phyllis Lyday, U.S. Bureau of Mines. October 11, 1994.

[6] "Iodine and Iodine Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., 1981, Vol. XIII, pp. 655-656.

EXHIBIT 2

THE BLOWING-OUT PROCESS

(Adapted from; 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-109 - 2-112.)



The Chilean nitrate industry employs another method for iodine recovery. Iodine is extracted from caliche as sodium iodate, along with sodium nitrate. The iodate accumulates in mother liquors during crystallization of the nitrate. Part is drawn off and treated with sodium bisulfite solution. Fresh mother liquor is added to the solution to liberate the iodine. The precipitated iodine is filtered in bag filters and the iodine-free mother liquor is returned to the nitrate leaching cycle after neutralization with soda ash. The iodine cake is washed, pressed, broken up, and sublimed in retorts. The product is then crushed and packaged.[7]

4. Beneficiation/Processing Boundaries

Based on a review of the process, there are no mineral processing operations involved in the production of iodine.

C. Process Waste Streams

Existing data and engineering judgement suggest that the wastes listed below from iodine production do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

1. Extraction/Beneficiation Wastes

Sulfur compounds from hydrogen sulfide removal are sent to a hazardous waste disposal facility.

Waste brine. Waste brine contains 6,800 kkg of spent brine solids per kkg of product iodine. Waste brine is processed for other solids recovery and then either used in chlor-alkali manufacture or returned to the source. Bromine, calcium chloride and magnesium hydroxide may be recovered from these spent brines.[8]

Precipitation with Chlorine

Waste bleed liquor.

Filtration

Filtrate wastes may be recycled.

Sludge.

Waste Acid.

2. Mineral Processing Wastes

None are identified.

D. Non-uniquely AssociatedWastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

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[7] Ibid.

[8] U.S. Environmental Protection Agency, Multi-Media Assessment of the Inorganic Chemicals Industry, Volume II, 1980, Chapter 9.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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IRON AND STEEL

A. Commodity Summary

The iron and steel industry, including primary and secondary producers, is composed of 79 companies that produce raw steel at 116 locations. Iron is generally produced from iron ore (taconite) in a primary mineral production process, while steel is produced using both primary and secondary processes. Primary production refers to those operations where the feedstock is composed of at least 50 percent ore (or ore that has been beneficiated). Electric arc furnaces use a high percentage of scrap steel as the feedstock in their operations and are therefore classified as secondary production and not considered primary minerals processing. Although the electric arc furnace process is described in this section, some of the wastes generated from this operation are currently regulated under RCRA Subtitle C. Specifically, electric arc furnace dust (K061) is a listed hazardous waste.

The annual aggregate raw steel production capacity is 99 million metric tons; 1993 production is reported to be 87 million metric tons. According to the U.S. Bureau of Mines, the iron and steel producers and ferrous foundries produced goods valued at $55 billion. Currently, pig iron (i.e., molten iron from iron blast furnaces) is produced at 15 companies operating integrated steel mills, with approximately 58 blast furnaces (of which 41 or 42 are in continuous operation). Integrated companies accounted for approximately 67% of steel production, including output of their electric arc furnaces (which are classified as secondary production).[1]

Pig iron production in 1994 is estimated at 49 million metric tons. Pig iron is sent to either basic oxygen furnaces or electric arc furnaces for further processing at steel facilities. Basic oxygen furnaces (BOFs) and electric arc furnaces (EAFs) account for 61 percent and 39 percent of steel production, respectively. Continuously cast steel accounted for 89 percent of steel production. Lastly, open hearth furnaces (OHFs) have been phased out and were not used domestically to produce steel in 1993.[2] Exhibit 1 presents the names and locations of facilities involved in the primary production of iron and steel.

EXHIBIT 1

SUMMARY OF PRIMARY IRON AND STEEL PRODUCERS IN 1989

Facility Name	Location	Type of Operations
Acme	Riverdale, IL	Iron; BOF Steel
Alleghany Ludlum	Brackenridge	Iron; BOF Steel
Armco Steel Co., L.P.	Middletown, OH	Iron; BOF Steel
Armco Steel Co., L.P.	Ashland, KY	Iron; BOF Steel
Bethlehem Steel	Sparrows Point, MD	Iron; BOF Steel
Bethlehem Steel	Bethlehem, PA	Iron; BOF Steel
Bethlehem Steel	Chesterton, IN	Iron; BOF,OHF Steel
Geneva Steel	Orem, UT	Iron; OHF Steel

[1] Gerald Houck, "Iron and Steel," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 86.

[2] Ibid.

EXHIBIT 1 (continued)

SUMMARY OF PRIMARY IRON AND STEEL PRODUCERS IN 1989

Facility Name	Location	Type of Operations
Gulf States Steel	Gadsden, AL	Iron; BOF Steel
Inland Steel	E. Chicago, IN	Iron; BOF Steel
LTV	E. Cleveland, OH	Iron; BOF Steel
LTV	W. Cleveland, OH	Iron; BOF Steel
LTV	Indiana Harbor, IN	Iron; BOF Steel
McLouth Steel	Trenton, MI	Iron; BOF Steel
National Steel	Granite City, IL	Iron; BOF Steel
National Steel	Escore, MI	Iron; BOF Steel
Rouge Steel	Dearborn, MI	Iron; BOF Steel
Sharon Steel	Farrell, PA	Iron; BOF Steel (shut down in November 1992)[a]
Shenango	Pittsburgh, PA	Iron
US Steel	Braddock, PA	Iron; BOF Steel
US Steel	Gary, IN	Iron; BOF Steel
US Steel	Fairless Hills, PA	Iron; OHF Steel
US Steel	Fairfield, AL	Iron; BOF Steel
US Steel/Kobe	Lorain, OH	Iron; BOF Steel
Warren Steel	Warren, OH	Iron; BOF Steel
Weirton Steel	Weirton, WV	Iron; BOF Steel
Wheeling-Pittsburgh Steel	Steubenville, OH	Iron; BOF Steel
Wheeling-Pittsburgh Steel	Mingo Junction, OH	Iron; BOF Steel

[a] Gerald Houck, "Iron and Steel." from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, p. 649.

On a tonnage basis, about nine-tenths of all metal consumed in the United States is iron or steel. Iron and steel are used in the manufacture of transportation vehicles, machinery, pipes and tanks, cans and containers, and the construction of large buildings, roadway superstructures, and bridges.[3] According to the U.S. Bureau of Mines in 1993, steel consumption was divided amongst the following uses: warehouse and steel service centers, 26%;

[3] Gerald Houck, "Iron and Steel," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, p. 412.

transportation (mainly for automotive production), 16%; construction 15%, cans and containers, 5%; and other uses, 38%.[4]

B. Generalized Process Description

1. Discussion of Typical Production Processes

The production of steel products from iron ore involves two separate steps: ironmaking and steelmaking. Each of these is described in detail below. Iron blast furnaces produce molten iron (pig iron) that can be cast (molded) into products; however, the majority of pig iron is used as the mineral feedstock for steel production. Steel furnaces produce a molten steel that can be cast, forged, rolled, or alloyed in the production of a variety of materials.

Ironmaking

Iron is produced either by blast furnaces or by one of several direct reduction processes; blast furnaces, however, account for over 98 percent of total domestic iron production.[5] The modern blast furnace consists of a refractory-lined steel shaft in which a charge is continuously added to the top through a gas seal. The charge consists primarily of iron ore, sinter, or pellets; coke; and limestone or dolomite. Iron and steel scrap may be added in small amounts. Near the bottom of the furnace, preheated air is blown in. Coke is combusted in the furnace to produce carbon monoxide which reduces the iron ore to iron. Silica and alumina in the ore and coke ash are fluxed with limestone to form a slag that absorbs much of the sulfur from the charge. Molten iron and slag are intermittently tapped from the hearth at the bottom. The slag is drawn off and processed. The product, pig iron, is removed and typically cooled, then transported to a steel mill operation for further processing in either an electric arc furnace or a basic oxygen furnace, as depicted in Exhibit 2. As shown in Exhibit 2, the iron can also be directly reduced before it is sent for further processing.

Recent changes in the process include modifications in the fluxing practices. Flux is often introduced through fluxed sinter or fluxed pellets rather than by direct charging. The use of external desulfurization of hot metals prior to steel making has also increased.[6]

Steelmaking

All contemporary steelmaking processes convert pig iron, scrap, or direct-reduced iron, or mixtures of these, into steel by a refining process that lowers the carbon and silicon content and removes impurities (mainly phosphorus and sulfur). Three major furnace types can be used for making steel:

- open hearth furnaces, no longer used for domestic steel production;
- basic oxygen furnaces, with 62 percent of the total; and
- electric arc furnaces, accounting for the remaining 38 percent.

The latter predominantly uses scrap (i.e., non-mineral material) as feedstock and is classified as a secondary process. The open-hearth process was prevalent in the United States between 1908 and 1969, but it is no

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[4] Gerald Houck, 1994, Op. Cit., p. 90.

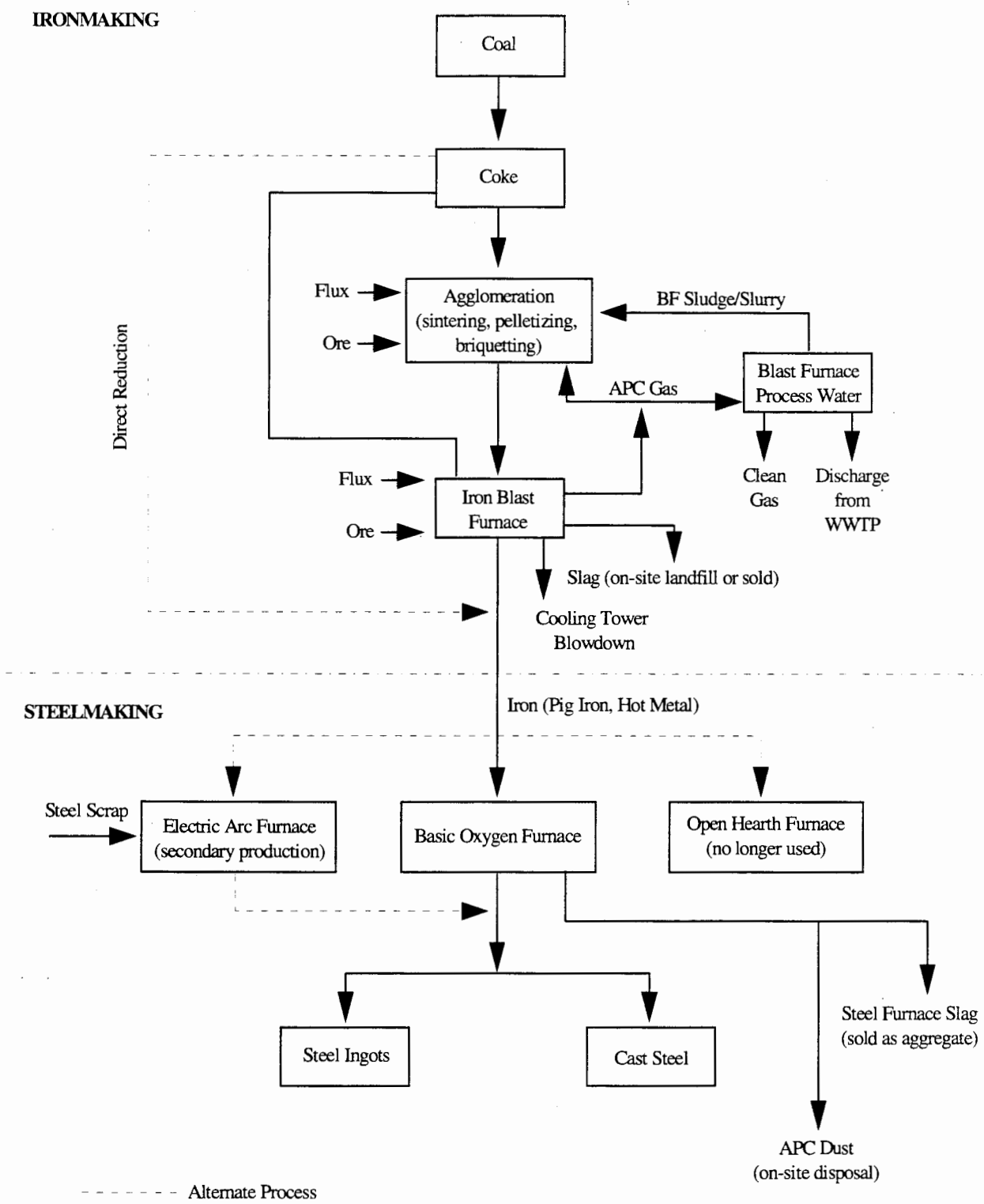
[5] American Iron and Steel Institute, "Annual Statistical Report," 1984, p. 78.

[6] Harold R. Kokal and Madhu G. Ranade, "Fluxes for Metallurgy," from Industrial Minerals and Rocks, 1994, pp. 668-669.

EXHIBIT 2

IRONMAKING AND STEELMAKING PROCESSES

(Adapted from: USS Lorain flow diagram.)



longer in use domestically. The basic oxygen process has supplanted it as the predominant primary steel-making process, making up approximately 95 percent of domestic primary steel production in 1987.[7]

Modern steelmaking also includes treatment of steel in ladles. This use of ladles (1) improves the cleanliness of the steelmaking process, (2) increases throughput in steel vessels, and (3) allows for shape control of inclusions in continuous casting operations.[8]

2. Generalized Process Flow Diagram

A general flow diagram for the production of raw steel from iron ore is presented in Exhibit 2. In general, the process involves (1) beneficiation of the iron ore, (2) either direct-reduction or reduction in an iron blast furnace, (3) processing in steelmaking furnaces, and (4) casting.

Ironmaking

Beneficiation of the Iron Ore: Sintering, Pelletizing, or Briquetting

There are a variety of beneficiation methods that can be used to prepare iron ores, depending on the iron content in the ores. Some ores contain greater than 60 percent iron and require only crushing and blending to prepare them for further processing. In other cases, operations including screening and concentrating are necessary to prepare the raw materials. The characteristics of the iron-bearing ores vary geographically. Specifically, magnetite is the main iron-bearing ore in the Lake Superior district and in the northeastern United States, while hematite and hematite magnetite mixtures tend to be found in ores in Alabama and the Southwest.

When magnetite occurs in lower grade deposits, the ore is ground, and the concentrate is separated magnetically from the gangue with the ore in a water suspension. Ore containing hematite can be high in clay content and requires washing to remove the clay and concentrate the iron. Low grade ores that can not be separated magnetically may also need to be concentrated via washing, jigging, heavy media separation, or flotation.[9]

Ores that will be sent to blast furnaces for ironmaking need to be permeable to allow for an adequate flow of gas through the system. Additionally, concentrates in raw ores that are very fine need to be agglomerated before they can be used as feed stock for the blast furnaces. The three major processes used for agglomeration include:

- sintering;
- pelletizing; and
- briquetting.

Sintering. Sintering involves mixing the iron-bearing material such as ore fines, flue dust, or concentrate with fuel (e.g., coke breeze or anthracite).[10] The mixture is then spread on surface beds which are ignited by gas burners. The heating process fuses the fine particles, and the resulting product is lumpy material known as sinter. The sinter is sized and the fines are recycled. Sintering operations are used to recycle wastes from other iron and steel manufacturing processes.

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[7] Frederick J. Schottman, "Iron an Steel," from Minerals Yearbook Volume I. Metals and Minerals, U.S. Bureau of Mines, 1989, p. 511.

[8] Harold R. Kokal and Madhu G. Ranade, 1994, Op. Cit., pp. 668-9.

[9] U.S. Environmental Protection Agency, "Iron and Steel," from 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, Office of Solid Waste, 1988, p. 3-128.

[10] Ibid.

Pelletizing. Pelletizing involves forming pellets from the raw ore or concentrates, then hardening the pellets by heating. Solid fuel can be combined with the concentrate to promote the heating necessary to harden the pellet. Common binders added to strengthen the pellets include limestone, dolomite, soda ash, bentonite, and organic compounds. After the pellets are sized, any remaining fraction of materials are recycled back through the sintering process.

Briquetting. Briquetting, another form of agglomeration, involves heating the ore and pressing it into briquettes while the materials are still hot. Once the briquettes are cooled, they are sent directly to the blast furnaces.

Reduction of the Iron Ore

There are two basic methods for reducing iron ore:

- direct reduction; and
- reduction in a blast furnace.

Direct Reduction. Direct reduction involves the reduction of iron ore that is in the solid state - at less than 1000 °C.[11] The solid primary metal produced by direct reduction of iron ores (DRI) can be used to supply electric arc furnaces.

Blast Furnace. During ironmaking, agglomerated iron ore is combined with prepared limestone, silica, and coke and placed into a blast furnace. Heated air is blown into the furnace and causes the limestone and silica to form a fluid slag which combines with other impurities. The slag can be separated from the molten iron and sent to a slag reprocessing unit. Generally, the molten iron from the blast furnace is transferred directly to the steelmaking furnaces.

A number of integrated steelwork facilities in the United States have increased their use of fluxed pellets, which are more easily reducible. The fluxed pellets are produced by adding limestone ($CaCO_3$) and/or dolomite [$(Ca,Mg)CO_3$] to the iron ore concentrate during the balling stage. Flux is added until the ratio of calcium and magnesium oxide to silicon dioxide and aluminum oxide ($(CaO+MgO)/(SiO2+Al_2O_3)$) in the pellet is above 0.6. The most common ratio documented is approximately 1.0.[12]

Steelmaking

Processing in Steelmaking Furnaces

There are three basic methods of steel production:

- open hearth furnaces (no longer in use domestically);
- basic oxygen furnaces; and
- electric arc furnaces (secondary production).

Open Hearth Furnace (no longer used). During the open-hearth process, a relatively shallow bath of metal was heated by a flame that passed over the bath from the burners at one end of the furnace while the hot gases resulting from combustion were pulled out the other end. The heat from the exhaust gas was retained in the exhaust system's brick liners, which were known as checker-brick regenerators. Periodically the direction of the flame was reversed and air was drawn through what had been the exhaust system; the hot checker-bricks preheated the air before it was used for combustion in the furnace. Impurities were oxidized during the process and fluxes formed a slag; this slag was drawn off and processed or discarded.

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[11] J. Astier, "Present Status of Direct Reduction and Smelting Reduction," from Steel Times, October 1992, pp. 453-458.

[12] William S. Kirk, "Iron Ore," from Minerals Yearbook Volume 1. Metals and Minerals, 1992, p. 618.

Basic Oxygen Furnace. The basic oxygen process uses a jet of pure oxygen that is injected into the molten metal by a lance of regulated height in a basic refractory-lined converter. Excess carbon, silicon, and other reactive elements are oxidized during the controlled blows, and fluxes are added to form a slag. This slag, one of the RCRA special wastes, is drawn off and processed or discarded.

The first step in the BOF process is charging the furnace. Hot metal (molten iron from the blast furnace) which accounts for most of the metallic charge is added to the furnace by ladles. Once the furnace has been charged, a water-cooled oxygen lance is lowered into the furnace and high purity oxygen is blown in the top of the furnace. One modification to this process is the Q-BOP in which the oxygen and other gases are blown in from the bottom of the furnace instead of the top. In the bottom blown process, oxygen is introduced through a number of tuyeres, consisting of two concentric pipes in the bottom of the converter.[13]

In the furnace, oxygen combines with the carbon and other unwanted elements to oxidize the impurities in the molten charge, and thereby converting the molten charge to steel. The lime and other fluxes help remove the oxidized impurities as a layer of slag. The refined steel is then poured into ladles. At this point, any alloys can be added to the steel to obtain the desired strength and characteristics required in the final product.

Electric Arc Furnace (secondary production). Electric arc furnaces are generally used for scrap processing and have traditionally been used to produce alloy, stainless, tool, and specialty steels. Scrap steel is the principal metallic charge to electric furnaces. Direct reduction of iron ore also produces pellets with high enough iron content to be used. Limestone and other fluxes are charged after the scrap becomes molten. As in the blast furnace operation, the impurities in the steel form a floating layer of slag that can be poured off. The molten steel is then poured into ladles and sent to be cast.

In all steelmaking operations, gases from the furnace must be cleaned in order to meet air pollution control requirements. Facilities may use dry collection (e.g., bag houses, filters, or electrostatic precipitators) or wet scrubbers or, as is most often practiced, both types of controls. Large volumes of dust and scrubber sludge are collected for either further processing or disposal. Some of these air pollution control residuals are RCRA special wastes.

The molten steel, from whichever type of furnace is used, flows into ladles and is sent for further processing at rolling mills to form the finished products.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

- **Dezincing and Detoxification of Electric Arc Furnace Steelmaking Dust via Ammonium Carbonate Leaching.** The use of ammoniacal ammonium carbonate (AAC) leaching for the treatment of carbon steel making EAF dust has been investigated on a laboratory scale. The tests were performed using dust samples from three European steel companies. The dusts were found to be toxic due to the leachability of silver, mercury, lead, and cadmium. After treatment, the toxicity tests indicated leachates below past and current EPA toxicity threshold limits.[14]

- **Recovery of Manganese from Steel Plant Slag by Carbamate Leaching**. The U.S. Bureau of Mines investigated the feasibility of using ammonium carbamate leaching to recover manganese from steel plant slag. It was found that treatment of the slag with hydrogen prior to the leaching increased the

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[13] Association of Iron and Steel Engineers, The Making, Shaping and Treating of Steel, 1985, pp. 539-652.

[14] R.L. Nyirenda et al, "Dezincing and Detoxification of Electric Arc Furnace Steelmaking Dust via Ammonium Carbonate Leaching," The Minerals, Metals, & Mining Society, 1993, pp. 894-906.

amount of manganese recovered. Results indicated that the method cannot be applied satisfactorily to all steelmaking slags.[15]

- **Glassification[16] of Electric Arc Furnace Dust.** A new process has been developed to treat hazardous materials, including electric arc furnace dust, slag, and spent refractories. The process, known as Glassification, utilizes electric arc furnace dust from both the steel and nonferrous metals industries to produce glass products.[17]

- **Treatment of Steel Plant Wastes by Magnetic Cyclones.** Steel plants generate sludges containing high concentrations of iron which display ferromagnetic properties. Methods of treating these wastes to take advantage of these properties using magnetic cyclones have been evaluated. The results indicated that the cycloning process creates an underflow with a high solids content and a clean water overflow.[18]

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between agglomeration (sintering, pelletizing, and briquetting) and reduction of iron ore in a blast furnace. EPA

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[15] S.N. McIntosh and E.G. Baglin, "Recovery of Manganese from Steel Plant Slag by Carbamate Leaching," U.S. Bureau of Mines, 1992.

[16] Glassification is a registered trademark.

[17] R.B. Ek and J.E. Schlobohm, "Glassification of Electric Arc Furnace Dust," from Iron and Steel Engineer, April 1993, pp. 82-84.

[18] John L. Watson and Suren Mishra, "The Treatment of Steel Plant Wastes by Magnetic Cyclones," Conference Paper from Symposium on Emerging Process Technologies for a Cleaner Environment, Phoenix, AZ, February 24-27 1992.

identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where a significant chemical change to the iron ore occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Waste characterization data, waste generation data, and waste management data are not available for all of the wastes identified as generated from the production of iron and steel.

Tailings. Wastes from magnetic separation include tailings consisting mostly of silicate rock. The magnetite ore from lower grade deposits is ground, and the concentrate is separated magnetically from the gangue with the ore in a water suspension. These wastes are typically managed in tailing impoundments.

Wastewater and Waste Solids. Ore containing hematite can be high in clay content and require washing to remove the clay and concentrate the iron. The wastewater and waste solids generated from washing ores containing clay are not expected to be hazardous. No information is available on management practices for these wastes.[19]

2. Mineral Processing Wastes

Ferrous metal production operations generate four RCRA special mineral processing wastes that are exempt from RCRA Subtitle C: iron blast furnace slag, iron blast furnace air pollution control dust/sludge, steel furnace slag, and steel furnace air pollution control dust/sludge. The Agency did not evaluate the four RCRA special mineral processing wastes further. Besides these RCRA special wastes, the only other types of wastes generated appear to be various types of wastewater, including cooling water, wash water, and scrubber water.

Iron Blast Furnace Slag. In 1988, iron blast furnace slag was reported as generated at 26 of the 28 ferrous metal production facilities in the United States surveyed by the U.S. Environmental Protection Agency in 1989 -- all 24 integrated iron/steel facilities and two additional blast furnace operations.

Blast furnace slag contains oxides of silicon, aluminum, calcium, and magnesium, along with other trace elements. There are three types of blast furnace slag: air-cooled, granulated, and expanded. Air cooled slag comprises approximately ninety percent of all blast furnace slag produced. The physical characteristics of the slags are in large part determined by the methods used to cool the molten slag. In the surveys, all facilities characterized their slags as solid, though slag is molten at the point of generation.[20]

The primary management practice for iron blast furnace slag is processing (e.g., crushing, sizing) and sale for use as aggregate. In 1990, only one facility disposed its slag in an adjacent water body in order to build up a land area that was intended for use managing other waste materials as part of an Army Corp of Engineers approved fill project.[21]

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[19] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-128.

[20] U.S. Environmental Protection Agency, "Chapter 8," from Report to Congress on Special Wastes from Mineral Processing, Vol II, Office of Solid Waste, July 1990.

[21] Ibid.

Iron Blast Furnace Air Pollution Control (APC) Dust/Sludge. In 1988, iron blast furnace APC dust/sludge was generated at 26 of the 28 ferrous metal facilities in the United States submitting surveys, including all 24 integrated iron/steel facilities and the two additional blast furnace operations.

Air pollution control (APC) devices treat the top gases emitted from iron blast furnaces. The air pollution control devices generate either dusts or sludges. APC dust/sludge is composed primarily of iron, calcium, silicon, magnesium, manganese, and aluminum.[22]

The two primary waste management practices at the iron facilities regarding APC dust/sludge are disposal in on-site units and the return of the material to the production process via the sinter plant operation or blast furnace.[23]

Steel Furnace Slag. In 1988, steel furnace slag was generated at 26 of the 28 ferrous facilities in the United States that submitted surveys, including all 24 integrated iron/steel facilities and the two additional steel production operations. Steel slag is composed primarily of calcium silicates and ferrites combined with fused oxides of iron, aluminum, manganese, calcium, and magnesium. At the point of generation, the slag is in a molten form. The molten slag is air cooled and is broken into varying sizes once processing (e.g., crushing) begins.[24]

The primary management practice for steel slag is processing (e.g., granulating, crushing, sizing) and sale for use as aggregate, though several facilities dispose or stockpile their steel slag.

Steel Furnace Air Pollution Control (APC) Dust/Sludge. Steel furnace APC dust/sludge was generated at 26 of the 28 domestic ferrous metal production facilities surveyed in 1989, including all 24 integrated iron/steel facilities and the two additional steel production facilities. Steel APC dust/sludge consists mostly of iron, with smaller amounts of silicon, calcium, and other metals.

Waste management practices were reported for only ten of the 26 facilities in 1989. Eight of the ten reportedly dispose the APC dust/sludge on-site; the remaining two return the material to the production process via the sinter plant operation.

Wastewater. Wastewater is generated from a number of sources during both the ironmaking and the steelmaking processes. In addition to process wastewaters, wastewater streams also are generated from non-contact operations (i.e., cooling tower water, cooling tower blowdown) and from non-process operations including maintenance and utility requirements. However, the primary source of wastewater from ironmaking is water used for the cleaning and cooling of gases. Most plants either recirculate or recycle their cooling process wastewater to reduce the total pollutant load discharged from their facilities. The wastewaters from the blast furnace process contain suspended particulate matter and cyanide, phenol, and ammonia. All of these pollutants are limited by NPDES permit requirements. Other wastewaters contain toxic metals (predominantly zinc) and organic pollutants which come from the raw materials or form during the reduction process.

Many of the pollutants in the process wastewaters are the result of compounds found in the charges and fluxes added to the furnace. In both iron and ferromanganese blast furnaces operations, ammonia is present in the exit gases and as a result is also present in the process wastewater. The ammonia is formed from the various nitrogen compounds that are removed from the coke charge during blast furnace operations. Fluoride is also present in the wastewater as a result of fluoride compounds, primarily calcium chloride from the limestone flux. Manganese is present in wastewaters from ferromanganese production and other elements may be present depending on the various

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[22] Ibid.

[23] Ibid.

[24] Ibid.

ores and alloys used in production. Lastly, cyanide is generated as a result of the reaction of nitrogen, in the blast air, with carbon from the coke charge in the reducing atmosphere of the blast furnace.

Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Wastes

Wastes associated with the coke making process, stainless steel production, and steel finishings are considered to be non-uniquely associated. In addition, ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naphtha), acidic tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and some waste oil and other lubricants. Other ancillary wastes associated with the coke making process, stainless steel production, and the spent pickling liquors resulting from steel finishing at some integrated steel mills are currently classified as listed and/or characteristic wastes and regulated under RCRA Subtitle C requirements.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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LEAD

A. Commodity Summary

Lead ore is mined domestically in several states. Seven lead mines in Missouri, along with mines in Alaska, Colorado, Idaho, and Montana yield most of the total ore production. (BOM, 1995, p. 94) In 1990, primary lead was processed at three integrated smelter-refineries in Glover, Boss, and Herculaneum, Missouri, a smelter in East Helena, Montana, and a refinery in Omaha, Nebraska. (U.S. EPA, 1990, p. 10-1) The integrated plant in Boss, Missouri is no longer operational. (BOM, 1995, p. 94; personal communication with Kenneth Buckley, Doe Run Company, April 18, 1994)

Expected yield from domestic mines was 365,000 metric tons (mt) of lead (in concentrates) in 1994. Expected primary lead production from domestic and imported ores totaled 330,000 mt and 30,000 mt, respectively, in 1994. In addition, domestic secondary production from lead scrap totaled 880,000 mt in 1993, up from 842,000 mt in 1989. United States lead reserves totaled 10 million mt in 1993. (BOM, 1995, pp. 94-95)

In 1990, total domestic primary lead production capacity was estimated to be 577,000 mt per year. However, this figure represented the aggregate of one smelter, one refinery, and three integrated smelter-refineries. (U.S. EPA, 1990, p. 10-2) Only four primary lead facilities are currently operational (BOM, 1995, p. 94). Exhibit 1 presents the names and locations of the lead mining, smelting, and refining facilities located in the United States. The lead mines shown were active as of 1990. As available, Exhibit 1 also presents information on potential site factors indicating whether the facility is located in a sensitive environment.

Lead was consumed by approximately 200 domestic manufacturing plants in 1993. The major end use was in transportation, with about 70 percent consumed in the manufacture of batteries, fuel tanks, solder, seals, and bearings. Electrical, electronic, and communications uses (including batteries), ammunition, TV glass, construction (including radiation shielding), and protective coatings consumed more than 25 percent. The remainder was used in ballast and weights, ceramics and crystal glass, tubes and containers, type metal, foil, wire, and specialized chemicals. Overall, lead acid batteries accounted for about 80 percent of lead consumption. (BOM, 1995, pp. 94-95).

B. Generalized Process Description

1. Discussion of Typical Production Processes

Primary lead facilities in the United States employ pyrometallurgical methods to produce lead metal. Treatment of lead ores begins with crushing, grinding, and concentrating. Pelletized concentrates are fed with other materials (e.g., smelter material formerly classified as byproducts, coke) to a sinter unit. The sinter process agglomerates fine particles, drives off volatile metals, converts metal sulfides to metal oxides and sulfates, and removes sulfur as sulfur dioxide (SO_2). The exit gas stream from the sinter machine is cleaned and routed to an acid plant to produce concentrated sulfuric acid. The sintered material is then introduced into a blast furnace along with coke and fluxes. (SAIC, 1991b, p. 2)

Inside the blast furnace, the lead is reduced (smelted), and the molten material separates into four layers: lead bullion; "speiss" and "matte," two distinct layers containing recoverable quantities of copper and other metals; and blast furnace slag. The speiss and matte are sold to operators of copper smelters for metals recovery, and the slag is stored and partially recycled. The bullion is drossed (agitated and cooled in a drossing kettle) to remove lead and other metal oxides, which form a layer of dross that floats on the bullion. The dross, composed of roughly 90 percent lead oxide, along with other elements, is skimmed and sent to a dross furnace for recovery of non-lead mineral values. Slag and residual lead from the dross furnace are returned to the blast furnace. The remaining material is sold to operators of copper smelters for recovery of copper and precious metals. The lead bullion may then be decopperized before being sent to the refining stages. (U.S. EPA, 1990, p. 10-2)

EXHIBIT 1

SUMMARY OF LEAD MINING, SMELTING, AND REFINING FACILITIES

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
ASARCO	East Helena, MT	Smelting	• Facility is partially located within a 100-yr. floodplain, a wetland, and a fault area • Approximately 3,500 residents live within one mile of the facility boundary • The nearest residence is located 100 yards from the facility boundary • Depth from the bottom of special mineral processing waste (slag) management units to water in the uppermost usable aquifer is 38 feet • One aquifer is located between the ground surface and the uppermost usable aquifer; this aquifer is contaminated • Surface water monitored upstream and downstream of the slag management units has exceeded national ambient surface water quality criteria for lead • Ambient air monitored near the slag management units has exceeded the NAAQS for lead (arithmetic 3-month average, 1.5 $\mu g/m^3$)

EXHIBIT 1 (Continued)

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
ASARCO	Glover, MO	Smelting and Refining	• Facility is partially located in karst terrain • One residence is located within one mile of the facility, approximately one-half mile from the facility boundary • Depth from the bottom of the slag management units to water in the uppermost usable aquifer is 5 feet at its highest seasonal level and 30 feet at the lowest seasonal level • Ground water monitoring wells located downgradient from the slag management units have shown exceedances of the NPDWS for cadmium and the NSDWS for zinc and total dissolved solids
ASARCO	Omaha, NE	Refining	• Facility is partially located in a 100-yr. floodplain and a fault area • Approximately 4,400 residents live within one mile of the facility boundary • The nearest residence is located approximately three-quarters of a mile outside the facility boundary • Ambient air monitored near the slag management units has exceeded the NAAQS for lead (arithmetic 3-month average, 1.5 $\mu g/m^3$)
ASARCO Leadville Unit	Leadville, CO	Mining	

EXHIBIT 1 (Continued)

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
Doe Run Co.	Herculaneum, MO	Smelting and Refining	• Facility located within 100-yr. floodplain • Approximately 1,000 residents live within 1 mile of the facility boundary • Nearest residence is 21 yards from the facility boundary • The active on-site surface impoundment is located 142 yards from the nearest residence outside the facility boundary • The depth from the bottom of the on-site solid waste management units to water in the uppermost usable aquifer is approximately 80 feet, at its highest and lowest levels.
Fourth of July Mine	Yellow Pine, ID	Extraction	
Galena Mine	Mullan, ID	Extraction	
Glass Mine	Pend Oreille County, WA	Extraction	
Greens Creek Mine	Admiralty Island, AK	Extraction	
Lucky Friday Mine	Mullan, ID	Extraction	
Magmont Mine	Bixby, MO	Extraction	
Montana Tunnels Mine	Jefferson County, MT	Extraction	
Red Dog Mine	Kotzebue, AK	Extraction	
Sunnyside Mine	Silverton, CO	Extraction	
Sweetwater Mine	Bunker, MO	Extraction	

EXHIBIT 1 (Continued)

Facility Name	Location	Type of Operations	Potential Factors Related to Sensitive Environments
Viburnum Mines (6 mines): Brushy Creek Casteel Fletcher Viburnum 28 Viburnum 29 Buick	Iron, Reynolds, and Washington Counties, MO	Extraction and Beneficiation	
West Fork Mine	Bunker, MO	Extraction	

Lead refining operations generally consist of several steps, including (in sequence) softening, desilverizing, dezincing, bismuth removal, and final refining. Various other saleable materials also may be removed from the bullion during these steps, such as gold and oxides of antimony, arsenic, tin, and copper. During final refining, lead bullion is mixed with various fluxes and reagents to remove remaining impurities (e.g., calcium, magnesium, and lead oxide). The lead is cooled and the impurities rise to the surface and are removed as slag; this slag may be recycled to the blast furnace. The purified bullion is then cast into ingots. (U.S. EPA, 1990, pp. 10-2, 10-3)

Recently, researchers at the former U.S. Bureau of Mines developed bench-scale alternative processes for producing lead. These techniques consist of hydrometallurgical methods (e.g., leaching and solvent extraction). Results of this research are discussed below, under Hydrometallurgical Beneficiation.

2. Generalized Process Flow Diagram

Exhibit 2 contains a process flow diagram that illustrates the steps used in primary lead production, and includes several waste streams. Process variations are indicated by dashed arrows. Slag from primary lead processing is a special waste, and hence is not subject to regulation under RCRA Subtitle C. In addition, material flow diagrams showing the source and fate of materials for ASARCO's Glover, MO and Helena, MT facilities are provided in Exhibits 3 and 4, respectively.

Extraction and Beneficiation

Lead is mined (extracted) almost exclusively in underground operations, though a few surface operations do exist. The use of underground or surface mining techniques depends on the proximity of the ore body to the surface, and the individual characteristics of each ore body determine the exact mining method. (U.S. EPA, 1993b, p. 14)

Lead ores are beneficiated in a series of steps, beginning with milling, a multi-stage crushing and grinding operation. Crushing is usually a dry operation that utilizes water sprays to control dust. Primary crushing is often performed at the mine site, followed by additional crushing at the mill. The crushed ore is mixed with water and initial flotation reagents to form a slurry, then ground in rod and ball mills. The slurried ore may be ground in autogenous mills (in which the ore acts as the grinding medium) or semi-autogenous mills (in which steel balls are added to the ore). Hydrocyclones are used between each grinding step to separate coarse and fine particles; coarse particles are returned to the mill for further size reduction. (U.S. EPA, 1993b, pp. 15-16)

Ground ores are further beneficiated by flotation. Flotation is a technique by which particles of a mineral or group of minerals are made to adhere preferentially to air bubbles by the action of a chemical reagent. During or after milling, ore may be treated with chemicals (known as conditioners and regulators) to modify the pH of the ore pulp prior to flotation. Once conditioned, the ore is then slurried with fresh or salt water and various types of chemical reagents that promote separation of different metals (collectors, frothers, activators, and depressants). Flotation typically occurs in a series of steps, and multiple floats may be required to remove different mineral values from a polymetallic ore. The residues (tailings) from one float are often used as the feed for a subsequent float to concentrate another metal. (U.S. EPA, 1993b, pp. 16-20)

Flotation typically occurs in a series of cells, arranged from roughers to scavengers to cleaners (roughers make a coarse separation of values from gangue, and scavengers remove smaller quantities of the remaining values). Froth from the cleaner cells is sent to thickeners, in which the concentrate is thickened by settling. The thickened concentrate is pumped out, dewatered by a filter press, and dried. The concentrate is then fed to a sintering operation. (U.S. EPA, 1993b, pp. 18-23)

Exhibit 2. Process Flow Diagram of Primary Lead Production in the U.S.

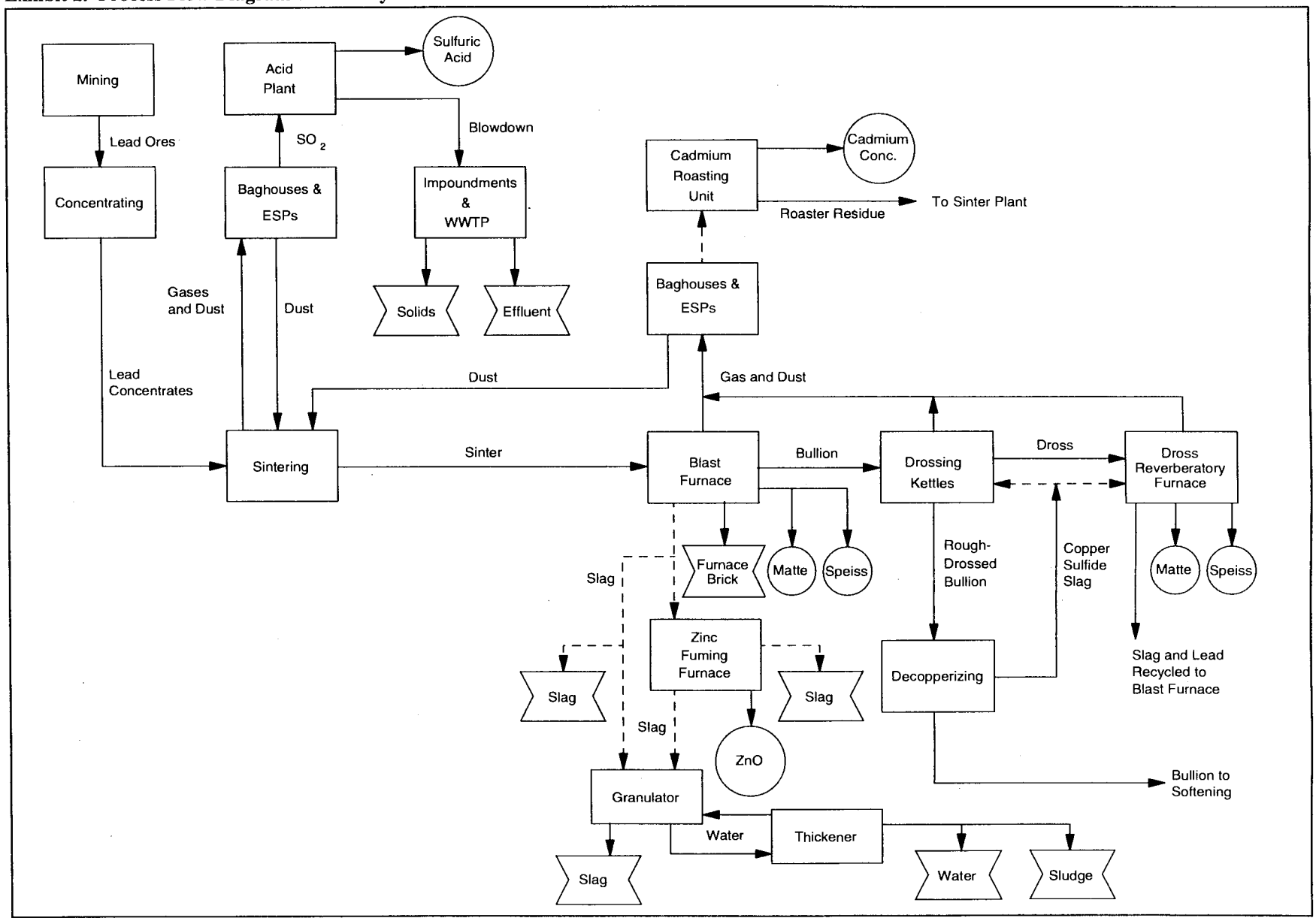


Exhibit 2 (Continued).

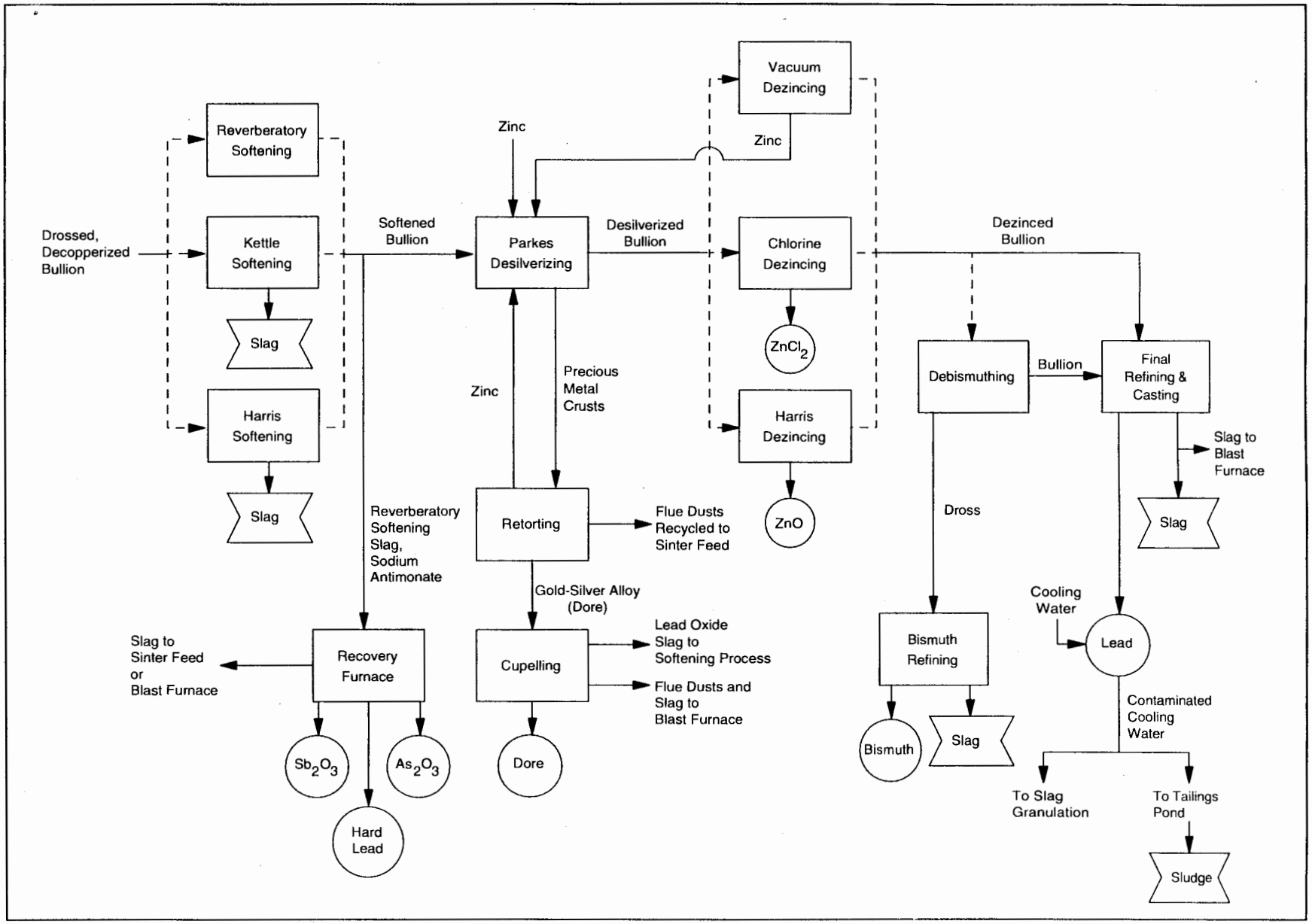


EXHIBIT 3

MATERIALS FLOW TO AND FROM ASARCO, GLOVER, MISSOURI

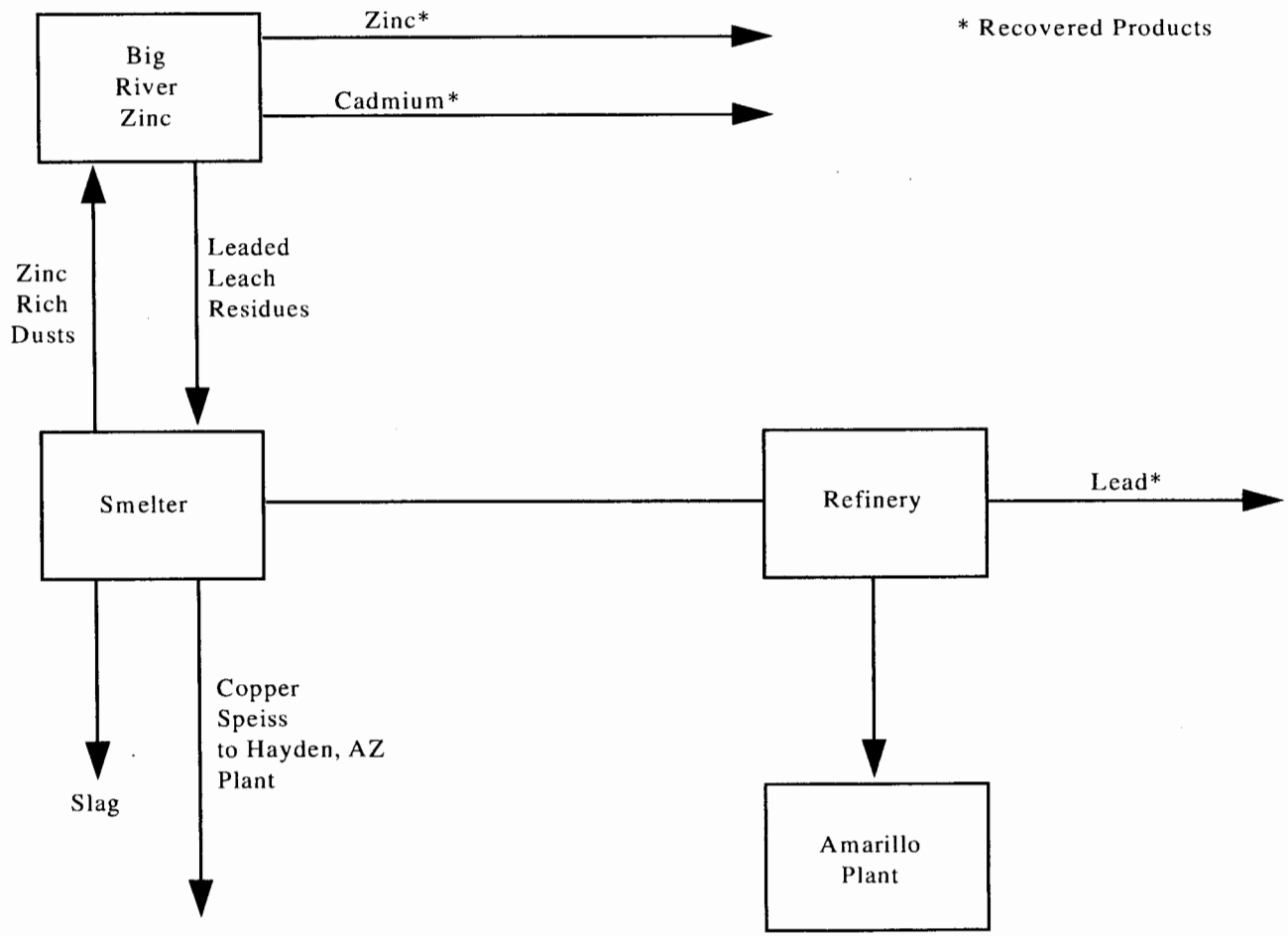
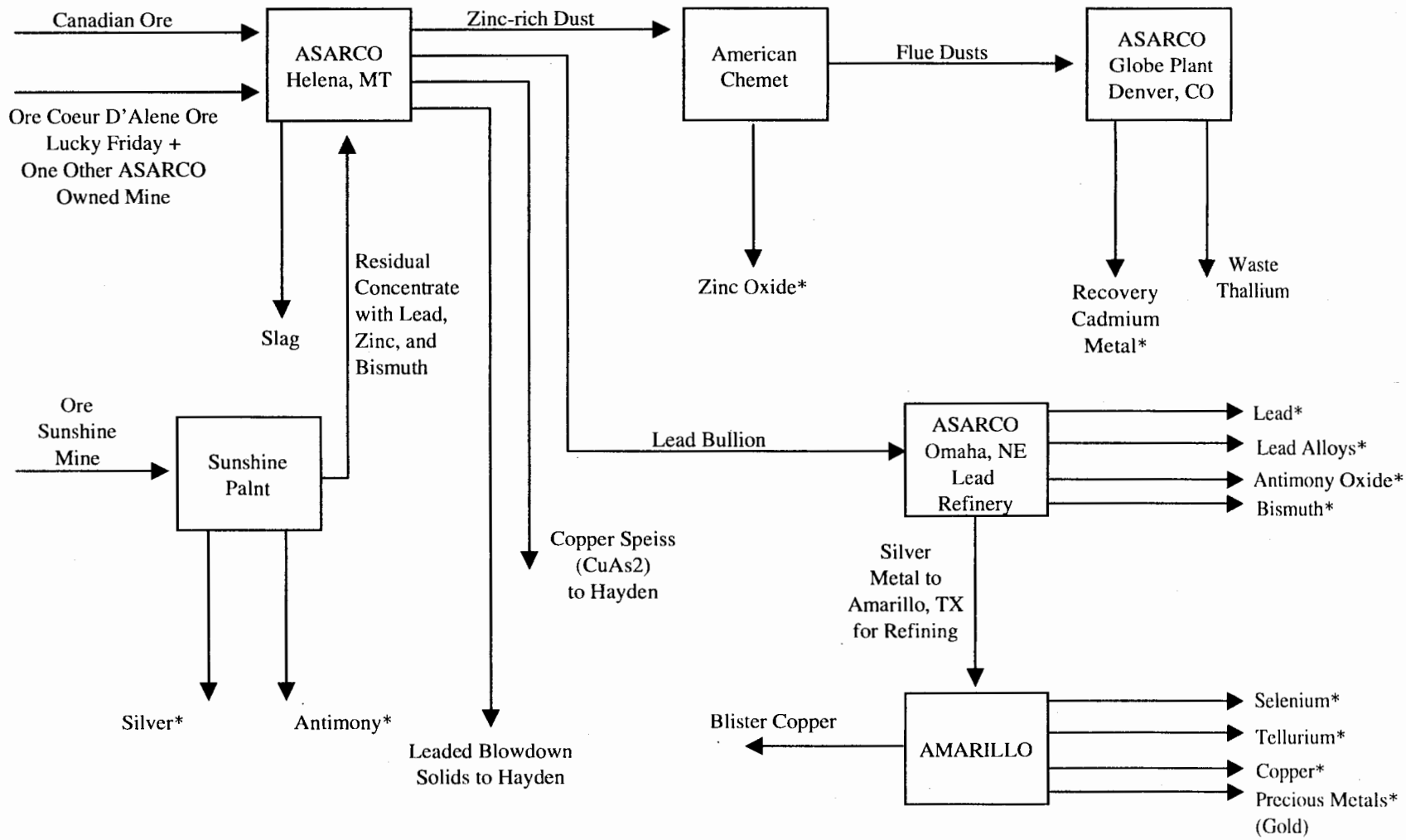


EXHIBIT 4

MATERIALS FLOW TO AND FROM ASARCO, HELENA, MONTANA



* Recovered Products

Liquid overflow from the thickeners, containing wastewater, flotation reagents, and dissolved and suspended mineral products, may be recycled or sent to a tailings pond. Wastes from the rougher, scavenger, and cleaning cells are collected and sent to a tailings thickener. Overflow from the tailings thickener (wastewater containing high solids and some reagent) is often recycled to the flotation cells, and the underflow (containing remaining gangue, unrecovered lead materials, chemical reagents, and wastewater) is pumped to a tailings pond. Clarified water from the tailings pond may be recycled to the mill. (U.S. EPA, 1993b, p. 20)

Sintering

Sintering occurs on a traveling grate furnace known as a "sinter machine." Ore concentrates are mixed with fluxes, recycled sinter, and flue dusts. After moisture is added, the mixture is pelletized and fed to the sinter machine. Inside the furnace, the mixture fuses into a firm porous material, known as sinter. Sintering converts metallic sulfides to oxides, removes volatile metals, and converts most sulfur to sulfur dioxide (SO_2). Product sinter is sized for use in the blast furnace, and fine sinter particles are recycled to the sintering machine feed mixture. (PEI, 1979, pp. 232-234; U.S. EPA, 1993b, p. 23) Sintering is the final beneficiation step in the primary production of lead (U.S. EPA, 1990).

Particulates emitted during sintering are collected using either baghouses or electrostatic precipitators (ESPs) and recycled. (PEI, 1979, p. 234) The sinter plant off-gases are reacted in a contact acid plant to produce concentrated sulfuric acid. Operation of the acid plant may generate wastewaters from scrubbing of the inlet SO_2 stream (acid plant blowdown). These wastewaters may be routed to treatment plants or recycled. Treatment often involves neutralization with lime, followed by thickening, filtering, and recycling of the effluent. (U.S. EPA, 1980, pp. 31-34)

Blast Furnace

Sinter is charged to a blast furnace with coke, limestone, and other fluxing materials and smelted. During smelting, metallic oxides are reduced to metal. The mixture separates into as many as four distinct liquid layers, depending on sinter composition, from the bottom up: lead bullion (94 to 98 percent lead by weight, and other metals); speiss (arsenides and antimonides of iron and other metals); matte (copper sulfides); and slag (flux and metal impurities). The matte and speiss layers are sold to operators of copper smelters for metal recovery, and crude bullion is fed to drossing kettles. Depending on its zinc content, the slag may be either disposed of or sent to a zinc fuming furnace. (PEI, 1979, pp. 235-6; U.S. EPA, 1990, p. 10-2)

Inside a zinc fuming furnace, blast furnace slag and coal are mixed with air and heated. Zinc oxide (ZnO) and lead oxide in the slag are reduced and volatilized, and then oxidized near the top of the furnace, forming particulates. The particulates are recovered in a baghouse and sent to a zinc refinery for zinc recovery. The residual slag is disposed of as described below. (PEI, 1979, pp. 237)

Disposal practices are similar for blast furnace slag and residual slag from zinc fuming operations. The slag may be either dumped while hot onto a slag pile, or granulated with cooling water and then dumped. Some plants dewater the slag; the granulating water may be cleaned in thickeners and recycled to the granulation unit. The granulation water also may be discharged. Particulates emitted from the blast furnace are collected in a baghouse or ESP, and can be recycled to the sinter feed or treated for cadmium recovery. If the cadmium content of the flue dust reaches 12 percent by weight, the dust is roasted to recover cadmium. Fume emissions from the roasting operation are cooled and recovered as a product (cadmium concentrate), and the residue is recycled to the sinter feed. Blast furnace off-gases also contain small quantities of SO_2 that may need chemical scrubbing, possibly generating a waste. (PEI, 1979, pp. 236-253; U.S. EPA, 1980, p. 52; U.S. EPA, 1990, p. 10-3)

Drossing

Lead bullion recovered from the blast furnace is fed to a drossing kettle, agitated with air, and cooled to just above its freezing point. Oxides of lead, copper, and other impurities form a dross on the surface that is skimmed. Sulfur may be added to the drossing kettle to enhance copper removal, forming copper sulfide (Cu_2S) that is skimmed off with the dross. Skimmed dross is sent to the dross reverberatory furnace for additional processing; off

gases and particulates from the drossing kettle are combined with blast furnace off-gases for treatment. The lead product is known as "rough-drossed" lead. (PEI, 1979, pp. 237-8; U.S. EPA, 1980, p. 47; U.S. EPA, 1990, p. 10-2)

Dross is fed into the reverberatory furnace with pig iron, silica sand, and possibly lime rock, and smelted. The products separate into four layers: slag, matte, speiss, and molten lead. The slag and lead are returned to the blast furnace, and the matte and speiss are removed separately, granulated, and shipped to copper smelters for metals recovery. Off gases from the reverberatory furnace are combined with blast furnace off gases. (PEI, 1979, p. 238; U.S. EPA, 1990, p. 10-2)

Decopperizing

Rough-drossed lead bullion is decopperized before refining, occasionally in the same kettle used for the drossing operation. Sulfur is added while the lead is agitated, forming a layer of Cu_2S that is skimmed and recycled either to the dross reverberatory furnace or the drossing kettle (in two-stage drossing). (PEI, 1979, pp. 238-9; U.S. EPA, 1990, p. 10-2)

Softening

Softening removes elements that make lead hard, and is accomplished using one of three techniques: reverberatory softening, kettle softening, or Harris softening. In reverberatory softening, air is blown through molten lead, causing metals such as antimony, arsenic, tin, and copper to form oxides. The oxides form a slag that is skimmed and can be treated for metals recovery. Lead oxide (litharge) may be added to lead with hardness greater than 0.3 to 0.5 weight percent antimony equivalent to increase the oxidation rate. (PEI, 1979, pp. 239-40)

Kettle softening can be used only on bullions with hardness less than or equal to 0.3 percent. The bullion is melted and agitated, and sodium hydroxide (NaOH) and niter ($NaNO_3$) are added as fluxes. The fluxes react with impurities to form salts such as sodium antimonate ($NaSbO_3$), resulting in a slag that is skimmed off and discarded. (PEI, 1979, pp. 240)

Harris softening utilizes the same reagents as kettle softening and also requires low levels of impurities. Harris softening occurs in two stages. The first stage is identical to kettle softening and generates a slag for further processing. During the second step, the slag is crushed and leached with hot water to dissolve the sodium salts. The solution is cooled to precipitate sodium antimonate ($NaSbO_3$), which is filtered from solution and processed to recover antimony. Calcium salts of arsenic and tin are then recovered separately by precipitation and sold. (PEI, 1979, p. 240)

Kettle softening slags and leached slags from Harris softening are discarded with blast furnace or zinc fuming furnace slags. Reverberatory softening slag and sodium antimonate from Harris softening may be treated to recover metal values. To recover antimonial lead ("hard lead"), the softening slag is heated in a furnace with a reducing agent and fluxes, reducing lead and antimony. The antimonial lead is recovered and sold; the slag may be sold if it is rich in tin or recycled to either the sinter feed or the blast furnace. To recover antimonial trioxide (Sb_2O_3), the sodium antimonate is heated to volatilize antimonial trioxide and arsenic trioxide (As_2O_3), and these compounds are separated by selective condensation. The antimony trioxide and arsenic trioxide are sent to antimony and arsenic producers, respectively. The furnace residue is recycled to the blast furnace. Arsenic trioxide becomes a waste if it cannot be sold. (PEI, 1979, pp. 240-1)

Parkes Desilverizing

This process is used to recover gold and silver from softened lead bullion. Gold and silver removal are usually performed in two steps. First, a small amount of zinc is added to the molten bullion to generate a skim with high gold content, because zinc alloys preferentially with gold and copper. After this layer is removed, more zinc is added to form a zinc-silver skim, which is also removed. Other metallic impurities, including arsenic, must be removed prior to this operation. The gold and silver-bearing crusts are retorted in furnaces to recover zinc, leaving behind a purified gold-silver alloy (Doré). The zinc can be recycled to the process. Flue dusts from the furnaces can

be cooled and collected with baghouses and recycled to the sinter feed. (PEI, 1979, pp. 241-2; U.S. EPA, 1980, p. 64)

Gold and silver are recovered by melting the alloy in a cupel and introducing air as well as oxidizing agents. Several successive slags are produced, most of which are recycled to the blast furnace. Slag containing lead oxide is recycled to the softening process. The remaining gold-silver alloy is cast and sold. Exhaust gases can be cooled and routed to baghouses; collected dusts are then recycled to the blast furnace. Desilverized lead is sent to the dezincing process. (PEI, 1979, p. 242; U.S. EPA, 1980, p. 65)

Dezincing

Excess zinc added during desilverizing is removed from lead bullion using one of three methods: Vacuum dezincing; chlorine dezincing; or Harris dezincing. During vacuum dezincing, a vacuum is drawn on the molten lead by submerging an inverted bell into the agitated metal. Vaporized zinc condenses on the inner surface of the bell, and solid zinc is scraped from the dome after the vacuum is broken. The zinc is recycled to desilverizing. In chlorine dezincing, molten desilvered lead is reacted with chlorine gas, forming a surface layer of zinc chloride contaminated with small amounts of lead chloride. The layer is skimmed, treated with zinc for lead recovery, and sold as $ZnCl_2$. In Harris dezincing, caustic soda (NaOH) saturated with lead oxide is mixed with molten lead in a reaction chamber, reducing lead oxide to lead and oxidizing zinc to zinc oxide. The zinc oxide reacts with the caustic to form sodium zincate. The contents of the reaction chamber are fed to a granulator and then reacted with hot water. Sodium zincate hydrolyzes to zinc oxide and sodium hydroxide. Zinc oxide (ZnO) precipitates from solution, and is filtered, dried, and sold. The sodium hydroxide solution is evaporated to anhydrous caustic, which is recycled. Antimony may also be recovered from spent granulated caustic. Dezinced lead is sent to a debismuthing step or to the final refining stage. (PEI, 1979, pp. 242-3; U.S. EPA, 1980, pp. 67-71)

Debismuthing

Desilvered and dezinced lead bullion containing greater than 0.15 percent by weight bismuth must be processed to remove bismuth before casting. Calcium and magnesium are mixed with molten lead, forming ternary compounds (e.g., $CaMg_2Bi_2$) that rise to the surface when the lead is cooled to just above its melting point, forming a dross, which is then skimmed. The purified lead is sent to a final refining step. Bismuth is recovered by melting the dross in a furnace and then injecting chlorine gas. Magnesium, calcium, and lead contained in the dross form chlorides, which are skimmed from the molten bismuth as a slag. Air and caustic soda are added to the melt to oxidize any remaining impurities, forming a slag which is also removed. The nearly pure bismuth is cast and sold, and the slags are disposed along with blast furnace slag. (PEI, 1979, p. 244; U.S. EPA, 1980, p. 74)

Final Refining and Casting

Lead bullion from dezincing or debismuthing is reacted with caustic soda and niter to remove lead oxide, calcium, and magnesium before final casting. A slag forms, which is removed and recycled to the blast furnace or disposed. The final refined lead is reheated and cast into ingots or pigs, which are cooled by direct contact with water. The cooling water becomes contaminated with particulate lead and lead oxides and can be recycled for use in slag granulation or treated. Treatment may include liming to precipitate solids. (PEI, 1979, pp. 244-5; U.S. EPA, 1980, p. 75; U.S. EPA, 1990, p. 10-2)

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Hydrometallurgical Beneficiation

The U.S. Bureau of Mines developed a laboratory-scale method that combines oxidative leaching and electrowinning to recover lead metal and elemental sulfur from lead sulfide (PbS) concentrates. Lead sulfide concentrates were leached with fluosilicic acid (H_2SiF_6), using hydrogen peroxide (H_2O_2) and lead dioxide as oxidants. After filtration to separate the lead fluosilicate ($PbSiF_6$) leach solution and the sulfur-containing residue, the $PbSiF_6$ was electrowon to produce lead metal and H_2SiF_6. The H_2SiF_6 was recycled to the leaching step, and sulfur was recovered from the leach residue by solvent extraction. (Lee et al., 1990, p. 2)

Since H_2O_2 proved to be an expensive oxidant, the Bureau of Mines researchers developed and tested a pressure leaching method for lead sulfide concentrates that utilizes oxygen gas (O_2) in place of H_2O_2. This method also utilizes H_2SiF_6 as the leach solution and electrowinning to recover lead metal. The researchers conducted several experiments, varying O_2 pressure, catalysts, temperature, acid concentration, and time. Lead metal with 99.96 percent purity was recovered by electrowinning from as-leached solution. Lead metal with at least 99.99 percent purity was recovered by electrowinning from leach solutions purified using either of two chemical methods. Finally, elemental sulfur was recovered from the leach residue by solvent extraction, and methods were developed to recover other valuable metals (e.g., Ag, Zn, and Cu) from the final residue. (Lee et al., 1990, pp. 2-3, 6)

The Bureau of Mines also conducted research on the leaching of mixed lead-zinc sulfide concentrates, followed by electrowinning, to produce lead metal. Lead-zinc sulfide concentrates were leached with H_2SiF_6, using either H_2O_2 or pure oxygen (O_2) as an oxidant. Lead was selectively leached and zinc remained in the solid residue. All experiments were performed on a bench-scale level. (Beyke, 1991, pp. 219-221)

The researchers conducted leaching experiments at both atmospheric pressure and at increased pressures. At atmospheric pressure and at 95 degrees C, 85 percent of the lead was leached from the concentrate, and 87 percent of the zinc remained in the residue. Using pressure leaching, 78 percent of the lead was recovered from the concentrate while 80 percent of the remained in the residue. After filtering the leach residue, the researchers recovered pure lead metal by electrowinning from a purified $PbSiF_6$ electrolyte produced from the leach solution. The electrowinning step produced H_2SiF_6 that could be recycled to the leaching stage. In addition, once lead was removed, the original leach solution could also be recycled to the leaching stage. (Beyke, 1991, pp. 219, 236) No information was available on whether these hydrometallurgical methods developed by the Bureau of Mines have been expanded to a pilot-scale or demonstration-scale process.

In the early 1980's, another experimental hydrometallurgical process was developed by the Bureau of Mines in cooperation with four U.S. primary lead producers. Galena (PbS) concentrate was leached with ferric chloride solution, and the lead chloride leachate was reduced by a process known as "fused salt electrolysis." The process generated a lead product that required no further refining. The leachate was also processed to yield 99 percent pure sulfur without sulfur dioxide emissions. The Bureau of Mines and the four primary lead producers concluded 18 months of testing in 1981, using a 500-pound-per-day demonstration unit. (BOM, 1985, p. 439) No information was available on whether this method is used today.

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from primary mineral production arise from mineral processing operations and which from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding) or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or substantial chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on

ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between sintering and smelting in a blast furnace. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where the sintered ore is chemically reduced and physically destroyed to lead metal. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) following the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated downstream of the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

As discussed above (and shown in Exhibit 2), the extraction, beneficiation, and processing of lead generate several solid, liquid, and gaseous wastes, that may be recycled or refined prior to disposal. The generation, treatment, and management of these wastes are discussed below.

Attachment 2 contains a summary of the operational history of and environmental contamination documented at a former lead production site that is now on the Superfund National Priority List.

1. Extraction/Beneficiation Wastes

Wastes generated from the extraction and beneficiation of lead from lead-bearing ores are exempt from RCRA Subtitle C and the scope of BDAT determinations. These wastes are discussed below.

Waste Rock

Lead mining operations generate two types of waste rock, overburden and mine development rock. Overburden results from the development of surface mines, while mine development rock is a material, formerly labeled as a byproduct, of mineral extraction in underground mines. The quantity and composition of waste rock generated at lead mines varies greatly among sites, but these wastes will contain minerals associated with both the ore and host rock. Overburden wastes are usually disposed of in unlined piles, while mine development rock is often used on-site for road or other construction. Mine development rock also may be stored in unlined on-site piles or in underground openings. Waste rock piles may be referred to as mine rock dumps or waste rock dumps. Runoff and leachate from waste rock dumps may contain heavy metals, and these piles may generate acid drainage if sufficient amounts of sulfide minerals and moisture are present. EPA found no information on the quantities of waste rock generated annually. (U.S. EPA, 1993b, pp. 25-26, 28, 105)

Mine Water

Mine water includes all water that collects in surface or underground mines, due to ground water seepage or inflow from surface water or precipitation. While a mine is operational, water may be pumped out to keep the mine dry and allow access to the ore body. The water may be pumped from sumps within the mine or from a system of wells. The recovered water may be used in beneficiation, pumped to tailings or mine water ponds, or discharged to surface water. EPA has no information on the quantities of mine water generated annually at all lead mining/milling locations. One facility, however, the Doe Run mine/mill facility in Fletcher, MO, generates an average of 4.63 million gallons of mine water per day, which is pumped to an on-site mine water pond. (U.S. EPA, 1993b, pp. 26, 109)

The composition and quantity of mine water varies among mining sites, and the chemical composition of mine water depends on the geochemistry of the ore body and the surrounding area. Mine water also may be contaminated with small quantities of oil and grease from mining equipment and nitrates from blasting operations.

When a mine is closed and pumping stops, the mine may fill with water. Through aeration and contact with sulfide minerals, the accumulated water can acidify and become contaminated with heavy metals. (U.S. EPA, 1993b, pp. 26, 28)

Concentration Wastes

Beneficiation operations used to concentrate mineral ores generate various types of wastes. Flotation systems discharge tailings consisting of liquids and solids. The solids include mostly gangue material and small amounts of unrecovered lead minerals. The liquid component consists of water, dissolved solids, and reagents not consumed during flotation. The reagents may include cyanide, which is used as a depressant in certain flotation operations. Flotation wastes are generally sent to tailings ponds, in which solids settle out. The clarified liquid may be recycled to the mill or discharged, provided it meets water quality standards. The characteristics of flotation tailings vary considerably, depending on the ore, reagents, and processes used. Other types of beneficiation wastes include waste slurries from milling and gravity concentration steps. These wastes also are disposed of in tailings impoundments. Site-specific data on tailings generation were available for one facility, the Doe Run mine/mill facility in Fletcher, MO. This facility generates approximately 1.4 million tons of tailings per year. (U.S. EPA, 1993b, pp. 28-29, 105) EPA has no information on the quantities of tailings generated annually at all lead mining/milling locations.

2. Mineral Processing Wastes

Smelting and Refining operations generate numerous solid, liquid, and gaseous wastes. Slag generated during primary lead smelting and refining is classified as a special waste, and is exempt from RCRA Subtitle C controls and, consequently, BDAT determinations. Descriptions of the other wastes follow.

Process Wastewater

Primary lead production facilities generate various process wastewaters, including slag granulation water, sinter plant scrubber water, plant washdown water, and plant run-off. (PEIA, 1984, p. 3-12; Doe Run Company, 1989b; Asarco, 1989a-c) Approximately 4,965,000 metric tons of process wastewater are generated annually (ICF, 1992). EPA/ORD sampling data, presented as Attachment 1, indicates that this waste stream exhibits the characteristic of toxicity (arsenic, cadmium, lead, and selenium). In addition, the waste stream may be toxic for mercury, based on best engineering judgment.

Site-specific information on process wastewater management practices were available only for one facility. At the Doe Run plant in Herculaneum, MO, a mixture consisting of granulated blast furnace slag and the accompanying slag granulation water are sent to a wastewater treatment plant (WWTP-3) for dewatering. The granulation water is sent to a second wastewater treatment plant (WWTP-1) for additional treatment such as pH adjustment and clarification. Other process wastewaters, including dross reverberatory furnace slag granulation water; sinter plant scrubber water; clothes washing liquids; plant runoff; and washdown from the sinter plant, blast furnace, drossing kettles, dross reverberatory furnace, refinery, baghouses, and pavement are sent directly to WWTP-1 for treatment. (Doe Run Company, 1989b) This waste was formerly classified as a spent material and may be partially recycled, based on best engineering judgment.

Surface Impoundment Waste Solids

Since 1980, the primary lead smelting industry has altered its management of process wastewaters, and the solids that settle from those wastewaters. The three operating primary lead smelters (Asarco in Glover, MO; Asarco in East Helena, MT; and Doe Run in Herculaneum, MO) no longer use surface impoundments and completely

recycle all wastewater treatment solids. The industry now uses tanks to settle solids from lead process wastewater. The collected solids are removed from the tanks for reintroduction to the smelting process.[1]

Spent Furnace Brick

Primary lead smelters generate used refractory brick during the reconstruction of blast furnaces. Some plant operators crush and recycle the brick to the blast furnace, while others discard the brick in on-site disposal piles. (PEIA, 1984, p. 3-10) Approximately 1,000 metric tons of spent furnace brick are generated annually (ICF, 1992).

The November 1984 PEI Associates study contains results of EP toxicity tests on two samples of used refractory brick. The plants from which the samples were taken were not identified. Both samples exhibited EP toxicity for lead (1,230 mg/L and 63.3 mg/L). (PEIA, 1984, pp. 5-16 to 5-17) This waste stream is recycled and was formerly classified as a spent material.

WWTP Liquid Effluent

Wastewater treatment plants are utilized in primary lead production for treatment of acid plant blowdown and other wastes, including slag granulation water, plant washdown, and run-on/run-off. These liquids may receive some treatment prior to the WWTP, consisting of settling in lined basins. Treatment in the WWTP often consists of lime neutralization and settling. Treated effluents may be either recycled within the plant or discharged through NPDES outfalls. (PEIA, 1984, pp. 3-6 to 3-7; pp. 3-12 to 3-15; SAIC 1991b, pp. 8-10)

At the Doe Run plant in Herculaneum, MO, a portion of the WWTP-1 liquid effluent is recycled to the sinter plant for use as scrubber water; the rest of the effluent is discharged through an NPDES outfall. Slag granulation water from WWTP-3, as well as neutralized acid plant blowdown from another treatment plant (WWTP-2) are routed to WWTP-1 for further treatment. (Doe Run Company, 1989b)

Approximately 3,500,000 metric tons of WWTP liquid effluent are generated annually (ICF, 1992). The NIMPW Characterization Data Set contains data indicating that this waste stream may exhibit a hazardous characteristic (ICF, 1992). Attachment 1 includes data from EPA/ORD sampling and shows that the waste stream exhibits the characteristic of corrosivity. However, since the effluent is not managed in a land-based unit, and is either recycled within the plant or discharged through a regulated outfall, this waste stream may not meet the definition of a solid waste under RCRA, in which case it would not be subject to Subtitle C regulation. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead. This waste stream is fully recycled and was formerly classified as a sludge.

WWTP Sludges/Solids

Wastewater treatment sludges/solids are now completely recycled and reintroduced into the smelting process. Thus, these materials are not considered to be within the definition of solid waste.[2]

Surface Impoundment Waste Liquids

Unlined surface impoundments are gradually being replaced by lined, engineered impoundments or wastewater treatment systems. At the ASARCO facility in Glover, MO, existing unlined surface impoundments are no longer used. Plant wastewaters (e.g., slag granulation water) are now clarified in two rubber-lined concrete

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[1] National Mining Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996. and The Doe Run Company. Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. May 12, 1997.

[2] National Mining Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

settling tanks. Overflow from the second tank collects in a lined retention pond; overflow from the retention pond is treated with lime in a wastewater treatment plant and discharged through an NPDES outfall. In addition, the Doe Run plant in Herculaneum, MO now continuously treats wastewaters that were formerly routed to unlined surface impoundments. (SAIC 1991b, pp. 9-12) The remaining operational primary lead smelting facility, Asarco, East Helena, MT, is reconstructing its wastewater management system. The modified system will allow the plant to discontinue its use of surface impoundments. (U.S. EPA, 1994, pp. 22-23) The Asarco primary lead refinery in Omaha, NE does not utilize any surface impoundments. (Asarco, 1989c)

The Newly Identified Mineral Processing Waste Characterization Data Set indicated that approximately 5,314,000 metric tons of surface impoundment liquids are generated annually. (ICF, 1992) However, this figure may no longer be accurate, due to changes in management practices for primary lead plant wastewaters and the closure of surface impoundments at several facilities. We used best engineering judgment to determine a waste generation rate of 1,100,000 mt/yr. The waste generation rate is more than one million metric tons per year per facility due to comingling of numerous waste streams.

The November 1984 PEI Associates study contains data on 4 samples of surface impoundment liquids collected at various smelters (the plants were not identified). EP toxicity tests were conducted on one sample of slag granulation water and one sample of granulated slag-pile run-off from separate impoundments at the same site. EP tests were also conducted on two water samples from impoundments at separate facilities that receive miscellaneous plant wastewaters (run-off, washdown, etc.). The samples of slag granulation water and slag pile run-off water did not exhibit EP toxicity. Both samples from impoundments containing miscellaneous plant waters exhibited EP toxicity. A sample from an impoundment that receives plant washdown and run-off (but not blowdown) exhibited EP toxicity for lead (69.1 mg/L). The other sample, from an impoundment that collects acid plant cooling water, sintering plant and concentrate storage area washdown, plant run-off, and personnel change-house water exhibited EP toxicity for arsenic (69.8 mg/L). (PEIA, 1984, p. 5-14 to 5-16) The NIMPW Characterization Data Set contains additional data indicating that this waste stream may exhibit a hazardous characteristic (ICF, 1992). We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristic of toxicity (arsenic, cadmium, and lead). This waste was formerly classified as a sludge.

Acid Plant Blowdown

This acidic liquid waste is generated from wet scrubbing of the sulfur dioxide gas stream that enters the contact acid plant from the sinter plant. The purpose of the scrubbing is to remove particulate matter from the gas before the gas is used to produce sulfuric acid. Some scrubbing solution is continuously purged to prevent a buildup of solids in the recirculating scrubber water. The purged solution is known as acid plant blowdown. (PEIA, 1984, p. 3-6; U.S. EPA, 1994, p. 22)

Typically, acid plant blowdown (APB) is treated through some combination of lime neutralization and settling. Some facilities treat APB with lime at the acid plant and then pump the resulting slurry to an on-site WWTP. Other plants mix APB with other wastewaters, allow settling to occur, and then treat the clarified liquid with lime. Solids derived from blowdown treatment are often recycled to the sinter feed preparation or to the smelter, while the liquids are either discharged through NPDES outfalls or recycled within the plant. The solids may also be sold for metals recovery. (PEIA, 1984, pp. 3-6, 3-7; SAIC, 1991b, pp. 8-12; ICF, 1989, pp. 2-3) Approximately 556,000 metric tons of acid plant blowdown are generated annually (ICF, 1992).

At the Doe Run facility in Herculaneum, MO, acid plant blowdown is neutralized in a wastewater treatment plant (WWTP-2), and the neutralized blowdown is sent to a second wastewater treatment plant (WWTP-1) for additional neutralization and clarification. (Doe Run Company, 1989b)

The November 1984 PEI Associates study contains results of EP toxicity tests on two samples of lime-neutralized acid plant blowdown collected at different smelters (the plants were not identified). Each sample exhibited the characteristic of EP toxicity, one for lead (22 mg/L) and the other for arsenic (24.4 mg/L) and cadmium (2.61 mg/L). The study also contains the results of an EP toxicity test on one sample of blowdown treatment material formerly labeled as sludge. The material sample exhibited EP toxicity for arsenic (304 mg/L) and cadmium (155 mg/L). (PEIA, 1984, pp. 5-14, 5-16, 5-17) The NIMPW Characterization Data Set contains additional data

indicating that this waste stream may exhibit a hazardous characteristic (ICF, 1992). Attachment 1 includes EPA/ORD sampling data which shows that this waste stream exhibits the characteristics of toxicity (arsenic, cadmium, lead, and selenium) and corrosivity. We used best engineering judgment to determine that this waste stream may exhibit the characteristic of toxicity for mercury. This waste is recycled and was formerly classified as a spent material.

Slurried APC Dust

At one integrated smelter/refinery, ESP dust and scrubber underflow from the cleaning of sinter plant off-gases destined for the acid plant were slurried into a thickener. The thickened solids were placed on the slag dump along with other solids for air drying, and eventually recycled to the sinter feed preparation step. The facility at which this practice occurred was not identified. (PEIA, 1984, p. 3-5) Approximately 7,000 metric tons of slurried APC dust are generated annually. (ICF, 1992)

The 1989 RTI Survey for the Doe Run facility in Herculaneum, MO, suggests another source of this waste stream. The flow diagram included with the survey shows that baghouses are used to collect particulates in off-gases generated by the sinter plant, blast furnace, and the dross reverberatory furnace. The diagram also shows that a liquid waste (process wastewater) known as "department washdown" flows from the baghouses to an on-site wastewater treatment plant (WWTP-1), for treatment that includes pH adjustment and clarification. (Doe Run Company, 1989b) However, the survey does not specify whether or not the department washdown contains entrained baghouse dust.

The November 1984 PEI Associates study contains results of EP toxicity tests on one sample of solids from sumps that collect slurried ESP dust, "cyclone underflow," and plant washdown. The study adds that the solids are stockpiled on-site before they are recycled. The sample exhibited the characteristic of EP toxicity for lead (959 mg/L) and cadmium (22 mg/L). (PEIA, 1984, pp. 5-16, 5-17) This waste stream is fully recycled and was formerly classified as a sludge.

Solids in Plant Washdown

At some plants, washdown liquids from storage and blending areas (sinter feed preparation) are typically sent to concrete sumps and allowed to settle. The water is recycled, and the solids are stored to allow dewatering and drying. The collected solids are returned to sinter feed piles or blending bins. (PEIA, 1984, p. 3-2)

Alternatively, plant washdown may be sent to on-site wastewater treatment plants. At the Doe Run facility in Herculaneum, MO, washdown from the sinter plant, blast furnace, drossing kettles, dross reverberatory furnace, refinery, and baghouses is sent along with other wastewaters, to a single treatment plant (WWTP-1) for neutralization, clarification, and other treatment. Dewatered material formerly labeled as sludge from this treatment plant is returned to the sinter feed. (Doe Run Company, 1989b) This washdown may contain entrained solids and particulates.

Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Acid Plant Sludge

This waste stream was identified in a 1987 draft of an EPA Report to Congress on mineral processing operations. The report provided an estimated annual generation rate of 14,600 metric tons per year, but did not include any specific information on how the waste was generated or its composition. (ICF, 1987, pp. 3-41 to 3-44) According to a process flow chart provided in the 1989 RTI survey, this waste stream was recycled to the sintering machine. We used best engineering judgment to determine that this waste may exhibit the characteristic of corrosivity. This waste was formerly classified as a sludge.

Solid Residues

This waste stream was identified in the 1989 RTI Survey for the Doe Run facility in Boss, MO. The waste consisted of two types of material, "rice paddy" and "filter cake," and the facility reported generating the waste as a residue from its sinter plant. (Doe Run Company, 1989a) According to the RTI Survey, this waste was recycled to the sintering process. The Boss primary lead facility is no longer operational, and it is not known whether this waste is generated by any other primary lead production facilities. This waste stream has a reported annual waste generation rate of 400 metric tons/yr. The NIMPW Characterization Data Set contains data indicating that this waste stream may exhibit a hazardous characteristic. (ICF, 1992) We used best engineering judgment to determine that this waste may be recycled and may exhibit the characteristic of toxicity for lead. This waste was formerly classified as a by-product.

Baghouse Dust

Several components of the primary lead production process generate off-gases that contain dusts or particulates. Particulates in off-gases from sintering operations are collected by baghouses and ESPs. These dusts are returned to the sinter feed preparation. Particulates in off-gases from the blast furnace, dross kettle, the dross reverberatory furnace, and silver/gold recovery operations are also collected using baghouses and ESPs and are recycled to the sinter feed. (PEI, 1979) Approximately 46,000 metric tons of baghouse dust are generated annually (ICF, 1992).

At the Doe Run facility in Herculaneum, MO, baghouses are used to collect particulates in off-gases generated by the sinter plant, blast furnace, and the dross reverberatory furnace. However, ultimate destination of the dust is unclear from the survey. The facility flow diagram indicates that a liquid waste (process wastewater) known as "department washdown" flows from the baghouses to an on-site wastewater treatment plant (WWTP-1). However, the survey does not specify whether or not the department washdown contains entrained baghouse dust. (Doe Run Company, 1989b)

Dust collected in baghouses at one of ASARCO's facilities (a smelter) accumulates in cellars beneath the baghouse. The baghouse is taken off-line every two to four weeks so that the dust can be removed from the cellar. This material is then stored in a containment area to await further processing.[3]

The November 1984 PEI Associates study contains results of EP toxicity tests on one sample of baghouse dust. The plant from which the sample was taken, the source of gas entering the baghouse, and the sample location were not identified. This sample exhibited EP toxicity for cadmium (3,580 mg/L) and lead (61.7 mg/L). (PEIA, 1984, pp. 5-16 to 5-17) This waste stream is fully recycled and was formerly classified as a sludge.

Cooling Tower Blowdown

The 1989 RTI Survey for the Doe Run facility in Herculaneum, MO indicated that an on-site surface impoundment received Acid Plant, Dross Furnace, and Blast Furnace cooling tower blowdown. (Doe Run Company, 1989b) However, the Herculaneum facility no longer uses surface impoundments as part of its wastewater management system. It is not known whether any of these wastes are still generated at the Herculaneum facility.

Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Waste Nickel Matte

The 1989 RTI Survey for the Doe Run facility in Herculaneum, MO indicated that the dross plant reverberatory generates a product known as nickel matte. (Doe Run Company, 1989b) It is not known whether this

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[3] ASARCO Incorporated. Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. May 12, 1997.

material is still generated at the Herculaneum facility. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

SVG Backwash

The 1989 RTI Survey for the Doe Run facility in Herculaneum, MO indicated that an on-site wastewater treatment plant (WWTP-1) received a liquid inflow known as "SVG Backwash." (Doe Run Company, 1989b) It is not known whether this material is still generated at the Herculaneum facility. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Baghouse Fume

The 1989 RTI Survey for the Doe Run facility in Herculaneum, MO indicated that in 1988, the sinter plant received approximately 30,000 short tons of "baghouse fume" as a material input, but does not describe the composition of this material or identify its source. (Doe Run Company, 1989b) No information is available on whether this material is a waste stream, or its current annual generation rate. In addition, it is not known whether this material is still generated at the Herculaneum facility.

Baghouse Incinerator Ash

At most primary lead production facilities, used bags from baghouses are fed to the blast furnace. At one integrated smelter/refinery, however, the bags are washed and then incinerated in a small, on-site industrial incinerator. The incinerator ash is landfilled on-site, and the bag washwater is sent to an on-site wastewater treatment plant. (PEIA, 1984, pp. 3-5 to 3-6) The facility was not identified.

The November 1984 PEI Associates study contains results of EP toxicity tests on one sample of ash from an incinerator that burned baghouse bags and other plant waste. The plant from which the sample was taken was not identified. This sample exhibited EP toxicity for cadmium (5.76 mg/L) and lead (19.2 mg/L). (PEIA, 1984, pp. 5-16, 5-17) Although no published information regarding waste generation rate was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 300 metric tons/yr, 3,000 metric tons/yr, and 30,000 metric tons/yr, respectively.

Stockpiled Miscellaneous Plant Waste

This waste stream consists of a mixture of consolidated refractory brick, slag, matte, sweepings, and other cleanup wastes. The November 1984 PEI Associates study contains results of EP toxicity tests on one sample of this materials, which includes refractory brick, slag, matte, "cleanups," and plant "sweepings." The sample exhibited the characteristic of EP toxicity for lead (1,380 mg/L) and cadmium (29.4 mg/L). (PEIA, 1984, pp. 5-16, 5-17) The plant from which the sample was obtained was not identified. Although EPA found no published information regarding waste generation rate, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 400 metric tons/yr, 88,000 metric tons/yr, and 180,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be partially recycled and was formerly classified as a spent material.

D. Non-uniquely Associated Wastes

Non-uniquely associated wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), acidic tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants. (U.S. EPA, 1993b, p. 110)

The Asarco facilities in East Helena, MT, Glover, MO, and Omaha, NE each generate less than 100 kg of solvents per month. These facilities hold RCRA identification numbers and are classified as conditionally exempt small quantity generators. At the Glover and Omaha facilities, used solvents are collected by Safety-Kleen for disposal. (ASARCO, 1989a-c) The Doe Run facility in Herculaneum, MO also holds a RCRA I.D. number, but no information was available on the types of hazardous wastes that are generated. (Doe Run, 1989b)

E. Summary of Comments Received by EPA

New Factual Information

Two commenters indicated that the three operating primary lead smelters (Asarco in Glover, MO; Asarco in East Helena, MT; and Doe Run in Herculaneum, MO) no longer use surface impoundments and completely recycle all wastewater treatment solids (COMM 58, 1019). This new information was used to update the Surface Impoundment Waste Solids section in the discussion of mineral processing wastes. One commenter mentioned that baghouse dust accumulates in cellars beneath the baghouse and is removed every two to four weeks (COMM 1034). This new information has been included in the Baghouse Dust section.

Sector-specific Issues

One commenter stated that certain operations downstream of sintering should be considered beneficiation, not processing (COMM 36). EPA disagrees with this conclusion because it maintains that smelting is a processing operation, while sintering (or other defined beneficiation operation preceding smelting) is a beneficiation activity. Another commenter indicated that it no longer uses surface impoundments and completely recycles wastewater treatment solids (COMM 58). Thus, the commenter believed that these wastes should not be considered as solid and hazardous wastes. EPA agrees that wastewater treatment solids may not be considered hazardous wastes if they are not stored on land and are reclaimed for their metal, acid, water, or cyanide values. The Agency has removed the WWTP sludges/solids waste stream from the RIA.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PROCESS WASTEWATER - LEAD

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.043	3.75	17.90	8/8	0.050	4.85	18.80	4/4	-	-
Antimony	0.005	2.97	21.90	9/9	0.050	7.82	30.20	4/4	-	-
Arsenic	0.029	765.04	3,800.00	9/9	0.002	530.41	3,160.00	6/6	5.0	2
Barium	0.001	0.18	0.50	7/7	0.050	0.25	0.50	5/5	100.0	0
Beryllium	0.0003	0.01	0.05	6/6	0.005	0.03	0.05	4/4	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.002	8.76	31.30	13/13	0.001	2.78	8.96	6/6	1.0	2
Chromium	0.001	0.13	0.50	7/7	0.001	0.19	0.50	6/6	5.0	0
Cobalt	0.006	0.49	2.10	9/9	0.050	0.28	0.50	4/4	-	-
Copper	0.009	30.20	250	10/10	0.138	0.72	1.75	4/4	-	-
Iron	0.035	26.51	77.80	9/9	0.050	1.38	5.69	5/5	-	-
Lead	0.002	1,820.30	21000	13/13	0.220	15.54	84.00	6/6	5.0	2
Magnesium	0.008	17.91	61.30	9/9	0.500	22.43	54.00	4/4	-	-
Manganese	0.010	4.97	33.60	8/8	0.030	0.93	2.86	5/5	-	-
Mercury	0.0001	12.86	90.00	7/7	0.0001	0.0032	0.0180	6/6	0.2	0
Molybdenum	0.020	1.07	4.62	6/6	0.050	1.66	4.67	4/4	-	-
Nickel	0.002	0.55	1.90	9/9	0.050	0.28	0.50	4/4	-	-
Selenium	0.004	0.23	1.66	9/9	0.001	0.94	4.96	6/6	1.0	1
Silver	0.001	0.16	0.50	9/9	0.005	0.19	0.50	6/6	5.0	0
Thallium	0.220	1.04	2.50	7/7	0.250	1.47	2.50	4/4	-	-
Vanadium	0.001	0.11	0.50	9/9	0.050	0.28	0.50	4/4	-	-
Zinc	0.010	99.61	690.00	11/11	0.500	20.18	83.20	5/5	-	-
Sulfide	25.00	136.33	207.00	3/3					-	-
Sulfate	270.00	1,785.88	5300	8/8					-	-
Fluoride	0.010	6.34	19.00	3/3					-	-
Chloride	5.00	1,158.09	7000	9/9					-	-
TSS	1.31	10,325.34	73700	8/8					-	-
pH *	2.22	8.41	13.30	17/17					2<pH>12	3
Organics (TOC)	4.56	16.47	39.20	5/5					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - ACID PLANT BLOWDOWN - LEAD

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.05	1.82	7.68	5/6	0.05	0.58	1.18	3/3	-	-
Antimony	0.05	29.57	148	6/6	0.05	30.72	91.60	3/3	-	-
Arsenic	0.05	785.14	2370	6/6	0.05	840.18	2,520.00	3/3	5.0	1
Barium	0.05	0.14	0.50	6/6	0.05	0.35	0.50	3/3	100.0	0
Beryllium	0.0005	0.02	0.05	5/5	0.005	0.035	0.050	3/3	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.41	77.21	362.00	7/7	3.67	126.78	368.00	3/3	1.0	3
Chromium	0.00	0.20	0.50	5/5	0.05	0.35	0.50	3/3	5.0	0
Cobalt	0.05	0.55	2.32	6/6	0.05	0.35	0.50	3/3	-	-
Copper	0.01	2.85	17.80	7/7	0.05	0.35	0.50	3/3	-	-
Iron	0.63	29.19	94.80	6/6	0.50	14.21	39.20	3/3	-	-
Lead	1.63	115.30	674.00	7/7	1.79	4.14	7.29	3/3	5.0	1
Magnesium	2.90	23.92	78.20	6/6	7.94	25.88	54.00	3/3	-	-
Manganese	0.53	1.71	3.81	6/6	0.78	0.99	1.17	3/3	-	-
Mercury	0.0010	1.23	4.80	5/5	0.0001	0.0001	0.0002	3/3	0.2	0
Molybdenum	0.05	0.22	0.50	3/3	0.05	0.35	0.50	3/3	-	-
Nickel	0.05	0.61	2.81	6/6	0.05	0.35	0.50	3/3	-	-
Selenium	0.05	1.91	5.59	3/3	0.05	1.36	3.54	3/3	1.0	1
Silver	0.01	0.18	0.50	5/5	0.05	0.35	0.50	3/3	5.0	0
Thallium	0.25	47.77	142.00	3/3	0.25	36.58	107.00	3/3	-	-
Vanadium	0.00	0.21	0.50	5/5	0.05	0.35	0.50	3/3	-	-
Zinc	0.32	47.43	160	7/7	0.29	59.50	113.00	3/3	-	-
Sulfate	536	1,126.83	3150	6/6					-	-
Fluoride	57	364.50	672	2/2					-	-
Chloride	3	1,250.56	4300	9/9					-	-
TSS	21.30	7,965.06	24730	8/8					-	-
pH *	0.62	3.91	9.04	7/7					2<pH>12	2
Organics (TOC)	8.81	125.90	350.00	3/3					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - MISCELLANEOUS SOLIDS - LEAD

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	10,000	10,000	10,000	1/1	-	-	-	0/0	-	-
Iron	100,000	100,000	100,000	1/1	-	-	-	0/0	-	-
Lead	500,000	500,000	500,000	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	50,000	50,000	50,000	1/1	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	-	-	-	0/0					-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT LIQUIDS - LEAD

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	18.00	18.00	18.00	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.05	5.53	20.70	4/4	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.01	0.23	0.50	4/4	-	-	-	0/0	-	-
Iron	0.25	0.52	1.00	3/3	-	-	-	0/0	-	-
Lead	0.95	2.28	3.18	4/4	-	-	-	0/0	5.0	0
Magnesium	18.00	18.00	18.00	1/1	-	-	-	0/0	-	-
Manganese	3.00	3.00	3.00	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	2.00	15.10	43.20	4/4	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	-	-	-	0/0					-	-
pH *	7.00	7.60	8.00	3/3					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT SLUDGE/SOLIDS - LEAD

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	19.00	19.00	19.00	1/1	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	2,500	2,500	2,500	2/2	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	1,290	27,430	59,000	3/3	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	68	64,689	98,000	3/3	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	-	-	-	0/0					-	-
pH *	0.00	7.55	13.00	5/5					2<pH>12	1
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT LIQUID EFFLUENT - LEAD

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	0.08	0.08	0.08	1/1	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	15.00	17.50	20.00	2/2	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	35.00	35.00	35.00	1/1	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	-	-	-	0/0					-	-
pH *	7.00	9.08	13.00	4/4					2<pH>12	1
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT SOLIDS - LEAD

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	0.00	46.95	304.00	7/7	5.0	2
Barium	-	-	-	0/0	0.15	1.08	2.60	6/6	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0		
Cadmium	640.00	670.00	700.00	2/2	0.01	54.34	155.00	7/7	1.0	6
Chromium	28.00	44.00	60.00	2/2	0.00	0.02	0.07	3/7	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	0.05	30.25	178.00	6/6	-	-
Lead	115000	127500	140000	2/2	0.22	188.01	959.00	7/7	5.0	3
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	0.03	513.63	3,560.00	7/7	-	-
Mercury	-	-	-	0/0	0.0001	1.1313	7.9000	7/7	0.2	1
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	0.001	0.077	0.420	7/7	1.0	0
Silver	-	-	-	0/0	0.015	0.018	0.030	5/5	5.0	0
Thallium	-	-	-	0/0	0.02	0.02	0.02	1/1	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	80000	106000	132000	2/2	0.02	65.66	184.00	7/7	-	-
Sulfate	-	-	-	0/0					-	-
Fluoride	-	-	-	0/0					-	-
Chloride	-	-	-	0/0					-	-
TSS	-	-	-	0/0					-	-
pH *	4.80	6.29	11.20	6/6					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

ATTACHMENT 2

Mining Sites on the National Priority List

Name of Site: Bunker Hill Mining and Metallurgical Complex

Owner of Site: Bunker Limited Partnership

Location of Site: Kellogg, Idaho

Climate Data: To be determined

Commodity Mined: Lead and Zinc

Facility History: The Bunker Hill Superfund Site is located in the Silver Valley of the South Fork of the Coeur d'Alene River in Northern Idaho. It is approximately 60 miles east of Spokane, Washington. The site is 3 miles wide and 7 miles long and bisected by Interstate 90. The site includes the cities of Wardner, Kellogg, Smelterville, and Pinehurst, with a total population of 5000. Lead and zinc mining began on the Bunker Hill site with the location of the Bunker Hill and Sullivan claims in 1885 by Noah Kellogg. The first mill began operations in 1886 and a larger mill was constructed in 1891. The lead smelter began operation in 1917. An electrolytic zinc plant, capable of producing 99.99% zinc, began operation in 1928. An electrolytic antimony plant was constructed in 1939, but it operated only for a few years. In 1943, a slag fuming plant was constructed to recover zinc from the blast furnace slag of the lead smelter. A cadmium recovery plant was added in 1945. A sink-float plant operated from 1941 to 1953. A phosphoric acid plant began operations in 1961. The plant used sulfuric acid from the zinc plant and phosphate rock from southern Idaho or Wyoming to produce phosphoric acid and gypsum. Sulfuric acid plants were added to the zinc facilities in 1954 and 1966. The lead smelting process was changed in 1970 from a downdraft ore-roasting operation to a Lurgi updraft sintering process with a sulfuric acid recovery plant. In 1976, a 715-foot stack was added to the lead smelter, and a 610-foot stack was added to the zinc plant in 1977. In December 1981, the smelter complex was shut down.

Waste(s) at Issue: The major environmental problems at the Bunker Hill site were caused by smelter operations and mining and milling. Contaminants of concern are lead, zinc, cadmium, antimony, arsenic, beryllium, copper, mercury, PCBs, selenium, silver, cobalt, and asbestos.

During smelter operations (1917-1981) wastes and feed stock were stored onsite. In addition, the smelter discharged heavy metal particulates and sulphur dioxide gas to the atmosphere. In order to capture the heavy metal particulates, baghouse filtration systems were installed at the lead and zinc plants. However, a 1973 fire severely damaged the baghouses. Two of the seven baghouses were destroyed and the remaining five were shut down for 6 months to be repaired. During this time, 20 to over 100 tons/month of particulates containing 50 to 70 percent lead were emitted from the stacks (compared to the normal 10 to 20 tons/month).

Originally, all liquid and solid residues from the milling operations were discharged directly into the South Fork of the Coeur d'Alene River and its tributaries. Periodic floods deposited contaminated wastes onto the valley floor. In the 1920's, mill tailings were discharged to a small impoundment, and lead smelter slag was placed in what became the slag pile. In 1928, the first impoundment at the Central Impoundment Area (CIA) began operation. After 1961, the coarse fraction of mill tailings were used as sand

backfill in the Bunker Hill Mine. The CIA also received mine drainage beginning in 1965, gypsum from the phosphoric acid and fertilizer plant after 1970, and wastes from the zinc plant and smelter after 1974. Decant from the CIA was discharged directly into the river until 1974, when the Central Treatment Plant began operation. After 1974, decant gypsum discharge was returned to the phosphate plant.

Disposal Site:

The Bunker Hill Mining Complex includes the Bunker Hill Mine (lead and zinc), a milling and concentrating operation, a lead smelter, a silver refinery, an electrolytic zinc plant, a phosphoric acid and phosphate fertilizer plant, sulfuric acid plants, and a cadmium plant. Also included within the site boundary are the Page Mine (inactive), the Page tailings disposal area known as the "Page Ponds" (currently the site of Silver Valley water treatment facility), and numerous old mines, mill sites, and prospects.

Soil Pathway:

Residual soil contamination with metals is a major concern at this site. During smelter operation, metal-laden particulates were discharged from the smelter. In 1974 the top 0.5 inch of hillside soil had lead concentrations ranging from 1,000 to 24,000 ppm and cadmium concentrations ranging from 50 to 236 ppm. On undisturbed areas, most of the metals were found in the top 3 inches, while in severely eroded areas, airborne contamination penetrated at least the top 10 inches. Soil near the smelting complex has also been severely impacted by metals deposition. Around the smelter complex, extremely high concentrations of lead (1,000 to 40,000 ppm) and cadmium (80 to 240 ppm) were detected. The upper 10 to 20 feet of soils on the valley floor were combined with mine and mill tailings generated by the mineral processing industry in the early part of the 20th century. These early milling practices resulted in the deposition of metals-rich tailings in low-lying areas. Lead and cadmium levels in the valley area are similar to those in the hillside soils. The Smelterville Flats encompass an area of approximately 2 square miles northwest of the City of Smelterville, where significant amounts of unconfined tailings have accumulated over time. Surface metal concentrations ranged from 6,000 to 25,000 ppm lead and 30 to 70 ppm cadmium. The Page Ponds and the CIA cover 240 acres and contain several million cubic yards of tailings. These areas are located close to major residential areas and have lead concentrations ranging from 2,000 to 20,000 ppm (1974 and 1977 studies). In 1986 and 1987, a soil survey was conducted in the communities of Smelterville, Kellogg, Wardner, and Page. Samples of the top 1 inch of mineral soil and litter were analyzed from 1,020 of 1547 homes (64%). Five percent of all homes sampled had lead levels below 500 ppm; 11 percent had lead levels between 500 and 1,000 ppm; and 84 percent had lead levels above 1,000 ppm.

Ground Water Pathway:

Primary sources of ground water contamination include: seepage from the CIA (estimated to be 1 ft^3/sec), infiltration and ground water flow through valley-wide deposits of tailings, and ground water inflow upgradient of the site. Other sources of ground water contamination include discharges from Magnet Gulch, Pine Creek, and Milo Gulch; infiltration of incident precipitation through the CIA; and seepage from Sweeney Pond, McKinley Pond, and other surface impoundments. Contaminants of primary concern include: arsenic, cadmium, lead, cobalt, and zinc. Maximum zinc and cadmium levels have been detected in wells adjacent to the CIA at 50 and 0.1 mg/L, respectively (1974). These values appear to have reflected partly diluted direct seepage from the CIA. While studies have been done to evaluate the seepage and metal transport to ground water from the CIA, they have not specifically targeted the extent and degree of ground water contamination, and thus, have not determined the spread of contaminants into the confined lower aquifer. Ground water in the Smelterville Flats area contain high levels of heavy metals, but the concentrations generally decrease with depth and linear distance from the South Fork. The ground water appears to be in hydraulic connection with surface ponds in the flats. In 1979, it was estimated that the flats discharge about 5.3 kg/day of zinc to the ground water. The Page Ponds discharged 8 kg/day of zinc to the ground water in 1975. The ponds have subsequently been converted for sewage

treatment. Information on the potential of heavy-metal contamination of ground water from these ponds remains unavailable.

Surface Water Pathway: The Bunker Hill site is situated in the Coeur d'Alene River basin. The main surface water features at the Bunker Hill Complex include: the Coeur d'Alene River, the CIA, which includes the central impoundment pond, the gypsum pond, and the slag pile. Other smaller impoundments areas are located near the lead and zinc smelter, including Sweeney Pond and the main reservoir in the lead smelter complex, and the main reservoir and settling ponds in the zinc plant area. Major streams on the complex include Government Creek, Bunker Creek, and Mile Creek. The streams in the vicinity of past mining activities at this site have received a heavy sediment load of mine and mill tailings. The South Fork of the Coeur d'Alene River has been receiving mine and mill wastes for approximately 90 years. Even though the site was closed in 1981, discharges to the South Fork still continue; including, for example, those from the operating wastewater treatment plant. As of 1984, concentrations of several contaminants were still significant in the South Fork: cadmium (28.6 μg/L), iron (1,146 μg/L), manganese (1,507 μg/L), and zinc (3,270 μg/L).

Air Pathway: Lead, cadmium, zinc, mercury, and arsenic emissions from the lead smelter main stack were calculated for the period of 1965 to 1981. In excess of 6 million lbs of lead; 560,000 lbs of cadmium; 860,000 lbs of zinc; 29,000 lbs of mercury; and 70,000 lbs of arsenic were emitted during this period. These figures do not include vent or fugitive emissions, which were believed to total more than stack emissions. Since smelter closure, ambient lead levels and total suspended particulates have generally been within primary National Ambient Air Quality Standards (NAAQS). Ambient lead levels have ranged from 0.1 to 0.5 $\mu g/m^3$ (on a quarterly basis) and ambient levels of total suspended particulates have ranged from 30 to 70 $\mu m/m^3$ (on an annual basis) with daily values ranging to 900 $\mu g/m^3$. The NAAQS for lead is 1.5 $\mu g/m^3$ (on a quarterly basis) and the primary NAAQS for particulate matter is 150 $\mu g/m^3$ (on a 24-hour basis, for particles <10 microns).

Environmental Issues: The pathways for human exposure include household dusts, soils, and locally grown vegetables. EPA has (through a health intervention program) recommended against eating the vegetables since 1985. Shown below are concentrations of lead, cadmium, and zinc from studies performed in 1974 and 1983.

	Lead (in ppm)		Cadmium (in ppm)		Zinc (in ppm)	
Media	**1974**	**1983**	**1974**	**1983**	**1974**	**1983**
Household Dust	11,920	3,994	NA	67	NA	2,840
Soils	7,224	3,504	63	54	2,340	126
Garden Vegetables	231	48	28	5	NA	73

NA - not analyzed

Environmental and ecological damage has also occurred. The Bunker Hill Company, as part of a revegetation effort beginning in the early 1970's, identified about 14,000 acres that had been damaged. Studies conducted as part of the Remedial Investigation concluded that site vegetation has been damaged by logging, fires, and emissions from the lead smelter, zinc plant, and phosphoric acid/fertilizer plant.

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LIGHTWEIGHT AGGREGATE

A. Commodity Summary

Lightweight aggregates are minerals, natural rock materials, rock-like products, and byproducts of manufacturing processes that are used as bulk fillers in lightweight structural concrete, concrete building blocks, precast structural units, road surfacing materials, plaster aggregates, and insulating fill. Lightweight aggregates are also used in architectural wall covers, suspended ceilings, soil conditioners, and other agricultural uses. Lightweight aggregates may be classified into four groups:

- *Natural lightweight aggregate materials* which are prepared by crushing and sizing natural rock materials, such as pumice, scoria, tuff, breccia, and volcanic cinders.
- *Manufactured structural lightweight aggregates* which are prepared by pyroprocessing shale, clay, or slate in rotary kilns or on traveling grate sintering machines.
- *Manufactured insulating ultralightweight aggregates* which are prepared by pyroprocessing ground vermiculite, perlite, and diatomite.
- *Byproduct lightweight aggregates* which are prepared by crushing and sizing foamed and granulated slag, cinders, and coke breeze.

The first three groups of lightweight aggregates are produced from naturally occurring materials, while the fourth is produced as a byproduct of iron and steel production. Lightweight aggregates are distinguished from other mineral aggregate materials by their lighter unit weights. Exhibit 1 presents the names and locations of facilities involved in the production of lightweight aggregates from naturally occurring raw materials. Exhibit 2 presents the names of facilities involved in the production of lightweight aggregates from iron and steel slags.

B. Generalized Process Description

Lightweight aggregate materials are produced mainly by two methods. The first method of lightweight aggregate production is from naturally occurring raw materials. The second method is byproduct production from iron and steel production. These processes are quite different and are described separately below. Section 1 describes lightweight aggregate production from naturally occurring raw materials. Section 2 describes byproduct lightweight aggregate production.

SECTION 1: Production From Naturally Occurring Raw Materials

1. Discussion of Typical Production Processes

While natural lightweight aggregates are prepared through basic operations including steps such as mining, grinding, and sizing, manufactured lightweight aggregate and manufactured ultralightweight aggregate products are produced by heating certain types of clay, shale, slate, and other materials in a rotary kiln which forces the materials to expand or "bloat;" resulting in a porous product. The product will retain its physical strength despite its lighter unit weight when cooled.[1] The process is described in more detail below.

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[1] Bruce Mason, "Lightweight Aggregates," from Industrial Minerals and Rocks, 6th ed., Society for Mining, Metallurgy, and Exploration, 1994, pp. 343-350.

EXHIBIT 1

FACILITIES PRODUCING LIGHTWEIGHT AGGREGATES FROM NATURALLY OCCURRING RAW MATERIALS

Facility Name	Location
Arkansas Lightweight Aggregate	West Memphis, AR
Big River	Livingstone, AL
Big River	Erwinville, LA
Buildex	Dearborn, MO
Buildex	Ottawa, KS
Buildex	Marquette, KS
Chandler Materials Co.	Tulsa, OK
Chandler Materials Co.	Choctaw, OK
Dakota Block Co.	Rapid City, SD
Featherlite	Strawn (Ranger), TX
HP Brick Co.	Brooklyn, IN
HP Brick Co.	Independence, OH
Jackson Concrete	Jackson, MS
Kanta	Three Forks, MT
Lehigh Portland Cement Co.	Woodsboro, MD
Lorusso Corp.	Plainville, MA
Norlite	Cohoes, NY
Parkwood Lightweight Plant	Bessemer, AL
Porta Costa	Porta Costa, CA
Ridgelite	Frazier Park, CA
Solite	Cascade, VA
Solite	Arvonia, VA
Northeast Solite	Mount Marion, NY
Carolina Solite	Norwood, NC
Kentucky Solite	Brooks, KY
Florida Solite	Green Cove Springs, FL
Strawn	Strawn, TX
Texas Industries	Streetman, TX
Utelite	Coalville, UT
Weblite	Blue Ridge, VA

Source: Determination of Waste Volume for Twenty Conditionally Retained Bevill Mineral Processing Wastes, 1990, pp. 5-9, A10.

Facilities that burn hazardous waste fuels are shaded.

EXHIBIT 2

BYPRODUCT LIGHTWEIGHT AGGREGATE PRODUCERS

Facilities	Location
Waylite Corporation	Bethlehem, PA
Standard LaFarge Corporation	Cleveland, OH
Edward C. Levy Company	Detroit, MI
Koch Minerals	Gary, IN

2. Generalized Process Flow Diagram

Naturally occurring lightweight aggregate raw materials, such as pumice and volcanic cinders, are normally mined by open pit or quarry methods, depending on the degree of consolidation of the raw materials. Shale, clay, and slate mined by open pit and quarry methods are dried in large sheds or open stockpiles to control water content in the raw feed prior to high temperature pyroprocessing in either rotary kilns or sintering machines. The resulting clinker may then be crushed before screening to yield proper gradation mixes for final use. Most lightweight aggregate plants use coal as a primary source of fuel. Waste-derived fuels and solvents from various industrial processes are also used as alternate fuel sources at a few locations (e.g., those operated by Solite and Norlite). Exhibit 3 presents a typical process flow diagram for lightweight aggregate production for facilities using a wet scrubber air pollution control technology or a dry collection method. All facilities currently use dry collection systems.

3. Identification of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

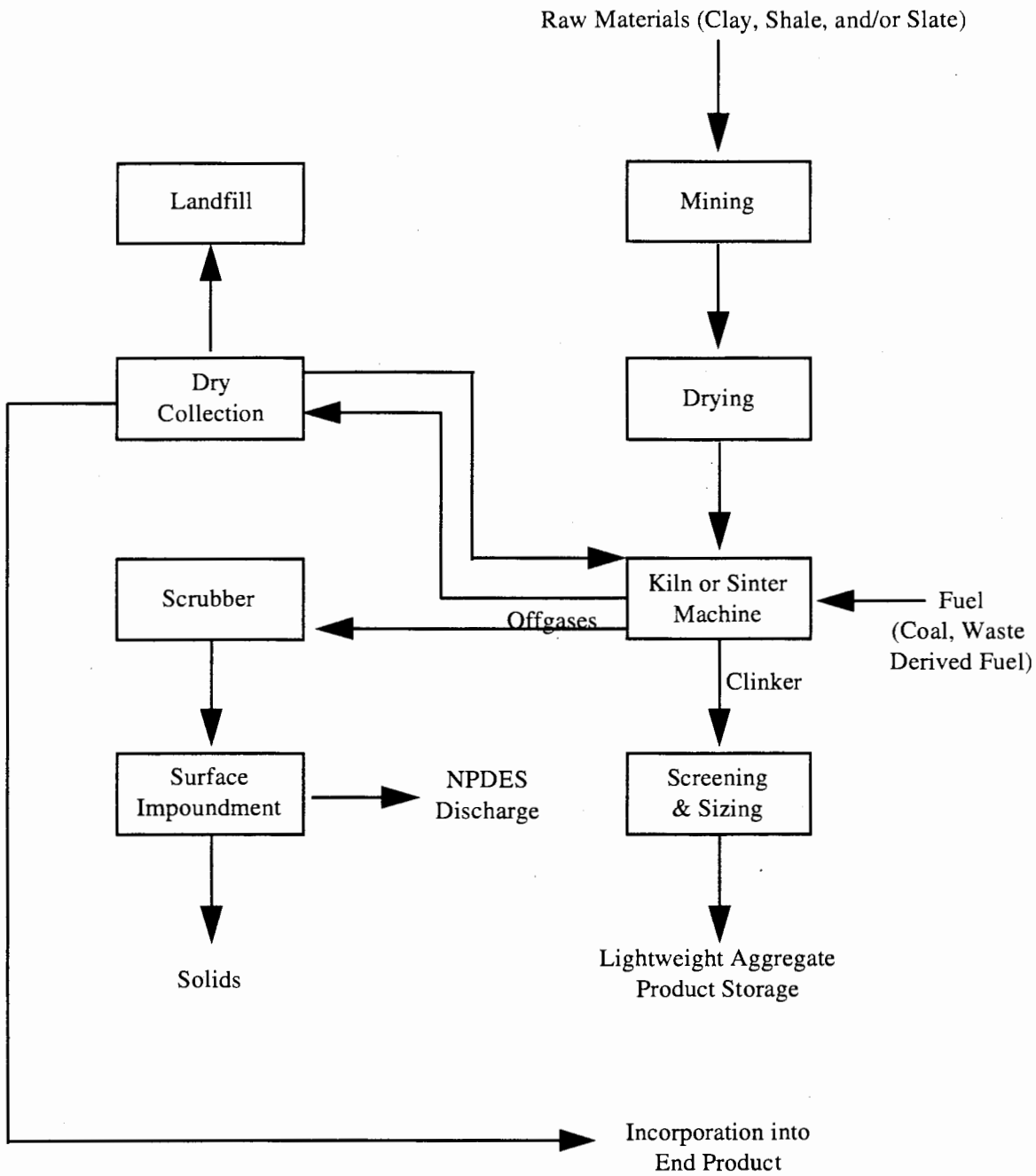
EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities.

EXHIBIT 3

LIGHTWEIGHT AGGREGATE PROCESS FLOW DIAGRAM



EPA determined that for the production of lightweight aggregates from naturally ocurring raw materials, the beneficiation/processing line occurs after drying at the kiln/sinter machine because the elevated temperatures destroy the physical structure of the raw material. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

SECTION 2: By-product Production

1. Discussion of Typical Production Processes

Both expanded slag and air-cooled slag are lightweight aggregate products produced as by-products from iron and steel production. The process is described below.

2. Generalized Process Flow Diagram

Expanded slag and air-cooled slag are byproducts of iron and steel production. Expanded slag is manufactured by spraying a stream of water through molten blast furnace slag as it is drawn from the furnace. The resulting foamed slag is crushed and screened for use in concrete block or structural concrete. Air-cooled slag is manufactured by pouring molten blast furnace slag into pits where it is cooled by water. It is then excavated, crushed, and screened.[2] Iron and steel slags are considered special wastes, and were addressed in the 1990 Report to Congress on Special Wastes from Mineral Processing. Exhibits 4 and 5 present flow diagrams for expanded slag and air-cooled slag, respectively.

3. Identification of Novel (or otherwise distinct) Processes

None identified.

4. Extraction/Beneficiation Boundaries

Because lightweight aggregates are recovered as by-products of mineral processing activities in the iron and steel sector, all of the wastes generated during lightweight aggregate recovery also are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, see the sector report for iron and steel presented elsewhere in this document.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

The preparation of natural lightweight aggregate materials only generates extraction/beneficiation wastes because no thermal processes are involved. However, production of manufactured lightweight aggregates generates both extraction/beneficiation and mineral processing wastes. **Overburden, waste rock, raw fines from primary crushing operations**, and **sludge from rock washing operations** are generated from the mining and extraction of lightweight aggregate minerals. These materials likely are left in place at the original mining site.

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[2] Bruce Mason, 1994, Op. Cit., pp. 343-350.

EXHIBIT 4

EXPANDED SLAG PROCESS FLOW DIAGRAM

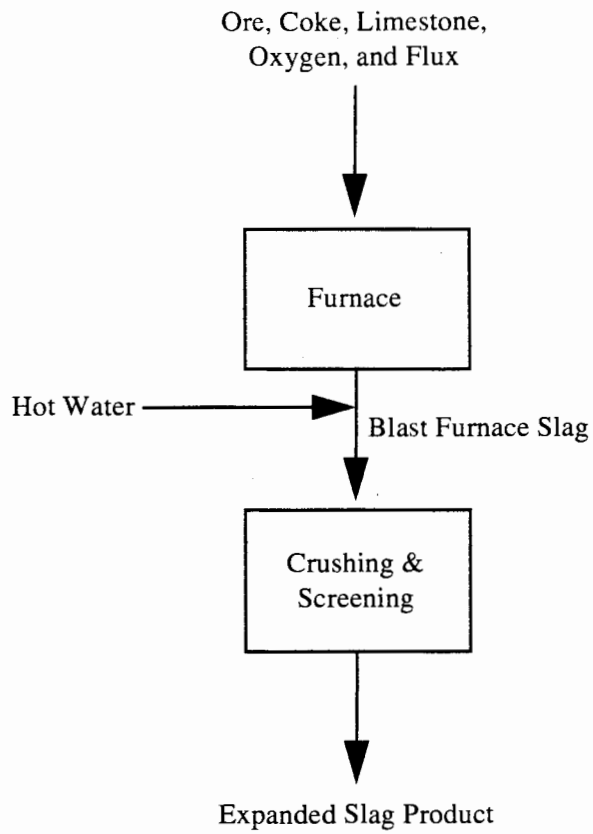
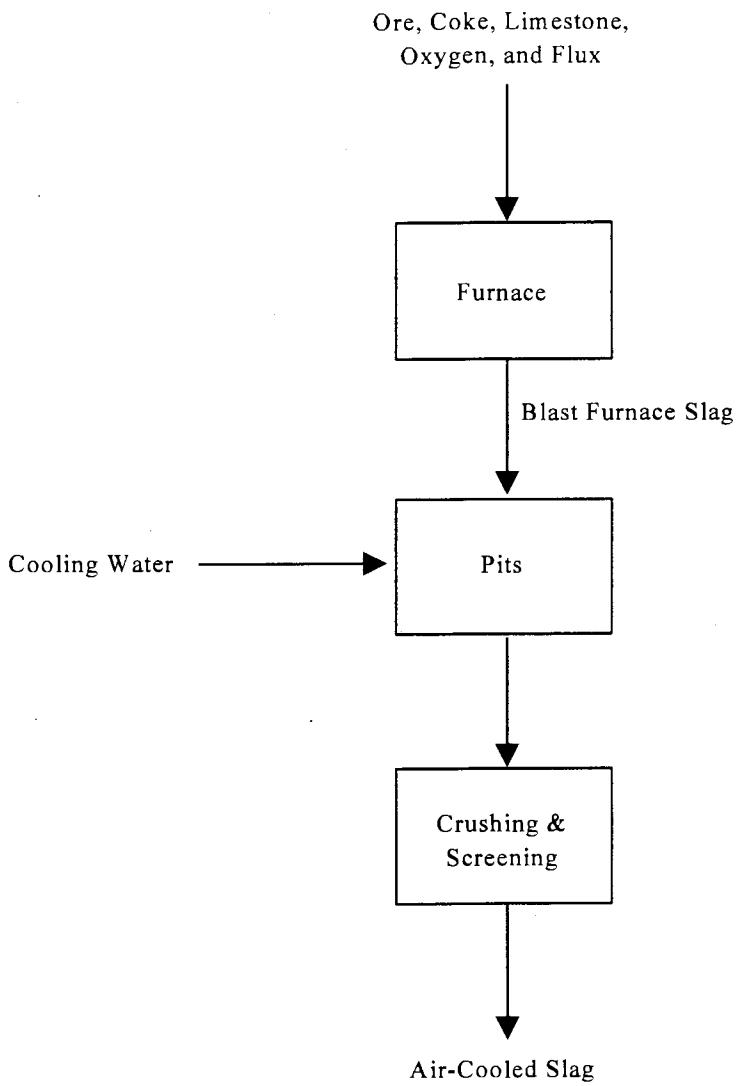


EXHIBIT 5

AIR-COOLED SLAG PROCESS FLOW DIAGRAM



2. Mineral Processing Wastes

Hazardous waste fuels may be burned for use as a heat source in the production of lightweight aggregates. Therefore, some of the waste streams discussed below would be considered hazardous through application of the derived-from rule. Likely waste-derived fuels are high in Btu values and oily substances. Waste generated from this process may contain metals, semivolatiles, and dioxins/furans. Six facilities burn listed hazardous waste as fuel in their kilns. These facilities are Carolina Solite, Florida Solite, Kentucky Solite, Norlite, and the two Solite facilities in Virginia.[3] However, the Solite facility in Cascade, VA generates no solid waste because all the APC dust that is generated is returned to the operation and the Florida Solite facility currently is inactive.[4]

Air pollution control scrubber water and solids. Most facilities now use dry collection systems and no longer generate this waste. However, two wet scrubbers continue to be operated as kiln air pollution control devices at Solites' North Carolina Plant.[5] Kilns equipped with wet scrubbers generate scrubber wastewater which contained particles from the kiln. In 1989, 18 of the active facilities used wet scrubbers for air pollution control. Lightweight aggregate production for these 18 facilities ranged from 23,123 to 907,185 mt/y, and the volume of scrubber solids generated ranged from 104 to 61,235 mt/y. Generally, the scrubber solids were managed in settling ponds, surface impoundments, or landfills where dewatering occurred and the particulate matter settled out in the form of sludge.[6] In 1989, this waste was generated at a rate of 2,420,000 mt/y.[7] Attachment 1 presents waste characterization data for this waste stream. Exhibit 6 presents facility specific management information as well as generation rates and waste characteristics for the facilities that do not burn hazardous waste fuels in their kilns.

Because of the derived-from rule, scrubber water and solids are considered a hazardous waste at facilities that use wet scrubbers and burn hazardous waste fuels in their kilns. Although this waste currently is generated at only one facility, Exhibit 7 presents waste generation rates for five facilities that, in the past, have generated hazardous scrubber water and solids.

Air pollution control dust/sludge. Lightweight aggregate facilities that use baghouses and other dry collection systems generate APC dust that is collected in dry form. Some facilities using dry collection systems recycle the dust to the process or use it in products (e.g., block mix). At Arkansas Lightweight Aggregate Corporation, particulate matter that is too fine to continue on in the kilning process is exhausted in the mechanical dust collector. After filtering, the waste dust drops into conical piles beneath the collector. Three piles collect beneath the collector, one consisting of heavier particles and two consisting of lighter particles. This waste is collected by a shovel loader and placed in a waste water impoundment onsite. The wet scrubber at the Arkansas facility operates for particulate removal only; no chemical treatment of water occurs.[8]

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[3] U.S. Environmental Protection Agency, Addendum to the Technical Background Document, Development of the Cost and Economic Impacts of Implementing the Bevill Mineral Processing Wastes Criteria, Office of Solid Waste, 1990.

[4] Solite Corporation. Op. Cit.

[5] Ibid.

[6] U.S. Environmental Protection Agency, 1990, Op. Cit., pp. 5-9, A10.

[7] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, 1992, Vol. I, pp. I-2 - I-8.

[8] U.S. Environmental Protection Agency, 1990, Op. Cit., pp. 5-9, A10.

EXHIBIT 6

APC SCRUBBERWATER AND SOLIDS AT FACILITIES NOT USING WASTE-DERIVED FUELS

Facility	RTI ID#	1988 Generation	pH	Management Practices
Buildex, Dearborn, MO	100685	Wastewater: 8,784,000 gallons	5.8	Sent to bedrock lined surface impoundment for settling
Chandler Materials, Tulsa, OK	101725	Wastewater: 17,900,000 gallons Solids: 177 cubic yards	5.5	Sent to bedrock lined surface impoundment for solids precipitation
Chandler, Choctaw, OK	101766	Wastewater: 14,100,000 gallons	5.6	Sent to in-situ clay lined surface impoundment for solids precipitation
Featherlite, Strawn, TX	101659	Wastewater: 4,535 mtons	NA	Sent to in-situ clay lined surface impoundment for solids precipitation
HP Brick, Brooklyn, IN	100263	Wastewater: 9,071 mtons	5.5	Sent to in-situ shale lined surface impoundment for dewatering
Texas Industries, Streetman, TX	101808	Wastewater: 250,000,000 gallons	9.94	Sent to in-situ clay lined surface impoundment for solids precipitation
Porta Costa, Porta Costa, CA	100792	Wastewater: 600 gallons	7.2	Sent to in-situ clay lined surface impoundment for water evaporation and solids recycling
Parkwood, Bessemer, AL	100180	Wastewater: 8,981 mtons	NA	Sent to bedrock lined surface impoundment for solids precipitation and pH adjustment with caustic soda
Jackson Ready Mix Concrete, Jackson, MS	100438	Wastewater: 104 mtons	NA	Sent to recompacted local clay lined surface impoundment for solids precipitation
Big River, Livingston, AL	NA	NA	NA	NA
Big River, Erwinville, LA	NA	NA	NA	NA
Arkansas Lightweight Aggregate, West Memphis, AR	NA	NA	NA	NA
NE Solite, Mt. Marion, NY	NA	NA	NA	NA

SOURCE: 1988 RTI Surveys.

EXHIBIT 7

1988 APC SCRUBBERWATER AND SOLIDS AT FACILITIES USING WASTE-DERIVED FUELS

Facility	Location	APC Scrubberwater and Solids (mt/y)	Percent Solids	APC Dust/Sludge (mt/y)
Carolina Solite	Norwood, NC	61,235	6.63	4,060
Florida Solite	Green Cove, FL	31,248	6.53	2,040
Kentucky Solite	Brooks, KY	43,293	19.28	8,347
Norlite	Cohoes, NY	NA	NA	NA
Solite	Arvonia, VA	NA	NA	NA

Source: Results of EPA's Final Analysis (Exhibit 4), Lightweight Aggregate Production and Air Pollution Control Wastes. Technical Background Document Supporting the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. EPA, Office of Solid Wasts. December 1995.

At Solite's facilities that burn hazardous wastes, the lightweight aggregate APC dust/sludge (baghouse dust) is collected in baghouses and conveyed to the finish end of Solite's lightweight aggregate plants where it is added to crushed and sized clinker. In some cases, it is returned to the beginning of the manufacturing process and reinserted into the kiln in extruded form, but the more usual practice is to incorporate the baghouse dust directly into a product referred to as "block mix."

Block mix is comprised of lightweight aggregate ranging in size from 3/16 of an inch in diameter to very fine material. The very fine material typically comprises no more than 12 to 16 percent of the block mix, and the percentage of bag house dust in the very fine material varies. Usually, about 75 percent of Solite's total lightweight aggregate output consists of block mix. However, this percentage can vary from plant to plant and in response to customer demand. The fine material is a necessary component of block mix, and if it is not introduced in the form of baghouse dust it must be produced by crushing the kiln clinker.

The finished block mix product is usually stored in an on-site pile prior to sale. It is kept damp during storage and transportation to control fugitive dust emissions and because substantial moisture is needed to mix the block mix with cement and other ingredients to make concrete. Block mix is transported by truck or rail car to concrete block manufacturing plants where it is used as a primary ingredient in the manufacture of lightweight concrete masonry units. The block mix confirms to ASTM Standard Number C 331 and individual customer specifications.

Although Solite is not currently selling LAKD as a separate product, the company believes that LAKD could be marketed as a mineral filler for asphalt and/or an ingredient in some concrete products. It may be necessary to pursue this market if the demand for block mix is insufficient to absorb all of the baghouse dust.[9]

This waste would be considered a hazardous waste at facilities that burn hazardous waste fuels because of the derived-from rule. These facilities are identified in Exhibit 1. The Solite facility in Cascade, VA does not generate this waste because all APC dust is returned to the process at this facility. Exhibit 7 presents waste generation rates for the remaining five facilities.

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[9] Solite Corporation. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

Wastewater treatment plant (WWTP) liquid effluent. Attachment 1 presents waste characterization data for this waste stream. In 1991, the waste generation rate for this waste stream was 1,094,000 metric tons per year.[10] At the Carolina Solite facility in Norwood, NC, WWTP liquid effluent is discharged under an NPDES permit.[11] This waste is not expected to be hazardous.

Surface impoundment waste liquids. Attachment 1 presents characterization data for this waste stream. The generation rate for this waste stream is 2,571,00 metric tons per year[12] (adjusted from a reported value to reflect recent changes in the sector). This waste is discharged under an NPDES permit at the Carolina Solite in Norwood, NC and the Norlite Corporation in Cohoes, NY.[13] This waste is not expected to be hazardous.

Byproduct Production

Waste streams from byproduct production of lightweight aggregate products from iron and steel production include **cooling water** and **slag**. These wastes are not expected to be hazardous.

D. Non-uniquely Associated Wastes

Non-uniquely associated wastes and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous) and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

One commenter addressed the lightweight aggregates sector report and provided new information about its facilities that burn hazardous waste. This information has been included in the sector report, as appropriate.

Sector-specific Issues

None.

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[10] U.S. Environmental Protection Agency, 1990, Op. Cit., pp. 5-9, A10.

[11] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, 1992, Vol. II, pp. 22-1 - 22-19.

[12] U.S. Environmental Protection Agency, 1990, Op. Cit., pp. 5-9, A10.

[13] U.S. Environmental Protection Agency, 1992, Op. Cit., Vol. II, pp. 22-1 - 22-19.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - APC SCRUBBER WATER AND SOLIDS - LIGHTWEIGHT AGGREGATE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	11.50	171	330	2/2	18.90	18.90	18.90	1/1	-	-
Antimony	0.030	0.14	0.25	0/3	0.050	0.050	0.050	0/1	-	-
Arsenic	0.0040	0.28	0.81	2/3	0.050	0.050	0.050	0/1	5.0	0
Barium	0.21	1.92	3.62	2/2	0.21	0.21	0.21	1/1	100.0	0
Beryllium	0.0050	0.016	0.025	1/3	0.0050	0.0050	0.0050	0/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.025	0.39	1.08	2/3	0.0050	0.0050	0.0050	0/1	1.0	0
Chromium	0.0025	0.44	1.08	1/3	0.050	0.050	0.050	0/1	5.0	0
Cobalt	0.25	0.31	0.36	1/2	0.050	0.050	0.050	0/1	-	-
Copper	0.025	0.21	0.34	1/3	0.050	0.050	0.050	0/1	-	-
Iron	1.16	145	289	2/2	2.07	2.07	2.07	1/1	-	-
Lead	0.013	0.13	0.35	3/3	0.025	0.025	0.025	0/1	5.0	0
Magnesium	90.60	212	334	2/2	21.60	21.60	21.60	1/1	-	-
Manganese	13.50	30.20	46.90	2/2	4.55	4.55	4.55	1/1	-	-
Mercury	0.0017	0.0018	0.0020	2/3	0.00010	0.00010	0.00010	0/1	0.2	0
Molybdenum	0.250	0.250	0.250	0/1	0.050	0.050	0.050	0/1	-	-
Nickel	0.050	0.30	0.53	3/3	0.050	0.050	0.050	0/1	-	-
Selenium	0.001	0.092	0.25	0/3	0.050	0.050	0.050	0/1	1.0	0
Silver	0.01	0.090	0.25	1/3	0.050	0.050	0.050	0/1	5.0	0
Thallium	0.074	0.52	1.25	1/3	0.25	0.25	0.25	0/1	-	-
Vanadium	0.050	0.31	0.56	2/2	0.050	0.050	0.050	0/1	-	-
Zinc	0.23	1.33	2.51	3/3	0.34	0.34	0.34	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	653	653	653	1/1	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	23.70	25.35	27.00	2/2	-	-	-	0/0	-	-
TSS	1,650	4,525	7,400	2/2	-	-	-	0/0	-	-
pH *	5.50	5.50	5.50	1/1					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - AIR POLLUTION CONTROL DUST/SLUDGE - LIGHTWEIGHT AGGREGATE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	16,900	20,050	23,200	2/2	-	-	-	0/0	-	-
Antimony	0.70	0.75	0.79	1/2	-	-	-	0/0	-	-
Arsenic	17.00	26.50	36.00	2/2	0.00050	0.038	0.25	8/13	5.0	0
Barium	193	470	746	2/2	0.10	1.12	8.10	7/13	100.0	0
Beryllium	0.81	1.26	1.70	2/2	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	9.40	9.40	9.40	1/1	0.0025	0.18	0.78	9/13	1.0	0
Chromium	9.90	74.95	140	2/2	0.0050	0.071	0.12	3/13	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	29.70	84.85	140	2/2	-	-	-	0/0	-	-
Iron	28,200	34,050	39,900	2/2	-	-	-	0/0	-	-
Lead	8.91	274	539	2/2	0.05	0.46	2.55	7/13	5.0	0
Magnesium	10,900	11,550	12,200	2/2	-	-	-	0/0	-	-
Manganese	611	816	1,020	2/2	-	-	-	0/0	-	-
Mercury	0.40	0.67	0.93	2/2	0.00020	0.0012	0.0050	3/12	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	14.70	26.85	39.00	2/2	-	-	-	0/0	-	-
Selenium	0.49	2.85	5.20	2/2	0.00050	0.031	0.15	6/13	1.0	0
Silver	1.70	1.70	1.70	1/1	0.0050	0.029	0.25	1/13	5.0	0
Thallium	0.55	5.08	9.60	1/2	-	-	-	0/0	-	-
Vanadium	31.00	41.50	52.00	2/2	-	-	-	0/0	-	-
Zinc	9.90	240	470	2/2	-	-	-	0/0	-	-
Cyanide	0.105	0.15	0.19	0/2	0.50	0.50	0.50	0/2	-	-
Sulfide	-	-	-	0/0	0.50	4.75	9.00	1/2	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	710,000	767,667	830,000	3/3	550,000	673,440	756,400	5/5	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT LIQUID EFFLUENT - LIGHTWEIGHT AGGREGATE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	10.00	10.00	10.00	2/2	-	-	-	0/0	5.0	0
Barium	57.00	57.00	57.00	2/2	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	8.00	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	12.00	12.00	12.00	2/2	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	11.00	11.00	11.00	2/2	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.100	0.100	0.100	2/2	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	0.700	0.700	0.700	2/2	-	-	-	0/0	1.0	0
Silver	0.400	0.400	0.400	2/2	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT LIQUIDS - LIGHTWEIGHT AGGREGATE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	500	500	500	2/2	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	100	100	100	2/2	-	-	-	0/0	-	-
TSS	400	400	400	2/2	-	-	-	0/0	-	-
pH *	6	6.00	6.00	2/2					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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LITHIUM AND LITHIUM CARBONATE

A. Commodity Summary

Primarily, lithium is produced in the United States by two companies: Cyprus-Foote Mineral Company and FMC Corp. Cyprus-Foote produces lithium carbonate from its brine deposit in Silver Peak, Nevada and spodumene concentrate at its mine in Kings Mountain, North Carolina. Cyprus-Foote also produces lithium chemicals and metals at plants in Virginia and Tennessee. FMC purchased the Lithium Corporation of America assets and mines and processes spodumene ores at the Bessemer City site.[1] Exhibit 1 presents the names and locations of all the facilities involved in the production of lithium and lithium carbonate.

EXHIBIT 1

SUMMARY OF LITHIUM AND LITHIUM CARBONATE FACILITIES

Facility Name	Location
Cyprus-Foote	New Johnsonville, TN
Cyprus-Foote	Sunbright, VA
Cyprus-Foote	Kings Mountain, NC
FMC Corp	Bessemer City, NC

Lithium is found primarily in the mineral spodumene in pegmatites containing mineral assemblages which are derived from the crystallization of post magnetic fluids or from metasomatic action by residual pegmatitic fluids.[2]

Lithium compounds are used primarily in ceramics, glass, and primary aluminum production. Lithium is also used in the manufacture of lubricants and greases as well as in the production of synthetic rubbers.[3] Specifically, lithium hydroxide is used in the production of lubricating greases and lithium carbonate is used as an additive in aluminum refining. Lithium chloride and bromide are used in absorption refrigeration systems and dehumidification systems.[4] The consumption rate of lithium was estimated at 2,300 metric tons in 1994.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Lithium is obtained either from spodumene concentrates or from lithium-containing brines. It is chiefly produced as lithium carbonate or as hydroxide salts. Each of these processes is described in detail below.

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[1] Joyce A. Ober, "Lithium," from Minerals Yearbook Volume 1. Metals and Minerals, 1992, U.S. Bureau of Mines, p. 754.

[2] U.S. Environmental Protection Agency, "Lithium," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, Office of Solid Waste, 1988, pp. 2-11-2-15.

[3] Joyce A. Ober, "Lithium." from Mineral Commodity Summaries, 1995, pp. 98-99.

[4] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 2-11.

2. Generalized Process Flow Diagram

Spodumene Concentrates

Exhibit 2 presents the process flow diagram for recovery from spodumene concentrates. After mining, the spodumene is crushed and ground. Following this, the spodumene undergoes a flotation process (e.g., froth flotation) to yield a spodumene concentrate. This concentrate is then heated to 1,075°C to 1,100°C (changing the molecular structure of the mineral) to make it more reactive with sulfuric acid.[5] Following the roasting and cooling, the spodumene is treated with sulfuric acid and reroasted to yield lithium oxide. This calcine is then leached, neutralized with limestone, and filtered to remove gangue constituents. The resulting lithium-containing filtrate is treated with lime and soda ash to remove the soluble calcium and magnesium compounds. Following this, the remaining solution is concentrated by evaporation to yield a lithium sulfate solution. Insoluble portions of ore are removed by filtration and the purified solution is treated with soda ash to precipitate lithium carbonate. The carbonate is separated, washed and dried for sale.[6] The lithium can also be used as the feedstock in the production of other lithium compounds.[7]

Lithium-containing Brines

Exhibit 3 presents the process flow diagram for the recovery of lithium from brines. In Nevada, brines enriched in lithium chloride (300 ppm) are pumped from the ground into solar evaporation ponds, where in a year to 18 months, the concentration of the brines increases to 6,000 ppm.[8] During the evaporation, halite and sylvite crystallize and magnesium is precipitated as hydroxide by the addition of lime.[9] When the proper concentration has been reached, the liquid is pumped to a recovery plant and treated with soda ash to precipitate the lithium carbonate. The carbonate can then be removed through filtration and dried for shipment.[10]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

EPA determined that this mineral commodity sector does not generate any mineral processing wastes.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

From Spodumene Concentrates

Although generation rates are available for the wastes generated during the recovery of lithium carbonate from spodumene, characterization and management data are not available for all of the wastes.

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[5] Joyce A. Ober, 1992, Op. Cit., p. 753.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 2-11.

[10] Joyce A. Ober, 1992, Op. Cit., p. 754.

EXHIBIT 2

LITHIUM CARBONATE FROM SPODUMENE

(Adapted from: Technical Background Document, 1989.)

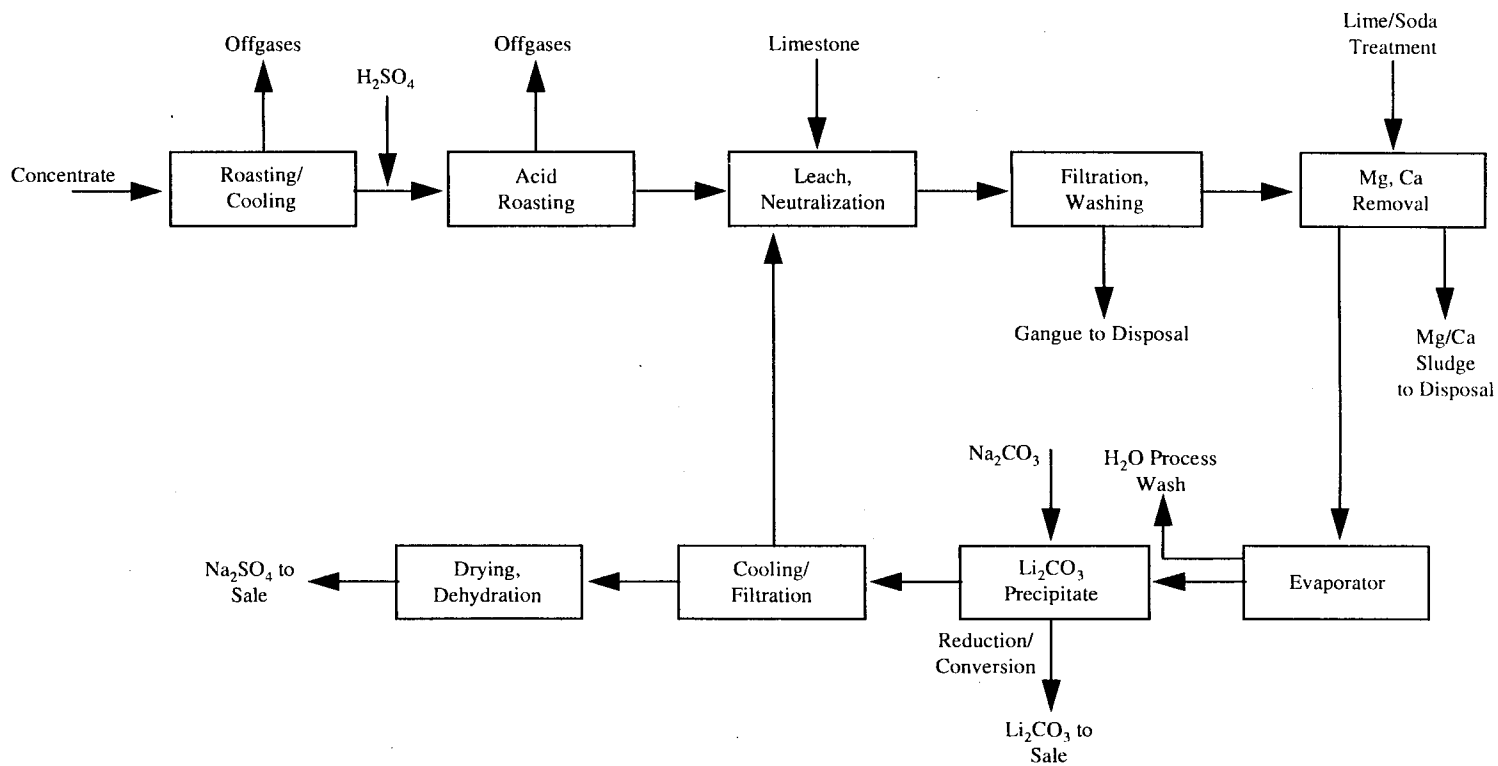
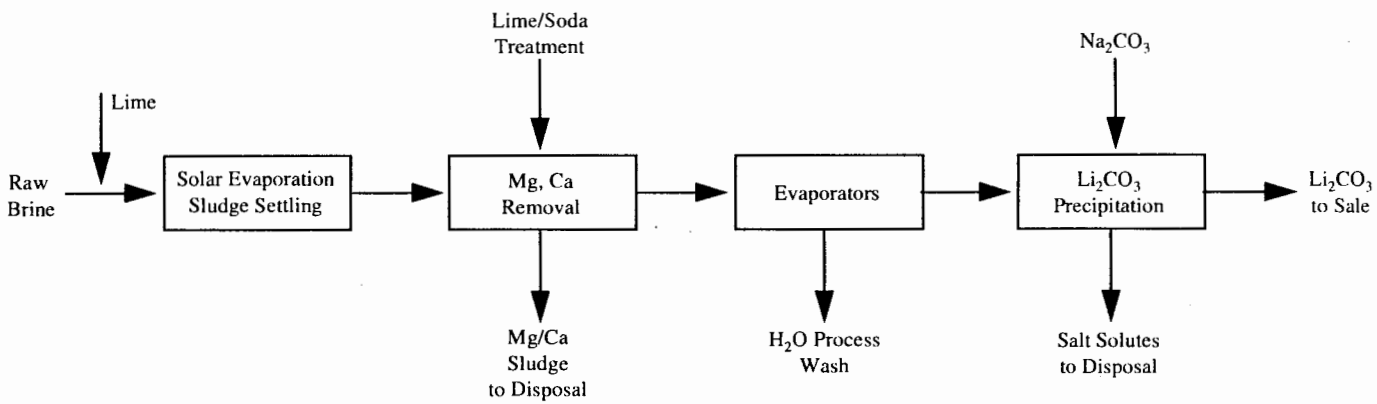


EXHIBIT 3

LITHIUM CARBONATE FROM BRINES

(Adapted from: Technical Background Document, 1989.)



Roaster Off-gases. Sources indicate the following generation rates: 600 ACF/lb, containing 0.01 lb dust/ lb. The generated dusts are concentrate fines.[11]

Acid roaster gases. Sources indicate the following generation rates: 60 ACF/lb, containing 0.001 lb dust/ lb. The off-gases contain trace amounts of sulfuric acid and sulfur dioxide.[12]

Gangue. Sources indicate the following generation rates for gangue: 35 lb/lb, aluminosilicate residues of concentrate gangue. The solids generated contain 25 lb/lb water with trace amounts of lithium and other salts.[13]

Magnesium/Calcium sludge. Sources indicate the following generation rates for Mg/Ca sludge: 0.1 lb/lb hydrous oxides/carbonates. The sludge contains trace amounts of lithium and other salts.[14]

Flotation Tailings. Solid residues are generated as a result of the froth flotation process. The solid residues may be directly recovered and landfilled on-site. Characterization data are not available for either the content or the generation rate for this waste.

Wastewater from Wet Scrubber. Wastewater generated as a result of wet scrubbing emissions may be used for process make-up water. Wastewater from the wet scrubbing acid roaster emissions can be used for process water after it has been neutralized. Alternatively, some plants may recycle the wastewater.[15]

From Brines

Magnesium/Calcium sludge. Sludge generated during recovery from brines, containing trace amounts of lithium and other salts in addition to magnesium and calcium, is sent to disposal. Some magnesium hydroxide sludge may be stored on-site.[16] Generation rates are not available.

Salt Solutions. Spent brines containing sodium and potassium chlorides and trace amounts of other brines are generated. These wastes may be sent to on-site evaporation ponds or reprocessed to recover potassium chloride.[17]

2. Mineral Processing Wastes

None Identified.

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[11] U.S. Environmental Protection Agency, "Lithium: Mineral Processing Waste Generation Profile," Technical Background Document: Development of the Cost, Economic, and Small Business Impacts Arising from Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, 1989.

[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] Versar, Inc., "Lithium Derivatives," Multi-media Assessment of the Inorganics Chemical Industry, 1980, p. 25-7.

[16] Versar, Inc., 1980, Op. Cit., p. 25-8.

[17] Ibid.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Commented Received by EPA

EPA received no comments that address this specific sector.

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MAGNESIUM AND MAGNESIA FROM BRINES

A. Commodity Summary

There are ten magnesium compound producers in the United States. Each of the facilities obtains its raw source material from either magnetite, lake brines, well brines, or seawater. In addition, there are three facilities that produce magnesium metal. Magnesia, the primary magnesium compound, is produced at three facilities. Exhibits 1 through 3 present the names and locations of facilities involved in the production of magnesium, magnesium metal, and magnesia from brines, respectively.

Magnetite and dolomite, which have a theoretical magnesium content of 47.6% and 22%, respectively, comprise the largest mineral sources of magnesium and magnesium compounds. Other sources of magnesium and its compounds include seawater, brines, and bitterns.[1]

Magnesium and its alloys are used in the manufacture of structural components for automobiles, trucks, aircraft, computers, and power tools. Because of its light weight and ease of machinability, magnesium is used by the iron and steel industry for external hot-metal desulfurization and in the production of nodular iron. Producers of several nonferrous metals often use magnesium as a reducing agent. Magnesium anodes are used for cathodic protection of underground pipe and water tanks. Small quantities of magnesium are used as a catalyst in the synthesis of organic compounds, as photoengraving plates, and in alloys (other than aluminum). Caustic magnesia can be used as a cement if combined with magnesium chloride.

Refractory magnesia represents the largest use of magnesium in compounds. It is used principally for linings in furnaces and auxiliary equipment used to produce iron and steel. Caustic-calcined magnesia (partially calcined magnesite) is used in the agricultural, chemical, construction, and manufacturing industries.[2]

The most commonly used source for magnesia is magnesium carbonate, with the largest source being magnesia-rich brines and seawater. Magnesite is one of the minerals directly and widely exploited for its magnesia content. When pure, it contains 47.8% magnesia and 52.2% carbon dioxide. Sintered magnesia is used for refractory manufacturing while lighter fired caustic magnesia is used in fluxes, fillers, insulation, cements, decolorants, fertilizers, chemicals, in the treatment of wastewater including pH control, and in the removal of sulfur compounds from gas exhaust stacks. In addition to naturally occurring magnesia, refractory grade magnesia can also be produced synthetically. This involves the calcination of either magnesium hydroxide or magnesium chloride.[3]

B. Generalized Process Description

1. Discussion of Typical Production Processes

The two main operation types for recovery of magnesium are (1) electrolytic production, and (2) thermal production. Each of these processes is described in more detail below.

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[1] Deborah A. Kramer, "Magnesite and Magnesia," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 163-173.

[2] Ibid.

[3] L.R. Duncan and W.H. McCracken, "Magnesite and Magnesia," from Industrial Minerals and Rocks, 6th ed., Society for Mining, Metallurgy, and Exploration, 1994, pp. 643-654.

EXHIBIT 1

SUMMARY OF MAGNESIUM PROCESSING FACILITIES

Facility Name	Location	Type of Operations
Barcroft Co.	Lewes, DE	MgO from seawater
Dow Chemical Co.	Freeport, TX	MgCl from seawater
Great Salt Lake	Ogden, UT	MgCl from lake brine
Marine Magnesium Co.	South San Francisco, CA	MgO from seawater
Martin Marietta Chemicals	Manistee, MI	MgCl from brine
Morton Chemical Co.	Manistee, MI	MgCl from brine
National Refractories & Minerals Corp.	Moss Landing, CA	MgO from seawater
Premier Services Inc.	Port St. Joe, FL	MgO from seawater
Premier Services Inc.	Gabbs, NV	Mine magnesium carbonate and calcine to MgO
Reilly Ind.	Wendover, UT	Brine Extraction

EXHIBIT 2

SUMMARY OF MAGNESIUM METAL PROCESSING FACILITIES

Facility	Location
Dow Chemical Co.	Freeport, TX
Magnesium Corp. of America	Rowley, UT
Northwest Alloys Inc.	Addy, WA

EXHIBIT 3

SUMMARY OF MAGNESIA (MGO) PROCESSING FACILITIES

Facility Name	Location	Type of Operations
Basic Incorporated	Gabbs, NV	Uncertain
Dow Chemical Co.	Freeport, TX	Brine Extraction
Magnesia Operations	San Francisco, CA	Uncertain

2. Generalized Process Flow Diagram

Electrolytic Production

Hydrous Magnesium Chloride Feed. The Dow Chemical Company is the only magnesium producer using hydrous magnesium chloride as feed for the electrolytic cells. A flow sheet of the Dow process is presented in Exhibit 4. In this process, magnesium is precipitated from seawater as magnesium hydroxide by addition of lime or caustic in large agitated flocculators. The magnesium hydroxide is then settled in Dorr thickeners. The overflow enters the plant wastewater system where it is neutralized and returned to the ocean. The thickened underflow is pumped to rotary filters where it is dewatered, washed, and reslurried with wash water from the magnesium chloride purification step. It is then pumped to the neutralizers where it is treated with hydrochloric acid and enough sulfuric acid to precipitate excess calcium as calcium sulfate. The brine is filtered to remove calcium sulfate and other solids such as clays and silica and is further purified to reduce sulfate and boron and forwarded to the dryer. The purified brine is dried by direct contact with combustion gases in a fluid-bed dryer to produce granules of magnesium chloride. The granules are stored in large tanks from which they are fed to the electrolytic cells. The cells are fed semicontinuously and produce both magnesium and chlorine. The dilute, wet chlorine gas is drawn into refractory regenerative furnaces and converted to HCl which is recycled to neutralize magnesium hydroxide. The magnesium collects in compartments in the front of the cell from which it is periodically pumped into a computer-controlled crucible car operating at ground level. The crucible is conveyed to the casting house where it is emptied into a holding furnace or into alloying pots from which the metal is pumped into molds on continuous mold conveyors.[4]

Surface Brine Feed. A second process for magnesium production, shown in Exhibit 5, utilizes surface brine from the Great Salt Lake as feed to a series of solar evaporation ponds. This brine is further concentrated and treated with $CaCl_2$. Solids such as calcium sulfate and potassium and sodium chlorides are removed in a thickener. Further concentration provides feed for the spray dryer whose waste gases provide heat for the concentration process. The spray dryers convert the brine into a dry $MgCl_2$ powder containing about 4% magnesia, 4% water, and other salts which comprise the cell bath. The dryers are heated with exhaust gases from gas-fired turbines that generated some of the power used to operate the cells. The spray-dried $MgCl_2$ powder is melted in large reactors and further purified with chlorine and other reactants to remove magnesium oxide, water, bromine, residual sulfate, and heavy metals. The molten $MgCl_2$ is then fed to the electrolytic cells. Only a part of the chlorine produced is required for chlorination, leaving up to 1kg/kg magnesium produced available for sale as byproduct chlorine.[5]

Underground Brine Feed. A third process for magnesium recovery uses underground brines as its source of raw material. Brine is pumped from below the ground into a large system of plastic-lined solar evaporation ponds, where the magnesium chloride concentration is increased to 25% which reduces the solubility of sodium chloride to 1%. The brine is then moved by pipeline to the plant where it is further concentrated, purified, and spray dried. The spray-dried feed is further purified by chlorination. The magnesium chloride is electrolyzed in diaphragmless cells and the molten magnesium is removed by vacuum ladle. It is then transported to a refining furnace where it is cast into ingots. The chlorine is collected, cleaned, and liquefied.[6] Exhibit 5 presents a flow diagram of the process for recovering magnesium from underground brines and surface brines.

Thermal Reduction

In the thermal reduction process, magnesium oxide, as a component of calcined dolomite, reacts with a metal such as silicon to produce magnesium. The silicon is usually alloyed with iron. There are two principle methods: (1) carbothermic, and (2) silicothermic.

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[4] Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XIV, 1981, pp. 576-586, 631-635.

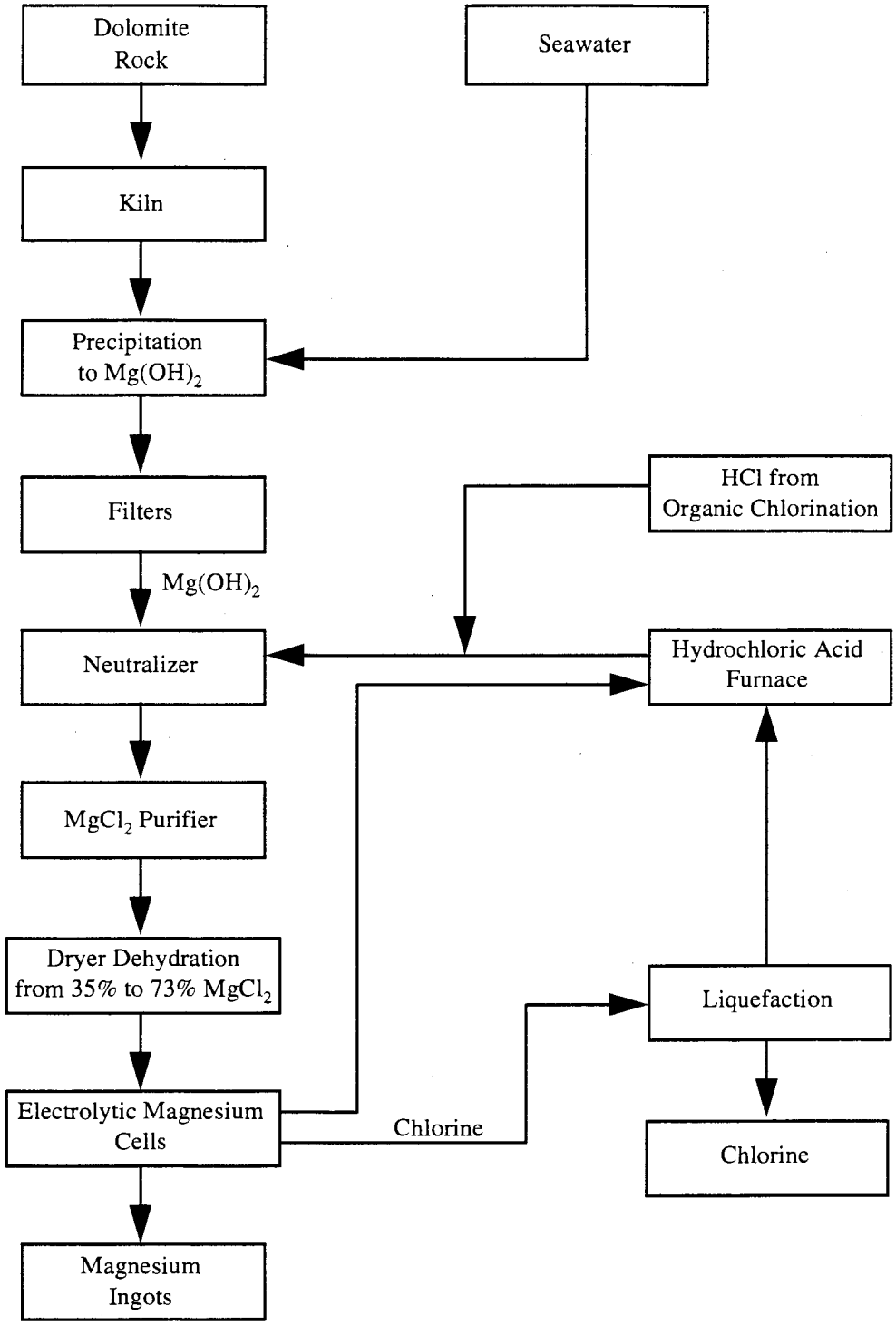
[5] Ibid.

[6] Ibid.

EXHIBIT 4

ELECTROLYTIC PRODUCTION USING HYDROUS MAGNESIUM CHLORIDE FEED

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 578.)

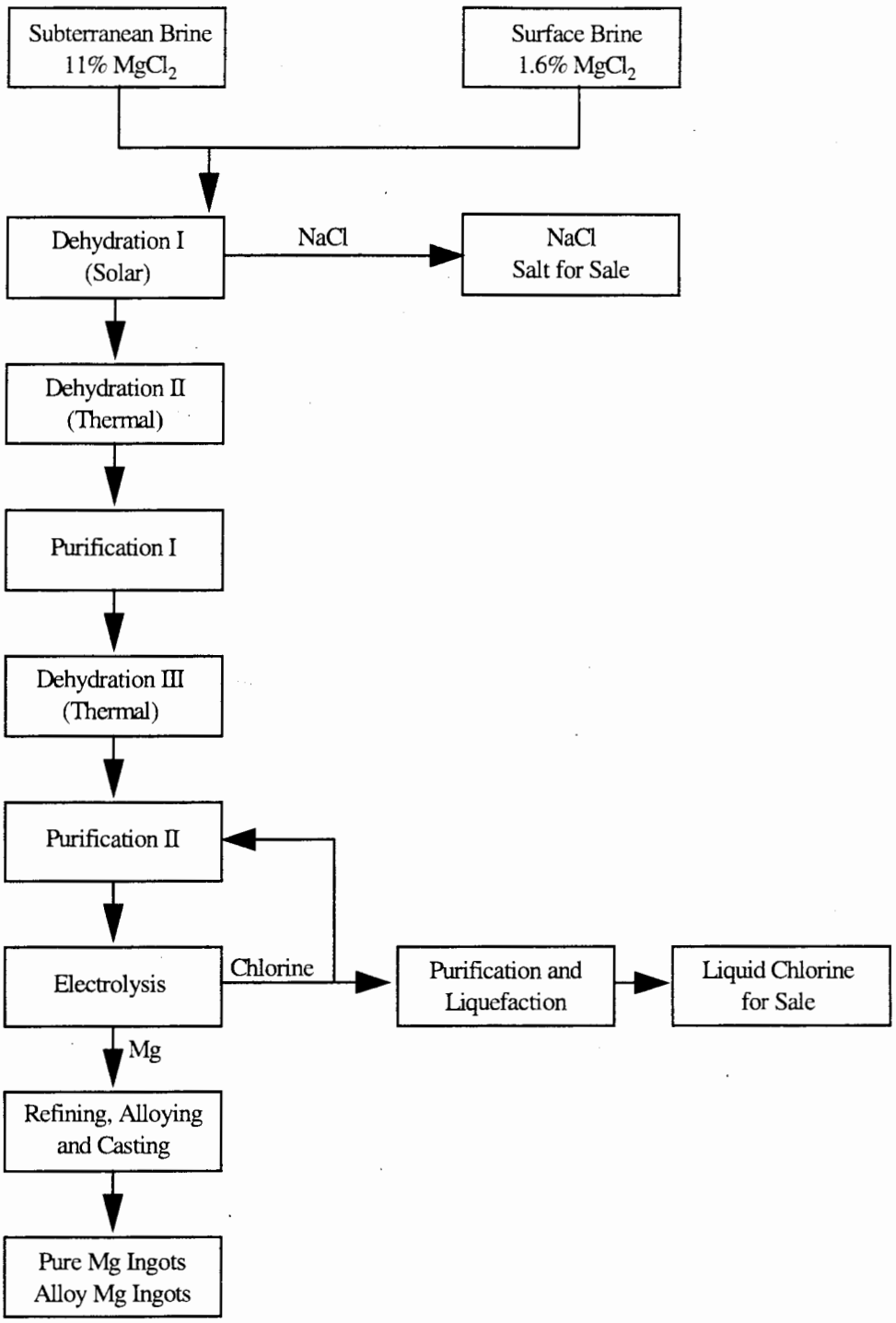


Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 578.

EXHIBIT 5

ELECTROLYTIC PRODUCTION USING SURFACE AND UNDERGROUND BRINES AS FEED

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 582.)



Source: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 582.

In the *carbothermic process*, magnesium oxide is reduced with carbon using modified shock cooling to produce magnesium and carbon monoxide. Both products are in the vapor phase. In order to recover the magnesium, the temperature must be dropped rapidly to prevent reversion. Shock cooling produces very finely divided magnesium dust which is pyrophoric.[7]

The *silicothermic process* is based on the reaction of silica with carbon to give silicon metal which is subsequently used to produce magnesium by reaction with calcined dolomite. The Pidgeon and Magnetherm processes employ this procedure.

The Pidgeon process is a batch process in which dolime and silicon are sized, briquetted, and charged into gas-fired or electrically heated retorts of nickel-chrome-steel alloy. The retort is equipped with removable baffles and a condensing section that extends from the furnace and is water-cooled. High purity crowns are remelted and cast into ingots.[8] Exhibit 6 presents a flow diagram of the Pidgeon process.

In the Magnetherm process, sufficient alumina is added to melt the dicalcium silicate slag that forms at around 1500° C. This permits the reactor to be heated by the electrical resistance of the slag and further allows the reaction products to be removed in the molten state. About 0.45 kg calcined bauxite or alumina, 2.7 kg dolime, and 0.45 kg ferrosilicon are required to produce 0.45 kg metallic magnesium. As the reactants are fed to the furnace, magnesium is evolved and passes through a large tuyere into the condensation chamber. Magnesium collects as a liquid and runs down into a collection pot where it solidifies. The slag is tapped twice a day by introducing argon into the furnace to break the vacuum. The slag outlet is electrically lanced and the molten calcium aluminum silicate is quenched in water to stabilize the slag (which can be used as cement). About 5.9 kg slag are produced per kg magnesium. The residual ferrosilicon containing 20% silicon is removed and can be used as low grade silicon alloy. The magnesium collection crucible is removed once a day and the magnesium is remelted, alloyed if required, and then cast into ingots.[9]

Magnesia from Brines

Magnesia, magnesium oxide, is usually produced by calcining the mineral magnesite or magnesium hydroxide obtained from seawater or brine by liming. It is also produced by the thermal decomposition of magnesium chloride, magnesium sulfate, magnesium sulfite, nesquehonite, and the basic carbonate.[10] A flow diagram of magnesia recovery from seawater is presented in Exhibit 7.

Magnesite ores contain varying amounts of silica, iron oxide, alumina, and lime as silicates, carbonates, and oxides. The deposits are mined selectively and the ores are often beneficiated to reduce lime and silica concentrations prior to calcining. Beneficiation methods include crushing and size separation, heavy-media separation, and froth flotation. Magnetic separation reduces iron concentration, but is effective only when the iron is present in the form of discrete ferromagnetic minerals rather than as ferrous carbonate.[11]

In chemical beneficiation processes, the magnesium is dissolved as a salt, the insoluble impurities are removed by filtration or sedimentation, and purified magnesia is recovered by thermally decomposing the clean salt solution. Special processes are needed to separate out calcium due to its similarity to magnesium. Three of these processes are discussed below.

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[7] Ibid.

[8] Ibid.

[9] Ibid.

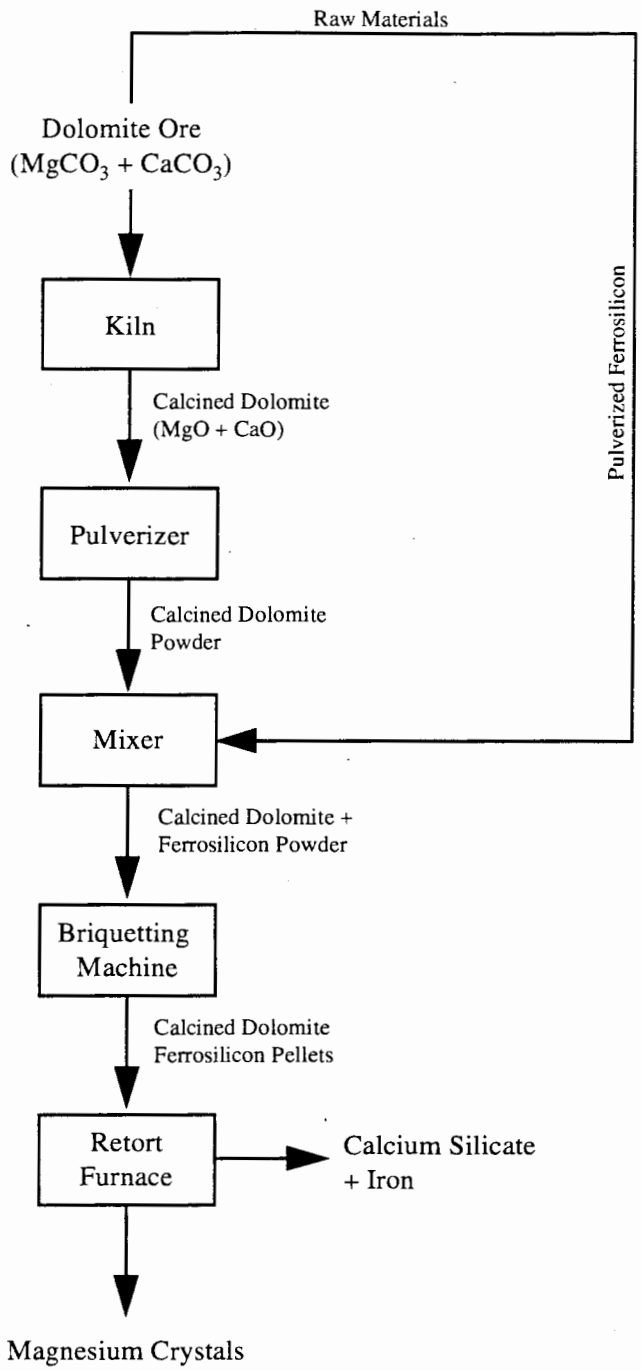
[10] Ibid.

[11] Ibid.

EXHIBIT 6

THE PIDGEON PROCESS

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 584.)

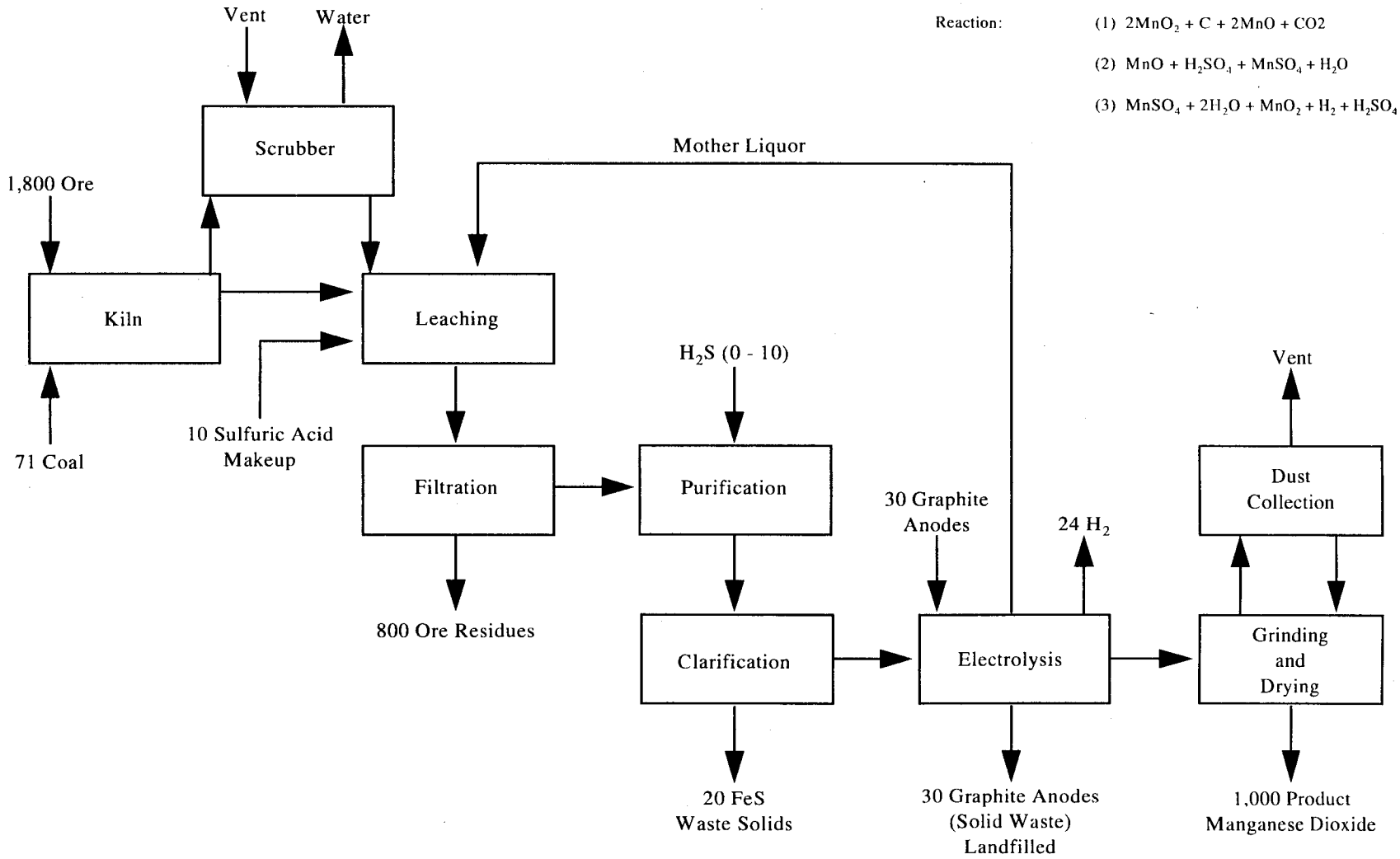


Source: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 584

EXHIBIT 7

PRODUCTION OF ELECTROLYTIC MANGANESE DIOXIDE

(Adapted from: Multi-Media Assessment of the Inorganic Chemicals Industry, 1980, pp. 6-14.)



Source: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 634.

The first process to separate out calcium is the Pattinson process. In this process, a suspension of magnesium hydroxide is carbonated to form a solution of magnesium bicarbonate. After the insoluble impurities are separated, the solution is decarbonated by heating or aeration and the magnesium carbonate precipitates as the trihydrate, the pentahydrate or the basic carbonate. The precipitate is recovered from the solution by filtration or sedimentation and converted to the oxide by thermal decomposition. The highly reactive grades of caustic-calcined magnesia are usually produced using a modified form of this process.[12]

In a second process for the separation of calcium impurities, magnesium is dissolved with the aid of sulfur dioxide or a mixture of sulfur dioxide and carbon. One variation of this method can be employed to remove SO_2 from flue gas. The flue gas is treated with a magnesium hydroxide slurry in a venturi scrubber to form $MgSO_3$ and some $MgSO_4$, which is subsequently calcined to recover the magnesium oxide and sulfur dioxide. The magnesium oxide is recycled and the sulfur dioxide may be used to manufacture sulfuric acid.[13]

In a third process, magnesia is dissolved in hydrochloric acid. After the insoluble impurities are removed, the magnesium chloride solution is thermally decomposed to recover the magnesia.[14]

There are several operations used to recover magnesium oxide from dolomite. Because calcite and magnesite decompose at different temperatures, a stepwise decomposition permits a selective calcination in which the magnesium carbonate is completely decomposed without decomposing the calcium carbonate. The magnesium oxide is then separated mechanically from the half-calcined dolomite by screening or air separation. Another scheme employs a modification of the Pattinson process in which the dolomite is calcined, slaked, and then carbonated in steps to precipitate calcium carbonate and magnesium carbonate trihydrate. This is further carbonated to dissolve the trihydrate as magnesium bicarbonate and the calcium carbonate is removed by filtration. The clean solution is finally decarbonated to precipitate magnesium carbonate trihydrate which is thermally decomposed to produce magnesia.[15]

Highly reactive grades of caustic-calcined magnesia are produced by calcining basic magnesium carbonate or magnesium carbonate trihydrate in small batches under carefully controlled conditions. They generally have magnesia contents above 99% and contain small quantities of carbon dioxide and moisture. The carbonates for these grades are prepared by a variation of the Pattinson process described above. The less reactive grades are obtained by calcining magnesium hydroxide or magnesite in multiple-hearth furnaces or rotary kilns.[16]

Dead-burned magnesia is used almost exclusively for refractory applications in the form of basic granular refractories and brick. It is produced in a number of grades.[17]

Fused magnesia is produced by melting calcined magnesia in an electric arc furnace. The furnaces have water-cooled shells and no refractory linings. The material serves as its own refractory because only a small pool of material in the center is actually melted. When magnesia is fused for the purpose of making grain, it is allowed to

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[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] Ibid.

[16] Ibid.

[17] Ibid.

cool in the furnace after the electrodes have been removed. After cooling, it is removed from the furnace, separated from the unfused material, and crushed.[18]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

Electrolytic Production of Magnesium

EPA determined that for the production of magnesium through this process, the beneficiation/processing line occurs when the dried $MgCl_2$ undergoes electrolytic refining at the electrolytic magnesium cells and chlorine is chemically removed to yield pure magnesium. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Production of Magnesium Through Thermal Reduction

EPA determined that in the production of magnesium through thermal reduction, the beneficiation/processing line is crossed when calcined dolomite ferrosilicon (CDF) pellets are introduced to the furnace for retorting when magnesium crystals are produced through the thermal destruction of the CDF pellets. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing

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[18] Ibid.

operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Magnesia from Brines

EPA determined that for the production of magnesia from brines, the beneficiation/processing line occurs between filtration or sedimentation and when trihydrates are converted to the oxide through thermal decomposition. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Ore Extraction and Beneficiation

Possible waste streams from ore extraction processes include **tailings** and **offgases** from calcining.

Brine Extraction and Beneficiation

Extraction waste streams from brines include **calcium sludge**, **spent seawater**, and **offgases**.

2. Mineral Processing Wastes

Electrolytic Production

Casting plant slag. This waste stream was generated at a rate of 3,000 metric tons per year in 1991.[19] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Smut (sludge and dross). This waste, generated at a rate of 26,000 metric tons per year, may be toxic for barium.[20] Management for this waste includes disposal in an unlined surface impoundment.[21] Waste characterization data are presented Attachment 1. This waste may be recycled and is classified as a byproduct.

Process wastewater is a possible waste stream from magnesium production. This waste was generated at a rate of 2,465,000 metric tons per year in 1991.[22] Process wastewater may contain calcium sulfate and boron and

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[19] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, Vol. I, August, 1992, pp. I-2 - I-8.

[20] Ibid.

[21] U.S. Environmental Protection Agency, Technical Background Document, Development of Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, August 1989, pp. 3-4--3-6.

[22] U.S. Environmental Protection Agency, Op. Cit., Vol. I, August, 1992, pp. I-2 - I-8.

have a low pH. This waste is may be discharged to a waste pond.[23] EPA determined in 1994 that the great majority of process wastewater is comprised of two special wastes -- scrubber underflow process wastewater and scrubber liquor process wastewater.[24]

Thermal Reduction

Cathode scrubber liquor. Dissociation of magnesium chloride molten salt from magnesium produces chlorine gas which is passed through a scrubber system. This produces a cathode scrubber liquor, which is discharged to surface impoundments with other wastewaters.[25] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

APC Dust/Sludge is a possible waste stream from magnesium production.[26] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Slag is a possible waste stream from magnesium production. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Casthouse dust. During the refining of magnesium metal, casthouse dust is produced. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 76 metric tons/yr, 760 metric tons/yr, and 7,600 metric tons, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for barium. This waste may be recycled and is classified as a sludge.

Magnesia from Brines

Possible waste streams from magnesia production from brines include **calciner offgases**, **calcium sludge**, and **spent brines** (which may be sold). Existing data and engineering judgement suggest that these materials do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[23] U.S. Environmental Protection Agency. Mineral Processing Waste Sampling Survey Trip Reports. AMAX Magnesium Company, Rowley, Utah. August 30, 1989.

[24] U.S. Environmental Protection Agency, Memorandum

[25] Ibid.

[26] U.S. Environmental Protection Agency, 1992, Op. Cit., pp. I-2 - I-8.

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U.S. Environmental Protection Agency. Newly Identified Mineral Processing Waste Characterization Data Set. Office of Solid Waste. Vol. I. August 1992. pp. I-2 - I-8.

U.S. Environmental Protection Agency. "Magnesium Production." From Report to Congress on Special Wastes from Mineral Processing. 1990. pp. 11-1 - 11-15.

ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SMUT (SLUDGE AND DROSS) - MAGNESIUM

Constituents	Total Constituent Analysis - PPM Minimum	Average	Maximum	# Detects	EP Toxicity Analysis - PPM Minimum	Average	Maximum	# Detects	TC Level	# Values In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	0.1	0.375	0.65	2/2	5.0	0
Barium	-	-	-	0/0	14.9	81.95	149	2/2	100.0	1
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	0.01	0.0185	0.027	2/2	1.0	0
Chromium	-	-	-	0/0	0.023	0.0385	0.054	2/2	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	0.025	1.2325	2.44	1/2	-	-
Iron	-	-	-	0/0	0.22	0.29	0.36	2/2	-	-
Lead	-	-	-	0/0	0.043	1.8415	3.64	2/2	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	0.03	0.1	0.17	1/2	-	-
Mercury	-	-	-	0/0	0.0008	0.0009	0.001	2/2	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	0.013	0.0145	0.016	2/2	1.0	0
Silver	-	-	-	0/0	0.05	0.095	0.14	2/2	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	0.02	0.355	0.69	1/2	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	4	4	4	0/2	-	-
Fluoride	-	-	-	0/0	0.2	1.3	2.4	2/2	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	25600	27150	28700	2/2	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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MANGANESE, MANGANESE DIOXIDE, FERROMANGANESE, AND SILICOMANGANESE

A. Commodity Summary

Approximately 95 percent of all manganese ore is consumed in the manufacture of steel, primarily as ferromanganese and silicomanganese, and other minor alloy-related industries. The other five percent is used by the non-alloying industries, including the chemical, paint, fertilizer, and battery industries, and in the production of manganese metal.[1] Manganese ore was consumed mainly by about 20 firms with plants principally in the Eastern and Midwestern United States. Metallic manganese is often too brittle and unworkable to be widely used.[2] However, leading identifiable end uses of manganese were construction, machinery, and transportation, which were estimated to be 14 percent, 9 percent, and 9 percent of total manganese demand, respectively. The other end uses include a variety of iron and steel applications.[3]

Manganese ore containing 35 percent or more manganese was not produced domestically in 1993.[4] The manganese industry in the United States relies almost entirely on foreign ores containing 35 to 55 percent manganese. The small amount of manganese ore produced in the United States is generally used as a pigment in the manufacture of brick.[5]

As of 1992, there were four companies that produced manganese, manganese oxide, ferromanganese or silicon manganese in six plants in the United States. Exhibit 1 presents the names, locations, products and types of processes used by the facilities involved in the production of manganese, manganese oxide, ferromanganese, and silicomanganese.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Almost all of the ore processed in the United States is imported as a concentrate. Nonetheless, typical operations used to produce concentrates include crushing, screening, washing, jigging, and tabling, as well as flotation, heavy-media, and high-intensity magnetic separation.[6] Ferromanganese is made by smelting ore (which contains both iron and manganese) with coke and limestone, and silicomanganese is produced by smelting the slag from standard ferromanganese with additional ore and coke. Manganese metal is frequently produced by preparing a solution of manganous sulfate from ore that has been reduction roasted, and electrolyzing this solution. Manganese dioxide is prepared either chemically or electrolytically. Each of these processes is described in greater detail below.

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[1] R.A. Holmes, "Manganese Minerals," from Industrial Minerals and Rocks, 6th ed., Society for Mining, Metallurgy, and Exploration, 1994, p. 657.

[2] T.S. Jones, "Manganese," from Minerals Yearbook. Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, p. 790.

[3] T. S. Jones, "Manganese," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 104.

[4] Ibid.

[5] R. A. Holmes, Op. Cit., p. 656.

[6] T. S. Jones, 1992, Op. Cit., p. 791.

EXHIBIT 1

SUMMARY OF MANGANESE, MANGANESE DIOXIDE, FERROMANGANESE, AND SILICOMANGANESE PRODUCERS[a]

Facility Name	Location	Products	Type of Process
Chemetals Inc.	Baltimore, MD	MnO_2	Chemical
Chemetals Inc.	New Johnsonville, TN	MnO_2	Electrolytic
Elkem Metals Co.	Marietta, OH	FeMn, SiMn, Mn	Electric Furnace and Electrolytic
Kerr McGee Chemical Corp.	Hamilton, MS	Mn	Electrolytic
Kerr McGee Chemical Corp.	Henderson, NV	MnO_2	Electrolytic
Everready Battery Co.	Marietta, OH	MnO_2	Electrolytic

[a] - Jones, T. S., "Manganese." Minerals Yearbook. Volume 1. Metals and Minerals. U.S. Bureau of Mines. 1992. p. 802.

2. Generalized Process Flow Diagram

Ferromanganese and Silicomanganese

In the United States, electrothermy is the predominant method of manufacturing manganese ferroalloys, using the submerged-arc furnace process. Standard or high-grade ferromanganese is the principal intermediate form into which manganese concentrates and other ore products are processed. Exhibit 2 shows a typical ferromanganese production process. Typically, a charge of ore, coke, and limestone is smelted in a submerged-arc furnace. In the manufacture of silicomanganese, an ore with a relatively high silica content, such as quartz or slag from standard ferromanganese is included in the charge introduced into the submerged-arc furnace. Smelting economics favor an integrated standard ferromanganese-silicomanganese electric-furnace operation, in which the high manganese slag from ferromanganese production is used as part of the charge to the silicomanganese furnace, along with ore and coke.[7] If silicomanganese is not co-produced, ore containing lower concentrations of manganese or higher concentrations of base oxides may be used, and the resulting slag is discarded.

Low carbon silicomanganese (or ferromanganese-silicon) is produced in a manner similar to standard silicomanganese, using standard silicomanganese, quartz, and coke or coal as the charge. Both standard ferromanganese and silicomanganese produce a slag and an off-gas containing CO_2. Low carbon silicomanganese manufacture is a slagless process, where the quartz is reduced to silicon and displaces the carbon in the remelted silicomanganese.[8] The gases are filtered through either wet scrubbers or baghouses. Ore fines are often sintered into bulkier particles before charging them to the furnace to lower the CO_2 concentration in the off-gas, and reduce energy consumption.[9]

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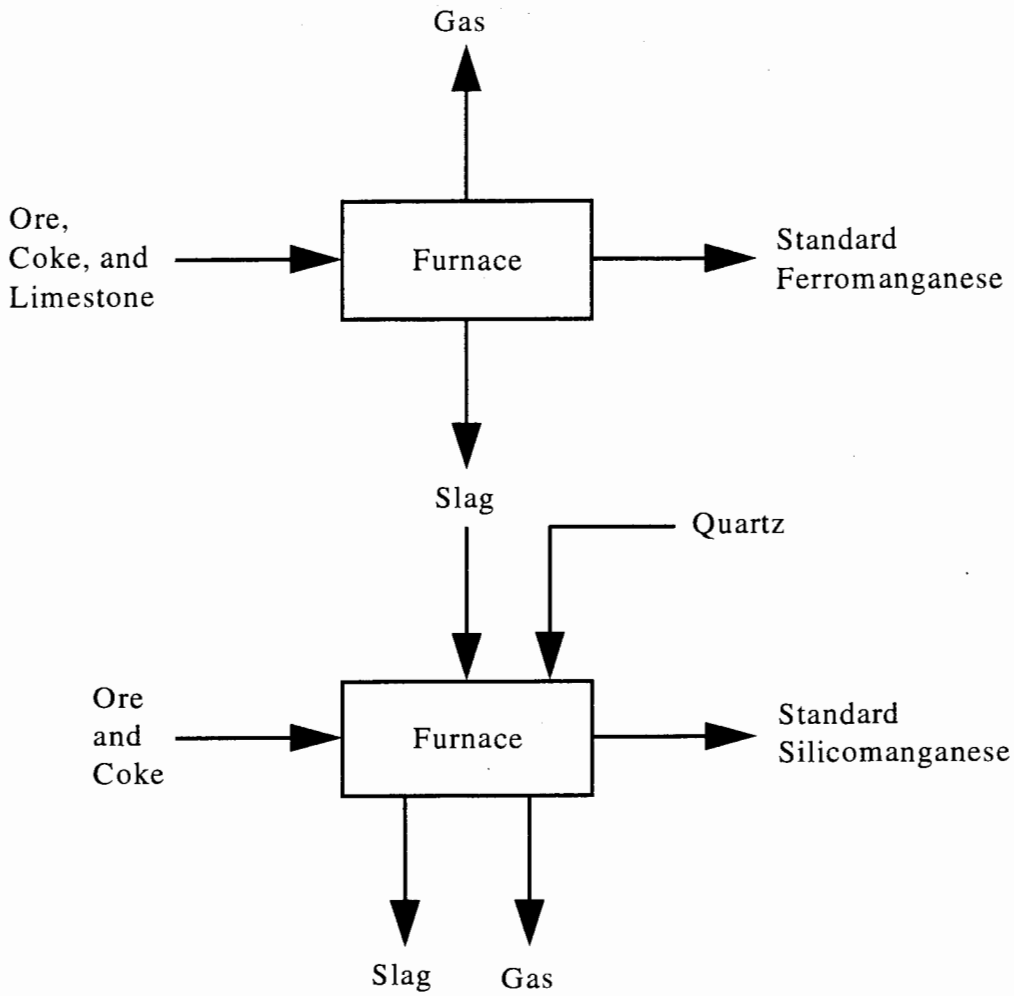
[7] T.S Jones, "Manganese," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, pp. 487-88.

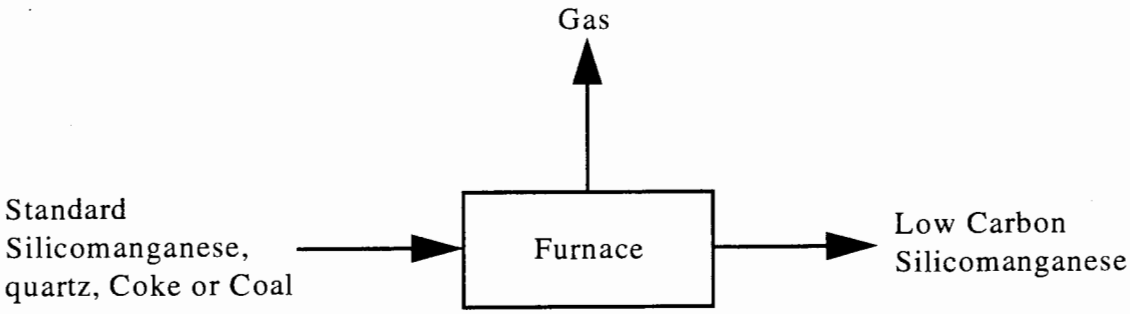
[8] "Manganese and Manganese Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd. ed., Volume XIV, 1981, p. 833.

[9] Ibid, p. 832.

EXHIBIT 2

FERROMANGANESE AND SILICOMANGANESE PRODUCTION





Medium and low carbon ferromanganese are called refined ferromanganese. Silicon in silicomanganese or low carbon silicomanganese reacts with manganese ore and lime to produce refined ferromanganese.[10] Exhibits 3 through 5 illustrate three variations of this process.

Manganese Metal

Manganese metal is frequently produced by preparing a solution of manganous sulfate from ore that has been reduction roasted, and electrolyzing this solution. Exhibit 6 depicts a typical production process of manganese metal from ore. Manganese ore is roasted to reduce the higher oxides to manganese (II) oxide. Slag from the production of high carbon ferromanganese may also supply manganese (II) oxide. The reduced ore or slag is leached with sulfuric acid to produce manganese (II) sulfate. Impurities, such as iron and aluminum, are precipitated and filtered. Other metal impurities are removed as sulfides, by introducing hydrogen sulfide gas. Either ferrous or ammonium sulfide and air are added to remove colloidal sulfur, colloidal metallic sulfides, and organic matter. The purified liquid is put into a diaphragm cell, and electrolyzed. The manganese metal deposits on the cathode in a thin layer, which is brittle and extremely pure.[11] Manganese metal can also be made electrolytically by fused-salt electrolysis (not shown.) Manganese ore that has been reduced to the manganese(II) level is charged to an electrolytic cell which contains molten calcium fluoride and lime. Fused electrolyte is periodically removed, as the volume of fused electrolyte increases.[12]

Manganese Dioxide

Manganese dioxide is prepared either chemically or electrolytically. Exhibit 7 illustrates the electrolytic production of manganese dioxide, which is similar to the electrolytic production of manganese metal. Manganese ore and coke are reacted in kilns at 600°C. The mixture is cooled and leached with a solution containing 50 grams per liter of manganese sulfate and 67 grams per liter of sulfuric acid at 90°C. After leaching, the solutions are filtered to remove the insoluble ore residues, which are discarded as a waste. The filtered solution are treated with hydrogen sulfide to precipitate iron salts and sulfides. These solids are removed by filtration and the purified solutions are fed to electrolytic cells. The cells used are generally lead lined with graphite cathodes and anodes. During electrolysis, manganese dioxide builds up a costing on the anodes as thick as 6 mm before it is removed. The manganese dioxide is periodically stripped from the electrodes, recovered from the cells, crushed, washed, first with dilute soda ash solutions and then with pure water, dried, pulverized and packaged. The hydrogen co-product from the electrolysis is flared, and the spent process liquor containing mostly sulfuric acid is recycled to the ore leaching step.

Manganese dioxide also may be prepared chemically, either by chemical reduction of permanganate (Type I) or by thermally decomposing manganese salts, such as $MnCO_3$ or $Mn(NO_3)_2$ under oxidizing conditions (Type II).[13] To produce Type I chemical manganese dioxide (not shown), the byproduct manganese dioxide from the oxidation of organics using potassium permanganate, is treated with hydrochloric or sulfuric acid, followed by $MnSO_4$. This treatment removes the excessive quantities of adherent and bound alkali. $KMnO_4$ is added to convert the ion exchanged divalent Mn into MnO_2. The product is washed and dried at low temperature, so as to avoid the undesirable loss of water of hydration.[14]

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[10] Ibid., pp. 834-837.

[11] Ibid., pp. 835-836.

[12] Ibid., p. 837.

[13] Ibid., p. 863.

[14] Ibid.

EXHIBIT 3

REFINED FERROMANGANESE PRODUCTION

MEDIUM-CARBON FERROMANGANESE RAW ORE PRACTICE

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 835 - 837.)

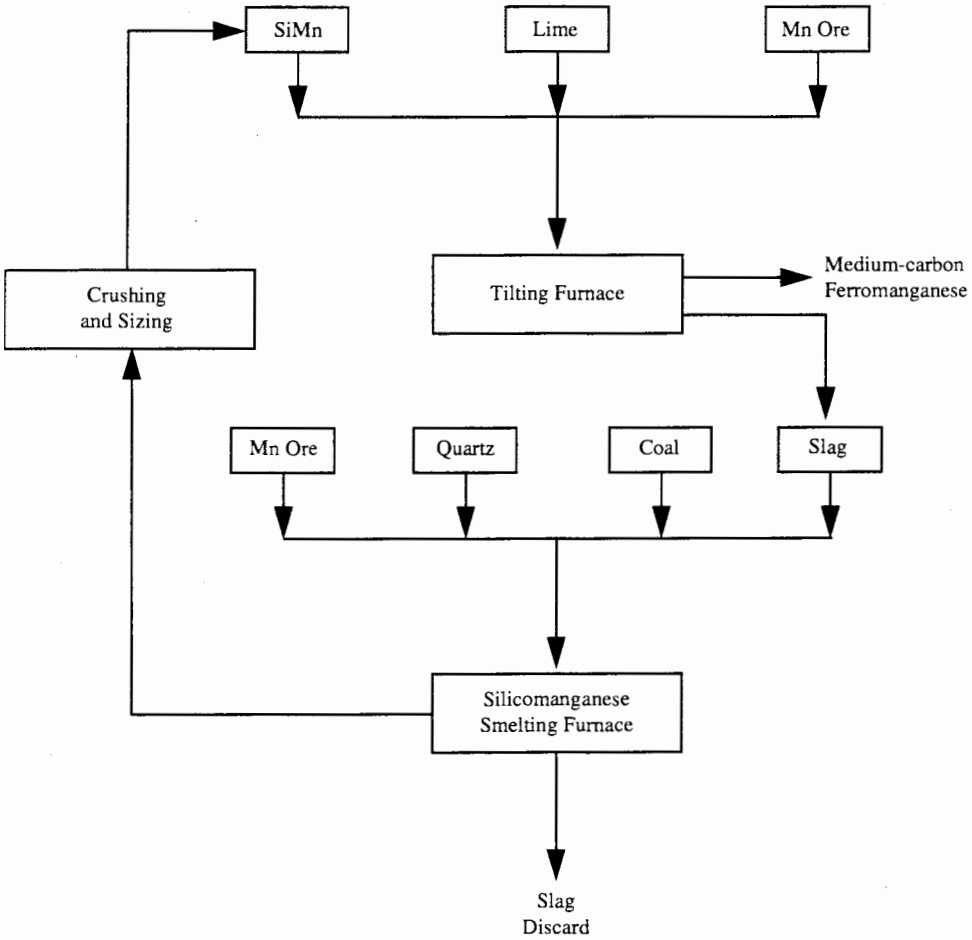


EXHIBIT 4

REFINED FERROMANGANESE PRODUCTION

MEDIUM-CARBON FERROMANGANESE FUSED ORE

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 835 - 837.)

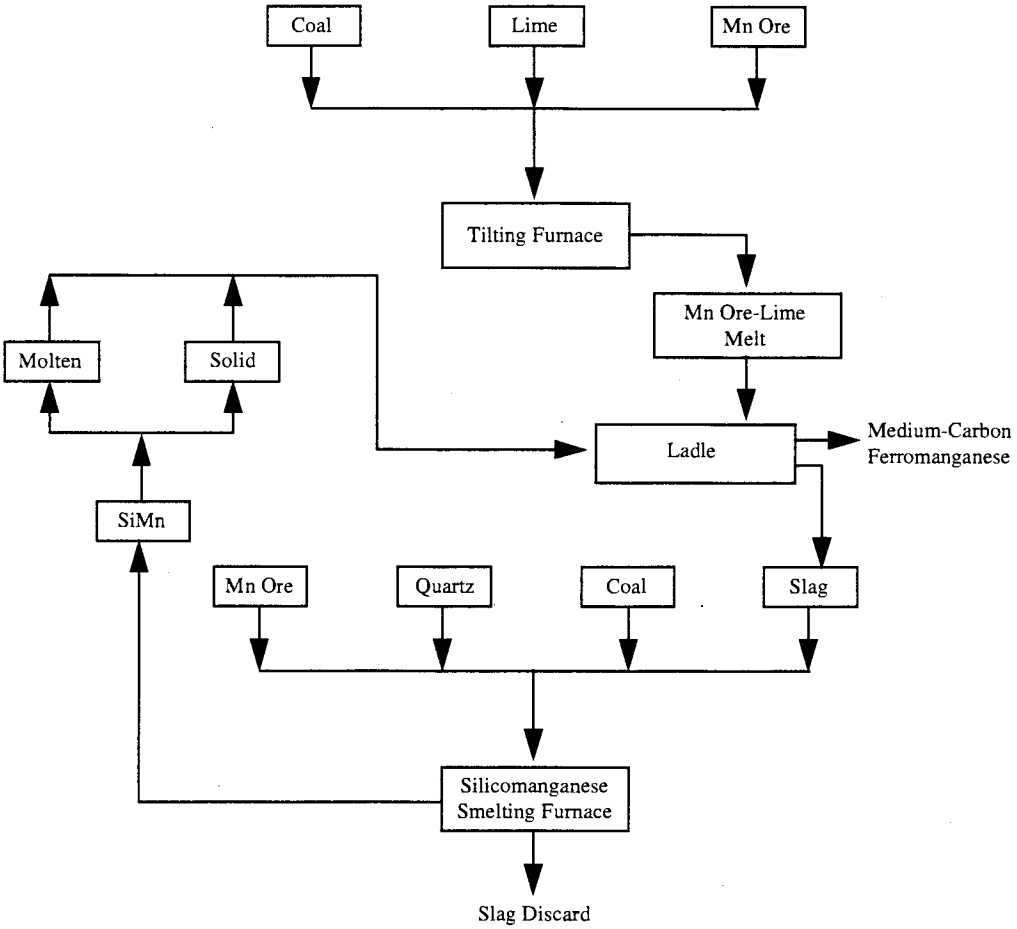


EXHIBIT 5

REFINED FERROMANGANESE PRODUCTION

MEDIUM-CARBON FERROMANGANESE FUSED ORE

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1981, pp. 835 - 837.)

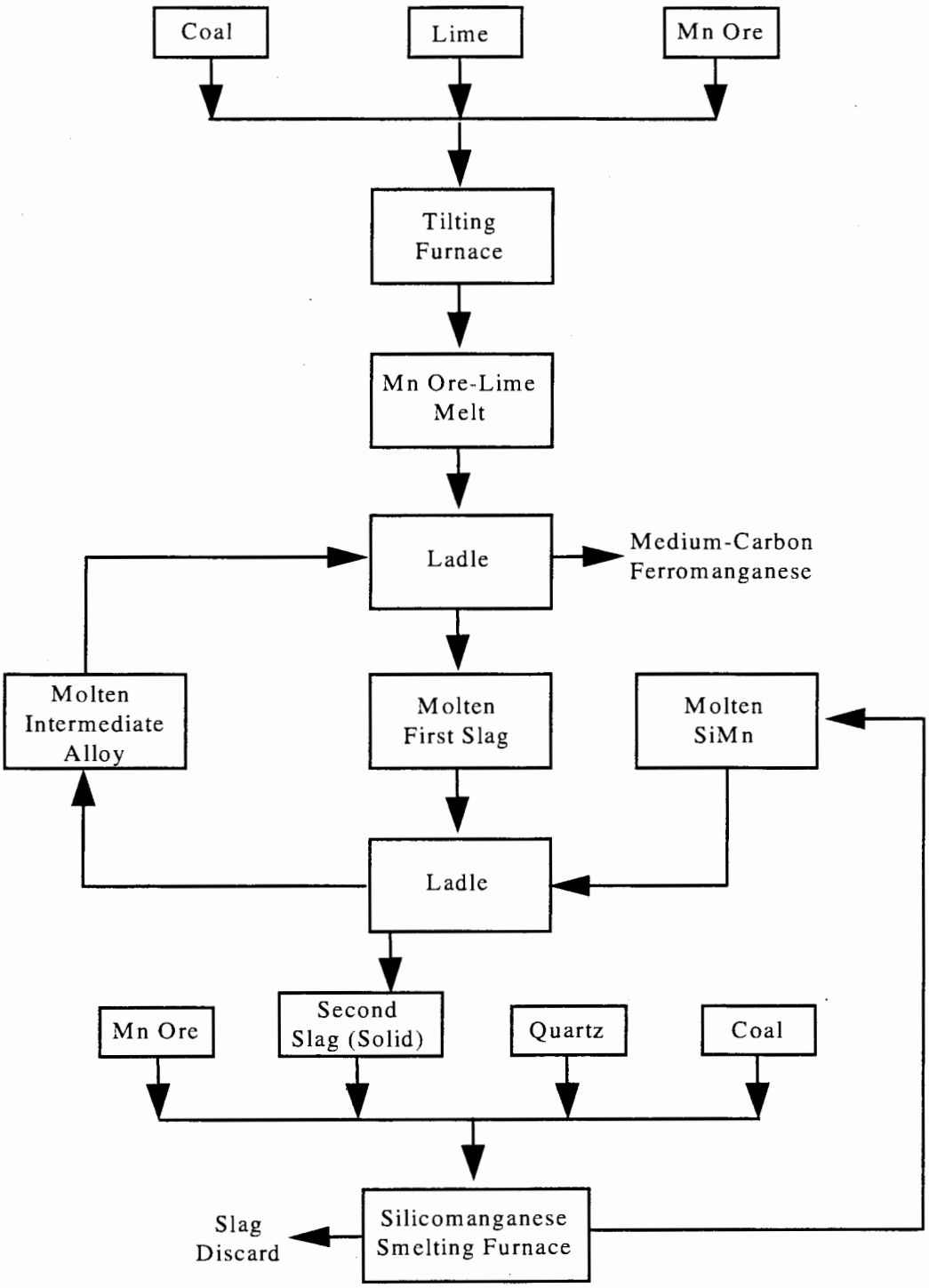


EXHIBIT 6

MANGANESE METAL PRODUCTION

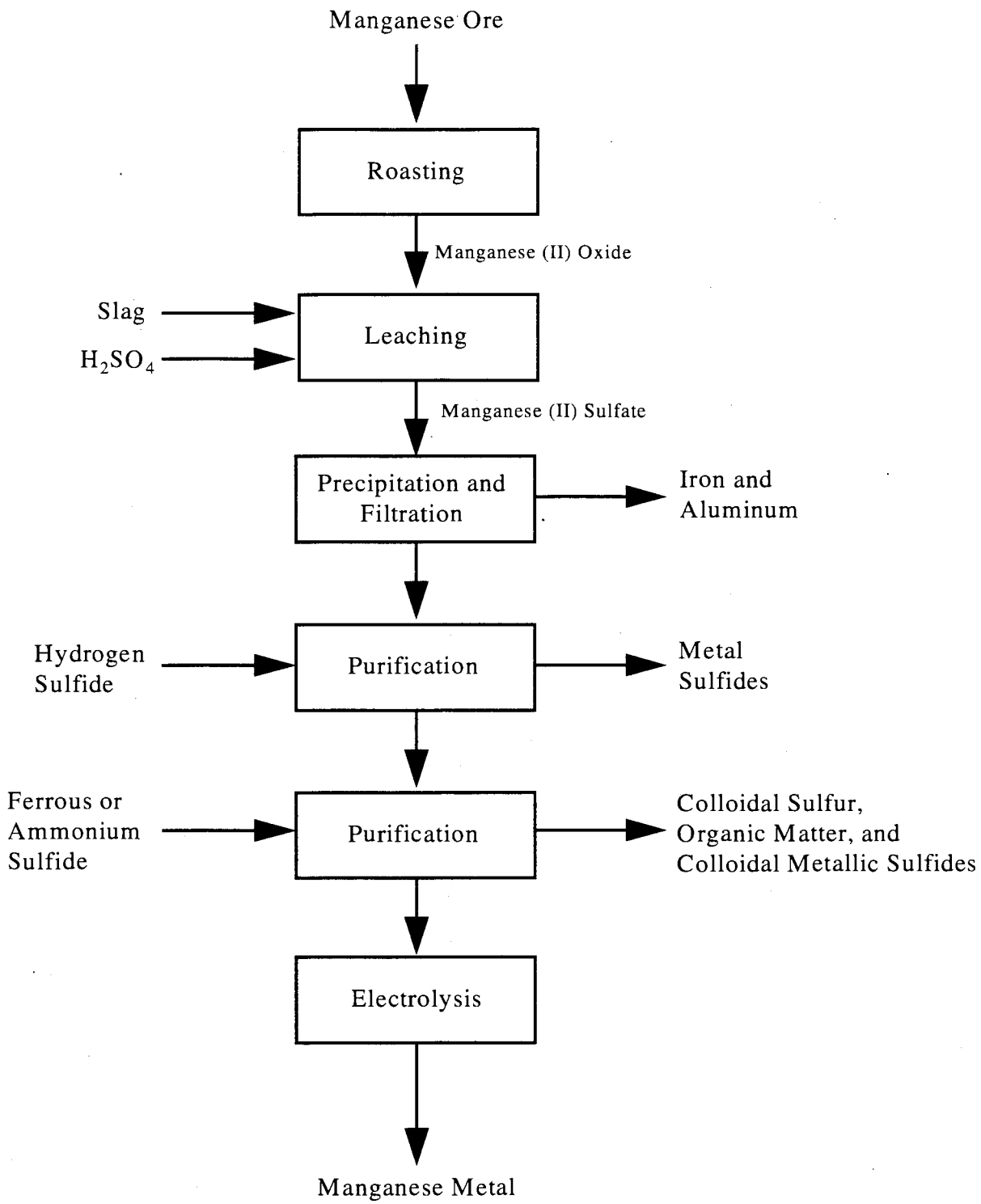
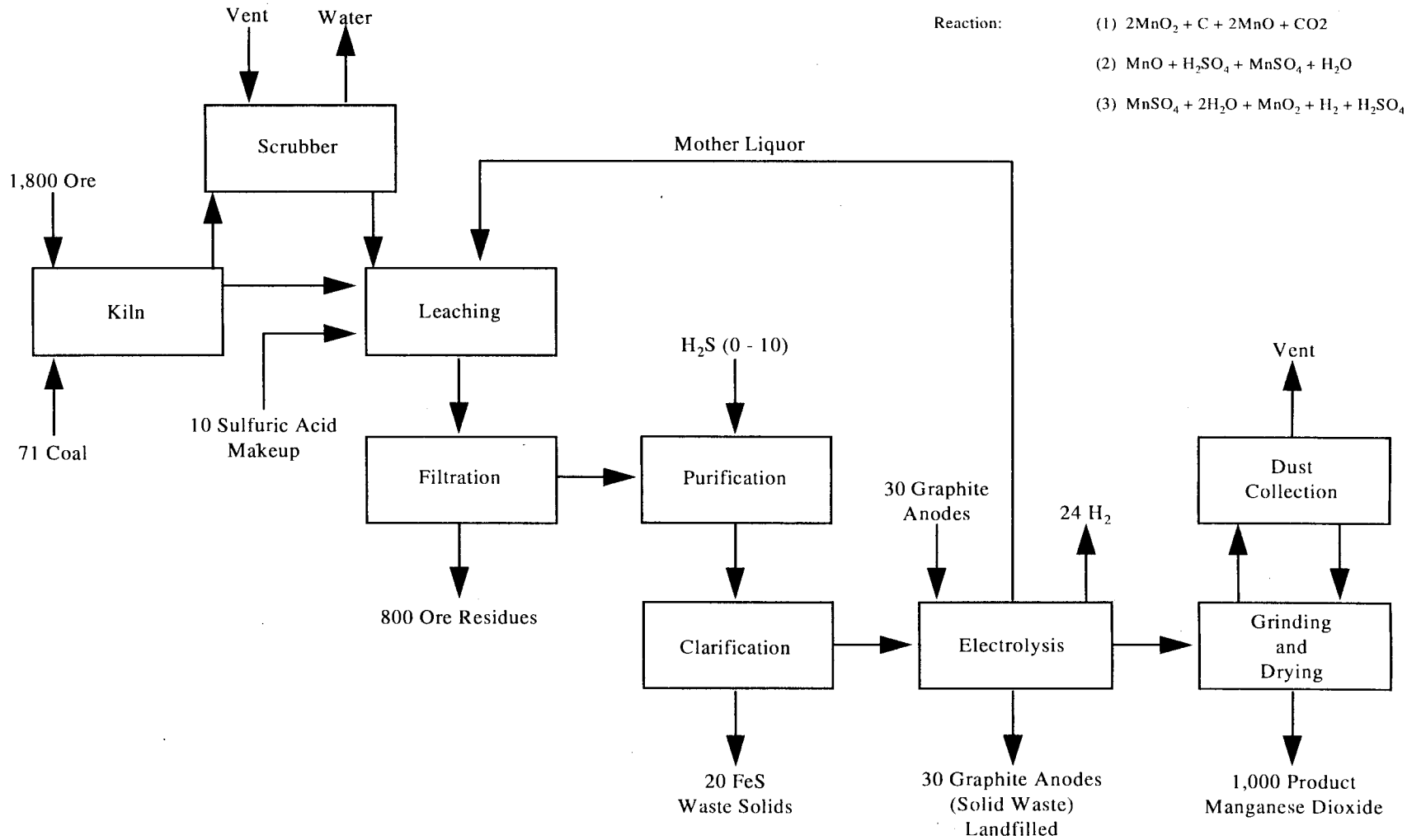


EXHIBIT 7

PRODUCTION OF ELECTROLYTIC MANGANESE DIOXIDE

(Adapted from: Multi-Media Assessment of the Inorganic Chemicals Industry, 1980, pp. 6-14.)



To make Type II chemical manganese dioxide, as shown in Exhibit 8, manganese ore is reacted with coke in kilns at 600°C, then cooled and leached with 10 percent nitric acid at 85°C to generate a neutral manganese nitrate solution. This solution is filtered to remove insoluble materials, treated with sulfides to precipitate iron impurities and refiltered. The ore residues and iron sulfides are discarded as waste. The purified manganese nitrate solution is evaporated to about half the original volume. Manganese nitrate crystals separate at this point and are recovered by centrifugation. The mother liquor is recycled to the evaporators and the recovered crystals are heated to 200°C to produce manganese dioxide and nitrogen dioxide, which is absorbed as nitric acid for reuse. The manganese dioxide is recovered and packaged.

Type II chemical manganese dioxide can also be made from finely ground manganese dioxide ore that has been reduced with H_2—CO to manganese (II) oxide (not shown). This substance is leached with sulfuric acid and the manganese sulfate solution neutralized to pH 4-6 to precipitate iron, aluminum, nickel, cobalt, and other impurities. The solution is filtered to remove the precipitates, and $(NH_4)_2CO_3$ is added to precipitate manganese carbonate. The $MnCO_3$ is filtered, dried, and roasted in air to produce manganese dioxide (MnO_2) and carbon dioxide (CO_2).[15]

Other Manganese Products

Both manganese sulfate and manganese carbonate can also be prepared from ore. Manganese sulfate is used primarily as an agricultural chemical, while manganese carbonate is used to prepare other manganese compounds for specialty purposes. Both the sulfate and the carbonate production use less than five percent of total manganese ore demand. Manganese sulfate can be prepared by either the hydroquinone process or the ore-coke process.[16]

In the hydroquinone process, as shown in Exhibit 9, manganese ore, aniline, and sulfuric acid are reacted to produce manganese sulfate, quinone and ammonium sulfate. The reacted mixture is steam distilled to separate quinone, which is collected and processed on-site to hydroquinone. The remaining materials are filtered, and gangue solids are removed as a waste material. The filtrate is partially evaporated and manganese sulfate crystallized from solution is recovered as a solid. The spent liquor containing ammonium sulfate is sent to waste treatment and the recovered manganese sulfate is dried and packaged. The ore-coke process for manufacturing manganese sulfate is shown in Exhibit 10. Manganese ore and coke are reacted in a kiln and the product is leached with sulfuric acid. The resulting slurry is evaporated to dryness to recover a 30 percent product for agricultural purposes. The insoluble residues are left with the product.[17]

To produce manganese carbonate, as shown in Exhibit 11, manganese sulfate and soda ash are reacted in solution to form the carbonate, which precipitates from solution and is recovered by filtration, dried and packaged. The spent solutions containing by-product sodium sulfate are normally wasted.[18]

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[15] Ibid.

[16] U.S. Environmental Protection Agency, Multi-Media Assessment of the Inorganic Chemicals Industry, Vol. II, August 1980, p. 6-1.

[17] Ibid., pp. 6-2 - 6-8.

[18] Ibid., pp. 6-8 - 6-9.

EXHIBIT 8

PRODUCTION OF CHEMICAL MANGANESE DIOXIDE (TYPE II)

(Adapted from: Multi-Media Assessment of the Inorganic Chemicals Industry, 1980, pp. 6-16.)

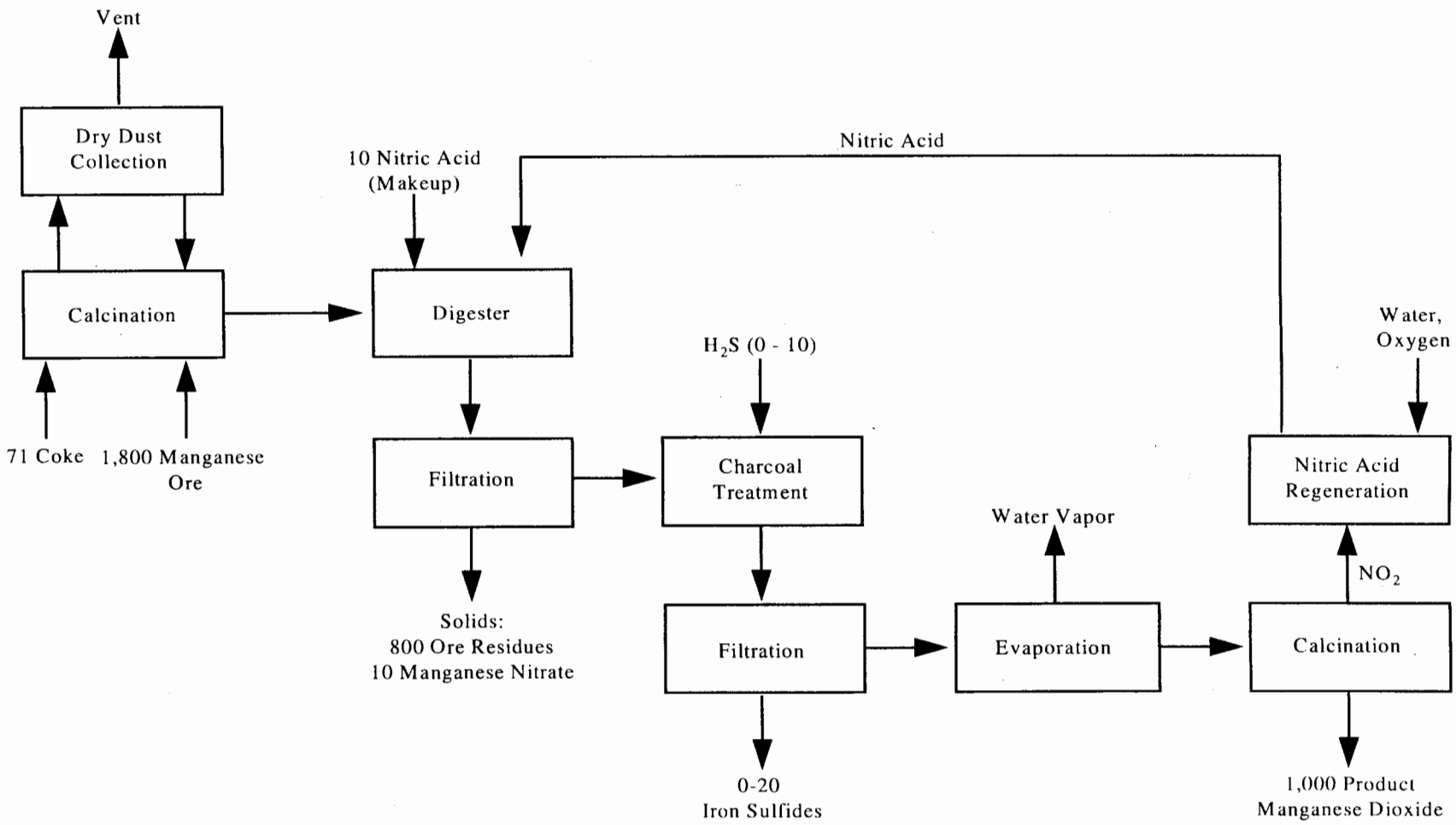


EXHIBIT 9

PRODUCTION OF MANGANESE SULFATE (HYDROQUINONE PROCESS)

(Adapted from: Multi-Media Assessment of the Inorganic Chemicals Industry, 1980, pp. 6-5.)

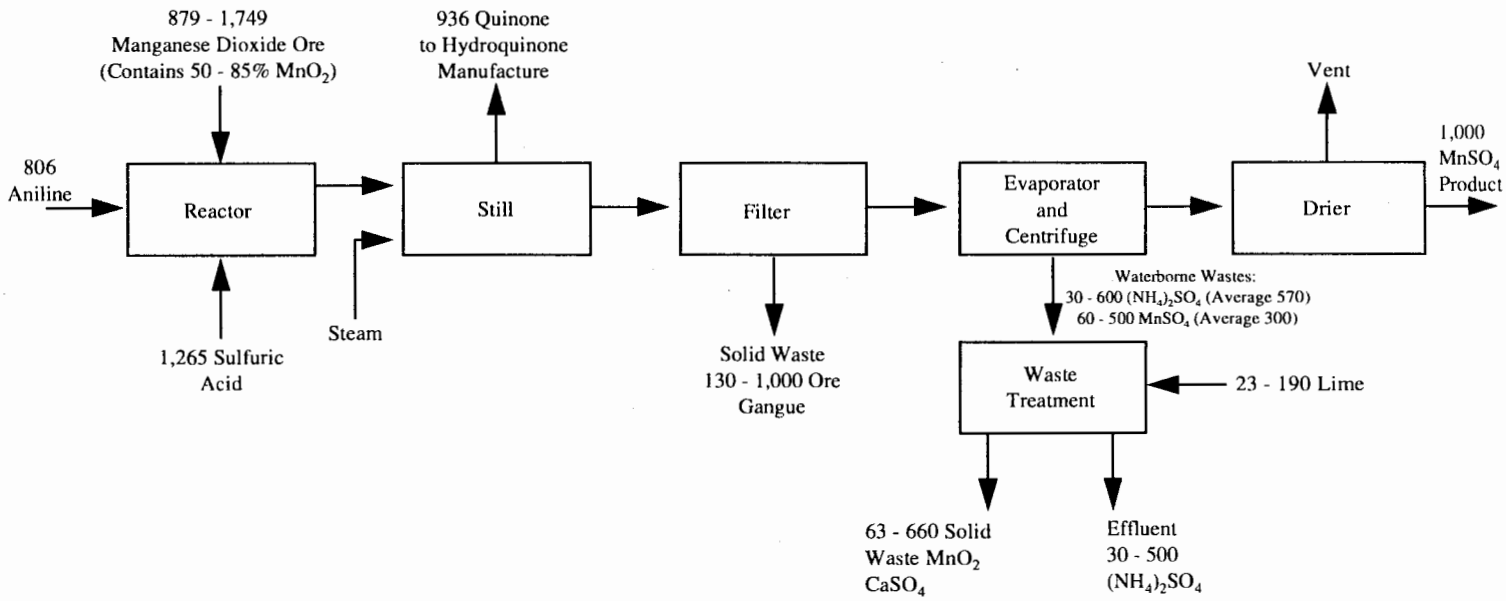


EXHIBIT 10

PRODUCTION OF MANGANESE SULFATE (ORE-COKE PROCESS)

(Adapted from: Multi-Media Assessment of the Inorganic Chemicals Industry, 1980, pp. 6-7.)

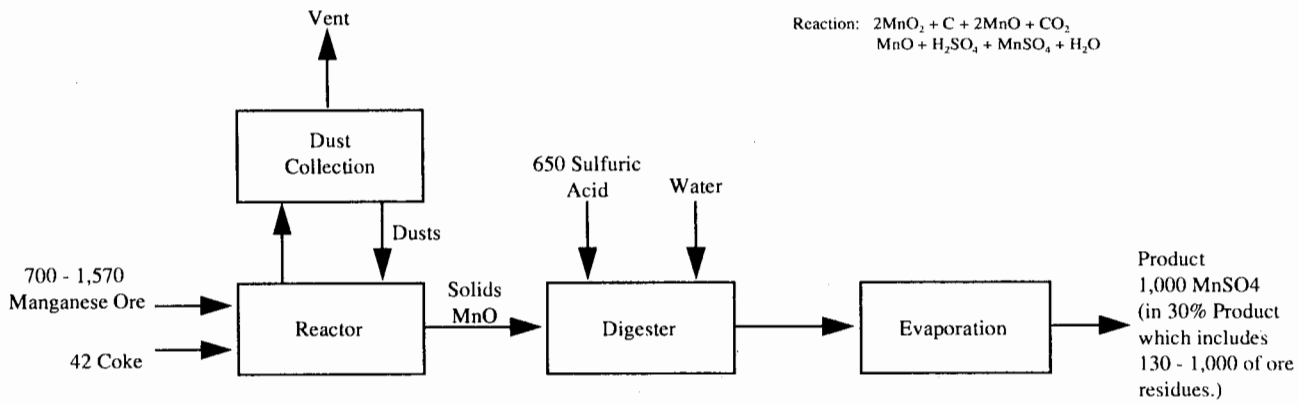
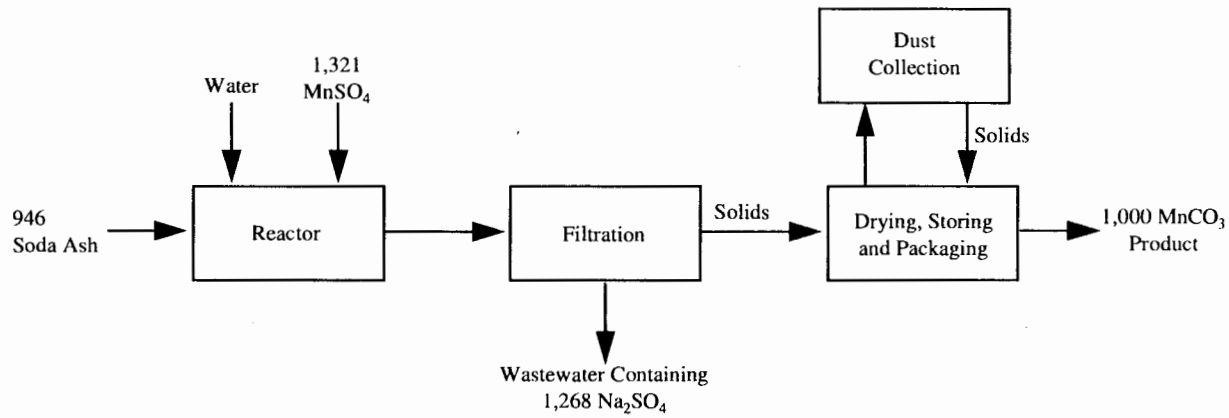


EXHIBIT 11

PRODUCTION OF MANGANESE CARBONATE

(Adapted from: Multi-Media Assessment of the Inorganic Chemicals Industry, 1980, pp. 6-9.)

Reaction: $MnSO_4 + Na_3CO_3 \rightarrow MnCO_3 + Na_2SO_4$



3. Identification/Discussion of Novel (or otherwise distinct) Processes

Researchers are investigating how to increase recovery of manganese from refractory ores and steel slag.[19,20,21]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

Ferromanganese and Silicomanganese

EPA determined that for ferromanganese and silicomanganese, processing begins with smelting in a submerged arc furnace because the ore undergoes physical/chemical reactions which significantly alter the physical/chemical structure. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

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[19] P. Comba, K.P.V. Lei, and T.G. Carnahan, "CaF_2-Enhanced Leaching of a Manganese-Bearing Silicate Ore," U.S. Bureau of Mines, Report of Investigations 9372, 1991.

[20] S.N. McIntosh, and E.G. Baglin, "Recovery of Manganese from Steel Plant Slag by Carbamate Leaching," U.S. Bureau of Mines, Report of Investigations 9400, 1992.

[21] P.A. Rusin, J.E. Sharp, R.G. Arnold, and N.A. Sinclair, "Enhanced Recovery of Manganese and Silver from Refractory Ores," Mineral Bioprocessing, The Minerals, Metals, and Materials Society, 1991.

Since production of low carbon silicomanganese uses standard silicomanganese, all of the wastes generated during silicomanganese production are mineral processing wastes.

Manganese Metal

EPA determined that for this specific mineral commodity, the beneficiation/processing line occurs between reduction roasting and leaching because the ore (manganese (II) oxide) is converted to manganese (II) sulfate. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Manganese Dioxide

Electrolytic Production

EPA determined that for manganese dioxide, mineral processing begins in the kiln because the ore reacts with coal to produce manganese dioxide. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Chemical (Type I) Production

Since this process begins with byproduct manganese dioxide, all of the wastes generated during the process are mineral processing wastes.

Chemical (Type II) Production

EPA determined that for this specific process, mineral processing begins with the reaction of manganese ore with coke in kilns because the reaction alters the chemical structure of the ore. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Other Manganese Products

Hydroquinone Process

EPA determined that for other manganese products produced via the hydroquinone process, mineral processing begins with reacting the ore, aniline, and sulfuric acid because the resulting chemical reaction alters the chemical structure of the ore. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes.

EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Ore-Coke Process

EPA determined that for other manganese products produced via the ore-coke process, mineral processing begins with the reaction of the ore and coke in kilns because the reaction alters the chemical structure of the ore. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Manganese Carbonate

Since manganese carbonate is produced from manganese sulfate, all of the wastes generated during manganese carbonate production are mineral processing wastes.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

The following wastes may be generated by extraction and beneficiation operations: gangue, flotation tailings, spent flotation reagents, and wastewater.

2. Mineral Processing Wastes

Ferromanganese Production

Both **Slag** and **APC Dust/Sludge** are recycled where possible. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Electrolytic Manganese Dioxide and Metal

Waste Electrolyte. Available data do not indicate that waste electrolyte exhibits hazardous characteristics.[22] Therefore, the Agency did not evaluate this material further.

Spent Graphite Anodes. The spent anodes are directly recovered from the process and landfilled.[23] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[22] U.S. Environmental Protection Agency, "Manganese," from 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, 1988, p. 3-149.

[23] U.S. Environmental Protection Agency, 1980, Op. Cit., pp. 6-13 - 6-15.

Iron Sulfide Sludge. This waste is generated by solution purification prior to electrolysis and is landfilled.[24] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

APC Water. Particulates generated during the calcination and product drying steps are collected by wet scrubbers. The scrubber waters are used as process make-up waters.[25] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater. This waste is generated during product washing and in slurring ore residues to disposal lagoons, and may contain suspended ore residue and minor amounts of soda ash. Wastewater is treated with lime to precipitate manganese salts and then discharges to lined evaporation ponds.[26] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Chemical Manganese Dioxide

APC Dust. Dry particulate collection methods are used to reduce ore calcination and product handling particulate emissions. Collected materials are recycled.[27] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Ore residues. These wastes are generated in the leaching operations, which are acid insoluble material such as aluminates and silicates, and in the purification of the intermediate manganese nitrate. There is also some unrecovered manganese nitrate entrained in these wastes, which are slurried to treatment lagoons. Lime is added to the lagoons to precipitate any soluble manganese present.[28] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater. This waste is generated by slurrying the ore residues to the treatment lagoons. After treatment the slurry water is discharged.[29] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[24] Ibid.

[25] Ibid., p. 6-13.

[26] Ibid.

[27] Ibid., p. 6-17.

[28] Ibid., p. 6-17.

[29] Ibid., p. 6-17.

Other Manganese Products - Manganese Sulfate (Hydroquinone Process)

APC Dust. This dust consists of particulates generated in the calcination and drying operations, which are captured and recycled.[30] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent Process Liquor. This waste contains ammonium sulfate and unrecovered manganese sulfate. This waste, along with washings from the ore residues are lime treated to precipitate residual manganese, settled, and discharged.[31] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater Treatment Solids. These solids formed by wastewater treatment (i.e., manganese oxides and calcium sulfate) are left in ponds. Solid ore residues wastes are washed free of soluble manganese and land disposed.[32] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Other Manganese Products - Manganese Sulfate (Ore-Coke Process)

APC Dust. This dust consists of particulates generated in the calcination and drying operations, which are captured and recycled.[33] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Other Manganese Products - Manganese Carbonate

APC Dust. This dust consists of particulates generated in the drying operation, which are captured and recycled.[34] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent Process Liquor. This waste contains sodium sulfate and small amounts of unrecovered product. This waste is lime treated to precipitate residual manganese salts, settled, neutralized, and discharged.[35] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater Treatment Solids. The solids formed by wastewater treatment (i.e., manganese oxides and calcium sulfate) are left in ponds.[36] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[30] Ibid., pp. 6-2 - 6-6.

[31] Ibid.

[32] Ibid., p. 6-6.

[33] Ibid., p. 6-8.

[34] Ibid., pp. 6-8 - 6-10.

[35] Ibid., p. 6-10.

[36] Ibid.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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MERCURY

A. Commodity Summary

Mercury, also known as quicksilver, is a liquid metal at room temperature. It is used in batteries, lighting, thermometers, manometers, and switching devices. Mercury compounds are used in agriculture as bactericides and disinfectants, in pharmaceutical applications in diuretics, antiseptics, skin preparations, and preservatives, and in the production of caustics, such as sodium and potassium hydroxide. Mercury also is used as a catalyst for production of anthraquinone derivatives, vinyl chloride monomers, and urethane foams. Mercury can be found in nature in more than a dozen minerals, including cinnabar, which is the most common. No mercury is mined in the United States, although mercury is recovered in small quantities as a coproduct of gold mining.[1,2] Seven gold mining operations in California, Nevada, and Utah recovered mercury as a result of gold retorting in 1994, as shown in Exhibit 1.[3]

EXHIBIT 1

Summary of Mines Producing Mercury as a Coproduct in 1994[a,b]

Company Name	Mine	Location
Barrick Mercur Gold Mines Inc.	Mercur	Toole, UT
FMC Gold Co.	Getchell	Humboldt, NV
FMC Gold Co.	Paradise Peak	Nye, NV
Homestake Mining Co.	McLaughlin	Napa, CA
Independence Mining Co. Inc.	Enfield Bell	Elko, NV
Newmont Gold Co.	Carlin Mines Complex	Eureka, NV
Placer Dome U.S.	Alligator Ridge	White Pine, NV

[a] "Mercury," Minerals Yearbook, Volume 1. Metals and Minerals. U.S. Bureau of Mines. 1991. p. 989.
[b] Personal Communication between ICF Incorporated and Steven M. Jasinski, U.S. Bureau of Mines, November 1994.

B. Generalized Process Description

1. Typical Production Processes

Mercury can be produced from mercury ores and gold-bearing ores by reduction roasting or calcining. The primary mercury production process is described below.

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[1] U.S. Environmental Protection Agency, "Mercury, Hg," from 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, 1988, pp. 1-2.

[2] Newmont Gold Company. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[3] Jasinski, S.M., "Mercury," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 108.

2. Generalized Process Flow Diagram

Exhibit 2 is a typical production flow diagram, illustrating the primary production of mercury. Although currently not in use domestically, mercury is recovered from primary mining operations by crushing the ore, and concentrating the mercury by flotation (not shown). The flotation operation produces a tailings stream. The concentrate is heated in a furnace to vaporize the mercury, and the resulting vapor is condensed.[4,5] The sulfur in the ore is oxidized to sulfur dioxide (SO_2). Some water may condense with the mercury and is discharged as a waste stream (labeled stream No. 4 in Exhibit 2). The mercury is recovered from the condenser and may be washed before being sold (creating wastewater stream No. 5). The sulfur dioxide and other gaseous emissions from the mercury roasting furnace are controlled with a multistage scrubber (creating stream No. 1). After SO_2 removal, the clean stack gases are cooled with contact cooling water and discharged to the atmosphere (stream No. 3). Waste streams may also result from the quenching of calciner wastes to reduce the temperature prior to disposal (stream No. 5).[6]

The process for recovering mercury from gold ore is shown in Exhibit 3, and it is similar to recovery from cinnabar ore. If the gold ore is a sulfide ore, it typically is sent to a roasting step prior to leaching. This roasting operation is similar to primary mercury ore roasting in that the mercury and sulfide are both volatilized. The exhaust gases are passed through wet electrostatic precipitators (ESPs), and if necessary, through carbon condensers. The sulfur dioxide is removed by lime prior to venting. If the treated sulfide ore has a high mercury content, the primary mercury recovery process occurs from the wet ESPs. However, if the concentration is sufficiently low, no attempt is made to recover mercury for sale.[7]

If the gold ore is an oxide-based ore, the crushed ore is mixed with water and sent to a classifier, followed by a concentrator, which reduces the water content. The concentrate is sent to an agitator containing cyanide leach solution. The slurry from the agitators is filtered, the filter cake is disposed, and the filtrate, which contains the gold and mercury, is transferred to the electrowinning process. If the carbon-in-pulp process is used, the cyanide pulp in the agitators is treated with activated carbon to adsorb the gold and mercury. The carbon is filtered from the agitator tanks and treated with an alkaline cyanide alcohol solution to desorb the metals. This liquid is then transferred to the electrowinning tanks. In the electrowinning process, the gold and mercury are electrodeposited onto a stainless steel wool cathode, which is sent to a retort to remove mercury and other volatile impurities. The stainless steel wool containing the gold is transferred from the retort to a separate smelting furnace where the gold is melted and recovered as crude bullion.[8] The exhaust gas from the retort, containing mercury, SO_2, particulates, water vapor, and other volatile components, passes through condenser tubes where the mercury condenses as a liquid and is collected under water in the launders. Slag quenchwater is stored prior to being recycled to the carbon-in-leach circuit (CIL). From the launders, the mercury is purified and sent to storage.[9]

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[4] Personal communication between ICF Incorporated and Steve Jasinski, U.S. Bureau of Mines, March 1994.

[5] Carrico, L.C., "Mercury," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, p. 501.

[6] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume V, Office of Water Regulations and Standards, May 1989, pp. 2167-68, 2178.

[7] Personal Communication between ICF Incorporated and Steven M. Jasinski, November 1994.

[8] U.S. Environmental Protection Agency, Technical Resources Document: Extraction and Beneficiation of Ores and Minerals, Volume 2: Gold, Office of Solid Waste, July 1994, p. 1-31.

[9] Personal Communication between ICF Incorporated and Steven M. Jasinski, November 1994.

EXHIBIT 2

PRODUCTION OF METALLIC MERCURY FROM PRIMARY MERCURY ORES

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989, p. 2175.)
(No primary mercury mining is now conducted in the U.S.)

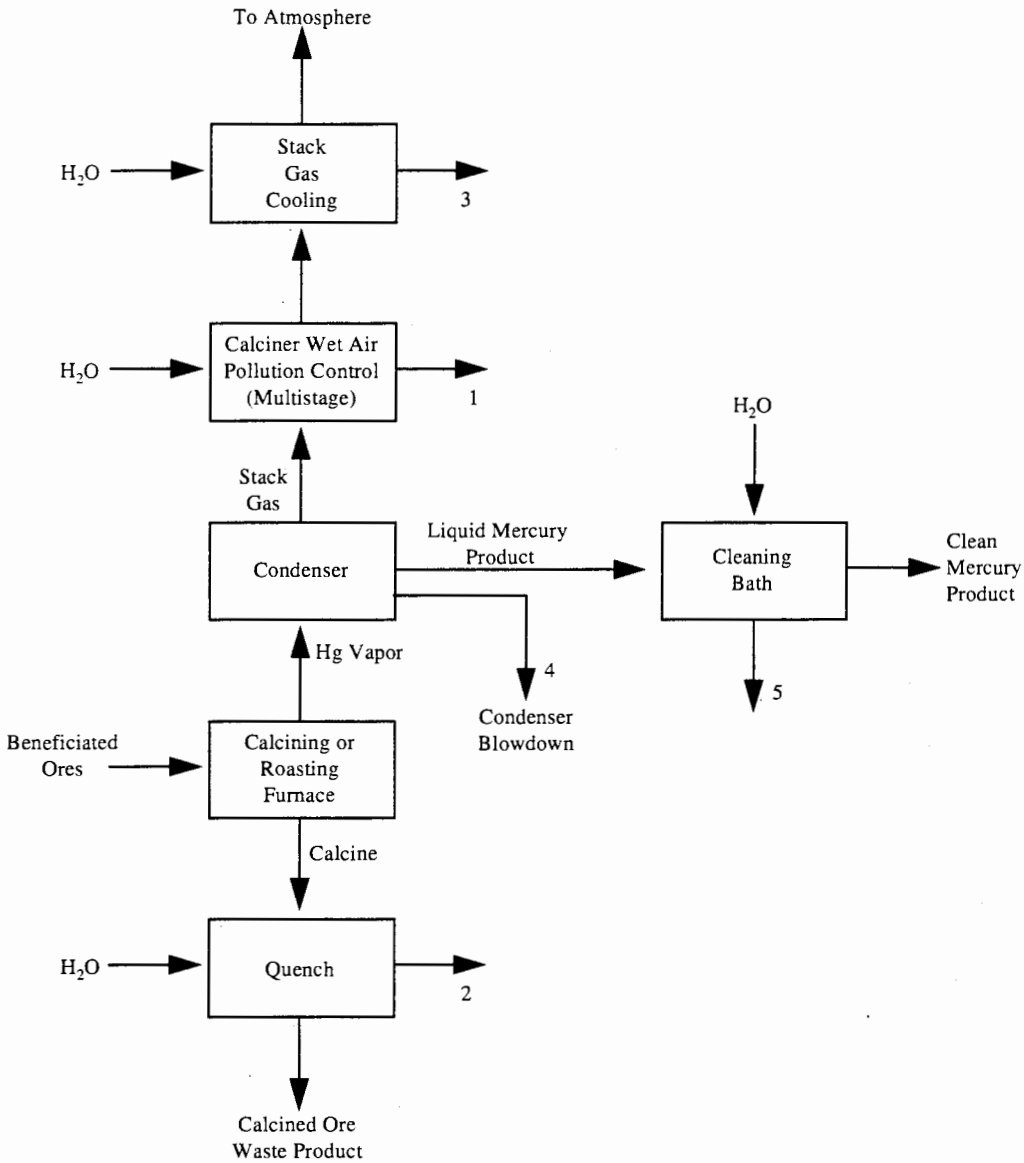
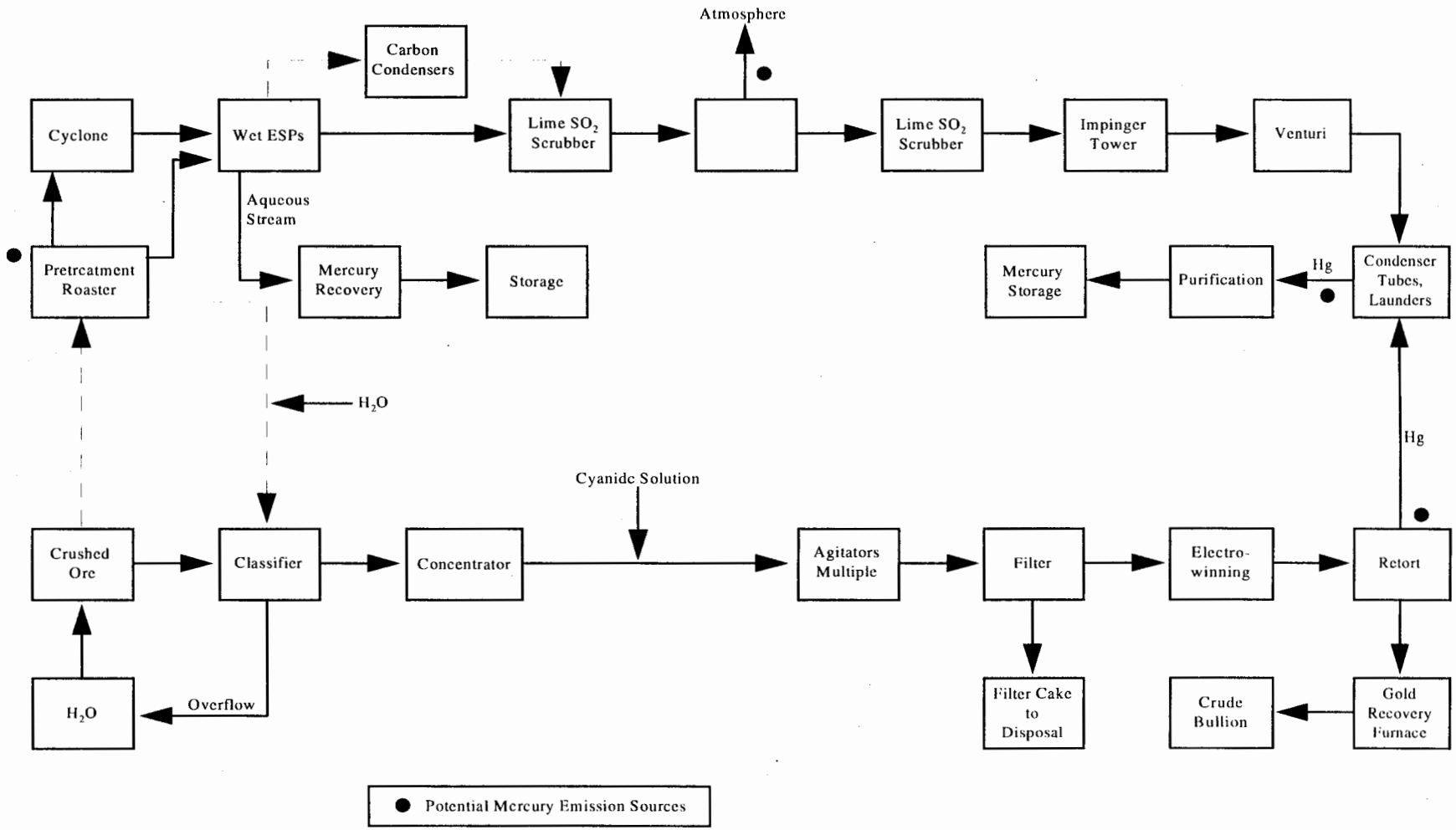


EXHIBIT 3

PRODUCTION OF METALLIC MERCURY FROM GOLD ORES

(Source: Personal Communication Between ICF Incorporated and Steven M. Jasinski, November 1994.)



Mercury is also recovered from industrial scrap and waste materials, such as discarded dental amalgams, batteries, lamps, switches, measuring devices, control instruments, and wastes and sludges generated in laboratories and electrolytic refining plants. Scrap products are broken down to liberate metallic mercury or its compounds, heated in retorts to vaporize the mercury, and cooled to condense the mercury.[10] This secondary recovery of mercury is outside primary mineral processing and is, therefore, outside the scope of the this report.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

There are several alternative processing options, including leaching with sodium sulfide and sodium hydroxide, followed by precipitation with aluminum or electrolysis. Alternatively, mercury can be dissolved in sodium hypochlorite solution, then passed through activated carbon to adsorb the mercury. The mercury is recovered from the carbon by heating, producing elemental mercury. Neither of these processes are in use today. A third option, also not in use, is electrooxidation.[11] Research is continuing on the best way to recover mercury from gold and silver solutions for coproduct mercury production.[12,13,14]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

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[10] "Mercury," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd Ed., Vol. XV, 1981, pp. 147-48.

[11] Carrico, L.C., 1985, Op. Cit., p. 501.

[12] "Mercury," 1981, Op. Cit., p. 148.

[13] Simpson, W.W., W.L. Staker, and R.G. Sandberg, "Calcium Sulfide Precipitation of Mercury From Gold-Silver Cyanide Leach Slurries," from Report of Investigations 9042, U.S. Bureau of Mines, 1986. p. 1.

[14] Sandberg, R.G., W.W. Simpson, and W.L. Staker, "Calcium Sulfide Precipitation of Mercury During Cyanide Leaching of Gold Ores," from Report of Investigations 8907, U.S. Bureau of Mines, 1984. p. 1.

Production of Metallic Mercury from Primary Mercury Ore

EPA determined that for the production of metallic mercury from primary mercury ore, the beneficiation/processing line occurs between calcining/roasting and condensing since there is no leaching directly after the roasting step and the resulting product undergoes further beneficiation (i.e., cleaning). Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Production of Metallic Mercury from Gold Ores

Because mercury is being recovered as a co-product of other metals obtained during mineral processing operations, all of the wastes generated during mercury recovery also are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral, see the gold and silver sector reports.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

The following wastes may be generated by extraction and beneficiation operations: **gangue**, **flotation tailings**, **spent flotation reagents**, and **wastewater**.[15]

2. Mineral Processing Wastes

Primary Retorting is not currently used in the United States, due to the economics of mining primary mercury ores. Therefore, the wastes associated with primary retorting are not included in the tables summarizing waste stream generation rates and waste characteristics. The following three primary retorting waste streams are included in this report for completeness.

Furnace Calcines. Approximately 10 metric tons of furnace calcines were produced annually in the United States in 1992. Available data do not indicate the waste exhibits hazardous characteristics.[16] No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

SO_2 Scrubber Effluent. Approximately 3,000 metric tons of SO_2 scrubber effluent were produced annually in the United States in 1992. Available data do not indicate the waste exhibits hazardous characteristics.[17] No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

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[15] Harty, D.M., and P.M. Terlecky, Characterization of Wastewater and Solid Wastes generated in Selected Ore Mining Subcategories, (Sb, Hg, Al, V, W, Ni, Ti), U.S. Environmental Protection Agency, August 21, 1981, pp. II-36 - II-40.

[16] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Volume I, Office of Solid Waste, August 1992, p. I-6.

[17] Ibid.

Particulate Control Effluent. Approximately 2,000 metric tons of particulate control effluent were produced annually in the United States in 1992. Available data do not indicate the waste exhibits hazardous characteristics.[18] No other information on waste characteristics, waste generation, or waste management was available in the sources listed in the bibliography.

Co-product Retorting. The wastes produced in coproduct retorting will vary greatly depending on the input materials. The wastes also may contain other metals.

Dust. Approximately 7 metric tons of dust are produced annually from the mercury sector in the U.S.[19] Although no published information regarding waste characteristics was found, we used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity for mercury. We also used best engineering judgment to determine that this waste stream is not believed to be recycled. This waste stream was formerly classified as a sludge.

Furnace Residues. Approximately 77 metric tons of furnace residues are produced annually from the mercury sector in the United States.[20] Although no published information regarding waste characteristics was found, we used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity for mercury. This waste stream is not recycled.

Quenchwater. During the retorting process, mercury gas is vaporized from the gold filter cake. The mercury gas is quenched with a direct contact water spray and condensed to form liquid mercury, which is collected for sale. Waste mercury quenchwater is generated at a rate of 20 to 30 gallons per minute at the facility, and is recycled to the CIL circuit. This waste generation rate corresponds to low, medium, and high sector-wide generation rates of 63,000 mt/y, 77,000 mt/y, and 420,000 mt/y, respectively. This waste may be toxic for lead and mercury. This waste stream is believed to be fully recycled and was formerly classified as a spent material.

D. Non-uniquely Associated Wastes

Non-uniquely associated wastes may be generated at on-site laboratories and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received By EPA

New Factual Information

Newmont Gold Company was the sole commenter on the mercury sector report. This commenter (COMM57) provided new factual information to be added to the mercury sector report, stating that the flow diagram depicting the mercury production process for recovery of mercury from gold ores and the accompanying narrative did not resemble the process used at Newmont Gold nor at other gold producers. The commenter did not provide any suggested changes and, therefore, the flow diagram was not revised.

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[18] Ibid.

[19] Ibid.

[20] Ibid.

Sector-specific Issues

The commenter also provided several suggestions related to sector-specific issues. The commenter stated that mercury is a "co-product," not a "by-product" because the mercury in question is not a secondary stream that is discarded or recycled for further mercury recovery. Therefore, it is not a RCRA Subtitle C byproduct. The same commenter stated that they were unaware of any statutory/regulatory language or EPA interpretive guidance that would lead to the conclusion that all wastes generated during mercury recovery as a coproduct of other metals are mineral processing wastes. In addition, this commenter stated that retort quenchwater can be a by-product or a spent material, depending on the circumstances. EPA has revised the report to indicate that mercury is recovered and may be a co-product of gold processing. EPA also has clarified that all wastes generated during mercury recovery from gold ores are mineral processing wastes because the mercury recovery process occurs during mineral processing operations for recovery of other metals. The report was not modified with respect to retort quenchwater because the distinction between by-product and spent material is made irrelevant by today's Rule.

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Personal Communication between ICF Incorporated and Steve Jasinski, U.S. Bureau of Mines. November 1994.

Sandberg, R.G., W.W. Simpson, and W.L. Staker. "Calcium Sulfide Precipitation of Mercury During Cyanide Leaching of Gold Ores." From Report of Investigations 8907. U.S. Bureau of Mines 1984. pp. 1-13.

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U.S. Environmental Protection Agency. Technical Resources Document: Extraction and Beneficiation of Ores and Minerals. Volume 2: Gold. Office of Solid Waste. July 1994.

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MOLYBDENUM, FERROMOLYBDENUM, AND AMMONIUM MOLYBDATE

A. Commodity Summary

Almost all molybdenum is recovered from low-grade deposits of the mineral molybdenite, naturally occurring molybdenum disulfide (MoS_2), mined either from a primary deposit, or as a byproduct of copper processing.[1] In 1993, one mine extracted molybdenum ore, and nine mines recovered molybdenum as a byproduct. Two plants converted molybdenite concentrate to molybdic oxide, which was used to produced ferromolybdenum, metal powder, and other molybdenum compounds.[2] Exhibit 1 presents the names and locations of molybdenum mines and processing facilities.

EXHIBIT 1

SUMMARY OF MOLYBDENUM, MOLYBDIC OXIDE, AND FERROMOLYBDENUM PRODUCERS[a]

Facility Name	Location
Cyprus-Climax - Henderson	Empire, CO
Cyprus-Climax	Fort Madison, IA
Cyprus-Climax	Clear Water, MI
Cyprus-Climax - Green Valley	Tucson, AZ
Cyprus-Climax	Baghdad, AZ
Kennecott	Bingham Canyon, UT
Molycorp Inc.	Washington, PA
Montana Resources Inc.	Butte, MT
Phelps Dodge	Chino, NM
San Manuel	San Manuel, AZ
San Manuel	Morenci, AZ
Thompson Creek	Chalis, ID
Thompson Creek	Langeloth, PA

[a] - Personal Communication between ICF Incorporated and John W. Blossom, U.S. Bureau of Mines, October 1994.

Molybdenum metal is a refractory metal used as an alloying agent in steels, cast irons, and superalloys.[3] Ferromolybdenum is an alloy of iron and molybdenum used primarily as an alternative additive in producing alloy steels, cast irons, and nonferrous alloys. The two most common grades of ferromolybdenum are low carbon- and high carbon ferromolybdenum. Ammonium molybdate is an intermediate in manufacturing both molybdenum metal and molybdic oxide, although it can also be sold as a product. Purified MoS_2 concentrate also is used as a lubricant.

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[1] J.W. Blossom, "Molybdenum," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, p. 849.

[2] J.W. Blossom, "Molybdenum," Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 114.

[3] J.W. Blossom, 1992, Op. Cit., p. 847.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Molybdenum and molybdenum products, including ammonium molybdate, are made by roasting concentrated ore, followed by purification and/or reduction. Ferromolybdenum is typically produced by reaction of technical grade molybdic oxide and iron oxide with a conventional metallothermic process using silicon and/or aluminum as the reductant. These processes are described in greater detail below.

2. Generalized Process Flow Diagram

Molybdenum Metal and Ammonium Molybdate

Molybdenum metal and ammonium molybdate are made by roasting concentrated molybdenite ore, as shown in Exhibit 2. The concentration operations, which are not shown, include crushing, grinding, and flotation of either primary or copper ores. Molybdenite is recovered from either primary molybdenite or copper sulfide ore by flotation, after the ore has been crushed and ground to a suitable size. Several stages of grinding and reflotation concentrate the molybdenite in the primary ore to a 90 to 95 percent purity concentrate.[4] The remainder of the concentrate is primarily silica.[5] Copper, iron and lead are the impurities removed as tailings by this flotation process. Several sequential stages of flotation also are used for the copper ore, first to separate the gangue, and then the copper. The molybdenite concentration is usually 70 to 90 percent purity, when recovered from copper ores.[6]

Technical grade molybdic oxide, consisting of 90 to 95 percent MoO_3, is produced by roasting molybdenite concentrate in a multiple hearth furnace at temperatures up to 650°C.[7] Molybdenum concentrates may be leached with nitric acid prior to roasting to reduce the alkali concentrations in the concentrates.[8] The roasting process removes sulfur and converts the sulfide to oxide. The flue gas contains products of combustion, SO_2, and may contain rhenium or selenium. The SO_2 in the flue gas is converted to sulfuric acid (H_2SO_4).[9] More information on the processing of the flue gas, and the production of sulfuric acid can be found in the Rhenium and Selenium sections of this document.

Pure molybdic oxide can be produced from technical grade molybdic oxide through sublimation and condensation or by leaching. In sublimation, the technical grade oxide is heated to approximately 1,100°C in a muffle type furnace. The oxide is vaporized and carried in a stream of forced air through cooling ducts and

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[4] Ibid., p. 850.

[5] "Molybdenum and Molybdenum Alloys," from Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XV, 1981, p. 670.

[6] Blossom, J. W., 1992, Op. Cit., p. 850.

[7] Ibid., p. 848.

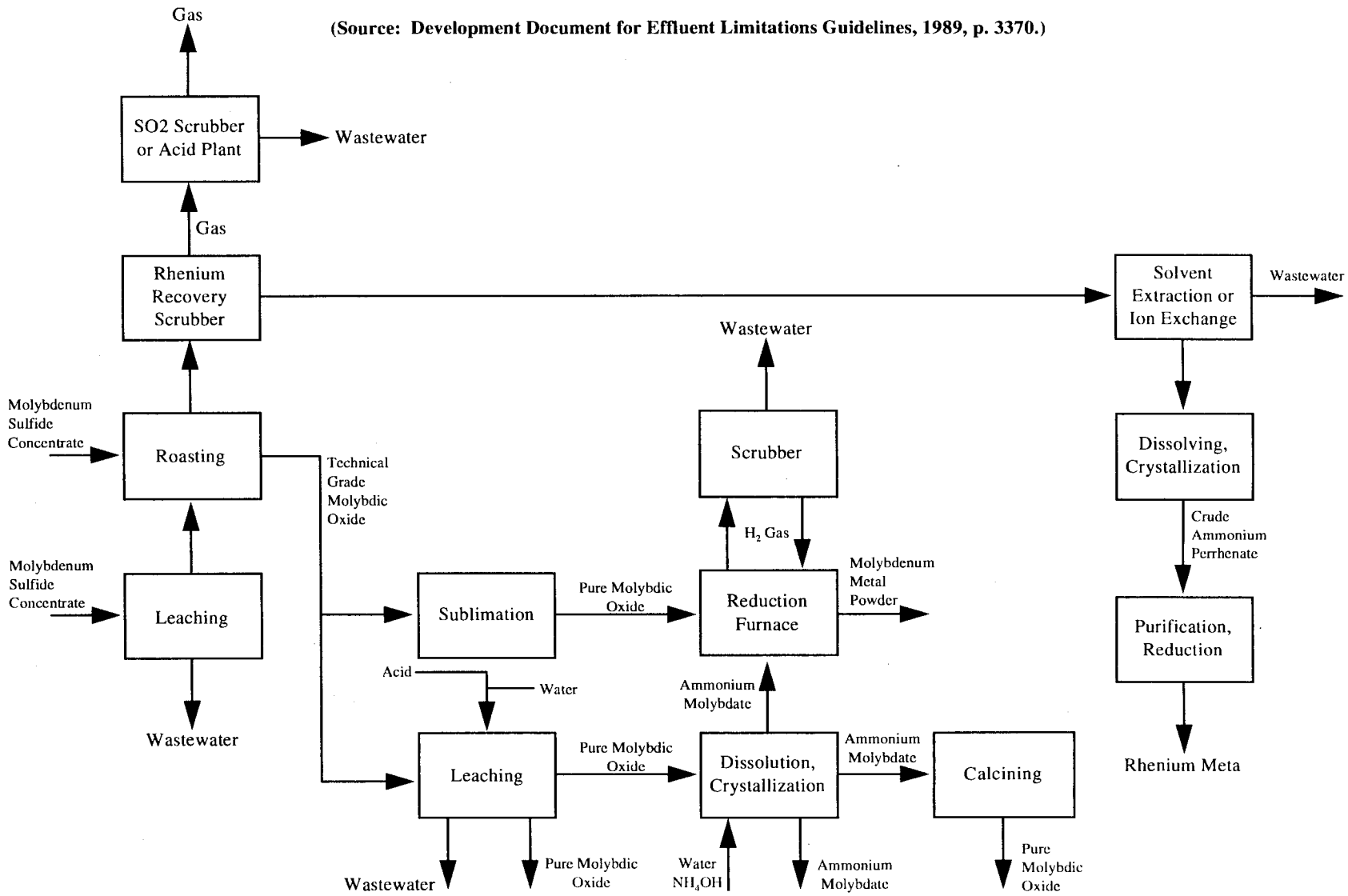
[8] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume VI, Office of Water Regulations and Standards, May 1989, p. 3364.

[9] "Molybdenum and Molybdenum Alloys," 1981, Op. Cit., p. 670.

EXHIBIT 2

MOLYBDENUM PRODUCTION

(Source: Development Document for Effluent Limitations Guidelines, 1989, p. 3370.)



the condensed oxide particles are collected in a fabric filter. The purified oxide contains greater than 99.5 percent MoO_3. Technical grade oxide may also be purified by leaching with a hydrochloric acid-ammonium chloride solution (not shown). The impurities are dissolved and separated from the solid molybdic oxide by filtration. The pure oxide may be sold as a product, reduced to molybdenum metal powder, or used to produce various molybdenum chemicals.[10]

Ammonium molybdate is formed by reacting technical grade molybdic oxide with ammonium hydroxide and crystallizing out the pure molybdate. The ammonium molybdate may be sold as product, calcined to form pure molybdic oxide, or reduced to form molybdenum metal powder.[11]

Hydrogen is used to reduce ammonium molybdate or pure molybdic oxide to molybdenum powder, at 500-1150°C, in a boat- or tube-type furnace. The metal powder is sintered and cast into ingots or bars.[12]

Ferromolybdenum

Exhibit 3 illustrates the production of low carbon and high carbon ferromolybdenum. Low carbon ferromolybdenum is produced by mixing technical grade molybdic oxide, aluminum, ferrosilicon, iron oxide, limestone, lime, and fluorspar, and igniting the aluminum (not shown). A metal button and a slag are formed, allowed to solidify, and then are separated.[13] One firm added that when it produces low carbon ferromolybdenum no furnace is necessary, only a sand bed.[14] High carbon content ferromolybdenum is made by reducing technical grade molybdic oxide, calcium molybdate, or sodium molybdate with carbon in the presence of iron in an electric furnace (not shown). The impurities from a slag which is discarded.[15] Low carbon ferromolybdenum produced by the thermite process is more common than the high carbon alloy.

3. Identification of Novel or Distinct Processes

One researcher has investigated the separation and recovery of critical metals (including molybdenum) from mixed and contaminated superalloy scrap.[16]

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[10] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3364.

[11] Ibid.

[12] "Molybdenum and Molybdenum Alloys," 1981, Op. Cit., p. 674.

[13] U.S. Environmental Protection Agency, "Molybdenum," 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, 1988, p. 3-154.

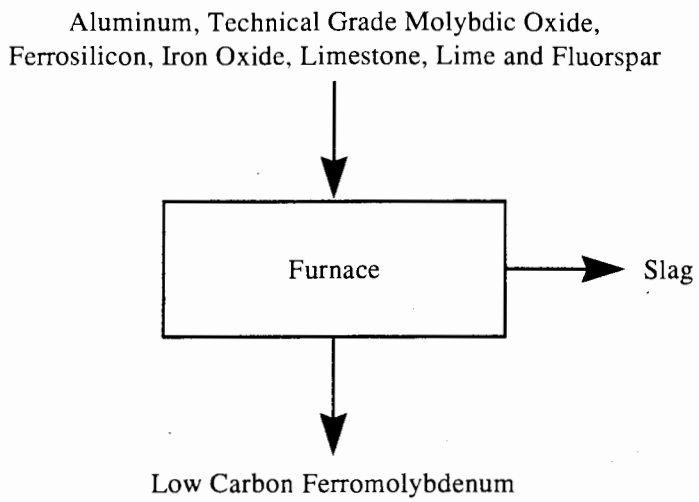
[14] Molycorp, Inc. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

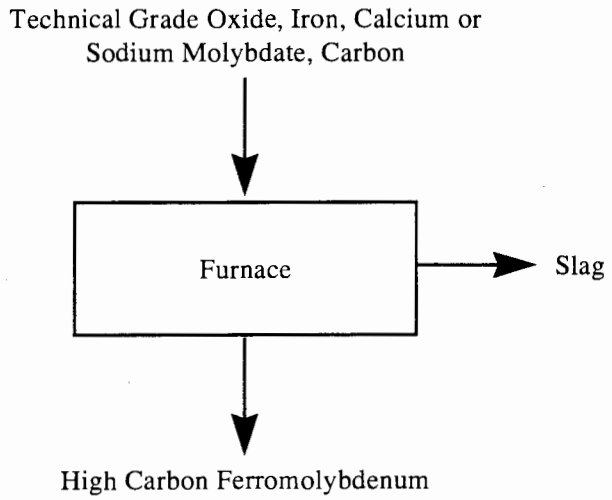
[15] Ibid., p. 3-154.

[16] Hundley, G.L., and D.L. Davis, "Recovery of Critical Metals from Superalloy Scrap by Matte Smelting and Hydrometallurgical Processing," U.S. Bureau of Mines Report of Investigations 9390, 1991, p. 1.

EXHIBIT 3

FERROMOLYBDENUM PRODUCTION





4. Extraction/Beneficiation Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes. The idea that beneficiation wastes are earthen in character is only a guide, and not a standard. There may be instances where beneficiation operations produce a waste that is "not" earthen in character. In such instances, the operation is not considered a processing operation, because of the waste's non-earthen characteristics, and instead remains a beneficiation operation.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

Molybdenum Powder

EPA determined that for the production of molybdenum powder, the beneficiation/processing line occurs between the roasting and sublimation steps because leaching does not follow and because the molybdenum disulfide is chemically roasted to pure molybdic oxide.[17] Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Ammonium Molybdate and Pure Molybdic Oxide

Based on a review of the process, there are no mineral processing operations involved in the production of either ammonium molybdate or pure molybdic oxide.

Ferromolybdenum

EPA determined that for ferromolybdenum, the beneficiation/processing line occurs at the furnace where the technical grade molybdic oxide and other materials are charged and undergo thermal reduction to form

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[17] Molycorp, Inc. Op. Cit.

ferromolybdenum. One firm, Molycorp Inc., reported that in their operations furnaces were restricted to high carbon ferromolybdenum production.[18]

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

The following wastes may be generated by extraction and beneficiation operations: gangue, flotation tailings, spent flotation reagents, and wastewater.[19,20] The tailings from molybdenite concentration are not expected to exhibit any hazardous characteristics, although metal leaching and acid formation may take place.[21]

2. Mineral Processing Wastes

Ammonium Molybdate Refining

Refining Wastes. Available data do not indicate that ammonium molybdate refining wastes exhibit any hazardous characteristics.[22] Therefore, the Agency did not evaluate this material further.

Technical Grade Molybdic Oxide Production

Liquid Residues. Approximately 1,000 metric tons of liquid residues are generated annually in the United States. Available data indicate that this waste is potentially TC toxic. Potentially hazardous constituents include arsenic, cadmium, lead, and selenium.[23] The waste is not recycled. Liquids from the quench and scrubber towers/thickener contained the following constituents: arsenic - 60 ppm; cadmium - 1.2 ppm; chromium - 1.8 ppm; lead - 5.8 ppm; molybdenum - 100 ppm; and selenium - 32 ppm.[24] Additional data is provided in Attachment 1. No other information on waste characteristics, or waste management was available in the sources listed in the bibliography.

Treatment Solids. Available data do not indicate that treatment solids exhibit any hazardous characteristics.[25] Silicon was found at a concentration of 10 percent in solids from the quench and scrubber towers/thickener.[26] Therefore, the Agency did not evaluate this material further.

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[18] Ibid.

[19] PEI Associates, Site Specific Data Summary Forms: Facilities Involved in the Extraction and Beneficiation of Ores and Minerals, Prepared for U.S. Environmental Protection Agency, Office of Research and Development, November 1986.

[20] Weiss, Norman L., Ed. "Molybdenum," SME Mineral Processing Handbook, Volume II, Society of Mining Engineers, 1985, pp. 16-1 - 16-36.

[21] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-152.

[22] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Volume I, Office of Solid Waste, August 1992, p. I-2.

[23] Ibid., p. I-6.

[24] Ibid., Vol. II, p. 28-11.

[25] Ibid., Vol. I, p. I-6.

[26] Ibid., Vol. II, p. 28-8.

Solid Residues. Available data do not indicate that solid residues exhibit any hazardous characteristics (see Attachment 1).[27] Therefore, the Agency did not evaluate this material further.

Roaster Gas Blowdown Solids. Approximately 100 metric tons of roaster gas blowdown solids are generated annually in the United States. Available data do not indicate that this waste exhibits any hazardous characteristics.[28] Therefore, the Agency did not evaluate this material further.

Molybdic Oxide Refining Wastes. Approximately 2,000 metric tons of molybdic oxide refining wastes are generated annually in the United States.[29] This waste is believed to not exhibit any hazardous characteristics[30] and has not been evaluated further by the Agency.

Flue Dust/Gases. The flue gases produced during the roasting of molybdenite concentrates could contain volatile metals in the flue dust, in addition to the SO_2. These metals may include lead, zinc, tin and others.[31] Although no published information regarding waste generation rate was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 1,100 metric tons/yr, 250,000 metric tons/yr, and 500,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead. This waste typically is not recycled. However, Molycorp Inc. reported that flue dust is recycled at its Washington, PA facility. It also reported that in its operations there was no difference between flue dust/gases and roaster gas blowdown solids.[32]

Metal Refining

Refining Wastes. Available data do not indicate that metal refining wastes exhibit any hazardous characteristics.[33] Therefore, the Agency did not evaluate this material further.

H_2 Reduction Furnace Scrubber Water. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste (see Attachment 1). Therefore, the Agency did not evaluate this material further.

Ferromolybdenum Production

APC Dust/Sludge. This waste is generated by the baghouse or other APC device receiving the fumes from the ferromolybdenum furnace. Available data do not indicate that APC dust/sludge exhibits any hazardous characteristics.[34] Therefore, the Agency did not evaluate this material further.

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[27] Ibid., Vol. II, p. I-6.

[28] Ibid.

[29] Ibid.

[30] Molycorp, Inc. Op. Cit.

[31] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-153.

[32] Molycorp, Inc. Op. Cit.

[33] U.S. Environmental Protection Agency, 1992, Op. Cit, Vol. I, p. I-6.

[34] Ibid., p. I-4.

Slag. This waste, formed in either the production of low carbon ferromolybdenum or high carbon ferromolybdenum, is not expected to exhibit any hazardous characteristics. The slag is usually discarded.[35] Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Hazardous Wastes

Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

Two commenters provided new information on facility specific operations and processes (COMM40, COMM69). This new information has been incorporated into the Agency's sector report.

Site-specific Issues

None.

[35] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-154.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SOLID RESIDUES - MOLYBDENUM OXIDE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	100,000	100,000	100,000	1/1	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - H2 REDUCTION FURNACE SCRUBBER WATER - MOLYBDENUM OXIDE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.001	0.0090	0.024	3/3	-	-	-	0/0	-	-
Arsenic	0.002	0.0107	0.024	3/3	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.001	0.0023	0.005	3/3	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.001	0.0010	0.001	3/3	-	-	-	0/0	1.0	0
Chromium	0.001	0.0040	0.006	3/3	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.004	0.3947	0.64	3/3	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.001	0.0657	0.17	3/3	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0002	0.0002	3/3	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.024	1.1613	2.8	3/3	-	-	-	0/0	-	-
Selenium	0.001	0.0010	0.001	3/3	-	-	-	0/0	1.0	0
Silver	0.001	0.0053	0.014	3/3	-	-	-	0/0	5.0	0
Thallium	0.001	0.0010	0.001	3/3	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.51	0.5733	0.63	3/3	-	-	-	0/0	-	-
Cyanide	0.01	0.0100	0.01	3/3	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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PHOSPHORIC ACID

A. Commodity Summary

Most phosphoric acid facilities are co-located with other manufacturing facilities.[1] The primary product from phosphoric acid facilities is commercial-grade wet process phosphoric acid, approximately 95 percent of which is used at co-located facilities to produce fertilizers and animal feed. Most of the remaining portion is used as a feedstock in chemical processing operations. Phosphoric acid producing facilities are listed in Exhibit 1.

EXHIBIT 1

SUMMARY OF PHOSPHORIC ACID PRODUCING FACILITIES

Facility Name	Locations	Type of Operations	Potential Factors Related to Sensitive Environments
Agrico Chem	Pierce, FL Uncle Sam, LA Donaldsonville, LA	Wet Process Wet Process Wet Process	Uncertain Uncertain Uncertain
Albright & Wilson	Fernald, OH Charleston, SC	Furnace Furnace	Uncertain Uncertain
Arcadian	Geismar, LA	Wet Process	Located in 100-year floodplain, within 1 mile of wetland
Cargill	Riverview (Tampa), FL	Wet Process	Located in 100-year floodplain, located in wetland
Central Phosphates	Plant City, FL	Wet Process	Within 1 mile of wetland, located in area of karst terrain
CF Ind.	Bartow, FL	Wet Process	Uncertain
Chevron	Rock Springs, WY	Wet Process	Uncertain
Conserv	Nichols, FL	Wet Process	Within 1 mile of wetland
Farmland	Pierce (Bartow), FL	Wet Process	Within 1 mile of wetland
FMC	Carteret, NJ Lawrence, KS Newark, CA	Furnace Furnace Furnace	Uncertain Uncertain Uncertain
Gardinier, Inc.	Riverview, FL	Wet Process	Uncertain
Hydrate	Milwaukee, WI	Furnace	Uncertain
IMC	Mulberry, FL	Wet Process	Located within 1 mile of wetland

[1] U.S. Environmental Protection Agency, "Phosphoric Acid Production," from Report to Congress on Special Wastes from Mineral Processing, Vol. II, Office of Solid Waste, July 1990, pp. 12-1 - 12-61.

EXHIBIT 1 (continued)

Facility Name	Locations	Type of Operations	Potential Factors Related to Sensitive Environments
JR Simplot	Pocatello, ID	Wet Process	Located in 100-year floodplain, located in fault zone
Mobil	Pasadena, TX	Wet Process	Located in 100-year floodplain
Monsanto	Trenton, MI Augusta, GA Carondelet, MO Long Beach, CA	Furnace Furnace Furnace Furnace	Uncertain Uncertain Uncertain Uncertain
Nu West	Soda Springs (Conda), ID	Wet Process	Uncertain
Nu South	Pascagoula, MS	Wet Process	
Occidental	Jeffersonville, IN Columbia, TN White Springs, FL Dallas, TX	Furnace Furnace Wet Process Furnace	Uncertain Uncertain Located within 1 mile of wetland Uncertain
Royster	Palmetto (Piney Pt.), FL Mulberry, FL	Wet Process Wet Process	Located within 6.5 miles of endangered species habitat, within 1 mile of wetland, located in area of karst terrain Located within 1 mile of wetland
Seminole	Bartow, FL	Wet Process	Located in endangered species habitat, located in 100-year floodplain, within 1 mile of wetland
Stauffer	Morrisville, PA Nashville, TN Richmond, CA Chicago Heights, IL Chicago, IL	Furnace Furnace Furnace Furnace Furnace	Uncertain Uncertain Uncertain Uncertain Uncertain
Texasgulf	Aurora, NC	Wet Process	Located in 100-year floodplain, located in wetland
US Agri-Chemicals Corp (USAC)	Ft. Meade, FL	Wet Process	Within 1 mile of wetland Uncertain

B. Generalized Process Description

There are two processes for producing phosphoric acid: (1) the wet process, and (2) the furnace process. Wet process acid, produced directly from phosphatic ores, is characterized by relatively high production volume, low cost, and low purity. It is used primarily in fertilizers. Furnace or thermal acid, manufactured from elemental phosphorus, is more expensive and considerably purer than wet-process acid. It also is produced in much smaller quantities, almost exclusively for applications requiring high purity.[2] As shown in Exhibit 1, there are 22 facilities that use the wet process and 18 that use the furnace process. There are significant differences in these processes and therefore, this report is divided into two sections. The wet process, as described in Section 1, is the main focus of this chapter. A brief discussion of the furnace process is provided in Section 2. (The furnace process uses a saleable mineral commodity as a primary raw material (element al phosphorous) and as such, is completely outside the scope of the Mining Waste Exclusion.) Finally, Section 3 describes several related processes such as ammoniated fertilizer production, animal feed production, superphosphoric acid production, fluoride recovery, and sulfuric acid production.

SECTION 1: The Wet Process

1. Discussion of the Typical Production Processes

Wet process steps include digestion, filtration, and concentration. Phosphate rock is dissolved in phosphoric acid, to which sulfuric acid is added. The slurry from this operation is sent to filters where solids are collected, washed, and sent to phosphogypsum stacks. The acid is concentrated by evaporation. The wet process is described in more detail below.

2. Generalized Process Flow Diagram

During digestion, the first step in phosphoric acid production, beneficiated phosphate rock is dissolved in phosphoric acid; sulfuric acid, which chemically digests the calcium phosphate, is added to this solution. The product of this operation is a slurry that consists of the phosphoric acid solution and a suspended solid, calcium sulfate, commonly known as phosphogypsum. The slurry is routed to a filtration operation where the suspended phosphogypsum is separated from the acid solution. The acid isolated during filtration is concentrated through evaporation to produce "merchant grade" (54 percent) phosphoric acid. The phosphogypsum is re-slurried, this time in recycled process wastewater, and sent to disposal in phosphogypsum stacks.[3] Exhibit 2 presents a process flow diagram of phosphoric acid production.[4]

Only five percent of raw product acid is purified. Purification of wet-process acid is accomplished by two primary methods: (1) solvent extraction, and (2) chemical precipitation. Exhibit 3 presents a typical flow diagram for solvent extraction purification of wet-process phosphoric acid. (Purification steps are outside the scope of mineral processing.) In the production of sodium phosphates using chemical precipitation, almost all wet-process acid impurities may be induced to precipitate as the acid is neutralized with sodium carbonate or sodium hydroxide. The main exception, sulfate, may be precipitated as calcium or barium sulfate. Most fluorine and silica can be removed with the sulfate filter cake as sodium fluorosilicate by the addition of sodium ion and control of the Si/F ratio in the process.[5]

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[2] "Phosphoric Acid and the Phosphides," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XVII, 1982, pp. 426-442.

[3] U.S. Environmental Protection Agency, 1990, Op. Cit., pp. 12-1 - 12-61.

[4] Ibid.

[5] Kirk-Othmer Encyclopedia of Chemical Technology, 1982, Op. Cit., pp. 426-442.

EXHIBIT 2

PHOSPHORIC ACID TREATMENT

(Adapted from: Report to Congress on Special Wastes from Mineral Processing, July 1990, pp. 12-1 - 12-61.)

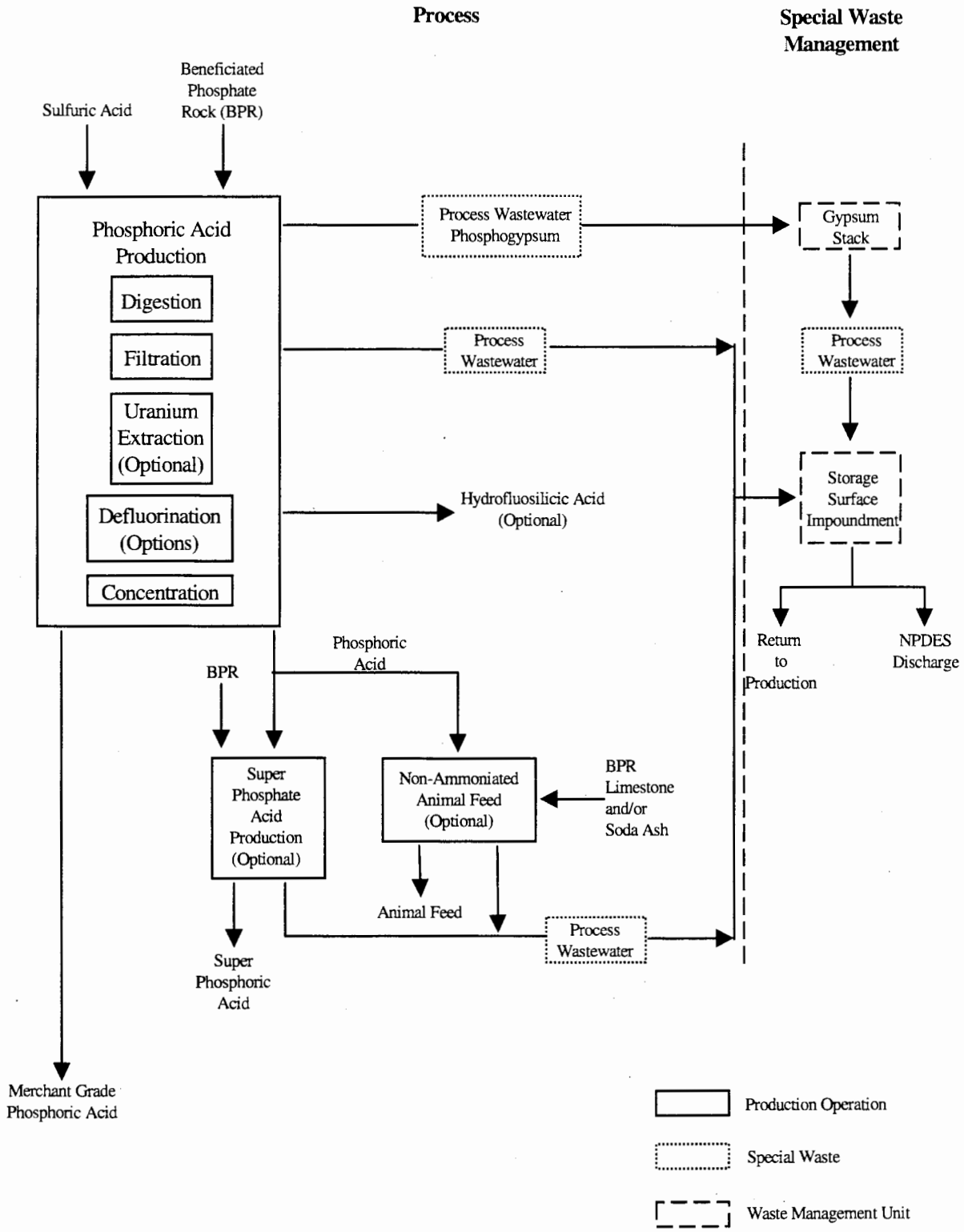
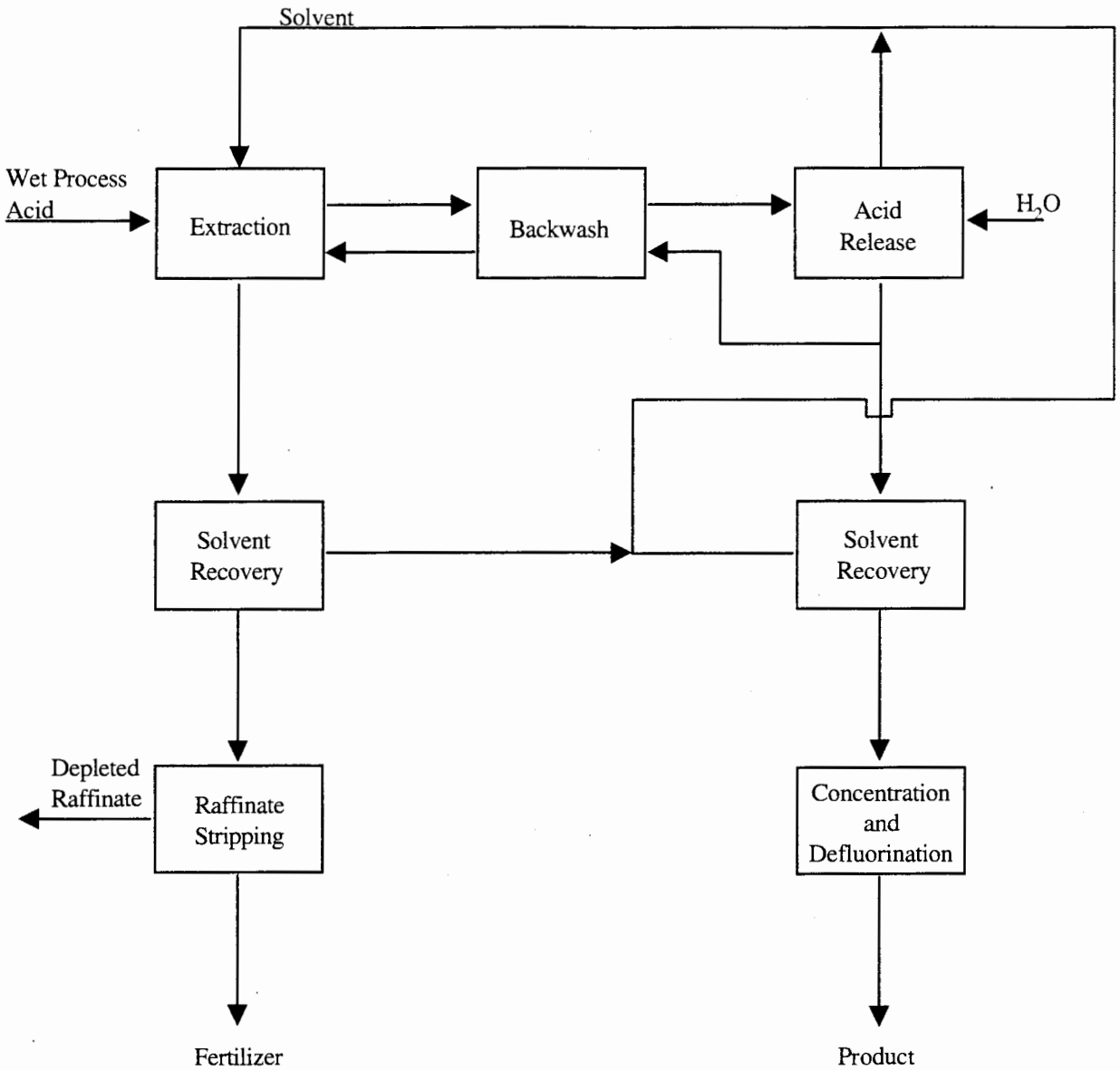


EXHIBIT 3

SOLVENT EXTRACTION PURIFICATION OF WET PROCESS PHOSPHORIC ACID

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1982, pp. 426 - 442.)



In the double-neutralization process for wet process acid purification, sodium fluorosilicate is precipitated and removed by filtration at a pH of 3-4. Upon raising the pH to 7-9, insoluble phosphates of iron, aluminum, calcium, and magnesium form and separate. Iron can be precipitated as hydrous ferric oxide, reducing the phosphate loss in the second filter cake. Both the fluorosilicate and metal phosphate filter residues tend to be voluminous cakes that shrink when dewatered; recovery of soluble phosphates trapped within the cakes is difficult.[6]

The double-neutralization process is used in the production of high volume detergent-builder phosphates because the phosphate precursor solutions occur at pH 7-9. More acidic salts, however, require an additional filtration to eliminate discoloration caused by remaining traces of ferric oxide that precipitate at higher pH.[7]

The increasing cost differential between the sulfur used in manufacture of wet-process acid and the electricity needed for thermal acid has encouraged the development of new processes for purifying wet-process acid. These are based mostly on solvent extraction using organic solvents with low miscibility in water. Crude wet-process acid is typically concentrated and clarified prior to extraction to remove sludge-forming components and improve partition coefficients. Chemical precipitation of sulfate, silicate, and fluoride may also be used as a prepurification step preceding solvent extraction.[8]

Organic-phase extraction of H_3PO_4 is accomplished in a series of countercurrent mixer-settlers, with extraction generally limited to 50-75 percent of the feed acid P_2O_5 content. Higher extraction results in sludge precipitation in the settlers and in the depleted raffinate stream. Raffinate is stripped of residual solvent and used in fertilizer production.[9]

The acid is washed from the organic stream by water or aqueous alkali in another series of countercurrent mixer-settlers, stripped of residual solvent, and concentrated to the desired P_2O_5 level. The solvent is recycled to the extraction section. Many variations of this basic scheme have been developed to improve extraction of phosphate and rejection of impurities to the raffinate stream, and numerous patents have been granted on solvent extraction processes.[10]

Processing phosphate rock to produce phosphate fertilizer is water-intensive. At larger wet process phosphoric acid plants, water use can reach 50,000 gallons per ton of phosphoric acid. At one phosphoric acid plant with a rated capacity of 4,500 tons per day, 155,000 gallons of water per minute are used. Water uses include phosphogypsum transport, phosphoric acid concentration, and phosphoric acid temperature control and cooling.[11]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

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[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] The Fertilizer Institute. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1995.

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for the production of phosphoric acid via the wet process, the beneficiation/ processing line occurs between beneficiation of phosphate rock and digestion, because the beneficiated phosphate rock undergoes a complete acid digestion, which destroys the physical matrix of the rock to yield phosphoric acid and phosphogypsum. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

SECTION 2: The Furnace Process

1. Discussion of the Typical Production Processes

In the furnace process, elemental phosphorus is burned to phosphorus pentoxide which is sent to hydration for the production of phosphoric acid. This entire operation uses a saleable mineral commodity as a primary raw material (elemental phosphorus) and therefore is completely outside the scope of the Mining Waste Exclusion.

2. Generalized Process Flow Diagram

In the manufacture of phosphoric acid from elemental phosphorus, phosphorus is burned in excess air, the resulting phosphorus pentoxide is hydrated, the heats of combustion and hydration are removed, and the phosphoric acid mist is collected. There are three principal process unit types used to deal with the very high combustion-zone temperatures, the reactivity of hot phosphorus pentoxide, the corrosive nature of hot phosphoric acid, and the difficulty of collecting the very fine phosphoric acid mist. These process unit types are (1) wetted wall, (2) water-

cooled, and (3) air-cooled; depending on the method used to protect the combustion chamber wall.[12] Exhibit 4 presents process flow diagrams for the three furnace-grade phosphoric acid production process units.

In wetted-wall units, the walls of a tall circular, slightly tapered combustion chamber are protected by a high volume curtain of cooled acid flowing down inside the wall. Phosphorus is atomized by compressed air or steam into the top of the chamber and burned in additional combustion air supplied by a forced or induced draft fan. Acid sprays at either the bottom of the chamber or in a subsequent, separate spraying chamber complete the hydration of phosphorus pentoxide.[13]

When all the acid is to be converted into sodium phosphate salt, a variation of the wetted-wall acid plant is used. In this case, a relatively noncorrosive, neutral sodium phosphate solution is circulated in lieu of phosphoric acid. Phosphorus pentoxide absorption is rapid and over 95 percent is collected by the circulating stream. Alkali and make-up water are added through a tail scrubber as dilute caustic soda, soda ash, or sodium sesquicarbonate solution adjusted to maintain the system materials balance.[14]

Air-cooled plants are characterized by a large refractory-lined combustion chamber from which waste heat is removed by radiation and convection. The combustion chamber is constructed of carbon steel lined with a single layer of high alumina refractory brick.[15]

Hot combustion gases from both the air-cooled combustion chamber and the water-cooled combustion chamber are quenched and saturated with water in a hydrator. An absorber bed of carbon or graphite rings may be mounted above the hydrator in the same structure to obtain more complete absorption of P_2O_5 and to assure that the gas stream is cooled to about 100°C. Weak acid from mist collection is sprayed on the absorber bed, and product acid at 75-85 percent H_3PO_4 leaves the hydrator through a heat exchanger.[16]

The P_2O_5 initially is hydrated and absorbed in the hot gas stream by direct contact with relatively strong acid. This is often followed by successive stages of scrubbing with progressively more dilute acid and finally, with incoming make-up water.[17]

Since most furnace grade phosphoric acid is used to make food-grade acid, the arsenic it contains must be removed in a purification step. The phosphoric acid is reacted with a small amount of hydrogen sulfide to precipitate arsenic sulfide which is removed by filtration.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

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[12] Kirk-Othmer Encyclopedia of Chemical Technology, 1982, Op. Cit., pp. 426-442.

[13] Ibid.

[14] Ibid.

[15] Ibid.

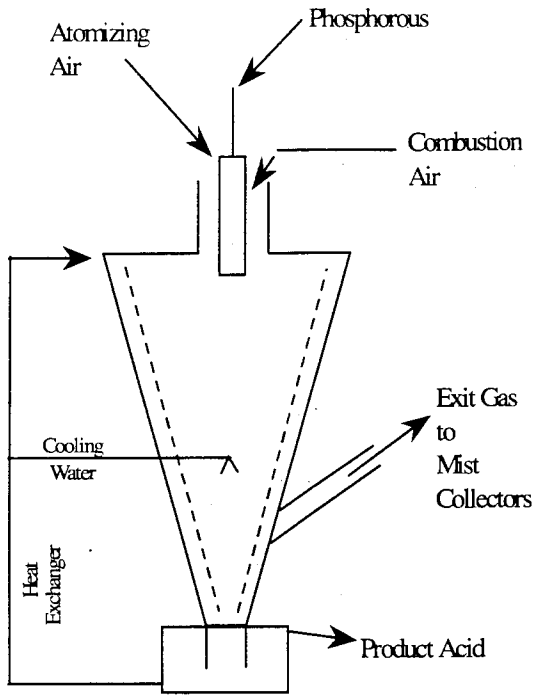
[16] Ibid.

[17] Ibid.

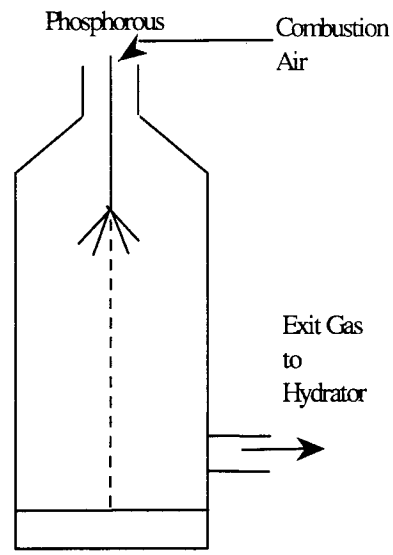
EXHIBIT 4

FURNACE-GRADE PHOSPHORIC ACID PROCESSES

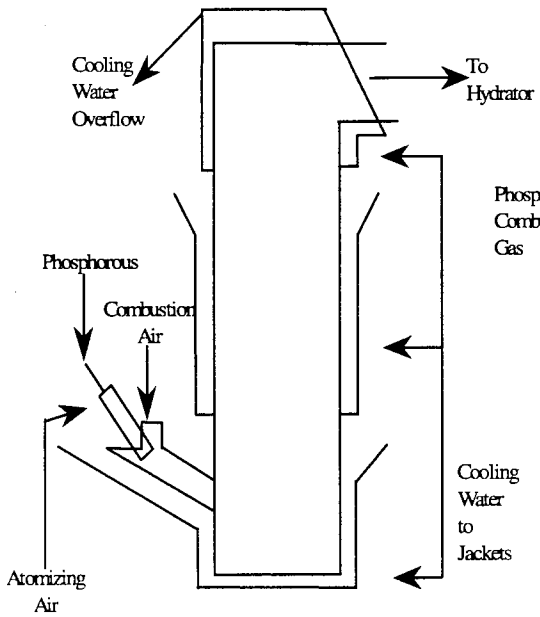
(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1982, pp. 426 - 442.)



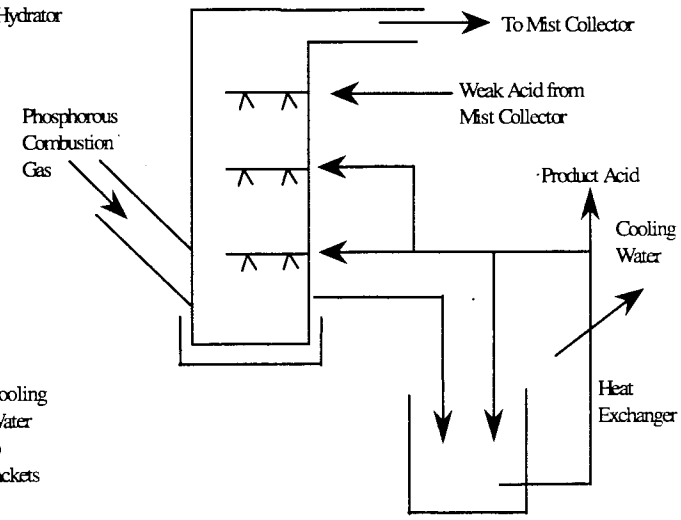
(a) Wetted-Wall Combustion Chamber



(b) Air-Cooled Combustion Chamber



(c) Water-Cooled Combustion Chamber



(d) Hydrator/Absorber

4. Extraction/Beneficiation Boundaries

The furnace process uses a refined mineral commodity and as such, is completely outside the scope of the Mining Waste Exclusion.

SECTION 3: Ancillary Processes

Feed and fertilizer plants, as well as sulfuric acid plants, often are co-located with phosphoric acid facilities. This section describes production of many products related to phosphoric acid. Exhibit 5 presents an overview of phosphoric acid and related product manufacturing operations. All of these ancillary processes use a saleable commodity (merchant grade phosphoric acid) as the primary raw material and, therefore, are outside the scope of the Mining Waste Exclusion.

Fertilizer Operations

About 95 percent of commercial phosphoric acid is used to make ammoniated fertilizer and animal feed. Several facilities produce ammoniated fertilizers such as DAP (diammonium phosphate), MAP (monoammonium phosphate), and GTSP (granular triple superphosphate). MAP and DAP are generated by ammoniating phosphoric acid and GTSP manufacturing involves reacting phosphate rock and phosphoric acid.[18]

Animal Feed Production

Ammonia is reacted with defluorinated P_2O_5 to produce the defluorinated ammonium phosphates Monofos and Duofos. Limestone is reacted with defluorinated P_2O_5 to produce the defluorinated calcium phosphates Dynafos and Biofos. IMC in Mulberry, FL produces up to 2,500 tons per day of these products.[19]

Superphosphoric Acid Operations

Superphosphoric acid is produced from concentrated (54 percent) acid by heating it in a shell and tube heat exchanger, routing it to an evaporator to remove the remainder of the free water, and concentrating the acid to 70 percent. This product can be sold or further filtered. Metallic phosphates are filtered out and routed to the granulated fertilizer feed.[20]

Liquid fertilizer may be produced by first diluting the superphosphoric acid back to 54 percent then ammoniating the acid. Liquid fertilizer is a low volume specialized product produced only on a limited basis.[21]

Silicofluoride Recovery

In order to produce low-fluorine animal feed supplements, P_2O_5 must be defluorinated. IMC in Mulberry, Florida defluorinates 600 tons per day of 54 percent P_2O_5 in a batch tank using silica to remove fluoride. IMC uses

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[18] U.S. Environmental Protection Agency, Supplemental Information on Phosphoric Acid Production: Alternative Management of Process Wastewater at Phosphoric Acid Facilities, Office of Solid Waste, December 1990, pp. A1-5.

[19] Ibid., pp. A2-6.

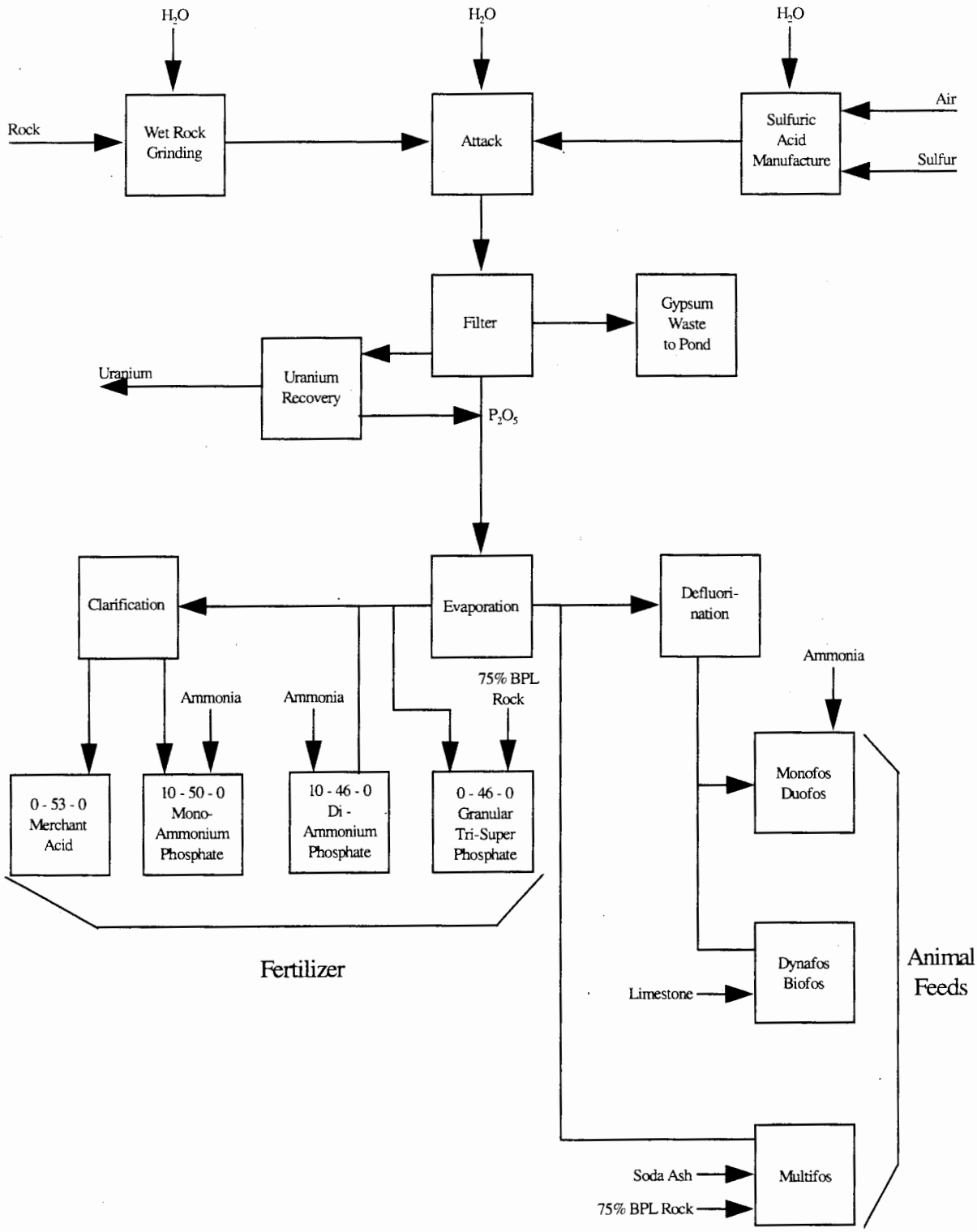
[20] Ibid.

[21] Ibid.

EXHIBIT 5

OVERVIEW OF PHOSPHORIC ACID AND RELATED PRODUCTS PRODUCTION

(Adapted from: Supplemental Information on Phosphoric Acid Production, 1990, pp. A2 - 11.)



16,000 gallons per minute of cooling pond water to condense vapors, which contain SiF_4 and P_2O_5, from two evaporators using barometric condensers. Upon condensing, the SiF_4 is converted to H_2SiF_6. IMC sends 6,000 gallons per minute of the flow to the Multifos plant; the remainder is returned to the cooling pond.[22] USAC in Ft. Meade, Florida recovers 25 percent fluosilicic acid (FSA) as a by-product from the phosphoric acid evaporators and from reaction vapors evolved from the reaction stage. Fluorine compounds are recovered from the vapor in fluosilicic absorption towers at a rate of 55 tons per day. Seventy-five percent of the fluoride present in the vapors is removed. USAC sells its recovered fluosilicic acid to a nearby ALCOA plant that manufactures aluminum fluoride.[23] Gardinier in Riverview, Florida also recovers FSA and in 1992 supplied 70 percent of the domestic market for drinking water fluoridation.[24] Agrico in Uncle Sam, Louisiana collects FSA and either sells it or processes it in an on-site plant to produce silicon tetrafluoride.[25] Agrico in Donaldsonville, LA sells the recovered FSA.

Multifos Plant

IMC reacts non-defluorinated 54 percent P_2O_5, soda ash, and phosphate rock in a high temperature calcining kiln to produce 300 tons per day of tricalcium phosphate, also known as Multifos, another low fluorine animal feed supplement. Wastewaters from this process are returned to the cooling ponds at IMC.[26]

Sulfuric Acid Production

Phosphate rock is reacted with sulfuric acid to make phosphoric acid. At many plants, sulfuric acid is produced on-site by burning sulfur. This process is exothermic and the heat generated is often used to run the plant. At Texasgulf in Aurora, North Carolina, fresh water is used to make sulfuric acid after being purified in a lime softening and ion exchange operation. Texasgulf has five sulfuric acid manufacturing process lines using double absorption with vanadium pentoxide catalysts. This produces 3.4 million tons of 95 percent acid annually.[27] IMC in Mulberry, Florida produces 13,000 tons per day of 98.5 percent sulfuric acid.[28] U.S. Agri-Chemicals in Fort Meade, Florida (USAC) produces sulfuric acid in two double absorption contact sulfuric acid manufacturing plants. Each plant has a capacity of 2,000 tons per day of 98 percent sulfuric acid.[29] Gardinier in Riverview, Florida also manufactures sulfuric acid for the wet process.[30]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

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[22] Ibid., pp. A2-6.

[23] Ibid., pp. A3-4.

[24] Ibid., pp. A4-3.

[25] Ibid., pp. A5-4.

[26] Ibid.

[27] Ibid., pp. A1-3.

[28] Ibid., pp. A2-3.

[29] Ibid., pp. A3-2.

[30] Ibid., pp. A4-2.

4. Extraction/Beneficiation Boundaries

These processes use a saleable mineral commodity as the primary raw material and as such, are completely outside the scope of the Mining Waste Exclusion.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

None are identified.

2. Mineral Processing Wastes

Wet Process

Process wastewater and phosphogypsum are the primary waste streams from the wet process. These wastes have been classified as RCRA special wastes, and are exempt from Subtitle C regulation.

The fertilizer industry typically manages its waste streams in the aggregate. Aggregation allows heat that has built up in the system to assist natural evaporation in water management. Aggregate management of waste streams also is essential to maintaining the water balance at phosphate rock processing facilities. Control of the water balance requires close consideration of a number of factors, including the amount of rainfall, the watershed area, and evaporation rates. Generally across the industry, more than 90 percent of the water used is recycled. Because production and cooling are primary uses, water is generally recycled through cooling ponds. The constant reuse and recycling of water results in buildup of acidity to the point that the recirculating water has significant acid values that make it valuable for reuse and causes it to exhibit the corrosivity characteristic.[31]

Waste scale. This waste is generated at a rate of 41,700 to 208,300 metric tons per year and is generally sent to a cooling pond.[32] This waste is not expected to be hazardous.

Furnace Process

The furnace process uses a refined mineral commodity (elemental phosphorus) and therefore is completely outside the scope of the Mining Waste Exclusion.

Arsenic sulfide sludge. Approximately 0.28 kg per kkg of product of arsenic sulfide is formed during product purification.[33]

Spent filter cake is a possible waste stream generated from the production of phosphoric acid by the furnace process.

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[31] The Fertilizer Institute. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1995.

[32] U.S. Environmental Protection Agency, Technical Background Document, Data and Analyses in Support of the Regulatory Determination for Special Wastes from Phosphoric Acid Production, Office of Solid Waste, Special Waste Program, 1991.

[33] U.S. Environmental Protection Agency, Supplemental Information on Phosphoric Acid Production: Alternative Management of Process Wastewater at Phosphoric Acid Facilities, Office of Solid Waste, December 1990, pp. A1-5.

3. Other Related Wastes

The other related wastes described below are commonly found at phosphoric acid facilities, but are outside of the scope of the Mining Waste Exclusion because they are associated with activities that are downstream of mineral processing and use a saleable commodity as the primary raw material.

Ammoniated Fertilizer Production

Process wastewater is a likely waste stream from ammoniated fertilizer production. In 1991, the waste generation rate for process wastewater from ammoniated fertilizer production was 132,517,000 metric tons per year.[34] This wastewater may be discharged to a cooling pond and may have a low pH.

Sludge is a likely waste stream from ammoniated fertilizer production.

Animal Feed Production

Process wastewater is a likely waste stream from animal feed production.

Sludge is a likely waste stream from animal feed production. The 1991 waste generation rate for this waste stream was 400 metric tons per year.[35]

Superphosphoric Acid Production

Sludge is a likely waste stream from superphosphoric acid production.

Silicofluoride Recovery

Filter cake and **process wastewater** are the waste streams likely to result from silicofluoride recovery operations.

Sulfuric Acid Production

Process wastewater is a likely waste stream from sulfuric acid production. This waste is generated from an ancillary process and as such is outside the scope of this report. At Texasgulf in Aurora, North Carolina, this process wastewater from sulfuric acid production has a pH of about 10 and goes to a neutralization plant. In 1990, the wastewater was discharged via an NPDES outfall at a rate of 80-100,000 gpd.[36] IMC in Mulberry, Florida and USAC in Ft. Meade, Florida create a cooling tower blowdown of pH 7 and a boiler blowdown of pH 11-12. USAC sends these wastewaters to a cooling pond. At IMC, sulfuric acid plant blowdown is kept separate from other process wastewater and is sent to a utility pond.[37]

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[34] Ibid.

[35] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, Vol. I, August 1992, pp. I-2 - I-8.

[36] U.S. Environmental Protection Agency, Op. Cit., 1990, pp. A1-3.

[37] Ibid., pp. A2-3.

On-site production of sulfuric acid for acidulation of phosphate rock also generates secondary materials such as sulfuric acid production vessel cleanout residues. About once a year, small amounts of secondary materials, such as precipitates are removed from sulfuric acid process vessels and product storage tanks. [38]

D. Non-uniquely Associated Wastes

Wastes associated with the ancillary processes often found at phosphoric acid plants are not uniquely associated because they are generated from chemical manufacturing activities, not from mineral processing. These wastes include the wastewaters, sludge, and filtercake (described above) resulting from the production of ammoniated fertilizer, animal feed, sulfuric and superphosphoric acid, and silicofluoride recovery.

Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous) and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

One commenter provided additional factual information about the phosphoric acid production process (COMM 45). This information, where appropriate, has been included in the sector report.

Sector-specific Issues

The commenter also addressed the potential negative implications of the Bevill mixture rule at phosphoric acid production facilities. The commenter noted that materials such as precipitates removed from sulfuric acid vessels and sulfuric acid spills may contain significant acid and sulfur values that can be useful in the phosphoric acid production process. The same may be true for wastes generated by recharging spent ion exchange resins (H_2SO4 and NaOH). According to the commenter, the Bevill Mixture Rule requires these materials to be neutralized before being reused, resulting in a loss of the sulfur and acid values (COMM 45).

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[38] The Fertilizer Institute. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1995.

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PLATINUM GROUP METALS (PGM)

A. Commodity Summary

The platinum-group metals refer to six metals: platinum, palladium, rhodium, ruthenium, iridium, and osmium. Commercially, the two most important metals are platinum and palladium. All of the platinum-group metals are valued for their corrosion resistance and their catalytic activity.[1] According to the U.S. Bureau of Mines, ore containing the platinum-group metals is mined, concentrated, and smelted in Montana. The resulting platinum-group matte is sent to Belgium to be refined and separated. Additionally, platinum-group metals are recovered as byproducts of copper refining by two companies in Texas and Utah. Approximately 30 firms refine secondary metal domestically. Platinum-group metals are used by the following industries: automotive, electrical and electronic, chemical, dental, and medical. The metals are primarily used as catalysts in the automotive and petroleum refining industries.[2] Domestic production was reported as 60,000 kilograms in 1994 (sales as reported to industry) and apparent domestic consumption was estimated at 127,000 kilograms during the same period.[3] Exhibit 1 presents the names and locations of all the facilities involved in the production and refining of platinum-group metals.

The six platinum-group metals can be separated into three pairs: platinum and palladium, ruthenium and osmium, and rhodium and iridium. Each pair exhibits similar physical and metallurgical properties. Platinum and palladium are corrosion resistant and the most malleable. Ruthenium and osmium have the strongest abrasion resistance. Osmium alloys are used as pen tips and ruthenium is used as an electrical contact and as a titanium coating alloy. Rhodium and iridium are the least abrasion resistant and often used as alloying elements for platinum. Rhodium, palladium, and platinum are also used as an automotive catalyst for NO_x reduction[4], and platinum is used in both automobile oxygen sensors and spark plugs.[5]

EXHIBIT 1

SUMMARY OF PLATINUM-GROUP METALS PROCESSING FACILITIES

Facility Name	Location	Type of Operations (source)
Stillwater Mine	Nye, MT	Mining and Beneficiation[a]
Allied Signal	Tulsa, OK	Secondary (spent automotive catalysts)
Allied Precious Metals	Tucson, AZ	Secondary (solutions and sludges)
ASARCO	Amarillo, TX	Secondary
AT & T Metals	Staten Island, NY	Secondary (electronic scrap)
Colonial Metals	MD	Secondary (spent industrial catalysts)
Degussa Corp.	South Plainfield, NJ	Secondary (solutions, electronic scrap, catalysts)

[1] J. Roger Loebenstein, "Platinum-Group Metals," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, p. 995.

[2] J. Roger Loebenstein, "Platinum-Group Metals," from Mineral Commodity Summaries, 1995, pp. 126-127.

[3] J. Roger Loebenstein, 1995, Op. Cit., p. 126.

[4] U.S. Environmental Protection Agency, "Platinum-Groups Metals," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, Office of Solid Waste, p. 3-159.

[5] J. Roger Loebenstein, 1992, Op. Cit., p. 997.

EXHIBIT 1

SUMMARY OF PLATINUM-GROUP METALS PROCESSING FACILITIES (CONTINUED)

Facility Name	Location	Type of Operations (source)
Eastern Smelting and Refining Corp.	Lynn, MA	Secondary (solutions, sludges, catalysts)
Engelhard Corp	Iselin, NJ	Secondary (spent industrial catalysts, electronic scrap)
Gemini Industries	Santa Ana, CA	Secondary (spent industrial catalysts, petroleum catalysts)
Handy and Harman	Fairfield, CT	Secondary
Handy and Harman	South Windsor, CT	Secondary (filter cake, metallic scrap, spent automotive catalysts)
Hauser & Miller	St. Louis, MO	Secondary
JM Ney Co	Bloomfield, CT	Secondary
Johnson Matthey	West Deptford, NJ	Secondary (filter cake, spent automotive catalysts, solutions, unrefined ingot)
Kinsbursky Brothers	Anaheim, CA	Secondary (solutions, electronic scrap, spent automotive catalysts)
Kennecott Copper	Magma, UT	Hydrometallurgical precious metals plant recovers platinum from tankhouse slimes from ore.[6]
Leach and Garner	Attleboro, MA	Secondary
Leytess Metal and Chemical	New York, NY	Secondary
LG Balfour CO	Attleboro, MA	Secondary
Martin Metals	Los Angeles, CA	Secondary (electronic scrap, solid scrap)
McRilley Mark Co.	CA	Secondary
Multimetco, Inc.	Anniston, AL	Secondary (spent automotive catalysts)
Noranda/Micrometallics Corp.	San Jose, CA	Secondary (electronic scrap, filter cakes, sludges, solutions, catalysts, filter media)
Noranda Sampling	Providence, RI	Secondary (electronic scrap, solid scrap)
PGP Industries, Inc.	Santa Fe, CA	Secondary (spent industrial catalysts, sludges, electronic scrap)
Sabin Metals	Rochester , NY	Secondary (electronic scrap, filter cakes, solid scrap)

[6] Kennecott Corporation. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

EXHIBIT 1

SUMMARY OF PLATINUM-GROUP METALS PROCESSING FACILITIES (CONTINUED)

Facility Name	Location	Type of Operations (source)
Sipi Metals	Chicago, IL	Secondary (electronic scrap)
Southwest Smelter & Refining	Dallas, TX	Secondary
Stern Metals	Attleboro, MA	Secondary
Techamet, Inc.	Houston, TX	Secondary (spent automotive catalysts, petroleum catalysts)
Technic, Inc.	Providence, RI	Secondary
Texas Instruments	MA	Secondary
Trifari, Krussman	Providence, RI	Secondary
William Gold Refining	Buffalo, NY	Secondary

[a]Stillwater Mines sends ore to its smelter facility in Columbus, MT.[7]

After the ores have been smelted, Stillwater Mines ships the platinum-group metal concentrate to Brussels, Belgium for refining. The concentrates are toll refined and although Stillwater Mines retains ownership of the metals, the products are generally sold overseas.[8]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Platinum-group metals can be recovered from a variety of different sources, including electrolytic slimes from copper refineries or metallic ores. Secondary platinum-group metals can also be recovered from used equipment, precious metal scrap, petroleum, and spent catalysts (both industrial and automotive). Each source is associated with a distinct recovery process. In one process the insoluble slimes from copper refining are collected and processed to recover any residual metal content. Alternatively, the production of platinum-group metals from ore involves mining, concentrating, smelting, and refining. In the concentrating step, platinum ore is crushed and treated by froth flotation. The concentrates are dried, roasted (sometimes), and fused in a smelter furnace. This step results in the production of a platinum-containing sulfide matte. Solvent extraction is used to separate and purify the six platinum-group metals in the sulfide matte.[9] Secondary platinum group metals recovered from scrap and spent catalysts are refined and used in the fiber glass industry and various catalytic applications.

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[7] Personal Communication between ICF Incorporated and J. Roger Loebenstein, U.S. Bureau of Mines. October 17, 1994.

[8] Ibid.

[9] J. Roger Loebenstein, 1992, Op. Cit., pp. 995-996.

2. Generalized Process Flow Diagram

There are several methods for recovering and refining platinum-group metals, depending on the source material used. Exhibit 2 presents the process flow diagrams for the recovery process of the platinum-group metals from electrolytic slimes. Platinum metals can also be recovered from the ores or from scrap materials. After recovery and initial processing, the concentrates are sent for refining. Exhibit 3 presents a typical refining process used to separate each of the six platinum-group metals from a concentrate.

Recovery From Electrolytic Slimes

Often, platinum-group metals are recovered from the slimes that collect in the electrolytic refining cells used at copper refineries. These slimes are the insoluble material from impure copper anodes that are dissolved as part of the copper refining process. As shown in Exhibit 2, after the slimes are heated, H_2SO_4 is added to the dried slimes which then undergo an acid digestion step. Following acid digestion, the slimes are often, but not always, roasted and then processed by several leaching steps to remove any remaining copper. After the leaching, the resultant decopperized slimes are melted with a soda-silica flux in a reverberatory furnace. This flux helps in the formation of a siliceous slag which is removed from the furnace. Air is then blown through the molten metal followed by the addition of a lime flux. The air oxidizes any remaining lead and the lead oxide forms a slag with the lime which is then removed from the furnace. The siliceous and lead slags are either recycled or sent to a lead smelter. Following slag removal, fused soda ash is added to the furnace to form soda slag which is also removed and sent off-site for tellurium and selenium recovery. The resultant metal is a dore alloy composed of gold, silver, and platinum-group metal and is processed to recover these metal values.[10]

Recovery From Metal Ores

Although alluvial deposits are the result of natural concentration processes involving weathering and gravity separation phenomena, further treatment is required to yield a product suitable for marketing and refining. At Stillwater, Montana, platinum and palladium are recovered via froth flotation of sulfide minerals. The ore is sent to a concentrator, followed by froth flotation, and then sent to a smelter operation in Columbus, Montana. The resulting precious metals matte (solid form) is then sent to MHO metallurgy in Belgium for refining.[11]

An alternative method of recovering platinum-group metals from ore in South Africa involves initial treatment to reduce the ore to a suitable size via crushing, followed by froth flotation to separate out the platinum-group metal particles. The flotation concentrates are separated into platinum-bearing minerals and free-metallic particles by conventional gravity methods. The remainder is further concentrated by smelting, oxygen blowing, magnetic separation, and pressure leaching.

The froth can be prepared for smelting by thickening, filtering, drying, and pelletizing. The pellets are smelted in an electric smelter with submerged-arc consumable electrodes. Fluxes and additions are made during smelting to obtain a matte that contains principally copper-nickel-iron and platinum-group metals. The matte is then treated by oxygen blowing to produce a high grade matte. The matte is crushed, ground, and magnetically separated. Any non-magnetic portion is treated by pressure leaching to release copper, nickel, and cobalt. The remaining solution is recirculated back into the magnetic stream and this mixture is then pressure leached, yielding a final concentrate. This concentrate along with the mineral material released previously are sent to a refinery for further treatment.[12]

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[10] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-159.

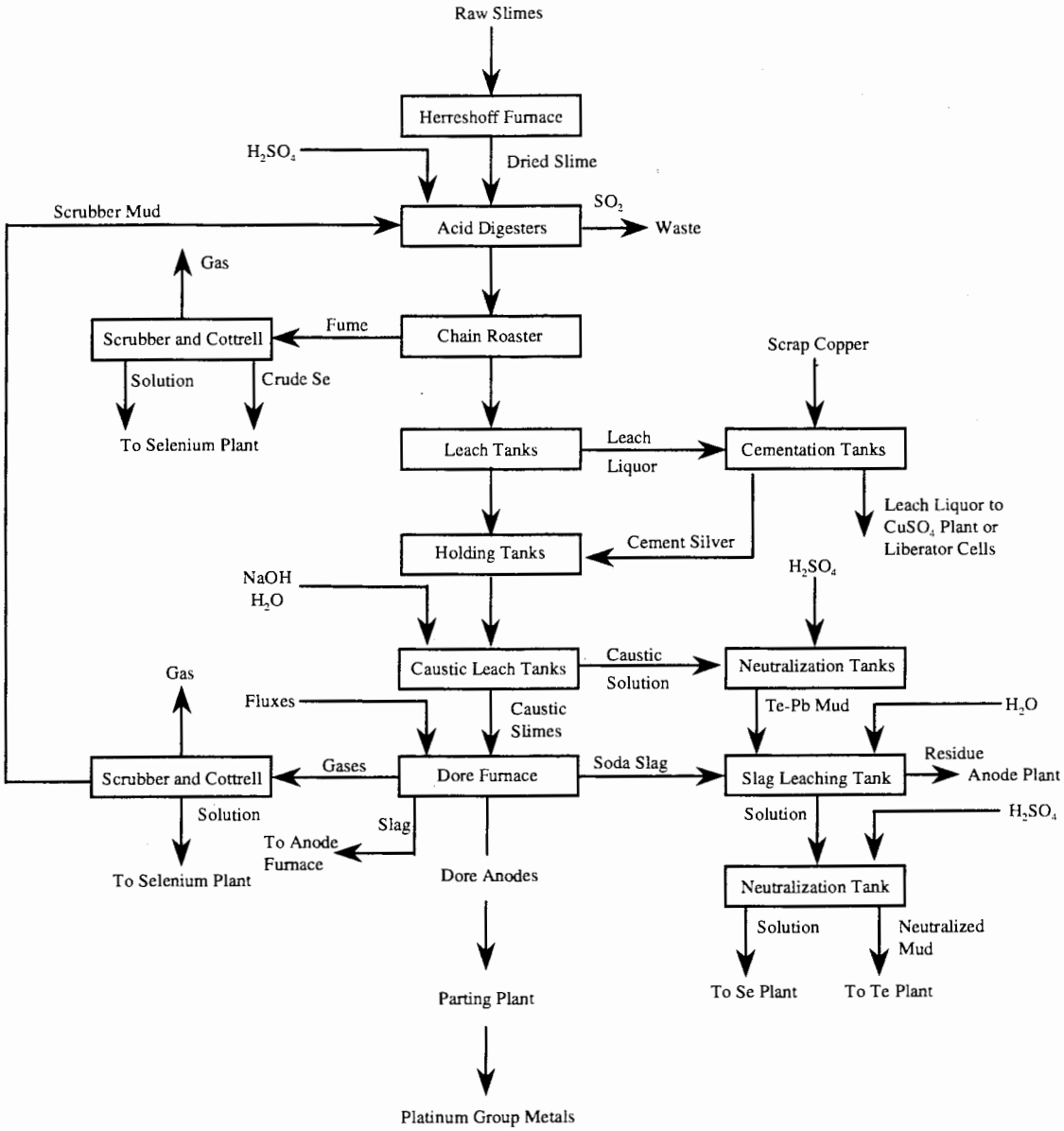
[11] Personal Communication between Jocelyn Spielman, ICF Incorporated and J. Roger Loebenstein U.S. Bureau of Mines, October 17, 1994.

[12] "Platinum-Group Metals," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed. Vol. XVIII, 1982, p. 234.

EXHIBIT 2

PLATINUM GROUP METAL RECOVERY FROM COPPER REFINING SLIMES

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-158 - 3-163.)



Refining

Stillwater Mine sends the platinum-group metal concentrate out of the country for refining after it is processed at their smeltering facility in Columbus, Montana.[13] Other platinum-group metals facilities in the United States refine secondary platinum-group metals from used equipment, scrap metals, petroleum, and spent catalysts. The refining process takes advantage of the solubility of platinum and palladium. Each platinum group metal is removed from the platinum-group metal concentrate in order of its solubility. Exhibit 3 presents the typical order of removal. In general, platinum and palladium are removed first, followed by rhodium, ruthenium, osmium, and iridium. Exhibit 3 also presents various compounds that may be produced through further purification of each individual platinum-group metal.

Platinum and palladium

Most refining procedures are based on the ready solubility of gold, platinum, and palladium in aqua regia and the ease with which gold can be reduced to the metallic form from the chloride solution by the addition of ferrous salts or sulfur dioxide. Solvent extraction is used as an alternative method for separating gold at some refineries.[14] In the aqua regia refining process, platinum metal concentrates are treated with aqua regia to dissolve platinum, palladium, and gold. The other platinum-group metals (ruthenium, osmium, iridium, and osmium) and silver are insoluble. After the gold is separated from the solution either by reduction or solvent extraction, the remaining solution is treated with ammonium chloride to precipitate the platinum as ammonium chloroplatinate. The palladium remains in solution.[15]

The filtrate from the platinum-recovery contains palladium chloride and can be treated with ammonia and hydrochloric acid. The solution is heated to yield a solution of palladium (II) tetrammine dichloride. The addition of hydrochloric acid causes the formation of palladium dichloride diammine as a precipitate which can easily be dissolved in cold dilute ammonia. The resultant high-purity salt, when heated, can be converted readily into metal. Some refineries reduce pure palladium salt to palladium black with formic acid. The palladium black can then be ignited to form a palladium sponge. The aqueous byproducts of the formic acid are easier to handle than the corrosive fumes that result from firing the salts.[16]

The undissolved materials remaining after the aqua regia and any platinum-group metals recovered after the removal of platinum and palladium from solution are combined with concentrates high in rhodium, ruthenium, and iridium. Fluxing materials, such as lead carbonate plus carbon, are added, following which the mixture is heated. The molten charge is poured into a conical mold and solidified. After solidification, the slag is removed and the lead which contains rhodium, iridium, ruthenium, and silver is melted, granulated, and treated with nitric acid. The lead and silver are dissolved and removed, leaving an insoluble residue containing the platinum-group metals.[17]

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[13] Personal Communication between ICF Incorporated and J. Roger Loebenstein, U.S. Bureau of Mines, October 17, 1994.

[14] "Platinum-Group Metals," 1982, Op. Cit., p. 238.

[15] Ibid.

[16] Ibid.

[17] Ibid.

EXHIBIT 3

PLATINUM GROUP METAL REFINING

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1982, pp. 228 - 239.)

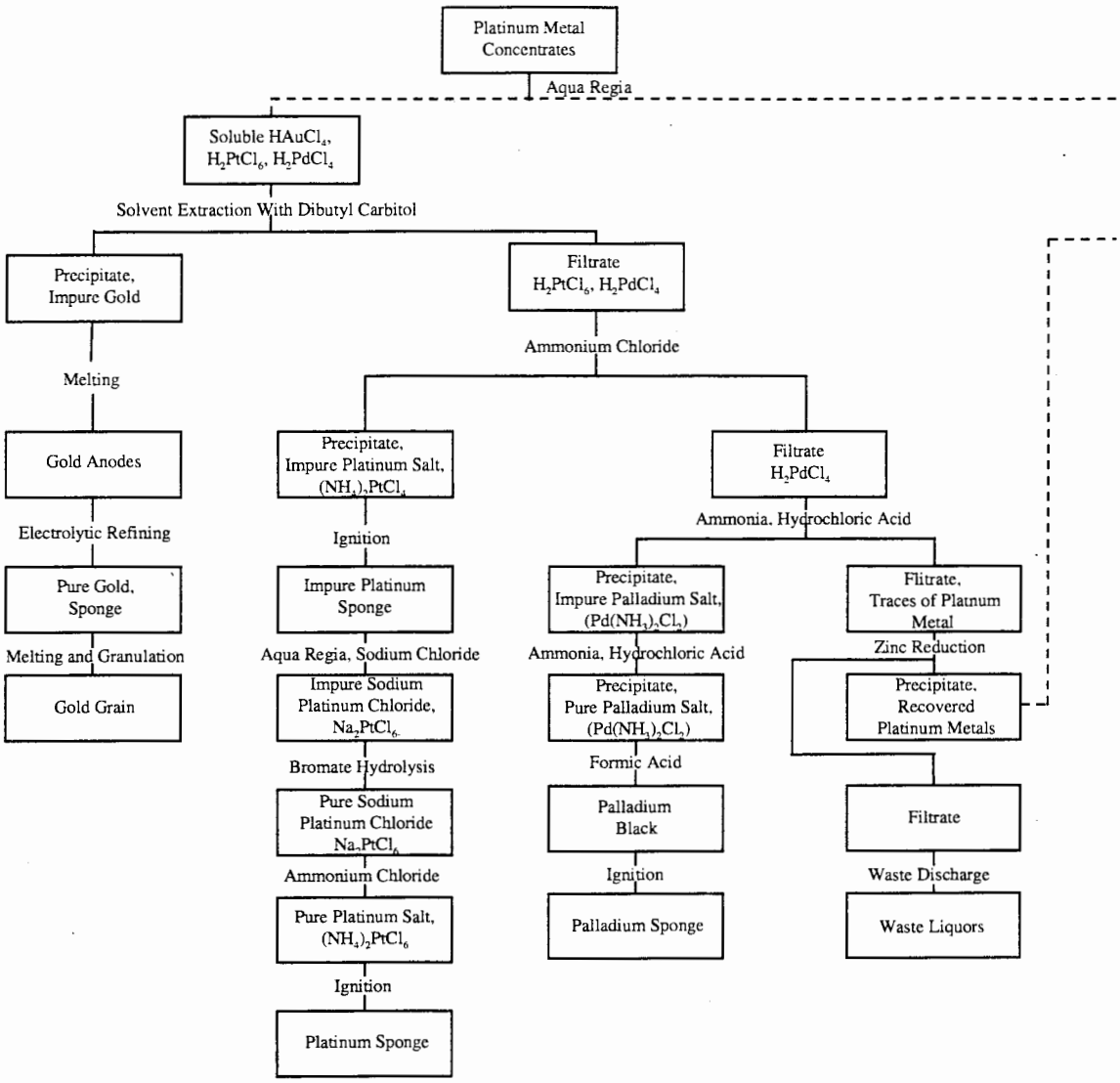
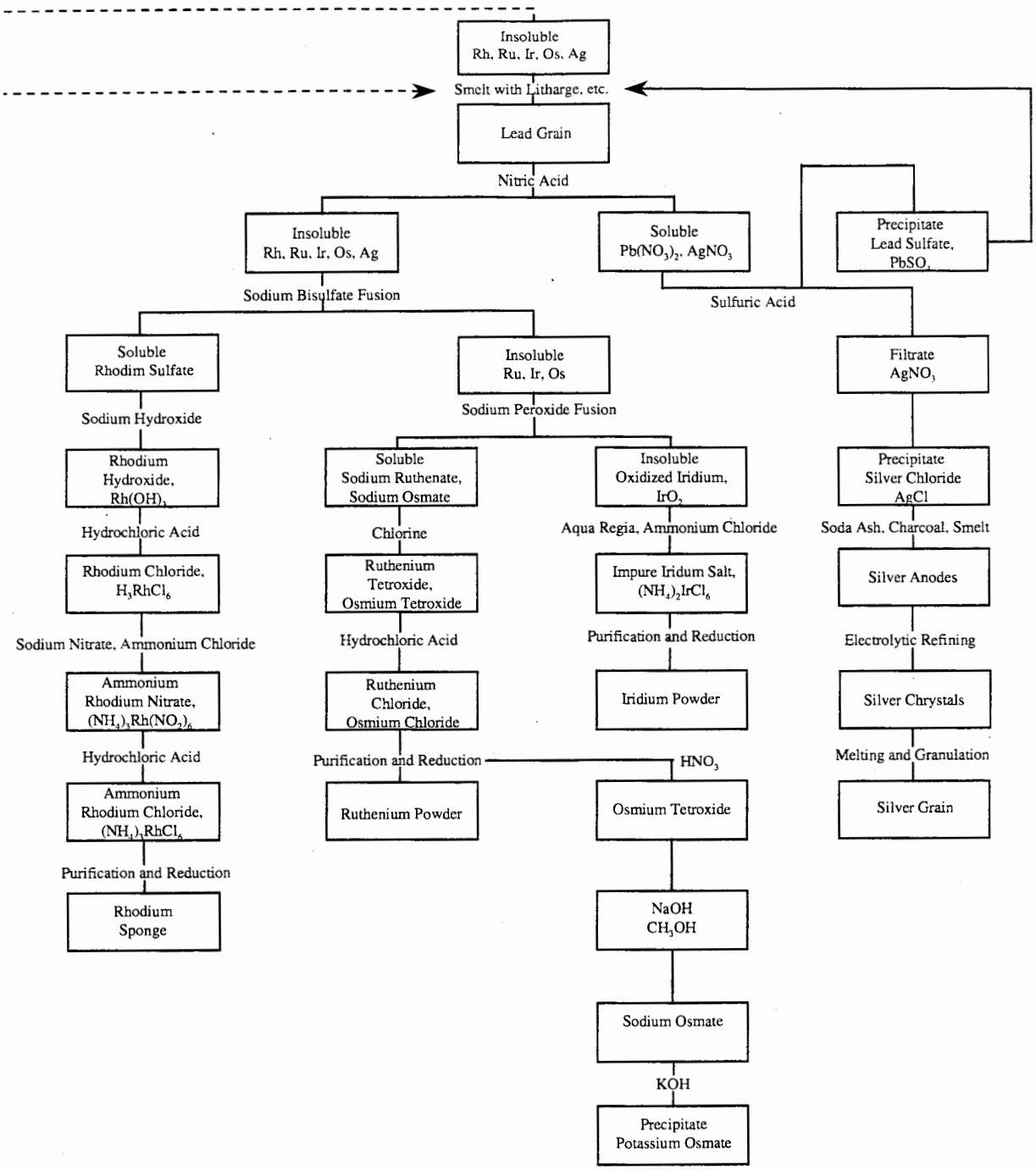


EXHIBIT 3 (Continued)



Rhodium

The residue is then treated with sodium bisulfate and heated to 500° C to convert rhodium into the sulfate. After sodium hydroxide is added, the resultant crude hydroxide is precipitated out, washed, dissolved in hydrochloric acid (HCl), neutralized with sodium carbonate and treated with sodium nitrite. These steps yield the stable complex $(NH_4)_3[Rh(NO_2)_6]$. The contaminating base metals can be precipitated out of solution through hydrolysis, while leaving rhodium in solution. Rhodium can be precipitated by the addition of ammonium chloride, following which the ammonium salt is treated with HCl and the solution is passed through an ion exchange column. Ion exchange separates ammonium and any base metals from the high-purity rhodium, leaving it in solution. The rhodium is precipitated as finely divided metal by boiling with formic acid. After washing, the metal is ignited then cooled under hydrogen.[18]

Ruthenium

The ruthenium, osmium, and iridium residue from the bisulfate fusion is mixed with sodium peroxide and heated to 500° C, yielding sodium ruthenate and sodium osmate. These compounds are dissolved in water and treated with chlorine in a distillation apparatus. The resultant ruthenium tetroxide and osmium tetroxide are absorbed in dilute HCl. After boiling, the chloride solution is mixed with nitric acid to remove osmium. The mixture is then treated with ammonium chloride to yield ammonium chlororuthenate crystals. The latter are washed and ignited to yield ruthenium which is treated and cooled in hydrogen to give pure ruthenium powder.[19]

Osmium

Osmium tetroxide is produced in the same process as ruthenium tetroxide. After the osmium is removed from the ruthenium solution, the osmium tetroxide is then converted to sodium osmate. The addition of KOH causes the formation of precipitate potassium osmate. The salt is stored and can be converted to osmium metal.

Iridium

The insoluble iridium dioxide is converted with aqua regia to the chloride which is then precipitated with additional nitric acid and ammonium chloride. This salt is dissolved in a dilute ammonium sulfide solution in which impurities precipitate as sulfides, whereas the iridium remains in solution. Treatment with nitric acid and ammonium chloride yields pure ammonium chloroiridate which, upon ignition and reduction by hydrogen, yields pure iridium powder.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

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[18] Ibid.

[19] Ibid.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between froth flotation and smelting for the recovery of platinum group metals from metal ores. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where a significant chemical change to the sulfide mineral ore occurs. EPA also determined that all wastes generated during the recovery of platinum group metals from copper electrolytic slimes are mineral processing wastes. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Although Exhibits 2 and 3 identify the following wastes as associated with the production of platinum-group metals, no characterization, generation, or management data are available for these wastes.

Concentration

Tailings and Filtrate. Tailings are generated during the froth filtration and sent to a tailings pond for disposal.

Wastewater. Wastewater from the thickening process is likely to contain heavy metals.

2. Mineral Processing Wastes

Recovery

Scrubber Off-gases. As shown in Exhibit 2, off gases are generated from the scrubber following roasting.

SO_2 Waste. As shown in Exhibit 2, waste sulfur dioxide is produced from acid digestion.

Smelting

Slag. The slag generated during smelting is likely to contain metallic particles and may be crushed and blended with concentrate for recycling to the electric furnace.[20] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 5 metric tons/yr, 46 metric tons/yr, and 460 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be recycled and may exhibit the characteristic of toxicity (lead and selenium). This waste is classified as a by-product.

Refining

Spent Solvents. After dissolving the material to be refined in aqua regia, a series of elements (e.g., gold, platinum, and palladium) are precipitated from the solution. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 300 metric tons/yr, 1,700 metric tons/yr, and 3,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (lead and silver) and ignitability.

Spent Acids. Following solvent extraction, the insoluble platinum-group metals (e.g., rhodium, iridium, osmium, and ruthenium) are separated to yield pure metals. The resultant wastes from these processes would most likely be spent acids which might contain residual metals.[21] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 300 metric tons/yr, 1,700 metric tons/yr, and 3,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (lead and silver), corrosivity, and reactivity.

D. Non-uniquely Associated Hazardous Wastes

Non-uniquely associated hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naphtha), and acidic tank cleaning wastes.

E. Summary of Comments Received by EPA

New Factual Information

One comment was received to correct information about one facility in Utah. EPA has incorporated this new information into the document. (COMM 40)

Sector-specific Issues

None.

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[20] Gregg J. Hodges, et. al., "Stillwater Mining Co.'s precious metals smelter: From pilot to production, Mining Engineering, July 1991.

[21] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-162.

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U.S. Environmental Protection Agency. "Platinum-Group Metals." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. Office of Solid Waste. 1988. pp. 3-158 - 3-163.

PYROBITUMENS, MINERAL WAXES, AND NATURAL ASPHALTS

A. Commodity Summary

Bituminous materials comprise a group of hydrocarbons including pyrobitumens, mineral waxes, and asphalts. Pyrobitumens are mined predominately in Utah and are used in rubber, paints, varnishes, and insulating and waterproofing compounds.

Mineral waxes are not present in the United States as a natural substance, and therefore, must be extracted from lignite or cannel coal. Although coal exists in many parts of the United States, the only known production of mineral waxes from coal occurs in California. The use of this extraction product, known as "Montan Wax," is limited to paints, wood fillers, floor polish, rubber mixtures, and candles.

In the United States, naturally occurring asphalt (gilsonite) is found in commercial quantities only in eastern Utah and western Colorado. There are three types of naturally occurring asphalt: native asphalt (bitumen), lake asphalt, and rock asphalt.[1] Asphalts have a variety of uses including paving, flooring, roofing, and waterproofing. American Gilsonite in Bonanza, Utah is the world's largest producer and exporter of gilsonite (natural asphalt). The only other producer of natural asphalt is Ziegler Chemical and Mineral Corporation, also in Utah.

B. Generalized Process Description

1. Discussion of Typical Production Processes

The production processes associated with the production of pyrobitumens, mineral waxes, and natural asphalts are limited to a few simple operations, including extraction, grinding, blending, and packaging. Exhibits 1 through 3 present simplified process flow diagrams for the production of pyrobitumens, mineral waxes, and natural asphalts. The production processes and wastes associated with each mineral commodity are discussed below.

2. Generalized Process Flow Diagram

Pyrobitumens

As shown in Exhibit 1, the production process for pyrobitumens consists of cracking in a still, recondensing, and grading. Due to the low cost and availability of petroleum refining substitutes, the production of pyrobitumens appears to be low.

Mineral Waxes

As shown in Exhibit 2, mineral wax processing consists of solvent extraction from lignite or cannel coal. Cannel coals yield a material that contains 60 to 90 percent light yellow or brown waxy substances. The crude wax is refined by extracting, typically with a mixture of benzene and methanols. Distilling the solvent leaves a wax too darkly colored to be used without added refining. Acid mixtures are used to oxidize and remove the dark materials, leaving a series of bleached waxes.[2] The extraction product is known as "Montan Wax." Extraction solvents used in the production of mineral waxes may be listed in 40 CFR 261 Subpart D.[3]

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[1] "Asphalt," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. III, 1992, pp. 689-724.

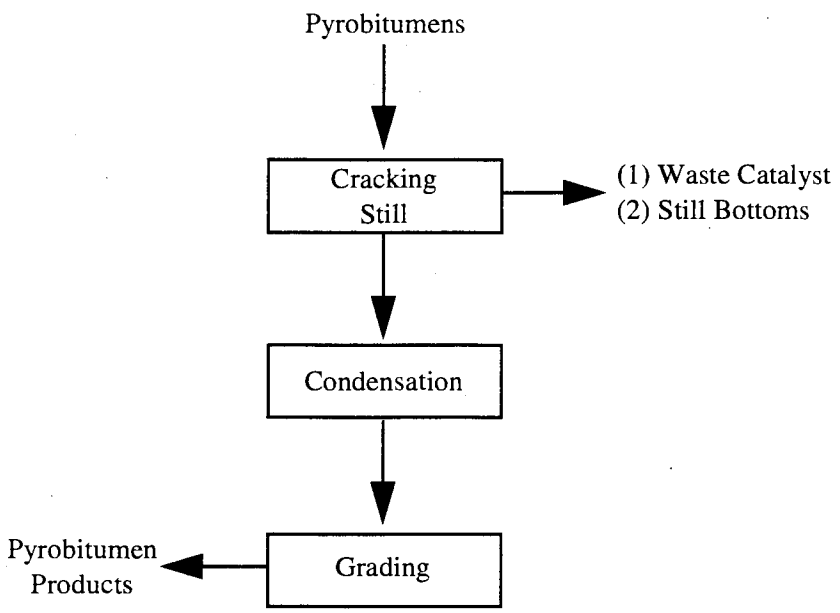
[2] "Lignite," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. XV, 1995, p. 316.

[3] U.S. Environmental Protection Agency, Technical Background Document, Development of the Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, Office of Solid Waste, 1989, pp. A-9.

EXHIBIT 1

PYROBITUMEN PROCESSING

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988.)

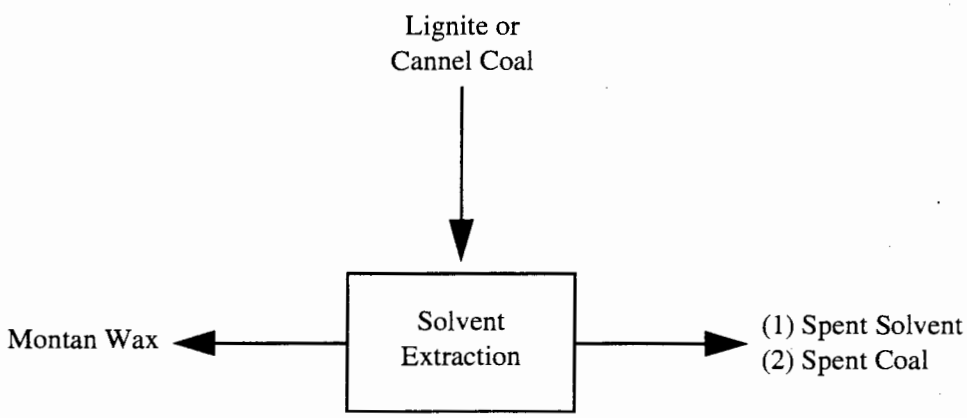


Source: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. 1988.

EXHIBIT 2

MINERAL WAX PRODUCTION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988.)



Source: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988.

Natural Asphalts

American Gilsonite operates a 110 ktpy facility in Bonanza, Utah. Mine development begins with the boring of shafts. The shafts are equipped with steel inserts that are comprised of four pipes equally spaced around the perimeter of the shaft. Once a shaft is bored, inserts are lowered into the borehole. As each section is lowered into the shaft the next section is lined up with it, and the two are welded together at the surface. This procedure is repeated until the inserts line the shaft from top to bottom. When a mine is worked out the liner assembly is pulled and reused. Hand-held pneumatic chipping hammers with moilpoint bits are used to break out the ore. Broken ore flows by gravity to the toe of the sloping face at the floor of the drift. From there it is airlifted to the surface through a pipe. When air lifted ore reaches the surface it enters a baghouse. The larger pieces drop first, and the rest is collected in filter bags. All solids are discharged into elevated storage bins and are then transferred by truck to a processing plant.

American Gilsonite's plant consists of concrete storage silos, truck receiving bins, a vibrating bed dryer, pulverizing machinery, and packaging equipment. Pneumatic conveying systems and sophisticated dust control equipment are state-of-the-art and allow for the handling of gilsonite in large quantities. Before entering the processing plant, gilsonite ore is segregated by grade in receiving bins. From these bins the ore is processed through a vibrating bed dryer, where excess moisture is removed. It is then passed over a double-deck screen, where it is classified according to particle size for storage in silos. From the silos, ore is fed to product bins from which it is either loaded directly as bulk product, fed to a bagging machine, or fed to a pulverizer. Pulverized product is segregated into product bins from which it can be loaded directly as bulk product or packaged at a second bagging machine.[4] Exhibit 3 contains the natural asphalt production process diagram.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as

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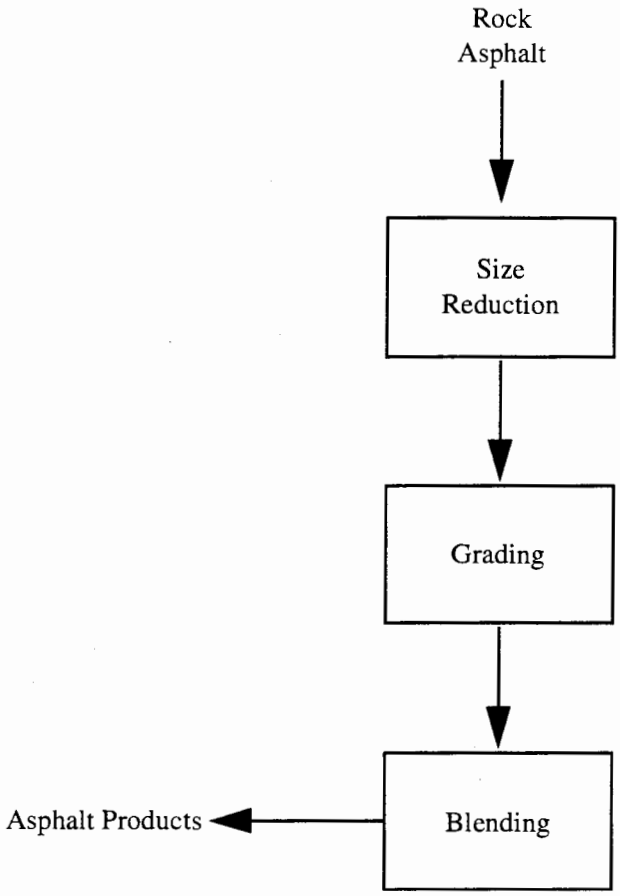
[4] Harry D. Lewis, "Gilsonite," from Industrial Minerals and Rocks, Society of Mining, Metallurgy, and Exploration, 1994, pp. 535-541.

EXHIBIT 3

NATURAL ASPHALT PRODUCTION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988.)



Source: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988.

information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

Pyrobitumens

EPA determined that for pyrobitumens, the beneficiation/processing line occurs when the pyrobitumens are thermally cracked in a still to produce a significantly altered material. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Mineral Waxes and Natural Asphalts

Based on a review of the processes, there are no mineral processing operations involved in the production of mineral waxes or natural asphalts.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Pyrobitumens

None identified.

Mineral Waxes

Probable wastes from the production of mineral waxes include **spent solvents** and **spent coal**.

Natural Asphalt

None identified.

2. Mineral Processing Wastes

Pyrobitumens

Still bottoms. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 2 metric tons/yr, 45,000 metric tons/yr, and 90,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic ignitability.

Waste catalyst. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 2 metric tons/yr, 10,000 metric tons/yr, and 20,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of toxicity for cadmium and selenium. This waste may be recycled and is classified as a spent material.

Mineral Waxes

None identified.

Natural Asphalt

None identified.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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U.S. Environmental Protection Agency. Technical Background Document, Development of the Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes. Office of Solid Waste. 1989. pp. A-9.

U.S. Environmental Protection Agency. "Bituminous Materials." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. 1988. pp. 2-70 - 2-76.

RARE EARTHS

A. Commodity Summary

The rare earth elements are comprised of scandium, yttrium, and 15 lanthanide elements, of which cerium, lanthanum, and neodymium are the most abundant. While rare earth elements are found in several minerals, almost all production comes from less than 10 minerals, primarily monazite and bastnasite. Because the scandium industry is, for the most part, separate and distinct from the yttrium and lanthanide industries it is the subject of a separate commodity summary (see the chapter on scandium).

The United States is a major producer and consumer of rare earth ores and compounds that are used in petroleum fluid cracking catalysts, chemical and pollution-control catalysts, metallurgical applications, glass and ceramics, permanent magnets, phosphors, and electronics.[1]

In 1993 two domestic mines, Molycorp, Incorporated and RGC (USA) Minerals Incorporated, produced rare earths. Molycorp, Inc.'s facility in Mountain Pass, CA is the sole producer of rare earth minerals from bastnasite ore.[2] In 1995, Molycorp supplied over 60 percent of U.S.-produced cerium products, with competition from China, the former states of the U.S.S.R., and India.[3] The use of bastnasite ore is preferred in the market over monzanite ore because of due to lower concentrations of natural radionuclides which results in lowers worker exposures to low level radiation.[4] The Mountain Pass facility is an integrated mining and beneficiation/processing facility.[5] Twenty facilities produce rare earth materials. Exhibit 1 presents the names, locations, and products of the facilities involved in the production of rare earth materials, however, not all of these facilities engage in primary mineral processing activities.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Most production of rare earth elements is from the minerals monazite and bastnasite. Processing of these ores is by sulfuric and hydrochloric acid digestion. The compounds recovered from these processes must be processed further to produce and recover rare earth metal compounds. Processes include solvent extraction and reduction.[6] Exhibits 2 through 6 present typical process flow diagrams for the production of rare earths.

Bastnasite is produced only by Molycorp at Mountain Pass, California. It is produced as a mineral concentrate and consumed captively at this facility. Monazite is produced by Associated Minerals at Green Cove Springs, Florida as a byproduct of beach sand mining for titanium and zircon minerals.[7]

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[1] James Hedrick, "Rare Earths," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 134-135.

[2] Molycorp, Inc., Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, January 25, 1996.

[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Ibid.

[7] U.S. Environmental Protection Agency, Technical Background Document, Development of the Cost, Economic and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, Office of Solid Waste, 1989, pp. A-21 - A-22.

2. Generalized Process Flow

Mining

At Mountain Pass, Molycorp mines rare earth ore in an open pit approximately 100 meters deep. Blast holes drilled at 3 to 4 meter spacing are routinely assayed for total rare earth oxides and other elements by fluorescence methods. Approximately 300 kilotons per year are mined with a stripping ratio of 5:1. The ore is crushed and blended in stockpiles that contain about 40 kilotons and fed to a mill located less than 100 meters from the pit.[8]

EXHIBIT 1

SUMMARY OF RARE EARTHS PROCESSING FACILITIES

Facility Name	Location	Products
Crucible Materials	Elizabethtown, KY	Rare earth magnets
Delco Remy Division of General Motors	Anderson, IN	Rare earth magnets, neodymium-iron-boron magnet alloys
Hitachi Magnetics	Edmore, MI	Rare earth magnets
IG Technologies	Valparaiso, IN	Rare earth magnets
Molycorp[9]	Mountain Pass, CA	Bastnasite mine
Mountain Pass Mine & Mill	Mountain Pass, CA	Uncertain
Neomet	West Pittsburgh, PA	Neodymium-iron-boron magnet alloys
Nord Resources	Jackson, NJ	Uncertain
Reactive Metals & Alloys Corp.	West Pittsburgh, PA	Mischmetal
Research	Phoenix, AZ	Uncertain
RGC (USA) Mineral Inc.	Green Cove Springs, FL	Byproduct monazite
Rhone-Poulenc Chemicals Co.	Phoenix, AZ Mineville, NY Freeport, TX	Neodymium-iron-boron magnet alloys Uncertain Uncertain
W.R. Grace	Chattanooga, TN	Uncertain

[8] James Hedrick, "Rare Earths, the Lanthanides, Yttrium, and Scandium," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 1035-1047.

[9] Molycorp, Inc., 1996, Op. Cit

Molycorp's mine was the leading producer of rare earths in both the United States and the rest of the world in 1992. In 1993, mine production decreased from the 1992 level of 22,713 tons to 16,465 tons of rare earth oxides.[10]

Almost all mining of heavy mineral sands from surface placer deposits is done by floating cutterhead or bucket wheel dredges that concentrate the heavy minerals onboard and discharge the unwanted tailings back into previously mined areas. An onboard wet mill separates the heavy minerals from the lighter weight fraction through wet gravity equipment that includes a series of screens, hydroclones, spirals, and cones. Wet mill mixed heavy mineral concentrate is sent to a dry mill to separate the individual heavy minerals and produce a concentrate. Dry mill processing includes a combination of scrubbing, drying, screening, electrostatic, electromagnetic, magnetic, and gravity processes. Gravity methods include the use of jigs, spiral and cone concentrators, and shaking tables. Sizing and preconcentration commonly is performed at the mine site by trommels, shaking screens, and gravity separation. Many dredges have such facilities on board or utilize floating preconcentration plants.[11] Monazite can be separated from zircon by electrostatic methods such as electromagnetic or gravity methods. Xenotime is usually separated from monazite by precise gravity methods. Some deposits may require acid leach treatment and calcining to eliminate iron oxide or other grain coatings.

Some sand deposits, too difficult to mine by dredging, are mined using dry methods. Ore is stripped with scrapers, bulldozers, and loaders. Sands recovered by these techniques are crushed, screened, and processed by the wet mill equipment described above.

Recovery

Monazite Ore Processing

Rare earth metals are recovered as oxides from monazite ore by sulfuric acid digestion (Exhibit 2). The ore undergoes grinding, spiraling, or other similar operations for the initial coarse purification of the ore. Magnetic separation removes the magnetic ore constituents which can be processed separately or discarded as waste. The refined ore is then digested with sulfuric acid at 200-220°C. Rare earth sulfates and thorium sulfates are then dissolved and removed from the waste monazite solids by filtration. Rare earth elements are then precipitated as oxalates or sulfates. These precipitates undergo caustic digestion or roasting to form rare earth oxides which are finally recovered by filtration. The resulting filtrate is discarded as waste.[12]

Bastnasite Ore Processing

To recover rate earths from bastnasite ore, the ore is crushed, ground, classified, and concentrated to increase rare earth concentrations.[13] These processes, as well as the subsequent beneficiation and mineral processing steps, are described in the following paragraphs. The final filtration step yields lead and iron filter cake while the final drying step yields the rare earth concentrates.[14]

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[10] U.S. Bureau of Mines, Rare Earths Annual Report, 1993.

[11] Stephen B. Castor, "Rare Earth Minerals," from Industrial Minerals and Rocks, 6th ed., Society for Mining, Metallurgy, and Exploration, 1994, pp. 827-837.

[12] U.S. Environmental Protection Agency, "Rare Earths," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-164 - 3-174.

[13] Molycorp, Inc., Comment submitted in response to the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, May 12, 1997.

[14] Ibid.

EXHIBIT 2

RECOVERY OF RARE EARTHS FROM MONAZITE BY THE SULFURIC ACID PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-164 - 3-174.)

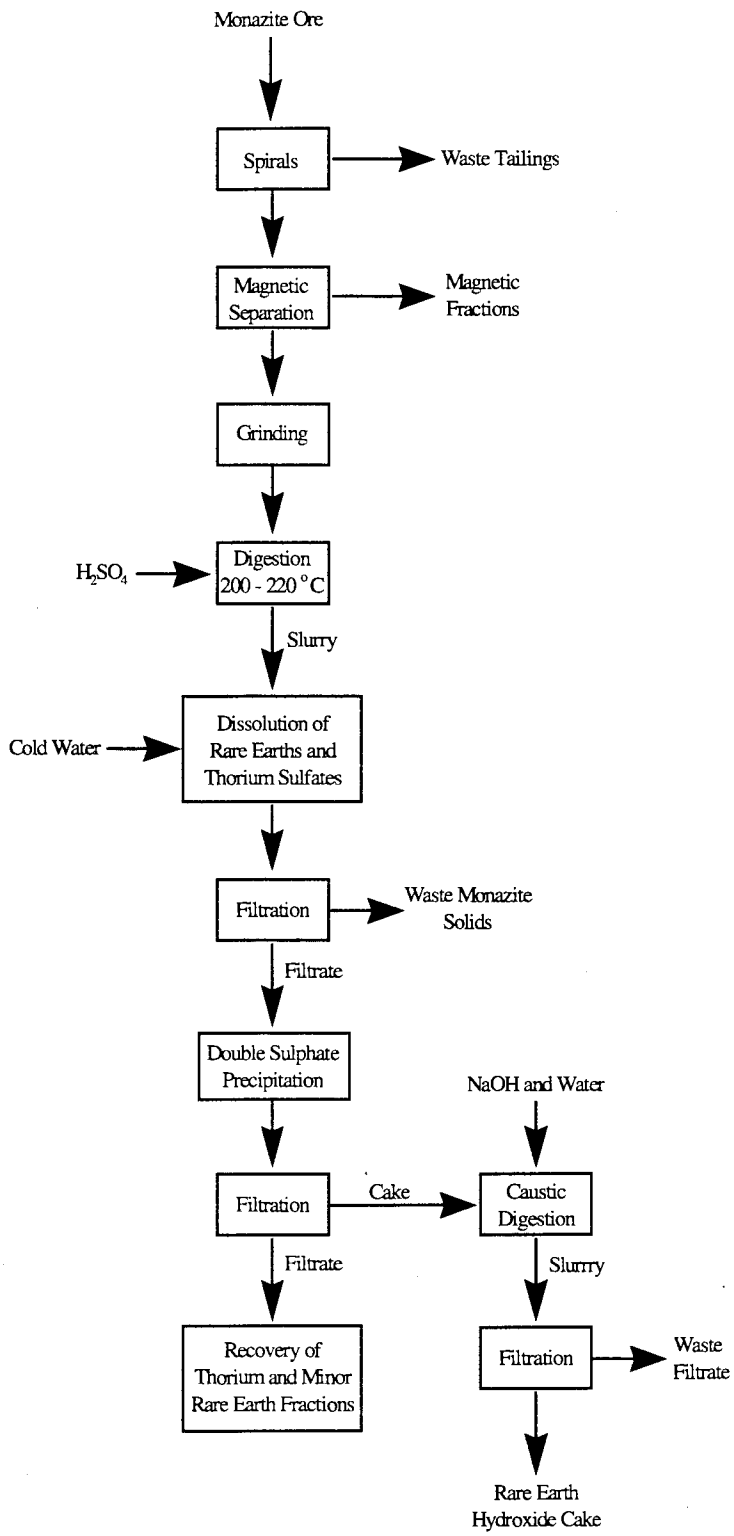
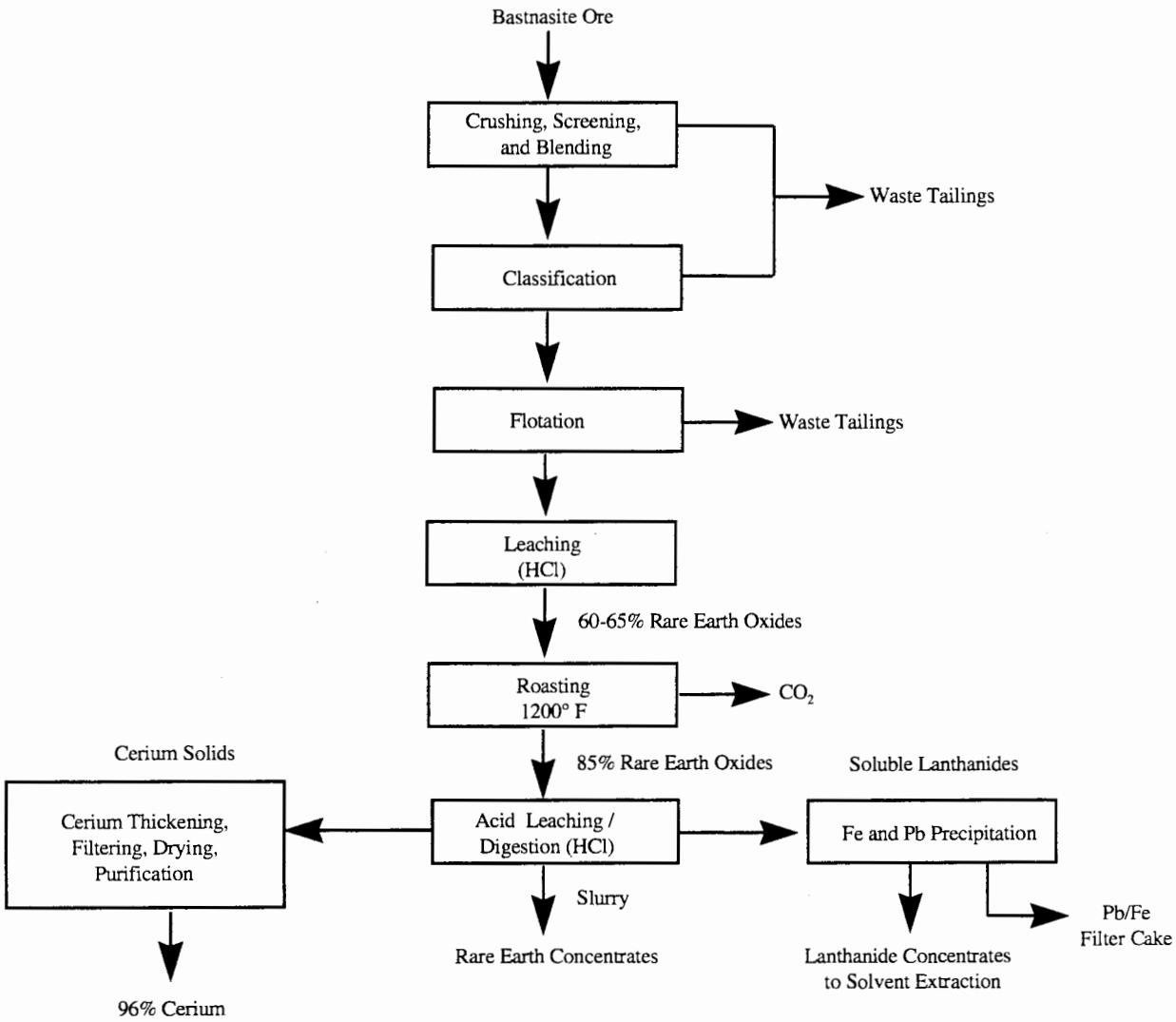


EXHIBIT 3
RECOVERY OF RARE EARTH CHLORIDES FROM BASTNASITE ORE

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-164 - 3-174., and Molycorp, Inc., Comment on Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, May 12th, 1997.)



Purification/Concentration

Flotation

Flotation is used at Mountain Pass to make a bastnasite concentrate containing about 60-65 percent rare earth oxides.[15] This concentrate is either used on-site as feed for chemical separation of rare earth elements, leached to produce a 70 percent rare earth oxide concentrate, or shipped off-site to customers.

Recovery of Concentrate

Recovery of rare earth concentrates from monazite and xenotime is accomplished by digestion in a hot concentrated base or acid solution. At Rhone-Poulenc Inc. plants, which process most of the world's monazite, rare earth elements are extracted in a concentrated solution of sodium hydroxide at 140 to 150°C. After cooling, hydroxides of rare earth elements and thorium are recovered by filtration, and thorium is separated by selective precipitation or dissolution. At Mountain Pass, bastnasite is roasted at 1200°F to drive off CO_2 and leached/digested with dilute, chilled HCl to dissolve most of the trivalent rare earth elements.[16, 17] Specifically, in this "leach" step the solid lanthanide ore is reacted with HCl to produce lanthanide chloride. This leaching also produces lead and iron chloride wastes, which are subsequently reacted with ammonia and sodium hydrogen sulfide, respectively, to form small volumes of solid iron hydroxide and lead sulfide wastes. In this step, cerium oxide is also leached to produce a higher concentrate cerium oxide product. In this roasting/leaching sequence, the roasting step converts cerium (III) fluorocarbonate to cerium (IV) oxide, which then undergoes leaching with HCl to produce a cerium oxide concentrate. This second leach step produces a final or intermediate product (low grade cerium concentrate) that does not undergo further beneficiation or processing.[18] The residue, cerium concentrate, is sold as a polishing abrasive.[19, 20]

The rare earth hydroxide and chloride concentrates recovered from sulfuric acid and hydrochloric acid leaching/digestion operations must undergo further processing to produce and recover individual rare earth metal compounds such as fluorides, nitrates, carbonates, oxides, and pure metals, for a variety of applications. Processes include solvent extraction and reduction.

Rare Earth Separation by Solvent Extraction

To separate individual rare earths in a mixture from each other, an aqueous solution containing rare earth salts is sent countercurrent to an immiscible organic stream which selectively extracts one rare earth from the others. Several stages of extractions are needed to separate each rare earth metal. Each organic stream is then scrubbed with an aqueous stream to transfer the rare earth element into an aqueous phase. Because all of the products are aqueous solutions, the spent solvents leave the process as wastes.[21] Exhibit 4 presents a process flow diagram for solvent extraction.

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[15] Ibid.

[16] Molycorp, Inc., 1997, Op. Cit.

[17] Molycorp, Inc., 1996, Op. Cit.

[18] U.S. Environmental Protection Agency, Lowrance, Sylvia K. to Mark A. Smith, Attorney, Unocal Corporation, April 7, 1992.

[19] Stephen Castor, 1994, Op. Cit., pp. 827-837.

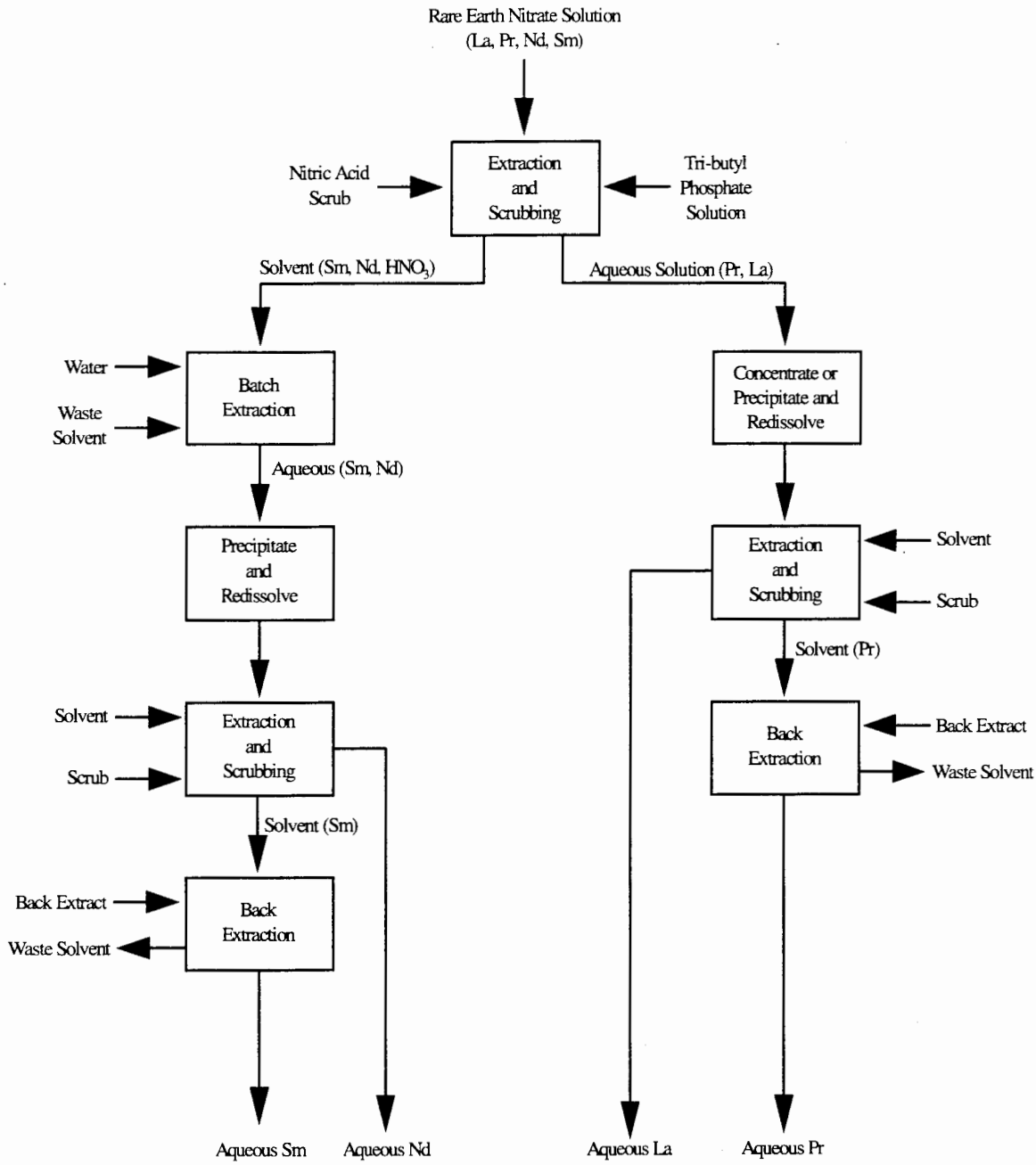
[20] Molycorp, Inc., 1996, Op. Cit.

[21] Molycorp, Inc., 1997, Op. Cit.

EXHIBIT 4

RARE EARTH SEPARATION BY SOLVENT EXTRACTION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-164 - 3-174.)



Calcium Reduction

High purity rare earth metals can be produced by the metallothermic reduction of rare earth halides. This process is used when 99.99 percent purity is required. After converting the rare earths into fluorides, they are reduced to the metallic state through contact with calcium or barium at high temperatures.[22] Exhibit 5 presents a flow diagram for calcium reduction.

Ten of the rare earths (lanthanum, cerium, praseodymium, neodymium, gadolinium, terbium dysprosium, holmium, erbium, and lutetium as well as scandium, and yttrium) are produced by calcium reduction. The raw material form of these metals is the metal fluoride. The individual metal fluoride is placed with calcium metal into a reduction vessel where a heat-driven reaction produces pure rare earth metal and calcium fluoride. The metals are further purified by melting in a vacuum to remove impurities. Casting is dependent upon the form in which a buyer wants the metal. Non-contact cooling water is used to cool both the reduction vessels and the melting and casting equipment.

Mischmetal

Mischmetal Production

Wet rare earth chlorides or hydrated rare earth compounds must be stripped of their water before electrolytic reduction can take place in order to prevent decay of the graphite anode during electrolysis. The anode could be decayed by the reaction of the liberated oxygen in the electrolyte with the carbon anode to form carbon dioxide. Batch or continuous mode dryers may be used. Both gas heat and electric heat have been used to run the dehydration furnaces.[23]

Dry rare earth chlorides are reduced to mischmetal in electrolytic cells. Batch process electrolysis reduces the rare earth salts to metal in 8 to 12 hours. Excess slag is removed and may be sold for its rare earth chloride content. Following reduction, the mischmetal is cast into bars or ingots for future uses.[24] Exhibits 6 and 7 present process flow diagrams for mischmetal production.

Mischmetal Reduction

Mischmetal is an alloy typically composed of cerium, lanthanum, neodymium, praseodymium, other rare earth metals, and iron. Mischmetal processing reduces the oxide form of the rare earth metals (samarium, europium, and ytterbium) to an elemental form. In this reaction, the mischmetal acts as a reducing agent and is oxidized to a mixture of rare earth metal oxides. The process is performed at a low pressure and a temperature below the melting point so that the metals vaporize or sublime. The pure metal is condensed and collected in a crystalline mass of high purity. These solids may be crushed into powder or melted and cast if a solid product form is desired.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

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[22] Ibid.

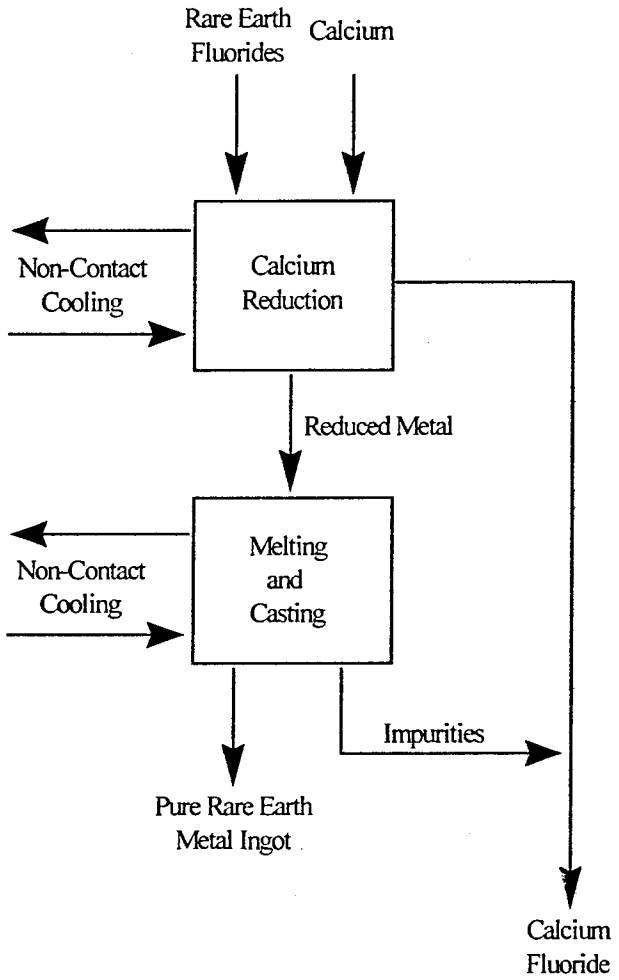
[23] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume X, Office of Water Regulations and Standards, May 1989, pp. 5376-5384.

[24] Ibid.

EXHIBIT 5

CALCIUM REDUCTION PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-164 - 3-174.)



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4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for rare earths and mischmetal, the beneficiation/processing line occurs between ore preparation and acid digestion when the ore is vigorously attacked with concentrated acids, resulting in the physical destruction of the ore structure.

After careful analysis of Molycorp's process information, EPA determined in 1991 and 1992, that two distinct operations occur during what Molycorp classifies as its "second leach step." The Agency believes that those determinations are still appropriate. Molycorp submitted extensive comments on EPA's conclusions, which are addressed in the response to comments document in the record.

Because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the

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mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

Rare earth element ores and commodities, as well as byproducts and waste materials from rare earth processing, are naturally radioactive, due to contained thorium.

1. Extraction/Beneficiation Wastes

Tailings and **magnetic fractions** are possible waste streams from the extraction and beneficiation of rare earths.

2. Mineral Processing Wastes

Off-gases from dehydration from the furnaces are treated by water or alkaline scrubbers to remove particulates and acid. The treated gases are vented.[25] Existing data and engineering judgment indicate that this waste does not exhibit any characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent iron hydroxide cake. Existing data and engineering judgment indicate that this waste does not exhibit any characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent lead and sand filter cinders. This waste contains waste components (e.g., lead) that originate from the orebody as a result of direct contact with the mineral values (i.e., lanthanides) being processed.

Spent monazite solids. Existing data and engineering judgment indicate that this waste does not exhibit any characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent offgases from electrolytic reduction. Off-gases from electrolytic reduction include chlorine gas, carbon monoxide and carbon dioxide gases from the carbon in the graphite anodes, and hydrochloric acid fumes. These gases are contacted with water to both cool the gases and to absorb particulates and hydrochloric acid vapors. The partially cleansed gases are then contacted with sodium hydroxide solution, resulting in the formation of sodium hypochlorite. After a sufficient hypochlorite concentration is attained, the solution may be sold as a byproduct.[26] Existing data and engineering judgment indicate that this waste does not exhibit any characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further.

Waste filtrate. Existing data and engineering judgment indicate that this waste does not exhibit any characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further.

Waste solvent. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 2,000 metric tons/yr, 1,000,000 metric tons/yr, and 2,000,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of ignitability. EPA does not considers this material to be a waste, because it is fully recycled.

Spent lead filter cake. This waste may be stabilized with a polysilicate material and then reinserted into the process for extraction of additional cerium. Tailings containing carbonates are used to precipitate iron. The resulting lead filter cake may exhibit the characteristic of toxicity for lead. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of

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[25] U.S. Environmental Protection Agency, 1989, Op. Cit, pp. 5376-5446.

[26] Ibid.

this report to estimate a low, medium, and high annual waste generation rate of 3,300 metric tons/yr, 4,200 metric tons/yr, and 5,000 metric tons/yr, respectively. EPA believes this material is fully recycled to recover metal values, and not land stored.

Lead backwash sludge. Existing data and engineering judgment indicate that this waste does not exhibit characteristics of a hazardous waste. Therefore, the Agency did not evaluate the material further. Further, Molycorp, Inc. asserted that its Mountain Pass facility no longer produces this waste.

Waste zinc contaminated with mercury. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 200 metric tons/yr, 45,000 metric tons/yr, and 90,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for mercury. One firm, Molycorp, Inc., asserted that its Mountain Pass facility no longer produces this waste.

Solvent extraction crud. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 200 metric tons/yr, 45,000 metric tons/yr, and 90,000 metric tons/yr, respectively. However, this waste is only generated at one facility and one firm, Molycorp, Inc., indicated that its Mountain Pass facility no longer produces this waste. We used best engineering judgment to determine that this waste may exhibit the characteristic ignitability. This waste may be recycled and formerly was classified as a spent material.

Spent surface impoundment liquids are a likely waste stream from rare earth production. Surface impoundment liquids were generated at a rate of 477,000 metric tons per year in 1991.[27] Waste characterization data are presented in Attachment 1. This waste is not expected to be hazardous.

Spent surface impoundment solids. This waste stream was generated at a rate of 100 metric tons per year in 1991 and may be toxic for lead.[28] This waste is not expected to be hazardous. Waste characterization data are presented in Attachment 1.

Lanthanide Production

Spent ammonium nitrate processing solution is a possible waste stream from lanthanide separation. The 1991 waste generation rate for the sector was 14,000 metric tons per year. This waste may exhibit the characteristic of corrosivity.[29] Attachment 1 presents waste characterization data.

Cerium Production

Process wastewater. This waste stream may be toxic for lead as well as contain detectable levels of ammonium. This wastewater may also be corrosive. The 1991 waste generation rate for the sector was 7,000 metric tons per year.[30] Waste characterization data are presented in Attachment 1. This waste may be recycled and formerly was classified as a spent material.

Mischmetal Production

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[27] U.S. Environmental Protection Agency, 1992, Op. Cit., Vol. I, pp. I-2 - I-8.

[28] Ibid.

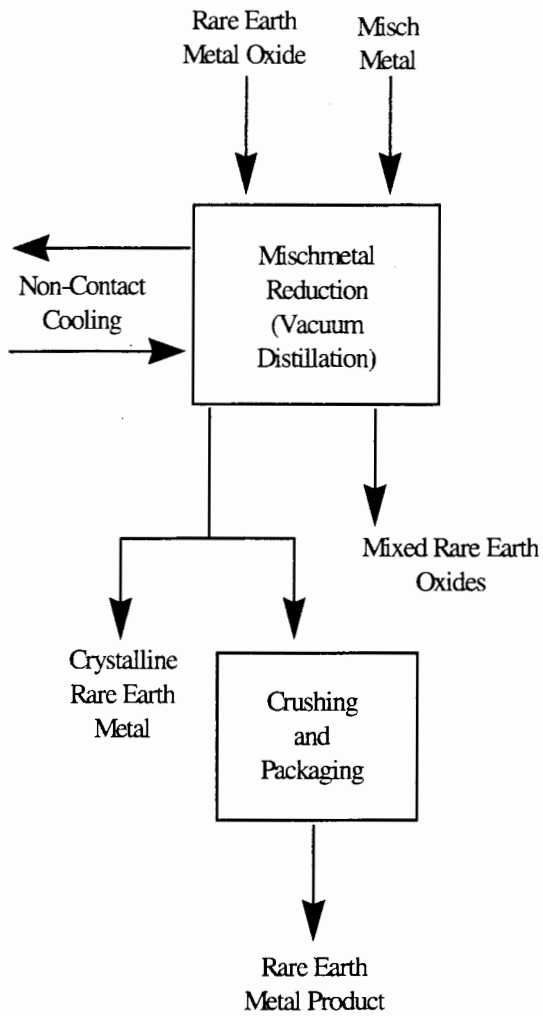
[29] Ibid.

[30] Ibid.

EXHIBIT 6

MISCHMETAL REDUCTION PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-164 - 3-174.)

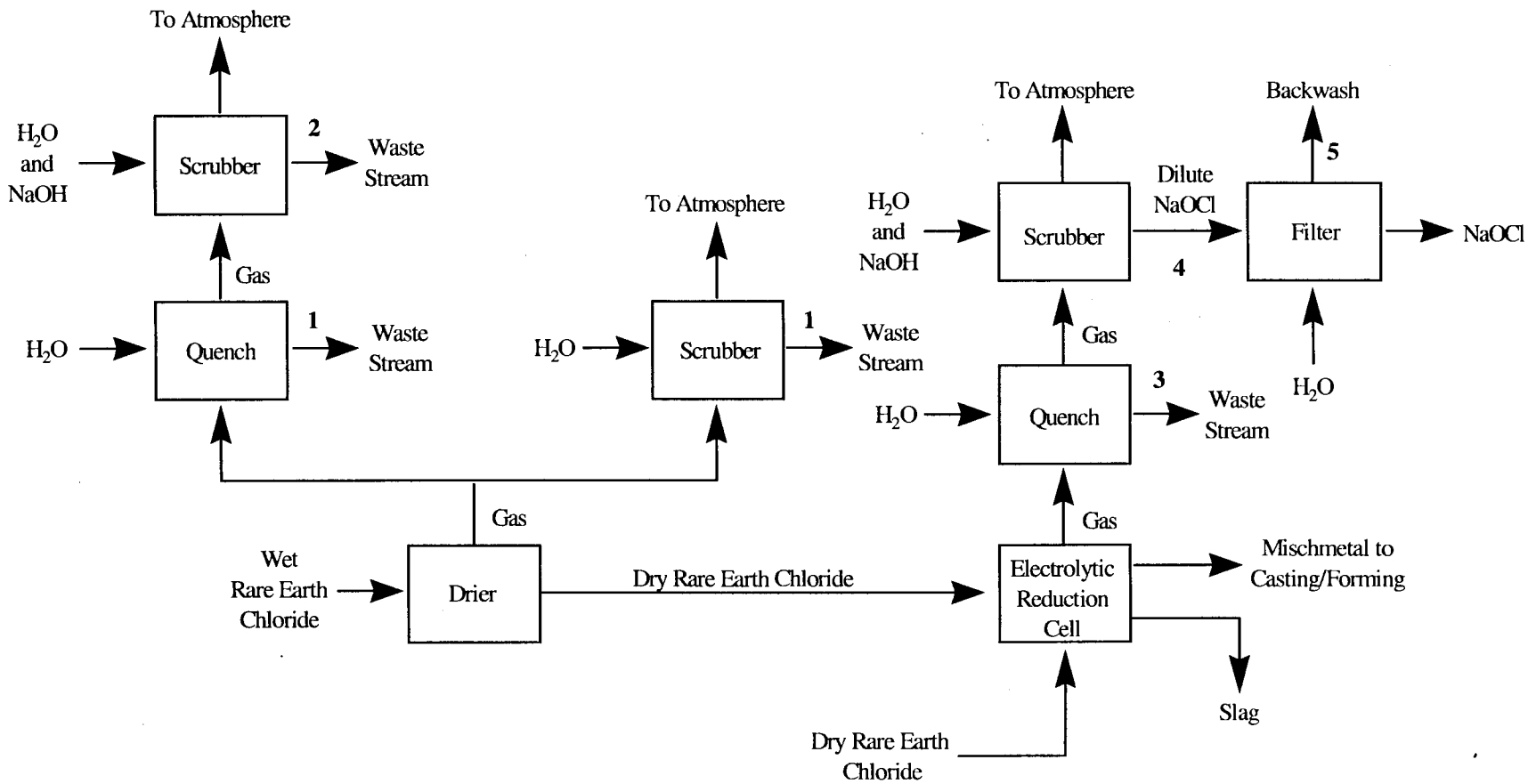


Spent scrubber liquor from wet air pollution control is generated from mischmetal production. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 500,000 metric tons/yr, and 1,000,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of corrosivity. This water may be recycled or discharged to wastewater treatment. This waste formerly was classified as a spent material.

EXHIBIT 7

MISCHMETAL PRODUCTION PROCESS

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989, pp. 5376 - 5446.)



Wastewater from caustic wet air pollution control. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 500,000 metric tons/yr, and 1,000,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity for chromium and lead and corrosivity. Scrubber liquor is recycled and the bleed stream is discharged to treatment. This waste formerly was classified as a spent material.

Spent electrolytic cell quench water and scrubber water. Waste characterization data are presented in Attachment 1. This waste is not expected to be hazardous.

Electrolytic cell caustic wet APC sludge. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 70 metric tons/yr, 700 metric tons/yr, and 7,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of corrosivity. This waste is recycled and is classified as a sludge.

Spent sodium hypochlorite filter backwash. The caustic wet air pollution control system following the water quench or water scrubber is designed to recover chlorine present in the gas stream. Sodium hydroxide is circulated through the scrubber and the reaction with chlorine forms sodium hypochlorite. When a 12 to 15 percent sodium hypochlorite concentration is attained, the solution is drawn off and sold for industrial use. This waste is not expected to be hazardous.

D. Non-uniquely Associated Hazardous Wastes

Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous), and other lubricants. At Molycorp, Inc's facility in Mountain Pass, CA several wastes are considered to be non-uniquely associated. These include pinion grease (contains 50 percent aromatic oils, 35 percent petroleum asphalts, and 0-10 percent 1,1,1 trichloroethane) and spilled solvent cleaned from the chemical plant's floor.

E. Summary of Comments Received by EPA

New Factual Information

Two commenters provided new information on facility specific operations and processes (COMM58, COMM68). This new information was incorporated into the Agency's sector report.

Sector-specific Issues

Two commenters objected to EPA's determination that mineral processing occurs in the rare earth sector, in that they believed this was a reversal of a prior determination by the Agency (COMM40, COMM58, COMM68). One commenter, Molycorp, Inc., responded to both the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes and the Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes (COMM68, COMM40). The concerns of Molycorp, Inc. stem from the Agency determining that mineral processing occurs in the rare earth sector, rather than it being strictly a beneficiation process, which the commenter believed contradicted the 1989 Mining Waste Exclusion Rule.

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U.S. Environmental Protection Agency. "Rare Earths." From 1988 Final Draft Summary Report of Mineral Industry Processing Waste. 1988. pp. 3-164 - 3-174.

ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT SURFACE IMPOUNDMENT LIQUIDS - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	0.008	0.008	0.008	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.03	0.03	0.03	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT SURFACE IMPOUNDMENT SOLIDS - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	20000	20000	20000	1/1	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	20000	20000	20000	1/1	-	-	-	0/0	-	-
Lead	7500	7500	7500	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	2000	2000	2000	1/1	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	110000	110000	110000	1/1	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	33	33	33	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT AMMONIUM NITRATE PROCESSING SOLUTION - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.046	0.38	0.97	3/3	-	-	-	0/0	-	-
Antimony	0.229	10.11	20	2/2	-	-	-	0/0	-	-
Arsenic	0.0025	0.01	0.025	4/5	0.002	0.049	0.132	3/3	5.0	0
Barium	0.038	0.07	0.11	5/5	0.006	6.99	20	3/3	100.0	0
Beryllium	0.009	0.01	0.009	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.0025	0.03	0.095	4/5	0.003	0.013	0.03	3/3	1.0	0
Chromium	0.009	0.06	0.24	3/5	0.027	0.048	0.079	3/3	5.0	0
Cobalt	0.054	4.93	9.8	2/2	0.0005	0.065	0.15	2/3	-	-
Copper	0.005	0.04	0.085	2/3	-	-	-	0/0	-	-
Iron	0.053	0.05	0.053	1/1	-	-	-	0/0	-	-
Lead	0.001	0.02	0.03	4/4	0.005	0.014	0.02	2/3	5.0	0
Magnesium	0.005	56.08	221	6/6	-	-	-	0/0	-	-
Manganese	0.005	0.02	0.045	3/4	-	-	-	0/0	-	-
Mercury	0.0001	0.00	0.0005	2/3	0.0065	0.06	0.094	2/3	0.2	0
Molybdenum	-	-	-	0/0	0.009	0.07	0.124	3/3	-	-
Nickel	-	-	-	0/0	0.004	3.28	9.8	3/3	-	-
Selenium	0.0025	0.01	0.016	1/3	0.023	0.05	0.095	3/3	1.0	0
Silver	0.005	0.04	0.097	3/5	0.009	0.02	0.038	3/3	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.001	0.02	0.046	3/4	-	-	-	0/0	-	-
Cyanide	0.005	0.09	0.25	0/3	-	-	-	0/0	-	-
Sulfide	0.025	0.34	0.5	0/3	-	-	-	0/0	-	-
Sulfate	69	595	1,494	3/3	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	1,126	11,108	21,300	3/3	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	0.1	7.07	9.59	9/9					2<pH>12	1
Organics (TOC)	107.13	109.17	111.2	2/2					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PROCESS WASTEWATER - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	27.9	35.7	43.5	2/2	23.2	25.6	28	2/2	-	-
Antimony	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Arsenic	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	5.0	0
Barium	0.50	0.50	0.50	0/2	0.50	0.85	1.20	1/2	100.0	0
Beryllium	0.05	0.05	0.05	0/2	0.05	0.05	0.05	0/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.00050	0.039	0.054	1/4	0.05	0.05	0.05	0/2	1.0	0
Chromium	0.00050	0.26	0.50	1/4	0.50	0.50	0.50	0/2	5.0	0
Cobalt	0.5	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Copper	0.5	1.08	1.65	1/2	0.50	1.56	2.62	1/2	-	-
Iron	8.57	10.19	11.80	2/2	7.55	7.76	7.97	2/2	-	-
Lead	0.0005	2.50	8.45	3/4	0.63	5.31	10.0	2/2	5.0	1
Magnesium	154	2,117	4,080	2/2	1,020	4,955	8,890	2/2	-	-
Manganese	3.68	104	204	2/2	2.52	10.4	18.3	2/2	-	-
Mercury	0.00010	0.00010	0.00010	0/2	0.0001	0.0001	0.0001	0/2	0.2	0
Molybdenum	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Nickel	0.008	1.25	4.00	2/4	0.50	0.50	0.50	0/2	-	-
Selenium	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	1.0	0
Silver	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	5.0	0
Thallium	2.50	2.50	2.50	0/2	2.50	2.50	2.50	0/2	-	-
Vanadium	0.50	0.50	0.50	0/2	0.50	0.50	0.50	0/2	-	-
Zinc	1.98	8.09	14.20	2/2	1.98	7.24	12.5	2/2	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	152	786	1,420	2/2	-	-	-	0/0	-	-
Fluoride	0.20	15.10	30.0	2/2	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	0.034	1,675	6,490	4/4	-	-	-	0/0	-	-
TSS	0.030	4,740	9,480	2/2	-	-	-	0/0	-	-
pH *	0.4	0.7475	1.1	4/4					2<pH>12	4
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT ELECTROLYTIC CELL QUENCH WATER - CERIUM\LANTHANIDES\RARE EARTHS

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.005	0.0067	0.01	3/3	-	-	-	0/0	-	-
Arsenic	0.006	0.0177	0.025	3/3	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.001	0.0010	0.001	3/3	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.001	0.0073	0.02	3/3	-	-	-	0/0	1.0	0
Chromium	0.001	0.0173	0.033	3/3	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.01	0.0230	0.033	3/3	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.14	0.2733	0.4	3/3	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0008	0.002	3/3	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.013	0.0380	0.051	3/3	-	-	-	0/0	-	-
Selenium	0.005	0.0110	0.023	3/3	-	-	-	0/0	1.0	0
Silver	0.001	0.0010	0.001	3/3	-	-	-	0/0	5.0	0
Thallium	0.001	0.0057	0.015	3/3	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.06	0.1167	0.19	3/3	-	-	-	0/0	-	-
Cyanide	0.0003	0.0075	0.022	3/3	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

RHENIUM

A. Commodity Summary

The principal source of rhenium is molybdenum concentrates which are derived from porphyry copper deposits. Rhenium-containing products include ammonium perrhenate, perhennic acid, and metal powder. Rhenium is used in high-temperature superalloys (such as those used for manufacturing jet engine components) because it improves the strength properties of nickel alloys at high temperatures (1,000 °C). Rhenium alloys are used in thermocouples, temperature controls, heating elements, ionization gauges, mass spectrographs, electron tubes and targets, electrical contacts, metallic coatings, vacuum tubes, crucibles, electromagnets, and semiconductors. Rhenium is also used in petroleum-reforming catalysts for the production of high octane hydrocarbons for use in lead-free gasoline. Bimetallic platinum-rhenium catalysts have replaced many of the monometallic catalysts.[1] Rhenium is usually traded either as ammonium perrhenate or rhenium metal.[2]

According to the U.S. Bureau of Mines, ores containing rhenium are mined domestically by eight companies. Exhibit 1 presents the names and location of those companies generating molybdenum concentrates that contain rhenium.

EXHIBIT 1

SUMMARY OF RHENIUM FACILITIES

Facility Name	Location	Type of Operation
Chino Mines Co.	Hurley NM	Molybdenum concentrates
Cyprus-Climax	Sierrita, AZ	Molybdenum concentrates
Cyprus-Climax	Bagdad, AZ	Molybdenum concentrates
Kennecott Minerals Co.	Bingham Canyon, UT	Molybdenum concentrates
Magna Copper Corp.	San Manuel, AZ	Molybdenum concentrates
Magna Copper Co.	Miami, AZ	Molybdenum concentrates
Phillips Dodge Corporation	Morenci, AZ	Molybdenum concentrates
Sheilds Resources Inc. (Continental Pit)	Butte, MT	Molybdenum concentrates

Although most of these companies typically send their concentrates out of the United States to be toll refined, there is one compnay that recovers and refines rhenium domestically. Cyprus-Climax roasts and recovers rhenium at their Sierrita facility. Additionally, Cyprus-Climax has a rhenium recovery operation at Fort Madison, Iowa.[3] Rhenium consumption was estimated as 6,000 kilograms in 1994.[4]

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[1] Blossom, J. W., "Rhenium," from Mineral Commodity Summaries, U.S. Bureau of Mines, 1995, pp. 136-137.

[2] Blossom, J.W., "Rhenium," from Mineral Facts and Problems, 1985, p. 667.

[3] Personal communication between Jocelyn Spielman, ICF Incorporated, and J.W. Blossom, U.S. Bureau of Mines, October 17, 1994.

[4] Blossom, J. W., 1995, Op. Cit., p.136.

B. Generalized Process Description

1. Discussion of Typical Production Processes

In general, rhenium is recovered from the off-gases produced when molybdenite, a byproduct of the processing of porphyry copper ores for molybdenum, is roasted. During the roasting process, molybdenite concentrates are converted to molybdic oxide and rhenium is converted to rhenium heptoxide. The rhenium oxides are sublimed and carried off with the roaster flue gas, sulfur oxides, and the entrained dust. Once the technical grade molybdic oxide is separated from the off-gases, it may be further processed to either molybdenum or ferromolybdenum.[5] The off-gases are then processed to recover rhenium as described in detail below. Exhibit 2 provides an overview of the rhenium recovery process and how it is associated with the production of molybdenum.

2. Generalized Process Flow Diagram

As shown in Exhibit 3, the rhenium recovery process can be separated into five main steps: (1) scrubbing; (2) solvent extraction or ion exchange; (3) precipitation (addition of H_2S and HCl) and filtration; (4) oxidation and evaporation; and (5) reduction.

Scrubbing

The rhenium heptoxide entrained in flue gas is readily soluble in aqueous ammonia solutions and can be removed by wet scrubbing. Collection efficiencies are on the order of 65% and the unrecovered rhenium remains in the off-gases that escape into the stack.[6]

Solvent Extraction or Ion Exchange

The rhenium heptoxide absorbed and dissolved in the scrubber liquor can be recovered at much greater efficiencies than the rhenium from the flue gas. Recoveries of better than 95% have been attained from liquor with rhenium concentrations in excess of 300 ppm. The rhenium is removed from the scrubber liquor via either solvent extraction or selective ion exchange in a solid bed.[7]

Precipitation and Filtration

After ion exchange treatment (or solvent extraction) rhenium is stripped from the resin (or solvent) and recovered from the resulting eluviate solution as ammonium perrhenate crystals (NH_4ReO_4).[888] As shown in Exhibit 2, the perrhenate solution is precipitated to ReS_2 through the addition of H_2S, HCl, and NH_4CNS, followed by filtration. The resulting salt solutions are then sent to further treatment.

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[5] U.S. Environmental Protection Agency, Development Document for Effluent Limitation Guidelines and Standards for Nonferrous Metals Manufacturing Point Source Category, Vol. II, Office of Water Regulations Standards, May 1989, pp. 3363.

[6] Ibid., p.3365.

[7] Ibid.

[8] Ibid.

EXHIBIT 2

MOLYBDENUM AND RHENIUM PRODUCTION PROCESSES

(Adapted from: Development Document for Effluent Limitation Guidelines and Standards for Nonferrous Metals Manufacturing Point Source Category, 1989, pp. 3341 - 3483.)

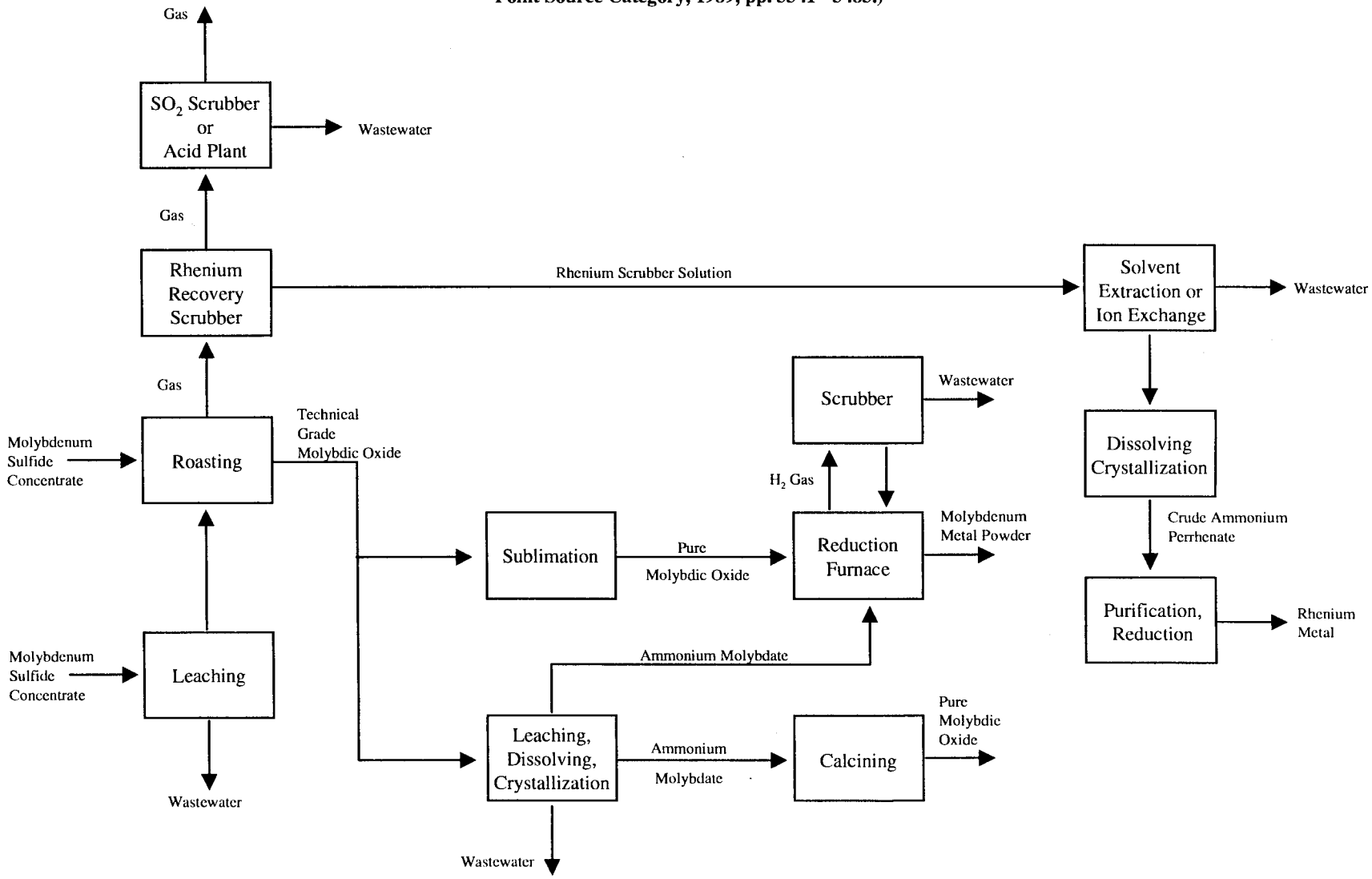
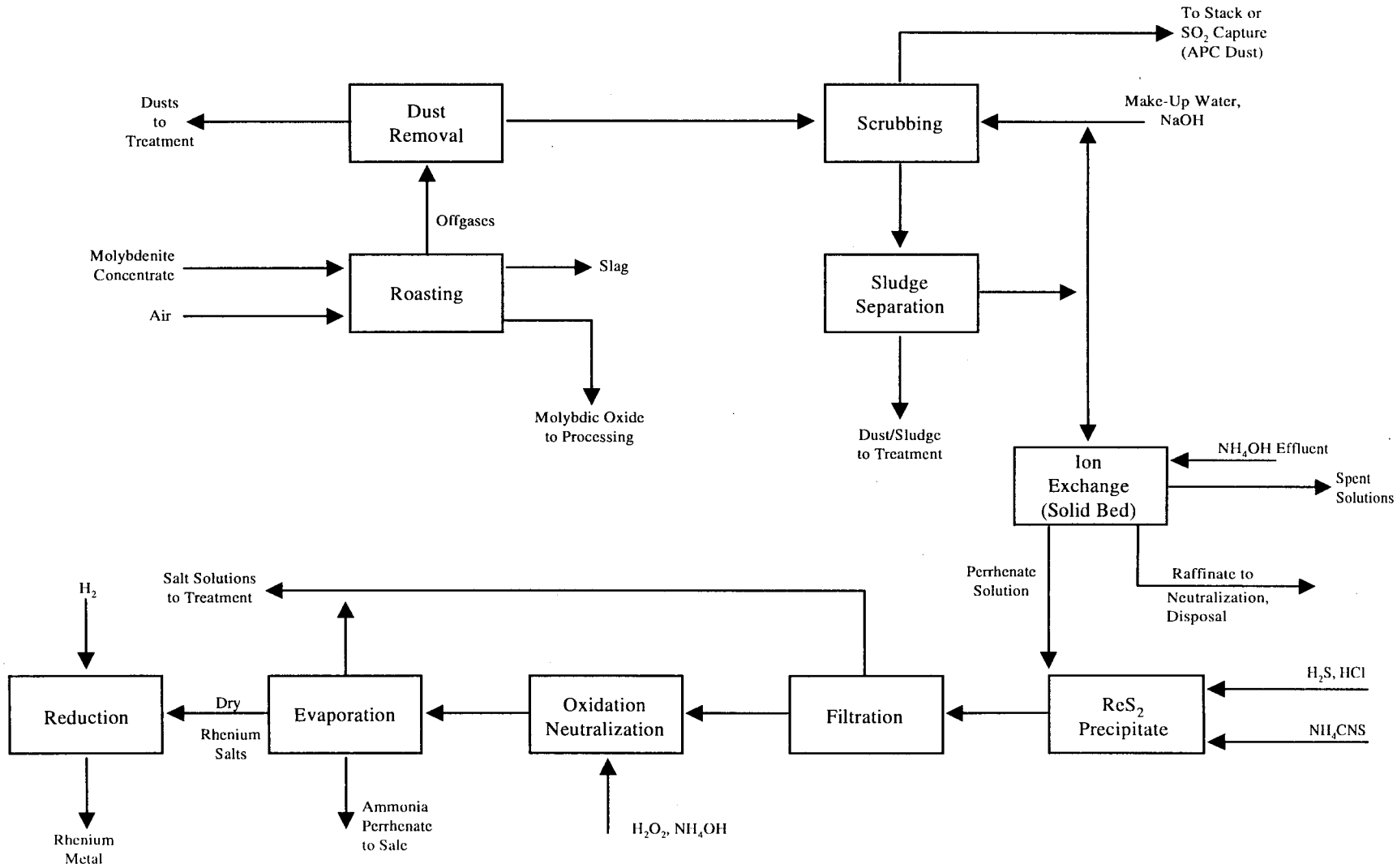


EXHIBIT 3

RECOVERY OF RHENIUM FROM MOLYBDENITE CONCENTRATES

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-175 - 3-178.)



Reduction

The dry ammonium perrhenate is generally reduced to high purity rhenium metal powder with purified dry hydrogen in an externally heated furnace. The hydrogen reduction is accomplished in two stages, the first at 300° to 350° C and the second at 700° to 800° C. The metal powder is then sintered into bars by compression at 45 to 50 kg per mm^2, using stearic acid in either stage as a plasticizer. The bars are then rolled to sheet, strip, and foil, or swaged and drawn into rod and wire. These products are annealed at recrystallization temperature after cold working to ensure maximum ductility.[9]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

Since rhenium is recovered from off-gases from the production of molybdenum, please see the report for molybdenum presented elsewhere in this background document for a description of where the beneficiation/processing boundary occurs for this mineral commodity sector.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

None Identified.

2. Mineral Processing Wastes

Exhibits 2 and 3 identify the following wastes associated with the recovery of rhenium.

Roasting and Wet Scrubbing

Slag. Slag is produced during roasting. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Roaster Dust. Dust removed after the roasting of molybdenum concentrates is sent to further treatment. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

APC Dust/Sludge. After wet scrubbing, unrecovered rhenium remains in the off-gases that are captured in the stacks. The captured dust and sludge are sent to further treatment. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent Barren Scrubber Liquor. Barren scrubber liquor generated during wet scrubbing contains treatable concentrations of toxic metals, particularly selenium. Although it is discharged as a wastewater stream, the two plants that report this waste stream achieve zero discharge. Specific practices at these two plants through lime addition and sedimentation, total reuse in other plant processes, evaporation, and contract hauling.[10] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 100 metric tons/yr, and 200 metric tons/yr, respectively. We used best engineering judgment to determine

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[9] J.W. Blossom, 1985, Op. Cit., p. 667.

[10] U.S. Environmental Protection Agency, 1989. Op. Cit. p. 3430

that this waste may be recycled and may exhibit the characteristic of toxicity for selenium. This waste was formerly classified as a spent material.

Ion Exchange and Solvent Extraction

Spent Rhenium Raffinate. As shown in Exhibit 3, raffinate results from the solid bed ion exchange and is sent for neutralization and disposal. This waste stream has a reported waste generation rate of 88 metric tons/yr. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

Spent Ion Exchange Solutions. Two facilities reporting this waste stream from ion exchange achieve zero discharge through treatment, reuse, evaporation ponds, and contract hauling. Although no analytical data are available for this waste stream, one facility reported that the solution contains treatable concentrations of selenium as well as high concentrations of molybdenum and iron. When rhenium recovery is achieved using solvent extraction, the resultant solution may also contain priority organics.[11] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Precipitation and Filtration

Spent Salt Solutions. The salt solutions that result from filtration are sent to further treatment. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[11] U.S. Environmental Protection Agency, 1989. Op. Cit. p. 3381

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RUTILE (Synthetic)

A. Commodity Summary

Synthetic rutile (TiO_2) is manufactured through the upgrading of ilmenite ore to remove impurities (mostly iron) and yield a feedstock for production of titanium tetrachloride through the chloride process. The chemical composition of synthetic rutile is similar to that of natural rutile, but differs in physical form. Synthetic rutile concentrates are composed of very fine crystals and are porous, whereas natural rutile grains are composed of single crystals.[1]

Since 1977, Kerr-McGee Chemical Corporation has produced synthetic rutile at its Mobile, Alabama plant; it is the only U.S. producer of synthetic rutile today. Because of its purity in comparison with ilmenite, rutile and synthetic rutile are the preferred feedstocks for production of titanium tetrachloride intended for sponge and metal production. The development of processes to produce synthetic rutile was necessitated by the small quantity of economic reserves of natural rutile worldwide.[2] Thus, despite the fact that the U.S. has large reserves of ilmenite, the majority of sponge produced is manufactured from imported rutile and synthetic rutile, primarily from Australia and Malaysia.[3]

Because it is relatively free of impurities, less wastes are generated using rutile and synthetic rutile to produce titanium tetrachloride and titanium dioxide pigment than with ilmenite. The process of converting ilmenite to synthetic rutile generates 0.7 tons of waste per ton of product, and the chloride process generates about 0.2 tons of waste per ton of TiO_2 product using rutile as a feedstock. In comparison, direct chlorination of ilmenite generates approximately 1.2 tons of waste (primarily ferric chloride) per ton of TiO_2.[4]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Several processes using oxidation, reduction, leaching, and/or chlorination have been developed to remove iron from low-grade, beach sand ilmenite and produce synthetic rutile having 90 to 97% TiO_2 and very low levels of impurities. These processes can be organized in three categories:

(1) Processes in which the iron in the ilmenite ore is completely reduced to metal and separated either chemically or physically;

(2) Processes in which the iron is reduced to the ferrous state and chemically leached from the ore; and

(3) Processes in which selective chlorination is used to remove the iron.[5]

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[1] J. Gambogi, Annual Report: Titanium-1992, U.S. Bureau of Mines, December 1993, p. 1.

[2] U.S. Environmental Protection Agency, Technical Background Document: Development of the Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, Office of Solid Waste, August 1989, p. B-39.

[3] J. Gambogi, 1993, Op. Cit., pp. 5, 18.

[4] J. Gambogi, "Rutile," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 141.

[5] J. Gambogi, 1993, Op. Cit., p. 3.

Kerr-McGee uses the Benelite Cyclic process, in which hydrochloric acid is used to leach iron from reduced ilmenite. The plant has an annual capacity of almost 91,000 metric tons. The plant recycles most of its waste streams and reportedly discharges no liquid wastes.[6]

2. Generalized Process Flow Diagram

Benelite Cyclic Process

In the Benelite Cyclic process (Exhibit 1), developed by the Benelite Corporation of America, raw ilmenite sand containing 54 to 65% TiO_2 is roasted with heavy fuel oil in a rotary kiln at 870° C. The fuel oil functions as a reducing agent, converting ferric iron (Fe^{3+}) in the ilmenite to the ferrous (Fe^{2+}) state. The fuel oil is burned at the discharge end of the kiln, and the resulting gases are passed through a cyclone and an incinerator to remove solids and unreacted hydrocarbons.[7]

The reduced ilmenite is then batch-digested in rotary-ball digesters with 18-20% HCl at 140° C. Ferrous oxide in the ilmenite is converted to soluble ferrous chloride, and the TiO_2 portion of the ilmenite is left as a solid. Spent acid liquor, which contains excess HCl and ferrous chloride, is sent to an acid regeneration circuit. The TiO_2 solids are washed with water and filtered and calcined at 870° C, yielding synthetic rutile with approximately 94% TiO_2. Exhaust gases from the calciner are treated to remove solids and acidic gases before they are released to the atmosphere.[8]

In the acid regeneration circuit, the spent acid liquor is sent to a preconcentrator where one-fourth of the water in the liquor is evaporated. The concentrated liquor is sprayed through atomizers, causing the droplets to dry out, yielding HCl gas and ferric oxide powder. The gas is cycloned and then sent to an absorber to remove HCl for reuse. The ferric oxide powder is slurried with water to create the waste stream iron oxide slurry.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

High-grade synthetic rutile (98% TiO_2) has been generated through batch-scale and continuous rotary kiln carbothermic metallization of ilmenite, followed by treatments such as catalytic rusting, acidic chloride leaching, and oxidation-leaching.[9]

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

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[6] D. Carr, ed., Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, Inc., 1994, p. 1085.

[7] U.S. Environmental Protection Agency, 1989, Op. Cit., p. B-40.

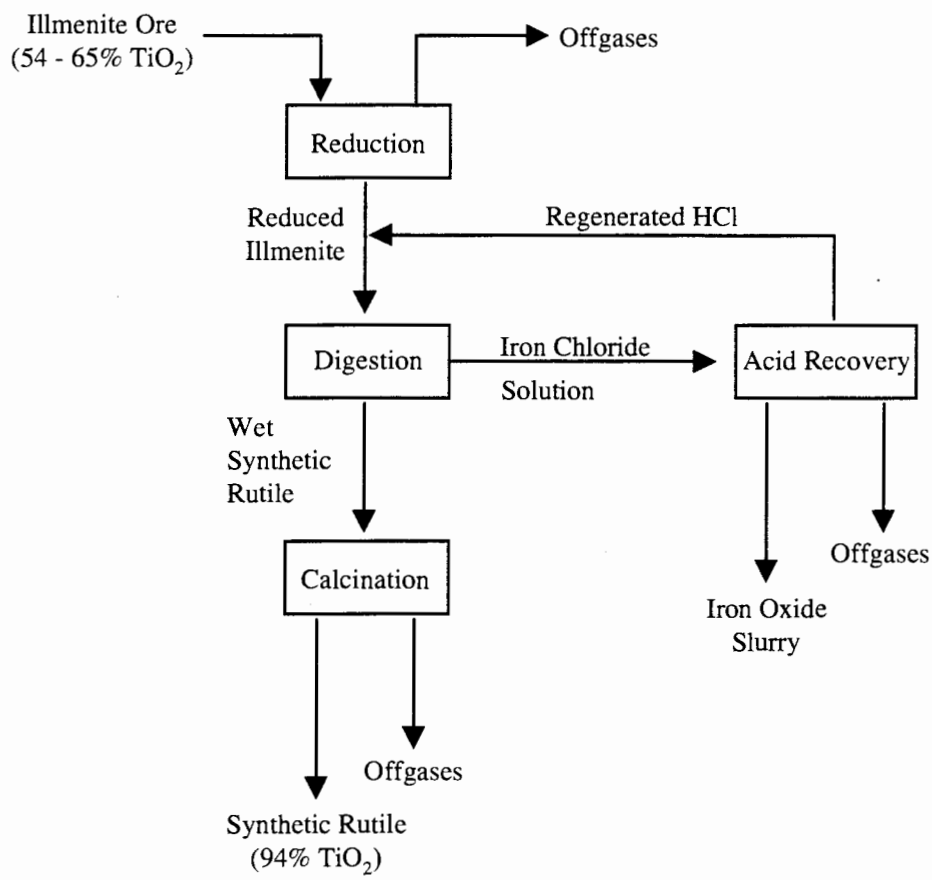
[8] U.S. Environmental Protection Agency, 1989, Op. Cit., p. B-40.

[9] A. Damodaran, et al., "On Extraction of High Grade Synthetic Rutile from Indian Ilmenite," The Minerals, Metals & Materials Society, 1992, p. 1079.

EXHIBIT 1

BENELITE CYCLIC PROCESS FOR SYNTHETIC RUTILE PRODUCTION

(Adapted from: Kerr-McGee Corp., Comments on Notice of Proposed Rulemaking, 1989.)



Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between screening/cleaning of sand and reduction in a rotary kiln. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where a significant chemical change to the ilmenite ore occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Beach/alluvial sands containing ilmenite are excavated by dragline, front-end loader, or suction dredging; the sands are spiral concentrated to remove low density tailings. The sands are then dried and separated electrostatically to remove quartz and other nonconducting minerals, which are processed to produce zircon and monazite product and wastes consisting of quartz and epidote minerals. Conducting materials are magnetically separated to sort ilmenite from rutile, followed by screening and cleaning. No wastes from beach sand processing are expected to exhibit hazardous characteristics.[10]

2. Mineral Processing Wastes

The **Benelite Cyclic process** for manufacturing synthetic rutile generates three mineral processing wastes, as described below.

Air Pollution Control Dust/Sludges

Air pollution control (APC) dust/sludges are generated by the cycloning of off-gases from the roasting step to remove solids. Solids are also removed from off-gases from the calcining step. Off-gases from the spray roaster used in the acid regeneration circuit are also cycloned to remove entrained solids, and subsequent gases from the absorber are scrubbed. APC dust/sludge is believed to be recycled back into the production process (possibly to the roasting step) and is not regarded as a solid waste.[11] This waste stream has a reported waste generation rate of

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[10] U.S. Environmental Protection Agency, "Titanium," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. 1988. p. 3-219.

[11] D. Carr, ed., 1994, Op. Cit., p. 1085.

30,000 mt/yr. Although no published information regarding characteristics was found, we used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity (cadmium and chromium).[12,13] This waste stream is fully recycled and is classified as a sludge.

Spent Iron Oxide Slurry

Iron oxide slurry is the primary waste stream generated in the production of synthetic rutile; it is generated in the acid regeneration circuit. Approximately one-half metric ton of slurry is generated for every metric ton of synthetic rutile. The disposal method for this waste is unknown.[14] This waste stream has a reported waste generation rate of 45,000 mt/yr. We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristic of toxicity (cadmium and chromium). This waste is classified as a by-product.

Spent Acid Solution

Spent acid solution is generated in the digestion step. Spent acid liquor, which contains excess HCl and ferrous chloride, is sent to an acid regeneration circuit to recover HCl for recycle back to the digester. This waste stream is generally recycled back into the process and is not regarded as a solid waste.[15] This waste stream has a reported waste generation rate of 30,000 mt/yr. Although no published information regarding characteristics was found, we used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (cadmium and chromium) and corrosivity. This waste stream is classified as a spent material.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[12] U.S. Environmental Protection Agency, 1989, Op. Cit., p. B-39.

[13] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, August 1992, p. I-6.

[14] U.S. Environmental Protection Agency, 1989, Op. Cit., p. B-40 - B-41.

[15] Ibid.

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U.S. Environmental Protection Agency. Newly Identified Mineral Processing Waste Characterization Data Set. Office of Solid Waste. August 1992.

SCANDIUM

A. Commodity Summary

Although scandium was not mined domestically in 1993, scandium ore was intermittently recovered from tailings and concentrates as needed. By-product scandium concentrates previously produced in Utah and tailings previously generated by mining fluorite in Montana were available for processing to recover high purity scandium oxide. Although four processing companies, two in Colorado, one in Illinois, and one in New Jersey, produced refined scandium products in 1993, no domestic facility recovered scandium from uranium.[1] One company in Iowa had the technology to produce ultra-high purity (99.9999%) scandium oxide. Companies in Arizona, Illinois, and Iowa possessed capacity to produce ingot and distilled scandium metal products. Exhibit 1 presents the names and locations of facilities once involved in the production of scandium.

EXHIBIT 1

SUMMARY OF SCANDIUM FACILITIES

Facility Name	Location	Type of Operation
Baldwin Metals Processing Co.	Phoenix, AZ	Ingot and distilled scandium metal production.
Boulder Scientific Co.	Mead, CO	Refining. Processed scandium concentrates derived from thortveitite-bearing tailings from the mined-out Crystal Mountain fluorite mine near Darby, Montana.
Interpro (subsidiary of Concord Trading Corp.)	Golden, CO	Refining. Processed stocks of scandium concentrates previously generated by the Energy Fuels Nuclear uranium plant at Bingham Canyon, Utah.
Materials Preparation Center	Ames, IA	Scandium Oxide and Ingot Production (research organization).
Rhone Poulenc, Inc.	Phoenix, AZ	Ingot and distilled scandium metal production.
Kennecott	Garfield, UT	Scandium is available for refining in the form of a byproduct generated during processing of uranium at the copper mine.
Climax Mine	Climax, CO	Scandium is available for refining from the tungsten byproduct generated during the molybdenum operation.
APL Engineered Materials	Urbana, IL	Refining. Ingot and distilled scandium metal production.
Sausville Chemical Co.	Garfield, NJ	Refining. Processed scandium concentrates to produce scandium oxide, fluoride, nitrate, chloride, and acetate.

[1] Personal communication between Jocelyn Spielman, ICF Incorporated and James B. Hedrick, Scandium Specialist, U.S. Bureau of Mines, October 20, 1994.

Scandium used in the United States is primarily from domestic sources. Some minor amounts of scandium are recovered by recycling laser crystal rods. The principal uses for scandium are metallurgical research, high-intensity metal halide lamps, analytical standards, electronics, lasers, and research.[2]

Scandium is a soft silver metal which has a slightly yellow cast when exposed to air. Scandium readily reacts with acids and is not easily attacked by water. The metal does not tarnish in air, but at high temperatures (500 to 800 °C) scandium can be oxidized in air. Scandium is extremely electropositive, and therefore, its oxide is basic and acid soluble. Scandium exhibits a trivalent state in compounds and has no other observed valences. Scandium is chemically similar to rare earth elements; however, its ion size places it in geochemical equilibria with aluminum, magnesium, hafnium, and zirconium. Therefore, scandium is rarely found in the earth ores, but has been noted in minor amounts in gadolinite, xenotime, allanite, davidite, and others.[3]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Scandium is generally produced by small, bench-scale batch processes. Much initial recovery is from in-plant streams where solvent extraction is being used to recover other metals such as uranium. These crude materials are then worked up to high purity oxides and metals. The principal domestic scandium resource is fluorite tailings from the Crystal Mountain deposit near Darby, Montana. Tailings from the mined-out fluorite operations, which were generated from 1952 to 1971, contain thortveitite and associated scandium-enriched minerals. Resources are also contained in the tungsten, molybdenum, and titanium minerals from the Climax molybdenum deposit in Colorado, and in the kolbeckite (sterrettite), varsite, and crandallite at Fairfield, Utah.[4] Scandium is extracted from thortveitite by several methods.

2. Generalized Process Flow Diagram

Recovery From Thortveitite

As shown in the attached process flow diagrams, scandium can be recovered from thortveitite using several methods. Each method involves a distinct initial step (i.e., acid digestion, grinding, or chlorination) followed by a set of common recovery steps, including leaching, precipitation, and filtration.

Acid Digestion, Grinding, and Chlorination. Scandium is extracted from thortveitite by several methods. The method shown in Exhibit 2 involves digestion of thortveitite with concentrated hydrochloric or sulfuric acid, yielding a gelatinous silica residue that contains scandium. Another method, shown in Exhibit 3, begins by finely grinding thortveitite and then combining it with charcoal at 1,800 °C to form scandium carbide. This carbide is then further decomposed with hydrochloric acid, forming soluble scandium chloride. Exhibit 4 presents a third method that involves heating thortveitite in the presence of chlorine gas and carbon at 850 °C to form scandium chloride.

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[2] James B. Hedrick, "Scandium," from Mineral Commodity Summaries, U.S. Bureau of Mines, 1995, pp. 148-149.

[3] U.S. Environmental Protection Agency, "Scandium," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, Office of Solid Waste, 1988, p. 3-20.

[4] James B. Hedrick, 1995, Op. Cit., pp. 148-149.

EXHIBIT 2

SCANDIUM FROM THORTVEITITE #1

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-20 - 3-30.)

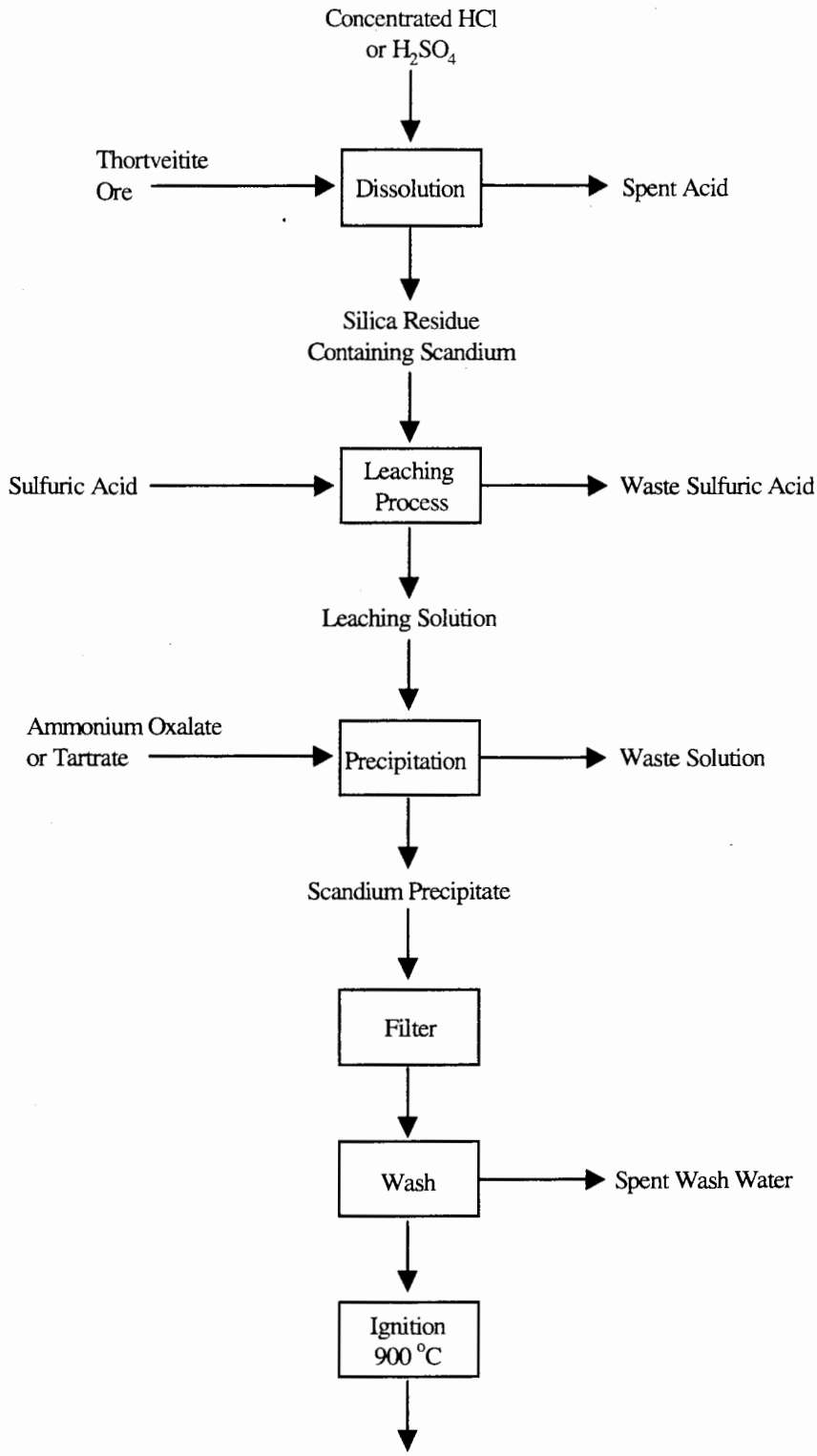


EXHIBIT 3

SCANDIUM FROM THORTVEITITE #2

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-20 - 3-30.)

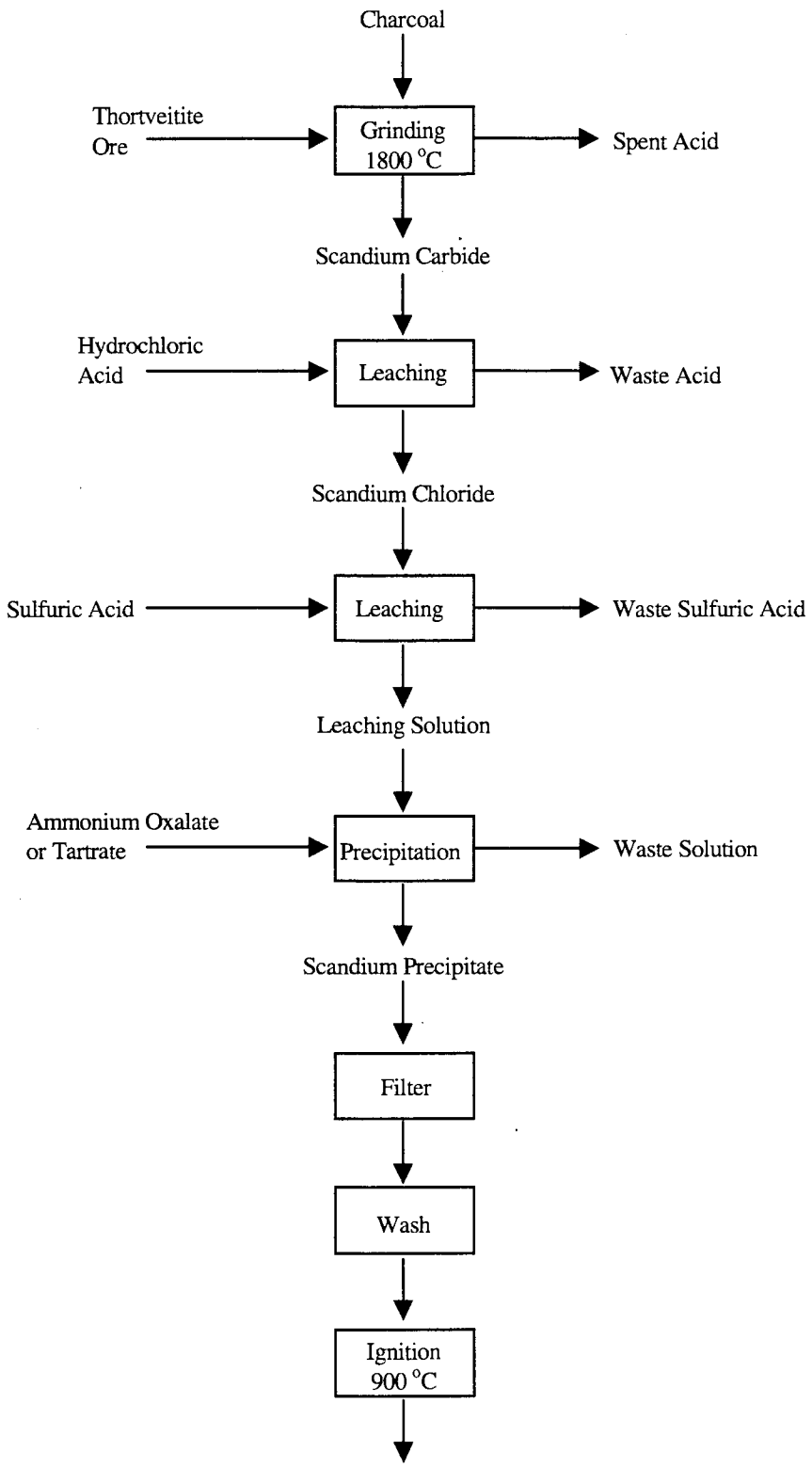


EXHIBIT 4

SCANDIUM FROM THORTVEITITE #3

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-20 - 3-30.)

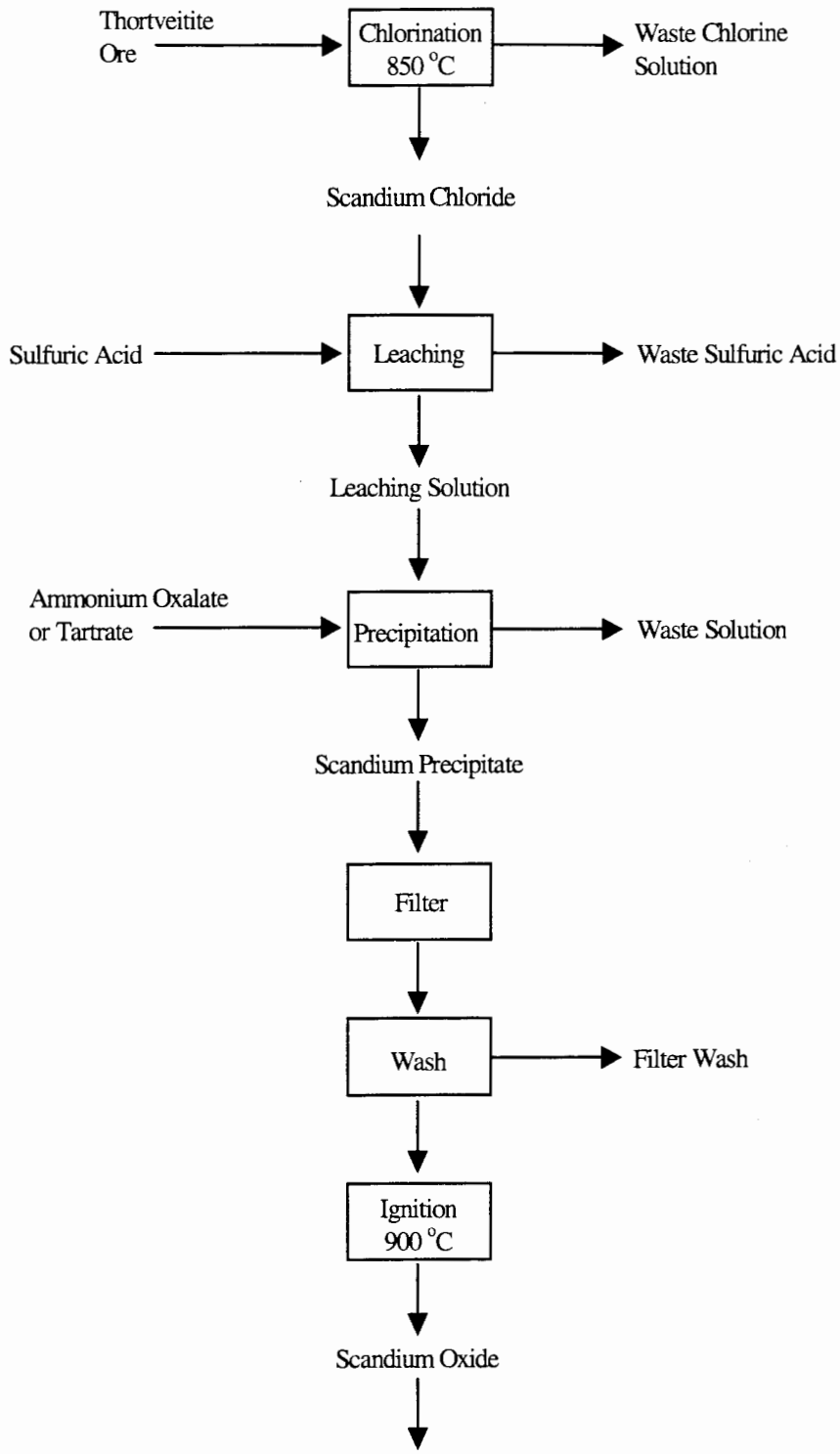
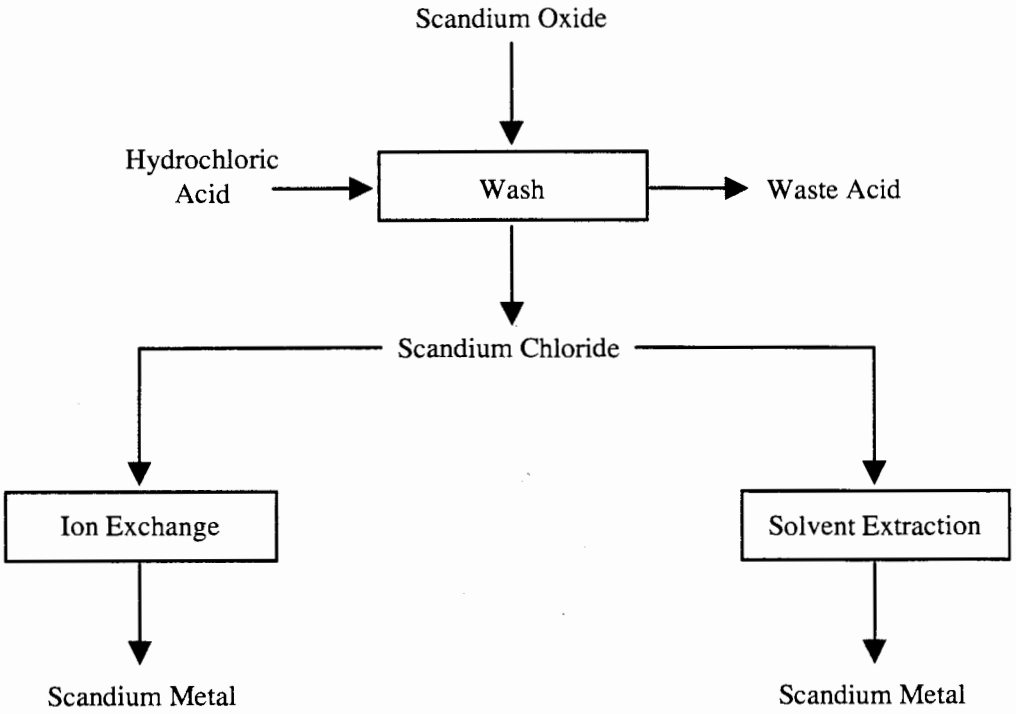


EXHIBIT 4 (Continued)

SCANDIUM FROM THORTVEITITE #3



In a fourth method, scandium can also be extracted from thortveitite using hydrofluoric acid in a similar method. Methods using magnesium or ammonium-hydrogen fluoride have also been used. Regardless of the method used, these initial recovery steps are followed by leaching, precipitation, filtration, washing, and ignition at 900 °C to form scandium oxide.[5]

Leaching, Precipitation, and Filtration. Scandium is obtained by leaching scandium chloride with sulfuric acid. Scandium is recovered from the leaching residues by adding ammonium oxalate or tartrate to the solution forming a scandium precipitate. This precipitate is filtered and washed, then decomposed by ignition at 900 °C, forming scandium oxide. The scandium oxide is then dissolved in hydrochloric acid to form scandium chloride.[6]

Purification. Scandium chloride is purified via distillation. Distillation removes a large quantity of metallic impurities, including iron, cadmium, magnesium, and chromium, along with carbon and nitrogen. Ion exchange or solvent extraction is also used for further purification.[7]

Recovery From Uranium (no longer used)

Alternatively, as shown in Exhibit 5, scandium was also once recovered from a byproduct generated during the processing of uranium at the copper mines in Garfield, Utah. The stripped solvent from uranium ore solvent extraction was acidified in stages. First the solvent was treated with hydrofluoric acid and filtered. Next, the resultant filter cake was treated with hydrochloric acid, followed by digestion and filtration. Oxalic acid was added to the resultant scandium, iron, and uranium filtrate to form scandium oxalate, which was calcined to yield scandium oxide. A second treatment with hydrochloric acid followed by extraction and stripping yielded scandium metal.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

In addition to the methods described, the U.S. Bureau of Mines has investigated solvent extraction methods for recovering scandium from the leach filtrates of sulfated tantalum tailings.[8]

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In

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[5] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-20.

[6] Ibid.

[7] Ibid.

[8] Michael D. Odekirk and Donna D. Harbuck, "Scandium Solvent Extraction from Liquors Produced by Leaching Sulfated Tantalum Tailings," EPD Congress, The Minerals, Metals & Materials Society, 1993, pp. 83-97.

EXHIBIT 5

SCANDIUM FROM URANIUM

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-20 - 3-30.)

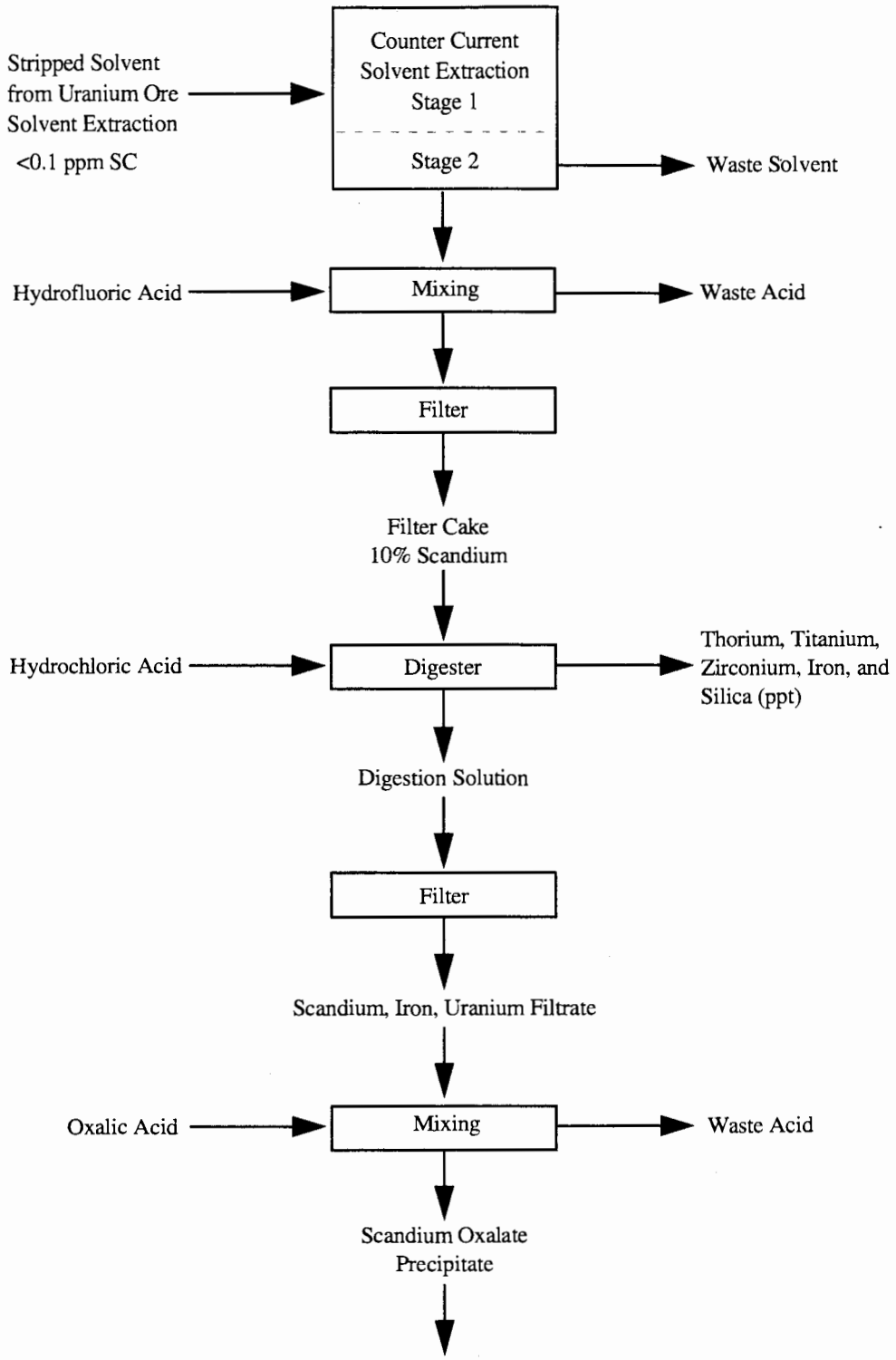
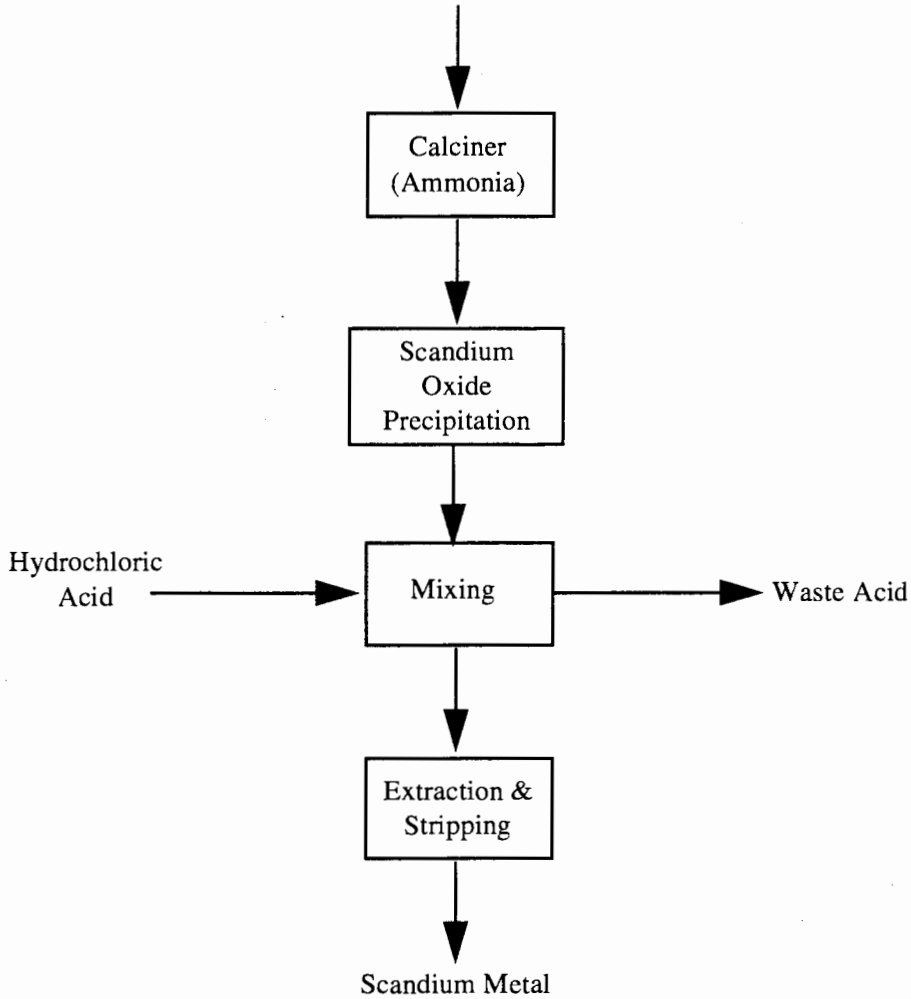


EXHIBIT 5 (Continued)

SCANDIUM FROM URANIUM



contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line for scandium recovery from thortveitite occurs between ore preparation and digestion, grinding, or chlorination for thortveitite processes 1, 2, and 3, respectively. EPA identified these points in the process sequences as where beneficiation ends and mineral processing begins because it is here where a significant chemical change to the thortveitite ore occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

The wastes generated by recovery from uranium may have been radioactive, however, no further characterization, management, or generation data are available. Those wastes identified in Exhibit 5 include:

Waste Solvent
Waste Hydrofluoric Acid

2. Mineral Processing Wastes

Waste streams are more likely to be associated with the primary products that produced the crude scandium concentrate. Although it is difficult to predict the amount and nature of wastes resulting directly from scandium production because of the wide variety of sources that are available as scandium starting materials, the attached process flow diagrams identify wastes that are generated as a result of scandium production processes.[9]

For example, using Exhibits 2 through 4 the following wastes result from the production of scandium:

Waste chlorine solution. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent ion exchange resins and backwash. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent solvents from solvent extraction. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low,

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[9] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-20.

medium, and high annual waste generation rate of 700 metric tons/yr, 3,900 metric tons/yr, and 7,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be recycled and may exhibit the characteristic of ignitability. This waste is classified as a spent material.

"Crud" from the bottom of the solvent extraction unit. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Dusts and spent filters from decomposition. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent acids (e.g., hydrochloric and sulfuric). Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 700 metric tons/yr, 3,900 metric tons/yr, and 7,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of corrosivity.

Waste solutions/solids from leaching and precipitation. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent wash water. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

As shown in Exhibit 5, the following wastes were generated when scandium was recovered through extraction from uranium ores. Since the process is no longer used, the Agency did not evaluate these materials further.

Digester precipitates
Waste Oxalic Acid
Waste Hydrochloric Acid

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Commented Received by EPA

EPA received no comments that address this specific sector.

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SELENIUM

A. Commodity Summary

Selenium is found in 75 different mineral species, however, pure selenium does not exist as an ore. For this reason, primary selenium is recovered from anode slimes generated in the electrolytic refining of copper. One facility, ASARCO - Amarillo, TX, processes this slime further to recover tellurium. For more information on tellurium recovery, see the tellurium report. According to the U.S. Bureau of Mines, three copper refineries, Asarco, Phelps Dodge, and Kennecott, accounted for all of the domestic production of primary selenium. The 1994 production was worth $3 million. End uses of selenium include:

- electronics, 35 percent;
- chemicals and pigments, 20 percent;
- glass manufacturing, 30 percent; and
- other, including agriculture and metallurgy, 15 percent.[1]

Exhibit 1 lists the names and locations of the facilities involved in the production of selenium.

EXHIBIT 1

SUMMARY OF SELENIUM PROCESSING FACILITIES

Facility Name	Location
ASARCO	Amarillo, TX
Kennecott (RTZ)	Garfield, UT
Phelps Dodge	El Paso, TX

B. Generalized Process Description

1. Discussion of Typical Production Processes

Generally, 30-80 percent of the selenium contained in copper anode slimes is recovered by commercial operations. Several methods of selenium recovery may be used. The two major processes for selenium recovery are smelting with soda ash and roasting with soda ash. Other methods include roasting with fluxes, during which the selenium is either volatilized as an oxide and recovered from the flue gas, or is incorporated in a soluble calcine that is subsequently leached for selenium. In some processes, the selenium is recovered both from the flue gas and from the calcine. At the process end points, selenium metal is precipitated from solutions of sodium selenite or selenious acid by sulfur dioxide.[2] Exhibits 2 through 4 present process flow diagrams for selenium production.

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[1] Stephen Jasinske, "Selenium," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 150-151.

[2] Neldon Jenson, "Selenium," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, pp. 705-711.

EXHIBIT 2

SODA ROASTING

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-187 - 3-193.)

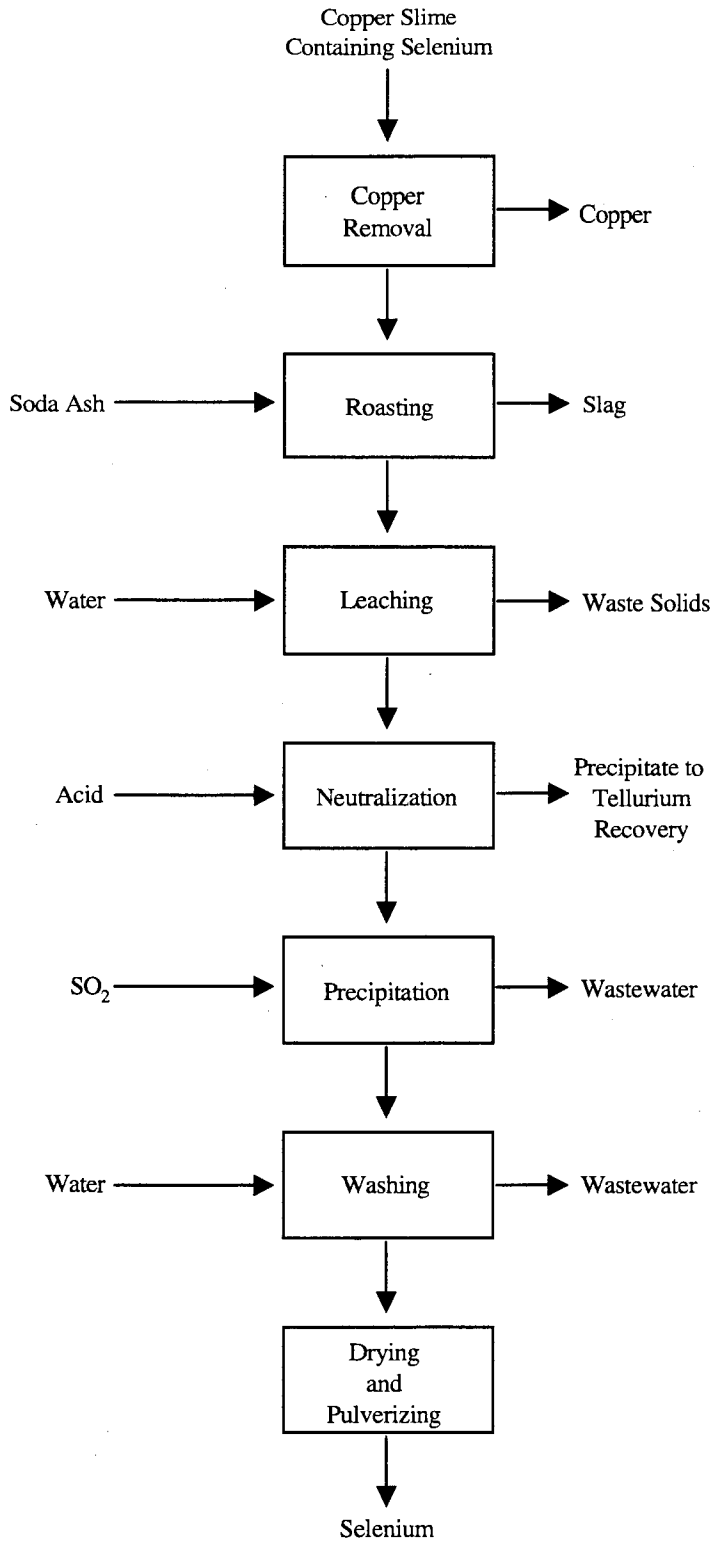


EXHIBIT 3

SODA SMELTING

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-187 - 3-193.)

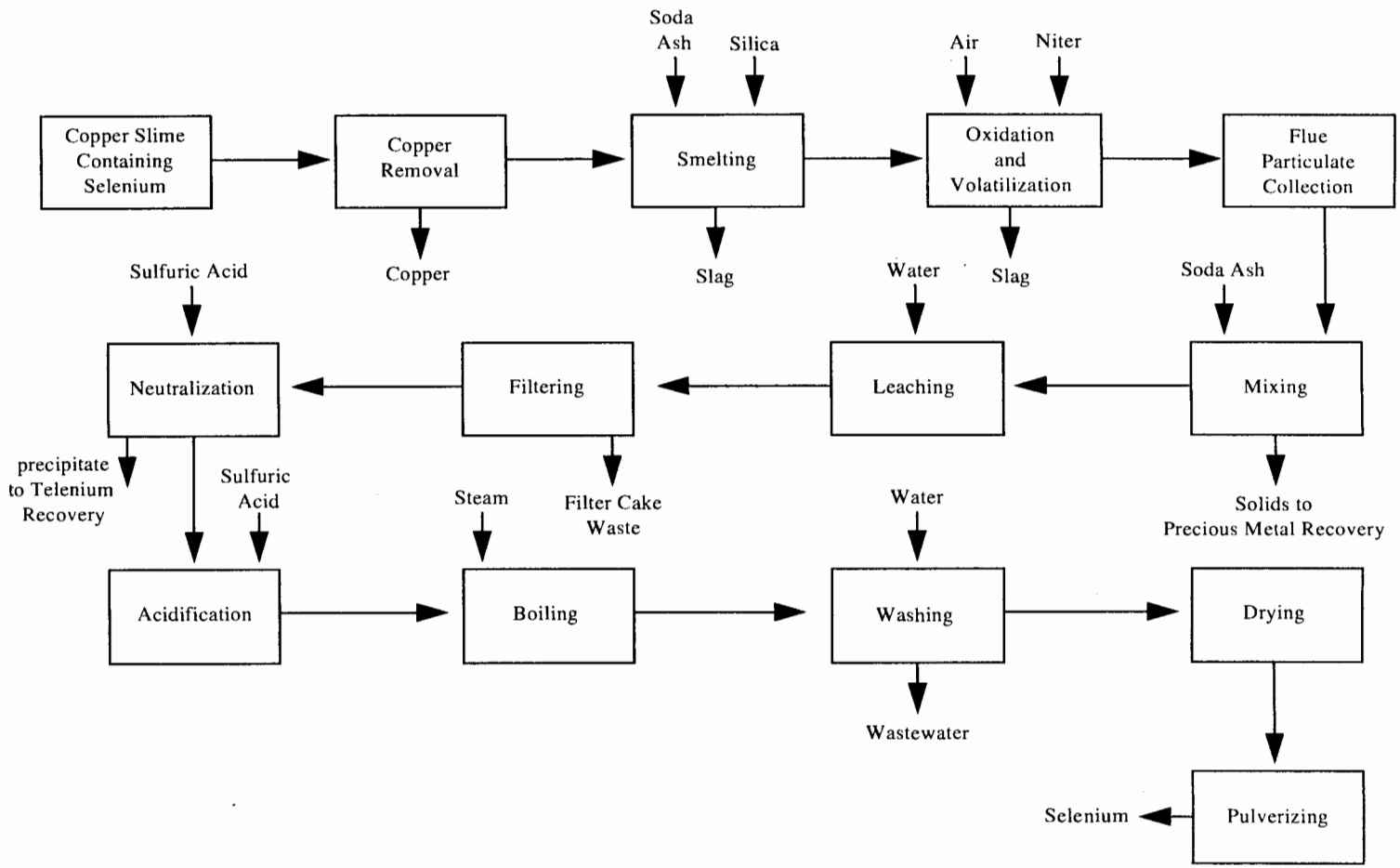
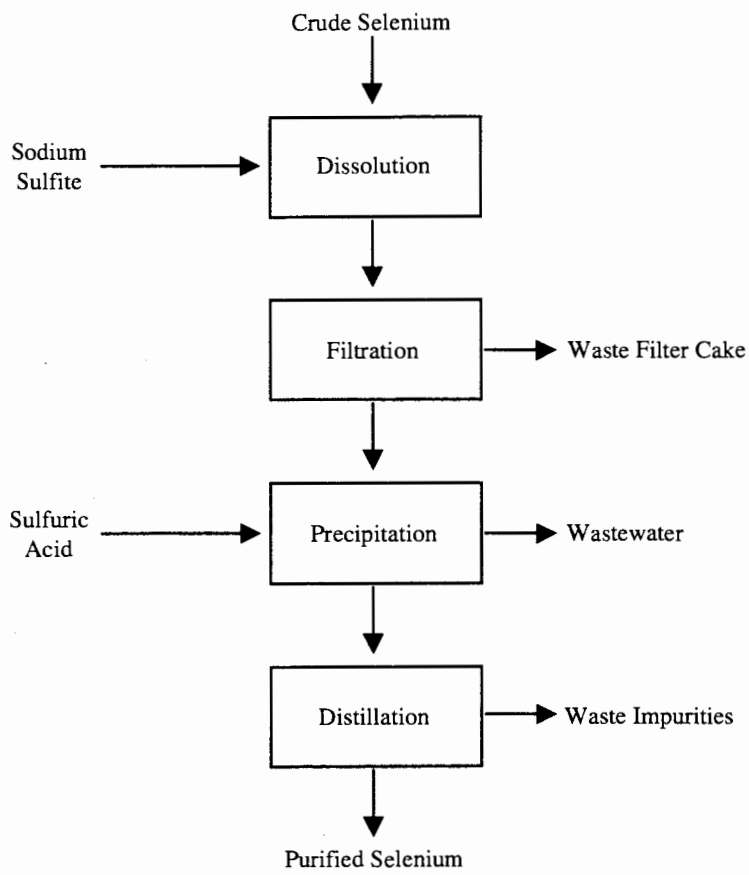


EXHIBIT 4

SELENIUM PURIFICATION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-187 - 3-193.)



2. Generalized Process Flow

Roasting with Soda Ash

As shown in Exhibit 2, decopperized slime is roasted with soda ash to produce sodium selenite and sodium selenate. The selenium is then leached with water, neutralized to precipitate tellurium, and then sparged with SO_2 to precipitate selenium.[3]

Smelting with Soda Ash

As shown in Exhibit 3, decopperized slime is mixed with soda ash and silica and smelted in a furnace. Slag containing silica, iron, and several other metal impurities is generated as waste. The molten charge containing selenium is aerated to oxidize and volatilize the selenium, and the remaining solids are removed for precious metal recovery. The soda ash is leached with water and filtered to separate unwanted solid impurities, which are discarded as waste. The selenium-containing filtrate is neutralized to precipitate out tellurium, and is acidified to precipitate selenium. The selenium containing material formerly classified as sludge is then boiled, washed, dried, and pulverized to yield the selenium product.[4]

Selenium Purification

The selenium obtained from either smelting with soda ash or roasting with soda ash is then purified. As shown in Exhibit 4, the crude selenium is dissolved in sodium sulfite, and the resulting solution is filtered to remove unwanted solids as waste filter cake. The resulting filtrate is acidified with sulfuric acid to precipitate the selenium. The selenium precipitate is distilled to drive off impurities, producing a high purity selenium for commercial and industrial use.

Kennecott Utah Copper Corporation (KUCC)

One company now recovers selenium via a hydrometallurgical process. Liquid from its gold recovery circuit is treated with SO_2 to precipitate crude selenium. The crude selenium is retorted (distilled) in an electric melting furnace. The offgas from the selenium retort is cooled to collect the selenium. After retorting and condensation, the pure selenium is crushed, sized, and packaged for shipment.[5]

High purity selenium is currently produced from crude coked selenium. After wet grinding, pulping, and decantation washing with hot water to (remove impurities such as arsenic), the high purity circuit feed is leached with hot sodium sulfite solution. Selenium dissolves to form a compound similar to sodium thiosulfate. After leaching, the slurry settles and the solution is decanted through a clarifier press to the precipitation tanks. Selenium is precipitated by acidification of this solution with concentrated H_2SO_4. The solutions are kept cool during acidification to obtain red amorphous selenium. After precipitation, the slurry is settled and most of the solution decanted to waste. Settled slurry is repulped with water and heated with steam. Heating converts the red selenium to a gray crystalline powder. The slurry is then centrifuged in a perforated bowl centrifuge and the solids washed by displacement with copious amounts of water.

Centrifuge cake is charged into the first stage of the three stage distillation circuit. Condensed selenium from these stills is collected in fractionating trays. Samples for spectrographic analysis of 19 elements are taken through the run. Early fractions are high in tellurium and other high-boiling-point impurities. Impure fractions are

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[3] Ibid.

[4] U.S. Environmental Protection Agency, "Selenium," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-187--193.

[5] Kenecott Utah Copper Corporation. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

rejected to sulfite leaching or redistillation in the first-stage stills. Acceptable fractions from the first-stage stills are advanced to second-stage distillation in a silicon carbide retort. Condensed selenium from this stage is passed through a shotter (pelletizer) and quenched with water. Seven fractions are normally made and a sample of each is analyzed spectrographically for 19 impurity elements. First and last fractions, as well as others showing abnormal impurity levels, are recycled to an appropriate part of the purification circuit. Acceptable fractions are advanced to third-stage distillation. Condensed selenium shot from third-stage distillation is again collected in seven fractions, each of which is analyzed spectrographically. Reject fractions are recycled back to an appropriate part of the circuit. Acceptable selenium shot from third-stage distillation is made up into lots and blended. Samples from the blended material are analyzed again spectrographically and chemical analysis is made for halogens, sodium sulfur, and nonvolatile material. Finally, acceptable lots are packaged for sale or stored for doped selenium production.[6]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

Since selenium is recovered as a by-product of other metals, all of the wastes generated during selenium recovery are mineral processing wastes. For a description of where the beneficiation/processing boundary occurs for this mineral commodity, see the sector report for copper presented elsewhere in this document.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Not applicable.

2. Mineral Processing Wastes

Selenium is recovered from anode slimes generated from the electrolytic refining of copper. Because of this, all wastes from selenium production generated after the production of the copper anode slimes are mineral processing wastes. Listed below are possible waste streams from selenium production.

Plant process wastewater (PWW). This waste may exhibit the characteristic of toxicity for lead. In addition, this waste may also exhibit the characteristic of corrosivity since it is expected to have a pH of 0.8 to 1.9. The 1991 generation rate for the sector was 66,000 metric tons per year.[7] Waste characterization data are presented in Attachment 1. This waste may be recycled and formerly was classified as a spent material.

Slag. This waste may contain silica, iron, and other metal impurities. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 50 metric tons/yr, 500 metric tons/yr, and 5000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for selenium. Slag may be recycled and formerly was classified as a byproduct.

Spent filter cake. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 50 metric tons/yr, 500 metric tons/yr, and 5,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for selenium. This waste may be recycled and formerly was classified as a byproduct.

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[6] Ibid.

[7] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, Vol. I, August, 1992, pp. I-2 - I-8.

Tellurium slime wastes are sent to tellurium product recovery. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 50 metric tons/yr, 500 metric tons/yr, and 5,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for selenium. This waste formerly was classified as a byproduct.

Waste solids. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 50 metric tons/yr, 500 metric tons/yr, and 5,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for selenium.

D. Non-uniquely Associated Wastes

Non-uniquely associated wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous), and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

One commenter provided new information about its facility's selenium recovery process (COMM 40). This new information has been included in the sector report.

Sector-specific Issues

None.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PLANT PROCESS WASTEWATER (ACID PLANT BLOWDOWN) - SELENIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.50	0.50	0.50	0/1	0.32	0.32	0.32	1/1	-	-
Antimony	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	-	-
Arsenic	0.50	1.45	2.40	1/2	0.95	0.95	0.95	1/1	5.0	0
Barium	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	100.0	0
Beryllium	2.000	0.050	0.050	0/1	0.0050	0.0050	0.0050	0/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.017	0.034	0.050	1/2	0.043	0.043	0.043	1/1	1.0	0
Chromium	0.50	0.50	0.50	0/1	0.11	0.11	0.11	1/1	5.0	0
Cobalt	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	-	-
Copper	0.090	0.30	0.50	1/2	0.050	0.050	0.050	0/1	-	-
Iron	1.63	1.63	1.63	1/1	1.50	1.50	1.50	1/1	-	-
Lead	1.42	9.16	16.90	2/2	12.00	12.00	12.00	1/1	5.0	1
Magnesium	14.90	14.90	14.90	1/1	14.10	14.10	14.10	1/1	-	-
Manganese	1.06	1.06	1.06	1/1	0.98	0.98	0.98	1/1	-	-
Mercury	0.00072	0.00072	0.00072	1/1	0.00088	0.00088	0.00088	1/1	0.2	0
Molybdenum	23.30	88.43	130	3/3	20.90	20.90	20.90	1/1	-	-
Nickel	0.10	0.30	0.50	1/2	0.050	0.050	0.050	0/1	-	-
Selenium	0.50	2.05	3.60	1/2	0.90	0.90	0.90	1/1	1.0	0
Silver	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	5.0	0
Thallium	2.50	2.50	2.50	0/1	0.25	0.25	0.25	0/1	-	-
Vanadium	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	-	-
Zinc	0.50	0.50	0.50	0/1	0.21	0.21	0.21	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	27,000	27,400	27,800	2/2	-	-	-	0/0	-	-
Fluoride	40.00	80.00	120	2/2	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	158	158	158	1/1	-	-	-	0/0	-	-
TSS	25	20,313	40,600	2/2	-	-	-	0/0	-	-
pH *	0.80	1.35	1.90	2/2					2<pH>12	2
Organics (TOC)	25.20	26.35	27.50	2/2					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SILICON AND FERROSILICON

A. Commodity Summary

Most ferrosilicon is used as an alloying element in the ferrous foundry and steel industries. Aluminum producers and the chemical industry were the main consumers of silicon metal. Ferrosilicon was produced by six companies in seven plants in the United States in 1992, and silicon metal was produced by six companies in eight plants.[1] Exhibit 1 lists these facilities and their locations. There are two standard grades of ferrosilicon, with one grade approximately 50 percent silicon and the other 75 percent silicon by weight.[2] The purity of silicon metal generally ranges from 96 to 99 percent.

EXHIBIT 1

SUMMARY OF FERROSILICON AND SILICON SMELTING AND REFINING FACILITIES (IN 1992)[a]

Facility Name	Location	Products
American Alloys Inc.	New Haven, WA	FeSi and Si
Applied Industrial Minerals Corp.	Bridgeport, AL	FeSi
Dow Corning Corp.	Springfield, OR	Si
Elkem Metals Co.	Alloy, WV	Si
Elkem Metals Co.	Ashtabula, OH	FeSi
Globe Metallurgical Inc.	Beverly, OH	FeSi and Si
Globe Metallurgical Inc.	Selma, AL	Si
Keokuk Ferro-Sil Inc	Keokuk, IA	FeSi
Silicon Metaltech Inc.	Wenatchee, WA	Si
Simetco Inc.	Montgomery, AL	Si
SKW Alloys Inc	Calvert City, KY	FeSi
SKW Alloys Inc	Niagara Falls, NY	FeSi and Si

[a] - Cunningham, L. D., "Silicon." Minerals Yearbook. Volume 1. Metals and Minerals. U.S. Bureau of Mines. 1992. p. 1191.

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[1] L.D. Cunningham, "Silicon," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 152.

[2] L.D. Cunningham, "Silicon," from Minerals Yearbook. Volume 1. Metals and Minerals. U.S. Bureau of Mines. 1992. p. 1183.

B. Generalized Process Description

1. Discussion of Typical Production Processes

In the United States all primary production of ferrosilicon and silicon metal is by the reduction of silica (SiO_2) to silicon (Si) in submerged arc electric furnaces. High purity silicon is made from metallurgical grade silicon, and is, therefore, secondary processing which is outside the scope of this report.

2. Generalized Process Flow Diagram

Exhibits 2 and 3 are typical production flow diagrams illustrating the production of silicon and ferrosilicon. As shown in the exhibits, the feed silica is washed, sized, and crushed. The silica is then mixed with a reducing agent, and either coal, coke, or charcoal. Wood chips are added for porosity. The mixture is fed into the furnace, and when ferrosilicon is being produced, iron or steel scrap is added.[3] The furnace is tapped periodically and the molten ferrosilicon or silicon metal is drawn out and cast into ingots. The ingots are allowed to cool, then are crushed to produce the final product.[4]

High purity silicon used in the electronics industry is made from silicon metal, and is therefore beyond the scope of this report. However, a brief overview of the production process is included for completeness. Naturally occurring quartz is converted to metallurgical grade silicon by heating it with coke in an electric furnace. The low grade silicon is then converted to high grade halide or halosilane which is then reduced with a high purity reagent.[5]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Research is being conducted in Austria on the production of ferrosilicon from lump quartz and charcoal using a plasma reactor. Other input substitutions also are being investigated, including using sand as a replacement for quartz, and taconite tailings instead of iron or steel. In addition, the use of plasma reactors in smelting silicon is being investigated in Austria.[6,7]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

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[3] U.S. Environmental Protection Agency, "Silicon and Ferrosilicon," from 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, 1988, pp. 3-194 - 3-195.

[4] L.D. Cunningham, 1992, Op. Cit., p. 1184.

[5] "Silicon and Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XX, 1982, p. 836.

[6] Goodwill, J. E., "Plasma Melting and Processing - World Developments," 48th Electric Furnace Conference Proceedings, New Orleans, LA, December 11-14th 1990, p. 280.

[7] Goodwill, J. E., "Developing Plasma Applications for Metal Production in the USA," Ironmaking and Steelmaking, Vol. XVII, No. 5, 1990, pp. 350-354.

EXHIBIT 2

SILICON PRODUCTION

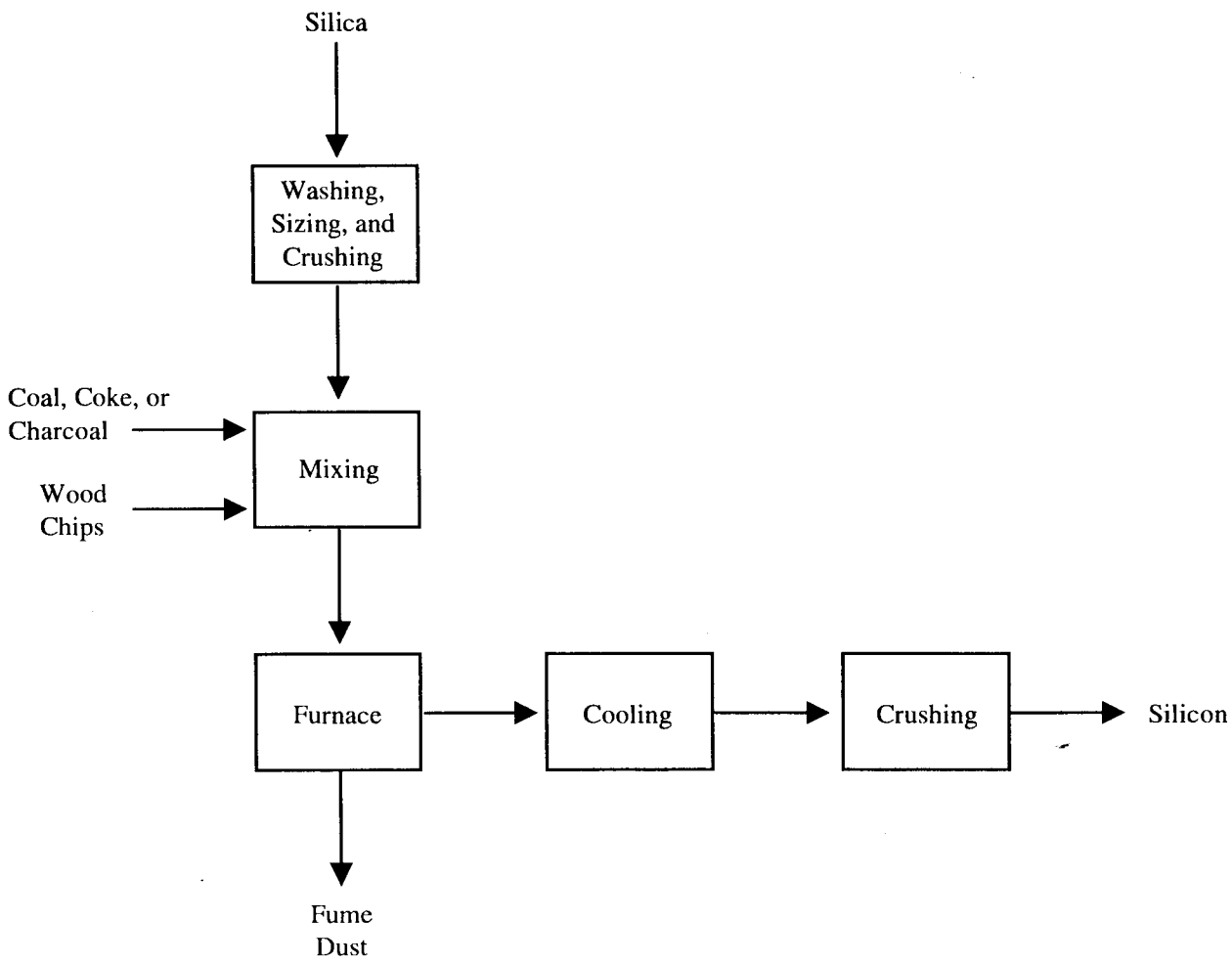
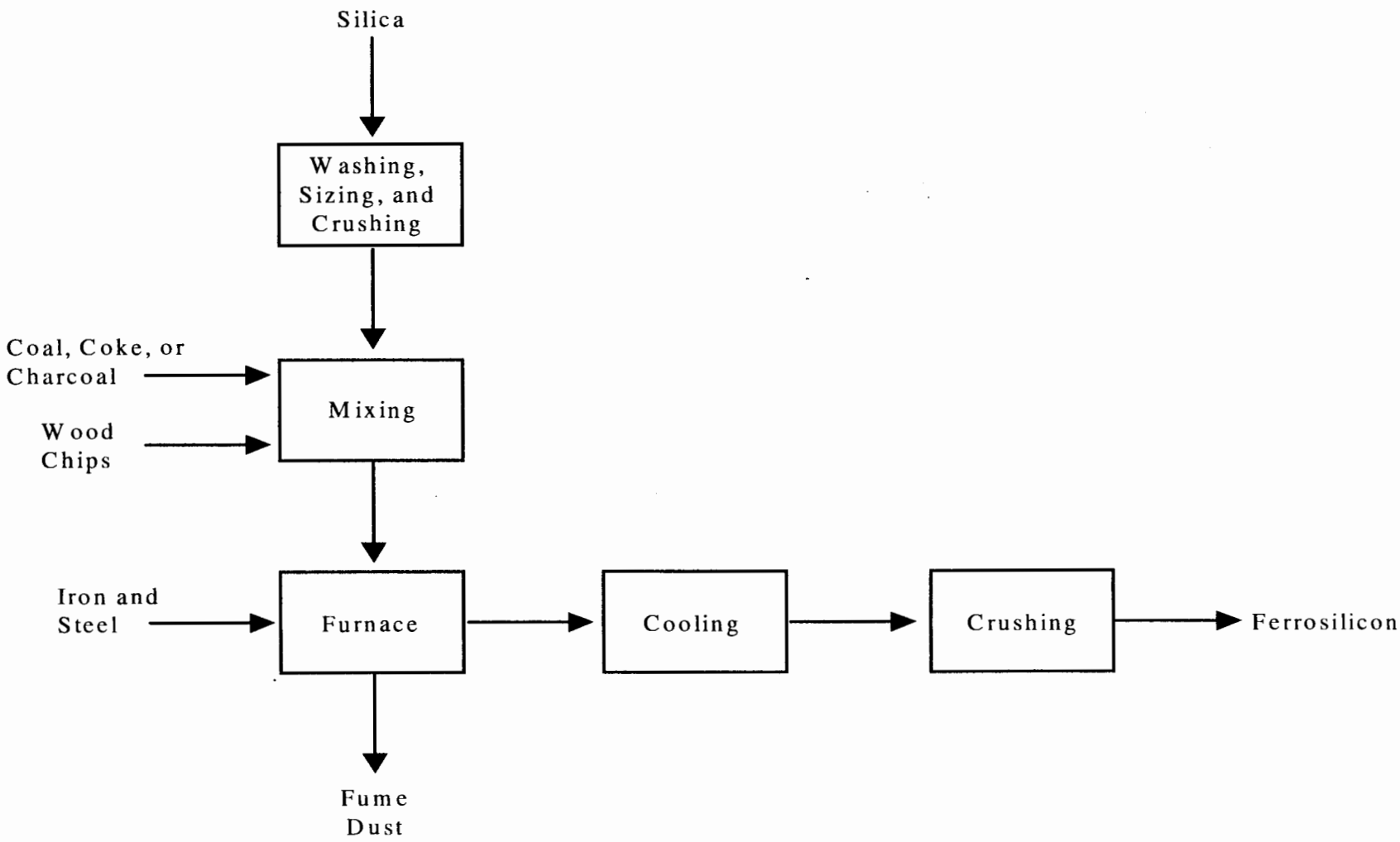


EXHIBIT 3

FERROSILICON PRODUCTION



Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between ore crushing and charging to the furnace because silica is thermally reduced to silicon or ferrosilicon in the furnace. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction and Beneficiation Wastes

The following wastes may result from beneficiation activities: gangue, spent wash water, and tailings. No information on waste characteristics, waste generation, or waste management for these waste streams was available in the sources listed in the bibliography.

2. Mineral Processing Wastes

Dross. The waste to product ratio for dross is approximately 1:99. Dross from the production of silicon metal can be used to produce ferrosilicon. Ferrosilicon dross can be used to produce silicomanganese. Dross can also be sold as an aggregate.[8] Dross is recycled and is not believed to be a solid waste.[9] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Slag. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

APC Dust/Sludge. The furnaces are generally equipped with fume collection systems and baghouses to reduce air pollution by capturing emissions from the furnace.[10] Originally, the baghouse dust (microsilica) was considered of little or no value. However, microsilica is now used as an additive in a number of different products,

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[8] Personal communication between ICF Incorporated and Joseph Gamboji, U.S. Bureau of Mines, June 28, 1989.

[9] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Volume I, Office of Solid Waste, August 1992, pp. I-4 and I-6.

[10] "Silicon and Ferrosilicon," Op. Cit., p. 3-195.

including high-strength concrete.[11] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[11] L.D. Cunningham, 1992, Op. Cit., p. 1184.

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U.S. Environmental Protection Agency. "Silicon and Ferrosilicon." From 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes. 1988. pp. 3-194 - 3-198.

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SODA ASH

A. Commodity Summary

Six companies in Wyoming and California comprise the United States soda ash industry, which is the largest in the world. The total estimated value of domestic soda ash produced in 1994 was $650 million. According the U.S. Bureau of Mines, the six producers had a combined nameplate capacity of 11 million tons per year and operated at 83% of that capacity in 1994. Soda ash is used in many products:

- glass, 49%
- soap and detergents, 13%
- flue gas desulfurization, 3%
- chemicals, 23%
- distributors, 5%
- pulp and paper, 2%[1]

Soda ash is the common name for sodium carbonate. This alkali compound is the eleventh largest inorganic chemical, in terms of production, of all domestic inorganic and organic chemicals, excluding petrochemical feedstocks. Natural soda ash is produced from trona ore, sodium carbonate-bearing brines, or surface mineralization. All of the active facilities produce natural soda ash from sodium carbonate-rich brines or from underground mining of trona ore.[2] Synthetic soda ash can be made by one of several chemical reactions that use common raw materials for feedstocks, such as limestone, salt, and coal. Other technologies produce soda ash as a byproduct.[3] Exhibit 1 presents the names and locations of the facilities involved in the production of soda ash.

EXHIBIT 1

SUMMARY OF SODA ASH PROCESSING FACILITIES

Facility Name	Location
FMC Corporation	Green River, WY
General Chemical Partners	Green River, WY
North American Chemical Company	Argus,CA Westend, CA
Rhone-Poulenc Mine	Green River, WY
Tenneco	Green River, WY
TG Soda Ash Mine	Green River, WY

[1] Dennis Kostick, "Soda Ash," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 156-157.

[2] Dennis S. Kostick, "Soda Ash and Sodium Sulfate," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 1237-1250.

[3] Dennis Kostick, "Soda Ash," from Industrial Minerals and Rocks, 6th ed., Society for Mining, Metallurgy, and Exploration, 1994, pp. 929-955.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Soda ash from Wyoming trona is mined, crushed, dried, dissolved, filtered, recrystallized, and redried. In California, soda ash from sodium carbonate-bearing brines in solution is mined, carbonated, filtered, dried, decomposed, bleached, and recrystallized to dense soda ash. These processes are described in more detail below.

2. Generalized Process Flow Diagram

All the Wyoming trona mines use room and pillar mining with multiple entry systems. Most use a combination of one or more types of mining: conventional, continuous, longwall, shortwall, or solution.[4] The FMC Corporation is the only natural soda ash producer that uses longwall mining to augment its mining technology. Shortwall mining is used exclusively by TG Soda Ash, Inc. Since the late 1980's, most Wyoming soda ash companies have installed continuous hauling systems to replace shuttle cars. FMC Corporation has been discharging tailings and spent solutions from solution mining to its tailing ponds since about 1953. Since then, sodium carbonate decahydrate crystals have been collecting on the bottom of these ponds at a rate of 20 to 30 cm per year. In 1985, FMC began using a bucket wheel dredge to extract almost 160 kt of crystals annually from the 485 hectare pond. The crystals are slurried, dewatered, melted, and processed into soda ash in the refinery. Other producers have similar ponds where sodium carbonate decahydrate has collected since the plants were built. Because of environmental considerations and the cost of constructing and maintaining tailing ponds, all the producers now inject waste tailings underground. This will reduce the future buildup of sodium decahydrate in the tailing ponds. In addition, several of the Wyoming soda ash producers are selling their spent purge liquors that contain dissolved sodium carbonate in solution to local power utility companies for pH control of process water.[5] Trona ore must be further refined to yield a 99% pure soda ash product.

Sodium sulfate, sodium chloride, potassium chloride, and borax must be physically and chemically removed from sodium carbonate bearing brines in order to process the sodium carbonate content into refined soda ash. The Wyoming facilities use one of two processes to refine soda ash from trona ore: (1) the monohydrate process or (2) the sesquicarbonate process. The two processes are essentially the same, differing only in the sequencing of procedures. The monohydrate method is the primary process used today to make soda ash. In addition to these two processes, the North American facilities at Searles Lake produce soda ash via another operation.[6]

Monohydrate Process

In the monohydrate process, trona is crushed and calcined in rotary gas-fired calciners operating at 150-300°C. Calcining removes water and carbon dioxide from the ore, and leaves an impure product containing 85% soda ash and 15% insolubles. The thermal decomposition of trona involves the following reaction:

$$2Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O \text{ (trona)} + \text{heat} \rightarrow 3Na_2CO_3 + CO_2 + 5H_2O$$

The calcinate is dissolved with hot water and sent to evaporative, multiple-effect crystallizers or mechanical vapor recompression crystallizers where sodium carbonate monohydrate crystals precipitate at 40-100°C. This is below the transition temperature of monohydrate to anhydrous soda ash. The insoluble portion of the ore containing shale and shortite are collected by clarifiers, filtered, and washed to recover any additional alkali before they are piped as a slurry to tailing ponds or injected underground. Some companies pass the liquor through activated carbon beds prior to crystallization to remove trace organics solubilized from the oil shale so that the organics do no interfere with crystal growth rate. The crystals are sent from the crystallizers to hydroclones and dewatered in centrifuges. The

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[4] Ibid.

[5] Ibid.

[6] Ibid.

centrifuge cake is conveyed to steam tube dryers where the crystals are dehydrated into anhydrous soda ash at 150°C, screened, and sent to storage or shipment. The final product made by the monohydrate process is dense soda ash.[7] Exhibit 2 presents a process flow diagram for the monohydrate process.

Sesquicarbonate Process

The sesquicarbonate process, the second process used to process Wyoming trona, produces light to intermediate grades of soda ash crystals. The trona is crushed, dissolved in hot mother liquor, clarified, filtered, and passed to cooling crystallizers where crystals of sodium sesquicarbonate precipitate. Activated carbon is added to filters to control the organics that interfere with crystal growth. The sodium sesquicarbonate is hydrocloned, centrifuged, and calcined using gas or indirect steam heat. Dense soda ash can be made by calcining the sodium sesquicarbonate at 350°C.[8] Exhibit 3 presents a process flow diagram of the sesquicarbonate process.

Searles Lake Process

At the North American Chemical Company facility at Searles Lake, complex brines are first treated with carbon dioxide gas in carbonation towers to convert the sodium carbonate in solution to sodium bicarbonate, which will precipitate under these conditions. The sodium bicarbonate is separated from the remainder of the brine by settling and filtration and is then calcined to convert the product back to soda ash. The decarbonated brine is cooled to recover borax and Glauber's salt. A second dissolving, precipitating with carbon dioxide, filtering, and calcining the light soda ash to dense soda ash, results in a refined product of better than 99% sodium carbonate.[9] Exhibit 4 presents the Searles Lake process.

Sodium Bicarbonate

Sodium bicarbonate, baking soda, is manufactured by percolating carbon dioxide gas through a carbonation tower containing a saturated soda ash solution. The sodium bicarbonate precipitate is collected, filtered, centrifuged, dried, screened, and packaged. Three of the five sodium bicarbonate producers are also soda ash producers.[10]

Sodium Hydroxide

Sodium hydroxide, or chemical caustic soda, is made from lime and soda ash by the following reaction:

$$Ca(OH)_2 + Na_2CO_3 \rightarrow CaCo_3 + 2NaOH$$

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[7] Ibid.

[8] Ibid.

[9] U.S. Bureau of Mines, 1992, Op. Cit., pp. 1237-1250.

[10] Dennis Kostick, 1994, Op. Cit., pp. 929-955.

EXHIBIT 2

THE MONOHYDRATE PROCESS

(Adapted from: Soda Ash: Mineral Processing Waste Generation Profile.)

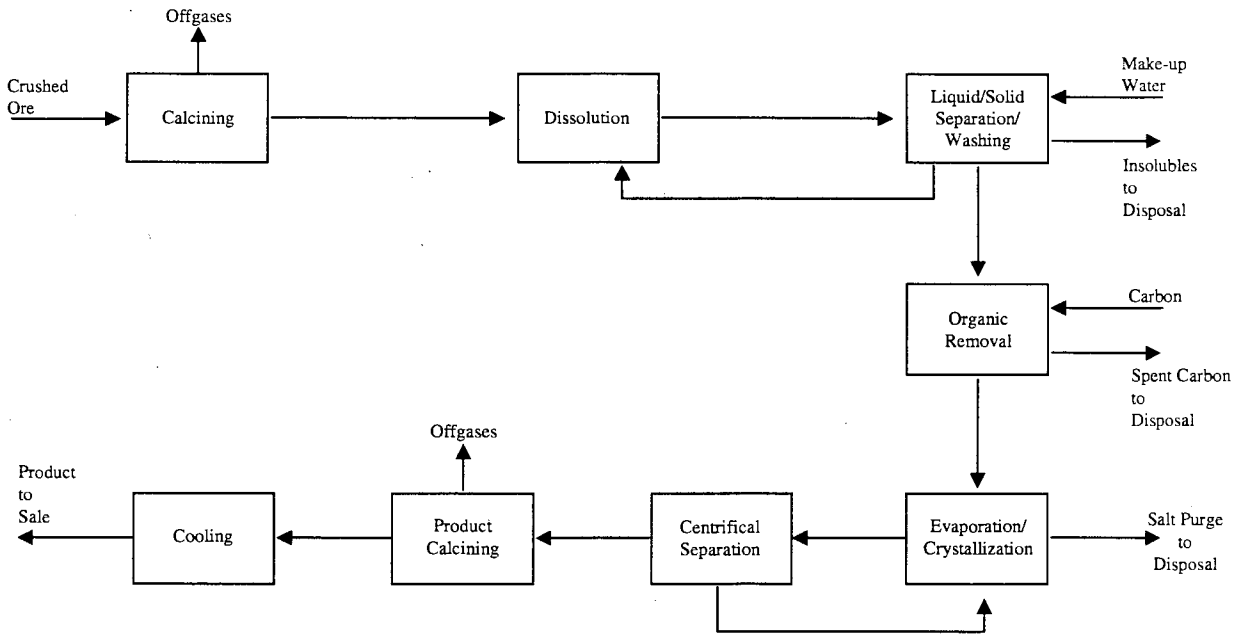


EXHIBIT 3

THE SESQUICARBONATE PROCESS

(Adapted from: Soda Ash: Mineral Processing Waste Generation Profile.)

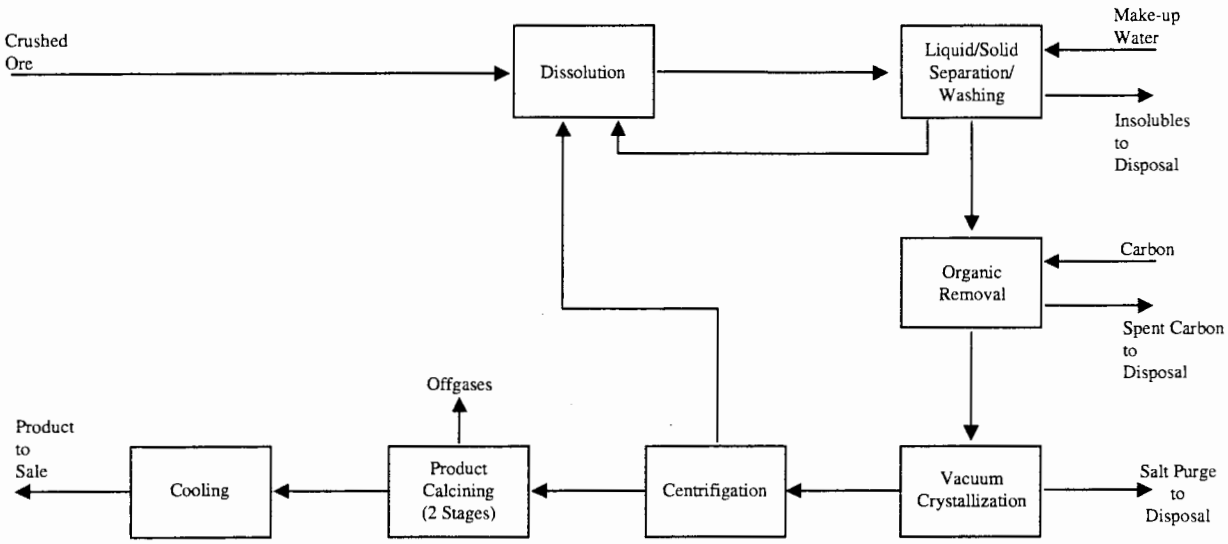
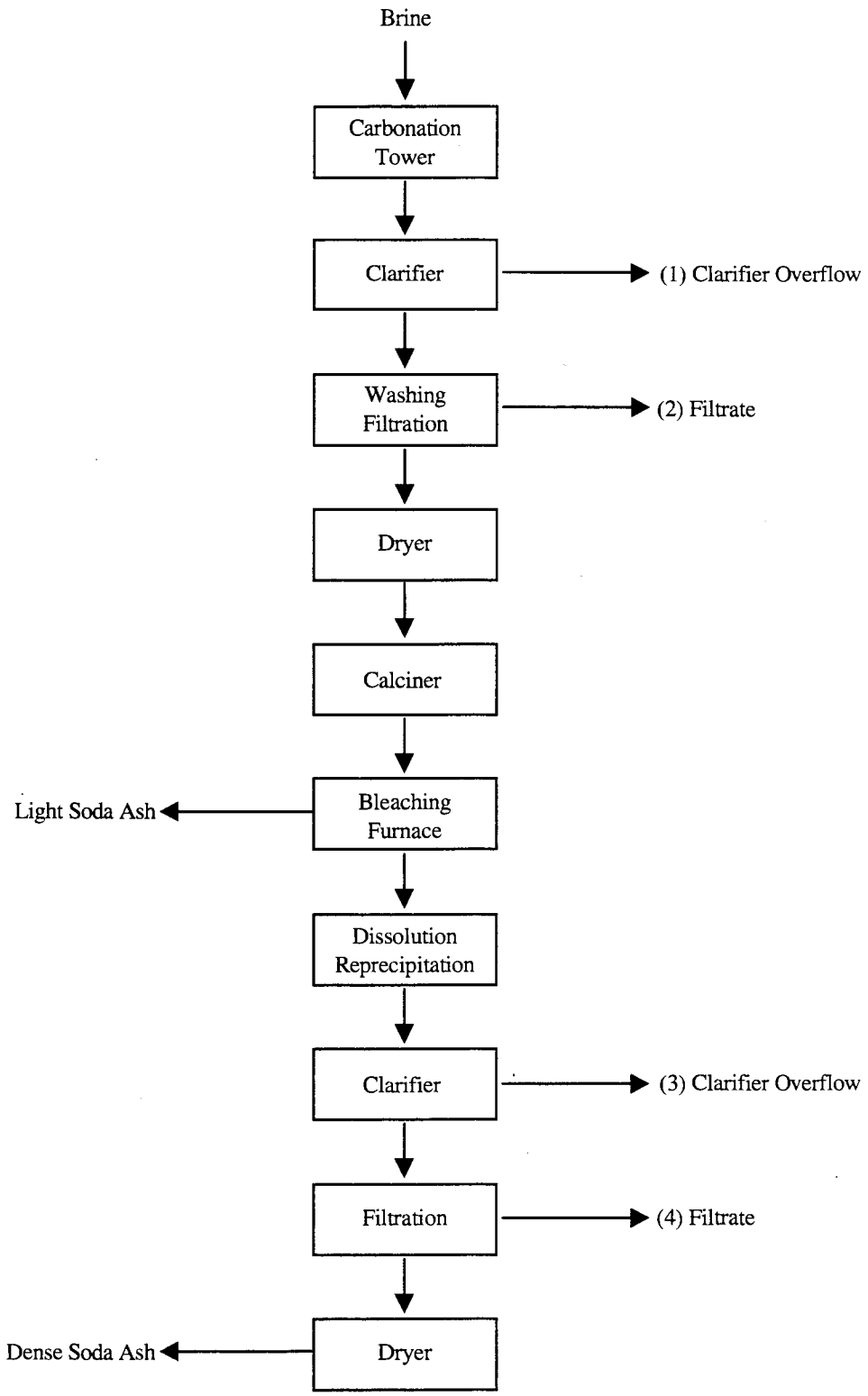


EXHIBIT 4

THE SEARLES LAKE PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-43 - 2-46.)



The lime is slaked and added to dissolved soda ash to produce chemical caustic soda. Calcium carbonate is precipitated from the reaction, calcined back to lime, and recycled. FMC uses about half of its caustic soda to produce captive sodium cyanide for precious metal recovery at its gold operation. [11]

Sodium Sesquicarbonate

Sodium sesquicarbonate is a hydrated compound containing soda ash and sodium bicarbonate. Trona ore is first crushed and dissolved to separate the insoluble impurities. The sodium compounds in solution are then clarified, filtered, crystallized, centrifuged, calcined, and recovered as long needle-shaped monoclinic crystals of sodium sesquicarbonate. FMC has a 50 ktpy sodium sesquicarbonate facility that sells mainly to the detergent industry. [12]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

Based on a review of the process, there are no mineral processing operations involved in the production of soda ash.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Extraction and beneficiation wastes include **overburden**, **tailings**, and **spent dissolution wastes**. The trona ore dissolution wastes are sent to tailings ponds. Waste tailings are injected underground.

Monohydrate Process Waste Streams

Ore insolubles. About 110 to 150 kg per kkg of ore insolubles are generated. These insolubles are transported to evaporation ponds for disposal.[13]

Filter aid and **carbon absorbent.** The waste generation for these wastes ranges from about 0.5 to 2 kg per kkg of product. Spent carbon absorbent and spent filter aids are sent to on-site evaporation ponds for disposal.[14]

Scrubber water. Scrubber liquor is recycled to the process for recovery of additional product.[15]

Particulates from crushing and calcination are generated. The calciner offgases contain carbon dioxide. Airborne particulate emissions from crushing are about 1.5 kg per kkg of product. From calcination, emissions are about 95 kg per kkg or product. The particulates from crushing and conveying are collected in bags and recycled to the ore bin which feeds the calciners. Residual emissions from the bag collectors are 0.015 kg per kkg of product. Particulates from the calciner consist of raw sodium carbonate dust. These particulates are passed through dry

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[11] Ibid.

[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] Ibid.

cyclones and electrostatic precipitators in series. The overall removal efficiency is 99.5%, resulting in residual particulates of 0.28 kg per kkg of product. Collected particulate is periodically recycled to the calciner.[16]

At the Tenneco Corporation facility in Green River, WY, tailings generated from the calcining process are discharged to the tailings tank. The tailings tank also receives fly ash and bottom ash generated from using coal to fire the calcining kiln and the steam boiler. This waste is treated in a thickening tank by adding anionic and cationic flocculants to the tailings to increase the solids content from approximately 10 to 50% solids. The waste is then disposed of in one of two waste management units, (1) the tailings pond, or (2) the mine void. The mine void is located in an old mine shaft approximately 800 feet below ground. Tailings which will be disposed of in the mine void are first accumulated in a holding tank adjacent to the mine shaft. The tailings are gravity fed into the mine when the holding tank fills. Tailing supernatant that accumulates in the mine is collected in a sump and periodically pumped and disposed of in the tailings pond. Eighty percent of the time thickened tailings are disposed of in the mine void and the remainder of the time thickened tailings are disposed of directly in the tailings pond.[17]

Airborne emissions from product drying, cooling, and packaging are generated from the monohydrate process. These wastes are controlled by the use of baghouses and wet scrubbers, with the recovered materials being recycled to the process. Emissions from the sodium carbonate drier are generated at about 2 kg per kkg of product. After wet scrubbing, residual emission is 0.02 kg per kkg of product. Product cooling generates about 0.7 kg of emissions per kkg of product. After bag dust collection, the residual emission is 0.005 kg per kkg of product. Product screening, storing, and packaging generates 1.4 kg of emissions per kkg of product. After bag dust collection, residual emission is 0.005 kg per kkg of product.[18]

Purge liquor. Purge liquor from calcining is often sold as a sulfur neutralizer or dust suppressant. At the California facility, purge liquor is produced in the brine operation and is sent back into the lake.

Mother liquor is a possible waste stream from centrifugation. This waste stream is recycled.

Trona ore processing waste is generated from the purification of calcined material.

At the Stauffer Chemical Company facility in Green River, WY, trona ore processing waste is generated at each of five calcining rakes after dissolution and purification. Waste from trona ore processing is pumped to a tank and combined with sluice water from a tailings pond so the waste can be pumped to one of the three on-site surface impoundments designated to receive the waste. The waste sent to the three impoundments contains approximately 10% sodium carbonate. As water evaporates the sodium carbonate dries forming sodium decahydrate.[19]

At General Chemical in Green River, WY, 1,451,488 metric tons of this waste was generated in 1988. This waste was characterized by a pH of 11.5. The waste is either sold or sent to an unlined surface impoundment.[20]

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[16] Ibid.

[17] U.S. Environmental Protection Agency, Mineral Processing Waste Sampling Survey Trip Reports, Tenneco Corporation, Green River, WY, August 1989.

[18] Ibid.

[19] Ibid.

[20] RTI survey for General Chemical Partners, Green River, WY, 1988, ID# 100388.

At the Tg Soda Ash facility in Green River, WY, 580 million gallons of this waste were reported in 1988. This waste reportedly had a pH of 11.5. The waste was sent to a surface impoundment lined with in-situ clay for solids precipitation and dewatering.[21]

Sesquicarbonate Process Waste Streams

Trona ore particulates are generated from crushing, drying, and calcination. About 1.5 kg per kkg of trona ore particulates are generated from crushing. About 2 kg per kkg of particulates are generated by drying operations. Approximately 95 kg per kkg of particulates are produced by calcination. Particulate emissions from drying and packaging are controlled by wet scrubbers and dry bag collectors, respectively. Emissions after control average 0.02 kg per kkg from the driers and 0.02 kg per kkg from the product packaging operations. Solids recovered from the dry bag collectors are recycled to product storage. Emissions from ore calcination are also collected and recycled.[22]

Scrubber water is generated from air pollution control devices. This is recycled to recover additional product.[23]

Ore residues. About 110 to 150 kg per kkg or ore residues, chiefly shale, are generated in the initial steps.[24]

Spent carbon and filter wastes from carbon absorption and filtration range from 0.5 to 2.0 kg per kkg per product. Waste filter aids and carbon absorbents are washed to the evaporation ponds for final disposal. Solid wastes from initial ore leaching are slurried to tailings ponds to settle out suspended materials and then to the final disposal ponds which serve as evaporation ponds from which there is no discharge.[25]

Suspended particulate matter is generated by the use of wet scrubbers for air pollution control, resulting in wastewater containing 2 kg per kkg of suspended particulates.[26]

Purge liquor from calcining. This waste is often sold as a sulfur neutralizer or dust suppressant.

Mother liquor from centrifugation. This waste stream is often recycled.

Searles Lake Process Waste Streams

Calciner offgases. About 170 kg of water vapor and 415 kg of carbon dioxide per kkg of soda ash are generated by calcination of the sodium bicarbonate intermediate. These offgases are cooled to recover water for other on-site uses and for use in product purification. After water removal, the carbon dioxide in recycled to the initial process calcination step.[27]

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[21] RTI Survey for Tg Soda Ash, Green River, WY, 1988, ID# 100206.

[22] U.S. Environmental Protection Agency, Multi-Media Assessment of the Inorganic Chemicals Industry, Volume III, August 1980, Chapter 13.

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] Ibid.

Particulate emissions from driers. These emissions are controlled by dry collectors, and the recovered solids are recycled to the process. Residual airborne particulate emissions are less than 1 kg per kkg of product.[28]

Spent brine. Spent brine from the initial carbonation and filtration steps contains about 16,000 kg per kkg of product of unrecovered sodium carbonate and other raw brine constituents. The spent brine contains about 65% water, 16% sodium chloride, and 19% of other constituents including sodium sulfate, borax, and potassium chloride. This waste stream is combined with other waterborne waste streams and returned to the brine source.[29]

Waste mother liquor. This waste stream is generated from product recrystallization and contains principally unrecovered sodium carbonates, along with smaller amounts of other raw brine constituents such as sodium sulfate, borax, and potassium chloride. This waste stream is combined with other waterborne waste streams and returned to the brine source.[30]

2. Mineral Processing Wastes

None identified.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[28] Ibid.

[29] Ibid.

[30] Ibid.

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SODIUM SULFATE

A. Commodity Summary

The domestic natural sodium sulfate industry consists of three producers in California, Texas, and Utah. In addition, the recovery of sodium sulfate as a byproduct from facilities that manufacture rayon and various chemicals accounts for nearly 50% of total domestic production. The total value of sodium sulfate sold was estimated at $50 million in 1994. End uses of sodium sulfate are soap and detergents (40%), pulp and paper (25%), textiles (19%), glass (5%), and other uses (11%).[1]

In its natural form, sodium sulfate is found in two minerals, mirabilite (Glauber's salt) and thenardite. Its occurrence is widespread and it is commonly found in mineral waters such as sea water, atmospheric precipitation, and saline lakes. Essentially all commercial deposits of sodium sulfate resulted from the accumulation and evaporation of surface and ground water in basins with interior drainage. These basins, or playas, are found in arid to semiarid regions.[2]

At the present time, sodium sulfate production is chiefly from brine deposits in Searles Lake, California; Great Salt Lake, Utah; and in Western Texas. North American Chemical Company processes sodium sulfate from Searles Lake at Trona, California. Great Salt Lake Minerals and Chemicals Corp., an affiliate of North America Chemical Co., operates a plant at the north end of the Great Salt Lake, which produces sodium sulfate as a byproduct. This facility has a sodium sulfate capacity of 22.7 to 32.9 kilotons per year. Ozark-Mahoning Company operates one plant in Western Texas near Seagraves. Exhibit 1 presents the names and locations of the facilities involved in the production of sodium sulfate.[3]

EXHIBIT 1

SUMMARY OF SODIUM SULFATE PROCESSING FACILITIES

Facility Name	Location
Great Salt Lake Minerals and Chemicals Corp.	Great Salt Lake, UT
North American Chemical, Inc.	Searles Lake, CA
Ozark-Mahoning Co.	Western Texas

B. Generalized Process Description

1. Discussion of Typical Production Processes

There are three principle methods used to produce sodium sulfate from brines: (1) the Ozark-Mahoning process used in Western Texas, (2) the North American Chemical Company process at Searles Lake, and (3) the process used by the Great Salt Lake Minerals and Chemical Corp. in Utah. Because these three processes are all

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[1] Dennis Kostick, "Sodium Sulfate," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 158-159.

[2] Sid McIlveen and Robert L. Cheek, Jr., "Sodium Sulfate Resources," from Industrial Minerals and Rocks, 6th edition, Society for Mining, Metallurgy, and Exploration, 1994, pp. 959-970.

[3] Ibid.

slightly different, each is described in more detail below. Exhibits 2 and 3 present process flow diagrams for sodium sulfate production.

2. Generalized Process Flow Diagram

Ozark-Mahoning Co. Process

The Ozark-Mahoning Company, the nation's second largest natural producer, operates a facility in Western Texas. As shown in Exhibit 2, brines are refrigerated to selectively precipitate Glauber's salt which is subsequently filtered and washed. Washing produces a saturated solution of Glauber's salt which is converted to the anhydrous form in mechanical vapor recompression crystallizers. Hydroclones and centrifuges separate the anhydrous crystals from the saturated solution, which is returned to evaporators. Anhydrous sodium sulfate is then dried in a rotary kiln and the resultant material is a product of 99.7% purity.[4]

North American Chemicals, Inc. Process (Searles Lake)

North American Chemicals, Inc. operates two facilities near Searles Lake, CA--the West End plant and the Argus plant. The West End plant is North America's only source of sodium sulfate. Here, sodium sulfate is recovered along with soda ash and borax. As shown in Exhibit 3, mixed brines are carbonated with carbon dioxide to precipitate sodium bicarbonate, which is removed by filtration. The decarbonated brine is cooled three times to produce two successive batches of borax and one of Glauber's salt. By heating, the sodium bicarbonate is converted to soda ash and the borax is either crystallized as a hydrate or dehydrated to anhydrous form. The Glauber's salt is washed, melted, and recrystallized as anhydrous sodium sulfate; 99.3% purity can be obtained.[5]

Great Salt Lake Minerals and Chemical Corp. Process

Great Salt Lake Minerals and Chemicals Corp. operates a facility on the Great Salt Lake for the production of potassium sulfate and magnesium chloride, of which sodium sulfate is a byproduct. Brine is pumped from the Great Salt Lake into solar evaporation ponds where sodium chloride precipitates. Sodium sulfate crystals precipitate in a fairly pure state when winter weather cools the brine to -1 to 4°C. The crystals are picked up by large earthmoving machinery and stored outdoors until further processing can take place. The harvested Glauber's salt is melted and anhydrous sodium sulfate precipitated by the addition of sodium chloride to reduce its solubility through the common ion effect. The final product is 99.5% pure.[6]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None identified.

4. Beneficiation/Processing Boundaries

Based on a review of the process, there are no mineral processing operations involved in the production of sodium sulfate.

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[4] Sid McIlveen and Robert L. Cheek, Jr., 1994, Op. Cit., pp. 959-970.

[5] Ibid.

[6] Ibid.

EXHIBIT 2

OZARK-MAHONING PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-47 - 2-51.)

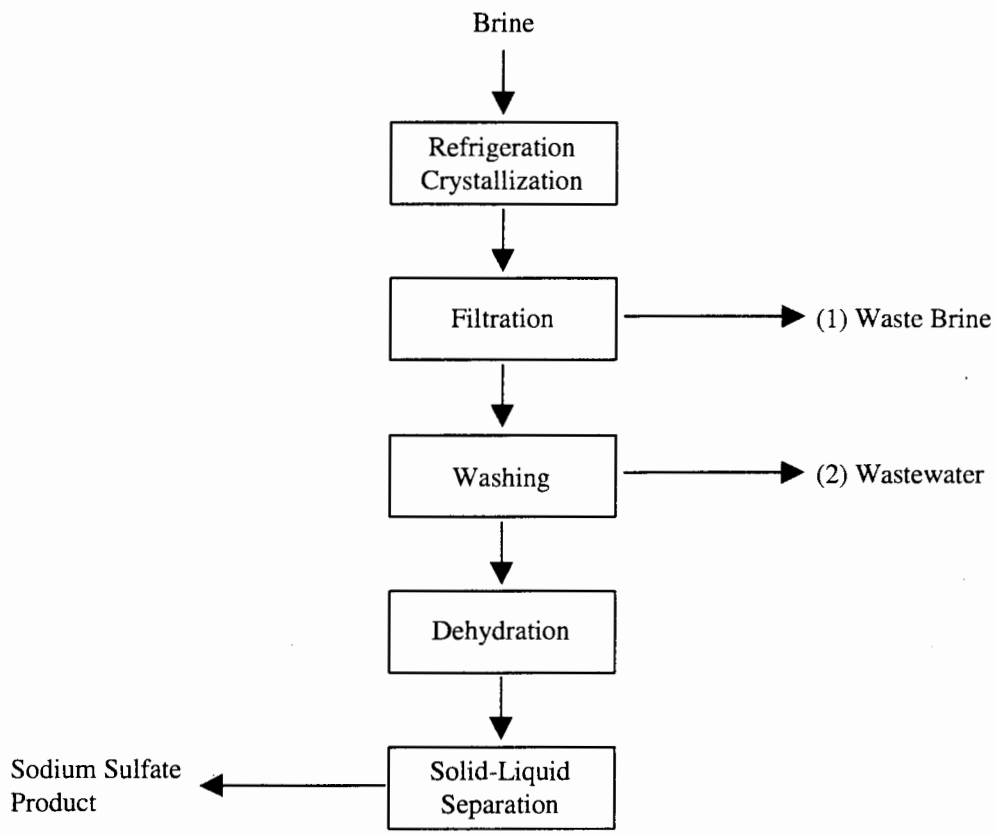
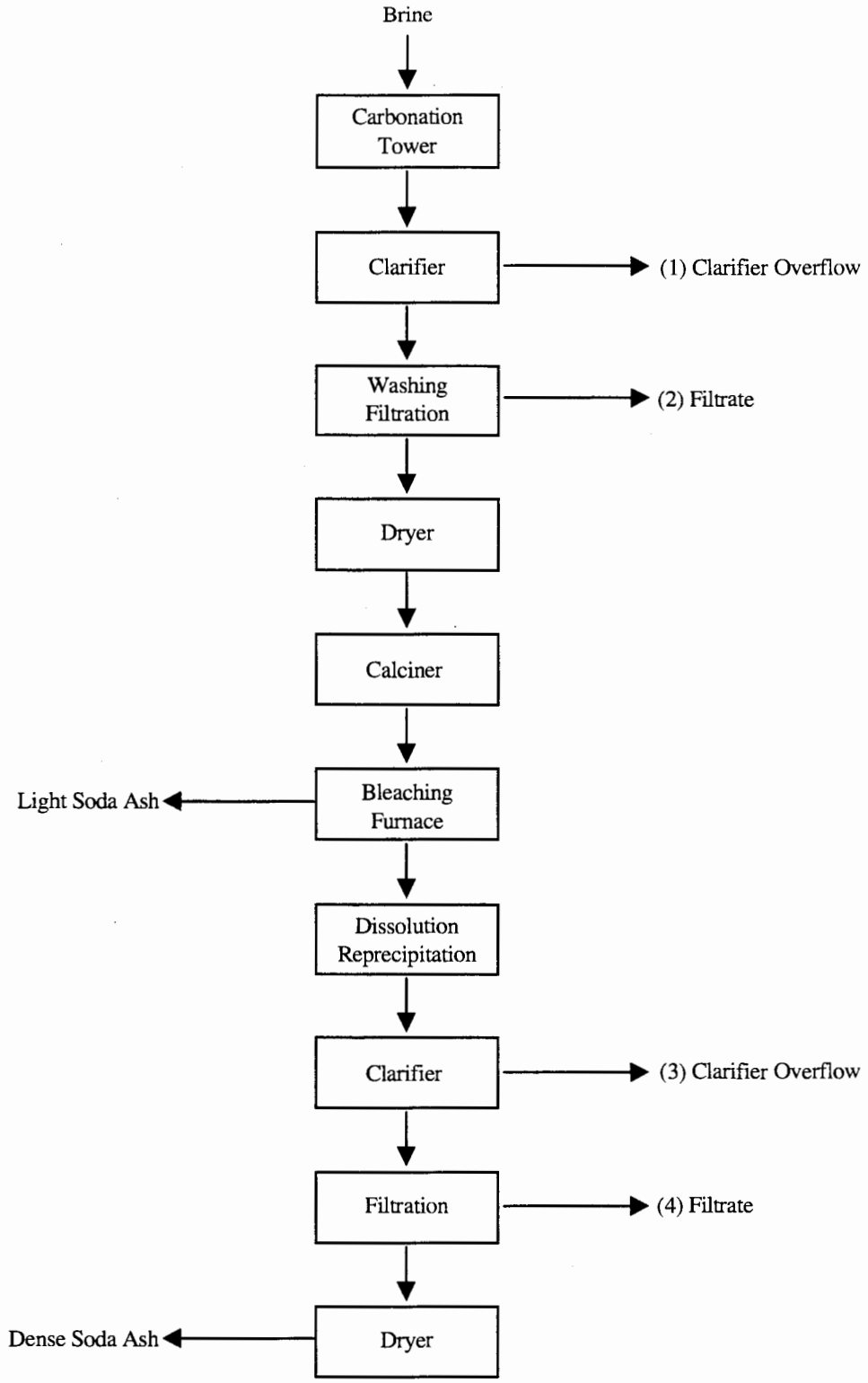


EXHIBIT 3

THE SEARLES LAKE PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-47 - 2-51.)



C. Process Waste Streams

Existing data and engineering judgement suggest that the wastes listed below from sodium sulfate production do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

1. Extraction/Beneficiation Wastes

Ozark-Mahoning Process

Waste brine and **wastewater** are wastes from filtrating and washing Glauber's salt. Literature reports that these wastes are reinjected into the salt formation.

Searles Lake Process

Clarifier overflow.

Filtrate.

2. Mineral Processing Wastes

None identified.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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STRONTIUM

A. Commodity Summary

According to the U.S. Bureau of Mines, no strontium minerals have been produced in the United States since 1959. The United States is however, a major producer of strontium compounds. In 1994, primary strontium compounds were used in color television picture tube glass (66%), pyrotechnic materials (11%), ferrite ceramic magnets (13%), and other miscellaneous uses (10%)[1]. Although consumption demands fluctuate from year to year, the overall consumption of strontium compounds and metals appears to be increasing.[2]

In early 1984, Chemical Products Corporation (CPC) in Cartersville, Georgia expanded its capacity by 30% to meet shortfalls in supply that resulted from the 1984 closure of the FMC Corporation plant in Modesto, California. CPC is now the sole domestic producer of strontium carbonate and strontium nitrate; CPC sells these products as raw materials to other industries.[3] Strontium metal is produced by CALSTRON near Memphis, Tennessee using an aluminothermic reaction.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Celestite, the most common strontium mineral, consists primarily of strontium sulfate. The second most common strontium mineral, strontianite, consists primarily of strontium carbonate.

Reportedly, it is very difficult to concentrate strontium minerals to grades acceptable for producing chemical compounds. The two most common celestite-to-strontium carbonate conversion processes are the soda ash process and the calcining process. Strontium metal is produced by (1) the thermal reduction of strontium oxide with metallic aluminum and (2) the electrolysis of fused strontium chloride and ammonium or potassium chloride.

Of the two strontium production processes, the soda ash method is a simpler process; however, the resulting product is of a lower grade. The calcining method or black ash method, produces chemical-grade strontium carbonate ($SrCO_3$) which is at least 98% strontium carbonate; whereas, the soda ash method only produces technical-grade strontium carbonate $\geq$95% pure. Although the soda ash method is a simpler process, the lower grade product causes it to be the less preferred method of recovery. The black ash method is used by CPC.

2. Generalized Process Flow Diagram

Strontium Carbonate Process

Soda Ash Process

Finely powdered celestite is mixed with soda ash and treated with steam for one to three hours. The celestite and soda ash react to produce less soluble strontium carbonate and soluble sodium sulfate. The two are separated by centrifuging. Exhibit 1 presents a process flow diagram for the soda ash process.

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[1] Joyce Ober, "Strontium," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 164-165.

[2] Joyce A. Ober, "Strontium," Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 1323-1332.

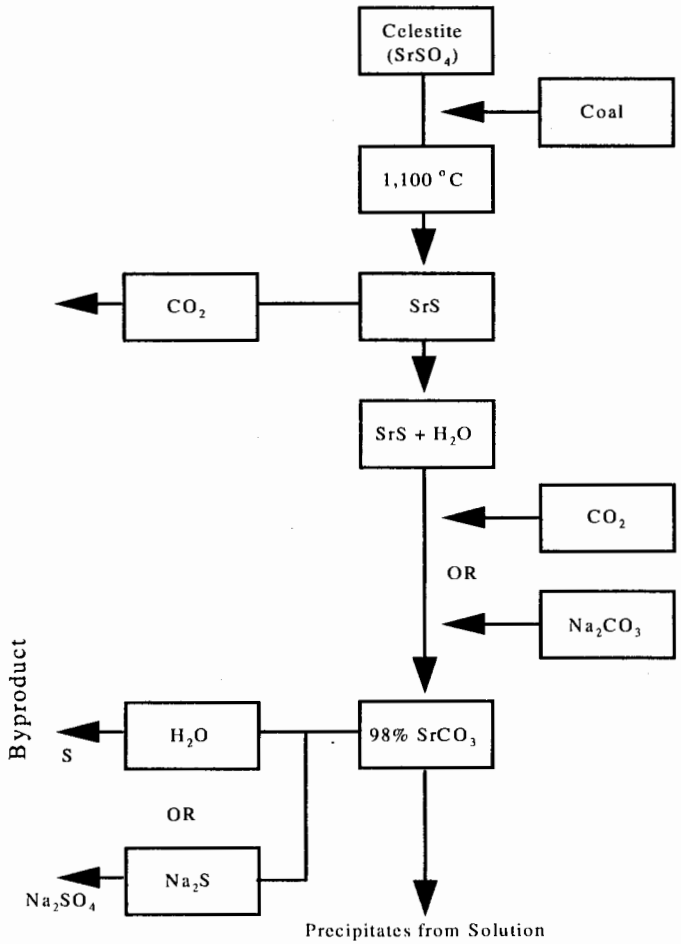
[3] Personal communication between ICF Incorporated and Joyce Ober, Bureau of Mines, July 21, 1994.

EXHIBIT 1

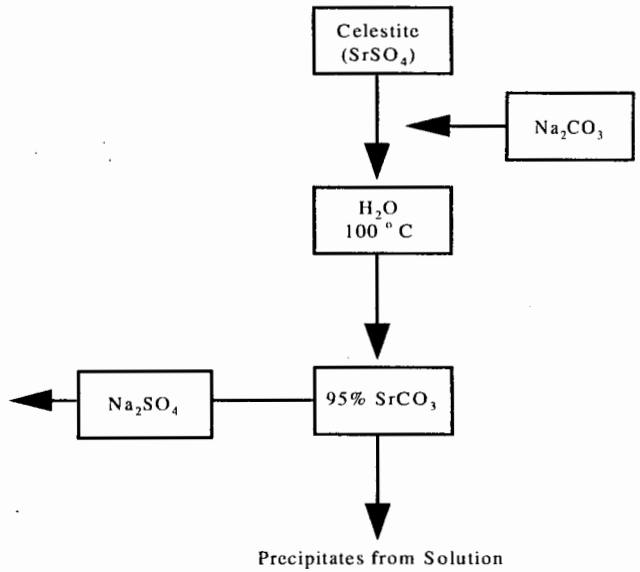
SIMPLIFIED FLOWCHART OF TWO METHODS FOR STRONTIUM CARBONATE PRODUCTION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-198 - 3-199.)

BLACK ASH



SODA ASH



Calcining Process (Black Ash Process)

Finely powdered coal is mixed with celestite which produces a "black ash." The mixture is heated to 1,100°C in a rotary kiln, expelling oxygen in the form of carbon dioxide from the insoluble strontium sulfate to form water-soluble strontium sulfide. The strontium sulfide is dissolved in water and the solution is filtered, and then either treated with carbon dioxide or soda ash in an agitation tank. Strontium carbonate may then form and precipitate from the solution. The strontium carbonate precipitate is removed from solution by filtering in vacuum drum filters, dried, ground, and packaged. The sulfur released in the process is either recovered as elemental sulfur or as other by-product sulfur compounds. This process is used by the CPC plant in Georgia but is called the "white ash method" because the sodium sulfide is white in color.[4] A process flow diagram is shown in Exhibit 1.

Production of Strontium Chemicals

Strontium nitrate is produced by reacting strontium carbonate with nitric acid. Other strontium chemicals are produced similarly by reacting strontium carbonate with the acid appropriate for the desired result.

Production of Other Strontium Compounds

Chemical-grade strontium carbonate can be used without further purification to produce most other strontium compounds. Either chemical-grade or technical-grade (greater than 95% pure) can be used for transformation to other strontium compounds, and in the conversion processes further purification occurs. For some processes, higher grades of strontium carbonate are necessary and elimination of contamination by particular elements is emphasized.

Strontium Metal Production

Strontium metal can be produced in two ways. The more common method is through the thermal reduction of strontium oxide and aluminum metal, subsequent distillation and condensation of metallic strontium on a cooled plate. The other method is electrolysis of a fused bath of strontium chloride and ammonium chloride or potassium chloride.[5]

Other Processes

Strontium ferrite magnets are usually prepared by mixing strontium carbonate, iron oxide, and crystal growth inhibitors and presintering at 1,000°C to 1,300°C. Strontium titanate is formed by reacting a mixture of high purity strontium carbonate and titanium dioxide at 2,000° to 2,200°C for several hours.[6]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Technologically, there is very little known about strontium. As technology becomes more sophisticated and the search for alternate materials is intensified, specific properties of strontium will become better known. Strontium appears to have applications in the metallurgy of aluminum, silicon, and other light metals, as well as potential use as a solid electrolyte in fuel cells.[7]

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[4] "Strontium--Uses, Supply, and Technology," U.S. Bureau of Mines Information Circular, 1989, p. 6.

[5] Ibid.

[6] Ibid.

[7] John E. Ferrell, "Strontium," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, pp.777-782.

A new process for the extraction and recovery of strontium from acidic waste streams is being developed. In this process, SREX (Strontium Extraction), strontium is extracted from acidic solution and is stripped from the organic phase using either water or dilute HNO_3. Prolonged exposure of the process solvent to nitric acid at elevated temperatures or to radiation from a ^{60}CO source produces essentially no deterioration in its performance. Experiments show that 99.7% of the strontium initially present in a feed solution can be removed using only three extraction stages.[8]

4. Beneficiation/Processing Boundaries

Based on a review of the process, there are no mineral processing operations involved in the production of strontium.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Black Ash Method

Calciner offgas. Calciner emissions may contain carbon dioxide which may or may not be recycled into the agitation tank. This offgas may also contain sulfur dioxide and ore particles.[9]

Dilute sodium sulfide solution
Filter muds
Spent ore
Vacuum drum filtrate
Waste solution

Soda Ash Method

Waste sodium sulfate solutions

2. Mineral Processing Wastes

None identified.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[8] Philip E. Horowitz, Mark L. Dietz, and Dan E. Fisher, "SREX: A New Process for the Extraction and Recovery of Strontium from Acidic Nuclear Waste Streams," Argonne National Laboratory, 1991, pg. 1.

[9] U.S. Environmental Protection Agency, "Strontium," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-198 - 3-203.

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Horwitz, E. Philip, Mark L. Dietz, and Dan E. Fisher. "SREX: A New Process for the Extraction and Recovery of Strontium from Acidic Nuclear Waste Streams." Argonne National Laboratory. 1991. pg. 1.

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Personal communication between ICF Incorporated and Joyce Ober, Bureau of Mines. July 21, 1994.

"Strontium--Uses, Supply, and Technology." U.S. Bureau of Mines Information Circular. 1989. p. 6.

U.S. Environmental Protection Agency. "Strontium." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. 1988. pp.3-198 - 3-199.

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SULFUR

A. Commodity Summary

The United States is the world's foremost producer and consumer of sulfur and sulfuric acid, with production from Frasch, recovered, and byproduct sources. According to the U.S. Bureau of Mines, sulfur (in all forms) was produced at 169 operations in 30 states, Puerto Rico, and the U.S. Virgin Islands for a total shipment value of nearly $500 million in 1994. Texas and Louisiana accounted for nearly 50% of domestic production. Agricultural chemicals (fertilizers) accounted for 61% of sulfur demand; organic and inorganic chemicals accounted for 10%; metal mining accounted for 5%; and petroleum refining accounted for 7%. Other miscellaneous uses, accounting for 17% of demand, were widespread because many products produced by industry require sulfur in one form or another during some stage of their manufacture.[1]

Sulfur is a non-metallic element widely used in industry both as elemental sulfur (brimstone) and as sulfuric acid. Sulfur production is from three sources: combined sulfur, recovered sulfur, and formed sulfur. Combined sulfur occurs in natural compounds such as iron pyrite, copper sulfides, and gypsum. Recovered sulfur is produced as a byproduct of other processes such as oil refining or air pollution control. Formed sulfur is elemental sulfur cast or pressed into particular shapes to enhance handling and to suppress dust generation and moisture retention.[2]

In 1994, recovered elemental sulfur was produced by 59 companies at 150 plants in 26 states, one plant in Puerto Rico, and one plant in the U.S. Virgin Islands. Byproduct sulfuric acid was produced by 16 facilities in 1994.[3] The three companies listed in Exhibit 1 produce the bulk of mined sulfur in the United States. These three companies accounted for 32% of the U.S. production of sulfur in all forms in 1990. All three companies use the Frasch process for sulfur mining. Penzoil produces sulfur from its Culberson mine in western Texas and is currently engaged in exploration activities in western Texas, the Gulf Coast, and elsewhere. Texasgulf currently operates one mine in Texas (Boling dome), extracting about 40,000 tpy of sulfur. Freeport currently operates two mines in the Gulf Coast.[4] The names and locations of the smaller facilities are not available.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Sulfur is mined from both surface and underground deposits, and is recovered as a byproduct from a number of industrial processes. In sulfur mining, three techniques are applied: conventional underground methods, conventional open pit methods, and the Frasch mining method. About 90% of all sulfur mined is obtained through Frasch mining.[5] Frasch mining and sulfur production from recovered, combined, and formed sulfur are described below in addition to the production process for sulfuric acid.

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[1] Joyce Ober, "Sulfur," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 166-167.

[2] Gregory R. Wessel, "Sulfur Resources," from Industrial Minerals and Rocks, 6th edition, Society for Mining, Metallurgy, and Exploration, 1994, pp. 1011-1046.

[3] Joyce Ober, 1995, Op. Cite., pp. 166-167.

[4] Gregory R. Wessel, 1994, Op. Cit., pp. 1011-1046.

[5] Ibid.

EXHIBIT 1

SUMMARY OF MAJOR PRIMARY SULFUR PROCESSING FACILITIES

Facility Name	Location
Freeport Sulphur Co.	Caminada, offshore LA
Penzoil Sulphur Co.	Culberson, W. TX
Texasgulf Inc.	Boling, TX

2. Generalized Process Flow

Frasch Mining

The Frasch mining process uses hot water to melt sulfur trapped in salt domes. The sulfur is then pumped to the surface and is either sold as a liquid or cooled and solidified into a number of forms for market. Exhibit 2 presents a process flow diagram for the Frasch process.

Recovered Elemental Sulfur (Claus Process)

Recovered elemental sulfur is a non-discretionary byproduct of petroleum refining, natural gas processing, and coking plants. Recovered sulfur is produced primarily to comply with environmental regulations applicable directly to processing facilities or indirectly by restricting the sulfur content of fuels sold or used. The principal sources of recovered sulfur are hydrogen sulfide in sour natural gas and organic sulfur compounds in crude oil. Recovery is mainly in the elemental form, although some is converted directly to sulfuric acid. Sulfur in crude oil is recovered during the refining process. Organic sulfur compounds in crude oil are removed from the refinery feed and converted to hydrogen sulfide by a hydrogenation process. The sulfur in natural gas is already in the form of hydrogen sulfide. Hydrogen sulfide from both sources is converted to elemental sulfur by the Claus process. In this process, concentrated hydrogen sulfide is fired in a combustion chamber connected to a waste heat boiler. Air is regulated to the combustion chamber so that part of the hydrogen sulfide is burned to produce sulfur dioxide, water vapor, and sulfur vapor. The high temperature gases are cooled in a waste heat boiler and sulfur is removed in a condenser. The efficiency of the process is raised by adding as many as three further stages in which the gases leaving the sulfur condenser are reheated and passed through catalytic converters and additional condensers. Finally, the total gas stream is incinerated to convert all remaining sulfur-bearing gases to sulfur dioxide before release to the atmosphere. The sulfur is collected in liquid form. Exhibit 3 presents a process flow diagram for the Claus process.

Combined Sulfur

Combined sulfur can be recovered during the smelting of nonferrous sulfides. Sulfur dioxide in the smelter gases is converted to sulfuric acid, liquid sulfur dioxide, or oleum. In the United States, byproduct sulfuric acid from nonferrous metal smelters and roasters supplied about 11% of the total domestic production of sulfur in all forms in 1990. Sulfur may also be recovered from sulfur dioxide emissions. Regenerative or throwaway flue-gas desulfurization methods may be used either to recover sulfur in a useful form or to dispose of it as solid waste. Both recovery methods may employ wet or dry systems and use a variety of compounds such as limestone, sodium carbonate, and magnesium oxide to neutralize or collect the sulfur dioxide. End products include gypsum, sulfuric

EXHIBIT 2

FRASCH PROCESS

(Adapted from: Multi-Medial Assessment of the Inorganic Chemicals Industry, 1980, Chapter 14.)

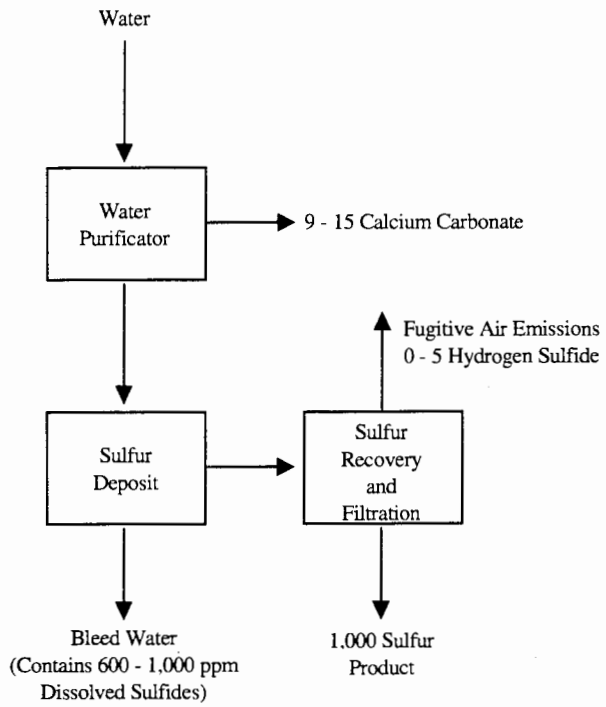
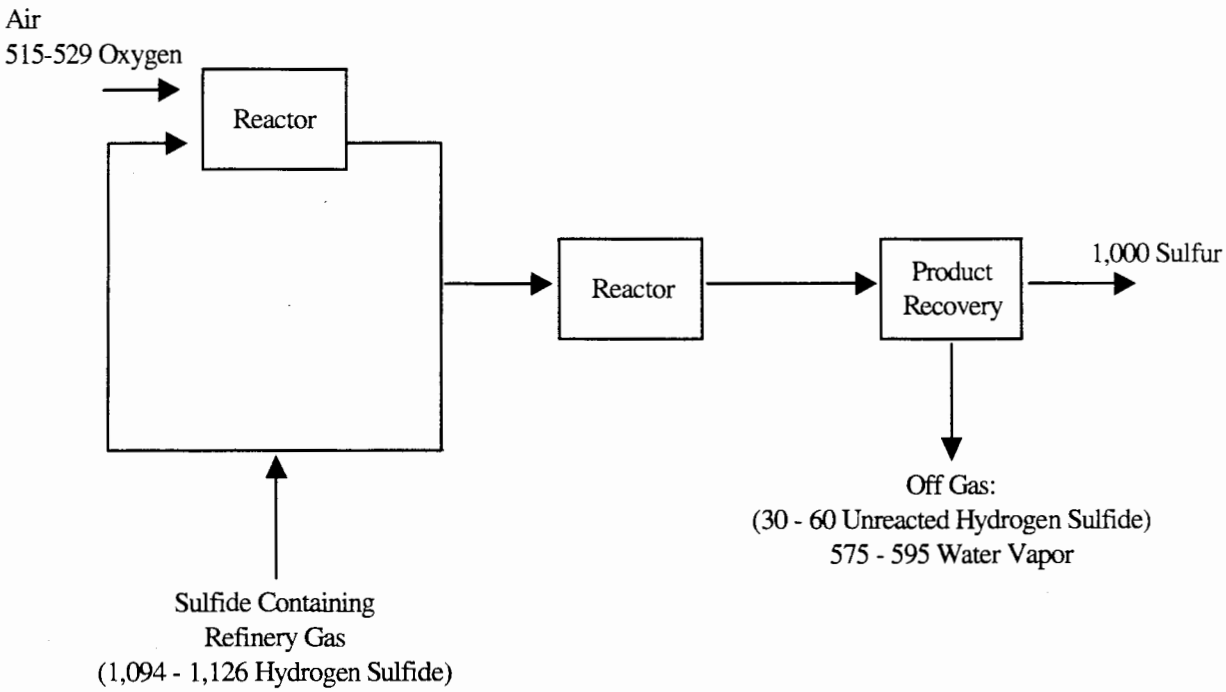


EXHIBIT 3

CLAUS PROCESS

(Adapted from: Multi-Medial Assessment of the Inorganic Chemicals Industry, 1980, Chapter 14.)



acid, liquid sulfur dioxide, and elemental sulfur, all of which can be used if a local market exists. If no local markets exist, large quantities of gypsum or sulfuric acid may have to be neutralized or otherwise disposed.[6]

Formed Sulfur

Formed sulfur may be made in one of several forms, including: flakes, slates, prills, nuggets, granules, pastilles, and briquettes. To produce flakes, the sulfur is cooled and solidified on the outside of large rotating drums, from which it peels off into small flakes. To produce slates, molten sulfur is cast onto a continuous conveyer belt and is cooled with air or water so that it solidifies into a thin sheet. As the slate reaches the end of the belt, the sheet breaks into smaller pieces. Sulfur prilling can be accomplished with air or water. In air prilling, molten sulfur is sprayed from the top of a tower against an upward flow of air. As it falls, the sulfur breaks into small droplets and cools into prills. In water prilling, the sulfur is sprayed into tanks containing water, from which the prills are collected and dried. Minor modifications to prilling techniques are used to produce nuggets. Granulation involves applying successive coats of sulfur to solid particles of sulfur in a granulator until the particle size reaches the required diameter. In the Procor GX granulation process, liquid sulfur is sprayed into a rotating drum in which small seed particles of sulfur are recycled from the end of the process. Pastilles are individual droplets of molten sulfur that have been dropped on a steel belt and cooled by conduction. The Sandvik Rotoform process uses a patented

[6] Ibid.

Rotoformer to distribute the sulfur on the belt. At the end of the belt, the pastilles are scraped off and fall onto a collecting conveyer.[7]

Sulfuric Acid

Sulfuric acid is usually produced near consumption sites. To produce sulfuric acid, elemental sulfur or any number of sulfur-bearing materials are burned. The resulting sulfur dioxide is mixed with additional air or oxygen and passed through a packed bed of supported vanadium pentoxide catalyst. The sulfur dioxide is converted to sulfur trioxide. The gases emerging from the catalytic reactor are cooled and absorbed in 98-99% sulfuric acid to generate 98-99% acid. Plants can be either single or double absorption units. In double absorption units, tail gases from the initial absorption step are mixed with additional sulfur dioxide, reheated and passed through another catalytic reactor to form additional sulfur trioxide. This material is cooled and absorbed in a second stream of sulfuric acid to generate additional 98-99% sulfuric acid. Exhibit 4 presents a process flow diagram for the production of sulfuric acid.[8]

The process is modified somewhat if feed materials other than pure sulfur are used. Materials such as spent sulfuric acid, hydrogen sulfide, and off-gases from smelters are also used for the manufacture of sulfuric acid.[9]

If spent acid is the feed material, it is thermally decomposed to yield a gas stream containing sulfur dioxide, small amounts of sulfur trioxide, water vapor, and small amounts of organic materials. The gas stream is cooled or the sulfuric acid is scrubbed to condense out water and organics, and is then demisted to remove residual water. The purified sulfur dioxide gas stream is reheated, mixed with additional air or oxygen, and sent to catalytic converters. The process proceeds from this point as it does with pure sulfur as the feed.[10]

When smelter or pyrite roasting off-gases containing sulfur dioxide are used as the feed material, the gas stream is passed through a series of dry filtration devices to remove entrained particulate matter. The gas is cooled to remove water vapor before it can be used in the process.[11]

Sulfur from pyrite is produced by roasting the iron sulfide to produce sulfur dioxide gas and iron oxide solid. The gas is treated to produce either elemental sulfur or sulfuric acid and the iron oxide is sold as feed for iron making. There are no wastes from this process.[12]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

There has been sporadic production of elemental sulfur from volcanic deposits in the western United States, but the selective mining techniques used would eliminate the generation of wastes.[13]

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[7] Ibid.

[8] U.S. Environmental Protection Agency, Multi-Media Assessment of the Inorganic Chemicals Industry, Vol. III, 1980, Chapter 14.

[9] Ibid.

[10] Ibid.

[11] Ibid.

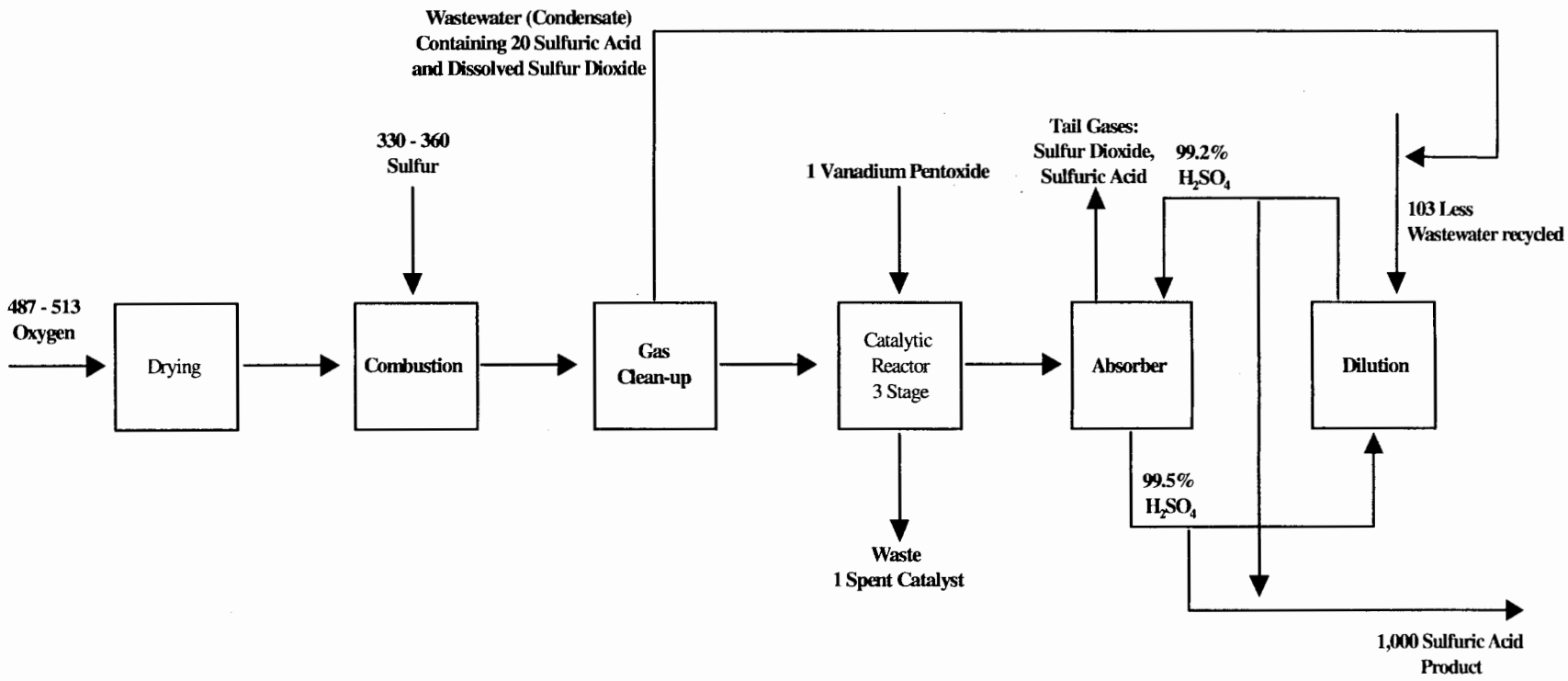
[12] Ibid.

[13] U.S. Environmental Protection Agency, "Sulfur," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 2-55 - 2-56.

EXHIBIT 4

SULFURIC ACID PRODUCTION

(Adapted from: Multi-Media Assessment of the Inorganic Chemicals Industry, 1980, Chapter 14.)



4. Beneficiation/Processing Boundaries

Frasch Processing

Based on a review of this process, there are no mineral processing operations involved in the production of sulfur via the Frasch proces.

Claus Process and Combined Sulfur

Based on EPA's review of these processes, both were determined to start with sulfur recovered from other operations such as petroleum refining and other mineral smelting operations and as such, are completely outside the scope of the Mining Waste Exclusion.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Based on existing data and best engineering judgement, none of the wastes listed below from sulfur production are expected to exhibit characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

Frasch Process Wastestreams

Wastewater. Wastewater from Frasch mining may contain 600 to 1,000 ppm dissolved sulfides and 14,000 to 60,000 ppm of dissolved chlorides. Bleed water retrieved from the formation is produced in amounts ranging from 38,000,000 to 1.6 billion liters per day. Well seal water is generated in amounts ranging from 5,000 to 20,000 liters per day and contains up to 60 ppm dissolved sulfides. At anhydrite plants, seal water and water recovered from the formation are treated and reused. At off-shore salt dome plants, bleed water and seal water are combined and discharged without further treatment. At on-shore facilities, bleed water, area runoff, seal water, and other wastewater are combined and sent to aeration lagoons. There, sulfides are oxidized to sulfates and thiosulfates. The sulfide content of the raw effluent is reduced from the range of 600 to 1,000 ppm to the range of 10 to 40 ppm prior to discharge.[14]

Air emissions. Emissions from the mine, generated during sulfur recovery, may contain hydrogen sulfide. The hydrogen sulfide fugitive emissions may range from 0 to 5 kg per kkg of product.[15]

Sludge. Calcium carbonate sludge is generated by water pretreatment and ranges from 9 to 15 kg per kkg of product. The calcium carbonate water treatment sludge is recovered and reused. At anhydrite plants, it is used as drilling mud.

Filter cake. At salt dome plants, about 3.5 kg per kkg of product of waste filter cakes from sulfur filtration are generated. At salt dome facilities, filter cakes from sulfur purification are stored for future recovery of additional product.

Miscellaneous wastes such as **residues** and **spilled sulfur** are generated from the Frasch process. After processing, residues are landfilled.

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[14] U.S. Environmental Protection Agency, 1980, Op. Cit, Chapter 14.

[15] Ibid.

2. Mineral Processing Wastes

Based on existing data and best engineering judgement, the wastes listed below from sulfur production and sulfuric acid production are not primary mineral processing wastes. Therefore, the Agency did not evaluate these materials further.

Claus Process

Tail gases. An airborne waste from product recovery is generated and contains unconverted hydrogen sulfide gas ranging from 5,000 to 12,000 ppm, 300 to 500 ppm carbon disulfide, 300 to 5,000 ppm carbon oxysulfide, and up to 200 ppm sulfur vapor. (The carbon disulfide and carbon oxysulfide are produced by side reactions of organic compounds present in the feed stream and sulfur dioxide generated in the process.) From 950 to 4,400 cubic meters of tail gases are produced per kkg of sulfur product.[16] Tail gases are typically recovered and processed to recycle sulfur compounds. There are several methods used to recover sulfur compounds from these gases. The processes are described briefly below.

The SCOT process reconverts sulfur compounds in tail gases to hydrogen sulfide. This stream is scrubbed from the tail gases with amine solution, the regeneration of which releases a purified hydrogen sulfide which is recycled to the Claus process. This process recovers over 98% of the sulfur compounds in the tail gases.[17]

The Beavon and Stretford processes are also used to recover sulfur from tail gases. The Beavon process catalytically reduces sulfur oxides to hydrogen sulfide and the Stretford process removes the hydrogen sulfide by absorption in an amine solvent. Regeneration of the solvent releases a purified hydrogen sulfide which is converted to sulfur. About 98% removal of sulfur compounds from the tail gases is achieved.[18]

The Citrate process, developed by the Bureau of Mines, and the Wellman Lord process are used to recover most sulfur compounds from the tail gases as sulfur. These processes involve reduction of the sulfur dioxide present in the tail gases to sulfur.[19]

Spent catalysts. Spent catalysts are recycled or landfilled.[20]

Sulfuric Acid Production

Airborne emissions from double absorption plants range from 0.5 to 3 kg per kkg of sulfur dioxide and from 0.1 to 0.15 kg per kkg of sulfuric acid mists. The high end of the range represents plants using wet feed materials. Emissions from single absorption plants are controlled in one of five ways: (1) demisters and wet scrubbers, (2) scrubbing with aqueous ammonia solutions, (3) the Wellman Lord process, (4) molecular sieves to absorb sulfur dioxide, and (5) no control.[21]

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[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Ibid.

Wastewater. This wastewater includes wastewater from wet scrubbing, spilled product, and condensates. This waste contains dissolved sulfur dioxide and sulfuric acid values. This wastewater is usually neutralized and lagooned to settle suspended solids prior to discharge.[22]

Spent catalyst. Spent catalyst, generally vanadium pentoxide, are usually landfilled and sometimes reprocessed.[23]

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific spector.

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[22] Ibid.

[23] Ibid.

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TANTALUM, COLUMBIUM, AND FERROCOLUMBIUM

A. Commodity Summary

Tantalum is used in the electronics industry, as well as in aerospace and transportation applications. Columbium (the commonly used synonym for the element niobium) is used as an alloying element in steels and in superalloys. Tantalum and columbium are often found together in pyrochlore and baripyrochlore, the main columbium containing minerals, as well as in columbite. These minerals contain relatively small amounts of tantalum, pyrochlore, and baripyrochlore, having a columbium pentoxide-to-tantalum pentoxide ratio of 200 to 1 or greater.[1] Columbite contains slightly larger amounts (up to eight percent) of tantalum.[2] Tantalite is the primary source of tantalum pentoxide, and contains small amounts of columbium pentoxide. Microlite is another source of tantalum pentoxide. Tantalum is also recovered from tin slags.[3] There has been no significant mining of tantalum or columbium ores in the United States since 1959. Producers of columbium metal and ferrocolumbium use imported concentrates, columbium pentoxide, and ferrocolumbium. Tantalum products are made from imported concentrates and metal, and foreign/domestic scrap.[4]

Ferrocolumbium is an alloy of iron and columbium. Ferrocolumbium is used principally as an additive to improve the strength and corrosion resistance of steel used in high strength linepipe, structural members, lightweight components in cars and trucks, and exhaust manifolds. High purity ferrocolumbium is used in superalloys for applications such as jet engine components, rocket assemblies, and heat-resisting and combustion equipment.[5] Exhibit 1 summarizes the principal producers of tantalum, columbium and ferrocolumbium in the United States in 1992. Only Cabot Corporation and Shieldalloy Metallurgical Corporation use ores as their starting material.[6]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Tantalum and columbium ores are processed by physically and chemically breaking down the ore to form columbium and tantalum salts or oxides, and separating the columbium and tantalum salts or oxides from each other. These salts or oxides may be sold, or further processed to reduce the salts to the respective metals. Ferrocolumbium is made by smelting the ore with iron, and can be sold as a product or further processed to produce tantalum and columbium products.[7] These processes are described in greater detail below.

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[1] L.D. Cunningham, "Columbium (Niobium) and Tantalum," Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 435-436.

[2] L.D. Cunningham, "Columbium," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, p. 187.

[3] L.D. Cunningham, 1992, Op. Cit., p. 438.

[4] L.D. Cunningham, "Columbium" and "Tantalum," Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 48 and 170.

[5] L.D. Cunningham, 1992, Op. Cit., pp. 435-436.

[6] Personal Communication between ICF Incorporated and Larry D. Cunningham, U.S. Bureau of Mines, November 1994.

[7] Ibid.

EXHIBIT 1

SUMMARY OF TANTALUM, COLUMBIUM, AND FERROCOLUMBIUM PRODUCERS (IN 1992)[a]

Facility Name	Location	Type of Products
Cabot Corp.	Boyertown, PA	Cb and Ta pentoxide/metal, FeCb, Ta capacitor powder
Kennametals, Inc.	Latrobe, PA	Cb and Ta carbide
Herman C. Stark Inc. (NRC, Inc.)	Newtown, MA	Cb and Ta metal, Ta capacitor powder
Reading Alloys, Inc.	Robesonia, PA	FeCb
Shieldalloy Metallurgical Corp.	Newfield, NJ	FeCb
Teledyne Wah Chang Albany	Albany, OR	Cb pentoxide/metal, FeCb
Thai Tantalum Inc.	Gernee, IL	Ta metal

[a] - Cunningham, L.D., "Columbium (niobium) and Tantalum," Minerals Yearbook Volume 1. Metals and Minerals. U.S. Bureau of Mines. 1992. p.453

[b] - Personal Communication between ICF Incorporated and Larry D. Cunningham, U.S. Bureau of Mines, November 1994.

2. Generalized Process Flow Diagram

Tantalum and Columbium Production

Exhibit 2 illustrates the processing of tantalum and columbium. There is no domestic mining of columbium or tantalum, and the ore is imported either directly or as a concentrate. Therefore, domestic processing of columbium and tantalum may begin after the milling step shown in Exhibit 2. Tantalum and columbium are extracted from the source materials, imported concentrates, and tin slags, by digestion and liquid-liquid extraction. (Teledyne Wah Chang Albany does not use this process. In previous years they had operated a chlorination/ hydrolysis process, but now operates an acid digestion process. However, their acid process does not use liquid-liquid extraction.)[8] When tin slags are used for the recovery of tantalum, they are sometimes upgraded in an electric furnace process (not shown), yielding a synthetic concentrate.[9] The slag is smelted with carbon to reduce the iron, tantalum, and columbium components, which are collected as a high carbon ferroalloy containing columbium- and tantalum carbides. This ferroalloy is treated with a metal oxide to selectively oxidize carbided components other than tantalum and columbium. The tantalum and columbium carbides are reoxidized and can be substituted for tantalum and columbium concentrates.[10]

[8] Personal Communication between ICF incorporated and Chuck Knoll, Teledyne Wah Chang, Albany, OR, November 1994.

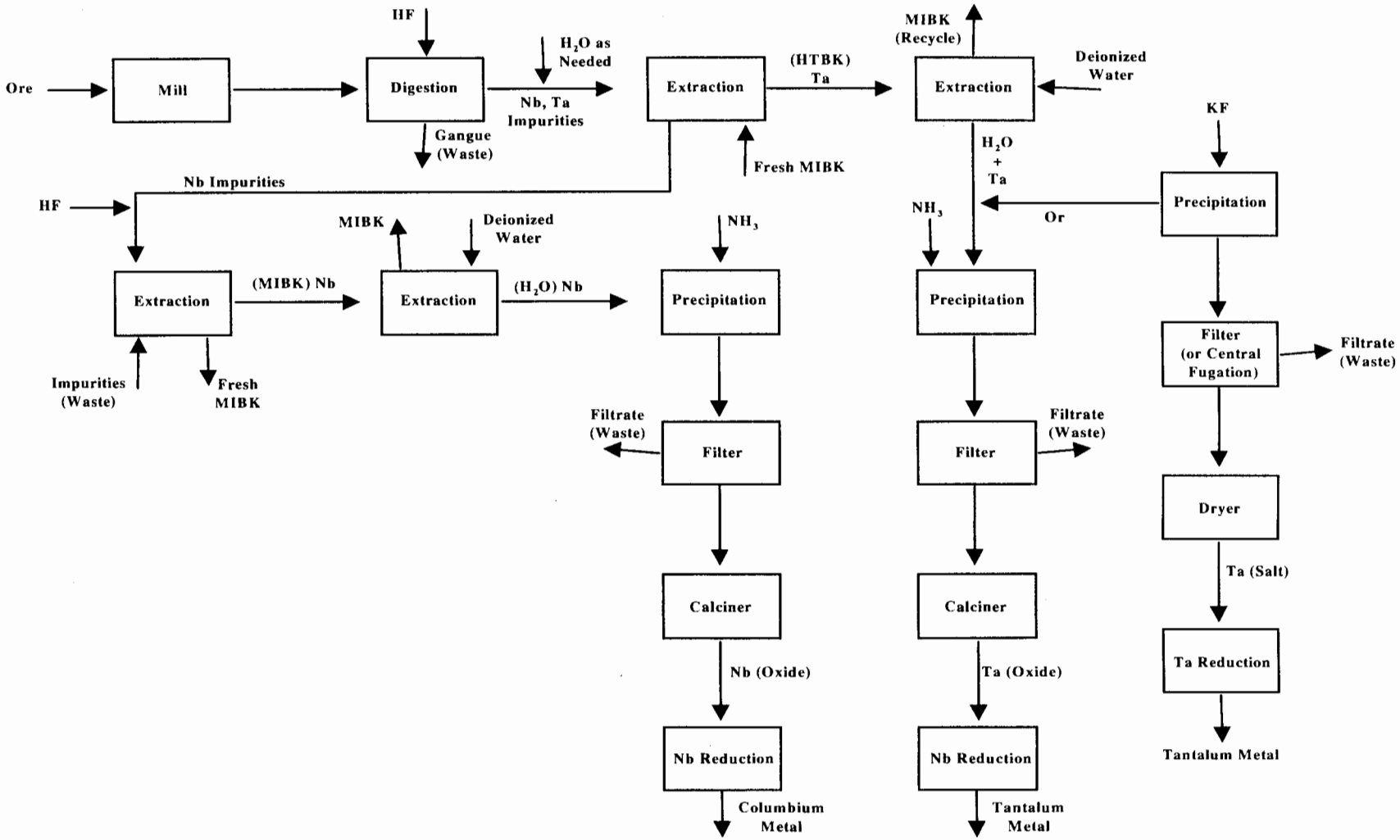
[9] L.D. Cunningham, 1992, Op. Cit., pp. 438-39.

[10] "Tantalum and Tantalum Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXIII, 1983, p. 549.

EXHIBIT 2

PRIMARY COLUMBIUM-TANTALUM PROCESS

(Adapted from: U.S. Environmental Protection Agency, 1989, p. 4359.)



The concentrate or slag is digested with aqueous hydrofluoric acid (sometimes in conjunction with sulfuric acid) to form fluoride salts of the metals. Unreacted concentrate or slag (gangue) is removed by settling and decantation and is disposed of as a low level radioactive waste. This leaching process also generates an acid mist that may be controlled by wet scrubbers. The scrubber liquor is a source of wastewater.[11]

These metal-fluoride salts are then extracted with methyl isobutyl ketone (MIBK). The liquid-liquid extraction procedure first recovers the tantalum salt. Additional hydrofluoric acid is added to change the solubility of the columbium salt, which is then extracted by MIBK. The raffinate (containing the spent hydrofluoric acid solution) from this step is considered wastewater. The salts are then recovered from each of the MIBK solutions by liquid-liquid extraction with deionized water. The raffinate from this second set of extractions is the barren MIBK, which is recycled. Fugitive air fumes from the solvent extraction process are controlled by wet air pollution control devices, which generate wastewater.[12] The water and tantalum solution from the extractor contains a fluotantalic acid solution, from which potassium fluotantalate (K-salt, K_2TaF_7) or tantalum pentoxide (Ta_2O_5) can be precipitated through the addition of either potassium fluoride, or ammonia. Potassium chloride (not shown) is used sometimes in place of potassium fluoride.[13] Columbium pentoxide is precipitated from the columbium stream by the addition of ammonia. A wet scrubber may be used to control fluoride fumes generated during precipitation of either metals' oxide or salt. The aqueous liquor (filtrate) is discarded. The resulting crystals are washed with water and dried.[14] The columbium oxide precipitates are calcined in a kiln; wet scrubbers are used to control gaseous fumes. Tantalum salts are also dried, but wet scrubbers are not normally used. The water vapor, however, may be condensed, captured, and discharged.[15]

Columbium and tantalum salts are reduced to metal by a number of methods, including: sodium reduction, aluminothermic reduction, carbon reduction, and electrolysis. Sodium reduction (not shown) is a popular method for producing both columbium and tantalum from their salts. In this process, sodium reduces the columbium or tantalum to metal. Layers of the columbium or tantalum salt are alternated with layers of sodium in a reaction vessel, then capped with sodium chloride to prevent oxidation of the reduced metal. The reaction mixture is often ignited electrically, but once ignited, the exothermic reaction is self-sustaining. Wet scrubbers are often used to control the gaseous emissions from the reaction vessel. After cooling, the columbium or tantalum metal-containing material is crushed, and any iron picked up from the reaction vessel is removed magnetically. The remaining metal powder is further purified by leaching with water, followed by nitric or hydrofluoric acid.[16]

The aluminothermic reaction (not shown) also may be used on both columbium and tantalum salts. This method also may be used on certain ferrocolumbium ores that do not require digestion and separation of columbium and tantalum salts. The salt (or ore) is mixed with aluminum powder. Potassium chlorate is added to provide additional reaction heat, and magnesium is added to properly ignite the mixture. Columbium and tantalum are reduced to metal while aluminum is oxidized.[17]

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[11] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume VIII, Office of Water Regulations and Standards, May 1989, p. 4352.

[12] Ibid.

[13] L.D. Cunningham, 1992, Op. Cit., pp. 438-39.

[14] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 4352.

[15] Ibid., p. 4353.

[16] Ibid.

[17] Ibid.

Carbon reduction (not shown) takes place through a two-step route known as the Balke process and can be used on both columbium and tantalum salts. Its predominant use, however, is in the reduction of the metal oxides. The metal oxide is first mixed with fine carbon and heated under vacuum to 1800°C, where a metal carbide and carbon monoxide are formed. The carbide is then mixed with more oxide and reacts to form the pure metals and additional carbon monoxide. No known wastewater is generated during this process.[18]

Electrolytic reduction (not shown) of tantalum is sometimes practiced, using fused salt techniques. Potassium fluotantalate (K-salt), the crystal which was precipitated by potassium fluoride in the separation of salts step, is electrolyzed to yield pure tantalum metal. The pure tantalum metal is then separated from the cathode by pulverizing the cathode and subsequent acid leaching, resulting in a metal solution and the cathode material (usually carbon).[19]

Electron beam melting is currently the most common method of consolidation, as shown in Exhibit 3.[20] A beam of high voltage, low current electrons is focused onto the crude metal and the top of a retractable tantalum ingot contained in a water cooled copper cylinder. The beam melts the crude metal, and the falling molten globules from a pool on top of the ingot. The process is continuous, with the ingot being lowered as the molten metal solidifies. Most impurities boil out of the pool into the high vacuum environment (required by the electron beam) and are removed.[21] Arc melting, as shown in Exhibit 4, occurs in much the same way as electron beam melting, except that a low voltage, high current arc of electricity melts the crude metal.[22]

Simultaneous compaction and direct resistance heating (not shown) is the oldest process and is somewhat undesirable, as the metal must be processed two or three times to reach sufficient purity. The metal is typically compacted at about 6,900 atmospheres and heated to 1,400-1,500°C for several hours. It is then rolled and sintered at 2,300°C. Several rolling and sintering steps may be required.[23]

Ferrocolumbium Production

Ferrocolumbium is made from pyrochlore concentrates, usually by an aluminothermic process with an iron-iron oxide mixture. Exhibit 5 illustrates this process. Pyrochlore, aluminum powder, and iron scrap, and/or iron oxide are mixed together, frequently with small amounts of lime or fluorspar as fluxing agents, in a batch reactor. Sometimes sodium chlorate or some other powerful oxidizer is added to provide additional reaction heat. A typical reactor consists of a refractory lined steel shell, and occasionally a floor consisting of slag from previous reduction reactions is used. After the reaction has come to completion, the molten ferrocolumbium lies at the bottom of the reactor and the slag floats on it. Most of the impurities go into the slag and some easily reduced metals go into the ferrocolumbium. After a period of cooling, the metal is separated from the slag, and is crushed and sized. At some facilities, an electric furnace is used to provide the heat necessary for the reaction, in place of the aluminothermic.

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[18] Ibid.

[19] Ibid.

[20] "Tantalum and Tantalum Compounds," 1983, Op. Cit., p. 552.

[21] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 4354.

[22] "Tantalum and Tantalum Compounds," 1983, Op. Cit., p. 551.

[23] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 4354.

EXHIBIT 3

ELECTRON BEAM MELTING

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1983, p. 552.)

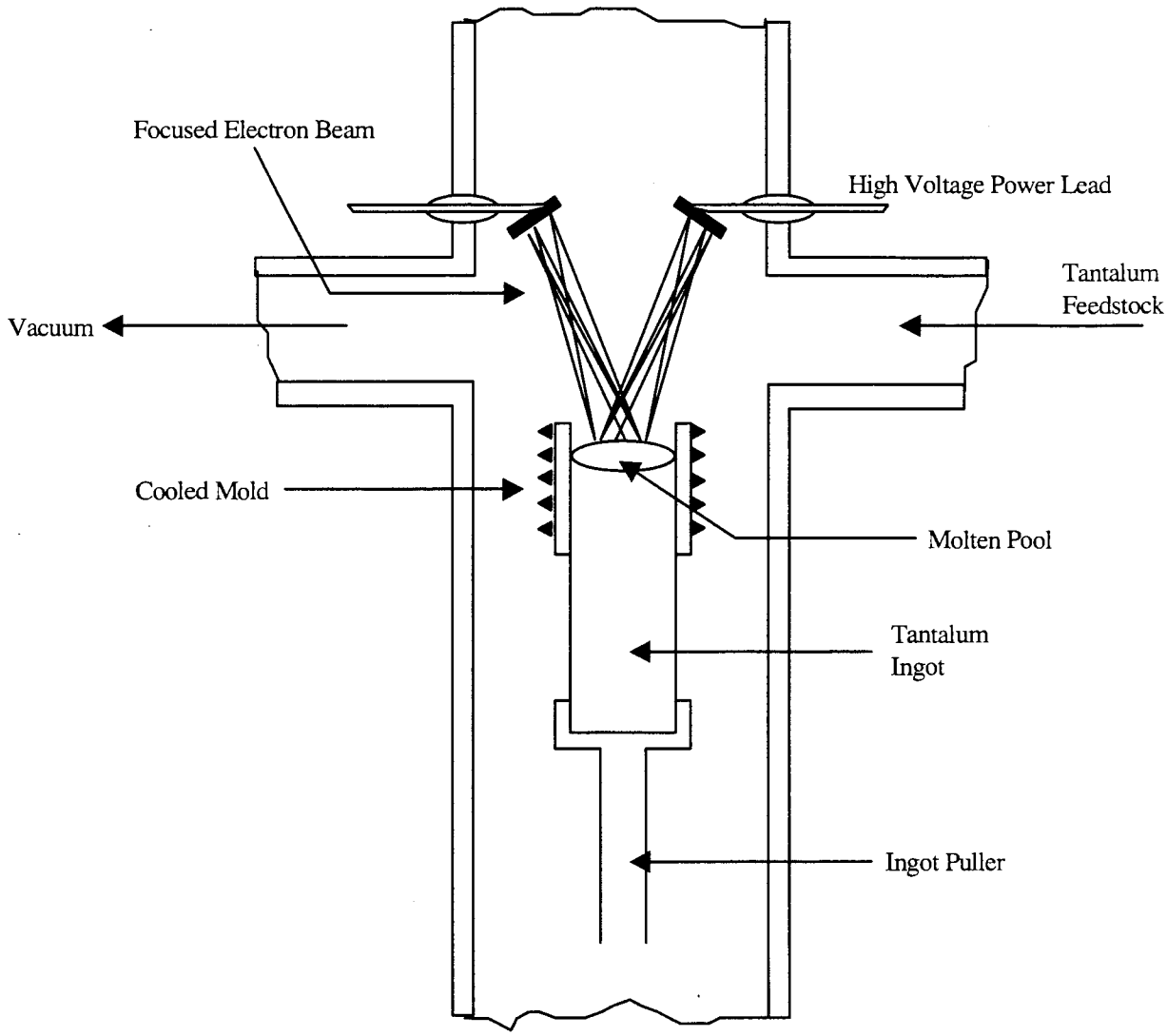


EXHIBIT 4

VACUUM ARC MELTING

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1983, p. 551.)

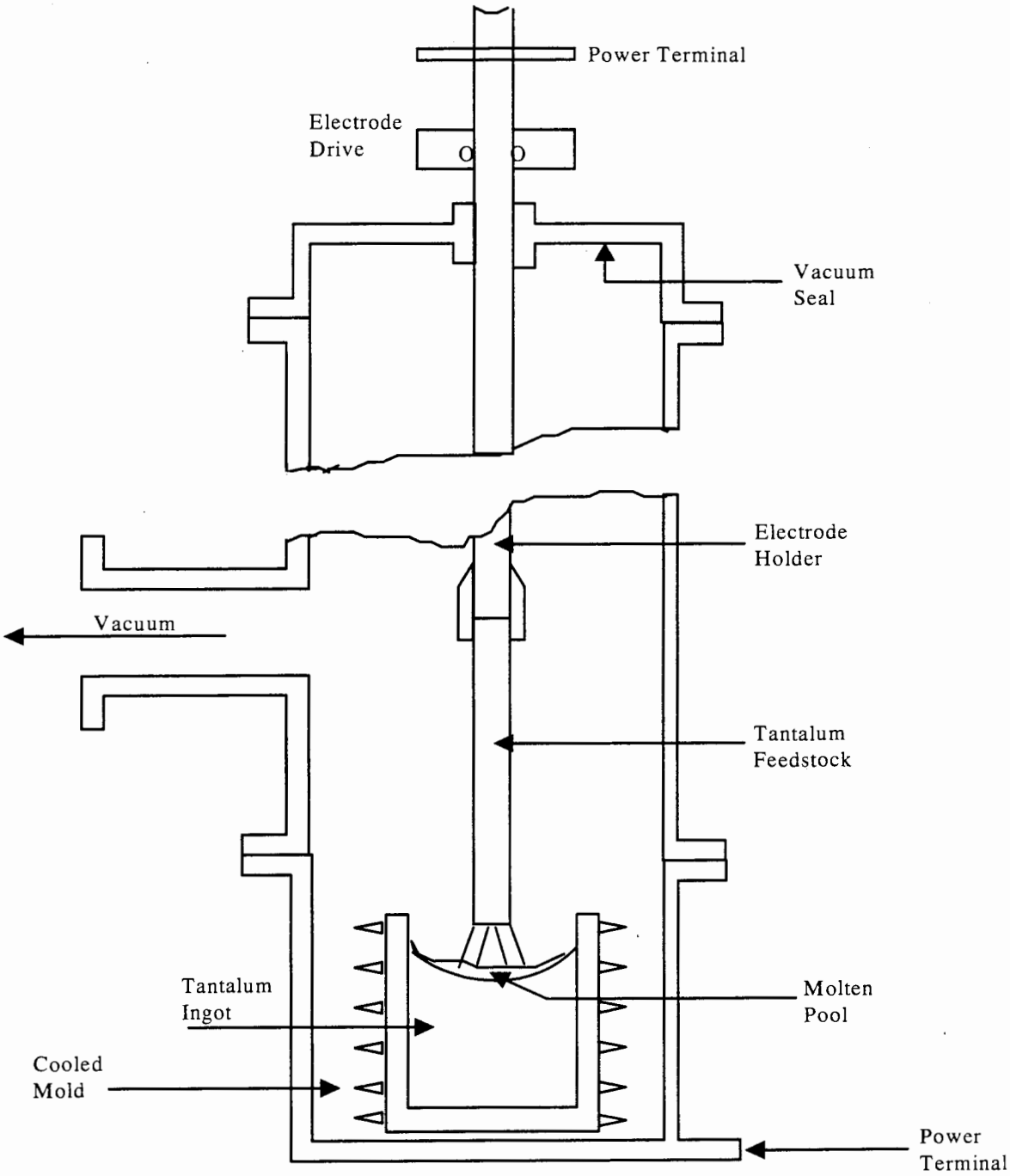
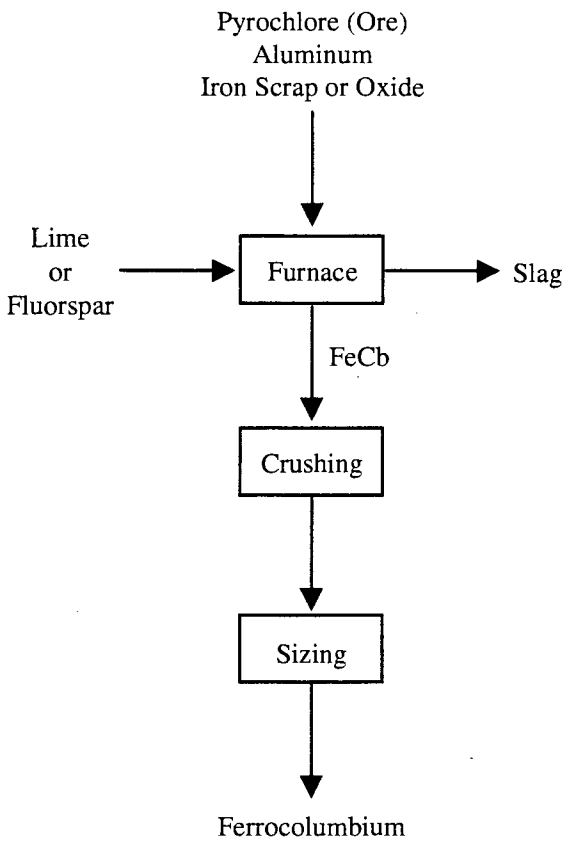


EXHIBIT 5

FERROCOLUMBIUM PRODUCTION



method. In this process, the quantity of aluminum can be substantially reduced and other reducing agents such as ferrosilicon can be used.[24] High purity ferrocolumbium cannot be made directly from pyrochlore because of the high alkali content. It can, however, be manufactured from columbium pentoxide produced by treating the lower purity ferrocolumbium made from pyrochlore concentrates.[25]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Direct chlorination of tin slag is being investigated as an alternative to digestion and leaching, as a way to reduce the amount of toxic waste generated.[26]

4. Extraction/Beneficiation Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

Tantalum/Columbium

EPA determined that for the production of tantalum/columbium, the beneficiation/processing line occurs between milling and digestion because the physical structure of the ore is destroyed. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams

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[24] "Niobium and Niobium Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XV, 1982, pp. 823-824.

[25] Cunningham, L.D., 1992, Op. Cit., p. 436.

[26] I. Gaballah, E. Allain, and M. Djona, "Chlorination and Carbochlorination of a Tantalum and Niobium Pentoxides Bearing Concentrates," Mineral Processing and Environmental Engineering, Vandoeuvre, France, 1993, p. 760.

generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Ferrocolumbium

EPA determined that for ferrochromium, processing begins with the reaction of iron and the ore in the furnace because the ore is changed into a more useful form by significant physical and chemical changes in the furnace. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

The following waste streams have been associated with the processing of tantalum and columbium concentrates and slags.

1. Extraction and Beneficiation Wastes

Currently, there is no domestic extraction of columbium or tantalum ores.

2. Mineral Processing Wastes

Digestion

Scrubber Overflow. Approximately 19,000 metric tons of scrubber overflow are produced annually in the United States. Available data do not indicate the waste exhibits hazardous characteristics.[27] Therefore, the Agency did not evaluate this material further.

WWTP Liquid Effluent. Approximately 206,000 metric tons of WWTP Liquid Effluent are produced annually in the United States.[28] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent Potassium Titanium Chloride. Available data do not indicate the waste exhibits hazardous characteristics.[29] Therefore, the Agency did not evaluate this material further.

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[27] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Volume 1, Office of Solid Waste, August 1992, p. I-7.

[28] Ibid.

[29] Ibid.

Spent Raffinate Solids. Approximately 2,000 metric tons of raffinate solids, from the liquid-liquid extraction procedure are produced annually in the United States.[30] This waste may exhibit the hazardous characteristic of corrosivity.[31] The waste is not recycled.

Digester Sludge. Approximately 1,000 metric tons of digester sludge are produced annually in the United States.[32] This waste may exhibit the hazardous characteristic of corrosivity.[33] The waste is not recycled.

WWTP Sludge. Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Process Wastewater. There are several operations which produce wastewater (see Exhibit 3). Process wastewater may contain fluoride, copper, lead, zinc, cadmium, 1,2-dichloroethane, chloroform, chromium, selenium, arsenic, nickel, and ammonia. The pH of the individual waste streams may be high or low depending on the operations that generated each waste stream. For instance, the pH of the wastewater generated through digestion is likely to be low, while wastewater resulting from ammonia precipitation is likely to be high.[34] Therefore, the pH of the mixture of these streams will depend on the quantity and pH of each contributing stream. We used best engineering judgement to determine that this waste stream may be recycled. The waste was formerly classified as a spent material. Approximately 146,000 metric tons of process wastewater are produced annually in the United States.[35] Attachment 1 contains data on process wastewater.

APC Dust Sludge. Available data do not indicate that APC dust sludge generated by the production of ferrocolumbium exhibits hazardous characteristics.[36] Therefore, the Agency did not evaluate this material further.

Slag. This material is generated by the aluminothermic production of ferrocolumbium. During the processing sequence, most of the impurities contained in the raw materials report to the slag. However, some of the easily reduced metals will go into the ferrocolumbium layer.[37] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[30] Ibid.

[31] U.S. Environmental Protection Agency, Technical background Document, Development of Cost, Economic, and Small Business Impacts Arising from the Reinterpretation of the Bevill Exclusion for Mineral Processing Wastes, August 1989, p. 3-6.

[32] Ibid.

[33] U.S. Environmental Protection Agency, Op. Cit., August 1989, p. 3-6.

[34] U.S. Environmental Protection Agency, "Columbium and Tantalum," 1988 Final Summary Report of Mineral Industrial Processing Wastes, 1988, pp. 3-84 - 3-85.

[35] U.S. EPA, 1992, Op. Cit., p. I-7.

[36] Ibid., p. I-4.

[37] "Niobium and Niobium Compounds," 1982, Op. Cit., pp. 823-824.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PROCESS WASTEWATER - TANTALUM/COLUMBRIUM

Constituents	Total Constituent Analysis - PPM Minimum	Average	Maximum	# Detects	EP Toxicity Analysis - PPM Min.	Avg.	Max.	# Detects	TC Level	# Values In Excess
Aluminum	50000	50000	50000	1/1	-	-	-	0/0	-	-
Antimony	0.010	6.461	30.00	10/10	-	-	-	0/0	-	-
Arsenic	0.003	6.256	45.00	13/13	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.001	0.126	0.500	13/13	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.008	6.392	40.00	13/13	-	-	-	0/0	1.0	0
Chromium	0.006	232.846	1000	13/13	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.200	56.553	300	13/13	-	-	-	0/0	-	-
Iron	25000	25000	25000	1/1	-	-	-	0/0	-	-
Lead	0.020	255.869	1000	13/13	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.000	0.013	0.063	13/13	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.500	2.460	10	10/10	-	-	-	0/0	-	-
Selenium	0.002	13.507	70	10/10	-	-	-	0/0	1.0	0
Silver	0.000	0.040	0.070	4/4	-	-	-	0/0	5.0	0
Thallium	0.000	0.365	1.180	9/9	-	-	-	0/0	-	-
Vanadium	7800	7800	7800	1/1	-	-	-	0/0	-	-
Zinc	0.600	331.960	1000	10/10	-	-	-	0/0	-	-
Cyanide	0.001	0.006	0.033	17/17	-	-	-	0/0	-	-
Sulfide	2650	14037.50	45000	4/4	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	10000	45750	130000	4/4	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	40000	40000	40000	1/1	-	-	-	0/0	-	-
Chloride	900	9450	18000	2/2	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	3.0	8.4	12.0	5/5					2<pH>12	2
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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TELLURIUM

A. Commodity Summary

According to the U.S. Bureau of Mines, commercial grade tellurium and tellurium dioxide are recovered from anode slimes at one electrolytic copper refinery in the United States (ASARCO - Amarillo, TX). Selenium is also recovered from the copper anode slimes during this process (see Selenium sector report). High purity tellurium, tellurium master alloys, and tellurium compounds are produced by primary and intermediate processors from commercial-grade metal and tellurium dioxide. Tellurium is used mainly in the production of free-machining steels. It is also used as a minor additive in copper and lead alloys and malleable cast iron, as an accelerator in rubber compounding, in thermoelectric applications, and as a semiconductor in thermal-imaging and photoelectric applications. Tellurium is added to selenium-base photoreceptor alloys to increase the photo speed. In 1994, iron and steel products remained the largest end use, followed by nonferrous metals, chemicals, and other uses.[1] Some common commercial tellurium products include tellurium dioxide, sodium tellurate, ferrotellurium, and tellurium diethyldithiocarbamate.[2]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Nearly all tellurium is obtained as a material formerly labeled as byproduct of the electrolytic refining of copper. Although copper slimes are valued primarily for gold, silver, and occasionally platinum-group metals, tellurium is available to the refiner for the added cost of recovery and refining.[3] Tellurium is present in copper refinery slimes in concentrations ranging from a trace to 8 percent and is recovered as precipitated tellurous acid. Tellurium metal can be produced from the crude tellurous acid by one of three purification methods described below. Metal tellurides for semiconductors are made by direct melting, after which, the excess tellurium is volatilized under reduced pressure. The resultant tellurium vapor is then passed over a heated metal in an inert gas carrier and undergoes a high temperature reduction of oxy compounds with hydrogen or ammonia.[4]

2. Generalized Process Flow Diagram

The process flow for the production of tellurium can be separated into two stages. The first stage involves the removal of copper from the copper slimes (an intermediary product is tellurous acid). The second stage involves the recovery of tellurium metal and purification of the recovered tellurium. The process flow diagrams for a typical recovery process are presented in Exhibits 1 through 3. Exhibit 1 shows the steps involved in producing tellurous acid from copper anode slimes. The process flow diagrams for two methods of recovering tellurium metal from tellurous acid, acid precipitation and electrolytic purification, are presented in Exhibits 2 and 3, respectively.

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[1] Stephen M. Jasinski, "Tellurium," from Mineral Commodities Summary, U.S. Bureau of Mines, 1995, pp. 172-173.

[2] "Tellurium," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXII, 1983, p. 663.

[3] Neldon L. Jensen, "Tellurium," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, p. 825.

[4] "Tellurium," 1983, Op. Cit., p. 663.

EXHIBIT 1

TELLURIUM RECOVERY FROM COPPER SLIMES

(Adapted from: 1988 Final Draft Summary Report of Mineral Processing Wastes, 1988, pp. 204 - 210.)

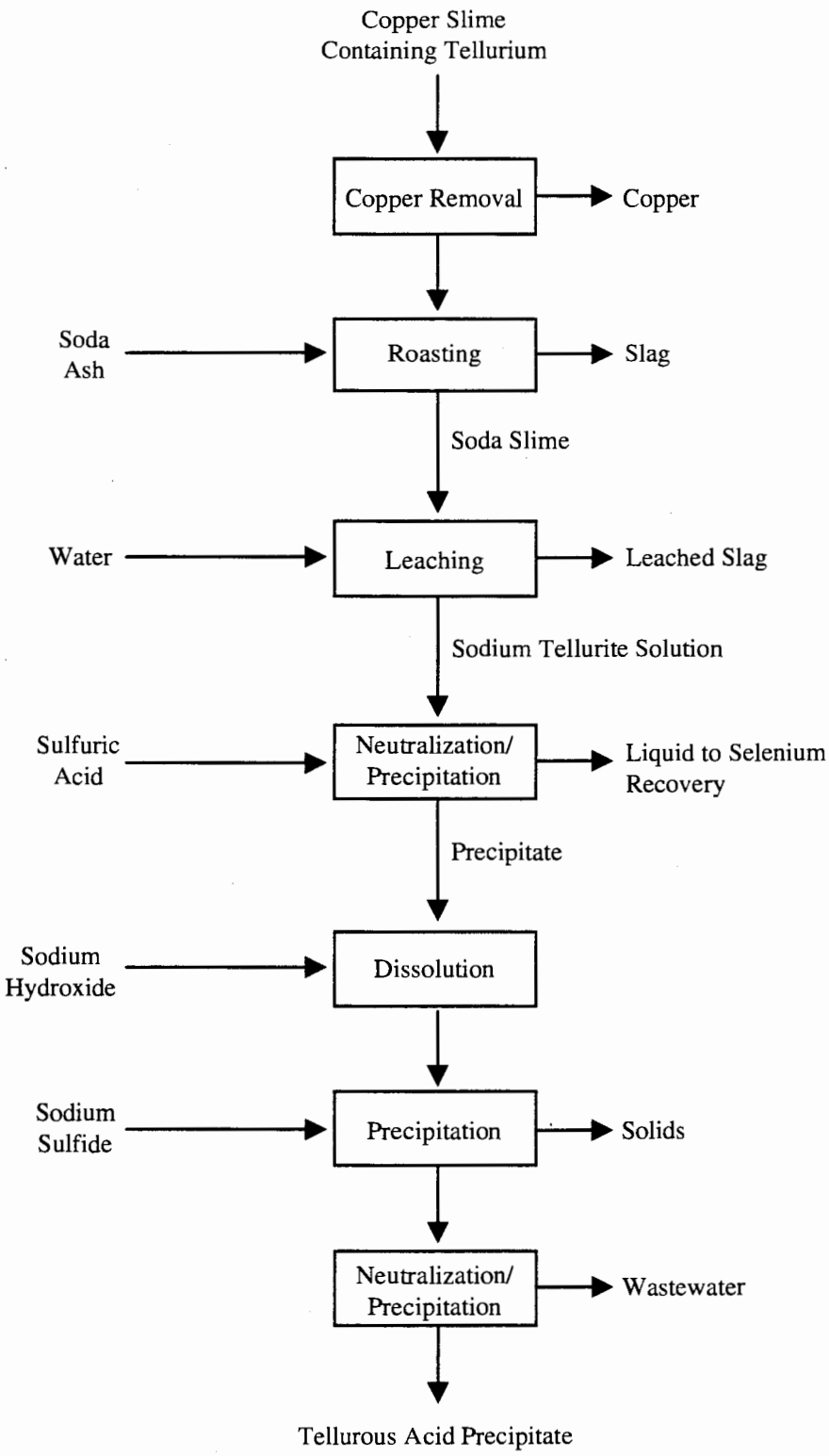


EXHIBIT 2

PURIFICATION OF TELLURIUM BY ACID PRECIPITATION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 204 - 210.)

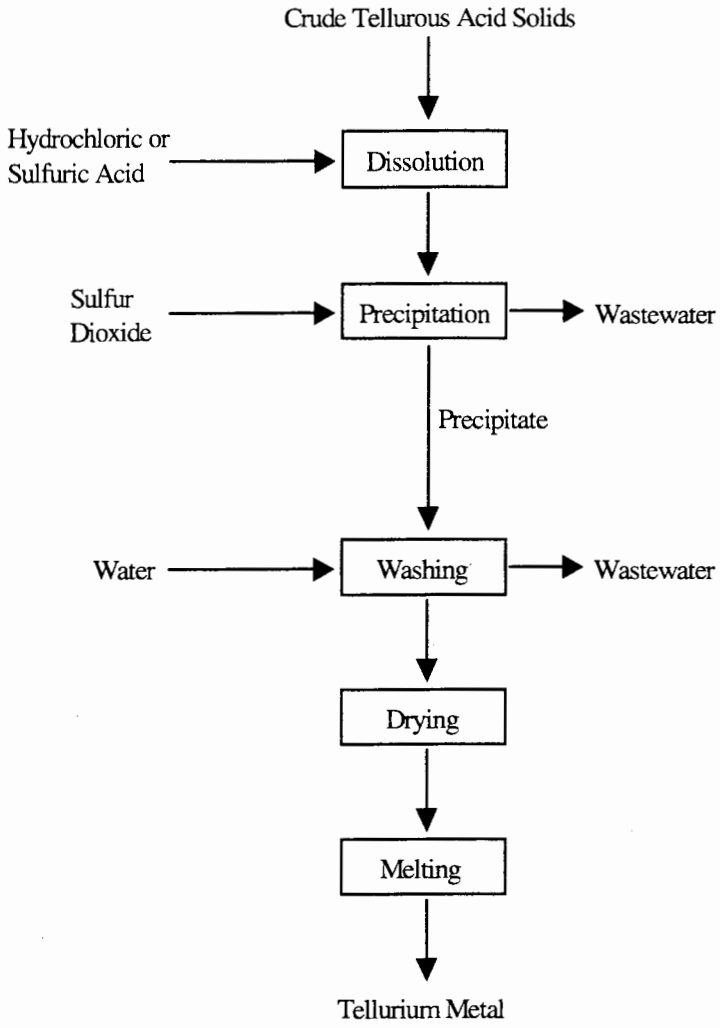
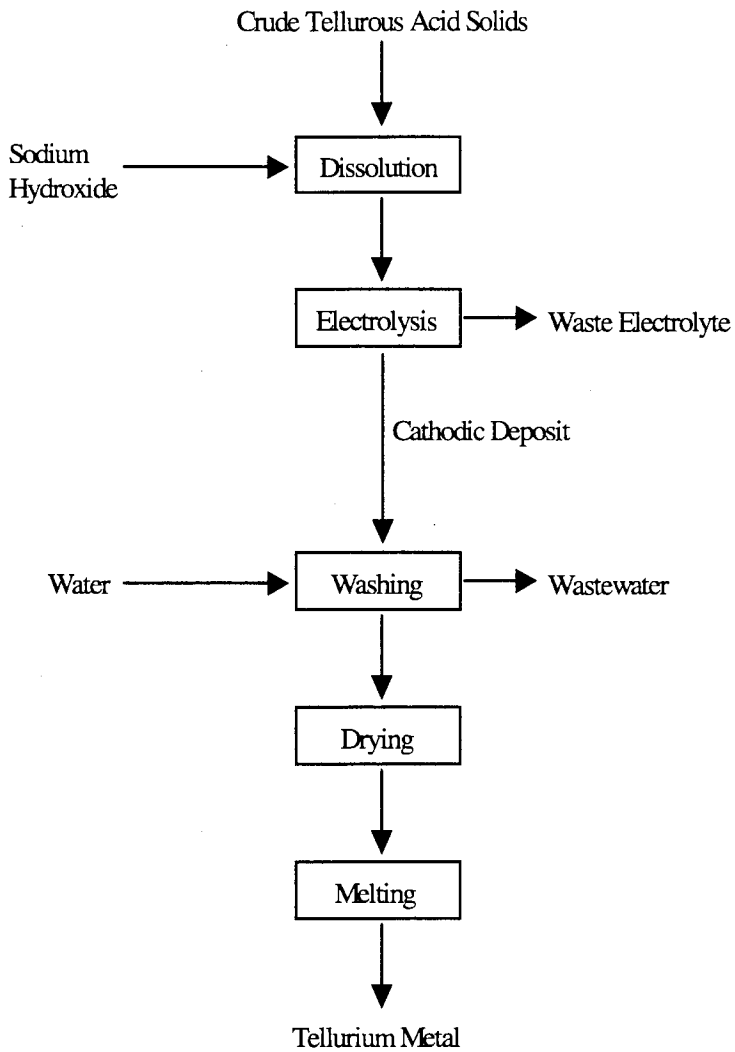


EXHIBIT 3

ELECTROLYTIC PURIFICATION OF TELLURIUM

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 204 - 210.)



Removal of copper and production of tellurous acid

Since tellurium is recovered from copper refinery slimes, the first step in the recovery process shown in Exhibit 1 is the removal of copper from the slimes. Copper is generally removed by aeration in dilute sulfuric acid, oxidative pressure-leaching with dilute sulfuric acid, or digestion with strong acid followed by water-leaching. During the copper removal, much of the tellurium is dissolved. This tellurium is recovered by cementing (precipitation of metallic copper), leaching the cement mud with dilute caustic soda, and neutralizing with sulfuric acid. The precipitate from the neutralization contains tellurium as tellurous acid suitable for recovery.[5] Some of the liquid wastes from this neutralization/precipitation step are sent to selenium recovery.

Copper-free slimes are treated by one of the four following methods: (1) refining with soda ash in a doré or cupeling furnace; (2) combined oxidation and alkalinization by roasting or baking a slime-soda ash mix; (3) removal of selenium by roasting and caustic soda leaching; or (4) boiling the slime with caustic soda. The soda slag from the soda refinement or the roasted product of the oxidation is leached with water to extract sodium tellurite. The insoluble sodium tellurate in the leached slag is returned to the copper-anode furnace. The liquor obtained from the selenium removal and the boiling with caustic soda contains lead. In all cases, the solution contains selenium and impurities. Whatever the method, the liquor is neutralized to pH 6-6.2 with sulfuric acid to precipitate impure tellurous acid as tellurium mud, which contains lead sulfate, silica, and other impurities. The mud is purified by redissolving in caustic soda and reprecipitating. Impurities, such as lead are, removed by careful precipitation from the caustic solution with sodium sulfide. Fractional neutralization of the initial impure caustic solution yields tellurous acid of a purity acceptable for reduction to the metal.[6]

Recovery and purification of tellurium

Tellurium is recovered from the precipitated tellurous acid by three methods: (1) direct reduction; (2) acid precipitation; and (3) electrolytic purification. The electrolytic purification method is the preferred method.[7] The high boiling temperature of tellurium precludes purification by atmospheric distillation, but low pressure distillation is feasible. Heavy metal impurities (iron, copper, tin, lead, antimony, bismuth) remain in the still residue. Volatile selenium is a persistent contaminant, and may be as high as 500 ppm in the distilled tellurium.[8]

Direct Reduction. Some of the drawbacks associated with direct reduction include heavy fuming of telluride dioxide and the formation of organic decomposition products. The reduction with sulfur is rapid and leaves a clean melt, but the heavy fumes are problematic.[9]

Acid Precipitation. As presented in Exhibit 2, purification by acid precipitation first involves dissolving the crude tellurous acid solids in hydrochloric acid or sulfuric acid. Crude common salt is added to the acidified solution, and tellurium is precipitated by adding sulfur dioxide. The resultant precipitate undergoes filtration, washing, drying, and melting. In an alternative method, tellurium is dissolved in a strong nitric acid, hydrolyzed to white $2TeO_2NO_3$ and precipitated by diluting and boiling, and separating. The resultant precipitate is washed (redissolving and rehydrolyzing, if desired), dissolved in hydrochloric acid, and reduced with sulfur dioxide. Ultra high-purity tellurium is prepared by zone refining in a hydrogen or inert-gas atmosphere.[10]

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[5] Ibid., p. 662.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] Ibid.

[10] Ibid.

Electrolytic Purification. As shown in Exhibit 3, electrolytic purification involves dissolving crude tellurous acid solids in caustic soda to yield a solution containing sodium tellurite and free caustic soda. The solution then undergoes electrolysis in a cell equipped with stainless-steel electrodes. The cathodes are then removed, washed, dried, and melted.[11]

As a result of a modernization, KUCC also recovers tellurium. Following decopperization, the autoclave liquid is processed through a column containing copper to extract copper telluride. The tellurium cementate is then packaged in drums for sale.[12]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

None Identified.

4. Beneficiation/Processing Boundary

Since tellurium is recovered from anode slimes from a copper refinery, all wastes generated by this mineral commodity sector are mineral processing wastes. For a description of the beneficiation/processing boundary for this sector, please see the report on copper presented elsewhere in this background document.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Not Applicable

2. Mineral Processing Wastes

Recovery from Copper Anode Slimes

Slag. As shown in Exhibit 1, slag is generated from roasting and leaching. Slag from leaching may be wasted or returned to a copper anode for further processing while the slag from roasting is wasted.[13] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 1,000 metric tons/yr, and 4,500 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristic of toxicity for selenium. This waste formerly was classified as a by-product.

Solid waste residues. Solids, likely containing sulfur, are generated from precipitation as impurities and are discarded as waste.[14] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 1,000 metric tons/yr, and 4,500 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for selenium.

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[11] Ibid.

[12] Kenecott Utah Copper Corporation. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[13] U.S. Environmental Protection Agency, "Tellurium", from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, Office of Solid Waste, 1988, pp. 204 - 210.

[14] U.S. Environmental Protection Agency, 1988, Op. Cit, pp. 204 - 210.

Wastewater. There is wastewater associated with the neutralization steps that follow both the addition of sulfuric acid and the addition of sodium sulfide in Exhibit 1. The liquid resulting from the addition of sulfuric acid is sent to selenium recovery. Generation rate estimates for this waste stream are included in the estimates for the wastewater stream from purification of tellurous acid as discussed below.

Purification of Tellurous Acid

The following wastes have been identified as generated during the purification step.

Fumes of Telluride dioxide. Telluride dioxide fumes are generated during the direct reduction step.

Wastewater. One of the waste streams associated with the acid precipitation step of tellurium recovery is wastewater from washing, with an acidic pH. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 10,000 metric tons/yr, and 20,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be recycled and may exhibit the characteristics of toxicity (selenium) and corrosivity. This waste formerly was classified as a spent material.

Waste Electrolyte. Waste electrolytes are generated during electrolytic purification. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 1,000 metric tons/yr, and 10,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity (lead and selenium).

D. Non-uniquely Associated Wastes

Non-uniquely associated wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naphtha), and acidic tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors.

E. Summary of Comments Received by EPA

New Factual Information

One commenter indicated that its facility now recovers tellurium (COMM 40). This new information has been incorporated in the "Recovery and puification of tellurium" section.

Sector-specific Issues

None.

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U.S. Environmental Protection Agency. "Tellurium." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. Office of Solid Waste. 1988. pp. 204-210.

TIN

A. Commodity Summary

The primary source of tin is the mineral cassiterite, SnO_2, which occurs in vein and lode deposits. More than 80% of the tin ore in the world is found in placer deposits with tin content as low as 0.015%.[1] Final uses of tin include cans and containers, electrical components, construction, transportation, and other uses.[2]

China and Brazil are the world's largest producers of tin, followed by Indonesia and Bolivia. These countries account for 77% of U.S. tin imports. Tin production in the United States is negligible, with small amounts of tin concentrates mined from a placer deposit at Cache Creek Gold Mine near Fairbanks, Alaska in 1993.[3] The sole U.S. tin smelter in Texas City, Texas ceased production in 1989.[4]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Tin concentrate is processed by smelting and refining. Prior to smelting, any impurities in the concentrate are removed by roasting, leaching with water, and acid leaching. Cassiterite, a carbon reducing agent, and limestone and silica are smelted to create molten tin, which is cast in slabs. These slabs are then refined either pyrometallurgically or electrolytically.

2. Generalized Process Flow Diagram

Tin smelting is most commonly conducted in reverberatory furnaces because they offer better process control and yield cleaner slags. Electric furnaces are sometimes used by smaller smelters for their energy efficiency.[5] Blast furnaces, kilns, and horizontal furnaces are used to smelt low-grade tin concentrate.[6]

As shown in Exhibit 1, smelting is conducted as a batch operation in which a charge of cassiterite (tin oxide) concentrate, a carbon reducing agent (coke), and fluxes consisting of limestone and silica is smelted for 10 to 12 hours in a two-stage process. In the first stage, carbon monoxide is formed in the furnace and reacts with cassiterite (tin oxide concentrate) to produce tin and carbon dioxide. The silica flux reacts with cassiterite under reducing conditions to yield stannous silicate. Iron, which is also present in the concentrate, reacts with silica to yield ferrous silicate. In the second stage, the silicates fuse with fluxes to create a liquid slag. Unreacted carbon in the fuel reduces the stannous silicate to tin and the ferrous silicate to iron.[7,8] In addition to molten tin and slag, an off-gas is

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[1] "Tin and Tin Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXIII, 1983, pp. 18, 23.

[2] J. Carlin, "Tin," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, pp. 182-178.

[3] Randol Mining Directory 1994/95, p. 189.

[4] J. Carlin, 1994, Op. Cit., pp. 182-183.

[5] U.S. Bureau of Mines, Mineral Facts and Problems, Bulletin 675, 1985, p. 850.

[6] Carr, D., ed., Industrial Minerals and Rocks, Society for Mining, Metallurgy, and Exploration, Inc., 1994, p. 672.

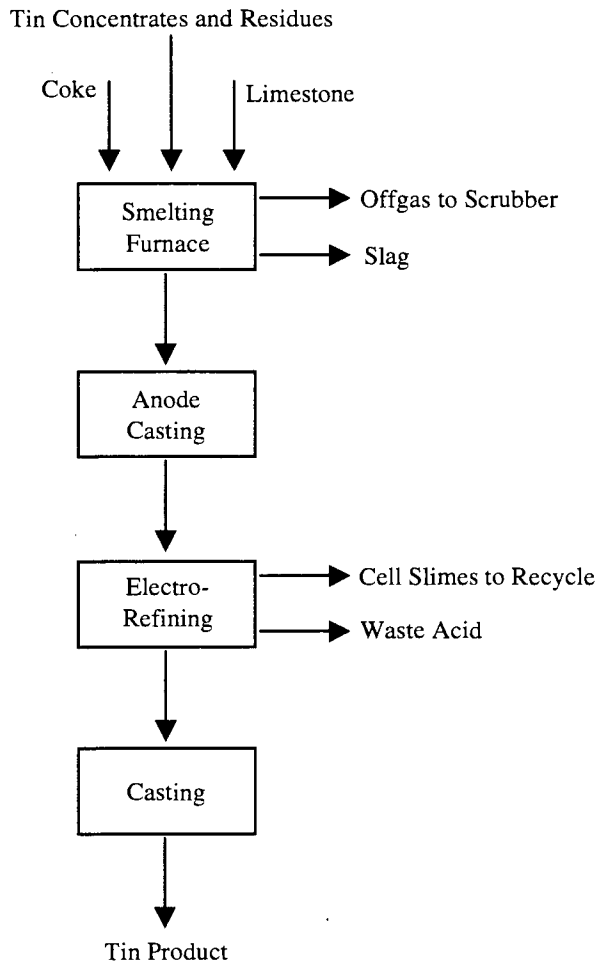
[7] U.S. Environmental Protection Agency, "Tin," from 1988 Final Draft Summary Report to Mineral Industry Processing Wastes, 1988, pp. 3-214.

[8] Carr, D., ed., 1994, Op. Cit., p. 672.

EXHIBIT 1

TIN SMELTING PROCESS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3 - 214.)



also generated and is sent to a caustic scrubber to control sulfur dioxide emissions. Additional wastes include brick linings from the furnace and spent fabric filters, both of which are recycled.

After smelting, the batch is tapped into a settler; slag overflows the settler and is collected and resmelted, while the remaining molten tin is cast into slabs (tin anodes) to be refined.[9] Crude tin is most commonly refined by heat treatment (pyrometallurgical) but can also be refined by electrolytic methods.

Heat treatment consists of heating the tin slab slightly above its melting point but below the melting points of impurities, such as iron and copper. The molten tin is poured into kettles and agitated in a process called boiling. Remaining impurities collect in a surface layer of dross, which is skimmed and resmelted. The remaining tin, with a purity greater than 99.8%, is cast in molds.

Electrolytic refining (see Exhibit 1) requires greater capital expenditures for equipment but yields a purer product. Electrorefining may be conducted in either an acid or alkaline bath.[10] The acid bath consists of stannous sulfate, creosulfonic or phenolsulfonic acids, and free sulfuric acid with beta naphthol and glue to prevent deposits from forming on the cathodes. Slimes can form on the tin anodes if the anodes have high lead levels; the slimes are scrubbed off. The alkaline bath consists of potassium or sodium stannite and free alkali. Lead is precipitated as lead plumbite in slimes that form on the anodes. Pure tin generated in either bath is recast into ingots for sale.[11] Waste slimes and waste acid or alkaline baths are shipped off-site for reprocessing and recycle.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

A research program is being conducted at the Colorado School of Mines for developing a pyrochemical process using molten salts for recovering reactive metals, including tin, from beneficiated ore. The process takes place in a hybrid reactor combining electrolytic production of a calcium reductant and *in situ* utilization of the reductant to reduce metal compounds, specifically tin oxide. The reactor operates at a temperature less than 1,000°C. The technology is reported to generate little waste.[12]

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

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[9] U.S. Bureau of Mines, 1985, Op. Cit., p. 850.

[10] "Tin and Tin Alloys," 1983, Op. Cit., p. 23.

[11] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-214.

[12] Mishra, B., D. Olson, and W. Averill, "Applications of Molten Salts in Reactive Metals Processing," presented at the Conference for Emerging Separation Technologies for Metals and Fuels, Palm Coast, FL, March 13-18, 1993, sponsored by the Minerals, Metals, & Materials Society, Warrendale, PA.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between acid leaching and smelting. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where a significant chemical change to the cassiterite occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Waste streams include tailings slurry and process wastewater from mining placer deposits, which are held in a tailings pond for settling of solids. The remaining water is either discharged to receiving waters through an NPDES outfall or reused in the mining process.[13] Most likely contaminants are arsenic, lead, and zinc. Other beneficiation wastes generated during roasting and acid leaching include spent waste acids, sludges, and waste liquids.

2. Mineral Processing Wastes

Smelting operations generate solid, liquid, and gaseous wastes. However, since tin is no longer produced domestically, these waste streams were not included in our analysis.

Slag

Slag is generated during smelting of tin concentrates through the fusion of ferrous silicate with limestone flux. Slag is collected when molten tin is tapped into a settler. Slag is believed to be resmelted and is therefore most likely not disposed as a solid waste. The Newly Identified Mineral Processing Waste Characterization Data Set (NIMPW Characterization Data Set) indicates that, when operating, the sole U.S. tin smelter generated approximately 15,000 metric tons of slag annually.[14] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Process Wastewater and Treatment Impoundment Sludge

Process wastewater is generated as blowdown from the scrubbing of off-gases generated during smelting. Approximately 83,000 metric tons are generated annually by two plants when they are operating;[15] in 1984, the

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[13] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-211.

[14] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, August 1992, p. I-7.

[15] Ibid.

Texas City smelter generated 22,000 liters of wastewater per metric ton of tin produced.[16] Process wastewater is disposed in impoundments and treated by chemical precipitation and sedimentation; solids settle to create treatment impoundment sludge.

EP toxicity tests conducted in 1984 on samples of scrubber solids and pond water revealed the wastes to exhibit the characteristic of EP toxicity for arsenic (15.5 ppm for scrubber solids, 22.9 ppm for scrubber pond water).[17] Sampling results are shown in Attachment 1.

Brick Lining and Fabric Filters

Furnaces used in smelting tin concentrates are lined with brick, which periodically must be replaced. Spent brick is resmelted for its tin value.

Fabric filters used in baghouses for filtering off-gases are recycled when spent.

Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Refining, both through heat treatment (pyrometallurgically) and electrolytically, generate solid and liquid wastes, as described below.

Dross

Dross forms during pyrometallurgical refining when tin slab is heated above its melting point; impurities such as lead and copper are captured in a layer of dross at the surface of the molten tin. Dross is skimmed and resmelted. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 100 metric tons/yr, and 200 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity for lead.

Waste Acid and Alkaline Baths

A waste electrolyte stream (waste baths), generated in electrolytic refining, most likely contains high metals concentrations and may exhibit the corrosivity and EP toxicity characteristics.[18] Waste baths are shipped off-site for reprocessing.[19] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 100 metric tons/yr, and 200 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (arsenic, cadmium, chromium, lead, and mercury) and corrosivity.

Slimes

Slimes, which form on tin anodes during electrolytic refining, may be corrosive and contain high levels of lead. Slimes are shipped off-site for reprocessing.[20] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low,

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[16] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-214.

[17] U.S. Environmental Protection Agency, 1992, Op. Cit., pp. 34-2.

[18] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-212.

[19] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-215.

[20] Ibid.

medium, and high annual waste generation rate of 0 metric tons/yr, 100 metric tons/yr, and 200 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (lead) and corrosivity.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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TITANIUM

A. Commodity Summary

Titanium (Ti) metal is known for its high strength-to-weight ratio and corrosion resistance. Titanium metal is alloyed with aluminum and vanadium, among other metals, for use in aircraft and spacecraft; in 1994, about 70 percent of titanium metal produced was used in jet engines, airframes, and space and missile applications.[1] Titanium metal is also employed in the chemical, power generation, marine, ordnance, and medical industries. Titanium is also used in ceramics, coatings for welding rods, heavy aggregate, and steel furnace flux. The major use of titanium, however, is as a white pigment for paints, rubber, paper, and plastics.[2] Titanium tetrachloride, an intermediate in TiO_2 production, is also sold for use in the production of titanium metal.

Ilmenite ($FeTiO_3$) is the most abundant titanium-bearing mineral and is comprised of about 43 percent to 65 percent titanium dioxide (TiO_2). A second major mineral form of titanium is rutile, a crystalline, high-temperature polymorph of TiO_2, containing about 95 percent TiO_2. Another crystalline form of TiO_2, anatase, is not commercially available at present, but deposits of anatase-bearing ore are being developed in Brazil.[3] Titanium minerals are found in hard rock deposits in New York, Virginia, North Carolina, Arkansas, Wyoming, and California, and in beach and alluvial sands ("black sands") in the Atlantic and Gulf Coastal Plain geologic provinces in the southeast and southern U.S.[4] Other sources of titanium include titaniferous slags (70-85 percent TiO_2) made by electric furnace smelting of ilmenite with carbon.

B. Generalized Process Description

1. Discussion of Typical Production Processes

Titanium dioxide pigment is manufactured through either the sulfate, chloride, sulfate-chloride, or chloride-ilmenite process. The sulfate process, used at two U.S. plants, employs digestion of ilmenite ore or TiO_2-rich slag with sulfuric acid to produce a cake, which is purified and calcined to produce TiO_2 pigment. The sulfate process generates sulfuric acid wastes in as much as two times the product weight, requiring treatment by neutralization before disposal of the wastes. In the more common chloride process, rutile, synthetic rutile, or high-purity ilmenite is chlorinated to form titanium tetrachloride, which is then purified to form TiO_2 pigment. The sulfate-chloride process, used by one facility, employs both the sulfate and chloride processes to manufacture TiO_2 pigment. In the sulfate phase of the sulfate-chloride process, TiO_2 rich slag is digested with sulfuric acid to produce a porous cake, which is purified and calcined to produce TiO_2 pigment. In the chloride phase, rutile ore is chlorinated to form titanium tetrachloride, which is then purified to form TiO_2 pigment. A fourth process, the chloride-ilmenite process, is similar to the chloride process, but a low-purity ilmenite is converted to titanium tetrachloride in a two-stage chlorination process. This proprietary process is conducted exclusively by Du Pont at its Edgemoor, DE and New Johnsonville, TN plants and at its DeLisle plant in Pass Christian, MS. Exhibit 1 presents active U.S. titanium dioxide production facilities and the processes and ores utilized at each.

Titanium sponge, which is cast into ingots for further processing into titanium metal, is produced by purifying titanium tetrachloride generated by the chloride process. Exhibit 2 presents the active U.S. titanium sponge and ingot production facilities.

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[1] J. Gambogi, "Titanium and Titanium Dioxide," from Mineral Commodity Summaries, U.S. Bureau of Mines, January 1995, p. 180.

[2] J. Gambogi, Annual Report: Titanium-1992, U.S. Bureau of Mines, December 1993, p. 1.

[3] J. Gambogi, 1993, Op. Cit., p. 1.

[4] U.S. Environmental Protection Agency, "Titanium," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. 1988. p. 3-217.

EXHIBIT 1
U.S. TITANIUM DIOXIDE PRODUCTION FACILITIES[a]

Facility Name	Location	Process	Ore Type
E.I. Du Pont de Nemours & Co., Inc. (Du Pont)	Antioch, CA	Chloride	Rutile
Du Pont	Edgemoor, DE	Chloride-Ilmenite	Ilmenite
Du Pont	New Johnsonville, TN	Chloride-Ilmenite	Ilmenite
Du Pont	Pass Christian, MS	Chloride-Ilmenite	Ilmenite
Kemira, Inc.	Savannah, GA	Sulfate-Chloride	Slag/Rutile
Kerr-McGee Chemical Corp.	Hamilton, MS	Chloride	Synthetic Rutile
Kronos, Inc.	Lake Charles, LA	Chloride	Unknown
SCM Chemicals, Inc.	Ashtabula, OH	Chloride	Rutile S. African Slag
SCM Chemicals, Inc.	Baltimore, MD	Chloride	Rutile
		Sulfate	S. African Slag

[a] J. Gambogi, 1993, Op. Cit., p. 13.

2. Generalized Process Flow Diagram

Sulfate Process

In the sulfate process, which is presented in Exhibit 3, ilmenite ore or slag with high TiO_2 content is digested with sulfuric acid, forming a porous cake; this cake is further dissolved by dilute acid to form titanyl sulfate ($TiOSO_4$). Scrap iron is added to the digestion process to ensure that iron impurities remain in the ferrous (Fe^{2+}) state so that the eventual TiO_2 product can be easily washed. The titanyl sulfate solution is then clarified, yielding what was formerly characterized as a waste sludge, and then concentrated through vacuum evaporation, which promotes crystallization of copperas (ferrous sulfate heptahydrate, $FeSO_4 \cdot 7H_2O$) to remove iron. (If low-iron, high-TiO_2 slag is used as feed, it is not necessary to crystallize copperas.) Copperas by-product is separated by filtration, which also removes a second material formerly characterized as a waste sludge. The filtered titanyl sulfate solution is vacuum-evaporated a second time and hydrolyzed at 90° C to precipitate hydrated titania ($TiO(OH)_2$). The titania hydrate is then filtered and washed, yielding filtrate waste and wastewater, respectively, before being calcined at 1,000° C to produce TiO_2 product.[5]

Chloride Process

In the chloride process, presented in Exhibit 4, rutile or high-grade ilmenite is converted to titanium tetrachloride ($TiCl_4$). The conversion takes place in a chlorinator (e.g., fluidized bed reactor) in the presence of

[5] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 3-221 - 3-222.

EXHIBIT 2
U.S. TITANIUM SPONGE AND INGOT PRODUCTION FACILITIES[b]

Facility Name	Location	Product
Howmet Corp., Titanium Ingot Div.	Whitehall, MI	Ingot
A. Johnson Metals Corp.	Lionville, PA	Ingot
Lawrence Aviation Industries, Inc.	Port Jefferson, NY	Ingot
Oregon Metallurgical Corp. (Oremet)	Albany, OR	Sponge & Ingot
RMI Co.	Niles, OH	Ingot
Teledyne Allvac	Monroe, NC	Ingot
Teledyne Wah Chang Albany	Albany, OR	Ingot
Titanium Hearth Technologies of America	Lionville, PA	Ingot
Titanium Metals Corp. of America (Timet)	Henderson, NV	Sponge & Ingot
Viking Metallurgical Corp.	Verdi, NV	Ingot
Wyman-Gordon Co.	Worcester, MA	Ingot

[b] J. Gambogi, 1993, Op. Cit., p. 11.

chlorine gas at 850° C to 950° C, with petroleum coke added as a reductant. All U.S. producers of $TiCl_4$ use fluid-bed chlorinators; static-bed systems also can be used.[6] The volatile metal chlorides, including $TiCl_4$, are collected, and the non-volatile chlorides and the unreacted solids that remain in the chlorinator are wasted, forming the special waste stream "chloride process waste solids."[7] The gaseous product stream is purified to separate the titanium tetrachloride from other chlorides. Separation is by fractional condensation, double distillation, and chemical treatment. Ferric chloride ($FeCl_3$) is removed as an acidic liquid waste stream through fractional condensation. Additional trace metal chlorides are removed through double distillation. Finally, vanadium oxychloride ($VOCl_3$), which has a boiling point close to that of $TiCl_4$ (136° C), is removed as a low-volume non-special waste by complexing with mineral oil and reducing with hydrogen sulfide to $VOCl_2$, or by complexing with copper (not shown in Exhibit 4). The purified $TiCl_4$ is then oxidized to TiO_2 at 985° C, driving off chlorine gas, which is recycled to the chlorinator. Aluminum chloride is added in the oxidation step to promote formation of the rutile crystal, which is the TiO_2 product.[8]

[6] J. Gambogi, 1993, Op. Cit., p. 3.

[7] U.S. Environmental Protection Agency, "Titanium Tetrachloride Production," from Report to Congress on Special Wastes from Mineral Processing, Vol. II, Office of Solid Waste, July 1990, p. 13-3.

[8] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-222.

EXHIBIT 3

SULFATE PROCESS FOR TITANIUM DIOXIDE PRODUCTION

(Adapted from: U.S. Environmental Protection Agency, 1988, p. 3-221.)

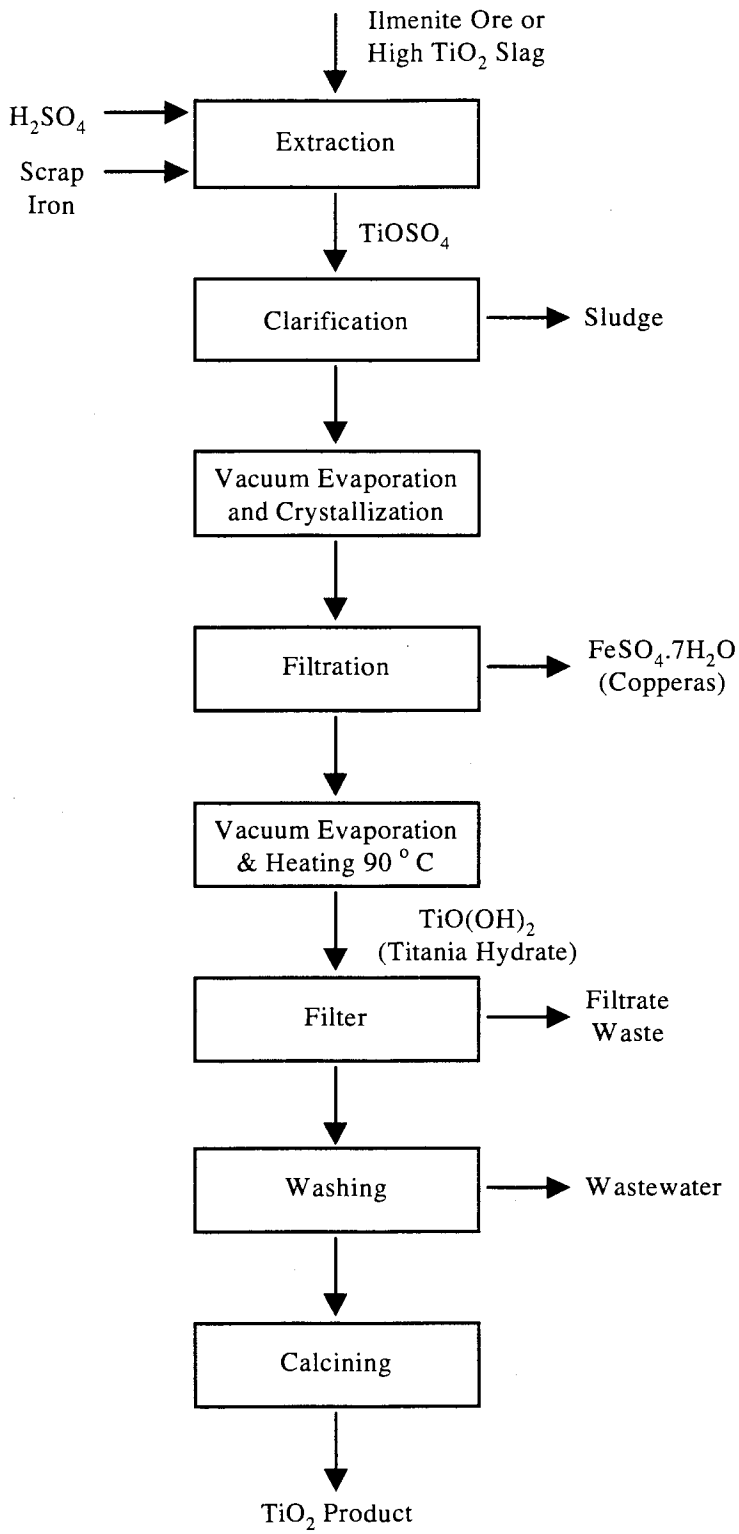
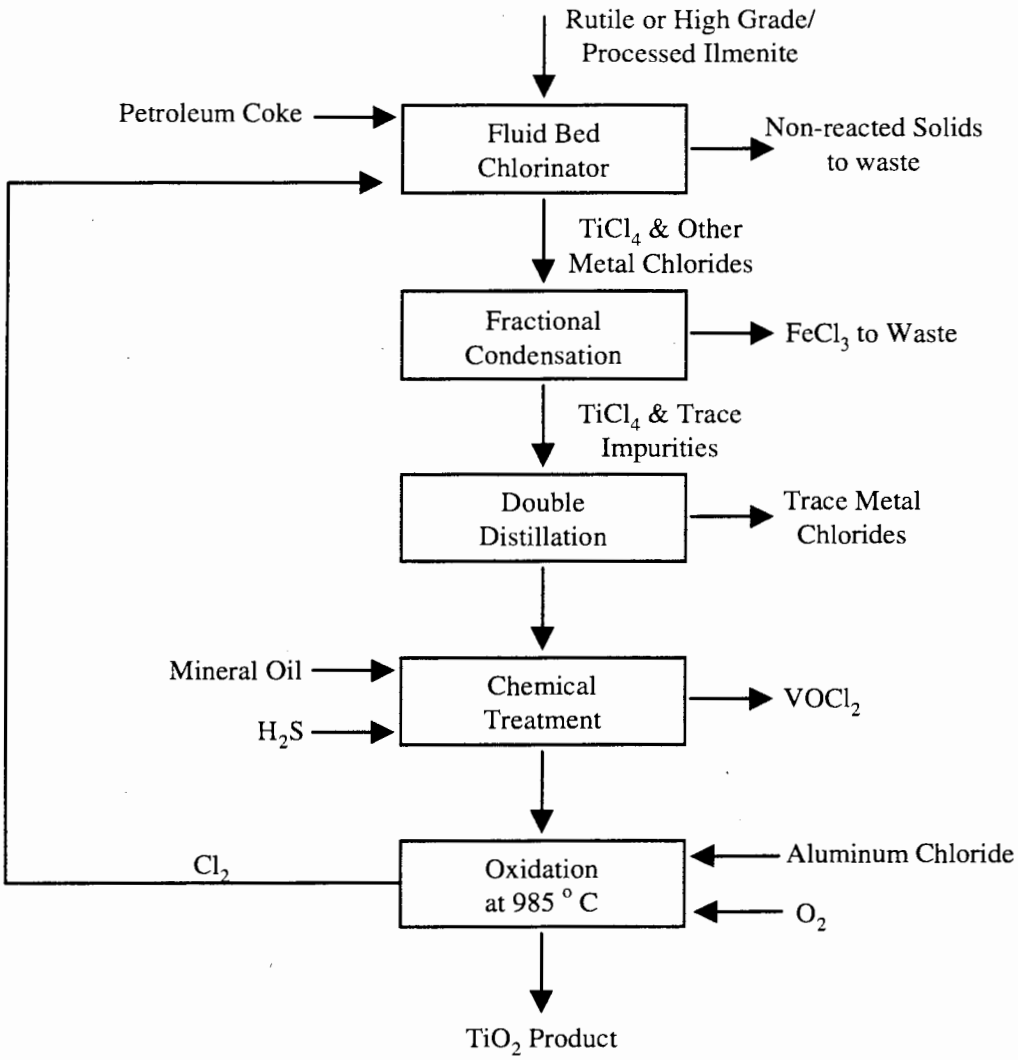


EXHIBIT 4

CHLORIDE PROCESS FOR TITANIUM DIOXIDE PRODUCTION

(Adapted from: U.S. Environmental Protection Agency, 1988, p. 3-223.)



Sulfate-Chloride Process

The sulfate-chloride processes uses both the sulfate and chloride processes. Kemira, located in Savannah, Georgia, is the only facility known to use this combined process to manufacture TiO_2 pigment. In the sulfate process, TiO_2 rich slag is digested with sulfuric acid to produce a porous cake, which is purified and calcined to produce TiO_2 pigment. In the facility's chloride process, rutile ore is chlorinated to form titanium tetrachloride, which is then purified to form TiO_2 pigment. As part of the sulfate process, the facility transports the weak acid wastewater from the manufacturing process in above ground pipes to an on-site elementary neutralization unit for neutralization. The wastewater is discharged via an NPDES-permitted outfall to the Savannah River; the remaining non-hazardous solids are then sold as a product. Other wastewater generated by Kemira is treated in an in-plant neutralization system, and pumped through a series of ponds and then discharged to an NPDES-permitted outfall.

Chloride-Ilmenite Process

In the chloride-ilmenite process, presented in Exhibit 5, low-grade ilmenite (approximately 65 percent TiO_2) is converted to $TiCl_4$. The ilmenite ore used in the process contains a much larger amount of iron than the other ores (i.e., rutile or high-grade ilmenite) used to produce $TiCl_4$. As in the chloride process, the chloride-ilmenite process takes place in a chlorinator in which the ore is chlorinated in the presence of coke as a reducing agent. According to Du Pont, however, the process differs from the chloride process in that it is a two-step reaction sequence referred to as "selective chlorination." Both of these steps occur in the chlorinator. In the first step, ilmenite ore is reacted with the chlorine gas and coke. Within seconds, the chlorine reacts with the iron oxide in the ilmenite ore, producing gaseous iron chlorides that are subsequently condensed in a spray condenser to form iron chloride waste acids, which are either sold as product or disposed as part of the waste stream "titanium tetrachloride waste acids." This step reportedly yields enriched ilmenite ore consisting of more than 95 percent TiO_2 and having the same basic particle structure as the original ilmenite ore feed.[9] In the second (or processing) step of the simultaneous beneficiation-chlorination process, the beneficiated ore, which remains in the chlorinator, is converted to gaseous $TiCl_4$ over a period of several hours. The $TiCl_4$ is further refined to remove contaminants, which are combined with the iron chloride waste stream.[10] The process for converting $TiCl_4$ to TiO_2 is similar to that used in the chloride process, as described above.

Titanium Sponge (Kroll Process)

The production of titanium sponge by the Kroll process, as shown in Exhibit 6, requires the same feed materials as does the chloride process for pigment production, because both require $TiCl_4$. $TiCl_4$ used for sponge production is made in the same manner as that for pigment production; however, because $TiCl_4$ needed for metal production must have high purity, more effort is expended to remove impurities, particularly oxygen and carbon compounds.[11] Rutile and rutile substitutes are the only titanium feed materials used for sponge production,[12] presumably because they offer a more pure source of titanium than ilmenite.

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[9] Memorandum from D. Derkics, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, "Notes of the October 24, 1989 Meeting with Representatives of E.I. DuPont de Nemours & Company," submitted to Mining Waste Docket No. F-89-MW2P-FFFFF, 1989, p. 2.

[10] Letter from C. Goldstein, Covington & Burling, Washington, D.C., to Randolph L. Hill, U.S. Environmental Protection Agency, Office of General Counsel, November 16, 1990, p. 2.

[11] "Titanium and Titanium Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXIII, 1981, p. 114.

[12] J. Gambogi, 1993, Op. Cit., p. 4.

EXHIBIT 5

CHLORIDE-ILMENITE PROCESS SCHEMATIC - DELISLE PLANT

(Adapted from: U.S. EPA National Survey of Solid Wastes from mineral Processing Facilities: Questionnaire # 102013, 1989.)

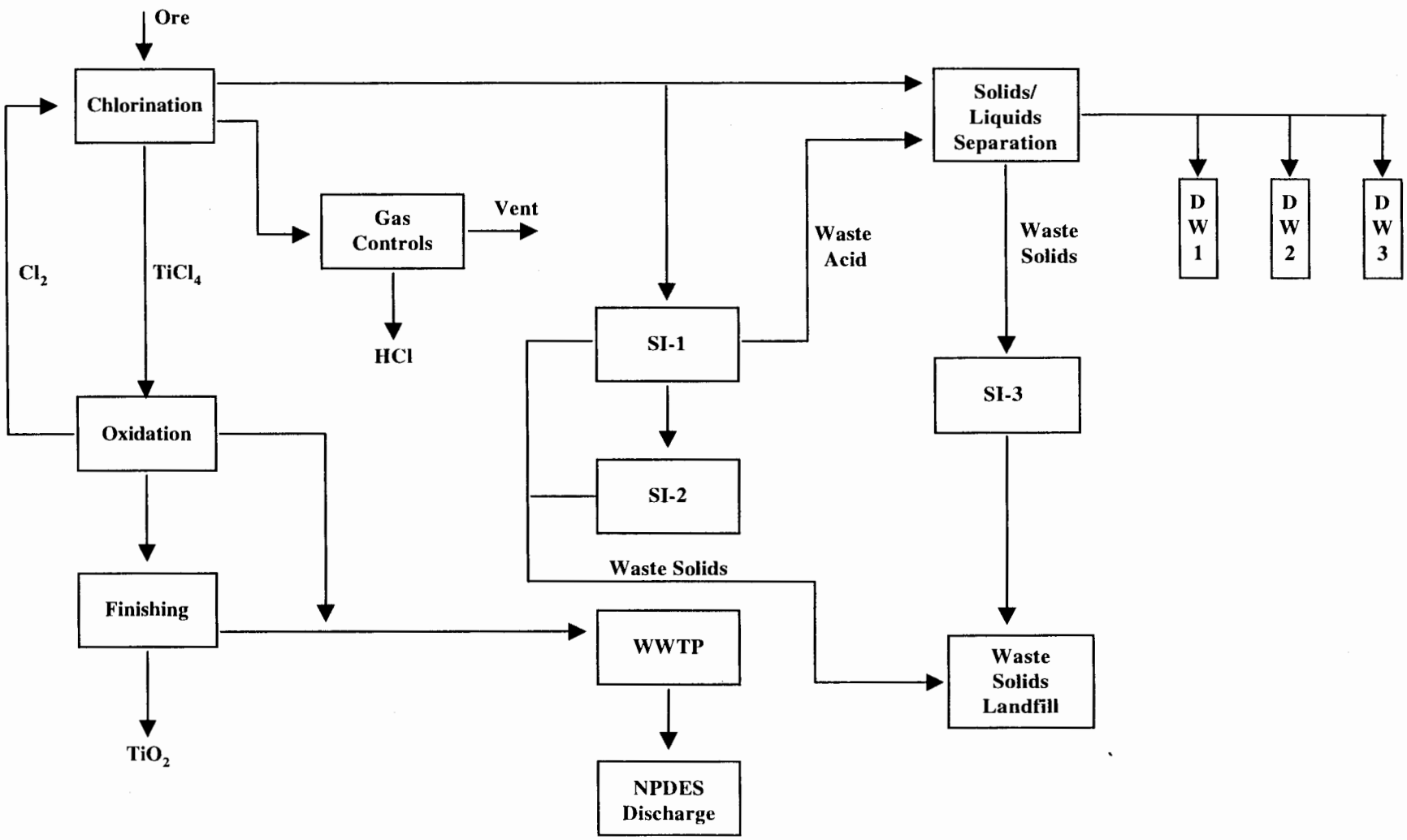
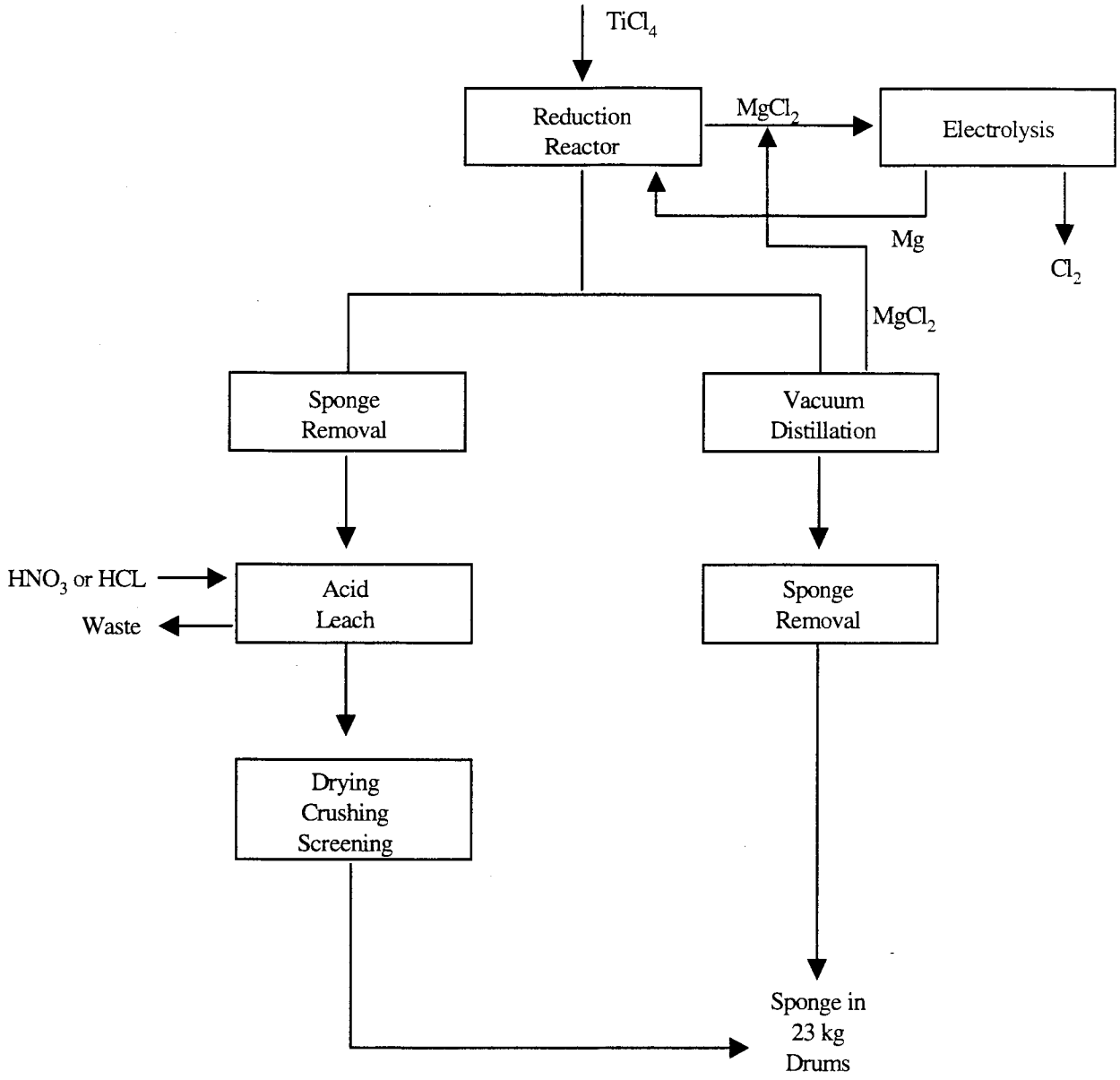


EXHIBIT 6

KROLL PROCESS FOR TITANIUM SPONGE PRODUCTION

(Adapted from: U.S. Environmental Protection Agency, 1988, p. 3-223.)



The Kroll process, based on the use of liquid magnesium as a reductant in an argon or helium atmosphere, is the major commercial process for producing titanium sponge. (The Hunter process, which relies on sodium as the reductant, is another sponge production process.) $TiCl_4$ and liquid magnesium are combined in a reduction reactor at 900° C to form molten magnesium chloride ($MgCl_2$), which is tapped from the bottom of the reactor. The $MgCl_2$ is reduced by electrolysis to form magnesium metal (which is recycled to the reactor) and chlorine gas. The product, called sponge because of its appearance and high porosity, is processed further to remove residual magnesium, $MgCl_2$, and unreacted $TiCl_4$, which can comprise as much as 30% by weight.[13] (Prior to purification, the sponge is crushed to improve purification.) Two methods are commonly used. Nitric acid (HNO_3) or hydrochloric acid (HCl) is used to acid leach the sponge, creating an acidic liquid waste, known as leach liquor, containing the impurities (primarily $MgCl_2$), while vacuum distillation at 960-1,020° C separates the sponge from a $MgCl_2$ stream that can be recycled to the electrolysis step and used in the reduction reactor.[14] Sponge can also be purified using an inert (argon) gas sweep at 1,000° C.[15,16] After drying, crushing, and screening, the sponge is packaged in air-tight 23-kg drums before further processing into ingots. Sponge also can be crushed to create titanium powder.

Titanium Ingot

Titanium ingots are formed from sponge using two or more successive vacuum-arc melting operations.[17] Scrap titanium metal or alloys can be added. Ingots can be milled by conventional methods of forging, hot- and cold-rolling, and extrusion.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

The U.S. Bureau of Mines has studied new processes to produce titanium alloys, with a focus on developing a continuous process to produce titanium powder for metallurgical applications. The Bureau also has researched methods to improve present methods of batch-type reduction, arc melting, and fabrication of titanium alloys.[18]

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming

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[13] "Titanium and Titanium Alloys," 1981, Op. Cit., p. 116.

[14] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 3-224 - 3-225.

[15] J. Gambogi, 1993, Op. Cit., p. 4.

[16] "Titanium and Titanium Alloys," 1981, Op. Cit., p. 116.

[17] J. Gambogi, 1993, Op. Cit., p. 4.

[18] J. Gambogi, 1993, Op. Cit., p. 8.

ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs just before the acid digestion step in the sulfate process (identified as the "extraction" step in Exhibit 3). EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because this is where TiO_2 in the ore undergoes a significant chemical change through conversion by H_2SO_4 to $TiOSO_4$. In both the chloride and chloride-ilmenite processes, the beneficiation/processing line occurs just before the chlorination step. Similarly, beneficiation ends and mineral processing begins at this point because TiO_2 is chemically converted to $TiCl_4$ through reaction with chlorine. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/ processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Hard rock deposits of ilmenite and rutile are mined in open pits; mined ore is crushed, ground, classified, magnetically separated, and floated to recover ore values. The major wastes from these operations are tailings from separators and flotation cells and, based on EPA data, these wastes are not expected to exhibit hazardous characteristics. Beach/alluvial sands containing ilmenite and rutile are excavated by dragline, front-end loader, or suction dredging; the sands are spiral concentrated to remove low density tailings. The sands are then dried and separated electrostatically to remove quartz and other nonconducting minerals, which are processed to produce zircon and monazite product and wastes consisting of quartz and epidote minerals. Conducting materials are magnetically separated to sort ilmenite from rutile, followed by screening and cleaning. No wastes from beach sand processing are expected to exhibit hazardous characteristics.[19]

2. Mineral Processing Wastes

The **sulfate process** for producing titanium dioxide yields two mineral processing wastes, waste solids and waste acids. These wastes are described below.

Sulfate Process Waste Solids

Waste solids are generated at two points in the sulfate process. The first point occurs when titanyl sulfate ($TiOSO_4$), which is generated by digesting ilmenite or slag with sulfuric acid, is clarified. This material (formerly characterized as a waste sludge) also is generated when copperas by-product ($FeSO_4 \cdot 7H_2O$) is separated from the solution containing titanyl sulfate after the solution is concentrated through vacuum evaporation. This waste stream was removed from the Mining Waste Exclusion because it is generated in volumes less than the high volume criterion of 45,000 metric tons per facility annually. (Volume data are unavailable for this waste stream due to

[19] U.S. Environmental Protection Agency, 1988, Op. Cit., p. 3-219.

confidential business information [CBI] designation.) The waste did pass the low hazard criterion for special waste status.[20]

Sulfate Process Waste Acids

Waste acids are generated when titania hydrate, generated by vacuum-evaporation and hydrolysis of titania sulfate, is filtered prior to washing. The operator of the Kemira, Inc. facility in Savannah, GA, treats this waste acid filtrate (which has a field pH of 0.5) with lime in its waste acid neutralization plant and discharges the treated effluent through an NPDES outfall to the Savannah River.[21] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 200 metric tons/yr, 39,000 metric tons/yr, and 77,000 metric tons/yr, respectively. This waste stream was removed from the Mining Waste Exclusion because it failed the low hazard criterion for chromium and pH (i.e., it exhibits the characteristics of toxicity and corrosivity).[22] Additional data (Attachment 1) also suggest that this waste stream exhibits the toxicity characteristic for arsenic, chromium, selenium, and silver.

The **chloride process** and **chloride-ilmenite process** for manufacturing $TiCl_4$ each generate two primary mineral processing wastes, waste acids and waste solids. Waste acids and solids are recovered from the fluid-bed chlorinator as a slurry and separated; descriptions of the separated acids and solids are provided below. Several other waste streams are generated in the treatment and disposal of these wastes, including wastewater treatment effluent and solids, which are commonly discharged to on-site surface impoundments prior to the effluent being discharged through an NPDES outfall and the solids being disposed in a landfill. In addition, the chloride and chloride-ilmenite processes generate several other waste streams, including ferric chloride and ferric chloride sludge, scrubber water and solids, and vanadium oxychloride.

Chloride and Chloride-ilmenite Process Waste Acid and Solids

Waste acids and solids from the chloride and the chloride-ilmenite processes are generated in the chlorination step as a combined acids/solids slurry. The combined waste acids and solids are treated by a solids/liquids separation process, and the resulting chloride process waste solids (a mineral processing special waste) are landfilled, while the chloride process waste acids are deep-well injected at some plants. Approximately 49,000 metric tons of waste acids and 414,000 metric tons of waste solids are generated annually.[23] We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristics of toxicity (chromium, selenium, and lead) and corrosivity. This waste was formerly characterized as a spent material. Data for this waste stream are presented in Attachment 1.

Waste Ferric Chloride and Ferric Chloride Treatment Sludge

Waste ferric chloride is generated in both the chloride and the chloride-ilmenite processes when gaseous titanium tetrachloride is separated from other chlorides. Ferric chloride is removed as an acidic, liquid waste stream through fractional condensation and treated with lime and either landfilled or sold as a by-product. Although EPA found no published information regarding waste generation rate or characteristics, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for waste ferric chloride of 22,000 metric tons/yr, 29,000 metric tons/yr, and 35,000 metric tons/yr, respectively. We used best engineering judgment to determine that waste ferric chloride may exhibit the characteristic of corrosivity and the characteristic of toxicity for cadmium, chromium, lead, and silver. This waste is fully recycled and was formerly

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[20] 55 FR 2341-2342.

[21] ICF Incorporated, Kemira, Inc.: Mineral Processing Waste Sampling Visit — Trip Report, September 1989, p. 3.

[22] 55 FR 2342.

[23] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, August 1992, p. I-7.

classified as a by-product. Data for this waste stream are presented in Attachment 1. For ferric chloride treatment sludge, we estimated that the medium annual waste generation rate would be 75 percent of that for waste ferric chloride, with the high and low rates ±20 percent of the medium rate. Therefore, we estimated a low, medium, and high annual waste generation rate for ferric chloride treatment sludge of 18,000 metric tons/yr, 22,000 metric tons/yr, and 26,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Two scrubber water waste streams are generated in the chloride process, as described below. Data describing these waste stream are presented in Attachment 1.

Chlorination Off-gas Scrubber Water

Chlorination off-gas scrubber water is generated by the scrubbing of off-gases created in the condensation of the reaction gas produced in the chlorination step. Off-gases are cleaned in water wash towers and then passed through a caustic tower and a Venturi scrubber. After leaving the scrubber, the gas stream is either released to the atmosphere, or passed through three additional scrubbers for further cleansing.[24] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for chlorination off-gas scrubber water of 1.2 million metric tons/yr, 1.5 million metric tons/yr, and 1.8 million metric tons/yr, respectively. (The excessive generation rate for this wastewater [i.e., greater than one million metric tons/yr] is due to commingling of numerous individual waste streams.) We used best engineering judgment to determine that chlorination off-gas scrubber water may exhibit the characteristics of corrosivity and toxicity for chromium.

Chlorination Area-Vent Scrubber Water

Chlorination area-vent scrubber water is generated by the scrubbing of cleaned gas from the chlorination off-gas scrubbers (described above) and ventilation vapors from $TiCl_4$ purification operations. This scrubber system, like that for chlorination off-gases, consists of a wash water tower and a Venturi scrubber operated in series. After leaving this scrubber system, the cleaned gases are vented to the atmosphere.[25] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for chlorination area-vent scrubber water of 150,000 metric tons/yr, 180,000 metric tons/yr, and 220,000 metric tons/yr, respectively. We used best engineering judgment to determine that chlorination area-vent scrubber water may exhibit the characteristics of corrosivity and toxicity for chromium.

Spent Vanadium Oxychloride

Vanadium chloride is removed from the gaseous product stream containing $TiCl_4$ by complexing with mineral oil and reducing to vanadium oxychloride ($VOCl_2$), a low-volume non-special mineral processing waste, with hydrogen sulfide, or by complexing with copper. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 22,000 metric tons/yr, and 45,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater Treatment Plant Liquid Effluent

Wastewater treatment plant liquid effluent, a post-mineral processing waste, consists of treated wastewaters such as contact cooling water and/or liquid wastes from the chlorination step (i.e., waste acids) and the $TiCl_4$

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[24] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category. Volume IX: Primary and Secondary Titanium, Primary Zirconium and Hafnium, EPA 440/1-89-019.9, Office of Water Regulations and Standards, May 1989, p. 4861.

[25] Ibid.

purification, oxidation, or finishing steps. Effluent is sent to a surface impoundment for settling of solids before discharge through an NPDES outfall. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 900 metric tons/yr, 140 million metric tons/yr, and 270 million metric tons/yr, respectively. (The excessive generation rate for this wastewater [i.e., greater than one million metric tons/yr] is due to commingling of numerous waste streams.) Existing data (Attachment 1) and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Wastewater Treatment Plant Sludge/Solids

Wastewater treatment plant sludge/solids, also a post-mineral processing waste, consists of what was formerly characterized as sludges and solids resulting from the treatment of the wastewaters described above. These materials are disposed in on- or off-site landfills. Approximately 420,000 metric tons are generated annually.[26] We used best engineering judgment to determine that this waste may exhibit the characteristics of toxicity (chromium). Data describing this waste stream are presented in Attachment 1.

Spent Surface Impoundment Liquids

Surface impoundment liquids consist of various waste streams, such as chloride process waste acids and solids in slurry form and wastewater treatment plant effluent. Waste acids managed in surface impoundments are generally routed to a solids/liquids separation process and then disposed by deep-well injection. Treated effluent is discharged through NPDES outfalls after solids have settled. This waste stream is considered post-mineral processing. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 630 metric tons/yr, 3,400 metric tons/yr, and 6,700 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be recycled and may exhibit the characteristics of toxicity (chromium and lead). This waste was formerly characterized as a spent material. Data describing this waste stream are presented in Attachment 1.

Spent Surface Impoundment Solids

Surface impoundment solids settle out of liquid and slurry waste streams, such as chloride process waste acids and solids in slurry form and wastewater treatment plant effluent, that are managed in surface impoundments. Surface impoundment solids may be dredged from the impoundment and moved to on- or off-site solids landfills. This waste stream is considered post-mineral processing; approximately 36,000 metric tons are generated annually.[27] We used best engineering judgment to determine that this waste may exhibit the characteristic of toxicity (chromium and lead). Data describing this waste stream are presented in Attachment 1.

The **Kroll process for manufacturing titanium sponge** from $TiCl_4$ generates seven waste streams, one of which is a mineral processing waste and the others, post-mineral processing wastes.

$TiCl_4$ Purification Effluent

$TiCl_4$ purification effluent, classified as a mineral processing waste, is generated in preparing $TiCl_4$ for the Kroll process. We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 26,000 metric tons/yr, 33,000 metric tons/yr, and 39,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[26] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-7.

[27] Ibid.

Reduction Area Scrubber Water

Reduction area scrubber water is generated by the scrubbing of vapors released during magnesium reduction of $TiCl_4$ in the reduction vessel. The vapors are cleansed in the reduction area scrubber and released to the atmosphere, while the resulting scrubber water is treated in the facility wastewater treatment plant.[28] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for reduction area scrubber water of 870,000 metric tons/yr, 1.1 million metric tons/yr, and 1.3 million metric tons/yr, respectively. (The excessive generation rate for this wastewater [i.e., greater than one million metric tons/yr] is due to commingling of numerous waste streams.) Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Melt Cell Scrubber Water

If the reduction process is conducted rapidly, excess $MgCl_2$ can be generated and is collected in a melt cell before it is recovered through electrolysis. The molten $MgCl_2$ generates vapors that are cleaned by wet scrubbers, which generates melt cell scrubber water containing low concentrations of toxic metals and acidity.[29] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for melt cell scrubber water of 230,000 metric tons/yr, 280,000 metric tons/yr, and 340,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Chlorine Liquefaction Scrubber Water

Chlorine liquefaction scrubber water is created by the scrubbing of chlorine gas generated in the electrolytic reduction of $MgCl_2$. The chlorine gas is passed first to bag filters and is then either returned to the reduction process or liquefied and sold. During liquefaction, air saturated with chlorine escapes and is treated by burning to convert the chlorine to hydrochloric acid vapor. This vapor is scrubbed with water, creating the scrubber wastewater.[30] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for chlorine liquefaction scrubber water of 1.6 million metric tons/yr, 2 million metric tons/yr, and 2.4 million metric tons/yr, respectively. (The excessive generation rate for this wastewater [i.e., greater than one million metric tons/yr] is due to commingling of numerous waste streams.) Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Sodium Reduction Container Reconditioning Wash Water

Sodium reduction container reconditioning wash water is generated in the cleaning the container (retort vessel) in which $TiCl_4$ is converted to titanium metal through sodium reduction.[31] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for sodium reduction container reconditioning wash water of 6,800 metric tons/yr, 8,600 metric tons/yr, and 10,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[28] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 4862.

[29] Ibid.

[30] Ibid.

[31] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 4863.

Chip Crushing Scrubber Water

Chip crushing scrubber water is generated in the cleaning of dust-laden air released during the crushing of titanium chips after they are removed from the reduction container.[32] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for chip crushing scrubber water of 260,000 metric tons/yr, 320,000 metric tons/yr, and 390,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Leach Liquor and Sponge Wash Water

Leach liquor, a post-mineral processing waste, is generated in the acid leaching of titanium sponge to remove impurities consisting of $MgCl_2$ and unreacted $TiCl_4$. At Timet in Henderson, NV, leach liquor is held in a polyvinyl chloride-lined pond, neutralized with lime in a concrete mixing tank, and concentrated in a series of solar evaporation ponds. The resulting solution, close to saturation with magnesium chloride, is sold for use as a dust suppressant on unpaved roads.[33] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for leach liquor and sponge wash water of 380,000 metric tons/yr, 480,000 metric tons/yr, and 580,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristics of corrosivity and toxicity (chromium and lead). This waste is classified as what was formerly characterized as a spent material. After the sponge is acid-leached, it is rinsed with water, generating sponge wash water, which may also exhibit the corrosivity characteristic. Data describing these waste streams are presented in Attachment 1.

Waste Non-Contact Cooling Water

Non-contact cooling water generated in the Kroll process is a post-mineral processing waste. We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for waste non-contact cooling water of 100 metric tons/yr, 500,000 metric tons/yr, and 1 million metric tons/yr, respectively. (The excessive generation rate for this wastewater [i.e., greater than one million metric tons/yr] is due to commingling of numerous waste streams.) Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Additional Waste Streams

Two additional waste streams are generated in the Kroll process: smut from magnesium recovery, and spent brine treatment filter cake. Smut is generated in the recovery of magnesium from the magnesium chloride solution generated in the reduction process. We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for smut from magnesium recovery of 100 metric tons/yr, 22,000 metric tons/yr, and 45,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be recycled and may exhibit the characteristic of reactivity with water. This waste was formerly classified as a by-product. Brine treatment filter cake is created in the solar evaporation of leach liquor. We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for spent brine treatment filter cake of 100 metric tons/yr, 22,000 metric tons/yr, and 45,000 metric tons/yr, respectively. Existing data (Attachment 1) and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[32] Ibid.

[33] ICF Incorporated, Timet Corporation: Mineral Processing Waste Sampling Visit — Trip Report, August 1989, p. 3.

Ingot production generates the following post-mineral processing waste streams:

Pickling Liquor and Wash Water

Three ingot plants use acid pickling to remove surface oxides from massive titanium scrap (plate and sheet metal) before the scrap is blended with titanium sponge and alloying metals. The pickling liquor is comprised of hydrochloric, hydrofluoric, and nitric acids; spent pickling liquor and wash water form an acidic wastewater stream.[34] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for pickling liquor and wash water of 2,200 metric tons/yr, 2,700 metric tons/yr, and 3,200 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristics of corrosivity and toxicity for cadmium, chromium, and lead. This waste was formerly characterized as a spent material. Data describing this waste stream are presented in Attachment 1.

Scrap Detergent Wash Water

Titanium scrap chips and millings are washed with a detergent solution before alloying to remove oil and dirt, creating an oily, caustic wastewater stream.[35] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for scrap detergent wash water of 360,000 metric tons/yr, 450,000 metric tons/yr, and 540,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristic of toxicity for cadmium, chromium, selenium, and lead; and the characteristic of corrosivity.

Scrap Milling Scrubber Water

Before alloying, titanium scrap chips and millings are also crushed. A dust scrubber cleans dust-laden air from this operation, generating scrubber water containing oil and grease, suspended solids, and metals.[36] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for scrap milling scrubber water of 4,000 metric tons/yr, 5,000 metric tons/yr, and 6,000 metric tons/yr, respectively. We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristic of toxicity for cadmium, chromium, selenium, and lead.

Casting Crucible Contact Cooling Water and Wash Water

At one ingot plant, water is used to cool the casting equipment, generating a wastewater containing oil and grease, metals, and solids. This cooling water is treated through lime precipitation and sedimentation. We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for casting crucible contact cooling water of 190,000 metric tons/yr, 240,000 metric tons/yr, and 290,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further. Casting crucibles are washed following casting, generating oily wastewater, which is treated by oil skimming, lime precipitation, and sedimentation.[37] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for casting crucible wash water of 4,000 metric tons/yr, 5,000 metric tons/yr, and 6,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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[34] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 4843, 4864, 4945.

[35] Ibid.

[36] Ibid.

[37] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 4946.

Finishing Scrap

Finishing scrap is generated in the melting or milling operations used to convert titanium sponge into ingots. Scrap is generally recycled back into the melting or milling operation and is not regarded as a solid waste.[38] We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate for finishing scrap of 100 metric tons/yr, 22,000 metric tons/yr, and 45,000 metric tons/yr, respectively. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Wastes

Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples (e.g., hydrofluoric acid at titanium sponge facilities). Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

Three commenters submitted comments on the titanium sector report.

New Factual Information

One commenter provided new factual information about its titanium dioxide pigment manufacturing facility in Savannah, GA that uses the sulfate-chloride process (COMM 49). This information has been included in the sector report.

Sector-specific Issues

Two commenters addressed the extraction/beneficiation boundary. One commenter agreed with the Agency's conclusion that iron chloride waste acid from the production of titanium tetrachloride by the chloride ilmenite process is a mineral processing waste not eligible for the Bevill Exemption (COMM 22). Another commenter disagreed with the Agency's position that chlorination constitutes beneficiation only when it is used in preparation for a leaching operation that does not produce a final or intermediate product that does not undergo further beneficiation or processing (COMM 18). This issue is more fully discussed in the Agency's technical background document on titanium thresholds.

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[38] Ibid.

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ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PICKLE LIQUOR AND WASH WATER FROM INGOT PRODUCTION - TITANIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.027	0.579	0.88	3/3	-	-	-	0/0	-	-
Arsenic	0.06	0.3167	0.62	3/3	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.0002	0.0011	0.002	3/3	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.19	0.227	0.28	3/3	-	-	-	0/0	1.0	0
Chromium	0.21	0.26	0.3	3/3	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.54	0.94	1.7	3/3	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	2.6	3.17	4	3/3	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0011	0.002	3/3	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	1.3	1.83	2.6	3/3	-	-	-	0/0	-	-
Selenium	0.009	0.14	0.22	3/3	-	-	-	0/0	1.0	0
Silver	0.0014	0.50	1.2	3/3	-	-	-	0/0	5.0	0
Thallium	1.7	2.83	3.8	3/3	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.43	0.53	0.67	3/3	-	-	-	0/0	-	-
Cyanide	0.01	3333.67	10000	3/3	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SPENT BRINE TREATMENT FILTER CAKE - TITANIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	40000	40,000	40,000	1/1	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	10.1	10.1	10.1	1/1					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT LIQUID EFFLUENT - TITANIUM DIOXIDE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	0.01	0.01	0.01	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	1.10	1.10	1.10	1/1	-	-	-	0/0	-	-
Lead	0.01	0.01	0.01	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.02	0.02	0.02	1/1	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	160,000	160,000	160,000	1/1	-	-	-	0/0	-	-
TSS	70,000	70,000	70,000	1/1	-	-	-	0/0	-	-
pH *	7	7.15	7.3	2/2					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT LIQUIDS - TITANIUM DIOXIDE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	3900	12,543	16,000	7/7	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	60	60.00	60.00	2/2	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	203	338	524	9/9	-	-	-	0/0	5.0	0
Cobalt	20	20.00	20.00	2/2	-	-	-	0/0	-	-
Copper	9	9.00	9.00	2/2	-	-	-	0/0	-	-
Iron	0.2	67,194	97,000	10/10	-	-	-	0/0	-	-
Lead	0.005	74.60	139	10/10	-	-	-	0/0	5.0	0
Magnesium	100000	100,000	100,000	1/1	-	-	-	0/0	-	-
Manganese	200	1,629	5,200	7/7	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	13.00	13.00	13.00	2/2	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	553	553	553	2/2	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	0.2	0	0	1/1	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	6,100	108,773	200,000	13/13	-	-	-	0/0	-	-
TSS	0.60	592	2,000	11/11	-	-	-	0/0	-	-
pH *	4.00	6.25	7.00	4/4					2<pH>12	0
Organics (TOC)	#VALUE!	#VALUE!	#VALUE!	2/2					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT SOLIDS - TITANIUM DIOXIDE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	2,822	11,502	14,395	4/4	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	43.00	138	169	4/4	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	10.00	497	887	6/6	-	-	-	0/0	5.0	0
Cobalt	20.00	20.00	20.00	1/1	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	17,000	51,509	70,000	5/5	-	-	-	0/0	-	-
Lead	8.00	113	167	5/5	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	730	2,200	3,700	5/5	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	6.00	60.75	79.00	4/4	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	10.00	628	893	5/5	-	-	-	0/0	-	-
Zinc	62.00	62.00	62.00	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	290	290	290	1/1	-	-	-	0/0	-	-
Silica	57,369	57,369	57,369	3/3	-	-	-	0/0	-	-
Chloride	1,500	26,175	100,000	4/4	-	-	-	0/0	-	-
TSS	98,000	512,000	800,000	4/4	-	-	-	0/0	-	-
pH *	3.9	5.9	7.0	7/7					2<pH>12	0
Organics (TOC)	19.00	318,755	425,000	4/4					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - LEACH LIQUOR AND SPONGE WASH WATER - TITANIUM AND TITANIUM DIOXIDE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	2.50	2.50	2.50	1/1	0.05	0.28	0.50	2/2	-	-
Antimony	0.07	1.29	2.50	2/2	0.50	0.50	0.50	2/2	-	-
Arsenic	0.10	1.30	2.50	2/2	0.01	0.26	0.50	2/2	5.0	0
Barium	2.50	2.50	2.50	1/1	0.50	0.72	0.93	2/2	100.0	0
Beryllium	0.00	0.13	0.25	2/2	0.025	0.038	0.050	2/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.16	0.21	0.25	2/2	0.025	0.038	0.050	2/2	1.0	0
Chromium	1.20	1.85	2.50	2/2	0.080	0.29	0.50	2/2	5.0	0
Cobalt	2.50	2.50	2.50	1/1	0.050	0.28	0.50	2/2	-	-
Copper	2.50	2.70	2.90	2/2	0.50	1.05	1.60	2/2	-	-
Iron	9.42	9.42	9.42	1/1	0.020	3.29	6.55	2/2	-	-
Lead	1.25	2.03	2.80	2/2	0.010	0.13	0.25	2/2	5.0	0
Magnesium	5,000	25,667	40,000	3/3	25,700	43,800	61,900	2/2	-	-
Manganese	2.50	2.50	2.50	1/1	0.50	3.24	5.98	2/2	-	-
Mercury	0.0002	0.0009	0.0016	2/2	0.00010	0.00055	0.0010	2/2	0.2	0
Molybdenum	2.50	2.50	2.50	1/1	0.50	0.50	0.50	1/1	-	-
Nickel	2.50	4.75	7.00	2/2	0.17	0.34	0.50	2/2	-	-
Selenium	0.01	1.26	2.50	2/2	0.010	0.26	0.50	2/2	1.0	0
Silver	0.03	1.27	2.50	2/2	0.03	0.26	0.50	2/2	5.0	0
Thallium	2.40	7.45	12.50	1/2	0.55	1.53	2.50	2/2	-	-
Vanadium	2.50	2.50	2.50	1/1	0.50	1.10	1.70	2/2	-	-
Zinc	0.54	1.52	2.50	2/2	0.50	0.52	0.54	2/2	-	-
Cyanide	0.01	0.01	0.01	1/1	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	198	198	198	1/1	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	115	43,023	80,000	5/5	-	-	-	0/0	-	-
TSS	50,000	50,000	50,000	1/1	-	-	-	0/0	-	-
pH *	0	0.50	1	2/2					2<pH>12	2
Organics (TOC)	1,670	1,670	1,670	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SRUBBER WATER - TITANIUM (CHLORIDE PROCESS)

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	-	-
Antimony	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	-	-
Arsenic	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	5.0	0
Barium	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	100.0	0
Beryllium	0.15	0.15	0.15	1/1	0.10	0.10	0.10	1/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.050	0.050	0.050	0/1	0.050	0.050	0.050	0/1	1.0	0
Chromium	0.50	0.50	0.50	0/1	6.45	6.45	6.45	1/1	5.0	1
Cobalt	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	-	-
Copper	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	-	-
Iron	0.50	0.50	0.50	0/1	25.70	25.70	25.70	1/1	-	-
Lead	0.25	0.25	0.25	0/1	0.25	0.25	0.25	0/1	5.0	0
Magnesium	5.87	5.87	5.87	1/1	6.56	6.56	6.56	1/1	-	-
Manganese	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	-	-
Mercury	0.00010	0.00010	0.00010	0/1	0.00028	0.00028	0.00028	1/1	0.2	0
Molybdenum	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	-	-
Nickel	0.50	0.50	0.50	0/1	2.79	2.79	2.79	1/1	-	-
Selenium	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	1.0	0
Silver	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	5.0	0
Thallium	2.50	2.50	2.50	0/1	2.50	2.50	2.50	0/1	-	-
Vanadium	1.51	1.51	1.51	1/1	1.82	1.82	1.82	1/1	-	-
Zinc	0.50	0.50	0.50	0/1	0.50	0.50	0.50	0/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	15.40	15.40	15.40	1/1	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	235,000	235,000	235,000	1/1	-	-	-	0/0	-	-
TSS	3,740	3,740	3,740	1/1	-	-	-	0/0	-	-
pH *	0.5	1.2	1.9	2/2					2<pH>12	2
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT SLUDGE/SOLIDS - TITANIUM DIOXIDE

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	58	679	1,300	2/2	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	17000	27,000	37,000	2/2	-	-	-	0/0	-	-
Lead	8	8.00	8.00	1/1	-	-	-	0/0	5.0	0
Magnesium	9000	9,000	9,000	1/1	-	-	-	0/0	-	-
Manganese	730	1,865	3,000	2/2	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	6	6.00	6.00	1/1	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	600	600	600	1/1	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	11000	11,000	11,000	1/1	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	40000	40,000	40,000	1/1	-	-	-	0/0	-	-
Chloride	1500	40,750	80,000	2/2	-	-	-	0/0	-	-
TSS	98000	98,000	98,000	1/1	-	-	-	0/0	-	-
pH *	7.8	9.4	11	2/2					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - FERRIC CHLORIDE - TITANIUM

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	930	930	930	1/1	-	-
Antimony	-	-	-	0/0	25	25	25	1/1	-	-
Arsenic	-	-	-	0/0	0.083	0.083	0.083	1/1	5.0	0
Barium	-	-	-	0/0	23	23	23	1/1	100.0	0
Beryllium	-	-	-	0/0	1.8	1.8	1.8	1/1	-	-
Boron	-	-	-	0/0	18	18	18	1/1	-	-
Cadmium	-	-	-	0/0	1.5	1.5	1.5	1/1	1.0	1
Chromium	-	-	-	0/0	310	310	310	1/1	5.0	1
Cobalt	-	-	-	0/0	9.9	9.9	9.9	1/1	-	-
Copper	-	-	-	0/0	18	18	18	1/1	-	-
Iron	-	-	-	0/0	48000	48000	48000	1/1	-	-
Lead	-	-	-	0/0	58	58	58	1/1	5.0	1
Magnesium	-	-	-	0/0	970	970	970	1/1	-	-
Manganese	-	-	-	0/0	2200	2200	2200	1/1	-	-
Mercury	-	-	-	0/0	0.02	0.02	0.02	1/1	0.2	0
Molybdenum	-	-	-	0/0	8.8	8.8	8.8	1/1	-	-
Nickel	-	-	-	0/0	30	30	30	1/1	-	-
Selenium	-	-	-	0/0	0.02	0.02	0.02	1/1	1.0	0
Silver	-	-	-	0/0	6.2	6.2	6.2	1/1	5.0	1
Thallium	-	-	-	0/0	0.004	0.004	0.004	1/1	-	-
Vanadium	-	-	-	0/0	320	320	320	1/1	-	-
Zinc	-	-	-	0/0	52	52	52	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	326	326	326	1/1	-	-
Fluoride	-	-	-	0/0	2	2	2	1/1	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	104160	104160	104160	1/1	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTE ACIDS - TITANIUM (CHLORIDE PROCESS)

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	447	10,612	16,000	4/4	-	-	-	0/0	-	-
Antimony	1.73	1.73	1.73	1/1	-	-	-	0/0	-	-
Arsenic	0.0050	0.0050	0.0050	0/1	-	-	-	0/0	5.0	0
Barium	0.50	0.50	0.50	0/1	-	-	-	0/0	100.0	0
Beryllium	0.05	0.05	0.05	0/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.11	0.11	0.11	1/1	-	-	-	0/0	1.0	0
Chromium	35.80	637	3,300	6/6	-	-	-	0/0	5.0	0
Cobalt	0.78	0.78	0.78	1/1	-	-	-	0/0	-	-
Copper	0.050	0.050	0.050	0/1	-	-	-	0/0	-	-
Iron	12.00	27,552	72,000	8/8	-	-	-	0/0	-	-
Lead	0.0025	38.67	58.00	2/3	-	-	-	0/0	5.0	0
Magnesium	7.60	1,916	4,800	3/3	-	-	-	0/0	-	-
Manganese	46.00	2,087	7,900	4/4	-	-	-	0/0	-	-
Mercury	0.00020	0.00020	0.00020	1/1	-	-	-	0/0	0.2	0
Molybdenum	0.25	0.25	0.25	0/1	-	-	-	0/0	-	-
Nickel	0.61	0.61	0.61	1/1	-	-	-	0/0	-	-
Selenium	0.0050	0.0050	0.0050	0/1	-	-	-	0/0	1.0	0
Silver	0.0050	0.0050	0.0050	0/1	-	-	-	0/0	5.0	0
Thallium	0.0050	0.0050	0.0050	0/1	-	-	-	0/0	-	-
Vanadium	13.00	331	1,500	5/5	-	-	-	0/0	-	-
Zinc	27.00	27.00	27.00	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	44.00	1,022	2,000	2/2	-	-	-	0/0	-	-
Chloride	76,000	124,500	210,000	4/4	-	-	-	0/0	-	-
TSS	10,000	47,000	200,000	6/6	-	-	-	0/0	-	-
pH *	2.00	2.00	2.00	1/1					2<pH>12	1
Organics (TOC)	40.00	40.00	40.00	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTE ACIDS - TITANIUM (SULFATE PROCESS)

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	2.50	253	480	3/4	0.05	363	1,030	2/4	-	-
Antimony	0.50	1.15	2.50	1/4	0.50	2.25	5.00	1/4	-	-
Arsenic	0.0050	0.88	2.50	0/4	0.01	1.33	5.00	1/5	5.0	1
Barium	0.50	1.00	2.50	0/4	0.05	1.31	5.00	2/5	100.0	0
Beryllium	0.050	0.10	0.25	0/4	0.0050	0.15	0.50	0/4	-	-
Boron	0.025	0.025	0.025	0/1	-	-	-	0/0	-	-
Cadmium	0.050	0.12	0.25	1/4	0.0050	0.12	0.50	1/5	1.0	0
Chromium	2.50	21.63	40.00	3/4	0.080	31.12	83.00	4/5	5.0	3
Cobalt	0.50	1.28	2.50	1/4	0.050	1.64	5.00	1/4	-	-
Copper	0.05	0.89	2.50	0/4	0.050	1.79	5.00	1/4	-	-
Iron	9.42	1544	3000	4/4	0.020	2,174	5,910	4/4	-	-
Lead	0.0025	0.44	1.25	0/4	0.010	0.77	2.50	1/5	5.0	0
Magnesium	223	13,195	40,000	6/6	941	22,685	61,900	4/4	-	-
Manganese	2.50	28.13	51.00	3/4	0.50	39.12	111	3/4	-	-
Mercury	0.00010	0.00048	0.0016	1/4	0.00010	0.00028	0.0010	0/5	0.2	0
Molybdenum	0.25	0.94	2.50	0/4	0.50	2.75	5.00	0/2	-	-
Nickel	0.50	1.03	2.50	1/4	0.17	1.89	5.00	1/3	-	-
Selenium	0.0050	0.88	2.50	0/4	0.010	1.21	5.00	0/5	1.0	1
Silver	0.0050	0.88	2.50	0/4	0.005	1.12	5.00	0/5	5.0	1
Thallium	0.0050	5.00	12.50	1/4	0.55	9.76	25.00	2/4	-	-
Vanadium	2.50	54.63	100	3/4	0.50	77.55	225	3/4	-	-
Zinc	0.50	13.75	27.00	2/4	0.50	7.51	24.00	2/4	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	0	99	198	2/2	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	2.50	30,735	80,000	6/7	-	-	-	0/0	-	-
TSS	50000	65,450	80,900	2/2	-	-	-	0/0	-	-
pH *	0	0.33	1	3/3					2<pH>12	3
Organics (TOC)	20.00	845	1,670	2/2					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

TUNGSTEN

A. Commodity Summary

More than 20 tungsten-bearing minerals are known, but the principle domestic ores used to produce ammonium paratungstate (APT) powder and tungsten metal powder are wolframite, ferberite, and scheelite. Tungsten occurs in association with minerals of copper, tin, bismuth, or molybdenum and can be recovered either as the primary product or as a coproduct or byproduct.[1]

Tungsten ores and concentrates are converted into the following intermediate products: APT, tungstic acid, sodium tungstate, tungsten metal powder, ferrotungsten, and tungsten carbide powder. Most of the APT is reduced to tungsten metal powder, which then may be processed into tungsten carbide powder or ferrotungsten.[2] End uses of tungsten include metalworking, mining, and construction machinery and equipment, 74%; electrical and electronic machinery and equipment and transportation, 10%; lamps and lighting, 9%; chemicals, 4%; and other, 3%. The total estimated value of primary tungsten material consumed in 1994 was $180 million.[3]

Eleven facilities in the United States produce either APT or tungsten metal. Three of the eleven facilities produce APT, a precursor to tungsten, as an end product. Four additional facilities are captive plants that produce APT, then tungsten. All seven of these plants appear to engage in beneficiation operations in the production of APT. They conduct a variety of operations, including milling (e.g., crushing, grinding, washing), physical separation (e.g., gravity concentration, magnetic or electrostatic separation, froth flotation), roasting as a pretreatment for leaching operations, concentration using liquid separation (e.g., soda autoclaving, solvent extraction, ion exchange), and calcining (i.e., heating to drive off water or carbon dioxide).

In addition, two plants produce tungsten powder and cemented tungsten carbide using proprietary processes. A Kennametal plant, located in Fallon, Nevada employs a unique process that produces tungsten carbide directly from ore. A Curtis Tungsten plant located in Upland, California was recently reopened and produces tungsten concentrate from ore. Little is known about the operations of these two facilities.

The two remaining facilities obtain APT (a "saleable" mineral product) and produce tungsten carbide or powder. Tungsten is produced from APT by reduction using hydrogen, followed by a second reduction step using aluminum, potassium, and silicon. The metal is then washed with hydrochloric acid, and cast into ingots. These two facilities do not perform beneficiation activities, and there is some question as to whether their operations could even be considered "mineral processing" operations, because they start with a saleable mineral product (see 54 FR 36592).

For the nine plants that conduct beneficiation and processing operations, names, locations, products, operations, and waste streams generated are presented in Exhibit 1. Two tungsten mines are in operation, Curtis Tungsten in Upland, California and U.S. Tungsten in Bishop, California. These are also listed in Exhibit 1.

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[1] Phillip T. Stafford, "Tungsten," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, pp. 881-891.

[2] Ibid.

[3] Gerald Smith, "Tungsten," from Mineral Commodity Summaries, January 1995, pp. 182-183.

EXHIBIT 1

SUMMARY OF TUNGSTEN FACILITIES

Facility Name	Location	Products
Buffalo Tungsten	Depew, NY	APT, Tungsten (carbide)
Curtis Tungsten, Incorporated	Upland, CA	Tungsten (concentrate)
General Electric	Euclid, OH	APT, Tungsten (carbide)
OSRAM Sylvania, Inc.	Towanda, PA	APT, Tungsten (carbide)
Kennametal	Fallon, NV LaTrobe, PA	Tungsten (carbide)
Teledyne Firth Sterling	La Vergne, TN	APT
Teledyne Advance Materials	Huntsville, AL	APT, Tungsten (carbide)
U.S. Tungsten	Bishop, CA	APT

B. Generalized Process Description

1. Discussion of Typical Production Processes

Tungsten is found primarily in quartz veins and contact-metamorphic scheelite deposits. Both underground and open pit methods are used in mining operations. Tungsten concentration operations, primarily gravity and flotation methods, usually are conducted at or near the mine. The concentrate is processed chemically to produce ammonium paratungstate (APT) from which tungsten metal powder is made. The metal is processed further into products such as tungsten carbide and ferrotungsten.[4]

2. Generalized Process Flow Diagram

The production of tungsten metal can be divided into four distinct stages - preparation of ores, leaching of ore concentrates, purification to APT, and reduction of APT to metal. The actual processes used in each stage vary with the type and purity of raw material used. The production steps are described in greater detail below. Exhibit 2 presents a process flow diagram of tungsten production.

Preparation of Ore Concentrates

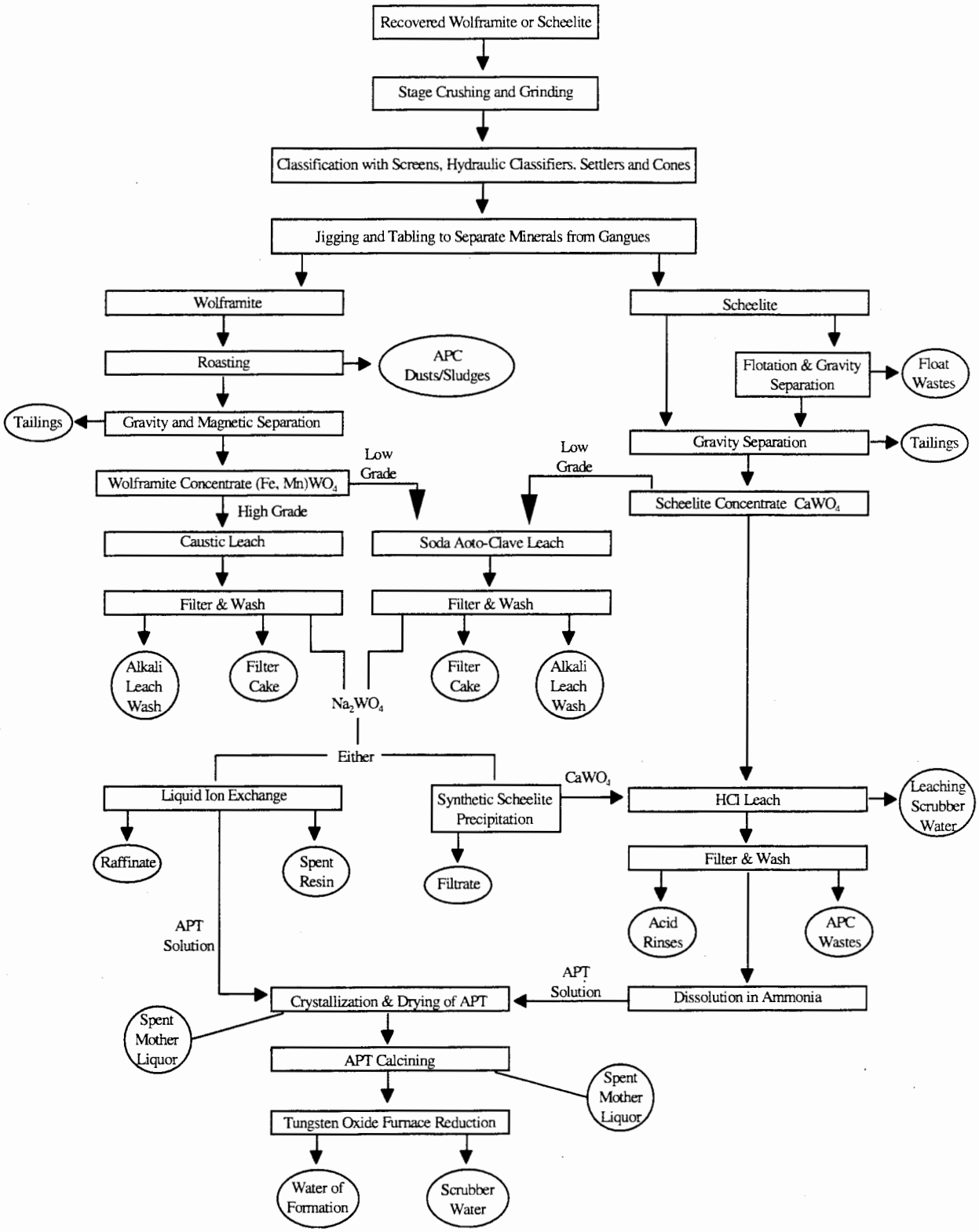
Scheelite and wolframite are the major tungsten containing minerals. Ores containing these minerals are generally very friable and over grinding can cause sliming problems. Therefore, the ores are generally crushed and ground in stages and waste fines are kept to a minimum. Concentration of tungsten is usually accomplished by froth flotation, supplemented by leaching, roasting, or magnetic or high tension separation. The tailings from froth

[4] Phillip T. Stafford, 1985, Op. Cit., pp. 881-891.

EXHIBIT 2

TUNGSTEN PRODUCTION

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989, pp. 2963 - 3037.)



flotation usually are sent through a reprocessing and scavenger froth flotation circuit to maximize tungsten recovery. The beneficiation processes vary with the type of ore being mined.[5]

The concentrate may be retreated by roasting to remove impurities such as sulfur, arsenic, and organic residues from flotation. These compounds are oxidized and volatilized. After preparation of the concentrate, the concentrate is processed to APT via either sodium tungstate or tungstic acid.[6]

Leaching of Ore Concentrates

Scheelite ores of high quality are usually leached with hot hydrochloric acid to remove phosphorus, arsenic, and sulfur. An insoluble tungstic acid intermediate is formed which is filtered and washed with dilute hydrochloric acid.[7]

Lower grade scheelites are sometimes processed by the high pressure soda process. In this process, the concentrate is ground and digested in an autoclave with sodium carbonate. This produces a sodium tungstate solution that is filtered to remove calcium carbonate and silica solids and then further processed to APT or $CaWO_4$. If molybdenum impurities are present, the sodium tungstate solution is reacted with sodium hydrosulfide to precipitate molybdenum trisulfide. The molybdenum trisulfide solids are removed with a filter and the sodium tungstate solution is further processed.[8]

Scheelite or wolframite can be converted to sodium tungstate solution by the alkali roasting process. In this process, sodium carbonate is mixed with the concentrate and heated. The roasted concentrate is then leached with hot water. The leachate, which contains sodium tungstate, is separated from the solids by filtration and sent to other processes for conversion to APT.[9]

Purification to APT (Precipitation, Crystallization, and Drying)

Tungstic Acid Purification

Purification of tungstic acid is accomplished by a simple process involving digestion and crystallization. Insoluble tungstic acid is digested with aqueous ammonia to solubilize the tungsten as ammonia tungstate. The solution is separated from any remaining solids and magnesium oxide is added. Magnesium ammonium phosphates and arsenate are precipitated. Activated carbon is added to purify the solution. The activated carbon and precipitates are removed from the solution by filtration. APT is formed by crystallizing it from solution. The APT crystals are filtered, washed, and dried. Ammonia evolved during the process is usually recovered and recycled.[10]

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[5] U.S. Environmental Protection Agency, "Tungsten," from 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-228 - 3-244.

[6] Ibid.

[7] Ibid.

[8] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Office of Water Regulations Standards, Vol. VI, 1989, pp. 2963-3037.

[9] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 3-228 - 3-224.

[10] Ibid.

Sodium Tungstate Purification

Sodium tungstate from the high pressure soda process and from the alkali roasting process is converted to APT by two processes. The first approach is to precipitate calcium tungstate (synthetic scheelite) from the sodium tungstate solution by adding calcium chloride. The solution is filtered to yield sodium chloride, and is discharged. The calcium tungstate can then be digested with hydrochloric acid. From this point, the purification is the same as described above for the purification of the tungstic acid intermediate.[11]

Synthetic scheelite is also prepared from recycled process solutions and cleanup water, such as spent crystallization liquor and floor wash, that may contain tungsten values. The calcium tungstate is precipitated with calcium chloride and can be processed as described above. Alternatively, the calcium tungstate may be sent through solvent extraction instead of digestion with hydrochloric acid.[12]

The second approach for purifying the sodium tungstate intermediate is a newer solvent extraction method, the liquid ion exchange system, where the sodium tungstate solution is converted to ammonia tungstate solution. The sodium tungstate solution is contacted countercurrently with an organic solvent, which removes the tungstate ions from solution. The organic solvent is washed with water to remove impurities and then recycled. The ammonium tungstate solution is fed to a crystallizer where APT crystals are formed. The APT crystals are filtered and dried.[13]

APT Conversion to Oxide (Calcining)

Dried APT is calcined in a rotary furnace heated indirectly to drive off ammonia and produce tungsten oxides. The type of oxide produced is a function of furnace atmosphere (i.e. N_2, H_2, etc.) and temperature. Blue, brown, or yellow tungsten oxides are possible products.[14]

Tungsten Oxide Reduction to Metal

Tungsten oxides are reduced to metal powder in high temperature furnaces. The reducing agent is typically hydrogen. Powders of various particle sizes are produced by varying furnace reaction time, temperature gradient, hydrogen flow, and layer thickness. Tungsten powder to be used in high-purity applications is leached with acids such as hydrochloric and hydrofluoric acids, rinsed with water, and dried.[15]

Tungsten Carbide Production

Tungsten carbide is formed by reducing APT or tungsten oxides in the presence of carbon. Tungsten ores may also be reduced and carburized in a single reaction. In this latter process, impurities are leached with hydrochloric, sulfuric, or hydrofluoric acid from the furnace product to yield tungsten carbide crystals.[16]

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[11] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 2963-3037.

[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] Ibid.

[16] Ibid.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

A recently developed technique processes tungsten carbide from concentrate eliminating the conventional method of producing APT. The technique involves the formation of tungsten monocarbide from a molten tungstate halide phase using gas sparging. The process involves treating concentrates with chloride and silicate salts, with the resulting product being treated with methane gas to produce high purity tungsten carbide powder.[17]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between APT calcining and tungsten furnace reduction because it is here, in the furnace, where tungsten oxide is thermally reduced in the presence of hydrogen to form tungsten powder. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics. and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Mining and Concentrating Ore

Waste fines are generated from handling tungsten ore. The tailings are sent to tailings ponds.[18]

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[17] Phillip T. Stafford, 1985, Op. Cit., pp. 881-891.

[18] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 2963-3037.

Wastewater is generated from processing tungsten ore. Wastewater from thickeners and separators are sent to tailings ponds. Waters from tailings ponds are discharged to surface water.[19]

Wet scrubber wastewater is a waste stream generated from roasting.

Waste rock and tailings from mining and concentrating, respectively, are generated from extraction and beneficiation operations associated with tungsten production. Waste management practices for mine waste rock and mill tailings appear to be fairly typical of those used throughout the mining industry to manage similar wastes. Waste rock is generally disposed of in piles or dumps, and tailings are usually piped in slurry form to a tailings (disposal) impoundment.

Leaching or Ore Concentrates

Tungstic acid rinse water is a waste stream from ore concentrate leaching. This wastewater can be characterized by acidic pH, concentrations of metals including lead and zinc, and suspended solids. Two plants appear to leach scheelite ores or synthetic calcium tungstate with hydrochloric acid. Treatment at these plants involves lime and settling to precipitate metals before discharging the rinse water effluent. Treatment sludges presumably report to RCRA Subtitle D landfills or disposal impoundments (i.e., as non-hazardous solid wastes).[20] Attachment 1 presents additional waste characterization data for this waste stream.

Scrubber wastewater is a waste stream generated from wet air pollution control. This wastewater may have an acidic pH. The scrubber water is usually treated and discharged or recycled.[21] One of the two plants that leaches scheelite ores or synthetic calcium tungstate with hydrochloric acid neutralizes the scrubber water with lime and precipitates metals from the waste stream prior to discharge. The other plant recycles the entire waste stream for use as a tungsten acid rinse water. Sludges from the waste treatment are sent to Subtitle D landfills or disposal impoundments.

Alkali leach wash is generated from digesting wolframite type ores in caustic solutions to produce sodium tungstate. Four plants use an alkali leach wash. Sodium tungstate is filtered from the digestion-wash liquor, and the resulting filtrate is evaporated in surface impoundments, recycled, or discharged. From EPA's Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Point Source Category, Volume 3, (1989), two plants reduced waste flow to zero by filtering the insoluble impurities and using a combination of evaporation and recycling steps. A third plant discharges this and all liquid wastes to a settling pond for evaporation, and one plant discharged its wastewater after neutralization and chemical oxidation. This waste stream is characterized by concentrations of metals and suspended solids.[22]

Leach filter cake residues and impurities may be generated from the leaching step. This waste contains gangue, with small amounts of tungsten and other trace elements. Other impurities may include molybdenum and heavy metals--many in hydrous forms. These wastes may be disposed of in a RCRA Subtitle D landfill or disposed of in surface impoundments.

Molybdenum sulfide precipitation wet air pollution control waste is generated from the leaching of ore concentrates. This waste stream is expected to be acidic and contain captured particulates.[23]

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[19] Ibid.

[20] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 2963-3037.

[21] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 3-228 - 3-244.

[22] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 2963-3037.

[23] Ibid.

Purification to APT

Spent mother liquor evolved during crystallization is a possible waste stream from purification of intermediate products to APT. This wastewater is either recycled or discarded.[24] This waste stream may contain high levels of ammonia.

Wastewater from drying APT crystals is usually evaporated.[25] This waste stream may contain high levels of ammonia.

Ion exchange raffinate from the liquid ion exchange process is a source of wastewater. This waste stream is characterized by a low pH and concentrations of toxic metals, suspended solids, and ammonia. This waste stream also has concentrations of organics such as acenaphthene, napthalene, phenol, and fluorene.[26] Of the two plants using this method, one plant pumps all of its wastes to a settling pond for evaporation, and the second plant treats this wastewater with a lime and settle process. Treatment sludge disposal may involve disposal into a RCRA Subtitle D landfill or impoundment.

Ion Exchange Resins may be generated by the two plants using the ion exchange process. These plants would need to replace ion exchange resins at regular intervals. These resins may contain constituents and exhibit characteristics similar to those of raffinate, but with higher concentrations of contained metals.

Calcium tungstate precipitate wash is generated from calcium tungstate precipitation. Four plants are believed to generate this waste from calcium tungstate precipitation. None of the plants are believed to recycle the wastewater. This waste stream is characterized by a basic pH, concentrations of ammonia, oil, and grease. Reportedly, in 1983, one plant achieved zero discharge by sending wastewater to an evaporation pond. Other facilities used lime treatment and settling techniques, coagulated with polymers and lime, or discharged the waste without treatment.[27]

APT Conversion to Oxide

Wet scrubber wastewater from calciners is generated during the conversion of APT to tungsten oxides. In 1989, six plants reported this activity. Of the six plants, one plant recycled and reused the wastewater, another evaporated the water, recovered ammonia, and reused the ammonia and water. Other treatments included direct discharge, lime and settle scrubber water, ammonia recovery, direct discharge, primary and secondary settling, and indirect discharge. Treatment sludges may be landfilled or disposed of in surface impoundments. This wastewater is characterized by concentrations of ammonia and suspended solids and an alkaline pH.[28]

2. Mineral Processing Wastes

Reduction to Metal

Scrubber wastewater is generated by reducing tungsten oxides to metal powder. This waste stream is characterized by concentrations of particulates and soluble salts from fluxes used in the reduction furnaces. In addition, concentrations of ammonia and an alkaline pH may also be characteristic of this wastewater. This waste

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[24] Ibid.

[25] Ibid.

[26] Ibid.

[27] Ibid.

[28] Ibid.

may be recycled. Attachment 1 presents additional waste characterization data for this waste stream.[29] This waste is not expected to be hazardous.

Rinse water and spent acid. This wastewater is discharged to wastewater treatment.[30] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 0 metric tons/yr, and 21,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of corrosivity prior to treatment. This waste may be recycled and is classified as a spent material.

Tungsten Carbide Production

Process Wastewater is generated from tungsten carbide production. This wastewater is likely to be very acidic and contain suspended solids.[31] This wastewater may be combined with rinse water, spent acid, and spent scrubber liquor for treatment. Attachment 1 presents waste characterization data for process wastewater treatment plant effluent. Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 1,800 metric tons/yr, 3,700 metric tons/yr, and 7,300 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of corrosivity. This waste may be recycled and is classified as a spent material.

Water of formation is produced from reducing tungsten oxides to metal in a hydrogen atmosphere. In some plants, this water may be recondensed in the reduction furnace scrubber system. This wastewater is characterized by a basic pH and concentrations of ammonia and suspended solids.[32] Attachment 1 presents additional waste characterization data for this waste stream. This waste is not expected to be hazardous.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[29] Ibid.

[30] Ibid.

[31] Ibid.

[32] Ibid.

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U.S. Environmental Protection Agency. Newly Identified Mineral Processing Waste Characterization Data Set. Office of Solid Waste. Vol. III. August, 1992. pp. 39-1 - 39-2.

U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and

ATTACHMENT 1

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SCRUBBER WASTEWATER - TUNGSTEN

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.1	0.1	0.1	2/2	-	-	-	0/0	-	-
Arsenic	0.1	0.1	0.1	2/2	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	0.04	0.04	0.04	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.02	0.02	0.02	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0003	0.0004	2/2	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.005	0.005	0.005	1/1	-	-	-	0/0	-	-
Selenium	0.01	0.01	0.01	2/2	-	-	-	0/0	1.0	0
Silver	0.02	0.02	0.02	2/2	-	-	-	0/0	5.0	0
Thallium	0.1	0.1	0.1	2/2	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.06	0.06	0.06	2/2	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - TUNGSTIC ACID RINSE WATER - TUNGSTEN

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.1	0.1	0.1	1/1	-	-	-	0/0	-	-
Arsenic	0.13	3.665	7.2	2/2	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.03	0.03	0.03	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.03	0.115	0.2	2/2	-	-	-	0/0	1.0	0
Chromium	0.1	1.05	2	2/2	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.2	2.6	5	2/2	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.2	10.1	20	2/2	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0005	0.0008	0.0011	2/2	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.05	0.525	1	2/2	-	-	-	0/0	-	-
Selenium	0.01	0.01	0.01	1/1	-	-	-	0/0	1.0	0
Silver	0.02	0.155	0.29	2/2	-	-	-	0/0	5.0	0
Thallium	0.1	0.4	0.7	2/2	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.6	1.3	2	2/2	-	-	-	0/0	-	-
Cyanide	0.001	0.00975	0.02	4/4	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - TREATMENT PLANT EFFLUENT - TUNGSTEN

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.002	0.116	0.8	7/7	-	-	-	0/0	-	-
Arsenic	0.018	0.118	0.446	9/9	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.002	0.009	0.01	7/7	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.02	0.044	0.08	10/10	-	-	-	0/0	1.0	0
Chromium	0.024	0.087	0.22	7/7	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.01	0.047	0.148	10/10	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.1	0.140	0.242	10/10	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.001	0.003	9/9	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.05	0.110	0.202	10/10	-	-	-	0/0	-	-
Selenium	0.016	0.234	1	8/8	-	-	-	0/0	1.0	0
Silver	0.03	0.030	0.03	1/1	-	-	-	0/0	5.0	0
Thallium	0.005	0.150	0.9	9/9	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.05	0.191	0.6	10/10	-	-	-	0/0	-	-
Cyanide	0.001	0.157	0.6	14/14	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WATER OF FORMATION - TUNGSTEN

Constituents	Total Constituent Analysis - PPM Minimum	Average	Maximum	# Detects	EP Toxicity Analysis - PPM Minimum	Average	Maximum	# Detects	TC Level	# Values In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	0.01	0.01	0.01	1/1	-	-	-	0/0	-	-
Arsenic	0.02	0.02	0.02	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	0.005	0.005	0.005	1/1	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.02	0.02	0.02	1/1	-	-	-	0/0	1.0	0
Chromium	0.02	0.02	0.02	1/1	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	0.25	0.25	0.25	1/1	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	0.05	0.05	0.05	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	0.0002	0.0002	0.0002	1/1	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	0.05	0.05	0.05	1/1	-	-	-	0/0	-	-
Selenium	0.01	0.01	0.01	1/1	-	-	-	0/0	1.0	0
Silver	0.01	0.01	0.01	1/1	-	-	-	0/0	5.0	0
Thallium	0.01	0.01	0.01	1/1	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.14	0.14	0.14	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

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URANIUM

A. Commodity Summary

Uranium is present in the earth's crust at approximately 2 ppm. Acidic rocks with a high silicate content, such as granite, have a uranium content that is above average, whereas the uranium contents of basic rocks such as basalts are lower than the average. However, 90 percent of the world's known uranium resources are contained in conglomerates and in sandstone.[1]

From 1980 to 1993, the domestic production of uranium declined from almost 44 million pounds U_3O_8 to about 3 million pounds (1,361 metric tons/yr).[2] A total of 17 uranium mines were operational in 1992; five conventional mines (both underground and open pit), four *in situ*, and eight reported as "other" (heap leach, mine water, mill tailings, or low-grade stock piles). Extraction/beneficiation operations produce yellowcake (precipitate containing uraniferous compounds), which is typically shipped to a uranium hexafluoride convertor for processing.[3,4] The number of mineral processing facilities is currently unknown. Uranium was also produced to a limited extent as a byproduct of phosphoric acid production at four sites. The primary demand for uranium is by commercial power generating facilities for use in fuel rods.[5]

Regulatory Status

Uranium mill tailings are by-product materials from uranium mining (i.e., waste acids from solvent extraction, barren lixiviants, slimes from solvent extraction and waste solvents generated in the beneficiation process during the extraction of uranium ore) and therefore, are excluded from the treatment standards being promulgated today for TC metal wastes. 40 CFR 261.4(a)(4) states that source, special nuclear or by-product material as defined by the Atomic Energy Act of 1954 as amended, 42 U.S.C. 2100 *et seq*, are not solid wastes and thus, subject to this rule. However, all other wastes not excluded under 40 CFR 261.4, including radioactive mixed wastes, which satisfy the definition of radioactive waste at 10 CFR Part 61, and also contain waste that is either a listed hazardous waste, or that exhibits any of the hazardous characteristics identified in Subpart C of 40 CFR Part 261, are subject to this rulemaking (assuming the waste is otherwise subject to this rule).

B. Generalized Process Description

1. Discussion of Typical Production Processes

Uranium ore is recovered using either conventional milling or solution mining (*in situ leaching*). Beneficiation of conventionally mined ores involves crushing and grinding the extracted ores followed by placement in a leaching circuit. *In situ* operations use a leach solution to dissolve desirable uraniferous minerals from in-place deposits. Uranium in either case is removed from pregnant leach liquor and concentrated using solvent extraction or ion exchange and precipitated to form yellowcake. Yellowcake is then processed to produce uranium hexafluoride

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[1] "Uranium and Uranium Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXIII, 1983, p. 504.

[2] Department of Energy, Decommissioning of U.S. Uranium Production Facilities, February 1995, p. vii.

[3] Kennecott Corporation. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[4] Rio Algom Mining Corp. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[5] U.S. Environmental Protection Agency, "Uranium," from Technical Resource Document, Extraction and Beneficiation of Ores and Minerals, Vol. 5, January 1995, pp. 3-5.

(UF_6), which is enriched and further refined to produce the fuel rods used in nuclear reactors.[6] Stockpiles of low grade ore removed from mines may be processed by heap leaching. It can also be economically feasible to separate the uranium as a by-product from the crude black acid (30 percent phosphoric acid) obtained from the leaching of phosphate for fertilizers.

2. Generalized Process Flow Diagram

Conventional Milling

Uranium ore is recovered by either open pit (for ore deposits close to the surface of the earth) or underground mining. The ore is blended, crushed, and ground. Ore high in vanadium is sometimes roasted with sodium chloride or soda ash prior to grinding in order to convert insoluble heavy metal vanadates (complex vanadium) into more soluble vanadate, which is then extracted with water. Two basic methods are employed to extract uranium from ore: acid leaching with sulfuric acid or alkaline leaching with a hot solution of sodium carbonate and sodium bicarbonate.[7] Exhibits 1 and 2 show process flow diagrams for two different leaching processes.[8,9] A process flow diagram for an alkaline leach mill is shown in Exhibit 3. Most mills use acid leaching, which provides a higher uranium-removal efficiency. Alkaline leaching is used in the treatment of uranium ores when the lime content results in excessive acid consumption (alkaline leaching is preferred if acid consumption exceeds 68 kg/ton of ore treated).[10,11] Leaching involves bringing a solvent (lixiviant) in contact with the crushed ore slurry. Uranyl ions are then dissolved by the lixiviant. The pregnant lixiviant is separated from the residual solids (tails); typically the solids are washed with fresh lixiviant until the desired level of recovery is attained. The pregnant leach solution then enters a solvent extraction or ion exchange circuit.[12]

Solution Mining (*In Situ* Leaching)

In situ leaching, the most commonly employed solution mining technique, involves injecting a barren solution and lixiviant into the permeable ore zone. The solution penetrates the pores in the ore, leaching out the uranium and other metals.[13] The pregnant solution is then pumped up through production wells, passed through sand filters to remove any large particles, and transferred to ion exchange units. Ultimately, the uraniferous compounds are stripped from the ion exchange resins and precipitated to form yellowcake.[14] After the uranium is removed, the barren solutions are reconditioned and recycled. A typical *in situ* leach process is shown in Exhibit 4.

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[6] U.S. Environmental Protection Agency, January 1995, Op. Cit., pp. 13-16.

[7] Werthman, P., and K. Bainbridge, "An Investigation of Uranium Mill Wastewater Treatability," Proceedings of the 35th Purdue Industrial Waste Conference, 1980, p. 248.

[8] Kennecott Corporation. Op. Cit.

[9] Rio Algom Mining Corp. Op. Cit.

[10] "Uranium and Uranium Compounds," 1983, Op. Cit., pp. 516-517.

[11] "Uranium," in SME Mineral Processing Handbook, Vol. 2, 1985, p. 24-3.

[12] U.S. Environmental Protection Agency, January 1995, Op. Cit., pp. 18, 21.

[13] Department of Energy, February 1995, Op Cit., p. 30.

[14] U.S. Environmental Protection Agency, January 1995, Op. Cit., p. 27.

EXHIBIT 1

PROCESS FLOW CHART FOR ACID-LEACH PROCESS 1

(Adapted from: Assessment of Environmental Aspects of Uranium Mining and Milling, U.S. EPA, 1976, p. 36.)

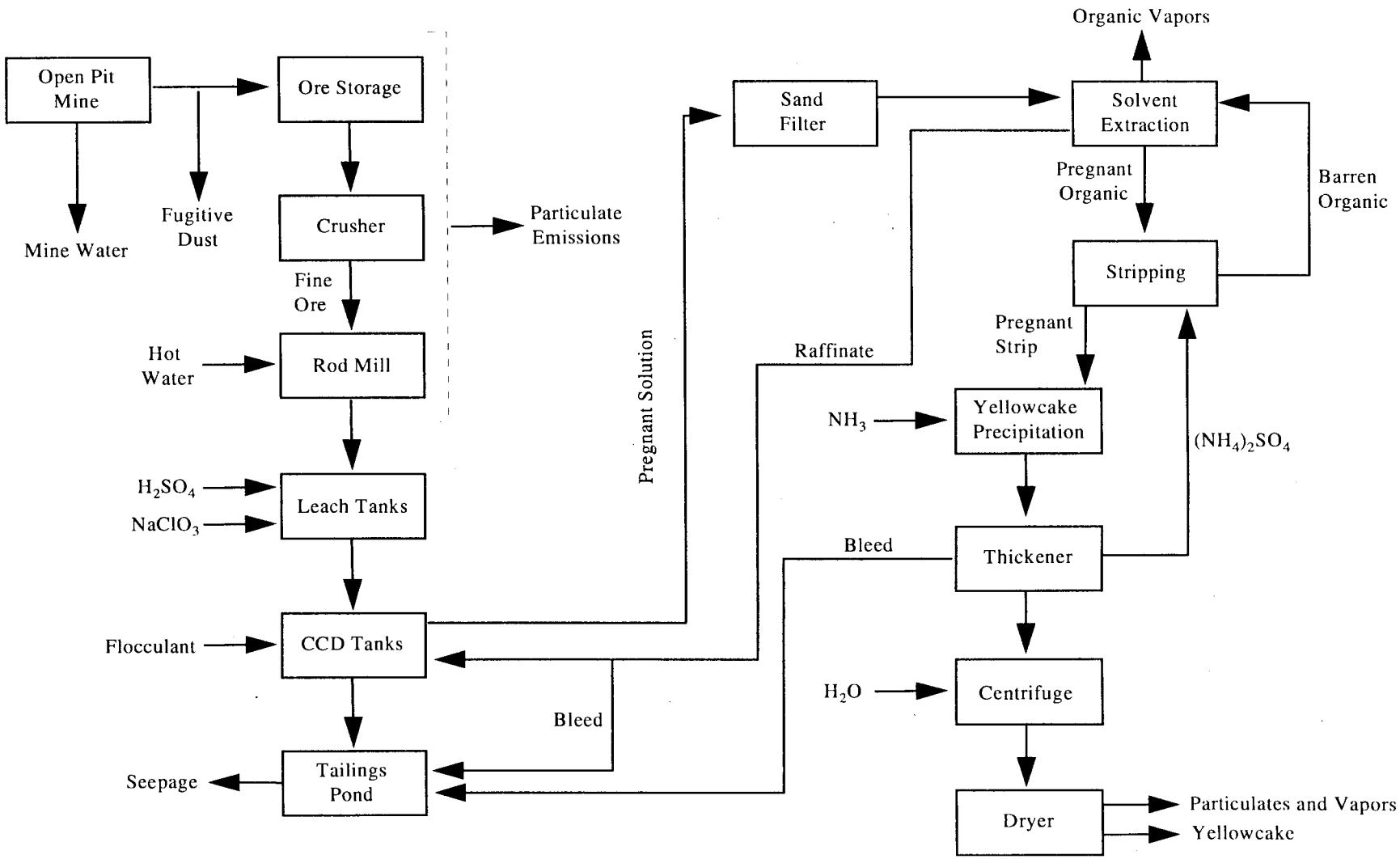


EXHIBIT 2

ACID LEACH PROCESS FLOW CHART FOR ACID-LEACH PROCESS 2

(Adapted from: Assessment of Environmental Aspects of Uranium Mining and Milling, U.S. EPA, 1976, p. 38.)

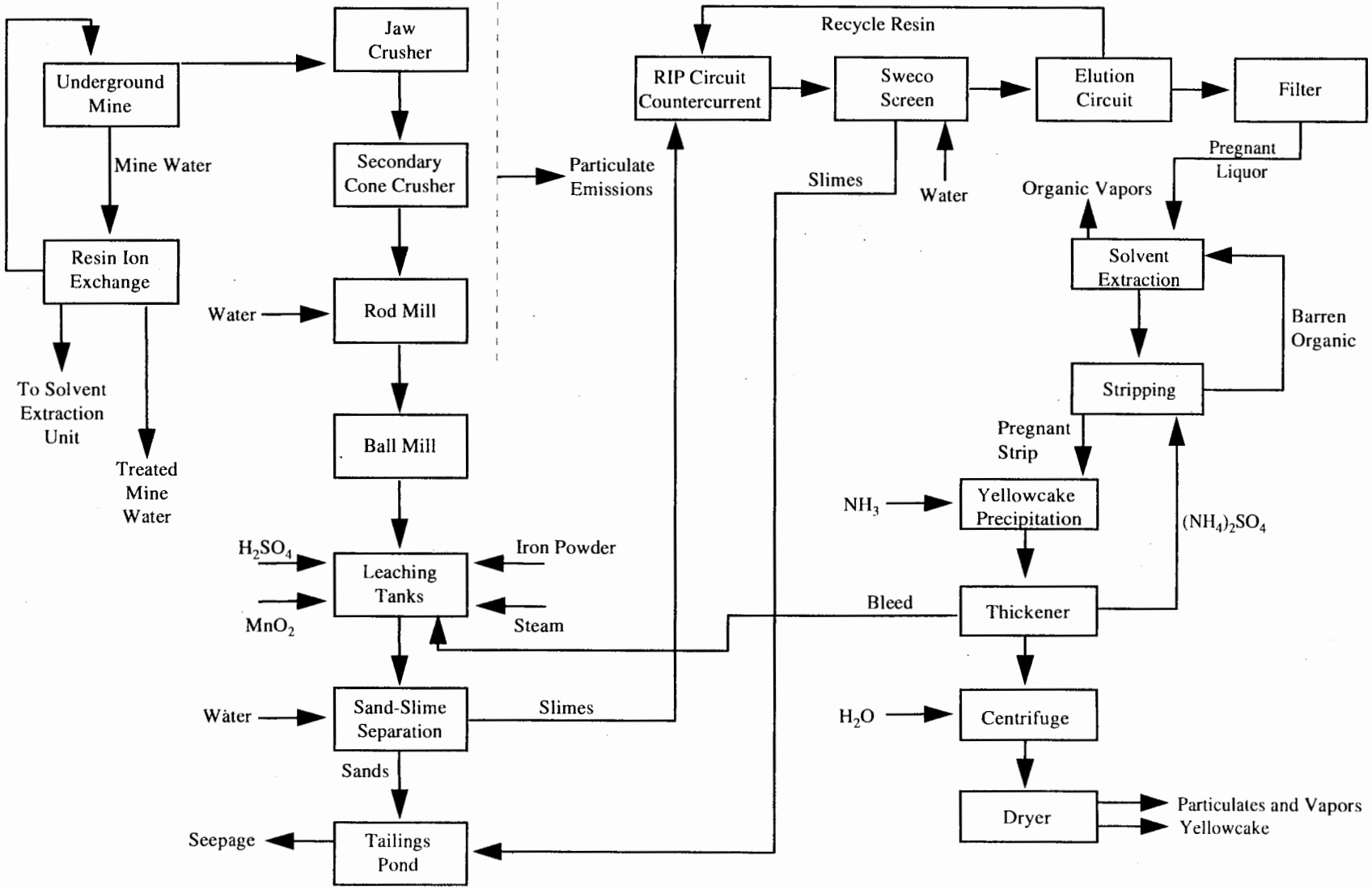


EXHIBIT 3

ALKALINE LEACH PROCESS FLOW CHART FOR AN UNDERGROUND MINE

(Adapted from: Assessment of Environmental Aspects of Uranium Mining and Milling, U.S. EPA, 1976, p. 41.)

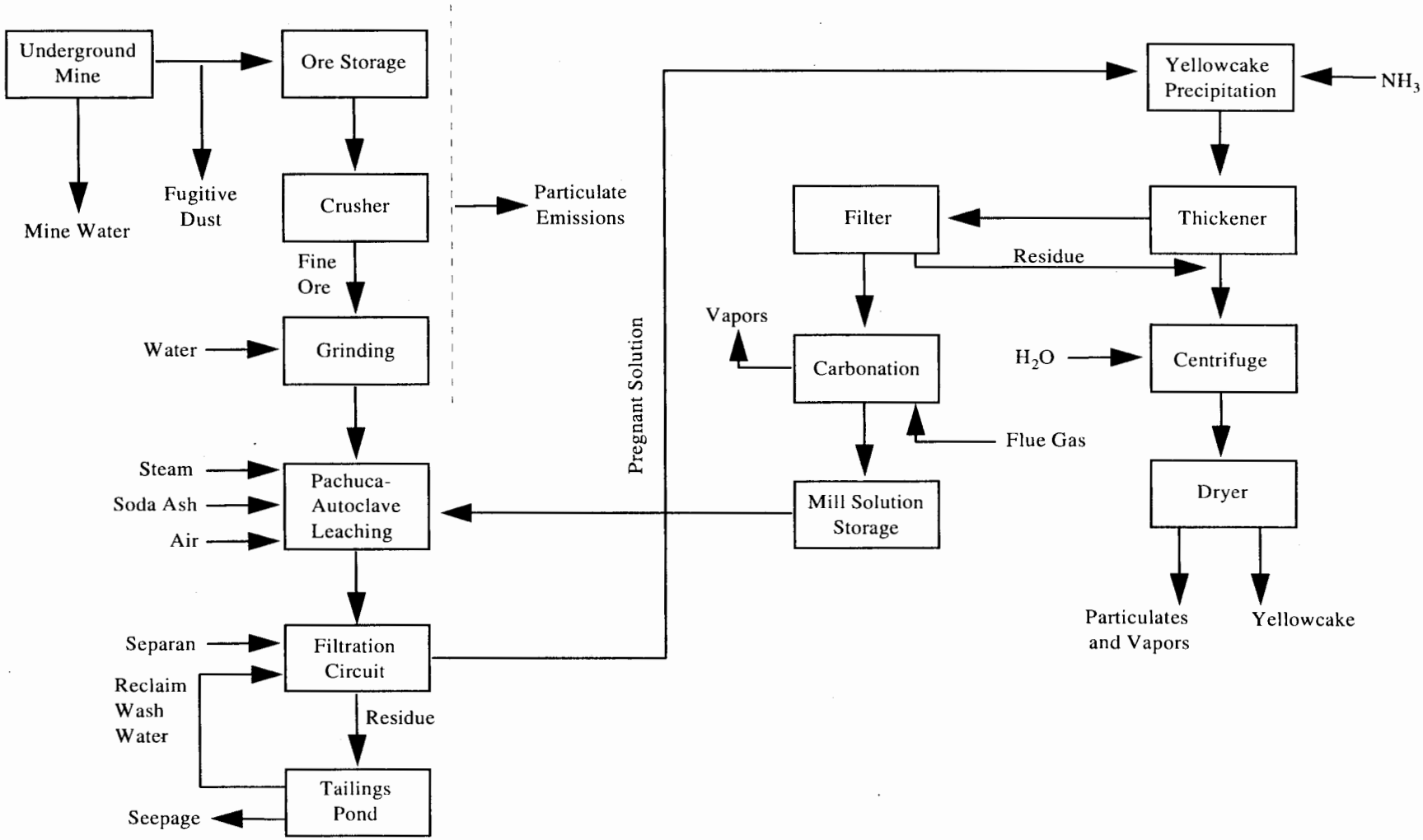
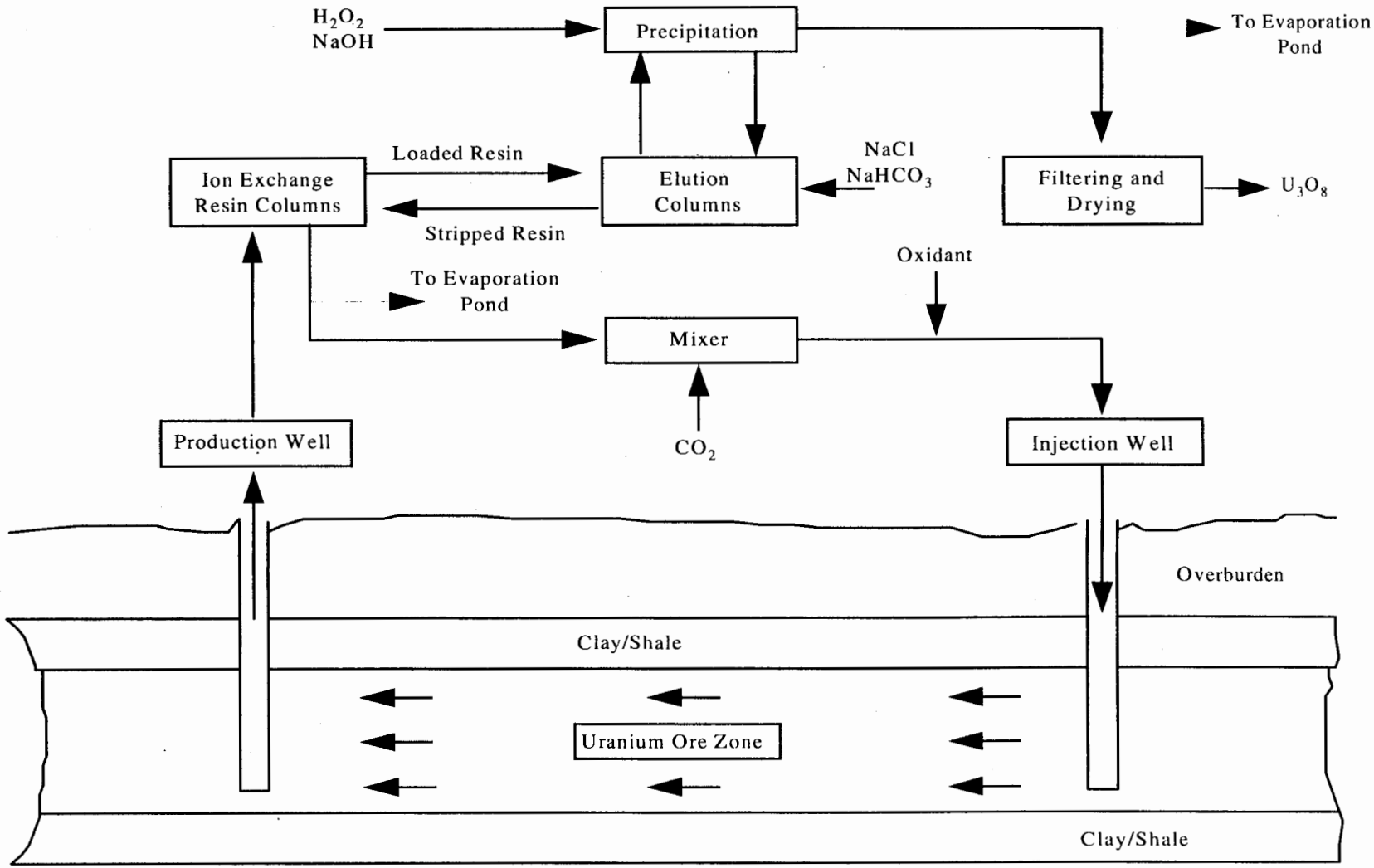


EXHIBIT 4

URANIUM *IN SITU* LEACH PROCESS

(Adapted from: DOE, Decommissioning of U.S. Uranium Production Facilities, 1995, p. 31.)



Solvent Extraction

Solvent extraction is typically employed by conventional milling operations. The pregnant leach solution is mixed in tanks with the solvent. Normally, the solvents are organic compounds that can combine with either solute cations or solute anions. The uraniferous ions preferentially move from the aqueous pregnant leach solution into the organic solvent as the two are mixed and agitated. After the uraniferous compounds have been extracted, the barren lixiviant (raffinate) is typically sent to the CCD tanks.[15,16] After the solute exchange has taken place, the pregnant solvent extraction liquor is stripped using various agents such as nitrates, chlorides, sulfates, carbonates, and acids. The pregnant stripping liquor is then pumped to the precipitation step while the stripped organic solvent is recycled to the beginning of the solvent extraction circuit.

Ion Exchange

Ion exchange operations, used by most if not all *in situ* operations and some mills, make use of organic compounds to perform solute concentration. Generally, fixed organic resins contained within a column are used to remove uraniferous compounds from the leach solution by ion exchange. As thepregnant leach solution passes through the ion exchange resins, the uraniferous compounds bind to the resins. The barren leach solution is recycled back to the leaching circuit. After adsorption, the uraniferous compounds attached to the resins are released (eluted) by passing a concentrated chloride salt solution through the loaded resins. The pregnant elute liquor can then be directed to the precipitation circuit. The liquor may be acidified slightly to prevent the premature precipitation of uraniferous compounds.[17]

Yellowcake Production

Concentrated uraniferous ions from solvent extraction or ion exchange units are precipitated out of solution to produce yellowcake. Uranium is usually precipitated from acid solutions by neutralization with ammonia or magnesia.[18] Hydrogen peroxide may also be added to an acid pregnant stripping liquor or pregnant elution liquor to precipitate uranium peroxide. All forms of the uraniferous precipitate are known as yellowcake.

Alkaline pregnant stripping liquors or pregnant elution liquors typically contain uranyl carbonates. Prior to the precipitation of the uranyl ions, the carbonate ions are destroyed by adding hydrochloric acid. The carbonates are converted to carbon dioxide, which is vented off. The acidified solution is neutralized with an alkali or treated with hydrogen peroxide to precipitate the uraniferous compounds. The yellowcake is separated from the precipitation solution by filtration. Thickeners may be used in conjunction with filtration units. The filtered yellowcake is then dried and/or calcined and packaged for shipping. The supernatant generated from the precipitation and dewatering circuits can be recycled to the respective solvent extraction or ion exchange stripping solutions.[19]

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[15] Kennecott Corporation. Op. Cit.

[16] Rio Algom Mining Corp. Op. Cit.

[17] U.S. Environmental Protection Agency, January 1995, Op. Cit., pp. 22-23.

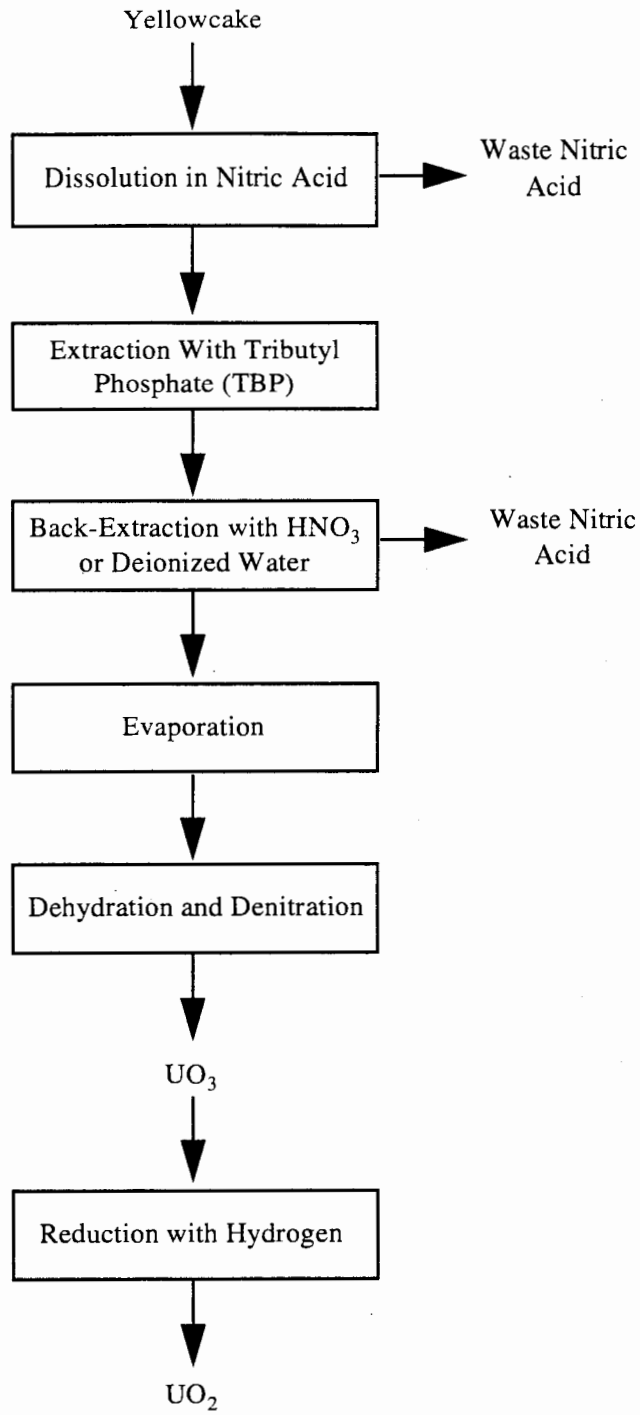
[18] "Uranium and Uranium Compounds," 1983, Op. Cit., p. 522.

[19] U.S. Environmental Protection Agency, January 1995, Op. Cit., p. 23.

EXHIBIT 5

PRODUCTION OF URANIUM DIOXIDE

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1983, p. 523.)



Conversion and Purification Processes

Production of UF_4. The crude product from the refineries is purified to a degree that is usable in nuclear applications. The purified material is converted to uranium dioxide (UO_2) as shown in Exhibit 5. UO_2 is then converted to uranium tetrafluoride (UF_4) based on the following reaction:

$$UO_2(s) + 4HF(g) \text{ ---> } UF_4(s) + 2H_2O(g)$$

The process used to convert UO_2 to UF_4 is shown in Exhibit 6. Uranium tetrafluoride is then converted to either uranium metal or uranium hexafluoride (UF_6), the basic compound for isotope separation.

Production of UF_6. Uranium hexafluoride is prepared by direct fluorination of UF_4 with elemental fluorine in a fluorination tower based on the following reaction:

$$UF_4(s) + F_2(g) \text{ ---> } UF_6(g)$$

Solid UF_4 is fed through suitable locks into the top of the fluorination tower. Filtered and preheated fluorine is introduced into the side of the tower. Unreacted UF_4 is collected in a hopper at the bottom. This material is periodically removed and recycled.

Production of Uranium Metal. Uranium metal is produced by reduction of UF_4 by the Ames process as shown in Exhibit 7. The reduction process is carried out in a bomb. A charge consisting of anhydrous UF_4 powder and magnesium chips is placed into the bomb. The charge is covered with MgF_2 powder, and the bomb is closed with a screwed-on flange cover. The charge is ignited spontaneously by heating, and the reduction of the UF_4 proceeds at a temperature of 700 °C.[20]

Uranium-235 Enrichment

Most nuclear reactors built for the generation of electric power are based on uranium fuel enriched in ^{235}U. Normally for such reactors, ^{235}U is enriched from a concentration of 0.7 percent to approximately 2-3 percent. The processes used to produce enriched uranium include the gaseous-diffusion process, centrifugal isotope separation, and electromagnetic separation.

3. Identification/Discussion of Novel (or otherwise distinct) Process

An improved Eluex process for uranium extraction was developed in 1957 and later improved by the U.S. Bureau of Mines.[21,22] In this process, a stage of uranium solvent extraction is coupled with each stage of resin elution rather than the elution and solvent extraction operations being conducted separately. The improved system reduces the number of stages, retention time, and resin inventory to about one-fourth or one-fifth that of other circuits.

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[20] "Uranium and Uranium Compounds," 1983, Op. Cit., pp. 523-528.

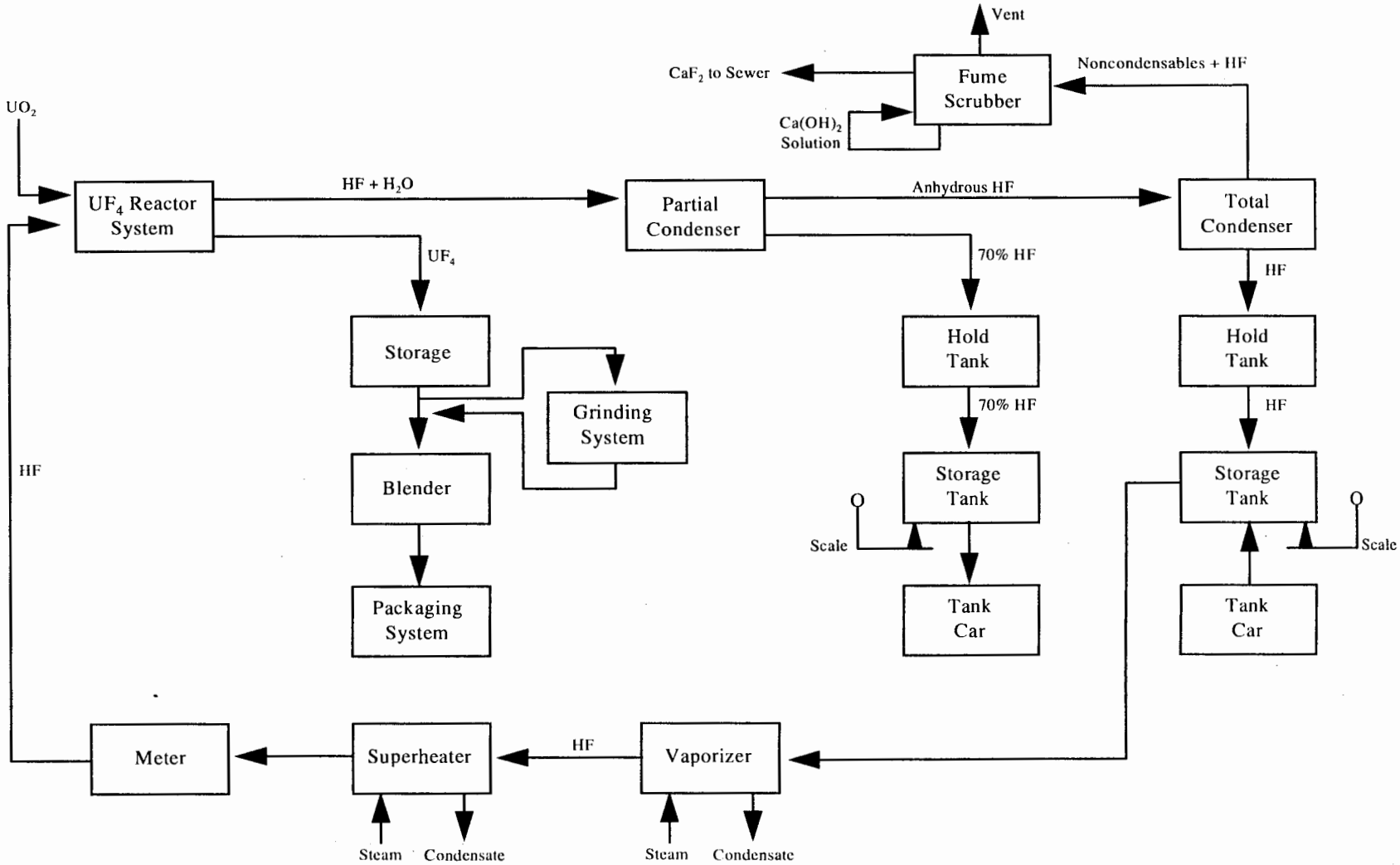
[21] Kennecott Corporation. Op. Cit.

[22] Rio Algom Mining Corp. Op. Cit.

EXHIBIT 6

FLOW SHEET FOR UF_4 PRODUCTION

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1983, p. 527.)

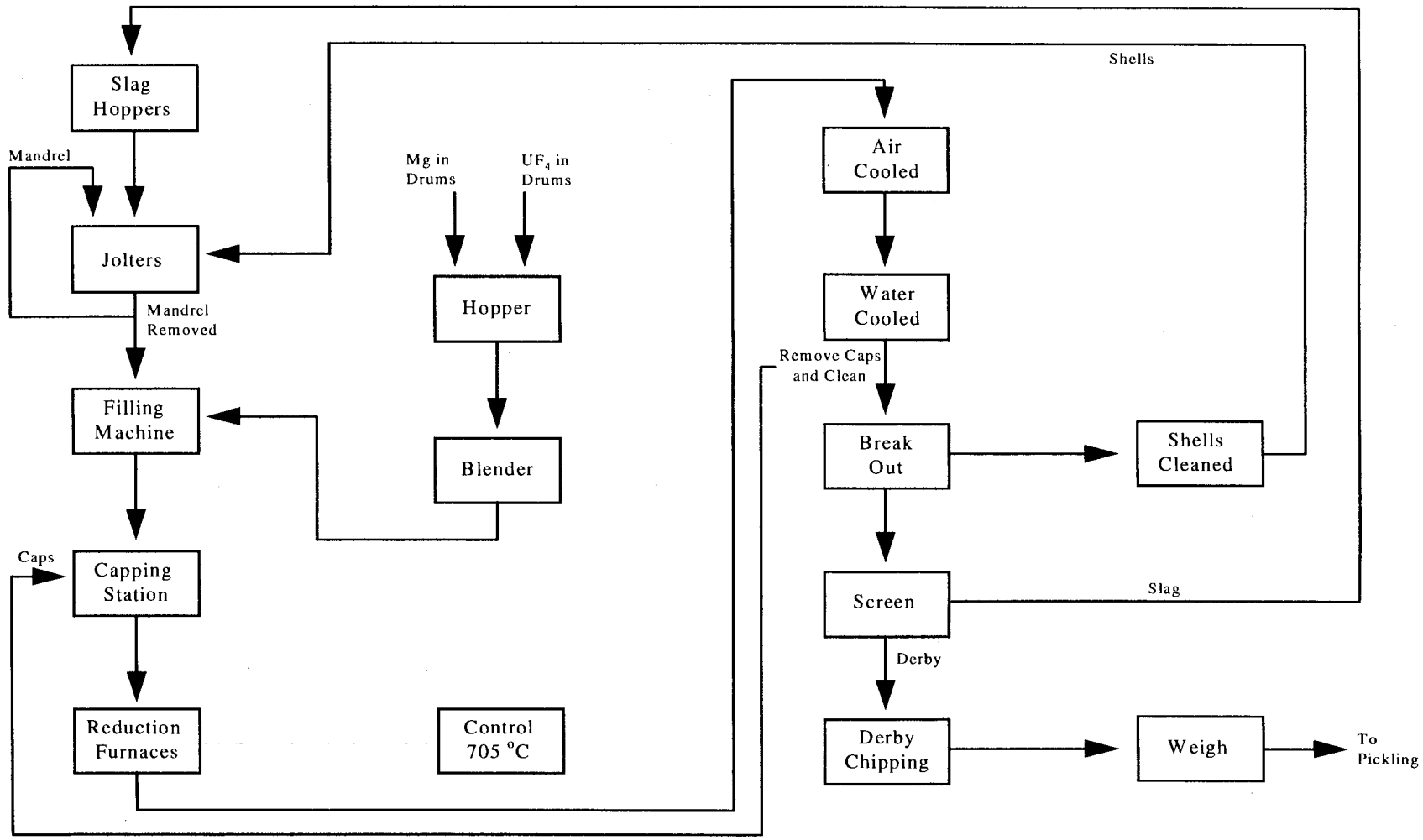


SOURCE: "Uranium and Uranium Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXIII, 1983, p. 527.

EXHI. . 7

THE AMES PROCESS

(Adapted from: Kirk-Othmer Encyclopedia of Chemical Technology, 1983, p. 530.)



Source: "Uranium and Uranium Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXIII, 1983, p. 530.

A flotation technique also has been developed to extract uranium from seawater. Uranium is present in seawater in concentrations of 2.9 to 3.3 micrograms per liter. Sea water is the lowest grade but the most abundant source of uranium. However, it is unlikely that this source of uranium would be considered unless ore reserves become depleted.

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between yellowcake production and the conversion/purification processes. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where yellowcake (uranium oxide) is chemically oxidized to uranium dioxide. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Wastes and materials generated by uranium mining operations include waste rock, tailings, spent extraction/leaching solutions, particulate emissions, organic vapors, and refuse.[23]

Waste rock and overburden are deposited in waste rock piles or dumps. During the late 1970s, the largest open pit uranium mines produced an average of 40 million metric tons of overburden annually. Underground mines produced an average of 2,000 metric tons per year of waste rock during the same time period. Limited data indicate

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[23] U.S. Environmental Protection Agency, Assessment of Environmental Aspects of Uranium Mining and Milling, December 1976, pp. 36-43.

that waste rock contained higher levels of arsenic, selenium, and vanadium than background levels. Constituents of concern for waste rock and ore piles include low concentrations of radionuclides as well as sulfur-bearing minerals that, under certain conditions, may generate acid and, thus, leach metals.[24]

Most wastes generated by conventional mills are disposed of in tailings impoundments. These wastes, disposed of in the form of a slurry, include tailings (reground and pulped waste rock from the leaching process), gangue (including dissolved base metals), spent beneficiation solutions, and process water bearing carbonate complexes (alkaline leaching), sulfuric acid (acid leaching), sodium, manganese, and iron. Two acid- and alkaline-leach mills were reported to generate approximately 7,400 and 3,200 to 10,900 m^3/day of tailings, respectively. The tailing pond seepage from the acid-leach mill had a mean pH of 1.7 and contained high concentrations of dissolved solids (31,780 ppm), radium-226 (127 ppm), and dissolved metals (including lead, nickel, chromium, arsenic, and selenium). The tailing pond decant from the alkaline-leach mill contained high concentrations of arsenic (4 - 5 ppm), selenium (17 - 20 ppm), vanadium (24 - 27 ppm), uranium (55 - 960 ppm), and radium-226 (30 - 667 ppm).[25] The generation rate for tailing pond seepage was estimated to be 1,800 m^3/day at the facility mentioned above. We used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 17,000 mt/yr, 3,833,500 mt/yr, and 7,650,000 mt/yr, respectively for the tailing pond seepage.

In situ bleed solutions and lixiviant leaching solutions constitute the major wastes directed to lined evaporation ponds. These solutions consist of barren lixiviant and usually have high levels of radium; other contaminants (metals, salts) are limited to what may have been solubilized by the lixiviant. Barium chloride is added to the ponds, which in the presence of radium, forms a barium-radium-sulfate precipitate. This precipitate forms the majority of sludges in the evaporation ponds. These sludges, which may contain metals, sulfates, chlorides, and amines, are either disposed of at an NRC-licensed disposal facility or deposited in the tailings impoundment. In certain locations, where climatic conditions limit the use of evaporation, treated bleed solutions are land applied.[26]

Reverse osmosis brines, generated during the *in situ* leaching process, typically contain high concentrations of salts (total dissolved solids) and may have radionuclide (including naturally occurring radionuclides) concentrations that exceed NPDES discharge limits. These wastes, along with laboratory wastes and other wastes, are typically injected into Class I deep disposal wells permitted under the Underground Injection Control (UIC) program. These deep disposal wells are used as an alternative source of disposal at operations that usually do not operate a tailings impoundment.[27,28]

Ion exchange resins are occasionally replaced. Spent resins from *in situ* operations are disposed of at an NRC-licensed disposal facility. Conventional mills typically dispose of the spent resins in the tailings impoundments. The contribution of spent resins to the volume of a tailings impoundment is minimal compared to the volumes of tailings.[29] No information regarding the types of contaminants present in spent ion exchange resins was found.

Waste solutions are generated during acid/alkaline leaching, solvent extraction, stripping, and precipitation. Stripping solution could contain nitrates, chlorides, sulfates, hydroxides or acids. Constituents that could accumulate

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[24] U.S. Environmental Protection Agency, January 1995, Op. Cit., pp. 30-37.

[25] Werthman P., and K. Bainbridge, 1980, Op. Cit., pp. 249-250.

[26] Kennecott Corporation. Op. Cit.

[27] Kennecott Corporation. Op. Cit.

[28] Uranium Resources, Inc. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[29] U.S. Environmental Protection Agency, January 1995, Op. Cit., pp. 30-37.

in the precipitation circuit are primarily anions - sulfates, chlorides, and possibly carbonates. Spent acids from leaching and wash waters from the washing of leached ore solids are generated at an approximate rate of 1,000 gallons per ton of ore processed and are discharged to the tailings ponds. In addition to radionuclides, solvent extraction solutions include phosphoric acids, amines, and ammonium salts. Process water from alkaline leaching is generated at a rate of 250 gallons per ton of ore processed and is discharged to the tailings pond.[30] The supernatant generated from precipitation and dewatering circuits can be recycled to the respective solvent extraction or ion exchange stripping solutions.

Solvent extraction generates by-products (as defined in Section 11e(2) of the Atomic Energy Act), including waste acids, barren lixiviant, slimes, and waste solvents. These materials are not considered solid wastes and are excluded from RCRA regulation at 40 CFR 261.4(a)(4).[31,32,33] Although no published information regarding generation rates for these materials was found, we used the methodology outlined in Appendix A of this report to estimate low, medium, and high annual generation rates (see Exhibit 8).

2. Mineral Processing Wastes

Although no published information regarding waste generation rates or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate low, medium, and high annual waste generation rates (see Exhibit 9).

10 CFR Part 61 provides the Nuclear Regulatory Commission with complete authority to regulate radioactive waste defined as by-product material at a land disposal facility. The following wastes, therefore, may not be subject to RCRA if they are not mixed hazardous wastes. It is unclear at this time if all wastes generated at in-situ uranium mines are NRC by-product wastes. RCRA clearly has jurisdiction over mixed hazardous and radioactive wastes.

Production of UO_2

Waste Nitric Acid from the Production of UO_2. Waste nitric acid is produced during dissolution of yellowcake in nitric acid and during back-extraction. We used best engineering judgment to determine that this waste may be partially recycled and may exhibit the characteristic of corrosivity. This waste was formerly classified as a spent material.

Production of UF_4

Waste Calcium Fluoride. Waste calcium fluoride, which typically contains elevated concentrations of radionuclides resulting from yellowcake production, is regulated by the Nuclear Regulatory Commission.[34] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Vaporizer Condensate. We used best engineering judgment to determine that this waste may exhibit the characteristic of corrosivity.

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[30] Clark, D., Op. Cit, pp. 50 - 51.

[31] Kennecott Corporation. Op. Cit.

[32] Rio Algom Corp. Op. Cit.

[33] Uranium Resources, Inc. Op. Cit.

[34] Rio Algom Corp. Op. Cit.

Superheater Condensate. We used best engineering judgment to determine that this waste may exhibit the characteristic of corrosivity.

EXHIBIT 8

Estimated By-Product Generation Rates

By-Product Material[35]	Generation Rate (metric tons/yr)		
	Low	Medium	High
Waste Acids from Solvent Extraction	1,700	9,350	17,000
Barren Lixiviant	0	1,700	17,000
Slimes from Solvent Extraction	1,700	9,350	17,000
Waste Solvents	0	0	1,700

EXHIBIT 9

Estimated Waste Generation Rates

Waste Stream	Waste Generation Rate (metric tons/yr)		
	Low	Medium	High
Waste Nitric Acid from Production of UO_2[36]	1,700	2,550	3,400
Vaporizer Condensate	1,700	9,350	17,000
Superheater Condensate	1,700	9,350	17,000
Slag	0	8,500	17,000
Uranium Chips from Ingot Production	1,700	2,550	3,400

Ames Process

Slag. We used best engineering judgment to determine that this waste may exhibit the characteristic of ignitability. This waste is fully recycled and was formerly classified as a by-product.

Uranium Chips from Ingot Production. We used best engineering judgment to determine that this waste may be recycled and may exhibit the characteristic of ignitability. This waste was formerly classified as a by-product.

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[35] These materials, generated during uranium beneficiation from the solvent extraction process are not considered solid wastes and are excluded from RCRA regulation at 40 CFR part 261.4(a)(4).

[36] This waste is not considered by the Agency as a mineral processing waste, but a related waste.

D. Non-uniquely Associated Wastes.

No non-uniquely associated waste streams have been identified in the uranium sector. However, standard ancillary hazardous wastes may include vehicular emissions including particulates, sulfur oxides, carbon monoxide, and hydrocarbons. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and some waste oil and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

Three commenters provided new information and clarifications of existing information related to the uranium sector that the Agency has included in this report. (COMM40, COMM66, COMM72)

Sector-specific Issues

One commenter raised an specific issue relating to the use of the term solvent extraction in conventional uranium milling operations. The commenter stated that the operation does not use halogenated hydrocarbons or degreasers, but instead uses mostly kerosene with isodecanol and tertiary amine. The commenter suggested that a better term for solvent extraction would be liquid ion exchange. EPA rejects this argument because the term "solvent extraction" does not imply use of halogenated solvents. (COMM40)

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VANADIUM

A. Commodity Summary

According to the U.S. Bureau of Mines, the domestic vanadium industry consists of twelve firms, of which only six are active.[1] Exhibit 1 presents the names and locations of the facilities involved in the production of vanadium. Raw materials include Idaho ferrophosphorus slag, petroleum residues, spent catalysts, utility ash, and vanadium bearing iron slag. Some vanadium is recovered from solution mining, however, that is only marginally economically feasible. Estimated domestic consumption of vanadium in 1994 was 4,100 metric tons.[2]

EXHIBIT 1

SUMMARY OF VANADIUM PROCESSING FACILITIES

Facility Name	Location	Type of Operations
Akzo Chemical Company	Weston, MI	Vanadium catalysts
AMAX Metals Recovery Corp	Braithwaite, LA	Vanadium Pentoxide
Bear Metallurgical Corp.	Butler, PA	Ferrovanadium
Cotter Corp.	Canon City, CO	Vanadium pentoxide from uranium byproducts (inactive)
Gulf Chemical & Metallurgical Corp.	Freeport, TX	Vanadium pentoxide
Kerr-McGee Chemical Corp	Soda Springs, ID	Vanadium pentoxide
Reading Alloys	Robesonia, PA	Aluminum-vanadium master alloy
Shieldalloy Metallurgical Corp	Cambridge, OH	Ferrovanadium, ammonium metavanadate, and aluminum-vanadium
Stratcor	Niagara Falls, NY	Ferrovanadium, aluminum-vanadium alloy, and Nitrovan (inactive)
Teledyne Wah Chang	Albany, OR	Vanadium metal and vanadium-zirconium alloy
Umetco Minerals	Blanding, UT	Vanadium pentoxide from uranium byproducts (inactive)
Stratcor	Hot Springs, AR	Vanadium pentoxide

Vanadium is principally used as an alloying element in iron and steel, with the steel industry accounting for more than 80% of the world's consumption of vanadium. Vanadium is added to the steel making process as a ferrovanadium alloy. This alloy is produced commercially by the reduction of vanadium pentoxide or vanadium

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[1] Henry E. Hillard, "Vanadium," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, p. 1463.

[2] Henry E. Hillard, "Vanadium," from Mineral Commodities Summary, U.S. Bureau of Mines, 1995, p. 184.

bearing-slag with aluminum, carbon, or ferrosilicon.[3] The addition of vanadium in amounts as small as 0.1% to an ordinary carbon steel can significantly improve both its toughness and its ductility. Such high-strength, low-alloy (HSLA) steels are attractive for highrise buildings, bridges, pipelines, and automobiles because of the weight savings obtained.[4] Vanadium is also used in the production of titanium alloys for the aerospace industry and as the catalyst for the production of maleic anhydride and sulfuric acid.[5]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Vanadium is usually produced as the byproduct or coproduct of another element, such as iron, uranium, molybdenum, or phosphorus. In the United States, vanadium is recovered: (1) as a principal mine product, (2) as a coproduct from carnotite ores, and (3) from ferrous slag as a byproduct in the production of elemental phosphorus. Increasingly, it is also being recovered by secondary processing of petroleum refinery residues, fly ash, and spent catalysts.[6] Exhibit 2 presents an overview of the processes used to recover vanadium from various raw materials.

As Exhibit 2 illustrates, the vanadium product from the primary process is sent either to an acid leach or a salt roast process. The recovered vanadium product, usually sodium hexavanadate, is further processed to produce vanadium pentoxide. The vanadium pentoxide can then be reduced further to produce vanadium metal either by the aluminothermic, calcium, or carbon reduction processes. Each of these processes for preparing ferrovanadium is described in more detail below.

Vanadium was also once extracted and recovered as a coproduct with uranium from carnotite by direct leaching of the ore with sulfuric acid. Alternatively, the uranium ore source was also roasted, followed by concurrent leaching with dilute sulfuric acid. In some cases, the first leach was with a sodium carbonate solution. The vanadium and uranium could then be separated from the pregnant liquor by liquid-liquid extraction techniques.[7] Due to market factors and the price of uranium, vanadium is not currently recovered from uranium.[8]

2. Generalized Process Flow Diagram

Vanadium can be recovered both from the primary processing of ores and from secondary processing of spent catalysts. In both cases, the production of vanadium can be separated into three general stages. Each of these stages is described below and outlined in the accompanying flow diagrams. The first stage involves the production of an oxide concentrate. The second stage involves the production of vanadium pentoxide either by fusion or dissolution. Production of vanadium metal or ingot is the third stage in the operation.

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[3] Ibid., pp. 1449-1450.

[4] Peter H. Kuck, "Vanadium," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, p. 895.

[5] Ibid.

[6] Henry E. Hillard, 1992, Op. Cit., pp. 1447-1466.

[7] Ibid., p. 1449.

[8] Personal communication between Jocelyn Spielman, ICF Incorporated and Henry E. Hillard, Vanadium Specialist, U.S. Bureau of Mines, October 20, 1994.

EXHIBIT 2

GENERALIZED FLOWSHEET FOR PROCESSING VANADIFEROUS RAW MATERIALS

(Adapted from: Mineral Facts and Problems, 1985, pp. 895 - 914.)

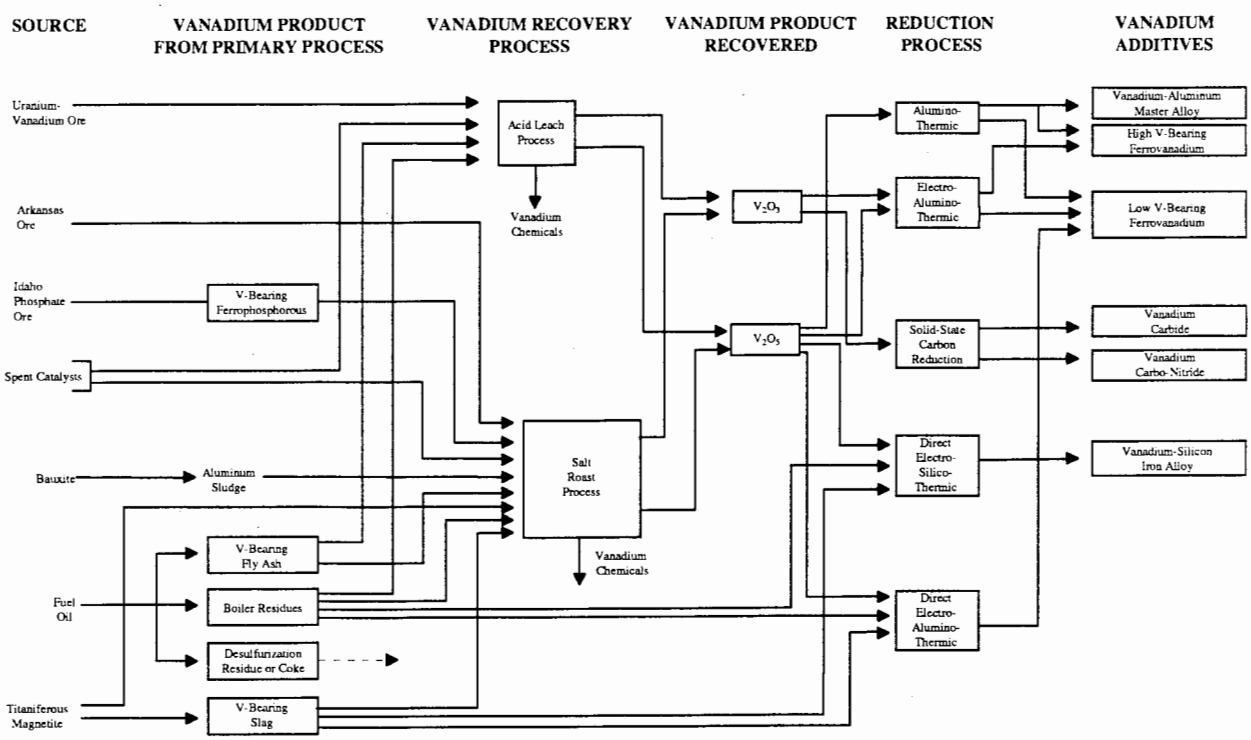


EXHIBIT 3

SODIUM HEXAVANDATE PRODUCTION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-245 - 3-253.)

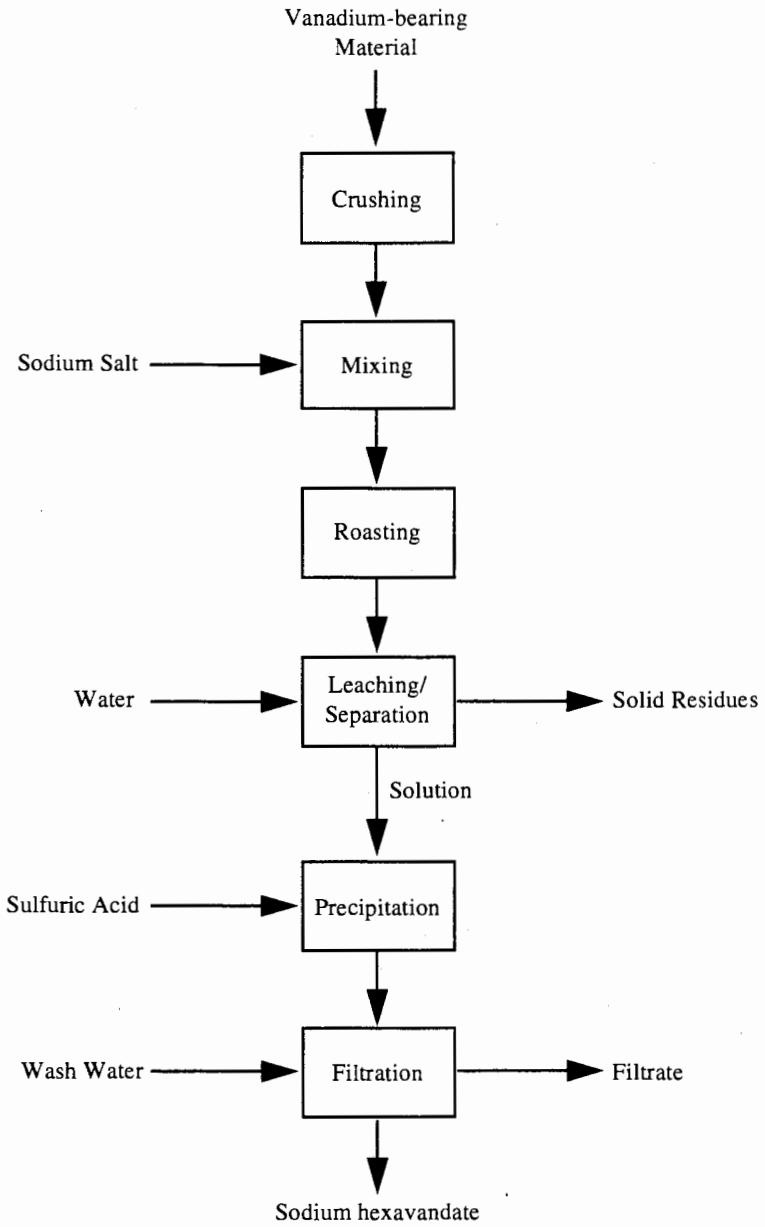
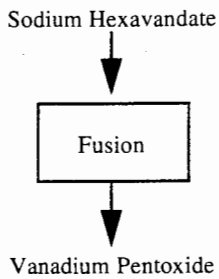


EXHIBIT 4

VANADIUM PENTOXIDE PRODUCTS

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-245 - 3-253.)

OPTION 1



OPTION 2

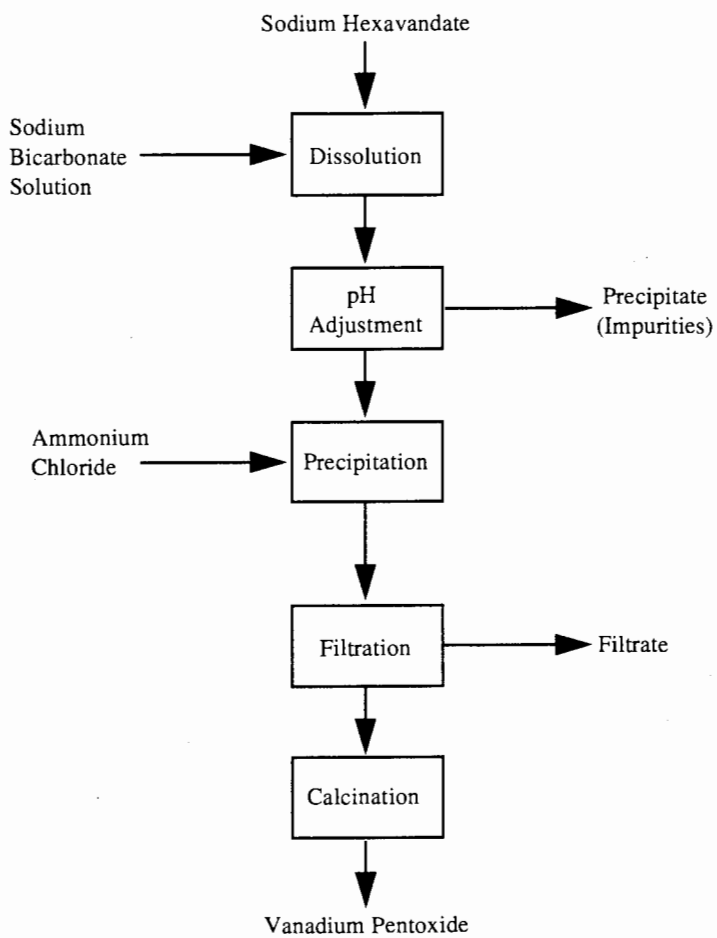


EXHIBIT 5

CALCIUM REDUCTION

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-245 - 3-253.)

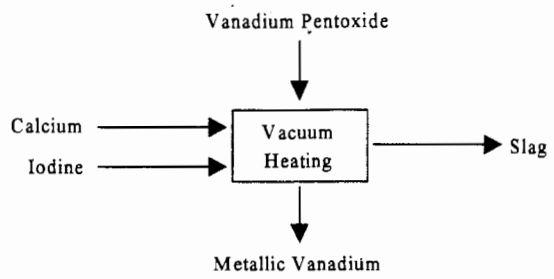


EXHIBIT 6

ALUMINOTHERMIC REDUCTION OF VANADIUM PENTOXIDE

(Adapted from: 1988 Final Draft Summary Report of Mineral Industry Processing Wastes, 1988, pp. 3-245 - 3-253.)

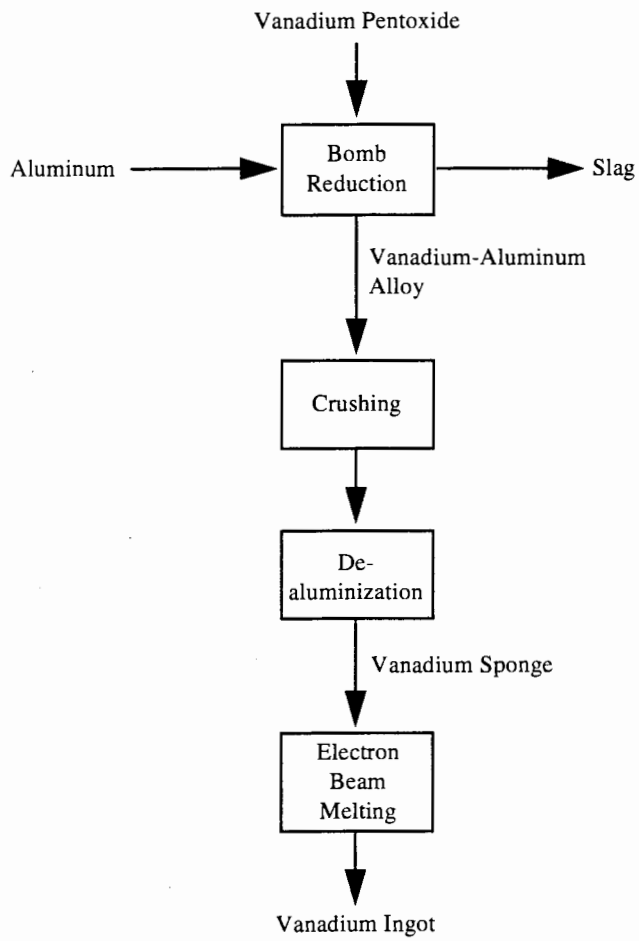


Exhibit 3 presents the process for preparing sodium hexavanadate. Exhibit 4 presents two alternative processes producing vanadium pentoxide. Exhibits 5 and 6 present two alternative processes for reducing the vanadium pentoxide to metal.

Production of Sodium Hexavanadate

Recovery From Ore. Regardless of the source of the ore, the first stage in the ore processing is the production of an oxide concentrate. As shown in Exhibit 3, the ore is crushed, ground, screened, and mixed with a sodium salt, e.g., NaCl or Na_2CO_3. This mixture is then roasted at about 850 °C to convert the oxides to water-soluble sodium metavanadate. The solid mixture is then leached with water to dissolve the metavanadate and the sodium chloride. The resulting slurry is filtered and the insoluble iron oxide and phosphate are sent to disposal. Sodium hexavanadate (red cake) or sodium decavanadate is precipitated out by the addition of sulfuric acid and recovered by filtration.[9]

If the recovery of vanadium is associated with the recovery of molybdenum, the initial step in the vanadium recovery process is the removal of phosphorous by precipitation as insoluble magnesium phosphates. Aluminum, if it is present in solution, is removed as the hydroxide by acidification followed by filtration. Vanadium is then precipitated as ammonium metavanadate with excess NH_4Cl, and is separated from the liquid phase by filtration. Molybdenum does not precipitate and the molybdenum-rich filtrate is routed to the molybdenum recovery process. When the source for the vanadium recovery is molybdenum, the ammonium metavanadate produced by the NH_4Cl precipitation is calcined and fused to produce vanadium pentoxide.[10]

Recovery From Spent Catalysts. Secondary processing of spent catalysts has become a major source of vanadium, either using an oxidation catalyst from the production of sulfuric acid or maleic anhydride or a hydroprocessing catalyst from petroleum refining. Vanadium is recovered by roasting, followed by milling, leaching, and filtration to separate the solids from the solution containing vanadium. The solutions then go through various precipitation steps before the precipitation of vanadium as ammonium metavanadate, which is then decomposed and fused to form vanadium pentoxide or used directly to make other vanadium chemicals.[11]

Production of Vanadium Pentoxide

Exhibit 4 presents two of the methods for producing vanadium pentoxide from sodium hexavanadate: (1) fusion and (2) dissolution.

Fusion. The red cake or sodium hexavanadate can be further processed and fused at 700° C to yield a dense black product which is sold as technical-grade vanadium pentoxide, as shown in Exhibit 5. This product contains a minimum of 86 weight-percent pentoxide and a maximum of 8 weight-percent sodium oxide.[12]

Dissolution. Alternatively, the red cake may be further purified by dissolving it in an aqueous solution of sodium carbonate. Aluminum, iron, and silicate impurities precipitate from solution upon pH adjustment.

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[9] Ibid.

[10] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for Nonferrous Metals Manufacturing Point Source Category, Vol. VI, Office of Water Regulations Standards, May 1989, p. 3512.

[11] Ibid.

[12] Henry E. Hillard, 1992, Op. Cit., p. 1449.

Ammonium metavanadate is then precipitated by the addition of ammonium chloride. The precipitate is calcined to give a vanadium pentoxide product of greater than 99.8% purity.[13]

Production of Metallic Vanadium or Vanadium Ingot

Exhibits 5 and 6 present two alternative methods for reducing vanadium pentoxide to metallic vanadium. Exhibit 5 shows the calcium reduction process and Exhibit 6 outlines the steps for aluminothermic reduction. Vanadium pentoxide can also be reduced using either the thermit reaction (a variation on the aluminothermic reduction) or by solid-state carbon reduction.

Calcium Reduction. Calcium reduction involves combining vanadium pentoxide with calcium, adding iodine as a flux, and heating the mixture in a vacuum to form metallic vanadium. [14] Neither calcium reduction nor carbon reduction are currently used.[15]

Aluminothermic Process. As shown in Exhibit 6, in the aluminothermic process for preparing ferrovanadium, a mixture of technical grade vanadium pentoxide, aluminum, iron scrap, and a flux are charged into an electric furnace, and the reaction between aluminum and pentoxide is initiated. The reaction is highly exothermic, producing very high temperatures. The temperature can be controlled by reducing the particle size of the reactants and the feed rate of the charge and by using partially reduced pentoxide or by replacing some of the aluminum with a milder reducing agent. Ferrovanadium containing up to 80 weight-percent vanadium can be produced by this method.[16]

Thermit Reaction. Ferrovanadium can also be prepared by the thermit reaction, a variation on the aluminothermic reduction, in which vanadium and iron oxides are coreduced by aluminum granules in a magnesia-lined steel vessel or in a water-cooled crucible. The reaction is initiated by a barium peroxide-aluminum ignition charge. This method is also used to prepare aluminum master alloys for the titanium industry.[17]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

Recent literature lists several new procedures for recovery of vanadium from industrial wastes, including:

- Extraction of vanadium from coke using microwave wet acid digestion.

  "Certified coal standards and Venezuelan petroleum coke samples were submitted to microwave acid digestion to evaluate the convenience of this procedure for the extraction of their vanadium content. The solution and the solid residue remaining after microwave treatment were separated by filtration and analyzed for vanadium."[18]

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[13] Ibid.

[14] U.S. Environmental Protection Agency, "Vanadium," from 1988 Final Draft Summary Report Mineral Industry Processing Wastes, Office of Solid Waste, 1988, p. 3-245 - 3-253.

[15] Personal communication between Jocelyn Spielman, ICF and Henry E. Hillard, Vanadium Specialist, U.S. Bureau of Mines, October 20, 1994.

[16] Henry E. Hillard, 1992, Op. Cit., p. 1450.

[17] Ibid.

[18] Alvarado, Jose, et al. "Extraction of vanadium from petroleum coke samples by means of microwave wet acid digestion," FUEL, 69, January 1990, pp. 128-130.

- Recovery of vanadium from titaniferous slags by sulphiding.[19]
- Recovery of vanadium from process residues.[20]
- Extraction of vanadium from industrial waste.[21]
- Recovery of pure vanadium oxide from Bayer sludge.[22]

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above in this section.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between the production of sodium hexavandate and the production of vanadium pentoxide and metallic vanadium. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here where a significant chemical change to the sodium hexavandate occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated

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[19] G. J. Njau, B. Pei, and T. Rosenqvist, "Recovery of Reactive Metals (Manganese, Chromium, Vanadium) From Titaniferous Slags by Sulfiding," Scandinavian Journal Of Metallurgy, 20, No. 2, 1991, pp. 149-156.

[20] C. R. Edwards, "The Recovery of Metal Values From Process Residues," JOM, 43, No. 6, June 1991, pp. 32-33.

[21] Y. K. Mukherjee and C. K. Gupta, "Extraction of Vanadium From an Industrial Waste," High Temperature Materials and Processes, 11, Nos. 1-4, January 1993, pp.189-206.

[22] Y. K. Mukherjee, S.P. Chakraborty, A.C. Bidaye, and C. K. Gupta, "Recovery of Pure Vanadium Oxide From Bayer Sludge," Minerals Engineering, 3, Nos. 3-4, 1990, pp.345-353.

after the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Described below are those wastes identified as generated from primary mineral processing. Wastes associated with the secondary processing and recovery from spent catalysts include ammonia emissions from leaching, wastewater from solvent extraction, wastewater from filtration, and waste alumina.

From Sodium Hexavandate Production.

The following wastes are generated during the production of sodium hexavandate from ore.

Solid residues. Some of the wastes generated during sodium hexavanadate production include solid residues from leaching and filtrates from filtration.[23]

Roaster Off gases
Spent Solvent
Spent Filtrate

2. Mineral Processing Wastes

Production of Vanadium Pentoxide.

Wet Scrubber Wastewater. At the facility that recovers vanadium from molybdenum, off gases from the calcine furnace are controlled with a dry baghouse which recovers the dust particulates. In series with the baghouse is a wet scrubber employing a dilute hydrochloric acid solution as the scrubbing medium. The scrubber liquor is routed to the ammonia recovery and reuse system.[24] The wastewater generated from scrubbing the emissions from calcination contains sodium chloride and suspended ferrophosphorus particulates. In 1980, these wastes were generated containing 30 kg of sodium chloride per kkg of product and up to 2 kg of ferrophosphorus particulates per kkg of vanadium product. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Spent Precipitate. If the vanadium pentoxide is produced using dissolution, impurities are removed during pH adjustment. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Solid Waste. Solid wastes generated as a result of calcination include insoluble ferrophosphorus oxidation products such as ferric oxide and ferric phosphate. In 1980, these wastes were reported to contain from 7,830 to 8,700 kg of ferric oxide per kkg of vanadium pentoxide product and from 14,670 to 16,300 kg of ferric phosphate per kkg of vanadium pentoxide product. The waste were water slurried and sent to disposal areas. These solid wastes are generally limestone treated to neutralize acidic material before the wastes are sent to evaporation ponds. In 1980, the wastewaters generated by slurrying the solid wastes contained from 22,500 to 25,000 kg of iron oxides

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[23] U.S. Environmental Protection Agency, "Vanadium," from 1988 Final Draft Summary Report Mineral Industry Processing Wastes, Office of Solid Waste, 1988, pp. 3-245 - 3-253.

[24] U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3513.

and iron phosphates per kkg of product.[25] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Filtrate and Process Wastewaters. Wastewater resulting from the filtration in Option 2 on Exhibit 5, contains sodium chloride and sodium sulfate. In 1980, these wastewaters contained from 1,750 to 2,000 kg of sodium chloride per kkg of product and 933 kg of sodium sulfate per kkg of product. Other process wastewater from the final vanadium pentoxide recovery steps contained 729 kg of ammonium sulfate per kkg of vanadium pentoxide product.[26] Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Alloying and Metal Finishing

Slag. Wastes generated from the production of metallic vanadium include slag from calcium and aluminothermic reduction.[27] No further generation or management data are available. Existing data and engineering judgment suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[25] Versar, Inc., "Vanadium Derivatives," from Assessment of the Inorganic Chemical Industry, Vol. IV, 1980, p. 32-7.

[26] Ibid.

[27] U.S. Environmental Protection Agency, 1988, Op. Cit., pp. 3-245 - 3-253.

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Mukherjee, Y. K., Chakraborty, S.P., Bidaye, A.C., and Gupta C. K. "Recovery of Pure Vanadium Oxide From Bayer Sludge." Minerals Engineering, 3, Nos. 3-4. 1990. pp.345-353.

Njau, G J., Pei, B, and Rosenqvist T. "Recovery of Reactive Metals (Manganese, Chromium, Vanadium) From Titaniferous Slags by Sulfiding." Scandinavian Journal Of Metallurgy, 20, No. 2. 1991. pp. 149-156.

Personal communication between Jocelyn Spielman, ICF and Henry Hillard, Vanadium Specialist, U.S. Bureau of Mines, October 20, 1994.

U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for Nonferrous Metals Manufacturing Point Source Category. Vol. VI. Office of Water Regulations Standards. May 1989. p. 3512.

U.S. Environmental Protection Agency. "Vanadium." From 1988 Final Draft Summary Report of Mineral Industry Processing Wastes. Office of Solid Waste. 1988. pp. 3-245-3-253.

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ZINC

A. Commodity Summary

The primary source of zinc is the mineral sphalerite (ZnS), which is the source of about 90 percent of zinc produced today; zinc can also be recovered from six additional minerals, including hemimorphite, smithsonite, zincite, hydrozincite, willemite, and franklinite.[1] The primary uses of zinc are as a protective coating for steel (galvanizing), as alloys in die casting, as an alloying metal with copper to make brass and bronze, and in chemical compounds (e.g., zinc oxide) in rubber and paints.[2]e

Canada and Australia were the world's largest producers of zinc in 1994, accounting for 31 percent of mine production, followed by China, Peru, the United States, and Mexico.[3] Canada, Australia, and the U.S. also possess 39 percent of the world's zinc reserves. In the U.S., mines in Alaska, Missouri, New York, and Tennessee produced more than 90 percent of the nation's total mine output in 1994 of 560,000 metric tons; the four largest U.S. mines (in order of output) in 1992 and their operators and locations were the following:

Mine Name	Operator	Location
Red Dog	Cominco Alaska, Inc.	Northwest Arctic, AK
Elmwood-Gordonsville	Jersey Miniere Zinc Co.	Smith, TN
Greens Creek	Greens Creek Mining Co.	Admiralty Island, AK
Balmat	Zinc Corp. of America (ZCA)	St. Lawrence, NY

All of these mines produce zinc ore. In addition, several mines in the U.S. produce lead-zinc ore or lead ore with secondary zinc values, which can be beneficiated to remove zinc for processing. The larger of these mines include the West Fork and Fletcher mines in Reynolds, MO; the Buick mine in Iron, MO; and the Lucky Friday mine in Shoshone, ID.[4]

Four primary zinc smelters (three using the electrolytic process, the fourth using the electrothermic or pyrometallurgical process) produced 240,000 metric tons of slab zinc in 1994.[5] These plants and their location and process type include the following:

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[1] "Zinc and Zinc Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. XXIII, 1983, p. 808.

[2] U.S. Bureau of Mines, Mineral Facts and Problems, Bulletin 675, 1985, p. 923.

[3] U.S. Bureau of Mines, "Zinc," from Mineral Commodity Summaries, January 1995, p. 191.

[4] Jolly, J., "Zinc," in Minerals Yearbook Volume 1. Metals and Minerals 1992, U.S. Bureau of Mines, 1992, p. 1477.

[5] U.S. Bureau of Mines, 1995, Op. Cit., p. 190.

Facility Name	Location	Process
Big River Zinc Corp.	Sauget, IL	electrolytic
Jersey Miniere Zinc Co.	Clarksville, TN	electrolytic
Zinc Corp. of America*	Bartlesville, OK	electrolytic
Zinc Corp. of America	Monaca, PA	pyrometallurgical

* This facility is no longer operating.[6]

Zinc oxide was produced from zinc metal and scrap by eight companies in 1992. All of these companies produced French-process zinc oxide, except for one company, Eagle Zinc Co., of Hillsboro, IL, which produced American-process zinc oxide (both processes are described below).[7] Total U.S. production of zinc oxide in 1992 was approximately 105,000 metric tons.

In addition, the U.S. also imported 25,000 metric tons of zinc ore and concentrate and 800,000 metric tons of slab zinc, scrap, and compounds in 1994.[8]

B. Generalized Process Description

1. Discussion of Typical Production Processes

Zinc minerals are usually associated with other metals minerals, the most common associations in ores being zinc-lead, lead-zinc, zinc-copper, copper-zinc, or zinc-silver. Zinc also occurs alone in ores. Due to low zinc content, zinc-bearing ores must be concentrated before processing. Beneficiation, which usually occurs at the mine, consists of crushing, grinding, and flotation to produce concentrates of 50-60 percent zinc.[9]

Zinc is processed through either of two primary processing methods, electrolytic or pyrometallurgical. However, before use of either method, zinc concentrate is roasted to remove the sulfur from the concentrate and produce impure zinc oxide, referred to as roasted concentrate or calcine. In electrolytic zinc processing, calcine is digested with sulfuric acid to form a zinc sulfate solution, from which zinc is deposited through electrolytic refining. In pyrometallurgical processing, calcine is sintered and smelted in batch horizontal retorts, externally-heated continuous vertical retorts, or electrothermic furnaces. The sole pyrometallurgical operation in the U.S., Zinc Corp. of America's Monaca smelter, uses an electrothermic furnace. In addition, zinc is smelted in blast furnaces through the Imperial Smelting Furnace (ISF) process, which is capable of recovering both zinc and lead from mixed zinc-lead concentrates. The process is used at 12 plants worldwide and accounts for 12 percent of world capacity. There are no ISF-process plants in the U.S.[10]

Zinc oxide is manufactured by either the French or American processes. In the French process, which is used at ZCA's Monaca smelter, high-grade zinc metal is smelted in horizontal retorts to produce zinc metal vapor,

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[6] National Mining Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[7] Jolly, J., 1992, Op. Cit., p. 1472.

[8] U.S. Bureau of Mines, 1995, Op. Cit., p. 190.

[9] "Zinc and Zinc Alloys," 1983, Op. Cit., pp. 809, 812.

[10] U.S. Bureau of Mines, 1985, Op. Cit., pp. 927-928.

which is burned in a combustion chamber. In the American process, zinc oxide is manufactured by oxidizing zinc vapor in burners; the resulting gases and fume are cooled, and zinc oxide is recovered in baghouses.[11]

2. Generalized Process Flow Diagram

Detailed descriptions of Zinc Corp. of America's Bartlesville, OK (electrolytic) and Monaca, PA (pyrometallurgical) facilities are presented below. These descriptions are based on sampling trips to the facilities in 1989 in support of EPA rulemaking activities. Although the ZCA facility is no longer operating, the information presented below still may be applicable to the two remaining operational facilities.

Electrolytic Process

The ZCA electrolytic zinc refinery in Bartlesville, Oklahoma produced several zinc products and associated by-products from zinc ore concentrates. Zinc products included zinc metal, roofing granules, and zinc sulfate solution. By-products included cadmium metal, sulfuric acid, lead/silver residue, copper residue, nickel/cobalt residue, lead scrap, and aluminum scrap. ZCA used zinc sulfide concentrates containing 50-55 percent zinc as the principal feed for its Bartlesville plant.

Production of zinc products from ore concentrates at this facility involved roasting, leaching (digestion), purification, and electrowinning. Roasting took place at the Zinc Ore Roaster (ZOR), and the remaining three processes occurred at the Zinc Refinery (ZRF), as shown in the process flow diagram in Exhibit 1. Both the ZOR and the ZRF are located at the Bartlesville plant.

Zinc ore concentrates were first slurried with water and then roasted, reacting with air to produce a crude zinc oxide calcine and off-gas from the roaster containing 7-10 percent sulfur dioxide. Calcine dusts were recovered from the off-gas by two cyclone separators and added to the calcine. The off-gas was humidified and passed through a wet electrostatic precipitator in a hot tower to remove remaining solids from the sulfur dioxide gas so that it could be used as feed to produce sulfuric acid in the Zinc Acid Plant (ZAP). Two-thirds of the resulting liquid stream from the precipitator, known as acid plant blowdown, was pumped directly to the facility's wastewater treatment plant, and the remaining third was recycled to the hot tower. Total acid plant blowdown flow was approximately 50 gallons per minute. Process wastewater generated by the ZOR consisted of non-contact cooling water used to cool the calcine as it exited the roaster and slurry water that leaked from a pump that directed the slurried ore concentrates to the roaster. These waters were collected in a clay-lined sump outside the roaster and were pumped to the wastewater treatment plant. A process wastewater stream generated at the ZAP, consisting of cooling tower blowdown, was pumped directly to the treatment plant.

The leaching (digestion) process dissolved the zinc in the calcine, creating a zinc sulfate solution from which the zinc could be removed through electrowinning. By mixing the calcine from the roaster with 150-170 g/L sulfuric acid in a step called neutral leaching, about 90 percent of the zinc in the calcine dissolved. The insoluble zinc calcine was separated from the leaching solution in a settling tank. Neutral leach zinc sulfate solution was sent to a purification system, and the solids containing the insoluble zinc were pumped to a residue treatment circuit, where additional sulfuric acid was added to the solids in a series of three hot acid leach tanks to dissolve another 6-7 percent of the zinc from the calcine. Remaining solids in the resulting slurry were separated in a second settling tank and filtered into a cake that was dried and sold for its lead and silver content (20 percent lead and up to 70 ounces of silver per ton).

When the calcine was leached with sulfuric acid in the hot acid leach tanks, iron in the calcine dissolved along with the zinc. Because this solution still contained recoverable zinc, ZCA recycled the solution to the original

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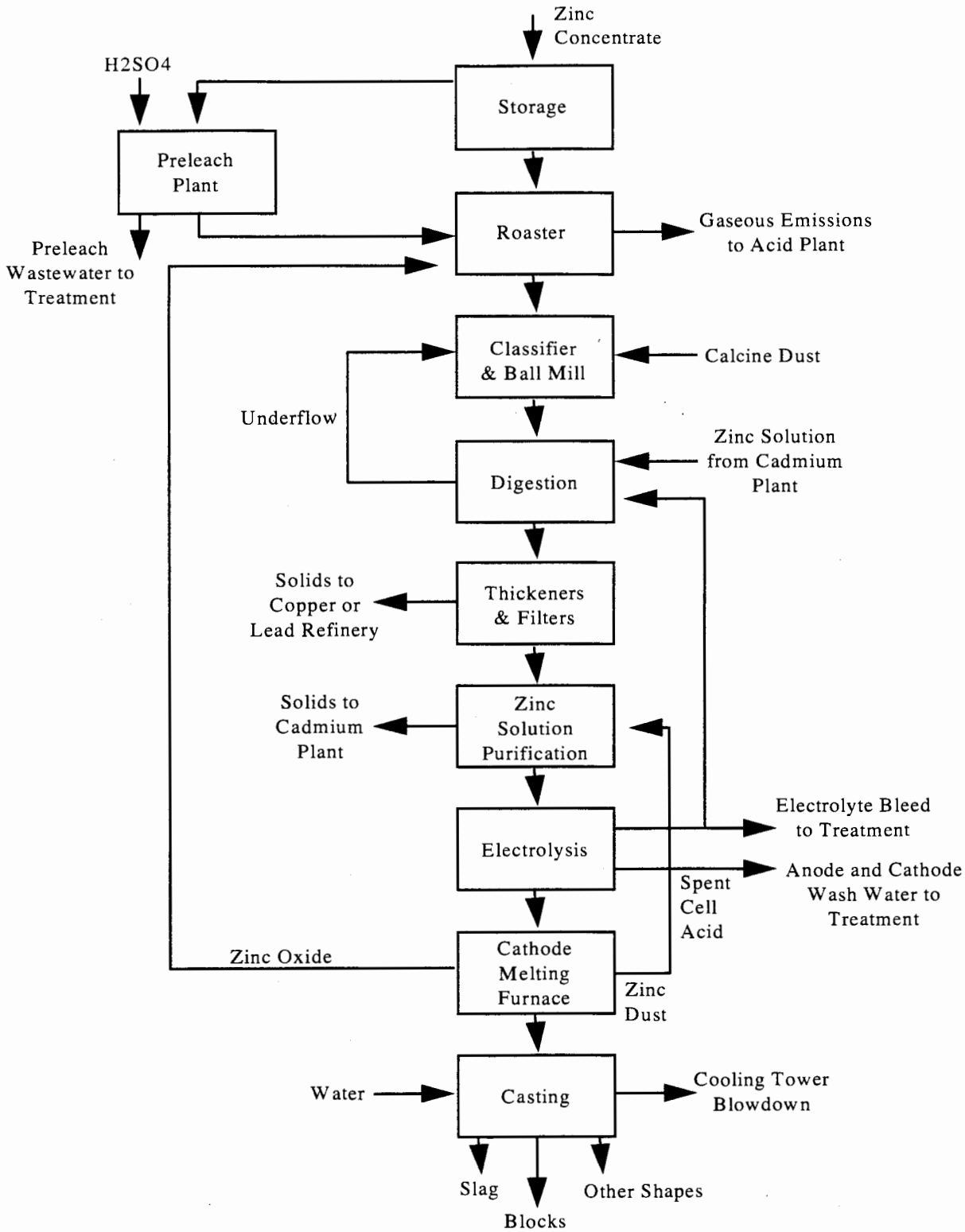
[11] "Zinc and Zinc Alloys," 1983, Op. Cit., pp. 855.

EXHIBIT 1

ELECTROLYTIC ZINC PRODUCTION PROCESS

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989, p. 479.)



neutral leach step described above. However, if the dissolved iron in the solution is not removed, it will prevent the eventual recovery of zinc metal. To remove iron from the solution, ZCA utilized the goethite process.[12] Zinc sulfide concentrates were added to the hot acid leach solution to reduce the dissolved iron to its ferrous or divalent state. Zinc calcine was added to neutralize remnant sulfuric acid from the hot acid leach step. Zinc oxide and air were then added to the solution to oxidize the iron from its divalent to trivalent state and precipitate goethite, a hydrated iron oxide, in a slurry. The slurry settled in a tank; the clarified solution containing recoverable zinc was recycled to the neutral leach step, and the iron oxide slurry (goethite) solids were washed and filtered.

Goethite removed from the filter contained 30-40 percent iron, but a 1989 study found that recovery of the iron was not economical.[13] Moist goethite cake was stored in an uncovered, unlined waste pile onsite that dates from 1978, when the electrolytic process began at the facility. Runoff from the pile flowed to a clay-lined sump pond and then to the wastewater treatment plant.

In the purification step, trace impurities from the zinc oxide calcine that dissolved in the leaching steps were removed from the neutral leach solution. Like iron, these impurities must be removed so that zinc can be converted to metal. Zinc dust was added to the solution to chemically replace copper and cadmium, which precipitate out of solution as a sludge. Cadmium metal and copper residue were recovered for sale. Zinc dust was again added, along with antimony as a catalyst, to replace nickel and cobalt, which also were recovered for sale. These residues were stockpiled along with others, such as sump and tank cleanings, on an unlined pad until they were sold or recycled. Runoff from the pad collected in a sump and was pumped to a large surface impoundment and eventually to the wastewater treatment plant.

Purified, zinc-rich solution was cooled in evaporative cooling towers and stored in tanks before the zinc was electrowon from the solution at the cell house. The cell house consisted of 128 electrolytic cells, each with 45 lead anodes and 44 aluminum cathodes. When electric current passes through the zinc sulfate solution, which serves as an electrolyte, positive zinc ions deposit on the negatively-charged aluminum cathodes. Half of the cathodes were removed from their cells each day so that the metallic zinc layer could be scraped off each cathode and so that zinc could continue to be removed from solution with the other cathodes. Spent solution containing dilute sulfuric acid was recycled to the neutral leach step of the leaching process. Because of heat build-up in the cells, the zinc sulfate solution has continuously passed through cooling towers. Non-contact cooling water along with boiler blowdown, condensate, and brushing water used to wash cathodes made up a process wastewater stream from the ZRF. This stream flowed through a feeder ditch to a clay-lined sump pond, then to a large, clay-lined surface impoundment, and was finally pumped to the wastewater treatment plant.

Zinc removed from cathodes was melted in a furnace and cast into 55-pound, 600-pound, or 2,400-pound ingots. Some zincwa s converted to dust used in the purification system. Zinc fume collected in the furnace baghouse was recycled. ZCA also converted scrap zinc from its plant and purchased scrap into usable zinc at its Zinc Secondaries Plant (ZSP), a process that is outside the scope of primary mineral processing and, thus, not described further.

Most process wastewaters at ZCA were made up of small streams from the roasting, purification, electrowinning, and zinc secondaries processes. Acid plant blowdown was generated when sulfur dioxide off-gas from the ZOR passed through a wet electrostatic precipitator in the hot tower to remove solids. Process wastewater from the ZSP consisted primarily of water from Venturi scrubbers used to collect dusts from rotary drying of calcine. Process wastewater from the ZRF consisted primarily of brushing water used to wash the aluminum cathodes that served as a depositional surface for zinc ions during electrowinning. The ZAP, which converted sulfur dioxide gas generated in the ZOR to commercial-grade sulfuric acid, generated process wastewater consisting of non-contact cooling tower blowdown. Smaller streams of boiler blowdown, non-contact cooling water from cooling towers, and condensate also made up the wastewater flow.

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[12] Additional methods to precipitate iron include the hematite and jarosite processes.

[13] As of July 1989, ZCA was studying a pilot system to recover iron from goethite; the status of this project is unknown.

Process wastewater and plant runoff that collected in the two large, clay-lined surface impoundments were pumped to the wastewater treatment plant. Following a two-stage neutralization process and clarification, sludge was recycled to the roaster and treated water was pumped to two synthetically-lined holding ponds before it was injected in a Class I industrial well.

Pyrometallurgical Process

The primary mineral processing operations at the Monaca facility produce a variety of zinc and other products from ore concentrate (primarily from a New York State mine) and, to a lesser extent, secondary materials (e.g., cast off material from galvanizing operations). Zinc products include zinc metal, zinc sulfate solution, zinc dust, and zinc oxide. Other products produced by the facility including sulfuric acid, lead sulfate, cadmium sponge, ferro-silicate, and processed slag. Due to variations in market conditions, some of these materials, especially ferro-silicate and slag, may be stored on-site for several years prior to sale.

Ore concentrate is first dried in an ore dryer and then roasted, as shown in the process flow diagram in Exhibit 2. Off-gas from the ore dryer is scrubbed prior to discharge to the atmosphere and off-gases from roasting are cleaned prior to being used as the feedstock for sulfuric acid production. Ore dryer scrubber water and acid plant blowdown (from roaster gas cleaning operations) are mixed in a concrete basin (the "Cottrell pond") where the pH is raised to prevent corrosion of plant piping prior to being returned to the scrubber or being used as feed in the sintering process.

The sintering process, which follows roasting, agglomerates the oxidized ore concentrate in preparation for furnacing. Dust removed from sintering off-gases in baghouses is returned to the sintering operation or used as a feed to the zinc sulfate circuit.[14] The zinc sulfate circuit consists of a series of steps in which the baghouse dust is first slurried with water and soda ash. The solids (metal carbonates) are then removed from this slurry in a clarifier, the overflow from which goes to the facility's wastewater treatment plant. Underflow from the clarifier is centrifuged; liquid removed by the centrifuge is pumped to a concrete basin and then returned to the clarifier and the solids are leached with sulfuric acid, which solubilizes zinc and cadmium sulfates. Solids are separated using a filter press and sold for lead recovery. Zinc dust is added to the remaining sulfate solution to precipitate cadmium sponge, which is sold to a cadmium metal producer, leaving a zinc sulfate solution, which also is sold as a product.

Sinter and coke are charged to an electrothermal furnace in which zinc gas is generated and subsequently condensed on molten zinc. Uncondensed zinc is removed from the off-gases by a wet scrubber. Water from the wet scrubber is sent to two concrete basins and then a series of three lined impoundments. About half of the water is then returned to the scrubber while the other half is sent to the wastewater treatment plant. Blue powder, a mixture of primarily zinc oxides and elemental zinc, settles out of the scrubber water in both the concrete basins and the impoundments. Blue powder is removed from the concrete basins on a weekly basis and placed in adjacent concrete basins to dry prior to being returned to the ore dryer or used to raise the pH of the combined acid plant blowdown and ore dryer scrubber water. Blue powder is removed from the impoundments along with the impoundment liners every two or three years, and both the powder and the liners are charged to the furnace.

Zinc from the furnace is made into a variety of final products including furnace grade and high purity zinc metal, zinc dust, and zinc oxide. Furnace residues are processed to recover coke, which is returned to the furnace as fines generated by the processing operations, to separate the ferrous and non-ferrous fractions. The ferrosilicates are stockpiled on site and sold to the iron and steel industry when market conditions permit. The non-ferrous slag is graded into four sizes and sold or used as a drainage material in the facility's fly ash landfill.

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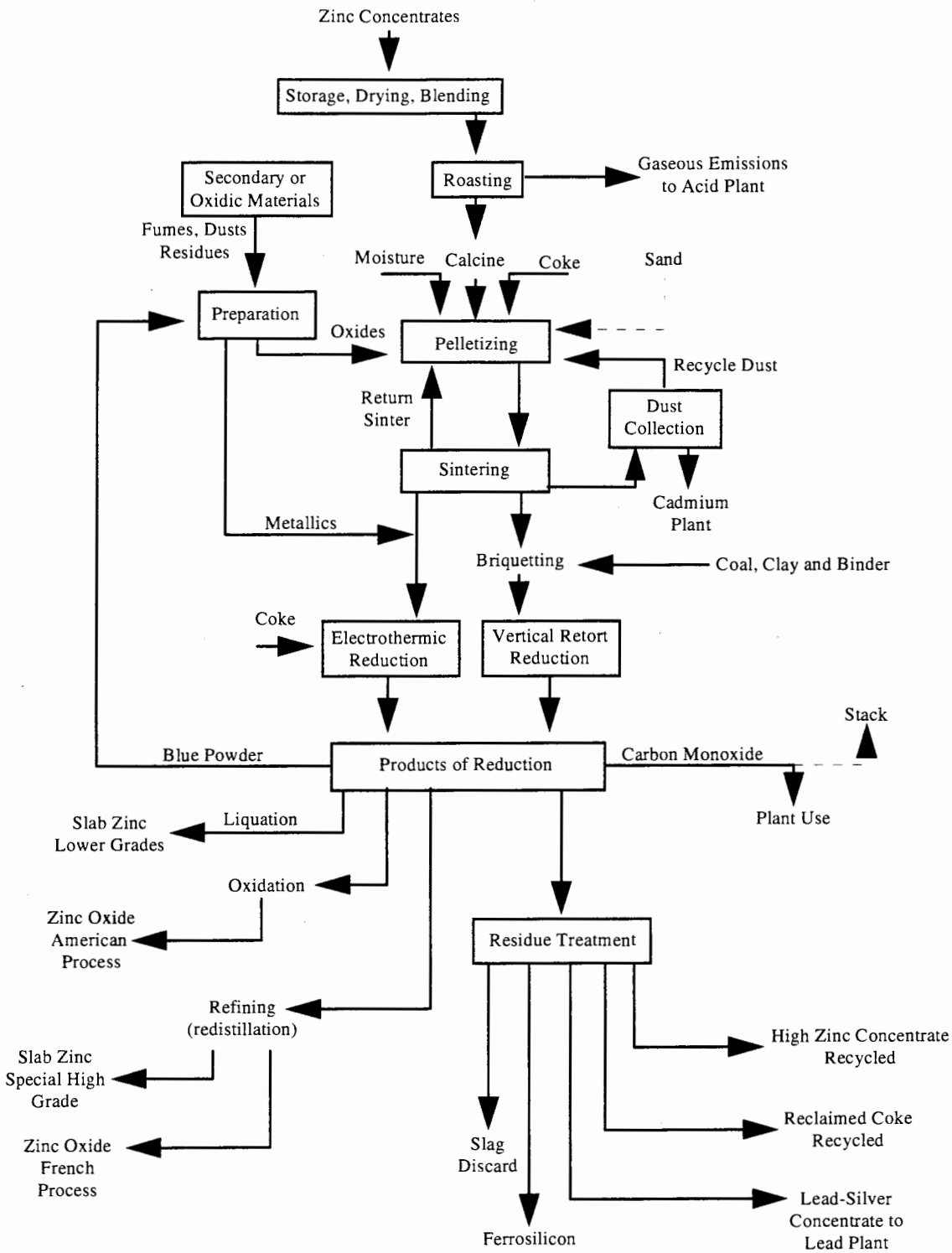
[14] Feed to the zinc sulfate circuit also consists of zinc carbonate that was generated before the zinc sulfate circuit became operational and that is stockpiled on site.

EXHIBIT 2

PYROMETALLURGICAL ZINC PRODUCTION PROCESS

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989, p. 480.)



Wastewaters, which include plant runoff as well as process wastewater from the blue powder impoundments and the zinc sulfate circuit, go to a lined equalization basin and then to a two-stage neutralization process, followed by clarification prior to discharge to the Ohio River through an NPDES-permitted outfall. Solids removed from the clarifier are filtered and then returned to the sintering operation.

3. Identification/Discussion of Novel (or otherwise distinct) Processes

In addition to the Imperial Smelting Furnace process, which is identified above, several other novel processes for zinc recovery are being (or have been) investigated or utilized.

A research program is being conducted at the Colorado School of Mines for developing a pyrochemical process using molten salts for recovering reactive metals, including zinc, from beneficiated ore. The process takes place in a hybrid reactor combining electrolytic production of a calcium reductant and *in situ* utilization of the reductant to reduce metal compounds. The reactor operates at a temperature of less than 1,000°C. The technology reportedly generates little waste.[15]

Two companies in Canada (Cominco and Kidd Creek) utilize pressure leaching to digest zinc ore concentrates, eliminating both the roasting step and the need for a sulfuric acid plant in the electrolytic process. Zinc concentrate is reacted with oxygen and electrolyte recovered from the electrowinning step in a pressure autoclave. Zinc dissolves and forms zinc sulfate, which is sent to the electrowinning step. Sulfur in the zinc concentrate is converted to elemental sulfur as part of the residue and is extracted or wasted with the residue. The process reportedly has lower capital costs than a traditional electrolytic plant.[16]

Sulfate roasting of copper-zinc-sulfide concentrate has been examined on a laboratory and pilot-plant scale in open-hearth and fluidized bed furnaces. The resulting calcine was leached with mild sulfuric acid; zinc and iron were co-extracted from the leach solution with D2-EPHA (a solvent extractant), and copper sulfate was crystallized from the purified solution. Recoveries of 95 percent and 99 percent were achieved for zinc and copper, respectively.[17]

A solvent extraction process for treating waste streams from electrowinning was developed using acid-base couple extractants composed of amines and organic acids. Approximately 95 percent of both zinc (as zinc sulfate) and sulfuric acid in the bleed stream was recovered at concentrations high enough for direct recycle to the process.[18]

AMAX created a process to recover zinc and other metals from RCRA-hazardous zinc leach residue through brine leaching. The process involves leaching the residue with a $CaCl_2$ brine solution at pH 2 for one hour at 90°C. Silver, lead, copper, cadmium, zinc, and iron were extracted at percentages of 95, 80, 50, 50, 30, and less than 0.5 percent, respectively. Zinc was recovered through sulfide precipitation. The remaining residue passed the EP toxicity test.[19]

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[15] Mishra, B., D. Olson, and W. Averill, "Applications of Molten Salts in Reactive Metals Processing," presented at the Conference for Emerging Separation Technologies for Metals and Fuels, Palm Coast, FL, March 13-18, 1993, sponsored by the Minerals, Metals, & Materials Society, Warrendale, PA.

[16] U.S. Bureau of Mines, 1985, Op. Cit., p. 927

[17] Ferron, C. and J. De Cuyper, "The Recovery of Copper and Zinc from a Sulphide Concentrate Using Sulfate Roasting, Acid Leaching and Solution Purification," International Journal of Mineral Processing, 35, No. 3-4, August 1992, pp. 225-238.

[18] Eyal, A., et. al., 1990, Op. Cit., pp. 209-222.

[19] Beckstead, L., et al., 1993, Op. Cit., pp. 862-875.

4. Beneficiation/Processing Boundary

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs prior to the initial roasting step in both the electrolytic and the pyrometallurgical processes. EPA identified this point in the process sequence as where beneficiation ends and mineral processing begins because it is here, where, as a result of a chemical reaction, sulfur is removed from the zinc sulfate feedstock. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents the mineral processing waste streams generated downstream of the beneficiation/processing line in section C.2, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Wastes generated by lead-zinc mining operations include materials such as waste rock, tailings, and refuse. Many of these materials may be disposed of either on-site or off-site, while others may be used or recycled during the active life of the operation. Waste constituents may include base metals, sulfides, or other elements found in the ore, and any additives used in beneficiation operations. The primary waste generated by mineral extraction in underground mines is mine development rock, which is typically used in on-site construction for road building or other purposes. Surface mines usually generate large volumes of overburden and waste rock that are generally disposed of in waste rock dumps.

After the removal of values in the flotation process, the flotation system discharges tailings composed of liquids and solids. Between ¼ and ½ of the tailings generated are made up of solids, mostly gangue material and small quantities of unrecovered lead-zinc minerals. The liquid component of the flotation waste is usually water and dissolved solids, along with any remaining reagents not consumed in the flotation process. These reagents may include cyanide, which is used as a sphalerite depressant during galena flotation. Most operations send these wastes to tailings ponds where solids settle out of the suspension. The liquid component either is recycled back to the mill or discharged if it meets water quality standards. The characteristics of tailings from the flotation process vary

greatly, depending on the ore, reagents, and processes used. Lead, zinc, chromium, iron, and sulfate were all found in the wastewater of the selected facilities.[20]

In general, most wastes from beneficiation of lead-zinc ores are disposed of in tailings impoundments from which water is likely to be reclaimed during the mine's life. In addition, other materials typically not considered wastes, such as mine water, may be managed on-site during the active life of the facility and may ultimately become wastes. The chemical composition of mine water generated at mines varies from site to site and is dependent on the geochemistry of the ore body and the surrounding area. Mine water may also contain small quantities of oil and grease from extraction machinery and nitrates (NO_3) from blasting activities. EPA[21] and the Bureau of Mines[22] reported concentration ranges in mine waters of 0.1-1.9 mg/L for lead, 0.12-0.46 mg/L for zinc, 0.02-0.36 mg/L for chromium, 295-1,825 mg/L for sulfate, and pH of 7.9-8.8. After the mine is closed and pumping stops, the potential exists for mines to fill with water. Water exposed to sulfur-bearing minerals in an oxidizing environment, such as open pits or underground workings, may become acidified.

In addition to wastes generated as part of beneficiation, facilities also store and use a variety of chemicals required by the mine and mill operations. A list of chemicals used at lead-zinc mines, compiled from data collected by the National Institute for Occupational Safety and Health (NIOSH), is provided below.[23]

Acetylene	Propane	Copper Solution
Calcium Oxide	Sodium Cyanide	Kerosene
Hexone	Sulfur Dioxide	Methane, Chlorodifuoro-
Hydrogen Chloride	Sulfuric Acid	Sodium Aerofloat
Methyl Chloroform	Diesel Fuel No. 1	Sulfuric Acid Copper (2+) Salt
Methyl Isobutyl Carbinol	Diesel Fuel No. 2	Zinc Solution
Nitric Acid	Chromic Acid, Disodium Salt	Zinc Sulfate

2. Mineral Processing Wastes

Electrolytic refining operations generate two mineral processing wastes: goethite and leach cake residues, and saleable residues. These are described below. Wastes formerly generated by the closed ZCA refinery in Bartlesville, OK have been removed from the input data set to the Regulatory Impact Analysis. The waste stream descriptions below also have been modified to reflect the fact that wastes from the ZCA facility are no longer being generated.

Spent Goethite and Leach Cake Residues

Goethite is generated to remove iron from the zinc sulfate solution generated by leaching calcine with sulfuric acid. Approximately 15,000 metric tons of goethite are generated annually in the U.S.[24] Site-specific information on management practices for goethite were available for only one facility, ZCA's Bartlesville, OK

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[20] Coppa, L., Waste Disposal Activities and Practices in the United States: Copper, Lead, Zinc, Gold, and Silver, U.S. Bureau of Mines, Division of Minerals Availability Open File Report, November, 1984, Washington, DC.

[21] U.S. Environmental Protection Agency, Report To Congress: Wastes From the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining and Oil Shale, EPA/530/SW-85-033, Office of Solid Waste, December, 1985, Washington, DC.

[22] Coppa, L., 1984, Op. Cit..

[23] National Institute for Occupational Safety and Health, 1990.

[24] U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, August 1992, pp. I-8.

refinery. Moist goethite cake was stored in an uncovered, unlined waste pile on-site that dated from 1978, when the electrolytic process began at the facility. Runoff from the pile flowed to a clay-lined sump pond and then to the facility's wastewater treatment plant. We used best engineering judgment to determine that spent goethite and leach cake residues may exhibit the characteristic of toxicity for arsenic, cadmium, chromium, lead, mercury, selenium, and silver. This waste stream is fully recycled and formerly was classified as a by-product. Data for this waste stream are presented in Attachment 1.

Saleable Residues

Approximately 10,000 metric tons of various saleable residues are recovered annually in the purification of the neutral leach zinc sulfate solution.[25] These include a lead- and silver-bearing filter cake; a copper and cadmium sludge, which is created by adding zinc dust to the solution; and a nickel and cobalt residue, also created by adding zinc dust along with antimony as a catalyst. These residues are stockpiled along with others, such as sump and tank cleanings, on an unlined pad until they are sold or recycled. Runoff from the pad collects in a sump and is pumped to a large surface impoundment and eventually to the wastewater treatment plant. Because these residues are recycled, they are not believed to be solid wastes. JMZ uses its wastewater treatment sludges to produce a commercial product, synthetic gypsum.[26] No chemical characterization data are available at present for these residues.

Oxide retorting, considered a secondary mineral process because it uses primary zinc metal as a feedstock, generates clinker as a secondary mineral processing waste. We used best engineering judgment to determine that this clinker may exhibit the characteristic of toxicity for cadmium.[27]

Production of primary zinc metal at both electrolytic and pyrometallurgical zinc processing plants generate several waste streams common to both processes, as described below.

Process Wastewater

Process wastewater is generated at all three of the operating zinc processing plants. Again using ZCA's formerly active electrolytic refinery in Bartlesville, OK as an example, process wastewaters consisted of small streams from the roasting, purification, electrowinning, and zinc secondary processes, as described above. Process wastewater and plant runoff collected in two large, clay-lined surface impoundments and were pumped to the wastewater treatment plant for neutralization. At ZCA's Monaca, PA smelter, wastewaters include plant runoff as well as process wastewater from the blue powder impoundments and the zinc sulfate circuit. These wastewaters collect in a lined equalization basin and are treated in a two-stage neutralization process. Approximately 6.6 million metric tons of process wastewater are generated annually at the four U.S. primary zinc facilities.[28] (The excessive generation rate for this wastewater [i.e., greater than one million metric tons/yr] is due to commingling of numerous individual waste streams.) We used best engineering judgment to determine that process wastewater may be recycled and may exhibit the characteristic of toxicity for arsenic, cadmium, chromium, lead, selenium, and silver; it may also exhibit the corrosivity characteristic. This waste formerly was classified as a spent material. Data for this waste stream are presented in Attachment 1.

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[25] Ibid.

[26] National Mining Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[27] U.S. Environmental Protection Agency, 1992, Op. Cit., pp. 1-8.

[28] Ibid.

Acid Plant Blowdown

Acid plant blowdown is generated when sulfur dioxide off-gas from the roasting operations passes through a wet electrostatic precipitator to remove solids. At ZCA's Bartlesville plant, two-thirds of the acid plant blowdown was pumped directly to the facility's wastewater treatment plant, and the remaining third was recycled to the hot tower. At the Monaca facility, acid plant blowdown is discharged to a concrete basin where the pH is raised to prevent corrosion of plant piping prior to being returned to the scrubber or being used as feed in the sintering process. Approximately 98,000 metric tons of acid plant blowdown are generated annually at the three U.S. primary zinc facilities.[29] We used best engineering judgment to determine that acid plant blowdown may exhibit the characteristic of toxicity for arsenic, cadmium, chromium, selenium, and silver; it may also exhibit the corrosivity characteristic. Data for this waste stream are presented in Attachment 1. We used best engineering judgment to determine that this waste may also exhibit the characteristic of toxicity for lead and mercury. Although this waste stream is listed as hazardous, it is no longer generated and accordingly, EPA has revoked its listing as a hazardous waste. Therefore, this waste stream was not included in our analysis.

Spent Cloths, Bags, and Filters

Cloths, bags, and filters are utilized in operations at each of the three zinc facilities and may become contaminated with potentially hazardous constituents. Approximately 150 metric tons of these waste materials are generated annually.[30] We used best engineering judgment to determine that spent cloths, bags, and filters may exhibit the characteristic of toxicity for cadmium, lead, mercury, selenium, and silver. This waste stream is recycled and formerly was classified as a spent material.

TCA Tower Blowdown

Approximately 250 metric tons of TCA tower blowdown are generated annually. We used best engineering judgment to determine that TCA tower blowdown may exhibit the characteristic of toxicity for cadmium, lead, mercury, and selenium; it may also exhibit the corrosivity characteristic.

Spent Synthetic Gypsum

Synthetic gypsum is generated during the treatment of bleed electrolyte from the electrowinning circuit. Approximately 16,000 metric tons are generated annually.[31] The management practice for this mineral processing waste is unknown, but the gypsum is most likely stockpiled on-site. We used best engineering judgment to determine that spent synthetic gypsum may exhibit the characteristic of toxicity for arsenic, cadmium, and lead. Data for this waste stream are presented in Attachment 1.

Wastewater Treatment Plant Liquid Effluent

Wastewater treatment plant liquid effluent results from the treatment of process wastewaters, including acid plant blowdown, and plant runoff. Approximately 2.6 million metric tons of effluent are generated annually by the three operating U.S. plants.[32] Effluent generated at ZCA's Bartlesville plant was discharged to a Class I industrial injection well on site, while effluent from the Monaca smelter is discharged through an NPDES-permitted outfall to the Ohio River. We used best engineering judgment to determine that wastewater treatment plant liquid effluent may be partially recycled and may exhibit the characteristic of toxicity for cadmium. This waste stream was formerly classified as a spent material. Data for this wastestream are presented in Attachment 1.

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[29] Ibid.

[30] Ibid.

[31] Ibid.

[32] Ibid.

Wastewater Treatment Plant Sludge

Wastewater treatment plant sludge also results from the treatment of process wastewaters, acid plant blowdown, and plant runoff. Approximately 34,000 metric tons of sludge are generated annually by the three operating U.S. plants.[33] At ZCA's Monaca plant and JMZ's Clarksville plant, these solids are recycled to the zinc ore roaster for recovery of metal values. We used best engineering judgment to determine that wastewater treatment plant sludge may exhibit the characteristic of toxicity for cadmium. Data for this waste stream are presented in Attachment 1.

Spent Surface Impoundment Liquids

Surface impoundment liquid consists of process wastewaters, acid plant blowdown, and plant runoff, the majority of which is sent on to the wastewater treatment plant. Approximately 1.9 million metric tons of liquids are generated annually by the three operating plants.[34] (The high generation rate for this wastewater is due to commingling of numerous individual waste streams.) We used best engineering judgment to determine that spent surface impoundment liquids may exhibit the characteristics of corrosivity and toxicity (cadmium). This waste stream may be partially recycled and was formerly classified as a spent material. Data for this waste stream are presented in Attachment 1.

Spent Surface Impoundment Solids

Surface impoundment solids primarily consist of solids that settle out of sludges from treatment of process water and/or acid plant blowdown. These materials, previously discharged to surface impoundments, are now managed in tanks and containers.[35] Approximately 750 metric tons of solids are generated annually by the three operating plants.[36] We used best engineering judgment to determine that these solids may exhibit the characteristic of toxicity for arsenic, cadmium, lead, mercury, selenium, and silver. Data for this waste stream are presented in Attachment 1.

Smelting of zinc ore concentrate generates four mineral processing wastes: zinc-rich slag, zinc-lean slag, ferrosilicon, and refractory brick.

Zinc-rich Slag

Zinc-rich slag results from the distillation of purified zinc vapor in the electrothermic furnace. Approximately 157,000 metric tons are generated annually at the Monaca facility.[37] EP leach test concentrations of all eight inorganic constituents with EP toxicity regulatory levels are available for one sample of zinc slag from the Monaca facility. Of these constituents, only lead was found to exceed the EP toxicity regulatory level, by a factor of 12. The zinc slag sample that failed the EP toxic level was also analyzed using the SPLP leach test, and the lead concentration measured using the SPLP leach test was three orders of magnitude below the EP toxic level.[38]

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[33] Ibid.

[34] Ibid.

[35] National Mining Association. Comment submitted in response to the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes. January 25, 1996.

[36] U.S. Environmental Protection Agency, 1992, Op. Cit., pp. 1-8.

[37] Ibid.

[38] U.S. Environmental Protection Agency, "Primary Zinc Processing," from Report to Congress on Special Wastes from Mineral Processing, Vol. II, Office of Solid Waste, July 1990, p. 14-3.

However, zinc-rich slag is considered to be a RCRA special waste because of the volume generated; consequently, it is exempt under the Bevill Exclusion from regulation as a hazardous waste. The slag is treated to recover coke and zinc fines, which are recycled to the process, and zinc-lean slag and ferrosilicon.

Zinc-lean Slag

Zinc-lean slag, or processed slag, is stored in slag waste piles, disposed in a flyash landfill, or sold for such uses as road gravel or construction aggregate. Approximately 17,000 metric tons are generated annually at the Monaca facility.[39] We used best engineering judgment to determine that zinc-lean slag may be recycled and may exhibit the characteristic of toxicity for lead. This waste was formerly classified as a by-product. Data for this waste stream are presented in Attachment 1.

Waste Ferrosilicon

Ferrosilicon is accumulated in a stockpile until it can be sold. Approximately 17,000 metric tons are generated annually at the Monaca facility.[40] We used best engineering judgment to determine that waste ferrosilicon may be recycled and may exhibit the characteristic of toxicity for lead. This waste was formerly classified as a by-product. Data for this waste stream are presented in Attachment 1.

Discarded Refractory Brick

Refractory brick is used to line the furnaces in which primary zinc smelting occurs. As furnaces are periodically relined, spent brick is removed from the furnaces and disposed, most likely in a landfill on-site. Approximately 1,000 metric tons of refractory brick are removed from furnaces annually.[41] We used best engineering judgment to determine that refractory brick may exhibit the characteristic of toxicity for arsenic, cadmium, chromium, and lead.

D. Non-uniquely Associated Wastes

There are no non-uniquely associated wastes in this specific sector. However, typical ancillary hazardous and non-hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naptha), and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

New Factual Information

One commenter provided new factual information about management of wastewater treatment plant sludge and spent surface impoundment solids (COMM 58). This commenter also indicated that one smelter, Zinc Corporation of America's electrolytic smelter in Bartlesville, OK is no longer operating. This information has been included in the sector report, and estimated waste streams have been reduced appropriately.

Sector-specific Issues

None.

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[39] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-8.

[40] Ibid.

[41] U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-8.

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ATTACHMENT 1

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SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - GOETHITE AND LEACH CAKE RESIDUES (ELECTROLYTIC) - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	3,130	3,130	3,130	1/1	5.00	5.00	5.00	0/1	-	-
Antimony	100	175	249	2/2	5.00	5.00	5.00	0/1	-	-
Arsenic	953	1,977	3,000	2/2	0.014	2.51	5.00	1/2	5.0	1
Barium	25.00	25.00	25.00	0/1	0.50	2.75	5.00	1/2	100.0	0
Beryllium	2.50	2.50	2.50	0/1	0.50	0.50	0.50	0/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	128	926	2,600	5/5	6.68	7.82	8.96	2/2	1.0	2
Chromium	25.00	37.50	50.00	1/2	0.001	2.50	5.00	0/2	5.0	1
Cobalt	25.00	113	200	1/2	5.00	5.00	5.00	0/1	-	-
Copper	3,400	11,456	24,000	5/5	3.62	14.26	24.90	2/2	-	-
Iron	150,000	273,500	400,000	4/4	0.050	2.53	5.00	0/2	-	-
Lead	2,530	11,606	20,000	5/5	1.43	1.97	2.50	1/2	5.0	0
Magnesium	1,470	1,470	1,470	1/1	70.90	70.90	70.90	1/1	-	-
Manganese	860	860	860	1/1	0.27	15.99	31.70	2/2	-	-
Mercury	0.050	0.050	0.050	0/1	0.0001	0.00345	0.0068	1/2	0.2	0
Molybdenum	25.00	25.00	25.00	0/1	5.00	5.00	5.00	0/1	-	-
Nickel	25.00	62.50	100	1/2	5.00	5.00	5.00	0/1	-	-
Selenium	25.00	25.00	25.00	0/1	0.0010	2.50	5.00	0/2	1.0	1
Silver	0.94	12.08	25.00	2/3	0.015	2.51	5.00	0/2	5.0	1
Thallium	125	125	125	0/1	25.00	25.00	25.00	0/1	-	-
Vanadium	25.00	25.00	25.00	0/1	5.00	5.00	5.00	0/1	-	-
Zinc	38,900	110,780	150,000	5/5	334	737	1,140	2/2	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	35,000	35,000	35,000	1/1	-	-	-	0/0	-	-
Sulfate	33,600	36,800	40,000	2/2	2,278	2,278	2,278	1/1	-	-
Fluoride	-	-	-	0/0	0.30	0.30	0.30	1/1	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	25.60	1,013	2,000	2/2	2.20	2.20	2.20	1/1	-	-
TSS	610,000	610,000	610,000	1/1	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	890	890	890	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - PROCESS WASTEWATER - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	0.050	15.28	123	7/10	0.050	18.27	133	3/8	-	-
Antimony	0.050	0.30	0.93	2/11	0.050	1.53	10.00	2/8	-	-
Arsenic	0.0020	0.52	2.54	4/11	0.020	1.59	10.00	2/10	5.0	1
Barium	0.050	0.20	0.50	3/11	0.050	1.25	10.00	2/10	100.0	0
Beryllium	0.005	0.02	0.05	2/10	0.005	0.14	1.00	0/8	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.0030	93.09	555	17/17	0.023	123	589	10/10	1.0	6
Chromium	0.0010	0.16	0.50	4/11	0.0050	1.13	10.00	1/10	5.0	1
Cobalt	0.050	1.21	6.60	3/10	0.050	2.19	10.00	1/8	-	-
Copper	0.025	19.83	205	7/11	0.050	37.61	289	4/8	-	-
Iron	0.030	373	3,500	12/13	0.050	174	737	3/8	-	-
Lead	0.00050	29.84	300	9/12	0.025	1.27	5.00	6/10	5.0	1
Magnesium	3.02	914	7,160	13/13	2.81	288	2,110	8/8	-	-
Manganese	0.025	311	2,500	9/11	0.050	108	722	6/8	-	-
Mercury	0.00010	0.038	0.348	8/11	0.00010	0.0020	0.014	4/10	0.2	0
Molybdenum	0.050	0.22	0.50	2/8	0.050	1.52	10.00	2/8	-	-
Nickel	0.030	2.48	10.50	4/11	0.050	2.93	12.70	1/8	-	-
Selenium	0.0025	8,333	100,000	2/12	0.0025	1.13	10.00	0/10	1.0	1
Silver	0.0015	0.12	0.50	1/11	0.0015	1.13	10.00	0/10	5.0	1
Thallium	0.024	0.92	3.59	3/11	0.25	7.03	50.00	0/8	-	-
Vanadium	0.005	0.12	0.50	1/11	0.050	1.41	10.00	0/8	-	-
Zinc	3.00	5,872	60,000	25/25	0.37	7,919	40,500	8/8	-	-
Cyanide	0.0050	0.0050	0.0050	0/1	-	-	-	0/0	-	-
Sulfide	4.60	4.60	4.60	1/1	-	-	-	0/0	-	-
Sulfate	155	7,902	60,500	14/14	-	-	-	0/0	-	-
Fluoride	0.30	18.67	56.00	6/6	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	1,300	1,300	1,300	1/1	-	-	-	0/0	-	-
Chloride	1.00	1,277	10,000	16/16	-	-	-	0/0	-	-
TSS	4.40	12,905	99,500	13/13	-	-	-	0/0	-	-
pH *	1.00	5.64	10.50	24/24					2<pH>12	4
Organics (TOC)	4.00	8.25	19.80	9/9					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - ACID PLANT BLOWDOWN - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	2.67	19.99	37.30	2/2	5.00	20.20	35.40	1/2	-	-
Antimony	0.48	0.49	0.50	1/3	0.50	2.75	5.00	0/2	-	-
Arsenic	0.99	1.11	1.20	3/3	1.10	2.12	5.00	3/4	5.0	1
Barium	0.21	0.40	0.50	1/3	0.14	1.45	5.00	1/4	100.0	0
Beryllium	0.050	1,475	4,400	1/3	0.050	0.28	0.50	0/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	3.71	155	840	6/6	0.83	8.58	19.00	4/4	1.0	2
Chromium	0.049	0.35	0.50	1/3	0.03	1.81	5.00	2/4	5.0	1
Cobalt	0.50	0.50	0.50	0/2	0.50	2.75	5.00	0/2	-	-
Copper	1.95	12.63	29.00	3/3	0.17	1.89	5.00	1/3	-	-
Iron	87.10	107	127	2/2	2.39	53.90	79.70	3/3	-	-
Lead	4.11	13.64	23.80	3/3	1.87	2.54	3.70	3/4	5.0	0
Magnesium	9.42	11.21	13.00	2/2	8.52	10.41	12.30	2/2	-	-
Manganese	1.37	4.12	6.87	2/2	0.10	2.20	5.00	2/3	-	-
Mercury	0.26	23,246	162,400	7/7	0.0064	0.079	0.13	4/4	0.2	0
Molybdenum	0.50	0.50	0.50	0/2	0.50	2.75	5.00	0/2	-	-
Nickel	0.50	0.67	1.00	1/3	0.50	2.75	5.00	0/2	-	-
Selenium	2.00	7.87	16.60	3/3	0.055	1.69	5.00	2/4	1.0	2
Silver	0.50	0.66	0.98	1/3	0.015	1.53	5.00	1/4	5.0	1
Thallium	0.0090	1.67	2.50	1/3	2.50	13.75	25.00	0/2	-	-
Vanadium	0.0010	0.33	0.50	1/3	0.50	2.75	5.00	0/2	-	-
Zinc	180	2,992	13,200	13/13	21.30	588	1,570	3/3	-	-
Cyanide	0.085	0.085	0.085	1/1	-	-	-	0/0	-	-
Sulfide	330	330	330	1/1	_	-	-	0/0	-	-
Sulfate	1,860	12,340	43,193	6/6	7,330	7,330	7,330	1/1	-	-
Fluoride	11.00	1,317	11,400	12/12	23.00	23.00	23.00	1/1	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	1.00	1,343	5,100	11/11	547	547	547	1/1	-	-
TSS	5,490	14,395	23,300	2/2	_	-	-	0/0	-	-
pH *	0.50	1.67	3.40	8/8					2<pH>12	6
Organics (TOC)	3.30	3.71	4.00	3/3					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SYNTHETIC GYPSUM - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	1,954	2,945	3,935	2/2	0.0030	0.0040	0.0050	1/2	5.0	0
Barium	-	-	-	0/0	0.80	2.25	3.70	2/2	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	665	779	893	2/2	0.52	5.81	11.10	2/2	1.0	1
Chromium	-	-	-	0/0	0.0010	0.0010	0.0010	0/2	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	0.51	0.51	0.51	2/2	-	-
Iron	-	-	-	0/0	0.15	0.23	0.30	2/2	-	-
Lead	290	296	302	2/2	2.36	3.00	3.63	2/2	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	0.57	23.24	45.90	2/2	-	-
Mercury	-	-	-	0/0	0.0029	0.016	0.029	2/2	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	0.0010	0.0010	0.0010	0/2	1.0	0
Silver	-	-	-	0/0	0.015	0.018	0.020	0/2	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	-	-	-	0/0	10.70	417	824	2/2	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	1,160	1,795	2,430	2/2	-	-
Fluoride	-	-	-	0/0	0.40	0.45	0.50	2/2	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	0.15	1.43	2.70	1/2	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	5.01	5.08	5.15	2/2					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT LIQUID EFFLUENT - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	0.027	0.039	0.050	1/2	5.0	0
Barium	-	-	-	0/0	0.50	3.25	6.00	1/2	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	1.00	12,101	24,200	2/2	0.070	0.125	0.180	2/2	1.0	0
Chromium	-	-	-	0/0	0.012	0.019	0.025	1/2	5.0	0
Cobalt	3,100	3,100	3,100	1/1	-	-	-	0/0	-	-
Copper	1,300	1,300	1,300	1/1	0.030	0.030	0.030	0/1	-	-
Iron	17,200	17,200	17,200	1/1	53.90	53.90	53.90	1/1	-	-
Lead	6,100	6,100	6,100	1/1	1.00	1.82	2.64	2/2	5.0	0
Magnesium	50.00	5,225	10,400	2/2	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	49.50	49.50	49.50	1/1	-	-
Mercury	-	-	-	0/0	0.000050	0.0012	0.0023	1/2	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	410	410	410	1/1	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	0.0030	0.102	0.20	2/2	1.0	0
Silver	58.29	58.29	58.29	1/1	0.020	0.045	0.070	1/2	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	20.00	150,673	450,000	3/3	1,320	1,320	1,320	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	545,000	545,000	545,000	1/1	1,340	1,340	1,340	1/1	-	-
Fluoride	-	-	-	0/0	18.50	18.50	18.50	1/1	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	102	102	102	1/1	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	4.88	6.73	8.80	3/3					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - WASTEWATER TREATMENT PLANT SLUDGE - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	23.80	1,887	3,750	2/2	0.13	2.40	4.67	2/2	-	-
Antimony	0.60	24.10	47.60	1/2	0.00080	0.035	0.070	0/2	-	-
Arsenic	0.46	57.23	114	1/2	0.0055	0.063	0.12	0/2	5.0	0
Barium	0.30	33.65	67.00	2/2	0.11	0.31	0.48	3/3	100.0	0
Beryllium	0.042	0.87	1.70	1/2	0.0050	0.0055	0.0059	1/2	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	44.40	11,415	24,200	3/3	0.19	0.88	2.13	3/3	1.0	1
Chromium	1.20	17.65	34.10	2/2	0.0015	0.049	0.099	2/3	5.0	0
Cobalt	3.30	1,171	3,100	3/3	0.82	1.50	2.18	2/2	-	-
Copper	8.20	1,159	2,170	3/3	0.020	0.68	1.35	1/2	-	-
Iron	407	12,736	20,600	3/3	13.83	25.06	36.30	2/2	-	-
Lead	55.50	4,862	8,430	3/3	0.42	1.85	4.56	3/3	5.0	0
Magnesium	1,980	6,740	10,400	3/3	74.70	267	460	2/2	-	-
Manganese	189	4,465	8,740	2/2	31.68	50.09	68.50	2/2	-	-
Mercury	4.10	12.20	20.30	2/2	0.00010	0.0075	0.022	1/3	0.2	0
Molybdenum	0.25	1.40	2.55	1/2	0.0088	0.012	0.015	1/2	-	-
Nickel	4.50	256	410	3/3	1.21	1.40	1.58	2/2	-	-
Selenium	5.60	113	220	2/2	0.0015	0.018	0.044	1/3	1.0	0
Silver	0.55	43.25	70.90	3/3	0.0051	0.017	0.024	3/3	5.0	0
Thallium	2.40	25.70	49.00	0/2	0.57	0.58	0.58	2/2	-	-
Vanadium	0.13	1.34	2.55	1/2	0.0036	0.009	0.015	1/2	-	-
Zinc	2,000	249,250	526,000	4/4	571	1,540	2,510	2/2	-	-
Cyanide	0.51	0.51	0.51	0/1	0.0050	0.0050	0.0050	0/1	-	-
Sulfide	3,120	3,120	3,120	1/1	143	143	143	1/1	-	-
Sulfate	545,000	545,000	545,000	1/1	-	-	-	0/0	-	-
Fluoride	173	173	173	1/1	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	430,000	430,000	430,000	1/1	-	-	-	0/0	-	-
pH *	8.80	9.38	9.96	2/2					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT LIQUIDS - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	990	990	990	1/1	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	214	214	214	1/1	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.00	2,834	40,000	16/16	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	3358	3,358	3,358	1/1	-	-	-	0/0	-	-
Iron	200	7,905	19,420	4/4	-	-	-	0/0	-	-
Lead	0.70	38,075	200,000	6/6	-	-	-	0/0	5.0	0
Magnesium	800	14,580	53,000	4/4	-	-	-	0/0	-	-
Manganese	22.90	162	302	2/2	-	-	-	0/0	-	-
Mercury	0.00	4.92	23.80	4/4	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	257	257	257	1/1	-	-	-	0/0	-	-
Selenium	11.00	11.00	11.00	1/1	-	-	-	0/0	1.0	0
Silver	185	185	185	1/1	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	0.80	132,673	800,000	22/22	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	0	10,955	35,000	3/3	-	-	-	0/0	-	-
Fluoride	0.00	216	2,300	12/12	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	0	990	2,800	8/8	-	-	-	0/0	-	-
TSS	41.00	41.20	41.40	2/2	-	-	-	0/0	-	-
pH *	2	6.02	10	23/23					2<pH>12	3
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - SURFACE IMPOUNDMENT SOLIDS - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	-	-	-	0/0	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	1.00	1.00	1.00	1/1	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	-	-	-	0/0	-	-	-	0/0	-	-
Lead	-	-	-	0/0	-	-	-	0/0	5.0	0
Magnesium	50.00	50.00	50.00	1/1	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	20.00	20.00	20.00	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	-	-	-	0/0	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	6.50	6.50	6.50	1/1					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - ZINC - LEAN SLAG (SMELTING) - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	8,120	24,060	40,000	2/2	1.45	1.45	1.45	1/1	-	-
Antimony	33.50	33.50	33.50	1/1	0.50	0.50	0.50	0/1	-	-
Arsenic	5.00	5.00	5.00	0/1	0.50	0.50	0.50	0/1	5.0	0
Barium	129	129	129	1/1	0.50	0.50	0.50	0/1	100.0	0
Beryllium	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	0.50	0.50	0.50	0/1	0.050	0.050	0.050	0/1	1.0	0
Chromium	22.70	22.70	22.70	1/1	0.50	0.50	0.50	0/1	5.0	0
Cobalt	5.00	5.00	5.00	0/1	0.50	0.50	0.50	0/1	-	-
Copper	650	650	650	1/1	0.50	0.50	0.50	0/1	-	-
Iron	7,240	73,620	140,000	2/2	27.20	27.20	27.20	1/1	-	-
Lead	1,720	2,860	4,000	2/2	59.40	59.40	59.40	1/1	5.0	1
Magnesium	1,100	1,100	1,100	1/1	8.16	8.16	8.16	1/1	-	-
Manganese	1,670	1,670	1,670	1/1	25.60	25.60	25.60	1/1	-	-
Mercury	0.050	0.050	0.050	0/1	0.00010	0.00010	0.00010	0/1	0.2	0
Molybdenum	10.60	10.60	10.60	1/1	0.50	0.50	0.50	0/1	-	-
Nickel	86.10	86.10	86.10	1/1	4.82	4.82	4.82	0/1	-	-
Selenium	5.00	5.00	5.00	0/1	0.50	0.50	0.50	0/1	1.0	0
Silver	5.00	5.00	5.00	0/1	0.50	0.50	0.50	0/1	5.0	0
Thallium	25.00	25.00	25.00	0/1	2.50	2.50	2.50	0/1	-	-
Vanadium	10.50	10.50	10.50	1/1	0.50	0.50	0.50	0/1	-	-
Zinc	6,710	58,355	110,000	2/2	325	325	325	1/1	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	943	943	943	1/1	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	100,000	100,000	100,000	1/1	-	-	-	0/0	-	-
Chloride	24.80	24.80	24.80	1/1	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	2,940	2,940	2,940	1/1					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

SUMMARY OF EPA/ORD, 3007, AND RTI SAMPLING DATA - FERROSILICON (SMELTING) - ZINC

	Total Constituent Analysis - PPM				EP Toxicity Analysis - PPM				TC	# Values
Constituents	Minimum	Average	Maximum	# Detects	Minimum	Average	Maximum	# Detects	Level	In Excess
Aluminum	40,000	40,000	40,000	1/1	-	-	-	0/0	-	-
Antimony	-	-	-	0/0	-	-	-	0/0	-	-
Arsenic	-	-	-	0/0	-	-	-	0/0	5.0	0
Barium	-	-	-	0/0	-	-	-	0/0	100.0	0
Beryllium	-	-	-	0/0	-	-	-	0/0	-	-
Boron	-	-	-	0/0	-	-	-	0/0	-	-
Cadmium	-	-	-	0/0	-	-	-	0/0	1.0	0
Chromium	-	-	-	0/0	-	-	-	0/0	5.0	0
Cobalt	-	-	-	0/0	-	-	-	0/0	-	-
Copper	-	-	-	0/0	-	-	-	0/0	-	-
Iron	300,000	300,000	300,000	1/1	-	-	-	0/0	-	-
Lead	5,000	5,000	5,000	1/1	-	-	-	0/0	5.0	0
Magnesium	-	-	-	0/0	-	-	-	0/0	-	-
Manganese	-	-	-	0/0	-	-	-	0/0	-	-
Mercury	-	-	-	0/0	-	-	-	0/0	0.2	0
Molybdenum	-	-	-	0/0	-	-	-	0/0	-	-
Nickel	-	-	-	0/0	-	-	-	0/0	-	-
Selenium	-	-	-	0/0	-	-	-	0/0	1.0	0
Silver	-	-	-	0/0	-	-	-	0/0	5.0	0
Thallium	-	-	-	0/0	-	-	-	0/0	-	-
Vanadium	-	-	-	0/0	-	-	-	0/0	-	-
Zinc	40,000	40,000	40,000	1/1	-	-	-	0/0	-	-
Cyanide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfide	-	-	-	0/0	-	-	-	0/0	-	-
Sulfate	-	-	-	0/0	-	-	-	0/0	-	-
Fluoride	-	-	-	0/0	-	-	-	0/0	-	-
Phosphate	-	-	-	0/0	-	-	-	0/0	-	-
Silica	120,000	120,000	120,000	1/1	-	-	-	0/0	-	-
Chloride	-	-	-	0/0	-	-	-	0/0	-	-
TSS	-	-	-	0/0	-	-	-	0/0	-	-
pH *	-	-	-	0/0					2<pH>12	0
Organics (TOC)	-	-	-	0/0					-	-

Non-detects were assumed to be present at 1/2 the detection limit. TCLP data are currently unavailable; therefore, only EP data are presented.

ZIRCONIUM AND HAFNIUM

A. Commodity Summary

Zirconium and hafnium occur most commonly in nature as the mineral zircon and less commonly as baddeleyite. Zircon is used both for its properties as a mineral and as an ore of zirconium and hafnium. Zircon is a byproduct from the mining and processing of heavy mineral sands for rutile and ilmenite. Zirconium and hafnium occur together in ores at ratios of about 50:1.[1]

Zircon sand is produced at two mines in Florida. Zirconium metal is extracted from imported zircon sand by two domestic producers, one in Oregon and the other in Utah. Exhibit 1 presents the names and locations of facilities associated with the production of zirconium/hafnium.

EXHIBIT 1

SUMMARY OF ZIRCONIUM/HAFNIUM MINING AND PROCESSING FACILITIES

Facility Name	Location	Operations/Products
Du Pont	Trail Ridge, FL	Mining, extraction
RGC	NE Florida	Mining, extraction
Teledyne	Albany, OR	Metals, and alloys
Western Zirconium	Ogden, UT	Metals, and alloys

The two metals can remain unseparated for all uses except nuclear applications. Because of the extremely opposite absorption characteristics for thermal neutrons in nuclear reactor cores, the zirconium-cladded fuel rods must be hafnium free. The strong-absorbing hafnium, if present, would decrease the relative transparency of the zirconium cladding, and the reactor's efficiency. For this reason, hafnium is used in reactor control rods to regulate the fission process via neutron absorption. Hafnium is also used as an additive in superalloys, as refractory and cutting tool coatings, and in oxide and nitride forms. Nuclear fuel rod cladding accounts for most of zirconium's use. Zircon refractories and foundry sands are used primarily in the production of finished metal and glass products.[2]

B. Generalized Process Description

1. Discussion of Typical Processes

Zircon is mined from a shoreline deposit in Green Cove Springs, FL and from the Trail Ridge deposit in north central Florida. Sand ores are mined with dredges, bulldozers, and elevating scrapers. The production processes used at primary zirconium and hafnium manufacturing plants depend largely on the raw material used. Six basic operations may be performed: (1) sand chlorination, (2) separation, (3) calcining, (4) pure chlorination, (5) reduction, and (6) purification. Plants that produce zirconium and hafnium from zircon sand use all six of these process steps. Plants which produce zirconium from zirconium dioxide practice reduction and purification only.

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[1] Thomas E. Garner, "Zirconium and Hafnium Minerals," from Industrial Minerals and Rocks, 6th ed., Society for Mining, Metallurgy, and Exploration, 1994, pp. 1159-1164.

[2] Ibid.

Exhibit 2 presents a process flow diagram for primary zirconium and hafnium production. These processes are described in further detail below.[3]

2. Generalized Process Flow Diagram

Sand Chlorination

After drying, concentrated zircon sand is mixed with coke, ground, and fed continuously to the top of a fluidized bed chlorinator. The basic sand chlorination reaction is as follows:

$$ZrSiO_4 + 2C + 4Cl_2 - ZrCl_4 + SiCl_4 + 2CO_2$$

Crude zirconium tetrachloride and silicon tetrachloride are condensed from the off-gases. ("Crude zirconium tetrachloride" is a mixture of zirconium tetrachloride and hafnium tetrachloride.) The crude zirconium tetrachloride is then hydrolyzed with water and the resulting solution is filtered to remove suspended solids. The reaction is as follows[4]:

$$ZrCl_4 + H_2O - ZrOCl_2 + 2HCl$$

Separation

Iron is removed from the zirconium-hafnium solution from the feed makeup step by extraction. The iron free zirconium and hafnium solution is passed through a series of liquid-liquid extractions, stripping, and scrubbing steps to separate zirconium from hafnium. Liquid-liquid extraction, using methyl isobutyl ketone (containing thiocyanate) as a solvent, separates zirconium from hafnium by preferentially extracting hafnium into the solvent phase. The zirconium ions are "complexed" with the ammonium thiocyanate and the hafnium is preferentially extracted by the MIBK. The solvent, MIBK, and the complexing agent, ammonium thiocyanate, are recovered by steam stripping and recycled to the process.[5] (According to a facility representative from Teledyne Wah Chang in Albany, Oregon, there is no ammonium thiocyanate bleed stream.[6])

Hafnium is stripped from the solvent to the aqueous phase by acidification and the recovered solvent is recycled, after treatment, within the separation operations. The hafnium solution is reacted with ammonium hydroxide to precipitate hafnium hydroxide. The precipitate is recovered by filtration and the residual wastewater discharged to treatment. After drying, the hafnium hydroxide is either stored or calcined to produce hafnium dioxide.[7]

Zirconium is recovered from the aqueous zirconium stream through chemical treatment and further extraction with methyl isobutyl ketone. Zirconium is precipitated and filtered as zirconium sulfate. The filter cake

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[3] U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Vol. IX, Office of Water Regulations and Standards, May 1989, pp. 5081-5106.

[4] Ibid.

[5] J.H. Schemel, ASTM Manual on Zirconium and Hafnium, American Society for Testing and Materials, 1977, pp. 58-59.

[6] Personal communication between ICF Incorporated and Chuck Knoll, Manager of Environmental Affairs, Teledyne Wah Chang, Albany, Oregon, October 24, 1994.

[7] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 5081-5106.

EXHIBIT 2

PRIMARY ZIRCONIUM AND HAFNIUM PRODUCTION

(Adapted from: Development Document for Effluent Limitations Guidelines, 1989, pp. 5081 - 5106.)

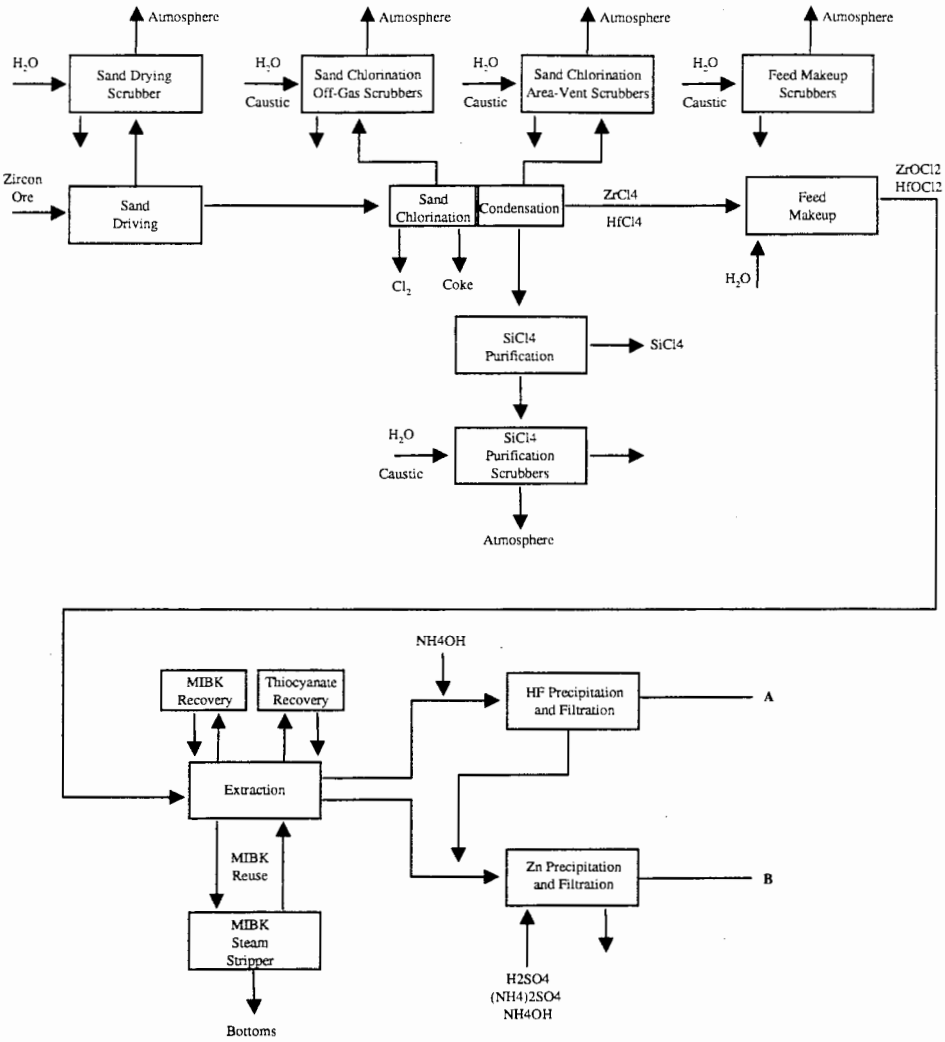


EXHIBIT 2 (CONTINUED)

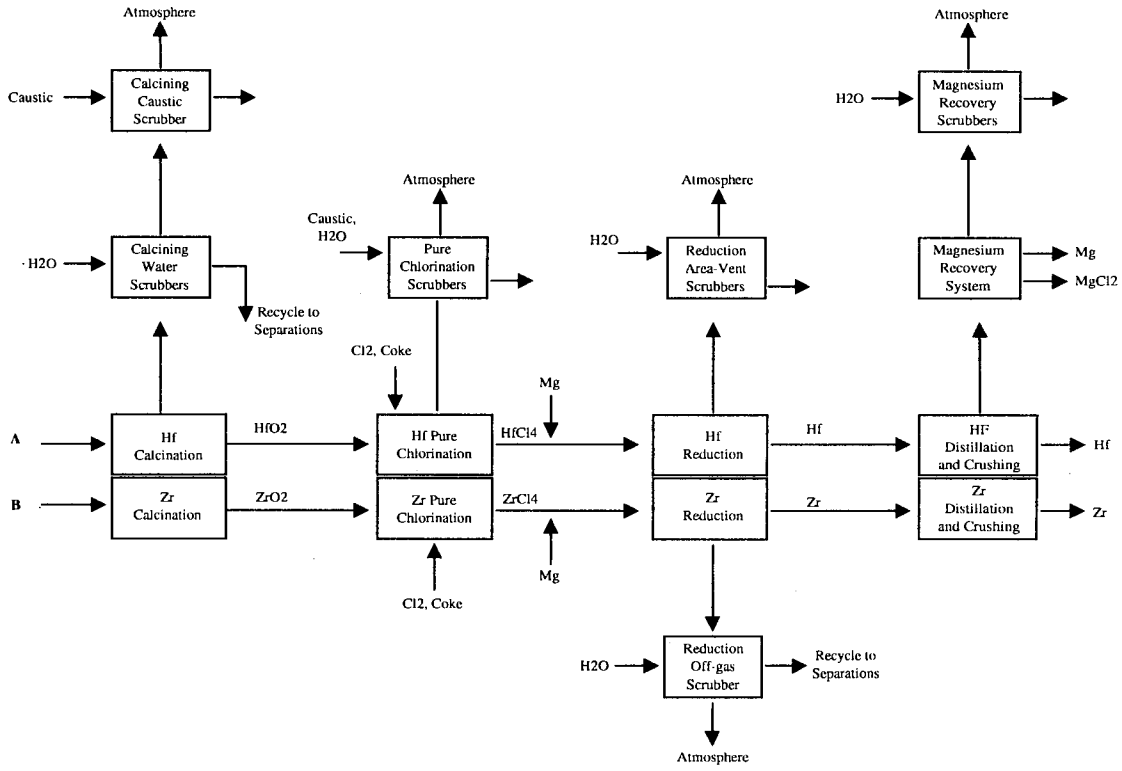
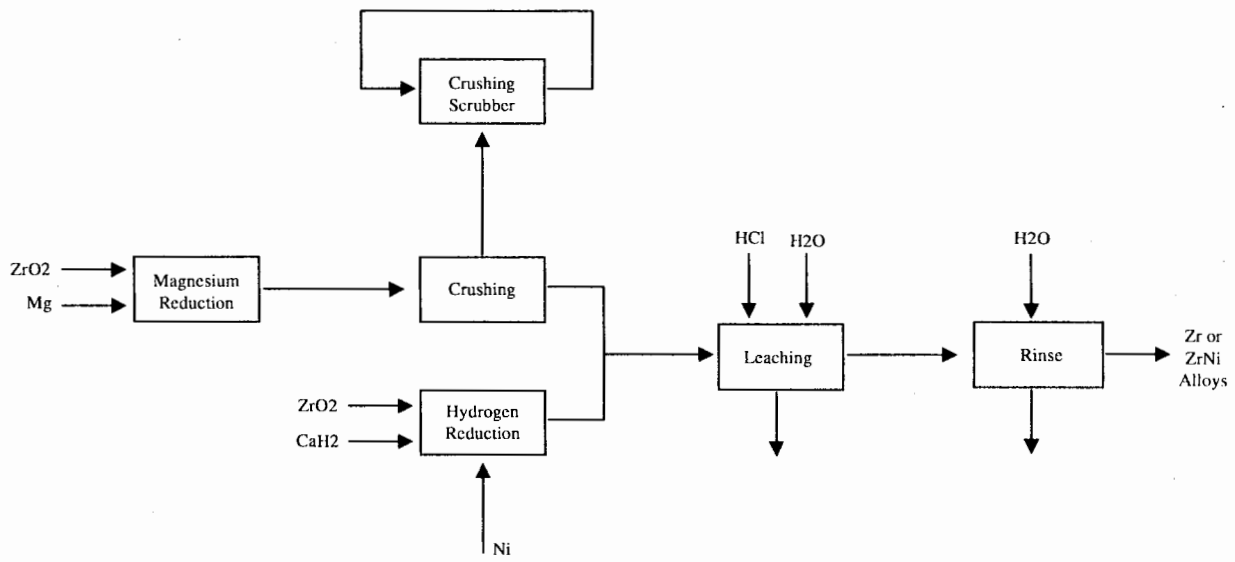


EXHIBIT 2 (CONTINUED)



can be either sent to calcining or repulped with ammonium hydroxide. Ammonium hydroxide is added to convert the zirconium sulfate to zirconium hydroxide and to remove trace metals from the zirconium product. The precipitate is filtered to remove water and sent to the calcining furnace for further processing.[8]

Calcining

From this point on in the process, zirconium and hafnium are processed separately but identically. The hafnium and zirconium filter cakes are calcined to produce hafnium oxide and zirconium oxide, respectively. Scrubber water from calciner emission control operations is recycled to the separation process to recover zirconium and hafnium.[9]

Pure Chlorination

Pure chlorination is essentially the same process as sand chlorination. The pure zirconium or hafnium oxide is mixed with fine coke and reacted with chlorine to produce the tetrachloride gas. The pure zirconium or hafnium tetrachloride is then recovered in condensers.[10]

Reduction

The zirconium tetrachloride and hafnium tetrachloride are reduced to their respective metals in a batch process using magnesium in a reduction furnace. The tetrachloride is added to magnesium in a retort furnace where it is converted to zirconium or hafnium metal and magnesium chloride. Off-gases from the furnace pass through a water scrubber before being released. The scrubber blowdown is recycled to the separation process to recover zirconium and hafnium.[11]

Zirconium oxide is mixed with magnesium metal powder and placed in a steel cylinder. The cylinder is then place in a furnace and retorted. Once initiated, the reaction becomes self-sustaining. Zirconium metal sponge and magnesium oxide are produced.[12]

Zirconium oxide can also be used to produce zirconium-nickel alloys. The process is similar to the magnesium reduction operation except that calcium hydride is used as the reducing agent in the furnace and nickel is added directly to the mixture of zirconium oxide and calcium.[13]

Purification

When zirconium or hafnium metal is produced by magnesium reduction of the tetrachloride, a crude metal regulus with magnesium chloride is formed in the furnace. The magnesium chloride is separated from the zirconium or hafnium regulus to produce zirconium or hafnium sponge.[14]

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[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] Ibid.

[12] Ibid.

[13] Ibid.

[14] Ibid.

A different purification process is used when zirconium metal or zirconium-nickel- alloys are produced by magnesium reduction of zirconium oxide. The zirconium sponge is removed from the reduction cylinder and pulverized. The impurities are leached out with acid, and the purified metal is rinsed with water. The product is then dried and sold as metal or alloy powder.[15]

3. Identification/Discussion of Novel (or otherwise distinct) Processes

A less complicated method may be found to separate hafnium from zirconium and to refine the hafnium. A new process is being developed where zirconium and hafnium are separated by fractional distillation of the zirconium tetrachloride. Such a process would eliminate the liquid-liquid extraction and associated precipitation, calcination, and rechlorination steps currently used.[16]

4. Beneficiation/Processing Boundaries

EPA established the criteria for determining which wastes arising from the various mineral production sectors come from mineral processing operations and which are from beneficiation activities in the September 1989 final rule (see 54 Fed. Reg. 36592, 36616 codified at 261.4(b)(7)). In essence, beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing. A chemical change in the mineral value does not typically occur in beneficiation.

Mineral processing operations, in contrast, generally follow beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting) or chemical reactions (e.g., acid digestion, chlorination) to change the chemical composition of the mineral. In contrast to beneficiation operations, processing activities often destroy the physical and chemical structure of the incoming ore or mineral feedstock such that the materials leaving the operation do not closely resemble those that entered the operation. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting or chemical changes.

EPA approached the problem of determining which operations are beneficiation and which (if any) are processing in a step-wise fashion, beginning with relatively straightforward questions and proceeding into more detailed examination of unit operations, as necessary. To locate the beneficiation/processing "line" at a given facility within this mineral commodity sector, EPA reviewed the detailed process flow diagram(s), as well as information on ore type(s), the functional importance of each step in the production sequence, and waste generation points and quantities presented above.

EPA determined that for this specific mineral commodity sector, the beneficiation/processing line occurs between ore preparation and sand chlorination because it is where a significant change to the metal occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

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[15] Ibid.

[16] Timothy Adams, "Zirconium and Hafnium," from Mineral Facts and Problems, U.S. Bureau of Mines, 1985, pp. 941-956.

C. Process Waste Streams

1. Extraction/Beneficiation Wastes

Sand Drying Wet Air Pollution Control (APC)

Wastewater.

Monazite inclusions within the zircon grains and/or ionic substitution of uranium, thorium, radium, and/or actinium for the zirconium and/or hafnium within the mineral lattice result in some radioactive contamination.[17]

2. Mineral Processing Wastes

Sand Chlorination

Existing data and engineering judgement suggest that the wastes listed below from sand chlorination do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

Silicon tetrachloride purification wet APC wastewater. Silicon tetrachloride purification requires wet air pollution control. That process practices 96 percent recycle of the scrubberwater before discharging it. The existing treatment for this wastewater consists of chemical precipitation and sedimentation. This waste is discharged at a rate of 7,498 l/kkg of zirconium dioxide and hafnium dioxide produced.[18]

Sand chlorination off-gas wet APC wastewater. After zircon ore is chlorinated, crude zirconium-tetrachloride and silicon tetrachloride are separated and recovered from the off-gases using a series of condensers. Wet air pollution control equipment is used to remove residual chlorine gas and particulates from the condenser off-gases. While one plant has achieved zero discharge of this wastewater stream using evaporation ponds, other plants discharge this stream after dechlorination, chemical precipitation, and sedimentation. Extensive recycle of scrubber liquor is practiced. This waste is generated at a rate of 16,540 to 43,470 l/kkg of zirconium dioxide and hafnium dioxide produced.[19]

Sand chlorination area-vent APC wastewater. Ventilation vapors from the sand chlorination area are routed to wet air pollution control equipment before being released to the atmosphere. At one plant, which reports a separate waste stream for area-vent scrubbers, the wastewater generated is discharged after dechlorination, chemical precipitation, and sedimentation. That plant reported recycling 96 percent of this wastewater. This waste is discharged at a rate of 8,524 l/kkg of zirconium dioxide and hafnium dioxide produced.[20]

Feed makeup wet APC wastewater. This wastewater is characterized by treatable concentrations of suspended solids, zirconium, cyanide, and a low pH. Feed makeup steps are intended to remove suspended solids from crude zirconium-hafnium tetrachloride. This process uses wet scrubbing systems to control emissions. A high rate of recycle and reuse (92 to 100 percent) of the feed makeup scrubber liquor is achieved prior to discharge.

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[17] Joseph M. Gambogi, "Zirconium and Hafnium," from Minerals Yearbook Volume 1. Metals and Minerals, U.S. Bureau of Mines, 1992, pp. 1487-1494.

[18] U.S. Environmental Protection Agency, 1989, Op.Cit., pp. 5081-5106.

[19] Ibid.

[20] Ibid.

Chemical precipitation and sedimentation is practiced for this waste stream. This waste is discharged at a rate of 5683 l/kkg of hafnium dioxide and zirconium dioxide produced.[21]

Separation

Existing data and engineering judgement indicate that the wastes listed below from separation do not exhibit characteristics of hazardous wastes. Therefore, the Agency did not evaluate these materials further.

Hafnium filtrate wastewater. Separated hafnium is precipitated from solution and filtered before being sent to the calcining furnace. The filtrate can be reused in the separation process to recover its zirconium content or disposed of in evaporation ponds.[22]

Zirconium filtrate wastewater. Separated zirconium is precipitated from solution and filtered before being sent to the calcining furnace. This wastestream is not recycled or reused. When this wastewater is discharged, it is treated by ammonia steam stripping, chemical precipitation, and sedimentation. This waste is generated at a rate of 37,640 to 39,900 l/kkg of zirconium dioxide and hafnium dioxide produced.[23]

Iron extraction (methyl isobutyl ketone) steam stripper bottoms. MIBK is recovered from the iron extraction wastewater stream using a steam stripper, from which the bottoms are discharged. When this stream is discharged, it is treated by ammonia steam stripping, chemical precipitation, and sedimentation.[24]

Ammonium thiocyanate bleed stream. Ammonium thiocyanate is recycled to the process. As stated before, according to a facility representative from Teledyne Wah Chang in Albany, Oregon, there is no ammonium thiocyanate bleed stream.

Calcination

Existing data and engineering judgement suggest that the wastes listed below from calcination do not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate these materials further.

Caustic wet APC wastewater. Wet air pollution control systems are used to clean the off-gases from the calcining furnaces. A high rate, 90 percent, of recycle or reuse of the discharge from the water scrubbers in the separations process is achieved. When the blowdown from this operation is discharged it is treated by dechlorination, chemical precipitation, and sedimentation. This waste is discharged at a rate of 1,539 to 8,997 l/kkg of hafnium dioxide and zirconium dioxide produced.[25]

Filter cake/sludge. Zirconium and hafnium filter cakes are calcined to produce zirconium oxide and hafnium oxide, respectively.

Furnace residue.

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[21] Ibid.

[22] Ibid.

[23] Ibid.

[24] Ibid.

[25] Ibid.

Pure Chlorination

Wet APC wastewater. Pure chlorination is similar to sand chlorination except that the chlorination of zirconium oxide and hafnium oxide is carried out in separate reactors at lower temperatures. The scrubbers used for reactor off-gasses and area ventilation vapors discharge a wastewater stream. This stream may be recycled and the blowdown is treated by dechlorination, chemical precipitation, and sedimentation before being discharged. It contains zirconium and chlorine as well as suspended solids. This waste is discharged at a rate of 38,317 l/kkg of zirconium and hafnium produced.[26] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of a hazardous waste. Therefore, the Agency did not evaluate this material further.

Reduction

Reduction area-vent wet air pollution control wastewater. The plants that reduce zirconium and hafnium tetrachloride to metal use scrubbers for area ventilation vapors. The scrubber liquor is recycled before it is discharged after treatment by chemical precipitation and sedimentation. This waste is discharged at a rate of 3,686 l/kkg of zirconium and hafnium produced.[27] Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Purification

Leaching rinse water from zirconium or hafnium metal production. After leaching with acid to remove impurities, the zirconium and hafnium metals are rinsed with water, dried, and packaged for sale. Treatment for this stream may consist of pH adjustment before discharge.[28] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 200 metric tons/yr, 1,000,000 metric tons/yr, and 2,000,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of corrosivity prior to treatment. This waste is classified as a spent material.

Leaching rinse water from zirconium and hafnium alloy production. After leaching with acid to remove impurities, the zirconium and hafnium alloys are rinsed with water, dried, and packaged for sale.[29] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 34,000 metric tons/yr, 42,000 metric tons/yr, and 51,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of corrosivity prior to treatment. This waste is classified as a spent material.

Spent acid leachate from zirconium and hafnium metal production. When zirconium and hafnium metals are purified by leaching, the resulting leachate is not reused or recycled. Existing treatment for this wastewater stream may consist of pH adjustment before discharge.[30] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 0 metric tons/yr, and 1,600,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of corrosivity.

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[26] U.S. Environmental Protection Agency, 1989, Op. Cit., pp. 5081-5106.

[27] Ibid.

[28] Ibid.

[29] Ibid.

[30] Ibid.

Spent acid leachate from zirconium and hafnium alloy production. When zirconium and hafnium alloys are purified by leaching, the resulting leachate is not reused or recycled. Existing treatment for this wastewater stream may consist of pH adjustment before discharge.[31] Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 0 metric tons/yr, 0 metric tons/yr, and 850,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristic of corrosivity.

Existing data and engineering judgement suggest that the purification wastes listed below do not exhibit any characteristics of hazardous wastes. Therefore, the Agency did not evaluate these materials further.

Zirconium chip crushing wet APC wastewater. The zirconium sponge formed by reduction is removed from the reduction container and crushed. Scrubbers, installed for air pollution control in the crushing operation, generate a wastewater. Zero discharge of this wastewater is achieved by 100 percent recycle of the scrubber liquor.[32]

Magnesium recovery off-gas wet APC wastewater. Scrubbers, installed for air pollution control in the magnesium recovery area, discharge a wastewater which is characterized by treatable concentrations of magnesium and solids. The scrubber liquor may be recycled prior to treatment which consists of chemical precipitation and sedimentation followed by discharge. This waste is discharged at a rate of 20,733 l/kkg of zirconium and hafnium produced.[33]

Magnesium recovery area vent wet APC wastewater. Ventilation air from the magnesium recovery area passes through a wet scrubber prior to being released to the atmosphere. The scrubber liquor is recycled prior to discharge and treatment consists of chemical precipitation and sedimentation. This waste is discharged at a rate of 11,518 l/kkg of zirconium and hafnium produced.[34]

D. Non-uniquely Associated Wastes

Non-uniquely associated and ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents, and acidic tank cleaning wastes. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

E. Summary of Comments Received by EPA

EPA received no comments that address this specific sector.

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[31] Ibid.

[32] Ibid.

[33] Ibid.

[34] Ibid.

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IV. SUMMARY OF FINDINGS

After careful review, EPA has determined that 48 mineral commodity sectors generated a total of 553 waste streams that could be classified as either extraction/beneficiation or mineral processing wastes (Exhibit 4-1). Based on further analysis, the Agency identified 358 waste streams out of the total that could be designated as mineral processing wastes from 40 mineral commodity sectors.

Exhibit 4-2 presents the 358 mineral processing wastes by commodity sector. Of these 358 waste streams, EPA has sufficient information (based on either analytical test data or engineering judgment) to determine that 133 waste streams are potential RCRA hazardous wastes because they may exhibit one or more of the RCRA hazardous characteristics (toxicity, ignitability, corrosivity, or reactivity) and, thus, would be subject to the Land Disposal Restrictions. The hazardous waste streams and their characteristics are listed in Exhibit 4-3. The mineral processing commodity sectors that generate these wastes are shown in Exhibit 4-4. This exhibit also summarizes the total number of hazardous waste streams by sector and the estimated total volume of hazardous wastes generated annually.

At this time, EPA does not have sufficient information to determine if the following eight sectors also generate wastes that could be classified as mineral processing wastes: Bromine, Gemstones, Iodine, Lithium, Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium.

EXHIBIT 4-1

SUMMARY OF EXTRACTION/BENEFICIATION AND MINERAL PROCESSING WASTE STREAMS BY COMMODITY

Commodity	Waste Stream	Nature of Operation
Alumina and Aluminum	Water softener sludge	Extraction/Beneficiation
	Anode prep waste	Mineral Processing
	APC dust/sludge	Mineral Processing
	Baghouse bags and spent plant filters	Mineral Processing
	Bauxite residue	Mineral Processing
	Cast house dust	Mineral Processing
	Cryolite recovery residue	Mineral Processing
	Wastewater	Mineral Processing
	Discarded Dross	Mineral Processing
	Flue Dust	Mineral Processing
	Electrolysis waste	Mineral Processing
	Evaporator salt wastes	Mineral Processing
	Miscellaneous wastewater	Mineral Processing
	Pisolites	Mineral Processing
	Scrap furnace brick	Mineral Processing
	Skims	Mineral Processing
	Sludge	Mineral Processing
	Spent cleaning residue	Mineral Processing
	Spent potliners	Mineral Processing
	Sweepings	Mineral Processing
	Treatment Plant Effluent	Mineral Processing
	Waste alumina	Mineral Processing
Antimony	Gangue	Mineral Processing
	Wastewater	Mineral Processing
	APC Dust/Sludge	Mineral Processing
	Autoclave Filtrate	Mineral Processing
	Spent Barren Solution	Mineral Processing
	Gangue (Filter Cake)	Mineral Processing
	Leach Residue	Mineral Processing
	Refining Dross	Mineral Processing
	Slag and Furnace Residue	Mineral Processing
	Sludge from Treating Process Waste Water	Mineral Processing
	Stripped Anolyte Solids	Mineral Processing
	Waste Solids	Mineral Processing
Beryllium	Gangue	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Beryllium (continued)	Acid Conversion Stream	Extraction/Beneficiation
	Bertrandite thickener slurry	Extraction/Beneficiation
	Beryl thickener slurry	Extraction/Beneficiation
	Spent Raffinate	Extraction/Beneficiation
	Sump Water	Extraction/Beneficiation
	Spent Barren filtrate streams	Mineral Processing
	Beryllium hydroxide supernatant	Mineral Processing
	Chip Treatment Wastewater	Mineral Processing
	Dross discard	Mineral Processing
	Filtration discard	Mineral Processing
	Leaching discard	Mineral Processing
	Neutralization discard	Mineral Processing
	Pebble Plant Area Vent Scrubber Water	Mineral Processing
	Precipitation discard	Mineral Processing
	Process wastewater	Mineral Processing
	Melting Emissions	Mineral Processing
	Scrubber Liquor	Mineral Processing
	Separation slurry	Mineral Processing
	Waste Solids	Mineral Processing
Bismuth	Alloy residues	Mineral Processing
	Spent Caustic Soda	Mineral Processing
	Electrolytic Slimes	Mineral Processing
	Excess chlorine	Mineral Processing
	Lead and Zinc chlorides	Mineral Processing
	Metal Chloride Residues	Mineral Processing
	Slag	Mineral Processing
	Spent Electrolyte	Mineral Processing
	Spent Material	Mineral Processing
	Spent soda solution	Mineral Processing
	Waste acid solutions	Mineral Processing
	Waste Acids	Mineral Processing
	Wastewater	Mineral Processing
Boron	Crud	Extraction/Beneficiation
	Gangue	Extraction/Beneficiation
	Spent Solvents	Extraction/Beneficiation
	Particulate Emissions	Extraction/Beneficiation
	Waste Brine	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation
	Spent Sodium Sulfate	Extraction/Beneficiation
	Waste liquor	Extraction/Beneficiation
	Underflow Mud	Extraction/Beneficiation

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Bromine	Slimes	Extraction/Beneficiation
	Waste Brine	Extraction/Beneficiation
	Water Vapor	Extraction/Beneficiation
Cadmium	Waste Tailings	Extraction/Beneficiation
	Caustic washwater	Mineral Processing
	Copper and Lead Sulfate Filter Cakes	Mineral Processing
	Copper Removal Filter Cake	Mineral Processing
	Iron containing impurities	Mineral Processing
	Spent Leach solution	Mineral Processing
	Lead Sulfate waste	Mineral Processing
	Post-leach Filter Cakes	Mineral Processing
	Spent Purification solution	Mineral Processing
	Scrubber wastewater	Mineral Processing
	Spent electrolyte	Mineral Processing
	Zinc Precipitates	Mineral Processing
Calcium Metal	Off-gases	Extraction/Beneficiation
	Overburden	Extraction/Beneficiation
	Calcium Aluminate wastes	Mineral Processing
	Dust with Quicklime	Mineral Processing
Cesium/Rubidium	Alkali Alums	Extraction/Beneficiation
	Calciner Residues	Extraction/Beneficiation
	Cesium Chlorosonnate	Extraction/Beneficiation
	Non-Pollucite Mineral Waste	Extraction/Beneficiation
	Precipitated Aluminum	Extraction/Beneficiation
	Precipitated Barium Sulfate	Extraction/Beneficiation
	Spent Chlorine solution	Extraction/Beneficiation
	Spent Ion-exchange solution	Extraction/Beneficiation
	Spent Metal	Extraction/Beneficiation
	Spent Ore	Extraction/Beneficiation
	Spent Solvent	Extraction/Beneficiation
	Waste Gangue	Extraction/Beneficiation
	Chemical Residues	Mineral Processing
	Digester waste	Mineral Processing
	Electrolytic Slimes	Mineral Processing
	Pyrolytic Residue	Mineral Processing
	Slag	Mineral Processing
Chromium, Ferrochrome, and Ferrochromium-Silicon	Gangue and tailings	Extraction/Beneficiation
	Dust or Sludge from ferrochromium production	Mineral Processing
	Dust or Sludge from ferrochromium-silicon production	Mineral Processing
	Treated Roast/Leach Residues	Mineral Processing
	Slag and Residues	Mineral Processing
Coal Gas	Baghouse Coal Dust	Extraction/Beneficiation

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
	Coal Pile Runoff	Extraction/Beneficiation
	Fines	Extraction/Beneficiation
	Gangue	Extraction/Beneficiation
	API Oil/Water Separator Sludge	Mineral Processing
	API Water	Mineral Processing
	Cooling Tower Blowdown	Mineral Processing
	Dissolved Air Flotation (DAF) Sludge	Mineral Processing
	Flue Dust Residues	Mineral Processing
	Liquid Waste Incinerator Blowdown	Mineral Processing
	Liquid Waste Incinerator Pond Sludge	Mineral Processing
	Multiple Effects Evaporator Concentrate	Mineral Processing
	Multiple Effects Evaporator Pond Sludge	Mineral Processing
	Sludge and Filter Cake	Mineral Processing
	Spent Methanol Catalyst	Mineral Processing
	Stretford Solution Purge Stream	Mineral Processing
	Surface Impoundment Solids	Mineral Processing
	Vacuum Filter Sludge	Mineral Processing
	Zeolite Softening PWW	Mineral Processing
Copper	Crud	Extraction/Beneficiation
	Spent Kerosene	Extraction/Beneficiation
	Raffinate	Extraction/Beneficiation
	Process Wastewaters from Cooling and Refining	Extraction/Beneficiation
	Slime	Extraction/Beneficiation
	Slimes or "Muds"	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Spent Ore	Extraction/Beneficiation
	Acid plant blowdown	Mineral Processing
	Acid plant thickener sludge	Mineral Processing
	APC dusts/sludges	Mineral Processing
	Spent bleed electrolyte	Mineral Processing
	Chamber solids/scrubber sludge	Mineral Processing
	Waste contact cooling water	Mineral Processing
	Discarded furnace brick	Mineral Processing
	Process wastewaters	Mineral Processing
	Scrubber blowdown	Mineral Processing
	Spent black sulfuric acid sludge	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	Tankhouse slimes	Mineral Processing
	WWTP liquid effluent	Mineral Processing
	WWTP sludge	Mineral Processing
Elemental Phosphorous	Calcining offgas solids	Extraction/Beneficiation
	Fugitive Dust	Extraction/Beneficiation

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
	Condenser phossy water discard	Mineral Processing
	Cooling water	Mineral Processing
	Furnace building washdown	Mineral Processing
	Dust	Mineral Processing
	Waste ferrophosphorus	Mineral Processing
	Furnace offgas solids	Mineral Processing
	Furnace scrubber blowdown	Mineral Processing
	Precipitator slurry scrubber water	Mineral Processing
	Precipitator slurry	Mineral Processing
	NOSAP slurry	Mineral Processing
	Sludge	Mineral Processing
	Spent furnace brick	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	Surface impoundment waste solids	Mineral Processing
	Waste Andersen Filter Media	Mineral Processing
	WWTP liquid effluent	Mineral Processing
	WWTP Sludge/Solids	Mineral Processing
Fluorspar and Hydrofluoric Acid	Gangue	Extraction/Beneficiation
	Lead and Zinc sulfides	Extraction/Beneficiation
	Spent flotation reagents	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	APC Dusts	Mineral Processing
	Off-spec fluosilicic acid	Mineral Processing
	Sludges	Mineral Processing
Gem Stones	Overburden	Extraction/Beneficiation
	Spent chemical agents	Extraction/Beneficiation
	Spent polishing media	Extraction/Beneficiation
	Waste minerals	Extraction/Beneficiation
Germanium	Waste Acid Wash and Rinse Water	Mineral Processing
	Chlorinator Wet Air Pollution Control Sludge	Mineral Processing
	Germanium oxides fumes	Mineral Processing
	Hydrolysis Filtrate	Mineral Processing
	Leach Residues	Mineral Processing
	Roaster off-gases	Mineral Processing
	Spent Acid/Leachate	Mineral Processing
	Waste Still Liquor	Mineral Processing
	Wastewater	Mineral Processing

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Gold and Silver	Black sand	Extraction/Beneficiation
	Filter cake	Extraction/Beneficiation
	Mercury bearing solution	Extraction/Beneficiation
	Mine water	Extraction/Beneficiation
	Carbon, carbon fines, and acid wash solution	Extraction/Beneficiation
	Spent leaching solution	Extraction/Beneficiation
	Spent ore	Extraction/Beneficiation
	Spent stripping solution	Extraction/Beneficiation
	Sulfur dioxide	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Waste rock, clay and sand from amalgamation	Extraction/Beneficiation
	Waste rock	Extraction/Beneficiation
	Waste sulfuric acid	Extraction/Beneficiation
	Waste steel wool	Extraction/Beneficiation
	Zinc cyanide solution	Extraction/Beneficiation
	Spent Furnace Dust	Mineral Processing
	Refining wastes	Mineral Processing
	Retort cooling water	Mineral Processing
	Slag	Mineral Processing
	Wastewater treatment sludge	Mineral Processing
	Wastewater	Mineral Processing
Iodine	Filtrate waste	Extraction/Beneficiation
	Sludge	Extraction/Beneficiation
	Sulfur compounds	Extraction/Beneficiation
	Waste acid	Extraction/Beneficiation
	Waste bleed liquor	Extraction/Beneficiation
	Waste brine	Extraction/Beneficiation
Iron and Steel	Tailings	Extraction/Beneficiation
	Wastewater and Waste Solids	Extraction/Beneficiation
	Wastewater	Mineral Processing
Lead	Concentration Wastes	Extraction/Beneficiation
	Mine water	Extraction/Beneficiation
	Waste Rock	Extraction/Beneficiation
	Acid Plant Blowdown	Mineral Processing
	Acid Plant Sludge	Mineral Processing
	Baghouse Dust	Mineral Processing
	Baghouse Incinerator Ash	Mineral Processing
	Cooling Tower Blowdown	Mineral Processing
	Waste Nickel Matte	Mineral Processing
	Process Wastewater	Mineral Processing
	Slurried APC Dust	Mineral Processing
Lead (continued)	Solid Residues	Mineral Processing

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
	Solids in Plant Washdown	Mineral Processing
	Spent Furnace Brick	Mineral Processing
	Stockpiled Miscellaneous Plant Waste	Mineral Processing
	Surface Impoundment Waste Liquids	Mineral Processing
	Surface Impoundment Waste Solids	Mineral Processing
	SVG Backwash	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludges/Solids	Mineral Processing
Lightweight Aggregate	Overburden	Extraction/Beneficiation
	Waste Rock	Extraction/Beneficiation
	Raw fines form primary crushing operations	Extraction/Beneficiation
	Sludge from rock washing	Extraction/Beneficiation
	APC control scrubber water and solids	Mineral Processing
	APC Dust/Sludge	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	WWTP liquid effluent	Mineral Processing
Lithium and Lithium Carbonate	Acid roaster gases	Extraction/Beneficiation
	Flotation Tailings	Extraction/Beneficiation
	Gangue	Extraction/Beneficiation
	Magnesium/Calcium Sludge	Extraction/Beneficiation
	Roaster Off-gases	Extraction/Beneficiation
	Salt solutions	Extraction/Beneficiation
	Wastewater from Wet Scrubber	Extraction/Beneficiation
Magnesium and Magnesia from Brines	Calcium sludge	Extraction/Beneficiation
	Offgases	Extraction/Beneficiation
	Spent seawater	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	APC Dust/Sludge	Mineral Processing
	Calciner offgases	Mineral Processing
	Calcium sludge	Mineral Processing
	Casthouse Dust	Mineral Processing
	Casting plant slag	Mineral Processing
	Cathode Scrubber Liquor	Mineral Processing
	Slag	Mineral Processing
	Smut	Mineral Processing
	Spent Brines	Mineral Processing
Manganese, Manganese Dioxide, Ferromanganese and Silicomanganese	Flotation tailings	Extraction/Beneficiation
	Gangue	Extraction/Beneficiation
	Spent Flotation Reagents	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Manganese, Manganese Dioxide, Ferromanganese and Silicomanganese (continued)	APC Dust/Sludge	Mineral Processing
	APC Water	Mineral Processing
	Iron Sulfide Sludge	Mineral Processing
	Ore Residues	Mineral Processing
	Slag	Mineral Processing
	Spent Graphite Anode	Mineral Processing
	Spent Process Liquor	Mineral Processing
	Waste Electrolyte	Mineral Processing
	Wastewater (CMD)	Mineral Processing
	Wastewater (EMD)	Mineral Processing
	Wastewater Treatment Solids	Mineral Processing
Mercury	Gangue	Extraction/Beneficiation
	Flotation tailings	Extraction/Beneficiation
	Spent flotation reagents	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation
	Dust	Mineral Processing
	Mercury Quench Water	Mineral Processing
	Furnace Residues	Mineral Processing
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	Flotation tailings	Extraction/Beneficiation
	Gangue	Extraction/Beneficiation
	Spent Flotation Reagents	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation
	APC Dust/Sludge	Mineral Processing
	Flue Dust/Gases	Mineral Processing
	Liquid Residues	Mineral Processing
	H2 Reduction Furnace Scrubber Water	Mineral Processing
	Molybdic Oxide Refining Wastes	Mineral Processing
	Refining Wastes	Mineral Processing
	Roaster Gas Blowdown Solids	Mineral Processing
	Slag	Mineral Processing
	Solid Residues	Mineral Processing
	Treatment Solids	Mineral Processing
Phosphoric Acid	Waste Scale	Mineral Processing
Platinum Group Metals	Filtrate	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation
	Slag	Mineral Processing
	Scrubber offgases	Mineral Processing
	SO2 waste	Mineral Processing
	Spent Acids	Mineral Processing
	Spent Solvents	Mineral Processing

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Pyrobitumens, Mineral Waxes, and Natural Asphalts	Spent coal	Extraction/Beneficiation
	Spent solvents	Extraction/Beneficiation
	Still bottoms	Mineral Processing
	Waste catalysts	Mineral Processing
Rare Earths	Magnetic fractions	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Spent ammonium nitrate processing solution	Mineral Processing
	Electrolytic cell caustic wet APC waste	Mineral Processing
	Spent Electrolytic cell quench water and scrubber water	Mineral Processing
	Spent iron hydroxide cake	Mineral Processing
	Spent lead filter cake	Mineral Processing
	Lead backwash sludge	Mineral Processing
	Monazite solids	Mineral Processing
	Process wastewater	Mineral Processing
	Spent scrubber liquor	Mineral Processing
	Off-gases from dehydration	Mineral Processing
	Spent off-gases from electrolytic reduction	Mineral Processing
	Spent sodium hypochlorite filter backwash	Mineral Processing
	Solvent extraction crud	Mineral Processing
	Spent surface impoundment solids	Mineral Processing
	Spent surface impoundment liquids	Mineral Processing
	Waste filtrate	Mineral Processing
	Waste solvent	Mineral Processing
	Wastewater from caustic wet APC	Mineral Processing
	Waste zinc contaminated with mercury	Mineral Processing
Rhenium	APC Dust/Sludge	Mineral Processing
	Spent Barren Scrubber Liquor	Mineral Processing
	Spent Rhenium Raffinate	Mineral Processing
	Roaster Dust	Mineral Processing
	Spent Ion Exchange/SX Solutions	Mineral Processing
	Spent Salt Solutions	Mineral Processing
	Slag	Mineral Processing
Scandium	Crud from the bottom of the solvent extraction unit	Mineral Processing
	Dusts and spent filters from decomposition	Mineral Processing
	Spent acids	Mineral Processing
	Spent ion exchange resins and backwash	Mineral Processing
	Spent solvents from solvent extraction	Mineral Processing
	Spent wash water	Mineral Processing
	Waste chlorine solution	Mineral Processing
	Waste solutions/solids from leaching and precipitation	Mineral Processing

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Selenium	Spent filter cake	Mineral Processing
	Plant process wastewater	Mineral Processing
	Slag	Mineral Processing
	Tellurium slime wastes	Mineral Processing
	Waste Solids	Mineral Processing
Silicon and Ferrosilicon	Gangue	Extraction/Beneficiation
	Spent Wash Water	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	APC Dust Sludge	Mineral Processing
	Dross discard	Mineral Processing
	Slag	Mineral Processing
Soda Ash	Airborne emissions	Extraction/Beneficiation
	Calciner offgases	Extraction/Beneficiation
	Filter aid and carbon absorbent	Extraction/Beneficiation
	Mother liquor	Extraction/Beneficiation
	Ore insolubles	Extraction/Beneficiation
	Ore residues	Extraction/Beneficiation
	Overburden	Extraction/Beneficiation
	Particulate emissions from driers	Extraction/Beneficiation
	Particulates	Extraction/Beneficiation
	Purge liquor	Extraction/Beneficiation
	Scrubber water	Extraction/Beneficiation
	Spent brine	Extraction/Beneficiation
	Spent carbon and filter wastes	Extraction/Beneficiation
	Spent dissolution wastes	Extraction/Beneficiation
	Suspended particulate matter	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Trona ore particulates	Extraction/Beneficiation
	Trona ore processing waste	Extraction/Beneficiation
	Waste mother liquor	Extraction/Beneficiation
Sodium Sulfate	Waste Brine	Extraction/Beneficiation
	Clarifier overflow filtrate	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation
Strontium	Calciner offgas	Extraction/Beneficiation
	Dilute sodium sulfide solution	Extraction/Beneficiation
	Filter muds	Extraction/Beneficiation
	Spent Ore	Extraction/Beneficiation
	Vacuum drum filtrate	Extraction/Beneficiation
	Waste sodium sulfate solution	Extraction/Beneficiation
	Waste solution	Extraction/Beneficiation

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Sulfur	Air emissions	Extraction/Beneficiation
	Filter cake	Extraction/Beneficiation
	Frasch process residues	Extraction/Beneficiation
	Sludge	Extraction/Beneficiation
	Spilled sulfur	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation
	Airborne emissions from sulfuric acid production	Mineral Processing
	Spent catalysts (Claus process)	Mineral Processing
	Spent vanadium pentoxide catalysts from sulfuric acid production	Mineral Processing
	Tail gases	Mineral Processing
	Wastewater from wet-scrubbing, spilled product and condensates	Mineral Processing
Synthetic Rutile	APC Dust/Sludges	Mineral Processing
	Spent Iron Oxide Slurry	Mineral Processing
	Spent Acid Solution	Mineral Processing
Tantalum, Columbium and Ferrocolumbium	APC Dust Sludge	Mineral Processing
	Digester Sludge	Mineral Processing
	Spent Potassium Titanium Chloride	Mineral Processing
	Process Wastewater	Mineral Processing
	Spent Raffinate Solids	Mineral Processing
	Scrubber Overflow	Mineral Processing
	Slag	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludge	Mineral Processing
Tellurium	Slag	Mineral Processing
	Fumes of telluride dioxide	Mineral Processing
	Solid waste residues	Mineral Processing
	Waste Electrolyte	Mineral Processing
	Wastewater	Mineral Processing
Tin	Process Wastewater	Extraction/Beneficiation
	Tailings Slurry	Extraction/Beneficiation
	Brick Lining and Fabric Filters	Mineral Processing
	Dross	Mineral Processing
	Process Wastewater and Treatment Sludge	Mineral Processing
	Slag	Mineral Processing
	Slimes	Mineral Processing
	Waste Acid and Alkaline baths	Mineral Processing

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Titanium and Titanium Dioxide	Flotation Cells	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Spent Brine Treatment Filter Cake	Mineral Processing
	FeCl Treatment Sludge	Mineral Processing
	Waste Ferric Chloride	Mineral Processing
	Finishing Scrap	Mineral Processing
	Leach Liquor and Sponge Wash Water	Mineral Processing
	Waste Non-Contact Cooling Water	Mineral Processing
	Pickling Liquor and Wash Water	Mineral Processing
	Scrap Detergent Wash Water	Mineral Processing
	Scrap Milling Scrubber Water	Mineral Processing
	Reduction Area Scrubber Water	Mineral Processing
	Chlorination Off gas Scrubber Water	Mineral Processing
	Chlorination Area - Vent Scrubber Water	Mineral Processing
	Melt Cell Scrubber Water	Mineral Processing
	Chlorine Liquefaction Scrubber Water	Mineral Processing
	Chip Crushing Scrubber Water	Mineral Processing
	Casting Crucible Contact Cooling Water	Mineral Processing
	Smut from Mg Recovery	Mineral Processing
	Spent Surface Impoundment Liquids	Mineral Processing
	Spent Surface Impoundment Solids	Mineral Processing
	TiCl4 Purification Effluent	Mineral Processing
	Spent Vanadium Oxychloride	Mineral Processing
	Sodium Reduction Container Reconditioning Wash Water	Mineral Processing
	Casting Crucible Wash Water	Mineral Processing
	Waste Acids (Chloride process)	Mineral Processing
	Waste Solids (Chloride process)	Mineral Processing
	Waste Acids (Sulfate process)	Mineral Processing
	Waste Solids (Sulfate process)	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludge/Solids	Mineral Processing
Tungsten	Alkali leach wash	Extraction/Beneficiation
	Calcium tungstate precipitate wash	Extraction/Beneficiation
	Ion exchange raffinate	Extraction/Beneficiation
	Ion exchange resins	Extraction/Beneficiation
	Leach filter cake residues and impurities	Extraction/Beneficiation
	Molybdenum sulfide precipitation wet air pollution control waste	Extraction/Beneficiation
	Scrubber wastewater	Extraction/Beneficiation
	Spent mother liquor	Extraction/Beneficiation
	Tungstic acid rinse water	Extraction/Beneficiation
	Waste fines	Extraction/Beneficiation
Tungsten (continued)	Waste rock and tailings	Extraction/Beneficiation

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
	Wastewater	Extraction/Beneficiation
	Wet scrubber wastewater	Extraction/Beneficiation
	Spent Acid and Rinse water	Mineral Processing
	Scrubber wastewater	Mineral Processing
	Process wastewater treatment plant effluent	Mineral Processing
	Water of formation	Mineral Processing
Uranium	Waste Rock	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Organic vapors	Extraction/Beneficiation
	Refuse	Extraction/Beneficiation
	Spent Extraction/Leaching Solutions	Extraction/Beneficiation
	Particulate Emissions	Extraction/Beneficiation
	Miscellaneous Sludges	Extraction/Beneficiation
	Spent Ion Exchange Resins	Extraction/Beneficiation
	Tailing Pond Seepage	Extraction/Beneficiation
	Waste Acids from Solvent Extraction	Extraction/Beneficiation
	Barren Lixiviant	Extraction/Beneficiation
	Slimes from Solvent Extraction	Extraction/Beneficiation
	Waste Solvents	Extraction/Beneficiation
	Waste Nitric Acid from Production of UO_2	Mineral Processing
	Vaporizer Condensate	Mineral Processing
	Superheater Condensate	Mineral Processing
	Slag	Mineral Processing
	Uranium Chips from Ingot Production	Mineral Processing
	Waste Calcium Fluoride	Mineral Processing
Vanadium	Roaster Off-gases	Extraction/Beneficiation
	Solid residues	Extraction/Beneficiation
	Spent Filtrate	Extraction/Beneficiation
	Spent Solvent	Extraction/Beneficiation
	Filtrate and Process Wastewaters	Mineral Processing
	Solid Waste	Mineral Processing
	Spent Precipitate	Mineral Processing
	Slag	Mineral Processing
	Wet scrubber wastewater	Mineral Processing
Zinc	Refuse	Extraction/Beneficiation
	Tailings	Extraction/Beneficiation
	Waste rock	Extraction/Beneficiation
	Acid Plant Blowdown	Mineral Processing
	Spent Cloths, Bags, and Filters	Mineral Processing
	Waste Ferrosilicon	Mineral Processing
Zinc (continued)	Spent Goethite and Leach Cake Residues	Mineral Processing
	Saleable residues	Mineral Processing

EXHIBIT 4-1 (Continued)

Commodity	Waste Stream	Nature of Operation
	Process Wastewater	Mineral Processing
	Discarded Refractory Brick	Mineral Processing
	Spent Surface Impoundment Liquid	Mineral Processing
	Spent Surface Impoundment Solids	Mineral Processing
	Spent Synthetic Gypsum	Mineral Processing
	TCA Tower Blowdown (ZCA Bartlesville, OK - Electrolytic Plant)	Mineral Processing
	Wastewater Treatment Plant Liquid Effluent	Mineral Processing
	Wastewater Treatment Plant Sludge	Mineral Processing
	Zinc-lean Slag	Mineral Processing
Zirconium and Hafnium	Monazite	Extraction/Beneficiation
	Wastewater	Extraction/Beneficiation
	Spent Acid leachate from zirconium alloy production	Mineral Processing
	Spent Acid leachate from zirconium metal production	Mineral Processing
	Ammonium Thiocyanate Bleed Stream	Mineral Processing
	Reduction area-vent wet APC wastewater	Mineral Processing
	Caustic wet APC wastewater	Mineral Processing
	Feed makeup wet APC wastewater	Mineral Processing
	Filter cake/sludge	Mineral Processing
	Furnace residue	Mineral Processing
	Hafnium filtrate wastewater	Mineral Processing
	Iron extraction stream stripper bottoms	Mineral Processing
	Leaching rinse water from zirconium alloy production	Mineral Processing
	Leaching rinse water from zirconium metal production	Mineral Processing
	Magnesium recovery area vent wet APC wastewater	Mineral Processing
	Magnesium recovery off-gas wet APC wastewater	Mineral Processing
	Sand Chlorination Off-Gas Wet APC wastewater	Mineral Processing
	Sand Chlorination Area Vent Wet APC wastewater	Mineral Processing
	Silicon Tetrachloride Purification Wet APC wastewater	Mineral Processing
	Wet APC wastewater	Mineral Processing
	Zirconium chip crushing wet APC wastewater	Mineral Processing
	Zirconium filtrate wastewater	Mineral Processing

EXHIBIT 4-2

SUMMARY OF MINERAL PROCESSING WASTE STREAMS BY COMMODITY

Commodity	Waste Stream	Nature of Operation
Alumina and Aluminum	Anode prep waste	Mineral Processing
	APC dust/sludge	Mineral Processing
	Baghouse bags and spent plant filters	Mineral Processing
	Bauxite residue	Mineral Processing
	Cast house dust	Mineral Processing
	Cryolite recovery residue	Mineral Processing
	Wastewater	Mineral Processing
	Discarded Dross	Mineral Processing
	Flue Dust	Mineral Processing
	Electrolysis waste	Mineral Processing
	Evaporator salt wastes	Mineral Processing
	Miscellaneous wastewater	Mineral Processing
	Pisolites	Mineral Processing
	Scrap furnace brick	Mineral Processing
	Skims	Mineral Processing
	Sludge	Mineral Processing
	Spent cleaning residue	Mineral Processing
	Spent potliners	Mineral Processing
	Sweepings	Mineral Processing
	Treatment Plant Effluent	Mineral Processing
	Waste alumina	Mineral Processing
Antimony	Gangue	Mineral Processing
	Wastewater	Mineral Processing
	APC Dust/Sludge	Mineral Processing
	Autoclave Filtrate	Mineral Processing
	Spent Barren Solution	Mineral Processing
	Gangue (Filter Cake)	Mineral Processing
	Leach Residue	Mineral Processing
	Refining Dross	Mineral Processing
	Slag and Furnace Residue	Mineral Processing
	Sludge from Treating Process Waste Water	Mineral Processing
	Stripped Anolyte Solids	Mineral Processing
	Waste Solids	Mineral Processing
Beryllium	Spent Barren filtrate streams	Mineral Processing
	Beryllium hydroxide supernatant	Mineral Processing
	Chip Treatment Wastewater	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
Beryllium (continued)	Dross discard	Mineral Processing
	Filtration discard	Mineral Processing
	Leaching discard	Mineral Processing
	Neutralization discard	Mineral Processing
	Pebble Plant Area Vent Scrubber Water	Mineral Processing
	Precipitation discard	Mineral Processing
	Process wastewater	Mineral Processing
	Melting Emissions	Mineral Processing
	Scrubber Liquor	Mineral Processing
	Separation slurry	Mineral Processing
	Waste Solids	Mineral Processing
Bismuth	Alloy residues	Mineral Processing
	Spent Caustic Soda	Mineral Processing
	Electrolytic Slimes	Mineral Processing
	Excess chlorine	Mineral Processing
	Lead and Zinc chlorides	Mineral Processing
	Metal Chloride Residues	Mineral Processing
	Slag	Mineral Processing
	Spent Electrolyte	Mineral Processing
	Spent Material	Mineral Processing
	Spent soda solution	Mineral Processing
	Waste acid solutions	Mineral Processing
	Waste Acids	Mineral Processing
	Wastewater	Mineral Processing
Cadmium	Caustic washwater	Mineral Processing
	Copper and Lead Sulfate Filter Cakes	Mineral Processing
	Copper Removal Filter Cake	Mineral Processing
	Iron containing impurities	Mineral Processing
	Spent Leach solution	Mineral Processing
	Lead Sulfate waste	Mineral Processing
	Post-leach Filter Cakes	Mineral Processing
	Spent Purification solution	Mineral Processing
	Scrubber wastewater	Mineral Processing
	Spent electrolyte	Mineral Processing
	Zinc Precipitates	Mineral Processing
Calcium Metal	Calcium Aluminate wastes	Mineral Processing
	Dust with Quicklime	Mineral Processing
Cesium/Rubidium	Chemical Residues	Mineral Processing
	Digester waste	Mineral Processing
	Electrolytic Slimes	Mineral Processing
	Pyrolytic Residue	Mineral Processing
Cerium/Rubidium (continued)	Slag	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
Chromium, Ferrochrome, and Ferrochromium-Silicon	Gangue and tailings	Extraction/Beneficiation
	Dust or Sludge from ferrochromium production	Mineral Processing
	Dust or Sludge from ferrochromium-silicon production	Mineral Processing
	Treated Roast/Leach Residues	Mineral Processing
	Slag and Residues	Mineral Processing
Coal Gas	API Oil/Water Separator Sludge	Mineral Processing
	API Water	Mineral Processing
	Cooling Tower Blowdown	Mineral Processing
	Dissolved Air Flotation (DAF) Sludge	Mineral Processing
	Flue Dust Residues	Mineral Processing
	Liquid Waste Incinerator Blowdown	Mineral Processing
	Liquid Waste Incinerator Pond Sludge	Mineral Processing
	Multiple Effects Evaporator Concentrate	Mineral Processing
	Multiple Effects Evaporator Pond Sludge	Mineral Processing
	Sludge and Filter Cake	Mineral Processing
	Spent Methanol Catalyst	Mineral Processing
	Stretford Solution Purge Stream	Mineral Processing
	Surface Impoundment Solids	Mineral Processing
	Vacuum Filter Sludge	Mineral Processing
	Zeolite Softening PWW	Mineral Processing
Copper	Acid plant blowdown	Mineral Processing
	Acid plant thickener sludge	Mineral Processing
	APC dusts/sludges	Mineral Processing
	Spent bleed electrolyte	Mineral Processing
	Chamber solids/scrubber sludge	Mineral Processing
	Waste contact cooling water	Mineral Processing
	Discarded furnace brick	Mineral Processing
	Process wastewaters	Mineral Processing
	Scrubber blowdown	Mineral Processing
	Spent black sulfuric acid sludge	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	Tankhouse slimes	Mineral Processing
	WWTP liquid effluent	Mineral Processing
	WWTP sludge	Mineral Processing
Elemental Phosphorous	Condenser phossy water discard	Mineral Processing
	Cooling water	Mineral Processing
	Furnace building washdown	Mineral Processing
	Dust	Mineral Processing
	Waste ferrophosphorus	Mineral Processing
	Furnace offgas solids	Mineral Processing
Elemental Phosphorous (continued)	Furnace scrubber blowdown	Mineral Processing
	Precipitator slurry scrubber water	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
	Precipitator slurry	Mineral Processing
	NOSAP slurry	Mineral Processing
	Sludge	Mineral Processing
	Spent furnace brick	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	Surface impoundment waste solids	Mineral Processing
	Waste Andersen Filter Media	Mineral Processing
	WWTP liquid effluent	Mineral Processing
	WWTP Sludge/Solids	Mineral Processing
Fluorspar and Hydrofluoric Acid	APC Dusts	Mineral Processing
	Off-spec fluosilicic acid	Mineral Processing
	Sludges	Mineral Processing
Germanium	Waste Acid Wash and Rinse Water	Mineral Processing
	Chlorinator Wet Air Pollution Control Sludge	Mineral Processing
	Germanium oxides fumes	Mineral Processing
	Hydrolysis Filtrate	Mineral Processing
	Leach Residues	Mineral Processing
	Roaster off-gases	Mineral Processing
	Spent Acid/Leachate	Mineral Processing
	Waste Still Liquor	Mineral Processing
	Wastewater	Mineral Processing
Gold and Silver	Spent Furnace Dust	Mineral Processing
	Refining wastes	Mineral Processing
	Retort cooling water	Mineral Processing
	Slag	Mineral Processing
	Wastewater treatment sludge	Mineral Processing
	Wastewater	Mineral Processing
Iron and Steel	Wastewater	Mineral Processing
Lead	Acid Plant Blowdown	Mineral Processing
	Acid Plant Sludge	Mineral Processing
	Baghouse Dust	Mineral Processing
	Baghouse Incinerator Ash	Mineral Processing
	Cooling Tower Blowdown	Mineral Processing
	Waste Nickel Matte	Mineral Processing
	Process Wastewater	Mineral Processing
	Slurried APC Dust	Mineral Processing
	Solid Residues	Mineral Processing
	Solids in Plant Washdown	Mineral Processing
	Spent Furnace Brick	Mineral Processing
Lead (continued)	Stockpiled Miscellaneous Plant Waste	Mineral Processing
	Surface Impoundment Waste Liquids	Mineral Processing
	Surface Impoundment Waste Solids	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
	SVG Backwash	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludges/Solids	Mineral Processing
Lightweight Aggregate	APC control scrubber water and solids	Mineral Processing
	APC Dust/Sludge	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	WWTP liquid effluent	Mineral Processing
Magnesium and Magnesia from Brines	APC Dust/Sludge	Mineral Processing
	Calciner offgases	Mineral Processing
	Calcium sludge	Mineral Processing
	Casthouse Dust	Mineral Processing
	Casting plant slag	Mineral Processing
	Cathode Scrubber Liquor	Mineral Processing
	Slag	Mineral Processing
	Smut	Mineral Processing
	Spent Brines	Mineral Processing
Manganese, Manganese Dioxide, Ferromanganese and Silicomanganese	APC Dust/Sludge	Mineral Processing
	APC Water	Mineral Processing
	Iron Sulfide Sludge	Mineral Processing
	Ore Residues	Mineral Processing
Manganese, Manganese Dioxide, Ferromanganese and Silicomanganese (continued)	Slag	Mineral Processing
	Spent Graphite Anode	Mineral Processing
	Spent Process Liquor	Mineral Processing
	Waste Electrolyte	Mineral Processing
	Wastewater (CMD)	Mineral Processing
	Wastewater (EMD)	Mineral Processing
	Wastewater Treatment Solids	Mineral Processing
Mercury	Dust	Mineral Processing
	Mercury Quench Water	Mineral Processing
	Furnace Residues	Mineral Processing
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	APC Dust/Sludge	Mineral Processing
	Flue Dust/Gases	Mineral Processing
	Liquid Residues	Mineral Processing
	H2 Reduction Furnace Scrubber Water	Mineral Processing
	Molybdic Oxide Refining Wastes	Mineral Processing
	Refining Wastes	Mineral Processing
	Roaster Gas Blowdown Solids	Mineral Processing
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	Slag	Mineral Processing
	Solid Residues	Mineral Processing
	Treatment Solids	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
Phosphoric Acid	Waste Scale	Mineral Processing
Platinum Group Metals	Slag	Mineral Processing
	Scrubber offgases	Mineral Processing
	SO2 waste	Mineral Processing
	Spent Acids	Mineral Processing
	Spent Solvents	Mineral Processing
Pyrobitumens, Mineral Waxes, and Natural Asphalts	Still bottoms	Mineral Processing
	Waste catalysts	Mineral Processing
Rare Earths	Spent ammonium nitrate processing solution	Mineral Processing
	Electrolytic cell caustic wet APC waste	Mineral Processing
	Spent Electrolytic cell quench water and scrubber water	Mineral Processing
	Spent iron hydroxide cake	Mineral Processing
	Spent lead filter cake	Mineral Processing
	Lead backwash sludge	Mineral Processing
	Monazite solids	Mineral Processing
	Process wastewater	Mineral Processing
	Spent scrubber liquor	Mineral Processing
	Off-gases from dehydration	Mineral Processing
	Spent off-gases from electrolytic reduction	Mineral Processing
	Spent sodium hypochlorite filter backwash	Mineral Processing
	Solvent extraction crud	Mineral Processing
	Spent surface impoundment solids	Mineral Processing
	Spent surface impoundment liquids	Mineral Processing
	Waste filtrate	Mineral Processing
	Waste solvent	Mineral Processing
	Wastewater from caustic wet APC	Mineral Processing
	Waste zinc contaminated with mercury	Mineral Processing
Rhenium	APC Dust/Sludge	Mineral Processing
	Spent Barren Scrubber Liquor	Mineral Processing
	Spent Rhenium Raffinate	Mineral Processing
	Roaster Dust	Mineral Processing
	Spent Ion Exchange/SX Solutions	Mineral Processing
	Spent Salt Solutions	Mineral Processing
	Slag	Mineral Processing
Scandium	Crud from the bottom of the solvent extraction unit	Mineral Processing
	Dusts and spent filters from decomposition	Mineral Processing
	Spent acids	Mineral Processing
Scandium (continued)	Spent ion exchange resins and backwash	Mineral Processing
	Spent solvents from solvent extraction	Mineral Processing
	Spent wash water	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
	Waste chlorine solution	Mineral Processing
	Waste solutions/solids from leaching and precipitation	Mineral Processing
Selenium	Spent filter cake	Mineral Processing
	Plant process wastewater	Mineral Processing
	Slag	Mineral Processing
	Tellurium slime wastes	Mineral Processing
	Waste Solids	Mineral Processing
Silicon and Ferrosilicon	APC Dust Sludge	Mineral Processing
	Dross discard	Mineral Processing
	Slag	Mineral Processing
Sulfur	Airborne emissions from sulfuric acid production	Mineral Processing
	Spent catalysts (Claus process)	Mineral Processing
	Spent vanadium pentoxide catalysts from sulfuric acid production	Mineral Processing
	Tail gases	Mineral Processing
	Wastewater from wet-scrubbing, spilled product and condensates	Mineral Processing
Synthetic Rutile	APC Dust/Sludges	Mineral Processing
	Spent Iron Oxide Slurry	Mineral Processing
	Spent Acid Solution	Mineral Processing
Tantalum, Columbium and Ferrocolumbium	APC Dust Sludge	Mineral Processing
	Digester Sludge	Mineral Processing
	Spent Potassium Titanium Chloride	Mineral Processing
	Process Wastewater	Mineral Processing
	Spent Raffinate Solids	Mineral Processing
	Scrubber Overflow	Mineral Processing
	Slag	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludge	Mineral Processing
Tellurium	Slag	Mineral Processing
	Fumes of telluride dioxide	Mineral Processing
	Solid waste residues	Mineral Processing
	Waste Electrolyte	Mineral Processing
	Wastewater	Mineral Processing
Tin	Brick Lining and Fabric Filters	Mineral Processing
	Dross	Mineral Processing
	Process Wastewater and Treatment Sludge	Mineral Processing
	Slag	Mineral Processing
	Slimes	Mineral Processing
Tin (continued)	Waste Acid and Alkaline baths	Mineral Processing
Titanium and Titanium Dioxide	Spent Brine Treatment Filter Cake	Mineral Processing
	FeCl Treatment Sludge	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
	Waste Ferric Chloride	Mineral Processing
	Finishing Scrap	Mineral Processing
	Leach Liquor and Sponge Wash Water	Mineral Processing
	Waste Non-Contact Cooling Water	Mineral Processing
	Pickling Liquor and Wash Water	Mineral Processing
	Scrap Detergent Wash Water	Mineral Processing
	Scrap Milling Scrubber Water	Mineral Processing
	Reduction Area Scrubber Water	Mineral Processing
	Chlorination Off gas Scrubber Water	Mineral Processing
	Chlorination Area - Vent Scrubber Water	Mineral Processing
	Melt Cell Scrubber Water	Mineral Processing
	Chlorine Liquefaction Scrubber Water	Mineral Processing
	Chip Crushing Scrubber Water	Mineral Processing
	Casting Crucible Contact Cooling Water	Mineral Processing
	Smut from Mg Recovery	Mineral Processing
	Spent Surface Impoundment Liquids	Mineral Processing
	Spent Surface Impoundment Solids	Mineral Processing
	TiCl4 Purification Effluent	Mineral Processing
	Spent Vanadium Oxychloride	Mineral Processing
	Sodium Reduction Container Reconditioning Wash Water	Mineral Processing
	Casting Crucible Wash Water	Mineral Processing
	Waste Acids (Chloride process)	Mineral Processing
	Waste Solids (Chloride process)	Mineral Processing
	Waste Acids (Sulfate process)	Mineral Processing
	Waste Solids (Sulfate process)	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludge/Solids	Mineral Processing
Tungsten	Spent Acid and Rinse water	Mineral Processing
	Scrubber wastewater	Mineral Processing
	Process wastewater treatment plant effluent	Mineral Processing
	Water of formation	Mineral Processing
Uranium	Waste Nitric Acid from Production of UO_2	Mineral Processing
	Vaporizer Condensate	Mineral Processing
	Superheater Condensate	Mineral Processing
	Slag	Mineral Processing
	Uranium Chips from Ingot Production	Mineral Processing
	Waste Calcium Fluoride	Mineral Processing

EXHIBIT 4-2 (Continued)

Commodity	Waste Stream	Nature of Operation
Vanadium	Filtrate and Process Wastewaters	Mineral Processing
	Solid Waste	Mineral Processing
	Spent Precipitate	Mineral Processing
	Slag	Mineral Processing
	Wet scrubber wastewater	Mineral Processing
Zinc	Acid Plant Blowdown	Mineral Processing
	Spent Cloths, Bags, and Filters	Mineral Processing
	Waste Ferrosilicon	Mineral Processing
	Spent Goethite and Leach Cake Residues	Mineral Processing
	Saleable residues	Mineral Processing
	Process Wastewater	Mineral Processing
	Discarded Refractory Brick	Mineral Processing
	Spent Surface Impoundment Liquid	Mineral Processing
	Spent Surface Impoundment Solids	Mineral Processing
	Spent Synthetic Gypsum	Mineral Processing
	TCA Tower Blowdown (ZCA Bartlesville, OK - Electrolytic Plant)	Mineral Processing
	Wastewater Treatment Plant Liquid Effluent	Mineral Processing
	Wastewater Treatment Plant Sludge	Mineral Processing
	Zinc-lean Slag	Mineral Processing
Zirconium and Hafnium	Spent Acid leachate from zirconium alloy production	Mineral Processing
	Spent Acid leachate from zirconium metal production	Mineral Processing
	Ammonium Thiocyanate Bleed Stream	Mineral Processing
	Reduction area-vent wet APC wastewater	Mineral Processing
	Caustic wet APC wastewater	Mineral Processing
	Feed makeup wet APC wastewater	Mineral Processing
	Filter cake/sludge	Mineral Processing
	Furnace residue	Mineral Processing
	Hafnium filtrate wastewater	Mineral Processing
	Iron extraction stream stripper bottoms	Mineral Processing
	Leaching rinse water from zirconium alloy production	Mineral Processing
	Leaching rinse water from zirconium metal production	Mineral Processing
	Magnesium recovery area vent wet APC wastewater	Mineral Processing
	Magnesium recovery off-gas wet APC wastewater	Mineral Processing
	Sand Chlorination Off-Gas Wet APC wastewater	Mineral Processing
	Sand Chlorination Area Vent Wet APC wastewater	Mineral Processing
	Silicon Tetrachloride Purification Wet APC wastewater	Mineral Processing
	Wet APC wastewater	Mineral Processing
	Zirconium chip crushing wet APC wastewater	Mineral Processing
	Zirconium filtrate wastewater	Mineral Processing

EXHIBIT 4-3

LISTING OF HAZARDOUS MINERAL PROCESSING WASTES BY COMMODITY SECTOR

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Alumina and Aluminum Metallurgical grade alumina is extracted from bauxite by the Bayer process and aluminum is obtained from this purified ore by electrolysis via the Hall-Heroult process. The Bayer process consists of the following five steps: (1) ore preparation, (2) bauxite digestion, (3) clarification, (4) aluminum hydroxide precipitation, and (5) calcination to anhydrous alumina. In the Hall-Heroult process, aluminum is produced through the electrolysis of alumina dissolved in a molten cryolite-based bath, with molten aluminum being deposited on a carbon cathode.	Cast house dust	19	19	19	19	23			Y			Y			N?	N?	N?
	Electrolysis waste	58	58	58	58	23					Y?				N?	N?	N?
Antimony Primary antimony is usually produced as a by-product or co-product of mining, smelting, and refining of other antimony-containing ores such as tetrahedrite or lead ore. Antimony can be produced using either pyrometallurgical processes or a hydrometallurgical process. For the pyrometallurgical processes, the method of recovery depends on the antimony content of the sulfide ore, and will consist of either volatilization, smelting in a blast furnace, liquation, or iron precipitation. Antimony also can be recovered hydrometallurgically by leaching and electrowinning.	Autoclave filtrate	NA	0.32	27	54	6	Y?		Y?		Y?	Y?			Y?	N?	N?
	Stripped anolyte solids	0.19	0.19	0.19	0.19	2	Y?								N?	N?	N?
	Slag and furnace residue	21	21	21	21	6					Y?				N?	N?	N?
Beryllium Bertrandite and beryl ores are treated using two separate processes to produce beryllium sulfate, $BeSO_4$: a counter-current extraction process and the Kjellgren-Sawyer process. The intermediates from the two ore extraction processes are combined and fed to another extraction process. This extraction process removes impurities solubilized during the processing of the bertrandite and beryl ores and converts the beryllium sulphate to beryllium hydroxide, $Be(OH)_2$. The beryllium hydroxide is further converted to beryllium fluoride, BeF_2, which is then catalytically reduced to form metallic beryllium.	Chip treatment wastewater	NA	0.2	100	2000	2				Y?					N?	N?	N?
	Spent barren filtrate	55	55	55	55	1							Y		N?	N?	N?
	Filtration discard	NA	0.2	45	90	2					Y?				N?	N?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Bismuth Bismuth is recovered mainly during the smelting of copper and lead ores. Bismuth-containing dust from copper smelting operations is transferred to lead smelting operations for recovery. At lead smelting operations bismuth is recovered either by the Betterton-Kroll process or the Betts Electrolytic process. In the Betterton-Kroll process, magnesium and calcium are mixed with molten lead to form a dross that contains bismuth. The dross is treated with chlorine or lead chloride and oxidized by using air or caustic soda to remove impurities. In the Betts Electrolytic process, lead bullion is electrolyzed. The resulting impurities, including bismuth, are smelted, reduced and refined.	Alloy residues	NA	0.1	3	6	1					Y?				N?	N?	N?
	Spent caustic soda	NA	0.1	6.1	12	1					Y?				N?	N?	N?
	Electrolytic slimes	NA	0	0.02	0.2	1					Y?				N?	N?	N?
	Lead and zinc chlorides	NA	0.1	3	6	1					Y?				N?	N?	N?
	Metal chloride residues	3	3	3	3	1					Y?				N?	N?	N?
	Slag	NA	0.1	1	10	1					Y?				N?	N?	N?
	Spent electrolyte	NA	0.1	6.1	12	1					Y?				N?	N?	N?
	Spent soda solution	NA	0.1	6.1	12	1					Y?				Y?	N?	N?
	Waste acid solutions	NA	0.1	6.1	12	1									Y?	N?	N?
	Waste acids	NA	0	0.1	0.2	1									Y?	N?	N?
Cadmium Cadmium is obtained as a byproduct of zinc metal production. Cadmium metal is obtained from zinc fumes or precipitates via a hydrometallurgical or a pyrometallurgical process. The hydrometallurgical process consists of the following steps: (1) precipitates leached with sulfuric acid, (2) cadmium precipitated with a zinc dust addition, (3) precipitate filtered and pressed into filter cake, (4) impurities removed from filter cake to produce sponge, (5) sponge dissolved with sulfuric acid, (6) electrolysis of solution, and (7) cadmium metal melted and cast. The pyrometallurgical process consists of the following steps: (1) cadmium fumes converted to water- or acid-soluble form, (2) leached solution purified, (3) galvanic precipitation or electrolysis, and (4) metal briquetted or cast.	Caustic washwater	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Copper and lead sulfate filter cakes	NA	0.19	1.9	19	2			Y?		Y?				N?	N?	N?
	Copper removal filter cake	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Iron containing impurities	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Spent leach solution	NA	0.19	1.9	19	2	Y?		Y?		Y?				Y?	N?	N?
	Lead sulfate waste	NA	0.19	1.9	19	2			Y?		Y?				N?	N?	N?
	Post-leach filter cake	NA	0.19	1.9	19	2			Y?						N?	N?	N?
	Spent purification solution	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Scrubber wastewater	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Spent electrolyte	NA	0.19	1.9	19	2			Y?						Y?	N?	N?
	Zinc precipitates	NA	0.19	1.9	19	2			Y?						N?	N?	N?
Calcium Calcium metal is produced by the Aluminothermic method. In the Aluminothermic method, calcium oxide, obtained by quarrying and calcining calcium limestone, is blended with finely divided aluminum and reduced under a high temperature vacuum. The process produces 99% pure calcium metal which can be further purified through distillation.	Dust with quicklime	0.04	0.04	0.04	0.04	1									Y?	N?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Chromium and Ferrochromium Chromite ore is prepared for processing using several methods, depending on the ore source and the end use requirements, although many of these beneficiation operations may not be conducted in the United States. Either ferrochromium or sodium chromate is initially produced, and may be sold or further processed to manufacture other chromium compounds, as well as chromium metal. Ferrochromium is made by smelting chromite ore in an electric arc furnace with flux materials and carbonaceous redcutant.	ESP dust	3	3	3	3	1				Y			Y		N?	N?	N?
	GCT sludge	NA	0.03	0.3	3	1				Y?					N?	N?	N?
Coal Gas Coal is crushed and gasified in the presence of steam and oxygen, producing carbon dioxide and carbon monoxide, which further react to produce carbon oxides, methane and hydrogen. The product gas is separated from the flue gas, and is processed and purified to saleable methane.	Multiple effects evaporator concentrate	NA	0	0	65	1	Y						Y		N?	N?	N?
Copper Copper is recovered from ores using either pyrometallurgical or hydrometallurgical processes. In both cases, the copper-bearing ore is crushed, ground, and concentrated (except in dump leaching). Pyrometallurgical processing can take as many as five steps: roasting, smelting, converting, fire refining, and electrorefining. Hydrometallurgical processing involves leaching, followed by either precipitation or solvent extraction and electrowinning.	Acid plant blowdown	5300	5300	5300	5300	10	Y		Y	Y	Y	Y	Y	Y	Y	N?	N?
	APC dusts/sludges	NA	1	220	450	10	Y?								N?	N?	N?
	Waste contact cooling water	13	13	13	13	10	Y?								N?	N?	N?
	Tankhouse slimes	4	4	4	4	10	Y?				Y?		Y?	Y?	N?	N?	N?
	Spent bleed electrolyte	310	310	310	310	10	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Spent furnace brick	3	3	3	3	10				Y?					N?	N?	N?
	Process wastewaters	4900	4900	4900	4900	10	Y		Y		Y	Y	Y?		Y	N?	N?
	WWTP sludge	6	6	6	6	10			Y?		Y?				N?	N?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Elemental Phosphorus Phosphate rock or sintered/agglomerated fines are charged into an electric arc furnace with coke and silica. This yields calcium silicate slag and ferrophosphorus, which are tapped. Dusts are removed from the furnace offgases and phosphorus is removed from the dusts by condensation.	Andersen Filter Media	0.46	0.46	0.46	0.46	2			Y						N?	N?	N?
	Precipitator slurry	160	160	160	160	2			Y?						N?	Y	Y
	NOSAP slurry	160	160	160	160	2									N?	N?	Y
	Phossy Water	670	670	670	670	2			Y?						N?	Y	Y
	Furnace scrubber blowdown	410	410	410	410	2			Y						Y	N?	N?
	Furnace Building Washdown	700	700	700	700	2			Y						N?	N?	N?
Fluorspar and Hydrofluoric Acid Raw fluorspar ore is crushed, ground, and concentrated. Acid grade fluorspar (a pure form of concentrate) is mixed with sulfuric acid in a heated retort kiln, reacting to produce hydrogen fluoride gas and fluorogypsum. The gas is cooled, scrubbed, and condensed, and sold as either hydrofluoric acid solution or anhydrous hydrogen fluoride.	Off-spec fluosilicic acid	NA	0	15	44	3									Y?	N?	N?
Germanium Germanium is recovered as a by-product of other metals, mostly copper, zinc, and lead. Germanium-bearing residues from zinc-ore processing facilities, a main source of germanium metal, are roasted and sintered. The sintering fumes, containing oxidized germanium, are leached with sulfuric acid to form a solution. Germanium is precipitated from the solution by adding zinc dust. Following precipitation, the germanium concentrates are refined by adding hydrochloric acid or chlorine gas to produce germanium tetrachloride, which is hydrolyzed to produce solid germanium dioxide. The final step involves reducing germanium dioxide with hydrogen to produce germanium metal.	Waste acid wash and rinse water	NA	0.4	2.2	4	4	Y?		Y?	Y?	Y?		Y?	Y?	Y?	N?	N?
	Chlorinator wet air pollution control sludge	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Hydrolysis filtrate	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?
	Leach residues	0.01	0.01	0.01	0.01	3			Y?		Y?				N?	N?	N?
	Spent acid/leachate	NA	0.4	2.2	4	4	Y?				Y?				Y?	N?	N?
	Waste still liquor	NA	0.01	0.21	0.4	4	Y?		Y?	Y?	Y?		Y?	Y?	N?	Y?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Gold and Silver Gold and Silver may be recovered from either ore or the refining of base metals. Extracted ore is crushed or ground and then subjected to oxidation by roasting, autoclaving, bio-oxidation, or chlorination, and then cyanide leaching (heap, vat, or agitation). The metals are recovered by activated carbon loading or the Merrill Crowe process. Activated carbon loading involves bringing precious metal leach solutions into contact with activated carbon by the carbon-in-column, carbon-in-pulp, or carbon-in-leach process. Gold and silver are then separated by acid leaching or electrolysis. The Merrill Crowe process consistes of filtering and deaerating the leach solution and then precipitating the precious metals with zinc powder. The solids are filtered out, melted and cast into bars. The recovery of precious metals from lead refinery slimes is a normal part of the operation called "desilverizing." Lead from previous stages of refining is brought into contact with a zinc bath which absorbs the precious metals. Base metals are removed and the dore is sent to refining.	Slag	NA	0.1	360	720	16								Y?	N?	N?	N?
	Spent furnace dust	NA	0.1	360	720	16								Y?	Y?	N?	N?
Lead Lead ores are crushed, ground, and concentrated. Pelletized concentrates are then fed to a sinter unit with other materials (e.g., smelter byproducts, coke). The sintered material is then introduced into a blast furnace along with coke and fluxes. The resulting bullion is drossed to remove lead and other metal oxides. The lead bullion may also be decopperized before being sent to the refining stages. Refining operations generally consist of several steps, including (in sequence) softening, desilverizing, dezincing, bismuth removal and final refining. During final refining, lead bullion is mixed with various fluxes and reagents to remove remaining impurities.	Acid plant sludge	14	14	14	14	3									Y?	N?	N?
	Baghouse incinerator ash	NA	0.3	3	30	3			Y		Y				N?	N?	N?
	Slurried APC Dust	7	7	7	7	3			Y		Y				N?	N?	N?
	Solid residues	0.4	0.4	0.4	0.4	3					Y?				N?	N?	N?
	Spent furnace brick	1	1	1	1	3					Y				N?	N?	N?
	Stockpiled miscellaneous plant waste	NA	0.3	67	130	3			Y		Y				N?	N?	N?
	WWTP solids/sludges	380	380	380	380	3			Y?		Y?				Y	N?	N?
	WWTP liquid effluent	2600	2600	2600	2600	3					Y?				Y?	N?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Magnesium and Magnesia from Brines Magnesium is recovered through two processes: (1) electrolytic and (2) thermal. In electrolytic production with hydrous feed, magnesium hydroxide is precipitated from seawater and settled out. The underflow is dewatered, washed, reslurried with wash water, and neutralized with HCL and H_2SO_4. The brine is filtered, purified, dried, and fed into the electrolytic cells. Alternatively, surface brine is pumped to solar evaporation ponds, where it is dried, concentrated, and purified. The resulting powder is melted, fed into the electrolytic cells, and then casted. The two thermal production processes for magnesium are the carbothermic process and the silicothermic process. In the carbothermic process, magnesium oxide is reduced with carbon to produce magnesium in the vapor phase, which is recovered by shock cooling. In the silicothermic process, silica is reacted with carbon to give silicon metal which is subsequently used to produce magnesium. Magnesia is produced by calcining magnesite or magnesium hydroxide or by the thermal decomposition of magnesium chloride, magnesium sulfate, magnesium sulfite, nesquehonite, or the basic carbonate.	Cast house dust	NA	0.076	0.76	7.6	1		Y?							N?	N?	N?
	Smut	26	26	26	26	2		Y							N?	N?	N?
Mercury Mercury currently is recovered only from gold ores. Sulfide-bearing gold ore is roasted, and the mercury is recovered from the exhaust gas. Oxide-based gold ore is crushed and mixed with water, and sent to a classifier, followed by a concentrator. The concentrate is sent to an agitator, where it is leached with cyanide. The slurry is filtered and the filtrate is sent to electrowinning, where the gold and mercury are deposited onto stainless steel wool cathodes. The cathodes are sent to a retort, where the mercury vaporizes with other impurities. The vapor is condensed to recover the mercury which is then purified.	Dust	0.007	0.007	0.007	0.007	7						Y?			N?	N?	N?
	Quench water	NA	63	77	420	7					Y?	Y?			N?	N?	N?
	Furnace residue	0.077	0.077	0.077	0.077	7						Y?			N?	N?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Molybdenum, Ferromolybdenum, and Ammonium Molybdate Production of molybdenum and molybdenum products, including ammonium molybdate, begins with roasting. Technical grade molybdic oxide is made by roasting concentrated ore. Pure molybdic oxide is produced from technical grade molybdic oxide either by sublimation and condensing, or by leaching. Ammonium molybdate is formed by reacting technical grade oxide with ammonium hydroxide and crystallizing out the pure molybdate. Molybdenum powder is formed using hydrogen to reduce ammonium molybdate or pure molybdic oxide. Ferromolybdenum is typically produced by reaction of technical grade molybdic oxide and iron oxide with a conventional metallothermic process using silicon and/or aluminum as the reductant.	Flue dust/gases	NA	1.1	250	500	11					Y?				N?	N?	N?
	Liquid residues	1	1	1	1	2	Y?		Y?		Y?		Y?		N?	N?	N?
Platinum Group Metals Platinum-group metals can be recovered from a variety of different sources, including electrolytic slimes from copper refineries and metal ores. The production of platinum-group metals from ore involves mining, concentrating, smelting, and refining. In the concentrating step, platinum ore is crushed and treated by froth flotation. The concentrates are dried, roasted, and fused in a smelter furnace, which results in the formation of platinum-containing sulfide matte. Solvent extraction is used to separate and purify the six platinum-group metals in the sulfide matte.	Slag	NA	0.0046	0.046	0.46	3					Y?		Y?		N?	N?	N?
	Spent acids	NA	0.3	1.7	3	3					Y?			Y?	Y?	N?	N?
	Spent solvents	NA	0.3	1.7	3	3					Y?			Y?	N?	Y?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Rare Earths Rare earth elements are produced from monazite and bastnasite ores by sulfuric and hydrochloric acid digestion. Processing of rare earths involves fractional crystallization and precipitation followed by solvent extraction to separate individual rare earth elements from one another. Ion exchange or calcium reduction produces highly pure rare earths in small quantities. Electrolytic reduction of rare earth chlorides followed by crushing produces a complex alloy of rare earth metals commonly known as mischmetal.	Spent ammonium nitrate processing solution	14	14	14	14	1									Y	N?	N?
	Electrolytic cell caustic wet APC sludge	NA	0.07	0.7	7	1									Y?	N?	N?
	Process wastewater	7	7	7	7	1					Y				Y?	N?	N?
	Spent scrubber liquor	NA	0.1	500	1000	1									Y?	N?	N?
	Solvent extraction crud	NA	0.1	2.3	4.5	1									N?	Y?	N?
	Spent lead filter cake	NA	0.17	0.21	0.25	1					Y?				N?	N?	N?
	Waste solvent	NA	0.1	50	100	1									N?	Y?	N?
	Wastewater from caustic wet APC	NA	0.1	500	1000	1				Y?	Y?				Y?	N?	N?
Rhenium In general, rhenium is recovered from the off-gases produced when molybdenite, a byproduct of the processing of porphyry copper ores for molybdenum, is roasted. During the roasting process, molybdenite concentrates are converted to molybdic oxide and rhenium is converted to rhenium heptoxide. The rhenium oxides are sublimed and carried off with the roaster flue gas. Rhenium is then recovered from the off-gases by the following five steps: (1) scrubbing; (2) solvent extraction or ion exchange; (3) precipitation (addition of H_2S and HCl) and filtration; (4) oxidation and evaporation; and (5) reduction.	Spent barren scrubber liquor	NA	0	0.1	0.2	2							Y?		N?	N	N
	Spent rhenium raffinate	88	88	88	88	2					Y?				N?	N?	N?
Scandium Scandium is generally produced by small bench-scale batch processes. The principal domestic scandium resource is fluorite tailings containing thortveitite and associated scandium-enriched minerals. Scandium can be recovered from thortveitite using several methods. Each method involves a distinct initial step (i.e., acid digestion, grinding, or chlorination) followed by a set of common recovery steps, including leaching, precipitation, filtration, washing, and ignition at 900 C to form scandium oxide.	Spent acids	NA	0.7	3.9	7	7									Y?	N?	N?
	Spent solvents from solvent extraction	NA	0.7	3.9	7	7									N?	Y?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Selenium The two principle processes for selenium recovery are smelting with soda ash and roasting with soda ash. Other methods include roasting with fluxes, during which the selenium is either volatilized as an oxide and recovered from the flue gas, or is incorporated in a soluble calcine that is subsequently leached for selenium. In some processes, the selenium is recovered both from the flue gas and from the calcine. To purify the crude selenium, it is dissolved in sodium sulfite and filtered to remove unwanted solids. The resulting filtrate is acidified with sulfuric acid to precipitate selenium. The selenium precipitate is distilled to drive off impurities.	Spent filter cake	NA	0.05	0.5	5	3							Y?		N?	N?	N?
	Plant process wastewater	66	66	66	66	2					Y				Y	N?	N?
	Slag	NA	0.05	0.5	5	3							Y?		N?	N?	N?
	Tellurium slime wastes	NA	0.05	0.5	5	3							Y?		N	N?	N?
	Waste solids	NA	0.05	0.5	5	3							Y?		N?	N?	N?
Synthetic Rutile Synthetic rutile is manufactured through the upgrading of ilmenite ore to remove impurities (mostly iron) and yield a feedstock for production of titanium tetrachloride through the chloride process. The various processes developed can be organized in three categories: (1) processes in which the iron in the ilmenite ore is completely reduced to metal and separated either chemically or physically; (2) processes in which iron is reduced to the ferrous state and chemically leached from the ore; and (3) processes in which selective chlorination is used to remove the iron. In addition, a process called the Benelite Cyclic process uses hydrochloric acid to leach iron from reduced ilmenite.	Spent iron oxide slurry	45	45	45	45	1			Y?	Y?					N?	N?	N?
	APC dust/sludges	30	30	30	30	1			Y?	Y?					N?	N?	N?
	Spent acid solution	30	30	30	30	1			Y?	Y?					Y?	N?	N?
Tantalum, Columbium, and Ferrocolumbium Tantalum and columbium ores are processed by physically and chemically breaking down the ore to form columbium and tantalum salts or oxides, and separating the columbium and tantalum salts or oxides from one another. These salts or oxides may be sold, or further processed to reduce the salts to the respective metals. Ferrocolumbium is made by smelting the ore with iron, and can be sold as a product or further processed to produce tantalum and columbium products.	Digester sludge	1	1	1	1	2									Y?	N?	N?
	Process wastewater	150	150	150	150	2	Y?		Y?	Y?	Y?		Y?		Y	N?	N?
	Spent raffinate solids	2	2	2	2	2									Y?	N?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Tellurium The process flow for the production of tellurium can be separated into two stages. The first stage involves the removal of copper from the copper slimes. The second stage involves the recovery of tellurium metal and purification of the recovered tellurium. Copper is generally removed from slimes by aeration in dilute sulfuric acid, oxidative pressure-leaching with sulfuric acid, or digestion with strong acid. Tellurous acid (in the form of precipitates) is then recovered by cementing, leaching the cement mud, and neutralizing with sulfuric acid. Tellurium is recovered from the precipitated tellurous acid by the following three methods: (1) direct reduction; (2) acid precipitation; and (3) electrolytic purification.	Slag	NA	0.2	2	9	2							Y?		N?	N?	N?
	Solid waste residues	NA	0.2	2	9	2							Y?		N?	N?	N?
	Waste electrolyte	NA	0.2	2	20	2					Y?		Y?		N?	N?	N?
	Wastewater	NA	0.2	20	40	2							Y?		Y?	N?	N?
Titanium and Titanium Dioxide Titanium ores are utilized in the production of four major titanium-based products: titanium dioxide (TiO_2) pigment, titanium tetrachloride ($TiCl_4$), titanium sponge, and titanium ingot/metal. The primary titanium ores for manufacture of these products are ilmenite and rutile. TiO_2 pigment is manufactured through either the sulfate, chloride, or chloride-ilmenite process. The sulfate process employs digestion of ilmenite ore or TiO_2-rich slag with sulfuric acid to produce a cake, which is purified and calcined to produce TiO_2 pigment. In the chloride process, rutile, synthetic rutile, or high-purity ilmenite is chlorinated to form $TiCl_4$, which is purified to form TiO_2 pigment. In the chloride-ilmenite process, a low-purity ilmenite is converted to $TiCl_4$ in a two-stage chlorination process. Titanium sponge is produced by purifying $TiCl_4$ generated by the chloride or chloride-ilmenite process. Titanium sponge is cast into ingots for further processing into titanium metal.	Pickle liquor and wash water	NA	2.2	2.7	3.2	3			Y?	Y?	Y?				Y?	N?	N?
	Scrap milling scrubber water	NA	4	5	6	1			Y?	Y?	Y?		Y?		N?	N?	N?
	Smut from Mg recovery	NA	0.1	22	45	2									N?	N?	Y
	Leach liquor and sponge wash water	NA	380	480	580	2				Y?	Y?				Y	N?	N?
	Spent surface impoundment liquids	NA	0.63	3.4	6.7	7				Y?	Y?				N?	N?	N?
	Spent surface impoundments solids	36	36	36	36	7				Y?	Y?				N?	N?	N?
	Waste acids (Sulfate process)	NA	0.2	39	77	2	Y			Y			Y	Y	Y	N	N
	Waste acids (Chloride process)	49	49	49	49	7				Y?	Y?		Y?		Y	N	N
	WWTP sludge/solids	420	420	420	420	7				Y?					N	N	N

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Tungsten Tungsten production consists of four distinct stages: (1) ore preparation, (2) leaching, (3) purification to APT, and (4) reducing APT to metal. Ore preparation involves gravity and flotation methods. Concentration is usually accomplished by froth flotation, supplemented by leaching, roasting, or magnetic or high tension separation. The concentrate is then processed to APT via either sodium tungstate or tungstic acid (which was digested with aqueous ammonia) to solubilize the tungsten as ammonia tungstate. Further purification and processing yields APT. APT is converted to tungsten oxide by calcining in a rotary furnace. Tungsten oxides are reduced to metal powder in high temperature furnaces. Tungsten carbide is formed by reducing APT or tungsten oxides in the presence of carbon.	Spent acid and rinse water	NA	0	0	21	6									Y?	N?	N?
	Process wastewater	NA	2.2	4.4	9	6									Y?	N?	N?
Uranium Uranium ore is recovered using either conventional milling or solution mining (*in situ leaching*). Beneficiation of conventionally mined ores involves crushing and grinding the extracted ores followed by a leaching circuit. *In situ* operations use a leach solution to dissolve desirable uraniferous minerals from deposits in-place. Uranium in either case is removed from pregnant leach liquor and concentrated using solvent extraction or ion exchange and precipitated to form yellowcake. Yellowcake is then processed to produce uranium fluoride (UF_6), which is then enriched and further refined to produce the fuel rods used in nuclear reactors.	Waste nitric acid from UO2 production	NA	1.7	2.5	3.4	17									Y?	N?	N?
	Vaporizer condensate	NA	1.7	9.3	17	17									Y?	N?	N?
	Superheater condensate	NA	1.7	9.3	17	17									Y?	N?	N?
	Slag	NA	0	8.5	17	17									N?	Y?	N?
	Uranium chips from ingot production	NA	1.7	2.5	3.4	17									N?	Y?	N?

EXHIBIT 4-3 (Continued)

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	TC Metals								Other Hazardous Characteristics		
			Min	Avg.	Max		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Corr	Ignit	Rctv
Zinc Zinc-bearing ores are crushed and undergo flotation to produce concentrates of 50 to 60% zinc. Zinc is then processed through either of two primary processing methods: electrolytic or pyrometallurgical. Electrolytic processing involves digestion with sulfuric acid and electrolytic refining. In pyrometallurgical processing, calcine is sintered and smelted in batch horizontal retorts, externally-heated continuous vertical retorts, or electrothermic furnaces. In addition, zinc is smelted in blast furnaces through the Imperial Smelting Furnace process, which is capable of recovering both zinc and lead from mixed zinc-lead concentrates.	Acid plant blowdown	130	130	130	130	1	Y		Y	Y	Y?	Y?	Y	Y	Y	N	N
	Waste ferrosilicon	17	17	17	17	1					Y?				N?	N?	N?
	Process wastewater	5000	5000	5000	5000	3	Y		Y	Y	Y		Y	Y	Y	N?	N?
	Discarded refractory brick	1	1	1	1	1	Y?		Y?	Y?	Y?				N?	N?	N?
	Spent cloths, bags, and filters	0.15	0.15	0.15	0.15	3			Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent goethite and leach cake residues	15	15	15	15	3	Y		Y	Y	Y?	Y?	Y	Y	N?	N?	N?
	Spent surface impoundment liquids	1900	1900	1900	1900	3			Y?						Y	N?	N?
	WWTP Solids	0.75	0.75	0.75	0.75	3	Y?		Y?		Y?	Y?	Y?	Y?	N?	N?	N?
	Spent synthetic gypsum	16	16	16	16	3	Y?		Y		Y?				N?	N?	N?
	TCA tower blowdown	0.25	0.25	0.25	0.25	1			Y?		Y?	Y?	Y?		Y?	N?	N?
	Wastewater treatment plant liquid effluent	2600	2600	2600	2600	3			Y?						N?	N?	N?
Zirconium and Hafnium The production processes used at primary zirconium and hafnium manufacturing plants depend largely on the raw material used. Six basic operations may be performed: (1) sand chlorination, (2) separation, (3) calcining, (4) pure chlorination, (5) reduction, and (6) purification. Plants that produce zirconium and hafnium from zircon sand use all six of these process steps. Plants which produce zirconium from zirconium dioxide employ reduction and purification steps only.	Spent acid leachate from Zr alloy prod.	NA	0	0	850	2									Y?	N?	N?
	Spent acid leachate from Zr metal prod.	NA	0	0	1600	2									Y?	N?	N?
	Leaching rinse water from Zr alloy prod.	NA	34	42	51	2									Y?	N?	N?
	Leaching rinse water from Zr metal prod.	NA	0.2	1000	2000	2									Y?	N?	N?

1/ Corr., Ignit., and Rctv. refer to the RCRA hazardous characteristics of corrosivity, ignitability, and reactivity.

EXHIBIT 4-4

IDENTIFICATION OF HAZARDOUS MINERAL PROCESSING WASTE STREAMS LIKELY SUBJECT TO THE LDRS

Mineral Processing Commodity Sectors	Number of Waste Streams 1/	Estimated Annual Generation Rate (1,000 mt/yr) (Rounded to the Nearest 2 Significant Figures)		
		Low Estimate	Medium Estimate	High Estimate
Alumina and Aluminum	2	77	77	77
Antimony	3	22	48	75
Beryllium	3	55	200	2,100
Bismuth	10	3.7	35	73
Cadmium	11	2.1	21	210
Calcium Metal	1	0.040	0.040	0.040
Chromium and Ferrochromium	2	3.0	3.3	6.0
Coal Gas	1	0	0	65
Copper	8	10,500	10,800	11,000
Elemental Phosphorus	6	2,100	2,100	2,100
Fluorspar and Hydrofluoric Acid	1	0	15	45
Germanium	6	0.84	5.0	9.2
Gold and Silver	2	0.2	720	1400
Lead	8	3,000	3,080	3,200
Magnesium and Magnesia from Brines	2	26	27	34
Mercury	3	63	77	420
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	2	2.1	250	500
Platinum Group Metals	3	0.45	3.5	6.5
Rare Earths	8	21	1,050	2,100
Rhenium	2	88	88	88
Scandium	2	1.4	7.8	14
Selenium	5	66	68	86
Synthetic Rutile	3	100	100	100
Tantalum, Columbium, and Ferrocolumbium	3	150	150	150
Tellurium	4	0.80	26	78
Titanium and Titanium Dioxide	9	890	1,050	1,250
Tungsten	2	2.2	4.4	30
Uranium	5	6.8	32	58
Zinc	11	9,800	9,800	9,800

EXHIBIT 4-4 (Continued)

Mineral Processing Commodity Sectors	Number of Waste Streams 1/	Estimated Annual Generation Rate (1,000 mt/yr) (Rounded to the Nearest 2 Significant Figures)		
		Low Estimate	Medium Estimate	High Estimate
Zirconium and Hafnium	4	34	1,000	4,500
TOTAL:	133	27,016	30,838	39,575

1/ In calculating the total number of waste streams per mineral sector, EPA included both non-wastewaters and wastewater mineral processing wastes and assumed that each of the hazardous mineral processing waste streams were generated in all three waste generation scenarios (low, medium, and high).

APPENDICES

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX A

Detailed Explanations of Methodology Used to Estimate Annual Waste Generation Rates For Individual Waste Streams

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Introduction

Due to the paucity of data for several of the mineral commodity sectors and waste streams, we developed a step-wise method for mineral processing waste volume estimation. We developed an "expected value" estimate for each waste generation rate using draft industry profiles, supporting information, process flow diagrams, and professional judgment. From the "expected value" estimate, we developed upper and lower bound estimates, which reflect the degree of uncertainty in our data and understanding of a particular sector, process, and/or waste in question. For example, we obtained average or typical commodity production rates from published sources (e.g., BOM Mineral Commodity Summaries) and determined input material quantities or concentration ratios from published market specifications. In parallel with this activity, we reviewed process flow diagrams for information on flow rates, waste-to-product ratios, or material quantities. We then calculated any additional waste generation rates and subtracted out known material flows, leaving a defined material flow, which we allocated among waste streams using professional judgment. Finally, we assigned a high, medium, and low volume estimate for each waste stream.

A key element in developing waste generation rates was the fact that by definition, average facility level generation rates of solids and sludges are less that 45,000 metric tons/year, and generation rates of wastewaters are less than 1,000,000 metric tons/year. Using this fact, in the absence of any supporting information, high values for solids and sludges were set at the highest waste generation rate found in the sector in question or 45,000 metric tons/year/facility, whichever is lower.

Precise methodology for determining waste generation rates varied depending on the quantity and quality of available information. The waste streams for which we had no published annual generation rate were divided into five groups and a methodology for each group was assigned.

1. **Actual generation rates for the waste in question from one or more facilities were available.** We extrapolated from the available data to the sector on the basis of waste-to-product ratios to develop the expected value, and used a value of +/- 20% of the expected value to define the upper and lower bounds.

2. **A typical waste-to-product ratio for the waste in question was available.** We multiplied the waste-to-product ratio by sector production (actual or estimated) to yield a sector wide waste generation expected value, and used one-half and twice this value for the lower and upper bounds, respectively.

3. **No data on the waste in question were available , but generation rates for other generally comparable wastes in the sector were.** We used the maximum and minimum waste generation rates as the upper and lower bounds, respectively, and defined the expected value as the midpoint between the two ends of the range. Adjustments were made using professional judgment if unreasonable estimates resulted from this approach.

4. **No data were available for any analogous waste streams in the sector, or information for the sector generally was very limited.** We drew from information on other sectors using analogous waste types and adjusting for differences in production rates/material throughput. We used upper and lower bound estimates of one order of magnitude above and below the expected value derived using this approach. Results were modified using professional judgment if the results seemed unreasonable.

5. **All we knew (or suspected) was the name of the waste.** We used the high value threshold (45,000 metric tons/year/facility or 1,000,000 metric tons/year/facility) as the maximum value, 0 or 100 metric tons per year as the minimum, and the midpoint as the expected value.

Detailed explanations of the methodology used for each waste generation rate estimate follow.

1997 UPDATE

Several of the waste generation rate estimates detailed below have been revised since December 1995 (the date of initial publication of this appendix) due to comments received on the January 25, 1996 Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes and the May 12, 1997 Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, as well as other new information received by the Agency. Changes to waste generation rate estimates are summarized in Exhibit A-1.

EXHIBIT A-1

CHANGES TO WASTE GENERATION RATE ESTIMATES SINCE DECEMBER 1995

Sector -- *Waste Stream*	**1995 Generation Rate Estimate (mt/yr)**		**Current Generation Rate Estimate (mt/yr)**	
Antimony -- *Autoclave Filtrate*	High: Medium: Low:	64,000 32,000 380	High: Medium: Low:	54,000 27,000 320
Beryllium -- *Chip Treatment Wastewater*	High: Medium: Low:	1,000,000 50,000 100	High: Medium: Low:	2,000,000 100,000 200
Beryllium -- *Filtration Discard*	High: Medium: Low:	45,000 23,000 100	High: Medium: Low:	90,000 45,000 200
Chromium and Ferrochromium -- *GCT Sludge*	Not Included		High: Medium: Low:	3,000 300 30
Elemental Phosphorous -- *Furnace Scrubber Blowdown*	High: Medium: Low:	270,000 0 0	High: Medium: Low:	410,000 410,000 410,000
Lead -- *Stockpiled Miscellaneous Plant Waste*	High: Medium: Low:	180,000 90,200 400	High: Medium: Low:	130,000 67,000 300
Molybdenum, Ferromolybdenum, and Ammonium Molybdate -- *Flue Dust/Gases*	High: Medium: Low:	540,000 270,000 1,200	High: Medium: Low:	500,000 250,000 1,100
Rare Earths -- *Solvent Extraction Crud*	High: Medium: Low:	90,000 45,000 200	High: Medium: Low:	4,500 2,300 100
Tellurium -- *Slag*	High: Medium: Low:	4,500 1,000 100	High: Medium: Low:	9,000 2,000 200
Tellurium -- *Solid Waste Residues*	High: Medium: Low:	4,500 1,000 100	High: Medium: Low:	9,000 2,000 200

EXHIBIT A-1 (continued)

Sector -- *Waste Stream*	**1995 Generation Rate Estimate (mt/yr)**		**Current Generation Rate Estimate (mt/yr)**	
Tellurium -- *Waste Electrolyte*	High: Medium: Low:	10,000 1,000 100	High: Medium: Low:	20,000 2,000 200
Tellurium -- *Wastewater*	High: Medium: Low:	20,000 10,000 100	High: Medium: Low:	40,000 20,000 200
Tungsten -- *Process Wastewater*	High: Medium: Low:	7,300 3,700 1,800	High: Medium: Low:	9,000 4,400 2,200

ANTIMONY

Autoclave Filtrate:	High:	64,000 mt/yr (32,000 * 2)
	Medium:	32,000 mt/yr ((64,000 + 380)/2)
	Low:	380 mt/yr (190 * 2)

A high of twice the highest waste generation rate in the sector was selected since this is a liquid waste stream. Similarly, the low was set equal to twice the lowest waste generation rate in the sector.

The waste stream may be corrosive (Table A, Text) and contains arsenic, cadmium, lead, and mercury at concentrations that may exceed TC levels.

BERYLLIUM

Chip Treatment Wastewater:	High:	1,000,000 mt/yr
	Medium:	50,000 mt/yr
	Low:	100 mt/yr

There was no information on the generation rates of this waste.

This waste may contain chromium above TC concentrations.

Filtration Discard:	High:	45,000 mt/yr
	Medium:	23,000 mt/yr
	Low:	100 mt/yr

There was no information on the generation rates of this waste.

This waste may contain lead above TC concentrations.

BISMUTH

Alloy Residues:	High:	6,000 mt/yr (3,000 * 2 * 1 facility)
	Medium:	3,000 mt/yr
	Low:	100 mt/yr

Comparing with the metal chlorides residue waste stream shown in Table (avg. waste generation rate = 3,000 mt/yr). Lower and upper bounds of 100 mt/yr and twice the medium value were used instead of an order of magnitude above and below the expected value since production rates are low (1,450 mt/yr).

Waste stream may contain lead since the process uses lead as the starting material.

Spent Caustic Soda:	High:	12,000 mt/yr (6,000 * 2 * 1 facility)
	Medium:	6,100 mt/yr ((12,000 + 100)/2)
	Low:	100 mt/yr (100* 1 facility)

No information about the waste stream was available. A high of 12,000 mt/yr was selected since low production rates (1,450 mt/yr) in the sector are expected to yield low waste generation rates. The low value was estimated as 100 mt/yr.

Common sense suggests that if large volumes of chemicals were being wasted, the process would not be economical. If large amounts of waste containing chemicals was being generated, the chemicals would probably be recovered.

Waste stream may contain lead since the process uses lead as the starting material.

Electrolytic Slimes:

High:	200 mt/yr (100 * 2 * 1 facility)
Medium:	20 mt/yr
Low:	0 (i.e., waste stream is reprocessed)

A low of zero was selected since the slimes are likely to be reprocessed (Text, Section C.2).

Total consumption in 1993 was only 1,450 mt. This was compared to the electrolytic waste stream (waste/product = .014) in the aluminum sector (1450 * .014 = 20 mt/yr). Upper bound of one order of magnitude above the estimate was selected to account for any differences in the waste streams.

Waste stream may contain lead since the process uses lead as the starting material.

Lead & Zinc Chlorides:

High:	6,000 mt/yr (3,000 * 2 * 1 facility)
Medium:	3,000 mt/yr
Low:	100 mt/yr

Comparing with the metal chlorides residue waste stream shown in Table (avg. waste generation rate = 3,000 mt/yr). Lower and upper bounds of 100 mt/yr and twice the medium value were used instead of an order of magnitude above and below the expected value since production rates are low (1,450 mt/yr).

Waste stream contains lead.

Slag:

High:	10,000 mt/yr
Medium:	1,000 mt/yr
Low:	100 mt/yr

Comparing with the Slag waste stream in the antimony sector (waste/product = 32,000/44,600 = 0.717), the medium value was calculated as (1,450 * 0.717 = 1,040). Upper and lower bound estimates of one order of magnitude above and below the expected value were used.

Waste stream contains lead.

Spent Electrolyte:

High:	12,000 mt/yr (3,000 mt/yr * 4)
Medium:	6,100 mt/yr ((12,000 + 100)/2)
Low:	100 mt/yr (100 * 1 facility)

Low production rates in the sector indicate that the waste generation rates will be low, therefore, a high value of four times the highest waste generation rate in the sector was selected.

Common sense suggests that if large volumes of chemicals were being wasted, the process would not be economical. If large amounts of waste containing chemicals was being generated, the chemicals would probably be recovered.

Waste stream may contain lead since the process uses lead as the starting material.

Spent Soda Solution:

High:	12,000 mt/yr (3,000 mt/yr * 4)
Medium:	6,100 mt/yr ((12,000 + 100)/2)
Low:	100 mt/yr (100 * 1 facility)

See previous comments.

Waste stream may be corrosive (engineering judgment) and may contain lead since the process uses lead as the starting material.

Waste Acid Solutions:	High:	12,000 mt/yr
	Medium:	6,100 mt/yr ((12,000 + 100)/2)
	Low:	100 mt/yr (100 * 1 facility)

See previous comments.

Waste stream may be corrosive (engineering judgment). No further information which may classify the waste stream as hazardous was found.

Waste Acids:	High:	200 mt/yr (100 * 2 * 1 facility)
	Medium:	100 mt/yr
	Low:	0

Text, Section C.2. Waste acids are neutralized and discharged with water. Therefore, a low of 0 was selected.

Waste stream may be corrosive (engineering judgment). No further information which may classify the waste stream as hazardous was found.

BORON

Waste Liquor:	High:	300,000 (100,000 * 3 Facilities)
	Medium:	150,000 mt/yr ((300,000 + 300)/2)
	Low:	300 mt/yr (100 * 3 Facilities)

Since some waste liquor may be recycled (text), the high waste generation rate was set at 100,000 mt/yr.

This waste is expected to exhibit the characteristic of toxicity for arsenic.

CADMIUM

Methodology for estimating waste generation rates for the waste streams listed below is provided at the end of the sector.

Caustic Washwater:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium and/or be corrosive.

Copper and Lead Sulfate Filter Cakes:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium and/or lead.

Copper Removal Filter Cake:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium.

Iron Containing Impurities:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium.

Spent Leach Solutions:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for arsenic, cadmium, and/or lead and/or may be corrosive.

Lead Sulfate Waste:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium and/or lead.

Post-Leach Filter Cake:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium.

Spent Purification Solution:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium and/or be corrosive.

Scrubber Wastewater:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium and/or be corrosive.

Spent Electrolyte:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium and/or be corrosive.

Zinc Precipitates:	High:	19,000 mt/yr
	Medium:	1,900 mt/yr
	Low:	190 mt/yr

This waste may be toxic for cadmium.

According to RTC II (Report to Congress on Solid Wastes from Selected Metallic Ore Processing Operations; Technical Memorandum for the Zinc Sector, 1988), saleable

metallic residues from both electrolytic and pyrometallurgical production of zinc amounts to .127 ton/ton product. This document also cites a production capacity for the sector of 400,000 metric tons, 83% of which is utilized. This amounts to a production rate of 332,000 metric tons per year of zinc. Using the above waste-to-product ratio, 42,164 metric tons of saleable metallic residues are generated per year. These metallic residues are used for cadmium recovery as well as the recovery of other heavy metals. Therefore, given an input of 42,164 metric tons and assuming a process efficiency of 50%, 21,082 metric tons of cadmium waste are generated annually. Assuming each of the 11 wastes from cadmium production is generated equally, a medium annual waste generation rate for each cadmium waste is 1,900 metric tons. The high estimate is one order of magnitude above the medium estimate and the low estimate is one order of magnitude below the medium estimate.

COAL GASIFICATION

MEE Concentrate:	High:	65,000 mt/yr
	Medium:	0 mt/yr
	Low:	0 mt/yr

This waste is most likely entirely recycled. Therefore, both the minimum and medium value of MEE Concentrate were estimated to be 0. The maximum generation rate was set at 64,600 mt/yr, based on a ratio of Cooling tower blowdown/MEE Concentrate of 500 gpm/50 gpm, and a cooling tower blowdown generation rate of 646,000 mt/yr.

This waste may contain arsenic and selenium above TC concentrations.

COPPER

Scrubber Blowdown:	High:	4,900,000 mt/yr
	Medium:	490,000 mt/yr
	Low:	49,000 mt/yr

This waste is similar to acid plant blowdown, but will be generated at a lower volume. Therefore, we assumed the medium value to be 10 percent of the acid plant blowdown. The minimum and maximum values are one order of magnitude below and above this rate, respectively.

This waste may contain arsenic, cadmium, mercury, and selenium above TC concentrations.

APC Dust/Sludge:	High:	450,000 mt/yr
	Medium:	220,000 mt/yr
	Low:	1,000 mt/yr

There was no information available for this waste stream so the minimum, medium, and maximum values were set at 100; 22,000; and 45,000 mt/y, respectively. These rates apply to 10 facilities so the sector wide generation rates were calculated to be the above values.

ELEMENTAL PHOSPHORUS

Furnace Scrubber Blowdown:	High:	270,000 mt/yr
	Medium:	0 mt/yr
	Low:	0 mt/yr

The Newly Identified Waste Characterization Data Set Reports that 680,000 mt/yr of Furnace Scrubber Blowdown was generated in 1989. This generation rate corresponds to 5 facilities. Today, there are only 2 facilities producing elemental phosphorous furnace scrubber blowdown. The 680,000 mt/yr value was readjusted as follows:

(680,000)/5 = 136,000

136,000 * 2 = 270,000 mt/yr

This waste stream may be treated prior to discharge, therefore, a generation rate of 0 mt/yr was selected for the low and medium estimates.

This waste may is corrosive and toxic for cadmium.

Slag Quenchwater:	High:	1,000,000 mt/yr
	Medium:	0 mt/yr
	Low:	0 mt/yr

Default rate is 1,000,000 mt/yr per facility. Since the generation rate is not expected to be nearly this high, half the default value was selected. Since there are two facilities, a maximum of 1,000,000 mt/yr was selected. Low and medium estimates were set at 0 mt/yr, since this waste may be treated prior to discharge.

This waste stream is toxic for cadmium and lead.

FLUORSPAR AND HYDROFLUORIC ACID

Off-Spec Fluosilicic Acid:	High:	44,000 mt/yr
	Medium:	15,000 mt/yr
	Low:	0 mt/yr

To estimate the maximum quantity of this waste, we assumed the entire three percent of impurity in acid grade fluorspar was silicon, and that this was the only source of silicon. Therefore, at Allied Signal three percent of 209,839 short tons fluorspar would be 6,295 short tons. If all of this silicon reacted to form fluosilicic acid (H_2SiF_6), approximately 32,297 short tons (29,299 metric tons) could be formed at one plant. However, the waste is off-spec fluosilicic acid, so we assumed that 50 percent could be sold, and there are three facilities in the sector. So the maximum value for industry is 43,950 mt/yr. We assumed the medium value to be one-third of the maximum, representing only one percent silicon in the acid grade fluorspar. Finally, since it is possible to sell this waste as a product, the minimum generation rate was assumed to be 0 mt/yr.

This waste may exhibit the hazardous characteristic of corrosivity.

GERMANIUM

Waste Acid Wash & Rinse Water:	High:	4,000 mt/yr (1,000 * 4 facilities)
	Medium:	2,200 mt/yr ((4,000 + 400)/2)
	Low:	400 mt/yr (100 * 4 facilities)

A high rate of 1,000 was selected which is three orders of magnitude below the average facility generation rate (1,000,000 mt/yr) since the annual consumption rate is only 25 metric tons/yr. The low estimate was set at 100 mt/yr.

Since Hydrofluoric Acid is very expensive and the water is being used for rinsing only, the volume of waste produced is expected to be low. Also, the total consumption rate in 1993 was 25,000 kg (25 mt) (text). Assuming that all of this was produced domestically, low waste generation rates are expected.

We used engineering judgment to determine that this waste stream may be corrosive and toxic (arsenic, cadmium, chromium, lead, selenium, and silver).

Chlorinator Wet APC Sludge:	High:	400 mt/yr (100 * 4 facilities)
	Medium:	210 mt/yr ((400 + 10)/2)
	Low:	10 mt/yr

A high rate of 100 was selected based on the low consumption rates (25 mt/yr). The low was set equal to the highest known production rate in the sector.

Since the wet APC system is primarily being used to control fumes, and concentrated germanium is being used in the process (as compared to germanium with lot of impurities), the sludge generated is expected to be low to medium in volume.

We used engineering judgment to determine that this waste stream may be toxic (arsenic, cadmium, chromium, lead, selenium, and silver).

Hydrolysis Filtrate:	High:	400 mt/yr (100 * 4 facilities)
	Medium:	210 mt/yr ((400 + 10)/2)
	Low:	10 mt/yr

A high rate of 100 was selected based on the low consumption rates (25 mt/yr). The low was set equal to the highest known production rate (10 mt/yr) in the sector.

We used engineering judgment to determine that this waste stream may be toxic (arsenic, cadmium, chromium, lead, selenium, and lead).

Spent Acid/Leachate:	High:	4,000 mt/yr (1,000 * 4 facilities)
	Medium:	2,200 mt/yr ((4,000 + 400)/2)
	Low:	400 mt/yr (100 * 4 facilities)

A high rate of 1,000 was selected which is three orders of magnitude below the average facility generation rate (1,000,000 mt/yr) since the annual consumption rate is only 25 tons/yr. The low estimate was set at 100 mt/yr.

Waste stream may be corrosive and toxic (arsenic and lead).

Waste Still Liquor:	High:	400 mt/yr (100 * 4 facilities)
	Medium:	210 mt/yr ((400 + 10)/2)
	Low:	10 mt/yr

A high rate of 100 was selected based on the low consumption rates (25 mt/yr). The low was set equal to the highest known production rate in the sector.

Waste stream may be ignitable (engineering judgment) and toxic (arsenic, cadmium, chromium, lead, selenium, and silver).

GOLD AND SILVER

Spent Furnace Dusts, Refining Wastes, Slag, and Wastewater Treatment Sludge:	High:	720,000 mt/yr
	Medium:	360,000 mt/yr
	Low:	100 mt/yr

By definition, average facility-level generation rates of solids and sludges are less than 45,000 metric tons. Therefore, due to lack of more precise information, this was used as a high-end in order to estimate waste generation rates for spent furnace dusts, refining wastes, slag, and wastewater treatment sludge from gold and silver production. There are 16 known gold and silver smelters and refineries. Therefore a high-end estimate of 720,000 metric tons, a low-end estimate of 100 metric tons, and a medium estimate of 360,000 metric tons (the midpoint between the high and low estimates) were set for the wastes.

Each of these wastes may be toxic for silver.

Wastewater:	High:	1,700,000 mt/yr
	Medium:	870,000 mt/yr
	Low:	440,000 mt/yr

According to the Effluent Guidelines, 1989, wastewater generated from the production of gold and silver is made up of wastewater from electrolyte preparation wet air pollution control, smelter wet air pollution control, silver chloride reduction spent solution, and electrolytic cells wet air pollution control. These are generated at the following waste-to-product ratios:

- Electrolyte preparation wet APC: .05 L/troy ounce silver in electrolyte
- Smelter wet APC: 6.73 L/troy ounce gold and silver smelted
- Silver chloride reduction spent solution: .4 L/troy ounce silver reduced
- Electrolytic cells wet APC: 19 L/troy ounce gold refined electrolytically

Gold and silver production rates of 2.10 million troy ounces and 59.3 million troy ounces, respectively, were used. These yield wastewater generation rates of 3,517; 791,912; 28,136; and 47,328 metric tons. Therefore, the medium estimate of total waste generation for wastewater is the sum of these four, 870,893 metric tons. One-half and twice the medium value were assigned as lower and upper bounds, respectively.

This waste may be toxic for arsenic, cadmium, chromium, lead, and/or silver.

LEAD

Baghouse Incinerator Ash:	High:	30,000 mt/yr
	Medium:	3,000 mt/yr
	Low:	300 mt/yr

A low generation rate of 100 mt/yr was selected. A high generation rate of 10,000 mt/yr was selected since the waste generation rates are not expected to be as high as 45,000 mt/yr. A medium value one order of magnitude above the low generation rate was estimated.

The waste may be TC toxic for cadmium and lead.

Stockpiled Miscellaneous Plant Waste:	High:	180,000 mt/yr
	Medium:	90,200 mt/yr
	Low:	400 mt/yr

High and low generation rates of 45,000 and 100 mt/yr,respectively were selected since no other information about the waste stream was available. The medium rate was calculated as the average of the high and low generation rates.

The waste may be TC toxic for cadmium and lead.

MAGNESIUM AND MAGNESIA FROM BRINES

Casthouse Dust:	High:	7,600 mt/yr
	Medium:	760 mt/yr
	Low:	76 mt/yr

Casthouse dust is analogous to aluminum production casthouse dust. Aluminum production casthouse dust is generated at a medium rate of 19,000 metric tons per year. Therefore, since the annual production rate for magnesium is about 25 times less than that of aluminum, a medium waste generation rate of 760 metric tons was assigned to casthouse dust. Upper and lower bound estimates of one order of magnitude above and below the medium value were assigned.

This waste may be toxic for barium.

MOLYBDENUM, FERROMOLYBDENUM, AND AMMONIUM MOLYBDATE

Flue Dust/Gases:	High:	540,000 mt/yr
	Medium:	270,000 mt/yr
	Low:	1,200 mt/yr

There was no information on the generation rates of this waste, but 12 facilities produce it. Therefore, we multiplied default values by 12 to estimate the minimum, medium and maximum generation rates.

This waste may contain lead above TC concentrations.

PLATINUM GROUP METALS

Slag:

High:	460 mt/yr
Medium:	46 mt/yr
Low:	4.6 mt/yr

Comparing with the slag waste stream in the antimony sector (waste/product = 32,000/44,600 = 0.717), the medium value was calculated as (65 * 0.717) 46 mt/yr. Upper and lower bound estimates of one order of magnitude above and below the expected value were used.

The waste stream may contain selenium and lead since these two TC metals are being produced in the process.

Spent Acids:

High:	3,000 mt/yr (1,000 * 3 facilities)
Medium:	1,700 mt/yr ((3,000 + 300)/2)
Low:	300 mt/yr (100 * 3 facilities)

A high rate of 1,000 mt/yr was selected which is three orders of magnitude below the highest possible average facility generation rate (1,000,000 mt/yr) since the production is only 65 mt/yr. The low estimate was set at 100 mt/yr.

The waste stream may be corrosive (engineering judgment). The waste stream may contain silver and lead, since these two TC metals are being produced in the process.

Spent Solvents:

High:	3,000 mt/yr (1,000 * 3 facilities)
Medium:	1,700 mt/yr (3,000 + 300/2)
Low:	300 mt/yr (100 * 3 facilities)

See the previous comment.

The waste stream may be ignitable. The waste stream may contain silver and lead, since these two TC metals are being produced in the process.

PYROBITUMENS, MINERAL WAXES, AND NATURAL ASPHALT

Methodology for estimating waste generation rates for the waste streams listed below is provided at the end of the sector.

Still Bottoms:

High:	90,000 mt/yr (45,000 mt/yr * 2 facilities)
Medium:	45,000 mt/yr
Low:	2 mt/yr

This waste may be ignitable.

Waste Catalysts:

High:	20,000 mt/yr (10,000 mt/yr * 2 facilities)
Medium:	10,000 mt/yr
Low:	2 mt/yr

This waste may be toxic for cadmium and/or selenium.

No information was available on waste generation rates from the production of pyrobitumens, mineral waxes, and natural asphalts. There are only two facilities that produce bituminous materials. Therefore, since the production must be less than 45,000 metric tons per facility, the waste generation rate for still bottoms was set as follows:

high, 90,000; medium, 45,000; and low, 2 metric tons. Waste catalysts are assumed to be generated in lower volumes because they are usually recycled. Therefore, a high value was set at 10,000 metric tons per facility. This yields waste catalyst generation rates of high, 20,000; medium, 10,000; and low, 2 metric tons.

RARE EARTHS

The methodology for estimating waste generation rates for the waste streams listed below is provided after the estimates.

Electrolytic Cell Caustic Wet APC:	High:	7,0 00 mt/yr
	Medium:	700 mt/yr
	Low:	70 mt/yr

This waste may be corrosive.

The Development Document for Effluent Limitations Guidelines, 1989, gives waste-to-product ratios for spent electrolytic cell quench water and scrubber water and spent sodium hypochlorite filter backwash from mischmetal production. Spent electrolytic cell quench water and scrubber water is produced at a rate of 9,390 to 12,683 L/kkg mischmetal produced. Spent sodium hypochlorite filter backwash is produced at a rate of 362 L/kkg mischmetal produced.

Since mischmetal is produced by only one company, Reactive Metals and Alloys Corporation in West Pittsburgh, Pennsylvania, information on production of mischmetal is CBI. For this reason an approximation must be made. The following facts guided the estimation:

- Mischmetal is produced from rare earth chlorides which are produced from bastnasite ore.
- Annual production of mischmetal will not exceed annual production of rare earth chlorides since mischmetal is a specialty product.
- Production of rare earth chlorides will not exceed production of bastnasite ore since rare earth chlorides come from bastnasite ore.
- Substituting production of bastnasite ore for production of mischmetal will yield conservative estimates of waste generation rates.

The 1994 Minerals Yearbook gives a production rate for bastnasite concentrates of 20,787 metric tons of rare earth oxide (REO) content. Mischmetal is made from rare earth chlorides which are made from bastnasite ore. According to the 1992 Minerals Yearbook, three grades of bastnasite ore are produced in the United States: (1) unleached concentrate, 60% REO, (2) acid-leached concentrate, 70% REO, and (3) calcined concentrate, 85% REO. These grades specifications were used to establish the total volume of bastnasite ore. The following relationship was used in the calculation.

$$\frac{\text{Ore production in metric tons of REO}}{\text{Total Ore Production}} = \frac{\%\text{REO in ore}}{100}$$

This calculation yields the following bastnasite ore production rates:

- Calcined: 24,000 metric tons bastnasite ore
- Acid-leached: 30,000 metric tons bastnasite ore
- Unleached: 35,000 metric tons bastnasite ore

Assuming all three grades are produced equally, dividing the above values by three gives the annual production of each of the three grades of bastnasite ore (calcined, 8,152 metric tons; acid-leached, 9,899 metric tons; and 11,548 metric tons). Totalling these three values provides the total production of bastnasite ore, 29,599 metric tons. Substituting this value for mischmetal in the waste-to-product ratios yields a high-end generation rate. The medium and low-end estimates are one and two orders of magnitude below this value, respectively.

The methodology for estimating waste generation rates for the waste streams listed below is provided at the end of the sector.

Solvent Extraction Crud:	High:	90,000 mt/yr
	Medium:	45,000 mt/yr
	Low:	200 mt/yr

The default value of 45,000 mt/yr was reduced by a factor of 10 since the generation rate is not expected to be that high.
This waste may be ignitable.

Spent Lead Filter Cake:	High:	5,000 mt/yr
	Medium:	4,200 mt/yr
	Low:	3,300 mt/yr

This waste may be toxic for lead.

Spent Scrubber Liquor:	High:	1,000,000 mt/yr (1,000,000*1 facility)
	Medium:	500,000 mt/yr
	Low:	100 mt/yr (100*1 facility)

This waste may be corrosive.

Waste Solvent:	High:	2,000,000 mt/yr
	Medium:	1,000,000 mt/yr
	Low:	200 mt/yr (100*14 facilities)

This waste may be ignitable

The default value of 1,000,000 mt/yr was reduced by a factor of 10 since waste solvents are presumed to be generated in smaller quantities than other wastes.

Wastewater from Caustic Wet APC:	High:	1,000,000 mt/yr (1,000,000*1 facility)
	Medium:	500,000 mt/yr
	Low:	100 mt/yr (100*1 facility)

This waste may be corrosive and/or toxic for chromium and/or lead.

Waste Zinc Contaminated with Mercury:	High:	90,000 mt/yr (45,000*14 facilities)
	Medium:	45,000 mt/yr
	Low:	200 mt/yr (100*14 facilities)

The default value of 45,000 was reduced by a factor of 10 since the rate is not expected to be that high.

RHENIUM

Spent Barren Scrubber Liquor:	High:	200 mt/yr (100 * 2 facilities)
	Medium:	100 mt/yr ((200 + 0)/2)
	Low:	0

Text indicates that plants achieve zero discharge through reuse and treatment. Therefore, a low of zero and a high of 100 mt/yr were selected.

The waste stream contains selenium.

SCANDIUM

Spent Acids:	High:	7,000 mt/yr (1,000 * 7 facilities)
	Medium:	3,900 mt/yr ((7,000 + 700)/2)
	Low:	700 mt/yr (100 * 7 facilities)

A high rate of 1,000 was selected which is three orders of magnitude lower than 1,000,000 mt/yr. Based on the very low production rates (0.5 tons/yr), the waste generation rate is not expected to be as high as 1,000,000 mt/yr. A low of 100 mt/yr was selected.

The waste stream may be corrosive (engineering judgment).

Spent Solvents from Solvent Extraction:	High:	7,000 mt/yr (1,000 * 7 facilities)
	Medium:	3,900 mt/yr ((7,000 + 700)/2)
	Low:	700 mt/yr (100 * 7 facilities)

A high rate of 1,000 was selected which is three orders of magnitude lower than 1,000,000 mt/yr. Based on the very low production rates (0.5 tons/yr), the waste generation rate is not expected to be as high as 1,000,000 mt/yr. A low of 100 mt/yr was selected.

The waste stream may be ignitable (engineering judgment).

SELENIUM

The methodology for estimating waste generation rates for the waste streams listed below is provided at the end of the sector.

Spent Filter Cake:	High:	5,000 mt/yr
	Medium:	500 mt/yr
	Low:	50 mt/yr

This waste may be toxic for selenium.

Waste Solids:	High:	5,000 mt/yr
	Medium:	500 mt/yr
	Low:	50 mt/yr

This waste may be toxic for selenium.

Slag:	High:	5,000 mt/yr
	Medium:	500 mt/yr
	Low:	50 mt/yr

This waste may be toxic for selenium.

Tellurium Slime Waste:	High:	5,000 mt/yr
	Medium:	500 mt/yr
	Low:	50 mt/yr

This waste may be toxic for selenium.

Selenium is produced from copper anode slimes or "tankhouse slimes." According to the Newly Identified Waste Characterization Data Set, 1992, 4,000 metric tons of these slimes are produced annually. Assuming a process efficiency of 50%, 2,000 metric tons of wastes from selenium production is generated annually. Assuming each of the wastes from selenium production is produced equally, a medium estimate of 500 metric tons of each of the above wastes is produced annually. (Plant process wastewater was not used in this calculation of medium waste generation rates.) The high and low estimates are one order of magnitude above and below the medium estimate.

TELLURIUM

Slag:	High:	4,500 mt/yr (4,500 * 1 facility)
	Medium:	1,000 mt/yr
	Low:	100 mt/yr

No information about production rates or waste stream is available, therefore, high and low estimates of 4,500 and 100 mt/yr were selected. A medium estimate of 1,000 mt/yr was selected because the number of refineries in the U.S. (1) and uses of the metal indicate that production rates and, therefore, waste generation rates would be low.

The waste stream may contain selenium.

Solid Waste Residues:	High:	4,500 mt/yr (4,500 * 1 facility)
	Medium:	1,000 mt/yr
	Low:	100 mt/yr

See previous comment.

The waste may contain selenium since selenium is produced in the process.

Waste Electrolyte:	High:	10,000 mt/yr (10,000 * 1 facility)
	Medium:	1,000 mt/yr
	Low:	100 mt/yr

No information about production rates was available. However, the number of refineries in the U.S. (1) and the uses of the metal indicate that production rates and, therefore, waste generation rates will be low. A medium value of 1,000 mt/yr was used for reasons discussed above. High and low values of 10,000 and 100 mt/yr, respectively, were selected for the same reasons.

The waste stream may contain selenium since selenium is produced in the process. Lead, as an impurity, may also be present in the waste stream.

Wastewater:	High:	20,000 mt/yr (20,000 * 1 facility)
	Medium:	10,000 mt/yr
	Low:	100 mt/yr

See previous comment.

The waste stream may be corrosive. The waste may contain selenium since selenium is also produced in the process.

TITANIUM

Sulfate Process

Waste Acids:	High:	77,000 mt/yr (Newly Identified Document)
	Medium:	39,000 mt/yr
	Low:	200 mt/yr (100 * 2 facilities)

Chloride and Chloride-Ilmenite Processes

Waste Ferric Chloride:	High:	75,000 mt/yr
	Medium:	29,000 mt/yr
	Low:	22,000 mt/yr

Ferric chloride is generated in the chloride-ilmenite process when gaseous titanium tetrachloride is separated from other chlorides. Ferric chloride is removed as an acidic, liquid waste stream through fractional condensation and treated with lime and either landfilled or sold as a by-product. Volume estimated as 10% of Waste Solids volume.

This waste may exhibit the corrosivity characteristic.

Surface Impoundment Liquids:	High:	6,700 mt/yr
	Medium:	3,400 mt/yr
	Low:	630 mt/yr

Surface impoundment liquids consist of various waste streams, such as chloride process waste acids and solids in slurry form and wastewater treatment plant effluent. Waste acids managed in surface impoundments are generally routed to a solids/liquids separation process and then disposed by deep-well injection. Treated effluent is discharged through NPDES outfalls after solids have settled.

This waste may be hazardous for chromium and lead.

Kroll Process for Ti Sponge (Metal) Production

Leach Liquor and Sponge Wash Water:	High:	580,000 mt/yr
	Medium:	480,000 mt/yr
	Low:	380,000 mt/yr

Use discharge rates from Vol. IX of Eff. Guidelines Develop. Doc. for Acid Leachate and Rinse Water (Table V-9, p. 4869) for 4 plants (unidentified). Because these two streams are given as a combined stream in the Dev. Doc., we should combine them in our analysis. Need to get an average value per plant for sponge (Ti metal) production. Use sponge production value for 1991 from Gambogi (1993, p. 12) (1992 data withheld due to CBI). This is for two plants. Calculate average water rate for the four reporting plants and multiply by 2 plants and the sponge production number to get liters of wastewater.

Convert to mtons using density of water at 20°C. This gives a medium estimate; use the ±20% rule to estimate upper and lower bounds.

Based on EPA sampling and responses to the RTI survey, leach liquor is believed to exhibit the hazardous characteristic of corrosivity (pH 0 and 1 recorded at Timet); according to the Eff. Guidelines Dev. Doc., it also contains treatable concentrations of copper, lead, nickel, thallium, and suspended solids.

Smut from Mg Recovery:	High:	45,000 mt/yr (high vol. threshhold)
	Medium:	22,000 mt./yr
	Low:	100 mt/yr

This waste may be reactive in water.

Ingot Production

Pickle Liquor & Wash Water:	High:	3,200 mt/yr
	Medium:	2,700 mt/yr
	Low:	2,200 mt/yr

Use discharge rates from Vol. IX of Eff. Guidelines Develop. Doc. for Acid Pickle & Wash Water (Table V-11, p. 4870) for 2 plants (unidentified). A third plant did not report, so assume its value is average of other two. Use scrap consumption value from Gambogi (1993, p. 12) to estimate volume of pickling liquor. Convert to mtons using density of water at 20°C. This gives a medium estimate; use the ±20% rule to estimate upper and lower bounds.

According to Eff. Guidelines Develop. Doc., this waste contains treatable concentrations of antimony, cadmium, chromium, copper, lead, nickel, and zinc; no concentrations were given. In absence of concentrations, assume potentially hazardous for cadmium, chromium, and lead.. Because HF acid is used as pickling acid, may also contain high concentration of fluoride and may exhibit corrosivity characteristic due to low pH.

Scrap Detergent Wash Water:	High:	540,000 mt/yr
	Medium:	450,000 mt/yr
	Low:	360,000 mt/yr

Use discharge rates from Vol. IX of Eff. Guidelines Develop. Doc. for Scrap Detergent Wash water (Table V-13, p. 4871) for 2 plants (unidentified). Use scrap consumption value from Gambogi (1993, p. 12) to estimate volume of scrap detergent wash water. Convert to mtons using density of water at 20°C. This gives a medium estimate; use the ±20% rule to estimate upper and lower bounds.

According to Eff. Guidelines Develop. Doc., this waste contains treatable concentrations of oil and grease, TSS, and toxic metals. No concentrations were given due to confidentiality. In absence of concentrations, assume potentially hazardous for cadmium, chromium, and lead. This waste may also exhibit the corrosivity characteristic because it is caustic.

Scrap Milling Scrubber Water:	High:	6,000 mt/yr
	Medium:	5,000 mt/yr
	Low:	4,000 mt/yr

Use discharge rates from Vol. IX of Eff. Guidelines Develop. Doc. for Scrap Milling Wet Air Pollution Control (Table V-12, p. 4870) for 1 plant (unidentified). Use scrap

consumption value from Gambogi (1993, p. 12) to estimate volume of scrap milling scrubber water. Convert to mtons using density of water at 20°C. This gives a medium estimate; use the ±20% rule to estimate upper and lower bounds.

According to Eff. Guidelines Develop. Doc., this waste contains treatable concentrations of TSS, titanium, and low concentrations of toxic metals. No concentrations were given due to confidentiality. In absence of concentrations, assume potentially hazardous for cadmium, chromium, and lead.

TUNGSTEN

Spent Acid and Rinse Water:	High:	2,100 mt/yr
	Medium:	0 mt/yr
	Low:	0 mt/yr

The Technical Background Document reports a production rate of 7,324 kkg for tungsten metal powder. The Development Document for Effluent Limitations Guidelines provides discharge rates for 2 plants for rinsewater and spent acid from tungsten powder production. An average of these 2 rates was used to calculate a waste generation rate. An average waste-to-product ratio of 2,400 L/kkg of tungsten was calculated. Using the annual production of tungsten metal above, this waste-to-product ratio corresponds to a high value of 21,000 metric tons of scrubber water annually. Medium and low values were set at 0 mt/yr since the waste is treated prior to discharge.

This waste may be corrosive.

Process Wastewater:	High:	7,300 mt/yr
	Medium:	3,700 mt/yr
	Low:	1,800 mt/yr

The generation rate for a comparable waste stream is assumed to be an acceptable medium estimate for wastes for which no generation rate information is available. Using this assumption, the waste generation rates for tungsten carbide process wastewater were set at those of water of formation.

This waste may be corrosive.

URANIUM

Note: Since the number of mineral processing facilities is currently unknown, we used the number of mining facilities (17) to calculate the quantity of wastes generated.

Tailing Pond Seepage:	High:	7,650,000 mt/yr (450,000 * 17 facilities)
	Medium:	3,833,500 mt/yr ((7,650,000 + 17,000)/2)
	Low:	17,000 mt/yr (1,000 * 17 facilities)

Seepage from one facility is estimated at 1,855 m^3/day (Werthman, P., Purdue Industrial Waste Conference). Using this value, a high annual waste generation rate of 450,000 mt/yr was calculated as shown below. Since this seepage is treated, the low value was estimated to be 1,000 mt/yr.

High Waste Generation Rate = 1,855 m^3/day * 250 days/yr * 1.01 mt/m^3
(using density for water) = Approximately 450,000 mt/yr per facility

Sampling data from a facility (Werthman, P., Proceedings of the Purdue Industrial Waste Conference) shows that this waste stream has a pH of 1.7 and may exhibit the characteristic of toxicity for lead, chromium, arsenic, and selenium.

Barren Lixiviant:	High:	17,000 mt/yr (1,000 mt/yr * 17 facilities)
	Medium:	1,700 mt/yr (100 mt/yr * 17 facilities)
	Low:	0 mt/yr

Barren lixiviant (raffinate) is recycled back to the leaching circuit. Therefore, a low of 0 mt/yr was selected. High and medium waste generation rates were estimated as 1,000 mt/yr and 100 mt/yr, respectively.

Engineering judgment suggests that this waste may exhibit the characteristics of toxicity (arsenic, chromium, lead, and selenium) and corrosivity.

Waste Solvents:	High:	1,700 mt/yr (1,000 mt/yr * 17 facilities)
	Medium:	0 mt/yr (100 mt/yr * 17 facilities)
	Low:	0 mt/yr

Low and medium waste generation rates were set equal to 0 mt/yr since organic solvents used in solvent extraction are recycled. However, due to incomplete phase separation, a small amount may be lost (0.5 gallon per 1,000 gallons of solution passing through the solvent extraction circuit). Therefore, a high waste generation rate of 100 mt/yr was selected.

Waste stream may be ignitable (engineering judgment).

Waste Acids from Solvent Extraction:	High:	17,000 mt/yr (1,000 mt/yr * 17 facilities)
	Medium:	9,350 mt/yr ((17,000 + 1,700)/2)
	Low:	1,700 mt/yr

High and low waste generation rates of 1,000 mt/yr and 100 mt/yr, respectively, were selected based on the low production rates (1,361 mt/yr).

This waste stream may exhibit the characteristics of toxicity (arsenic, chromium, lead, and selenium) and corrosivity.

Slimes from Solvent Extraction:	High:	17,000 mt/yr (1,000 mt/yr * 17 facilities)
	Medium:	9,350 mt/yr ((17,000 + 1,700)/2)
	Low:	1,700 mt/yr

High and low waste generation rates of 1,000 mt/yr and 100 mt/yr, respectively, were selected based on the low production rates (1,361 mt/yr).

This waste stream may exhibit the characteristic of toxicity (arsenic, chromium, lead, and selenium).

Waste Nitric Acids from the Production of UO_2:	High:	3,400 mt/yr
	Medium:	2,550 mt/yr ((3,400 + 1,700)/2)
	Low:	1,700 mt/yr

High and low waste generation rates of 200 mt/yr and 100 mt/yr, respectively, were selected based on the low production rates.

This waste stream may be corrosive (engineering judgment).

Vaporizer Condensate:	High:	17,000 mt/yr (1,000 mt/yr * 17 facilities)
	Medium:	9,350 mt/yr
	Low:	1,700 mt/yr

High and low waste generation rate of 1,000 mt/yr and 100 mt/yr, respectively, were estimated based on the low production rates for uranium (1,361 mt/yr).

This waste may be corrosive since the process uses hydrofluoric acid.

Superheater Condensate:	High:	17,000 mt/yr (1,000 mt/yr * 17 facilities)
	Medium:	9,350 mt/yr
	Low:	1,700 mt/yr

High and Low waste generation rate of 1,000 mt/yr and 100 mt/yr, respectively, were estimated based on the low production rates for uranium (1,361 mt/yr).

This waste stream may be corrosive (engineering judgment) since the process uses hydrofluoric acid.

Slag:	High:	17,000 mt/yr (1,000 mt/yr * 17 facilities)
	Medium:	8,500 mt/yr
	Low:	0 mt/yr

High waste generation rate of 1,000 mt/yr was estimated based on the low production rates for uranium (1,361 mt/yr). The low generation rate was set equal to 0 mt/yr since the slag is recycled.

This waste stream may be ignitable since it may contain uranium metal (engineering judgment, DOT Emergency Response Guidebook).

Uranium Chips from Ingot Production:	High:	3,400 mt/yr
	Medium:	2,550 mt/yr ((3,400 + 1,700)/2)
	Low:	1,700 mt/yr

High and low waste generation rates of 100 mt/yr and 200 mt/yr, respectively, were selected based on the low production rates.

This waste stream may be ignitable (engineering judgment) since it contains uranium metal (DOT Emergency Response Guidebook).

ZIRCONIUM AND HAFNIUM

Spent Acid Leachate Zirconium and Hafnium Alloy Production:	High:	850,000 mt/yr
	Medium:	0 mt/yr
	Low:	0 mt/yr

For spent acid leachate from zirconium alloy production, waste-to-product ratios were given in the Effluent Guidelines, 1989. The waste-to-product ratios for acid leachate were 12,617 to 18,925 L/kkg zirconium in alloys. A production rate for zirconium in alloys was not available so the production rate for zirconium was used instead. (It is assumed that the production of zirconium alloys does not exceed the production of zirconium.) The above mentioned waste-to-product ratios were used to calculate an average generation rate. This generation rate was used as the high rate. Low and medium rates were set equal to zero since the waste may be treated prior to discharge.

This waste may be corrosive.

Spent Acid Leachate Zirconium and Hafnium Metal Production:	High:	1,600,000 mt/yr
	Medium:	0 mt/yr
	Low:	0 mt/yr

For spent acid leachate from zirconium metal production, waste-to-product ratios were given in the Effluent Guidelines, 1989. The waste-to-product ratio for acid leachate was 29,465 L/kkg zirconium produced. The production rate for zirconium used was 45,350 metric tons. Using the production of zirconium and the waste-to-product ratio, a high sector wide estimate of 1,600,000 mt/yr was calculated. Low and medium rates were set equal to zero since the waste may be treated prior to discharge.

This waste may be corrosive.

Leaching Rinsewater from Zirconium Alloy Production:	High:	51,000 mt/yr
	Medium:	42,000 mt/yr
	Low:	34,000 mt/yr

For leaching rinsewater, waste-to-product ratios (632 to 946 L/kkg zirconium in alloys) were given in the 1989 Effluent guidelines. A production rate for zirconium was not available so the production rate for zirconium was used instead. (It is assumed that the production of zirconium alloys does not exceed the production of zirconium). The above mentioned waste-to-product ratios correspond to low and high estimates.

This waste may be corrosive

Leaching Rinsewater from Zirconium Metal Production:	High:	2,000,000 mt/yr (1,000,000 * 2 facilities)
	Medium:	1,000,000 mt/yr
	Low:	200 mt/yr

This waste may be corrosive.

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX B

Work Sheet for Waste Stream Assessment of Recycling, Recovery, and Reuse Potential

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WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: _____
Waste Stream: _____
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ___ Partially Recyclable

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX C

Definitions Formerly Used to Classify Mineral Processing Waste Streams

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DEFINITIONS FOR CLASSIFYING MINERAL PROCESSING WASTESTREAMS

Sludge - any solid, semi-solid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility exclusive of the treated effluent from a wastewater treatment plant. Examples include:

- baghouse dusts
- cast house dusts
- wastewater treatment plant sludges and solids
- chlorinator wet air pollution control sludges
- scrubber wastewater
- APC dust/sludges

Spent Material - any material that has been used and as a result of contamination can no longer serve the purpose for which it was produced without processing (e.g., treatment or regeneration). Examples include:

- process wastewaters
- spent barren filtrate
- spent raffinate
- spent caustic soda
- spent electrolyte
- waste acid solutions
- waste liquors
- caustic washwaters
- spent bleed electrolyte
- contact cooling water
- slag quench water
- spent furnace brick

By-Product - a material that is not one of the primary products of a production process and is not solely or separately produced by the production process. Examples are process residues such as slags or distillation column bottoms. The term does not include a co-product that is produced for the general public's use and is ordinarily used in the form it is produced by the process. Other examples include:

- anode or tankhouse slimes
- beryl thickener slurry
- post-leach filter cake
- furnace residues
- synthetic gypsum

Note: If a surface impoundment is used for pollution control, then both the liquid and solid components are considered to be "sludge." If a surface impoundment is not used for pollution control, then the liquid is probably a "spent material" and the solid is probably a "by-product."

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX D

Recycling Work Sheets for Individual Mineral Processing Waste Streams

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1997 UPDATE

Several of the recycling status conclusions and former RCRA waste type classifications detailed on the following worksheets have been revised since December 1995 (the date of initial publication of this appendix) due to comments received on the January 25, 1996 Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes and the May 12, 1997 Second Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, as well as other new information received by the Agency. Changes in recycling status are summarized in Exhibit D-1, and changes in former RCRA waste type classification are summarized in Exhibit D-2. Note that in Exhibit D-1, the symbols Y and Y? are equivalent to the term "Recyclable," the symbol N is equivalent to "Not Recyclable," and the symbols YS and YS? are equivalent to "Partially Recyclable" on the following worksheets.

EXHIBIT D-1
Changes in Recycling Status Since December 1995

Sector -- *Waste Stream*	**1995 Recycling Status**	**Current Recycling Status**
Beryllium -- *Spent Barren Filtrate*	YS?	YS
Elemental Phosphorous -- *Furnace Scrubber Blowdown*	N	Y
Magnesium and Magnesia from Brines -- *Smut*	Y?	N
Mercury -- *Dust*	YS?	N
Rare Earths -- *Solvent Extraction Crud*	YS?	N
Selenium -- *Tellurium Slime Wastes*	YS?	Y?
Zinc -- *WWTP Solids*	N	YS

EXHIBIT D-2
Changes in Former RCRA Waste Type Classification Since December 1995

Sector -- *Waste Stream*	**1995 Former RCRA Waste Type Classification**	**Current Former RCRA Waste Type Classification**
Cadmium -- *Scrubber Wastewater*	Spent Material	Sludge
Copper -- *Acid Plant Blowdown*	By-Product	Sludge
Elemental Phosphorous -- *Furnace Scrubber Blowdown*	N/A	Sludge
Lead -- *WWTP Liquid Effluent*	Sludge	Spent Material
Rare Earths -- *Spent Scrubber Liquor*	Spent Material	Sludge
Rare Earths -- *Wastewater from Caustic Wet APC*	Spent Material	Sludge
Rhenium -- *Spent Barren Scrubber Liquor*	Spent Material	Sludge

EXHIBIT D-2 (continued)

Sector -- *Waste Stream*	**1995 Former RCRA Waste Type Classification**	**Current Former RCRA Waste Type Classification**
Titanium and Titanium Dioxide -- *Scrap Milling Scrubber Water*	Spent Material	Sludge
Zinc -- *Acid Plant Blowdown*	Spent Material	Sludge
Zinc -- *WWTP Solids*	N/A	Sludge

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Alumina / Aluminum
Waste Stream: Cristnaux dust
Waste Generation Rate: 19000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C. R (T)
Hazardous Constituents (major): cadmium and mercury

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Casting
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Air pollution control

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Alumina / Aluminum
Waste Stream: Electrolysis Waste
Waste Generation Rate: 58,000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Electrolysis (APC Dust)
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: (Yes)/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/(Recovery)/Reuse: (Yes)/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

ustrial Sector and Process: Antimony, Hydrometallurgical Recovery
Waste Stream: Autoclave Filtrate
Waste Generation Rate: 380, 32000, 64000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Pb, Hg

1. **Process Flow Diagram & Waste Characterization:** By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Autoclave
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Waste stream may be recycled for water reuse

2. **Reasons for Waste Generation:** Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. **Waste Management Alternatives:** Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. **Material Classification:** Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Antimony, Smelting and Refining
Waste Stream: Slag and furnace residue
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Antimony, Hydrometallurgical Recovery
Waste Stream: Stripped Anolyte Solids
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Beryllium
Waste Stream: Spent Barren Filtrate Streams
Waste Generation Rate: 88,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Filtration of $BeCO_3$ + $Be(OH)_2$
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Filtrate from $BeCO_3$ is sometimes concentrated to recover uranium

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: 1 Facility

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Beryllium
ste Stream: Beryl Thickener Slurry
Waste Generation Rate: 3000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major):

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Counter Current Decantation
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: 1 facility

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: Leaching Agents Reduced pH

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Beryllium
Waste Stream: Chip treatment wastewater
Waste Generation Rate: 100 mt/yr ; 50,000 mt/yr + 1,000,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cr?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Beryllium Pebble Thickener
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: has 0.3% beryllium which may be recoverable

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable Y Partially Recyclable

4. Material Classification: (circle one) Sludge Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Beryllium
Waste Stream: Filtration discard
Waste Generation Rate: 100 mt/yr; 23,000 mt/yr; 45,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Pb ?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Filtration of Ammonium Fluoroberyllate
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: 1 Facility

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: removes heavy metal from ore & lead from lead precipitation step immediate

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___X Non-Recyclable ___ Partially Recyclable

4. Material Classification: *(circle one)* Sludge Spent Material (By-Product)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Beryllium
Waste Stream: Spent Raffinate
Waste Generation Rate: 380,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: $BeSO_4$ Solvent Extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: contains magnesium, aluminum & kerosene

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: 1 facility

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY AND REUSE POTENTIAL

Industrial Sector and Process: EXTRACTION OF BERYLLIUM ORE AS BERYLLIUM SULFATE
Waste Stream: BERTRANDITE THICKENER SLURRY
Waste Generation Rate: 370,000 MT/YEAR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I,C,R,T
Hazardous Constituents (major): NONE

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: EXIT FROM CCD THICKENER AS A SLURRY DISCARDED TO TAILPOND.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: PRECLUDES SOLIDS UNREACTED WITH SULFURIC ACID OR NOT DISSOLVING IN WATER

2. Reasons for Waste Generation: Based on the description of the process, waste generation and its management practices given in a sector profile of the industry, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Don't Know
   Comment: WASTE CHARACTERIZATION MAY VARY WITH ORE QUALITY, ACID LEACHING PERFORMED AND CONTENT OF LEACHABLE METALS

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps, etc.)?
   Comment: WASTE GENERATED AFTER LEACHING BERYLLIUM IN THE ORE LEAVING DISCARDABLE MATERIALS OUT

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, during impurity removal, etc.)?
   Comment: RESIDUAL ACIDITY IN THE WASTE AFTER LEACHING OPERATION. CAN THIS WASTE BE DECHARACTERIZED DURING PROCESS?

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Don't Know
   Comment: HOW TO PREVENT RESIDUAL ACIDITY IN WASTE.

   B. Water Use Reduction: Yes/No/Don't Know
   Comment: MAY HAVE TO DILUTE WASTE TO REDUCE ACIDITY

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Don't Know
   Comment: RECYCLING FEATURES ALREADY EXISTING IN PRESENT OPERATIONS

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Don't Know
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Refining
Waste Stream: Alloy Residues
Waste Generation Rate: 100, 3,000, 6,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: oxidation of impure bismuth
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Refining produces 99.999% pure bismuth.

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: only one producer

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Refining
Waste Stream: Lead and Zinc Chlorides
Waste Generation Rate: 100, 3000, 6000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Parkes Desilverization
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Chlorides are removed as impurities.

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: only one producer

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Extraction
Waste Stream: Spent caustic soda
Waste Generation Rate: 100, 6100, 12000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Spent soda may be recycled.

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: only one producer

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Betts Electrolytic Process
Waste Stream: Spent Electrolyte
Waste Generation Rate: 100, 6100, 12000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Electrolytic Refining
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: only one producer

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Refining
Waste Stream: Spent soda solution
Waste Generation Rate: 100, 6100, 12000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Mixer
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Spent soda solution may be reused after processing

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: only one producer

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Extraction from Bismuth bearing mate
Waste Stream: Waste Acid Solutions
Waste Generation Rate: 100, 6100, 12000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Purification of Bismuth oxychloride, Oxychloride Proc
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: only one producer

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Extraction
Waste Stream: Electrolytic Slimes
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Betterton-Kroll Process
Waste Stream: Metal Chloride Residues
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
   (circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Extraction
Waste Stream: Waste Acids
Waste Generation Rate: 0, 100, 200 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major):

1. **Process Flow Diagram & Waste Characterization:** By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Waste Acids may be processed and reused

2. **Reasons for Waste Generation:** Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. **Waste Management Alternatives:** Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. **Material Classification:** Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Bismuth, Betterton-Kroll Process
Waste Stream: Slag
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
   (circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIA

Industrial Sector and Process: Boron, Boric Acid Production
Waste Stream: Waste liquor
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physi separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: Caustic Wash Water
Waste Generation Rate: P.C/1900 mtl/yr, 1190
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Wash
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Rinsing

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: copper and lead nitrate filter cake
Waste Generation Rate: 190/1900 mtl/1900
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium and lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: filtration
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: copper cement filter cake
Waste Generation Rate: 190/900 mt/2/1900
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: filtration
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: Iron containing impurities
Waste Generation Rate: 10/1995 mt/year 1/1996
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: filter
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: Spent leach solution
Waste Generation Rate: 90/1900 Mt/year/1900
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I . (C) R . (T)
Hazardous Constituents (major): arsenic, cadmium and lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: leaching process
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: lead nitrate filter
Waste Generation Rate: 90/1900 mt/year 1990
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium and lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: filter
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: Post-leach filter cake
Waste Generation Rate: [illegible] 1900 mt/year [illegible]
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Leaching
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ✗ Non-Recyclable ___ Partially Recyclable ~~post leach - nothing should be in~~

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: spent purification solution
Waste Generation Rate: 8,1900 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Purification
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: Scrubber Water
Waste Generation Rate: 190/1920 mt/yr 1/1000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): Cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: APC
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: spent electrolite
Waste Generation Rate: 4000 mt/year / 1000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Electolyte
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Cadmium
Waste Stream: Zinc Precipitates
Waste Generation Rate: 190/1000 mtl/yr/1 [illegible]
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Galvanic Precipitation
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Calcium Metal ; Aluminothermic Process
Waste Stream: Dust with Quicklime
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) Sludge Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Chromium, Ferrochromium, & Ferrochromium-Silicon
te Stream: Dust or Sludge from Ferrochromium production
..ste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Ba?, Cr, Pb?, Se, Ag?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Furnace
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: "In efficiently operated furnace, furnace dust is collected & resmelted"

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Coal Gas
Waste Stream: Multiple efforts evaporator concentrate
Waste Generation Rate: 0, 0, +65000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): As?, Se?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Cooling Tower blowdown → MEE unit
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Can be recycled sometimes w/o treatment

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: 1 Facility

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: remove impurities

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: long, long ago in processing (progressive concentration of impurities)

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable
YS

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Coal Gas
Waste Stream: Stretford solution Purge Stream
Waste Generation Rate: 5000 mt/yr, 17,000 mt/yr, 45,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry) ??
Hazard Characteristics (all): I C R? T
Hazardous Constituents (major): Reactive?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Stretford Unit
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: 1 facility

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: purge stream

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: R reactive, was reactive as a fresh material

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Copper
ste Stream: wwtp sludge
ste Generation Rate: 6000 mt
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Cd?, Pb?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: WWTP (wastewater sources throughout process)
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: high copper concentration ~(40%)
   recycled to Flash Furnace at Chino + Filter Plant to process staging area, sludge sent to S.I. or Kennecott

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: Similar but constituent conc vary greatly

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable
This should be YS not YS?

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Copper
Waste Stream: WWTP liquid effluent
Waste Generation Rate: 4,590,000 MT/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Pb?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Multiple sources feed into WWTP
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: this is treated effluent recycled to concentrate at Kennecott; sent to tailing pond

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____
   The haz portion of this stream is recycled at one facility
   The other facility does not produce haz effluent, so this waste should fall o

Conclusion: ___ Recyclable ___ Non-Recyclable ___ Partially Recyclable
Recyclable = Yes (not Y?)

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Elemental Phosphorus
Waste Stream: dusts
Waste Generation Rate: 4400 Mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Crushing / Screening / Conveyors
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

Part of process rather than APC.

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Elemental Phosphorus
Waste Stream: AFM rinsate
Waste Generation Rate: 2000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium and selenium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Elemental Phosphorus
Waste Stream: Furnace offgas solids
Waste Generation Rate: 24,000 metric tons
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: __ Recyclable __ Non-Recyclable __ Partially Recyclable

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Elemental Phosphorus
Waste Stream: Furnace Scrubber Blowdown
Waste Generation Rate: 9/0/272,000 mil/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): cadmium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: APC
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Elemental Phosphorus
Waste Stream: slag quenchwater
Waste Generation Rate: 11,000,000 metric tons
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium and lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: furnace
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: for more coding

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Fluorspar + Hydro Fluoric Acid
Waste Stream: OFF-spec ~~Fluor~~ Fluosilic Acid
Waste Generation Rate: 0, 15000 mt/yr + 44000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major):

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Water scrubber
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: when Fluosilic acid meets specs it is solid ~~of~~ therefore ~~when~~ this material will only be reused (ie solid) if it meets specs.

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable _X_ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Germanium, Primary & Secondary Germanium Proc
Waste Stream: Waste Acid Wash and Rinse Water
Waste Generation Rate: 400, 2200, 4000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Cr, Pb, Se, Ag

1. **Process Flow Diagram & Waste Characterization:** By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Germanium Ingot Washing
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Waste Acids may be processed and reused

2. **Reasons for Waste Generation:** Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. **Waste Management Alternatives:** Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. **Material Classification:** Sludge (Spent Material) By-Product
   (circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Germanium, Primary & Secondary Germanium Products. Proce
Waste Stream: Chlorinator Wet APC Sludge
Waste Generation Rate: 10,210,400 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Cr, Pb, Se, Ag

1. **Process Flow Diagram & Waste Characterization:** By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Wet Scrubber
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. **Reasons for Waste Generation:** Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. **Waste Management Alternatives:** Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives:

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. **Material Classification:** (circle one) Sludge Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

ndustrial Sector and Process: Germanium, Primary & Secondary Germanium Product
Waste Stream: Hydrolysis Filtrate
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
   (circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Germanium, Recovery of Ge during Zinc Ore Pro
Waste Stream: Leach Residues
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Germanium, Primary & Secondary Germanium Production Pro.
Waste Stream: Spent Acid/Leachate
Waste Generation Rate: 400, 2200, 4000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Pb

1. **Process Flow Diagram & Waste Characterization:** By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Leaching
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. **Reasons for Waste Generation:** Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. **Waste Management Alternatives:** Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. **Material Classification:** Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Germanium, Primary & Secondary Germanium Produc
Waste Stream: Waste - Still Liquor
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physica separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product 911
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Gold and Silver
Waste Stream: Refinery waster
Waste Generation Rate: 101 J 320,000 mt/year 172 000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): silver

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: acid

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: too large volume

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: (circle one) (Sludge) Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Gold and Silver
Waste Stream: Slag
Waste Generation Rate: 100 / 320,000 mt/year / 72000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Silver

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: Too large volume

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Gold and Silver
Waste Stream: WWTP sludge
Waste Generation Rate: 10/320,000 m³/year / 72,000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Silver

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: Too large volume

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Gold and Silver
Waste Stream: Wastewater
Waste Generation Rate: ~~1100~~/370,000 mt/year / 170000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I. C R (T)
Hazardous Constituents (major): silver, arsenic, cadmium, chromium, and lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) (Sludge) Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Gold and Silver
Waste Stream: Refining Wastes
Waste Generation Rate: 1000 / 360,000 / 720000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): silver

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead
Waste Stream: Acid - Plant Blowdown
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead, Primary smelting and refining
Waste Stream: Acid plant sludge
Waste Generation Rate: 14,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Sludge is recycled according to RTI survey flowdiagro

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) Sludge Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead
Waste Stream: Baghouse Dust
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) **Sludge** Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead, Primary smelting and refining
Waste Stream: Baghouse Incinerator Ash
Waste Generation Rate: 500, 5000, 50,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cd, Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Incinerator burning used baghouse bags
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: Waste is reported to be generated at only one facility

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead, Primary smelting and Refining
Waste Stream: Process Wastewater
Waste Generation Rate: 5,000,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Pb, Hg, Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Various sources; wastewater is aggregated
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead
Waste Stream: Slurried APC Dust
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) **Sludge** Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead, Primary Smelting and Refining
Waste Stream: Solid Residues
Waste Generation Rate: 400 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Sintering Plant
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: waste is recycled back to sintering plant (RTI Survey

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead
Waste Stream: Spent Furnace Brick
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physic separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead, Primary smelting and refining
Waste Stream: Stockpiled miscellaneous plant waste
Waste Generation Rate: 500, 110,000, 225,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cd, Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Various (refractory brick, slag, sweepings, matte).
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead.
Waste Stream: Surface impoundment Waste Liquids
Waste Generation Rate: 5,300,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Pb

1. **Process Flow Diagram & Waste Characterization:** By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Various Sources
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. **Reasons for Waste Generation:** Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. **Waste Management Alternatives:** Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. **Material Classification:** (circle one) Sludge Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead
Waste Stream: WWTP Liquid Effluent
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) **Sludge** Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Lead
Waste Stream: WWTP Sludge/Solids
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) Sludge Spent Material By-Product

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WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Magnesia / Magnesium
Waste Stream: cathode dust
Waste Generation Rate: 76/ 760 mt/yr / 7600
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Barium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: casting - refining a metal
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) (Sludge) Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Magnesia / Magnesium
Waste Stream: smut (sludge and dross)
Waste Generation Rate: 2600 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Barium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: casting
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
   (circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Mercury
Waste Stream: Filter cake waste
Waste Generation Rate: 900 mt/yr 200,000 mt/yr 405,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Hg?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Filtration of cyanide solution
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: May contain gangue, cyanide and/or metallic precipitates

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable _X_ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Mercury
Waste Stream: Furnace Residues
Waste Generation Rate: 100 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Hg?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: ~~Filtration of cyanide solution~~ Roaster?
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: ~~[illegible]~~ No data available

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable _X_ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Mercury
Waste Stream: ~~Concentrate wastewater~~ Dust
Waste Generation Rate: ~~[illegible]~~ 10. mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Hg?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Some APC Device?
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: unknown part of generation + contaminants

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ___✓ Partially Recyclable

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Molybdenum
Waste Stream: Molybdic Oxide Refining Waste
Waste Generation Rate: 2000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Unknown
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: No info

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Molybdenum / Tech Grade Molybdic Oxide Production
Waste Stream: Flue Dust / Gases
Waste Generation Rate: 1,200 mt/yr ; 270,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Rhenium Recovery Scrubber and/or SO_2 Scrubber
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: may have rhenium/selenium in low quantities

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: Waste Char may differ as Rhenium is not recovered and/or based on ore content

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: impurities in ore

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: (Sludge) Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Molybdenum
te Stream: Liquid ~~Reef~~ Residues
.aste Generation Rate: ~~As? Cd? Pb? Se?~~
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): As?, Cd?, Pb?, Se?

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Liquids From quench and scrubber towers/thickeners (which follow Roaster APC unit but before acid Plant)
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Cooling

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: If quench (cooling) ~~scrubber~~ waters are ~~not~~ contact, separation would reduce amount of haz. wastewater

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: Currently shipping offsite for treatment & Disposal

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable _Y_ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Platinum Group Metals, Refining
Waste Stream: Spent Solvents
Waste Generation Rate: 300, 1700, 3000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Precipitation of metals (used along with HCl)
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: waste may contain very low concentrations of recoverable materials (not enough to warrant recycling)

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Platinum Group Metals, Refining
Waste Stream: Spent Acids
Waste Generation Rate: 300, 1700, 3000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Refining (used to produce chloride salts of various metals)
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Waste may contain very low concentrations of recoverable prod. (not enough information to determine recyclability)

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Platinum Group Metals, Smelting
Waste Stream: Slag
Waste Generation Rate: 5,46,460 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb, Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Top blown rotary converter (TBRC)
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Stillwater Mining Co's (only primary company in U.S.) process flow chart shows that slag is recycled to the furnace.

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Pyrobitumerus
Waste Stream: still bottoms
Waste Generation Rate: 2/45000 utlyear/90000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): (I) C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: cracking still
   B. Waste generation is closest to: (Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: fuel burning?

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Pyrobitumens
Waste Stream: Waste catalyst
Waste Generation Rate: 2/10,000 mt/year / 20,000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): cadmium and selenium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: cracking still
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earthr
Waste Stream: spent ammonium nitrate processing solution
Waste Generation Rate: 14,000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major):

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare Earth
Waste Stream: Spent lead filter cake
Waste Generation Rate: 3,300 / 4,200 / 5,000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: filtration
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earths
Waste Stream: electrolytic cell solution wet APC sludge
Waste Generation Rate: 70/700/7,000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): _____

1. **Process Flow Diagram & Waste Characterization**: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. **Reasons for Waste Generation**: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. **Waste Management Alternatives**: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. **Material Classification**: (Sludge) Spent Material By-Product
   (circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earths
Waste Stream: Process Wastewater
Waste Generation Rate: 7000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Washwater / cooling water
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earthes
Waste Stream: Spent Scrubber liquor
Waste Generation Rate: 100/500/1000 000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I / (C) / R / T
Hazardous Constituents (major): 100/500 000/1000 000 mt/year

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Scrubber
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable V Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earthx
Waste Stream: solvent extraction mud
Waste Generation Rate: 200 / 450,000 mt/year / 90000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): (I) C R T
Hazardous Constituents (major): 20000/45000/90000 mt/year

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Solvent extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: volume too large

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earths
Waste Stream: waste solvent
Waste Generation Rate: 200 / 1000000 mt/year / 200000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): (I) C R T
Hazardous Constituents (major): 2000 / 1000 / 2000 mt/year

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Batch extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: on-site distillation

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: volume too large

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earths
Waste Stream: Wastewater from caustic wet APC
Waste Generation Rate: 120/50000/1000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): chromium and lead

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: APC
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: neutralize

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: volume too large

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rare earth
Waste Stream: Waste zinc contaminated with mercury
Waste Generation Rate: 2001 45000 mt/year / 9000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Mercury

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: May send some to recovery

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rhenium, Roasting and Wet Scrubbing
Waste Stream: Spent Barren Scrubber Liquor
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Rhenium, Recovery of Rhenium from Molybdenate co
Waste Stream: Spent Rhenium Raffinate
Waste Generation Rate: 88,000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Solid-bed ion exchange
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Ion-exchange removes 95% of Rhenium

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Synthetic Rutile, Acid Regeneration Circuit
Waste Stream: Spent Iron Oxide Slurry
Waste Generation Rate: 45000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cd, Cr

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Acid Recovery
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: Sludge Spent Material By Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

ustrial Sector and Process: Synthetic Rutile, Benelite Cyclic Process
waste Stream: APC - Dust/Sludges
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: (circle one) **Sludge** Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Synthetic Rutile; Spent Acid Solution
Waste Stream: Spent Acid Solution
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Scandium, Scandium from thortveitite #1
Waste Stream: Spent Acids
Waste Generation Rate: 700, 3900, 7000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Various Leaching and dissolution steps
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Spent Acids are not expected to contain recoverable prod.

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Scandium, Scandium from Thortveitite #3
Waste Stream: Spent Solvents from Solvent Extraction
Waste Generation Rate: 700, 3900, 7000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Solvent Extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Solvents could be recycled and reused

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Selenium
Waste Stream: spent filter cake
Waste Generation Rate: 500 mt/year / 500
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): selenium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: filtering
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: other precious metals

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: other precious metals

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Selenium
Waste Stream: Plant process wastewater
Waste Generation Rate: 66,000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I . (C) R (T)
Hazardous Constituents (major) Nad

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: precipitation, washing
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Selenium
Waste Stream: slag
Waste Generation Rate: 50 / 8500 mt/year / 5000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Selenium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Selenium
Waste Stream: Tellurium plume water
Waste Generation Rate: 20/ 500mt/year / 5000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Selenium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: neutralization
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Selenium
Waste Stream: Waste solids
Waste Generation Rate: 50/500 mt/year/500
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): selenium

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: leaching
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable nothing in it after leaching

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tantalum, Columbium, Ferrocolumbium
Waste Stream: Process Wastewater
Waste Generation Rate: 150,000 mt/yr ⇒ 0, 0, 150,000 mt/y
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry) 1-10% solids
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): As?, Co?, Cr?, Pb?, Se?,

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Multiple
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Seem to go to WWTP (since we cannot confirm, we are leaving in analysis in max case)

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: Treatment & Reuse (i.e. WWTP)

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tantalum, Columbium + Ferrocolumbium
Waste Stream: Digester Sludge
Waste Generation Rate: 1000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Digester
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: recycling will be hampered because of radioactivity

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: inefficiency of digestion and/or removal of impurities

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: w/ HF acid

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tantalum, Columbium + Ferrocolumbium
Waste Stream: Spent Raffinate solids
Waste Generation Rate: 2000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry) (or sludge)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major):

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: liquid-liquid extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: with HF acid or

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material (By-Product)
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

ustrial Sector and Process: Tellurium, Purification of Tellurous Acid
waste Stream: Waste Water
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tellurium, Purification of Tellurous Acid
Waste Stream: Waste Electrolyte
Waste Generation Rate: 100, 1000, 10000 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): Pb, Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Electrolysis
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tellurium, Recovery from Copper Slimes
Waste Stream: Solid Waste Residues
Waste Generation Rate: 100, 1000, 4500 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): -- I C R T
Hazardous Constituents (major): Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Precipitation
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Waste residues are solid impurities and are discarded as waste

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tellurium, Recovery from Copper Slimes
Waste Stream: Slag
Waste Generation Rate: 100, 1000, 4500
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Roasting and Leaching
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Slag from leaching may be returned to a copper anode for further processing; slag from Roasting is wasted

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Waste Ferric Chloride
Waste Generation Rate: 33000 – 50000 MT/YR
Waste Form: Liquid (Aq/Non-Aq)/Slurry/Solids (Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): Cd, Cr, Pb, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Fractional condensation of gaseous product stream containing TiCl4 and other metal chloride
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Pickle Liquor and Wash Water
Waste Generation Rate: 2200 – 3200 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Cd, Cr, Pb possibly corrosive.

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Generated as spent acid pickling used to remove surface oxides from scrap
   B. Waste generation is closest to: Raw Material/~~Major Intermediates~~/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: possibly.

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: But should be done on-site.

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Scrap Milling Scrubber Water
Waste Generation Rate: 4000 - 6000 MT/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Cd, Cr, Pb, Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: dust scrubber used to clean dust generated in crushing Ti scrap chips
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. ~~What was~~ the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Scrubbing

   C. Why did ~~this waste become~~ hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Scrap Detergent Wash Water
Waste Generation Rate: 360,000 - 540,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): Cd, Cr, Pb, Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Washing of Ti scrap chips & millings w/ detergent solution.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for ~~generating this~~ waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing/other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Smut from Mg Recovery
Waste Generation Rate:
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major):

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: generated in recovery (through electrolysis) of Mg from MgCl solution generated in reduction process
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: Currently recycled to reduction reactor.

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product ?
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Leach liquor and sponge wash water.
Waste Generation Rate: 380,000 – 580,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cr, Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: acid leaching of Ti sponge and rinsing of leached sponge
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: acid leaching

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: currently neutralized with resulting solution sold as dust suppressant.

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Spent surface impoundment liquids
Waste Generation Rate: 900 – 9,500 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cr, Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Various waste streams, such as Cl process waste acids and solids in slurry form and wastewater effluent
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Collection of various waste streams for equalization prior to treatment.

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Spent Surface Impoundment Solids
Waste Generation Rate: 51,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cr, Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: settleable solids from wastestreams collected in surface impoundments.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process? Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Collection of various wastestreams for equalization prior to treatment.

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Waste acids (Chloride Process)
Waste Generation Rate: 77,000 MT/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cr, Pb, Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: generated in chlorination step as slurry; acids separated by solids/liq. sep. process
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ? Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: Waste Acids (Sulfate process)
Waste Generation Rate: 200 – 77,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cr, Se, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: filtration of titania hydrate
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Filtration of intermediate product.

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
ste Stream: WWTP sludge/solids
ste Generation Rate: 600,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cr

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: created in treatment of wastewaters in chloride process
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: _____
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: _____
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Titanium and Titanium Dioxide
Waste Stream: _____
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tungsten
Waste Stream: spent acid and rinse water
Waste Generation Rate: 21,000 mt/year
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Reduction to Metal
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Tungsten
Waste Stream: Process Wastewater
Waste Generation Rate: 1800/1 3700 mton/year 1>300
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Tungsten Carbide Production
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Uranium, Production of UO_2
Waste Stream: Waste Nitric Acid from UO_2 Production
Waste Generation Rate: 1700, 2500, 3400 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major):

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Dissolution and Back-Extraction
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Waste Acid may be processed for re-use

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable X Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Uranium, Ames Process
Waste Stream: Uranium Chips from Ingot Production
Waste Generation Rate: 1700, 2500, 3400 mt/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. **Process Flow Diagram & Waste Characterization:** By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Derby Chipping
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: Chips may be recycled to the Reduction Furnace

2. **Reasons for Waste Generation:** Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: producing Ingots

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. **Waste Management Alternatives:** Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. **Material Classification:** Sludge Spent Material By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

ustrial Sector and Process: Uranium, Production of UF_4
Waste Stream: Vaporizer Condensate
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Uranium, Production of UF_4
Waste Stream: Super heater Condensate
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable X Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

ustrial Sector and Process: Uranium, Ames Process
Waste Stream: Slag
Waste Generation Rate: _____
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: X Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: Acid Plant Blowdown
Waste Generation Rate: 520,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): As, Cd, Cr, Pb, Hg, Se, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: electrostatic precipitation of sulfur dioxide off-gas from roasting operation.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc (Pyrometallurgical Process)
Waste Stream: Waste ferrosilicon
Waste Generation Rate: 17,000 MT/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: from treatment of residues from reduction process.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: Residue treatment

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable sold for off-site use by iron/steel industry

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc (Electrolytic Process)
Waste Stream: Spent goethite and leach cake residues
Waste Generation Rate: 15,000 mT/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): As, Cd, Cr, Pb, Hg, Se, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: generated in removal of iron from zinc sulfate solution generated by leaching calcine w/ H_2SO_4
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: Process Wastewater
Waste Generation Rate: 6,600,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Cr, Pb, Se, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: from various ~~processes~~ steps (roasting, purification, etc.) in both electrolytic & pyrometallurgical proc.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product All
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell ~~Process~~ ~~Plant~~
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc (Pyrometallurgical proc.)
Waste Stream: Discarded refactory brick
Waste Generation Rate: 1000 mt/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Cr, Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: removed from furnaces during relining
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
ste Stream: Spent cloths, bags, and filters
vaste Generation Rate: 200 MT/Yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cd, Pb, Hg, Se, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Various operations
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: Spent Surface-impoundment liquids
Waste Generation Rate: 2,500,000 MT/YR.
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): Cd

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Various operations; collected in ST prior to treatment
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: __ Recyclable __ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: Spent surface impoundment solids
Waste Generation Rate: 1000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Pb, Hg, Se, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: settleable solids from process wastewaters collected in SI.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: Spent synthetic gypsum
Waste Generation Rate: 21,000 MT/yr
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R (T)
Hazardous Constituents (major): As, Cd, Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: treatment of bleed electrolyte from electrowinning circuit.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
ste Stream: TCA tower Blowdown
Waste Generation Rate: 1000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R (T)
Hazardous Constituents (major): Cd, Pb, Hg, Se

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: Cooling tower blowdown from casting operations.
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process? Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable
YS (gm)

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

1000

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: WWTP Liquid Effluent
Waste Generation Rate: 3,500,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Cd

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: effluent from on-site WWTP (several waste streams)
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: WWTP Sludge
Waste Generation Rate: 45,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): As, Cd, Pb, Hg, Se, Ag

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: from treatment of process wastewater in on-site WWTP
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable

recycled to zinc ore waste at one plant.

Y? GJM

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zinc
Waste Stream: Zinc lean slag
Waste Generation Rate: 17,000 MT/YR
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I C R T
Hazardous Constituents (major): Pb

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: treatment of zinc-rich slag
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment:

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment:

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment:

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment:

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment:

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment:

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment:

Conclusion: ✓ Recyclable ___ Non-Recyclable ___ Partially Recyclable — sold as road gravel or construction aggregate.

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zirconium / Hafnium
Waste Stream: Spent acid leachate from zirconium metal production
Waste Generation Rate: 0 mt/year (treated prior to discharge) / 10 / 100,000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): ___

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: ___
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: ___

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: ___

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: ___

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: ___

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: ___

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: ___

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: ___

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: ___

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zirconium / Hafnium
Waste Stream: Spent acid leachate from zirconium alloy production
Waste Generation Rate: 2 mtlyr (treated prior to discharge) 0/25,000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physica separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ✓ Non-Recyclable ___ Partially Recyclable

4. Material Classification: Sludge Spent Material By-Product
(circle one)

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zirconium / Hafnium
Waste Stream: leaching rinsewater from zirconium metal production
Waste Generation Rate: 20/1000000 units/year / 200000
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): ___

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: ___
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: ___

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: ___

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: ___

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: ___

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: ___

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: ___

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: contaminate some rinsewater

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: ___

Conclusion: ___ Recyclable ___ Non-Recyclable V Partially Recyclable

4. Material Classification: (circle one) Sludge (Spent Material) By-Product

WORK SHEET FOR WASTE STREAM ASSESSMENT FOR RECYCLING, RECOVERY, AND REUSE POTENTIAL

Industrial Sector and Process: Zirconium / Hafnium
Waste Stream: leaching rinse water from zirconium alloy production
Waste Generation Rate: 3400 / 42,000 million / 5100
Waste Form: Liquid(Aq./Non-Aq.)/Slurry/Solids(Wet/Dry)
Hazard Characteristics (all): I (C) R T
Hazardous Constituents (major): _____

1. Process Flow Diagram & Waste Characterization: By looking at both documents, try to answer the following questions for each major source of the same waste generated in the process. *Complete a separate form for each major source.*

   A. Source: _____
   B. Waste generation is closest to: Raw Material/Major Intermediates/Final Product
   C. Waste appears to have: recoverable products/removable contaminants/neither
   D. Comment: _____

2. Reasons for Waste Generation: Based on the description of the process, and waste generation and its management practices given for a sector, make the following assessment.

   A. Is the same waste generated at every facility using the process?: Yes/No/Can't Tell
   Comment: _____

   B. What was the basic purpose for generating this waste (e.g., plant maintenance, chemical reaction, physical separation, water rinsing, other purification steps)?
   Comment: _____

   C. Why did this waste become hazardous (e.g., physical contact during production, mixing with other waste streams, results from impurity removal)?
   Comment: _____

3. Waste Management Alternatives: Review the potential for reducing the quantities of waste generated at any of its sources by considering the following waste management alternatives.

   A. Waste Segregation: Yes/No/Can't Tell
   Comment: _____

   B. Water Use Reduction: Yes/No/Can't Tell
   Comment: _____

   C. On-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: can reuse some of it

   D. Off-site Waste Recycling/Recovery/Reuse: Yes/No/Can't Tell
   Comment: _____

Conclusion: ___ Recyclable ___ Non-Recyclable ✓ Partially Recyclable

4. Material Classification: Sludge (Spent Material) By-Product
(circle one)

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX E

Listing of Waste Streams Generated by Mineral Production Activities by Commodity

Note: The failure to list a mineral processing waste on this table in no way assumes that the Agency has determined that the waste is not a mineral processing waste. A company has an obligation to determine whether it is generating a mineral processing wastestream subject to the 1989 rulemaking.

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EXHIBIT E-1

SUMMARY OF MINERAL PROCESSING WASTE STREAMS BY COMMODITY

Commodity	Waste Stream	Nature of Operation
Alumina and Aluminum	Anode prep waste	Mineral Processing
	APC dust/sludge	Mineral Processing
	Baghouse bags and spent plant filters	Mineral Processing
	Bauxite residue	Mineral Processing
	Cast house dust	Mineral Processing
	Cryolite recovery residue	Mineral Processing
	Wastewater	Mineral Processing
	Discarded Dross	Mineral Processing
	Flue Dust	Mineral Processing
	Electrolysis waste	Mineral Processing
	Evaporator salt wastes	Mineral Processing
	Miscellaneous wastewater	Mineral Processing
	Pisolites	Mineral Processing
	Scrap furnace brick	Mineral Processing
	Skims	Mineral Processing
	Sludge	Mineral Processing
	Spent cleaning residue	Mineral Processing
	Spent potliners	Mineral Processing
	Sweepings	Mineral Processing
	Treatment Plant Effluent	Mineral Processing
	Waste alumina	Mineral Processing
Antimony	Gangue	Mineral Processing
	Wastewater	Mineral Processing
	APC Dust/Sludge	Mineral Processing
	Autoclave Filtrate	Mineral Processing
	Spent Barren Solution	Mineral Processing
	Gangue (Filter Cake)	Mineral Processing
	Leach Residue	Mineral Processing
	Refining Dross	Mineral Processing
	Slag and Furnace Residue	Mineral Processing
	Sludge from Treating Process Waste Water	Mineral Processing
	Stripped Anolyte Solids	Mineral Processing
	Waste Solids	Mineral Processing
Beryllium	Spent Barren filtrate streams	Mineral Processing
	Beryllium hydroxide supernatant	Mineral Processing
	Chip Treatment Wastewater	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Beryllium (continued)	Dross discard	Mineral Processing
	Filtration discard	Mineral Processing
	Leaching discard	Mineral Processing
	Neutralization discard	Mineral Processing
	Pebble Plant Area Vent Scrubber Water	Mineral Processing
	Precipitation discard	Mineral Processing
	Process wastewater	Mineral Processing
	Melting Emissions	Mineral Processing
	Scrubber Liquor	Mineral Processing
	Separation slurry	Mineral Processing
	Waste Solids	Mineral Processing
Bismuth	Alloy residues	Mineral Processing
	Spent Caustic Soda	Mineral Processing
	Electrolytic Slimes	Mineral Processing
	Excess chlorine	Mineral Processing
	Lead and Zinc chlorides	Mineral Processing
	Metal Chloride Residues	Mineral Processing
	Slag	Mineral Processing
	Spent Electrolyte	Mineral Processing
	Spent Material	Mineral Processing
	Spent soda solution	Mineral Processing
	Waste acid solutions	Mineral Processing
	Waste Acids	Mineral Processing
	Wastewater	Mineral Processing
Cadmium	Caustic washwater	Mineral Processing
	Copper and Lead Sulfate Filter Cakes	Mineral Processing
	Copper Removal Filter Cake	Mineral Processing
	Iron containing impurities	Mineral Processing
	Spent Leach solution	Mineral Processing
	Lead Sulfate waste	Mineral Processing
	Post-leach Filter Cakes	Mineral Processing
	Spent Purification solution	Mineral Processing
	Scrubber wastewater	Mineral Processing
	Spent electrolyte	Mineral Processing
	Zinc Precipitates	Mineral Processing
Calcium Metal	Calcium Aluminate wastes	Mineral Processing
	Dust with Quicklime	Mineral Processing
Cesium/Rubidium	Chemical Residues	Mineral Processing
	Digester waste	Mineral Processing
	Electrolytic Slimes	Mineral Processing
	Pyrolytic Residue	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Cerium/Rubidium (continued)	Slag	Mineral Processing
Chromium, Ferrochrome, and Ferrochromium-Silicon	Gangue and tailings	Extraction/Beneficiation
	Dust or Sludge from ferrochromium production	Mineral Processing
	Dust or Sludge from ferrochromium-silicon production	Mineral Processing
	Treated Roast/Leach Residues	Mineral Processing
	Slag and Residues	Mineral Processing
Coal Gas	API Oil/Water Separator Sludge	Mineral Processing
	API Water	Mineral Processing
	Cooling Tower Blowdown	Mineral Processing
	Dissolved Air Flotation (DAF) Sludge	Mineral Processing
	Fluc Dust Residues	Mineral Processing
	Liquid Waste Incinerator Blowdown	Mineral Processing
	Liquid Waste Incinerator Pond Sludge	Mineral Processing
	Multiple Effects Evaporator Concentrate	Mineral Processing
	Multiple Effects Evaporator Pond Sludge	Mineral Processing
	Sludge and Filter Cake	Mineral Processing
	Spent Methanol Catalyst	Mineral Processing
	Stretford Solution Purge Stream	Mineral Processing
	Surface Impoundment Solids	Mineral Processing
	Vacuum Filter Sludge	Mineral Processing
	Zeolite Softening PWW	Mineral Processing
Copper	Acid plant blowdown	Mineral Processing
	Acid plant thickener sludge	Mineral Processing
	APC dusts/sludges	Mineral Processing
	Spent bleed electrolyte	Mineral Processing
	Chamber solids/scrubber sludge	Mineral Processing
	Waste contact cooling water	Mineral Processing
	Discarded furnace brick	Mineral Processing
	Process wastewaters	Mineral Processing
	Scrubber blowdown	Mineral Processing
	Spent black sulfuric acid sludge	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	Tankhouse slimes	Mineral Processing
	WWTP liquid effluent	Mineral Processing
	WWTP sludge	Mineral Processing
Elemental Phosphorous	Condenser phossy water discard	Mineral Processing
	Cooling water	Mineral Processing
	Furnace building washdown	Mineral Processing
	Dust	Mineral Processing
	Waste ferrophosphorus	Mineral Processing
	Furnace offgas solids	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Elemental Phosphorous (continued)	Furnace scrubber blowdown	Mineral Processing
	Precipitator slurry scrubber water	Mineral Processing
	Precipitator slurry	Mineral Processing
	NOSAP slurry	Mineral Processing
	Sludge	Mineral Processing
	Spent furnace brick	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	Surface impoundment waste solids	Mineral Processing
	Waste Andersen Filter Media	Mineral Processing
	WWTP liquid effluent	Mineral Processing
	WWTP Sludge/Solids	Mineral Processing
Fluorspar and Hydrofluoric Acid	APC Dusts	Mineral Processing
	Off-spec fluosilicic acid	Mineral Processing
	Sludges	Mineral Processing
Germanium	Waste Acid Wash and Rinse Water	Mineral Processing
	Chlorinator Wet Air Pollution Control Sludge	Mineral Processing
	Germanium oxides fumes	Mineral Processing
	Hydrolysis Filtrate	Mineral Processing
	Leach Residues	Mineral Processing
	Roaster off-gases	Mineral Processing
	Spent Acid/Leachate	Mineral Processing
	Waste Still Liquor	Mineral Processing
	Wastewater	Mineral Processing
Gold and Silver	Spent Furnace Dust	Mineral Processing
	Refining wastes	Mineral Processing
	Retort cooling water	Mineral Processing
	Slag	Mineral Processing
	Wastewater treatment sludge	Mineral Processing
	Wastewater	Mineral Processing
Iron and Steel	Wastewater	Mineral Processing
Lead	Acid Plant Blowdown	Mineral Processing
	Acid Plant Sludge	Mineral Processing
	Baghouse Dust	Mineral Processing
	Baghouse Incinerator Ash	Mineral Processing
	Cooling Tower Blowdown	Mineral Processing
	Waste Nickel Matte	Mineral Processing
	Process Wastewater	Mineral Processing
	Slurried APC Dust	Mineral Processing
	Solid Residues	Mineral Processing
	Solids in Plant Washdown	Mineral Processing
	Spent Furnace Brick	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Lead (continued)	Stockpiled Miscellaneous Plant Waste	Mineral Processing
	Surface Impoundment Waste Liquids	Mineral Processing
	Surface Impoundment Waste Solids	Mineral Processing
	SVG Backwash	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludges/Solids	Mineral Processing
Lightweight Aggregate	APC control scrubber water and solids	Mineral Processing
	APC Dust/Sludge	Mineral Processing
	Surface impoundment waste liquids	Mineral Processing
	WWTP liquid effluent	Mineral Processing
Magnesium and Magnesia from Brines	APC Dust/Sludge	Mineral Processing
	Calciner offgases	Mineral Processing
	Calcium sludge	Mineral Processing
	Casthouse Dust	Mineral Processing
	Casting plant slag	Mineral Processing
	Cathode Scrubber Liquor	Mineral Processing
	Slag	Mineral Processing
	Smut	Mineral Processing
	Spent Brines	Mineral Processing
Manganese, Manganese Dioxide, Ferromanganese and Silicomanganese	APC Dust/Sludge	Mineral Processing
	APC Water	Mineral Processing
	Iron Sulfide Sludge	Mineral Processing
	Ore Residues	Mineral Processing
Manganese, Manganese Dioxide, Ferromanganese and Silicomanganese (continued)	Slag	Mineral Processing
	Spent Graphite Anode	Mineral Processing
	Spent Process Liquor	Mineral Processing
	Waste Electrolyte	Mineral Processing
	Wastewater (CMD)	Mineral Processing
	Wastewater (EMD)	Mineral Processing
	Wastewater Treatment Solids	Mineral Processing
Mercury	Dust	Mineral Processing
	Mercury Quench Water	Mineral Processing
	Furnace Residues	Mineral Processing
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	APC Dust/Sludge	Mineral Processing
	Flue Dust/Gases	Mineral Processing
	Liquid Residues	Mineral Processing
	H2 Reduction Furnace Scrubber Water	Mineral Processing
	Molybdic Oxide Refining Wastes	Mineral Processing
	Refining Wastes	Mineral Processing
	Roaster Gas Blowdown Solids	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Molybdenum, Ferromolybdenum, and Ammonium Molybdaten (continued)	Slag	Mineral Processing
	Solid Residues	Mineral Processing
	Treatment Solids	Mineral Processing
Phosphoric Acid	Waste Scale	Mineral Processing
Platinum Group Metals	Slag	Mineral Processing
	Scrubber offgases	Mineral Processing
	SO2 waste	Mineral Processing
	Spent Acids	Mineral Processing
	Spent Solvents	Mineral Processing
Pyrobitumens, Mineral Waxes, and Natural Asphalts	Still bottoms	Mineral Processing
	Waste catalysts	Mineral Processing
Rare Earths	Spent ammonium nitrate processing solution	Mineral Processing
	Electrolytic cell caustic wet APC waste	Mineral Processing
	Spent Electrolytic cell quench water and scrubber water	Mineral Processing
	Spent iron hydroxide cake	Mineral Processing
	Spent lead filter cake	Mineral Processing
	Lead backwash sludge	Mineral Processing
	Monazite solids	Mineral Processing
	Process wastewater	Mineral Processing
	Spent scrubber liquor	Mineral Processing
	Off-gases from dehydration	Mineral Processing
	Spent off-gases from electrolytic reduction	Mineral Processing
	Spent sodium hypochlorite filter backwash	Mineral Processing
	Solvent extraction crud	Mineral Processing
	Spent surface impoundment solids	Mineral Processing
	Spent surface impoundment liquids	Mineral Processing
	Waste filtrate	Mineral Processing
	Waste solvent	Mineral Processing
	Wastewater from caustic wet APC	Mineral Processing
	Waste zinc contaminated with mercury	Mineral Processing
Rhenium	APC Dust/Sludge	Mineral Processing
	Spent Barren Scrubber Liquor	Mineral Processing
	Spent Rhenium Raffinate	Mineral Processing
	Roaster Dust	Mineral Processing
	Spent Ion Exchange/SX Solutions	Mineral Processing
	Spent Salt Solutions	Mineral Processing
	Slag	Mineral Processing
Scandium	Crud from the bottom of the solvent extraction unit	Mineral Processing
	Dusts and spent filters from decomposition	Mineral Processing
	Spent acids	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Scandium (continued)	Spent ion exchange resins and backwash	Mineral Processing
	Spent solvents from solvent extraction	Mineral Processing
	Spent wash water	Mineral Processing
	Waste chlorine solution	Mineral Processing
	Waste solutions/solids from leaching and precipitation	Mineral Processing
Selenium	Spent filter cake	Mineral Processing
	Plant process wastewater	Mineral Processing
	Slag	Mineral Processing
	Tellurium slime wastes	Mineral Processing
	Waste Solids	Mineral Processing
Silicon and Ferrosilicon	APC Dust Sludge	Mineral Processing
	Dross discard	Mineral Processing
	Slag	Mineral Processing
Sulfur	Airborne emissions from sulfuric acid production	Mineral Processing
	Spent catalysts (Claus process)	Mineral Processing
	Spent vanadium pentoxide catalysts from sulfuric acid production	Mineral Processing
	Tail gases	Mineral Processing
	Wastewater from wet-scrubbing, spilled product and condensates	Mineral Processing
Synthetic Rutile	APC Dust/Sludges	Mineral Processing
	Spent Iron Oxide Slurry	Mineral Processing
	Spent Acid Solution	Mineral Processing
Tantalum, Columbium and Ferrocolumbium	APC Dust Sludge	Mineral Processing
	Digester Sludge	Mineral Processing
	Spent Potassium Titanium Chloride	Mineral Processing
	Process Wastewater	Mineral Processing
	Spent Raffinate Solids	Mineral Processing
	Scrubber Overflow	Mineral Processing
	Slag	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludge	Mineral Processing
Tellurium	Slag	Mineral Processing
	Fumes of telluride dioxide	Mineral Processing
	Solid waste residues	Mineral Processing
	Waste Electrolyte	Mineral Processing
	Wastewater	Mineral Processing
Tin	Brick Lining and Fabric Filters	Mineral Processing
	Dross	Mineral Processing
	Process Wastewater and Treatment Sludge	Mineral Processing
	Slag	Mineral Processing
	Slimes	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Tin (continued)	Waste Acid and Alkaline baths	Mineral Processing
Titanium and Titanium Dioxide	Spent Brine Treatment Filter Cake	Mineral Processing
	FeCl Treatment Sludge	Mineral Processing
	Waste Ferric Chloride	Mineral Processing
	Finishing Scrap	Mineral Processing
	Leach Liquor and Sponge Wash Water	Mineral Processing
	Waste Non-Contact Cooling Water	Mineral Processing
	Pickling Liquor and Wash Water	Mineral Processing
	Scrap Detergent Wash Water	Mineral Processing
	Scrap Milling Scrubber Water	Mineral Processing
	Reduction Area Scrubber Water	Mineral Processing
	Chlorination Off gas Scrubber Water	Mineral Processing
	Chlorination Area - Vent Scrubber Water	Mineral Processing
	Melt Cell Scrubber Water	Mineral Processing
	Chlorine Liquefaction Scrubber Water	Mineral Processing
	Chip Crushing Scrubber Water	Mineral Processing
	Casting Crucible Contact Cooling Water	Mineral Processing
	Smut from Mg Recovery	Mineral Processing
	Spent Surface Impoundment Liquids	Mineral Processing
	Spent Surface Impoundment Solids	Mineral Processing
	TiCl4 Purification Effluent	Mineral Processing
	Spent Vanadium Oxychloride	Mineral Processing
	Sodium Reduction Container Reconditioning Wash Water	Mineral Processing
	Casting Crucible Wash Water	Mineral Processing
	Waste Acids (Chloride process)	Mineral Processing
	Waste Solids (Chloride process)	Mineral Processing
	Waste Acids (Sulfate process)	Mineral Processing
	Waste Solids (Sulfate process)	Mineral Processing
	WWTP Liquid Effluent	Mineral Processing
	WWTP Sludge/Solids	Mineral Processing
Tungsten	Spent Acid and Rinse water	Mineral Processing
	Scrubber wastewater	Mineral Processing
	Process wastewater treatment plant effluent	Mineral Processing
	Water of formation	Mineral Processing
Uranium	Waste Nitric Acid from Production of UO_2	Mineral Processing
	Vaporizer Condensate	Mineral Processing
	Superheater Condensate	Mineral Processing
	Slag	Mineral Processing
	Uranium Chips from Ingot Production	Mineral Processing
	Waste Calcium Fluoride	Mineral Processing

EXHIBIT E-1 (Continued)

Commodity	Waste Stream	Nature of Operation
Vanadium	Filtrate and Process Wastewaters	Mineral Processing
	Solid Waste	Mineral Processing
	Spent Precipitate	Mineral Processing
	Slag	Mineral Processing
	Wet scrubber wastewater	Mineral Processing
Zinc	Acid Plant Blowdown	Mineral Processing
	Spent Cloths, Bags, and Filters	Mineral Processing
	Waste Ferrosilicon	Mineral Processing
	Spent Goethite and Leach Cake Residues	Mineral Processing
	Saleable residues	Mineral Processing
	Process Wastewater	Mineral Processing
	Discarded Refractory Brick	Mineral Processing
	Spent Surface Impoundment Liquid	Mineral Processing
	Spent Surface Impoundment Solids	Mineral Processing
	Spent Synthetic Gypsum	Mineral Processing
	TCA Tower Blowdown (ZCA Bartlesville, OK - Electrolytic Plant)	Mineral Processing
	Wastewater Treatment Plant Liquid Effluent	Mineral Processing
	Wastewater Treatment Plant Sludge	Mineral Processing
	Zinc-lean Slag	Mineral Processing
Zirconium and Hafnium	Spent Acid leachate from zirconium alloy production	Mineral Processing
	Spent Acid leachate from zirconium metal production	Mineral Processing
	Ammonium Thiocyanate Bleed Stream	Mineral Processing
	Reduction area-vent wet APC wastewater	Mineral Processing
	Caustic wet APC wastewater	Mineral Processing
	Feed makeup wet APC wastewater	Mineral Processing
	Filter cake/sludge	Mineral Processing
	Furnace residue	Mineral Processing
	Hafnium filtrate wastewater	Mineral Processing
	Iron extraction stream stripper bottoms	Mineral Processing
	Leaching rinse water from zirconium alloy production	Mineral Processing
	Leaching rinse water from zirconium metal production	Mineral Processing
	Magnesium recovery area vent wet APC wastewater	Mineral Processing
	Magnesium recovery off-gas wet APC wastewater	Mineral Processing
	Sand Chlorination Off-Gas Wet APC wastewater	Mineral Processing
	Sand Chlorination Area Vent Wet APC wastewater	Mineral Processing
	Silicon Tetrachloride Purification Wet APC wastewater	Mineral Processing
	Wet APC wastewater	Mineral Processing
	Zirconium chip crushing wet APC wastewater	Mineral Processing
	Zirconium filtrate wastewater	Mineral Processing

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX F

Mineral Processing Sectors Generating Hazardous Wastes

This list is not exclusive. Other sectors may generate mineral processing wastes that are hazardous. A generator has the obligation to test each wastestream to determine if a waste has hazardous characteristics.

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EXHIBIT F-1

LIST OF SECTORS GENERATING HAZARDOUS MINERAL PROCESSING WASTE STREAMS*

Alumina and Aluminum
Antimony
Beryllium
Bismuth
Cadmium
Calcium
Chromium and Ferrochromium
Coal Gasification
Copper
Elemental Phosphorous
Fluorspar and Hydrofluoric Acid
Germanium
Gold and Silver
Lead
Magnesium and Magnesia from Brines
Mercury
Molybdenum, Ferromolybdenum, and Ammonium Molybdate
Platinum Group Metals
Rare Earths
Rhenium
Scandium
Selenium
Synthetic Rutile
Tantalum, Columbium, and Ferrocolumbium
Tellerium
Titanium and Titanium Dioxide
Tungsten
Uranium
Zinc
Zirconium and Hafnium

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX G

Mineral Processing Sectors Not Generating Hazardous Wastes

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EXHIBIT G-1

LIST OF SECTORS NOT GENERATING HAZARDOUS MINERAL PROCESSING WASTE STREAMS

Arsenic Acid
Boron
Bromine
Cesium and Rubidium
Gemstones
Iodine
Iron and Steel
Lightweight Aggregates
Lithium and Lithium Carbonate
Manganese, MnO_2, Ferromanganese, and Silicomanganese
Phosporic Acid
Pyrobitumens, Mineral Waxes, and Natural Asphalts
Scandium
Silicon and Ferrosilcon
Soda Ash
Sodium Sulfate
Strontium
Tungsten
Vanadium

Note: This list is not exclusive. Generators of these waste streams should not assume that their wastes are non-hazardous simply because they are found on this list. Each generator should test its wastes to determine if they are hazardous.

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IDENTIFICATION AND DESCRIPTION OF MINERAL PROCESSING SECTORS AND WASTE STREAMS

APPENDIX H

List of Commenters

January 25, 1996 Supplemental Proposed Rule

May 12, 1997 Second Supplemental Proposed Rule

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Commenter List, January 1996 Proposed Rule

Number	Name(s)
COMM1	National Mining Association
COMM2	PTI Environmental Services
COMM3	The Ferroalloys Association
COMM4	Heritage Environmental Services, Inc.
COMM5	Marine Shale Processors, Inc.
COMM6	U.S. Department of Energy
COMM7	American Electric Power
COMM8	Arizona Public Service Company
COMM9	Institute for Interconnecting and Packaging Electric Circuits
COMM10	Lead Industries Association, Inc.
COMM11	New York State Department of Environmental Conservation
COMM12	Anson County ACTUS, Chapter of the Blue Ridge Environmental Defense League
COMM13	Avocet Tungsten, Inc.
COMM14	Chemgold, Inc.
COMM15	General Motors Corporation
COMM16	Public Service Electric and Gas Company
COMM17	Chemical Waste Management, Inc.
COMM18	DuPont White Pigment and Mineral Products
COMM19	Westinghouse Electric Corporation
COMM20	U.S. Borax, Inc.
COMM21	Association of Container Reconditioners
COMM22	SCM Chemicals, Inc.
COMM23	Montana Department of Environmental Quality
COMM24	Homestake Mining Company
COMM25	KRONOS, Inc.
COMM26	Jersey Central Power & Light Company
COMM27	Union Carbide Corporation
COMM28	South Carolina Electric and Gas company
COMM29	Sonora Mining Corporation
COMM30	Chemical Waste Management
COMM31	Laidlaw Environmental Services, Inc.
COMM32	Kodak

Commenter List, January 1996 (continued)

Number	Name(s)
COMM33	International Precious Metals Institute
COMM34	Institute of Scrap Recycling Industries, Inc.
COMM35	Metal Industries Recycling Coalition
COMM36	ASARCO
COMM37	Sierra Club's Midwest Office and the Mining Impact Coalition of Wisconsin, Inc.
COMM38	Phelps Dodge Corporation
COMM39	Solite Corporation
COMM40	Kennecott Corporation
COMM41	Environmental Defense Fund
COMM42	Phosphorus Producers Environmental Council
COMM43	Precious Metals Producers Battle Mountain Gold Company Barrick Gold Corporation Echo Bay Mines Independence Mining Company Santa Fe Pacific Gold Corporation
COMM44	Battery Council International
COMM45	The Fertilizer Institute
COMM46	Cyprus Amax Minerals Company
COMM47	Safety-Kleen Corp.
COMM48	SKW Metals & Alloys, Inc.
COMM49	Kemira Pigments, Inc.
COMM50	New Jersey Natural Gas Company
COMM51	South Jersey Gas Company
COMM52	Robert Lucht, Mining Engineer and Geologist
COMM53	INCO LTD INCO United States, Inc. International Metals Reclamation Company, Inc.
COMM54	RSR Corporation
COMM55	Copper & Brass Fabricators Council, Inc.
COMM56	Utility Solid Waste Activities Group Edison Electric Institute American Public Power Association National Rural Electric Cooperative Association
COMM57	Newmont Gold Company
COMM58	National Mining Association

Commenter List, January 1996 (continued)

Number	Name(s)
COMM59	Brush Wellman, Inc.
COMM60	Brush Wellman, Inc.
COMM61	Brush Wellman, Inc.
COMM62	Brush Wellman
COMM63	Brush Wellman, Inc.
COMM64	Utah Mining Association
COMM65	Aluminum Company of America
COMM66	Rio Algom Mining Corp.
COMM67	BHP Copper
COMM68	Molycorp, Inc.
COMM69	Molycorp, Inc.
COMM70	FMC
COMM71	U.S. Department of Defense
COMM72	Uranium Resources, Inc.
COMM73	Copper Range Company
COMM74	U.S. Department of Interior
COMM75	Recyclers of Copper Alloy Products, Inc.
COMM76	Kerr-McGee Corporation
COMM77	The Aluminum Association
COMM78	Rhone-Poulenc
COMM79	The Colorado Mining Association
COMM80	Molten Metal Technology
COMM81	OxyChem
COMM82	Horsehead Resource Development Company, Inc.
COMM83	Electronics Industries Association
COMM84	Chemical Manufacturers Association
COMM85	Nevada Mining Association
COMM86	U.S. Borax
COMM87	Kennecott
COMM88	California Mining Association
COMM89	Arizona Department of Environmental Quality
LCOMM1	American Gas Association

Commenter List, January 1996 (continued)

Number	Name(s)
LCOMM2	Environmental Technology Council
LCOMM3	U.S. Department of Agriculture
LCOMM4	The Ferroalloys Association
LCOMM5	Association of Battery Recyclers, Inc.
LCOMM6	Northern Plains Resource Council
LCOMM7	MISSING
LCOMM8	State of Wyoming Department of Environmental Quality

Commenter List for May 12, 1997 Second Supplemental Proposed Rule

Commenter #	Commenter Name
COMM1001	ASARCO Incorporated
COMM1002	American Wood Preservers Institute
COMM1003	Chemical Products Corporation
COMM1004	Occidental Chemical Corporation (OxyChem)
COMM1005	American Chrome & Chemicals, L.P.
COMM1006	Marine Shale Processors, Inc. (MSP)
COMM1007	Frontier Technologies Inc. (FTI)
COMM1008	Florida Phosphate Council
COMM1009	World Resources Company
COMM1010	International Metals Reclamation Company, Inc. (INMETCO) and INCO United States, Inc.
COMM1011	CITGO Petroleum Corporation
COMM1012	The Ferroalloys Association (TFA)
COMM1013	GF Industries
COMM1014	Westinghouse Electric Corporation
COMM1015	Ms. Linda W. Pierce
COMM1016	Chemical Manufacturers Association
COMM1017	Battery Council International (BCI) and Association of Battery Recyclers (ABR)
COMM1018	Collier, Shannon, Rill & Scott, PLLC for Specialty Steel Industry of North America (SSINA)
COMM1019	The Doe Run Company (DRC)
COMM1020	American Portland Cement Alliance (APCA)
COMM1021	American Petroleum Institute
COMM1022	Eastman Kodak Company
COMM1023	U.S. Department of Energy (DOE)
COMM1024	Lead Industries Association, Inc. (LIA)
COMM1025	RSR Corporation
COMM1026	Homestake Mining Company
COMM1027	Solite Corporation
COMM1028	Laidlaw Environmental Services
COMM1029	Newmont Gold Company
COMM1030	Chemical Products Corporation (CPC)
COMM1031	Florida Institute of Phosphate Research (FIPR)
COMM1032	Savage Zinc, Incorporated
COMM1033	General Motors Corporation (GM)

Commenter List, May 12, 1997 (Continued)

Commenter #	Commenter Name
COMM1034	ASARCO Incorporated
COMM1035	Utility Solid Waste Activities Group (USWAG)
COMM1036	Okanogan Highlands Alliance (OHA)
COMM1037	CF Industries, Inc.
COMM1038	The Fertilizer Institute
COMM1039	American Iron and Steel Institute (AISI)
COMM1040	Molycorp, Inc.
COMM1041	Cyprus Amax Minerals Company
COMM1042	Law Office of David J. Lennett (for Environmental Defense Fund, Mineral Policy Center, Southwest Research and Information Center, North Santiam Watershed Council, Pamlico-Tar River Foundation, Siskiyou Regional Education Project, Okanogan Highlands Alliance, and the Louisiana Environmental Action Network
COMM1043	BHP Copper
COMM1044	National Lime Association
COMM1045	The Silver Council
COMM1046	Mineral Policy Center
COMM1047	American Gas Association (AGA)
COMM1048	National Mining Association
COMM1048-D	National Mining Association
COMM1048-E	National Mining Association
COMM1049	Lake Superior Alliance (LSA)
COMM1050	Reynolds Metals Company
COMM1051	Brush Wellman Inc.
COMM1052	Brush Wellman Inc.
COMM1053	Brush Wellman, Inc.
COMM1054	Kennecott
COMM1055	Mr. William R. Schneider, P.E. (Consultant to Macalloy Corp.)
COMM1056	Nexsen, Pruet, Jacobs & Pollard, LLP (Counsel to Macalloy Corporation)
COMM1057	Photo Marketing Association International
COMM1058	Menominee Indian Tribe of Wisconsin
COMM1059	Lake Michigan Federation
COMM1060	Mr. David Isbister
COMM1061	Ms. Marianne Isbister
COMM1062	Rolling Stone Lake Protection & Rehabilitation District
COMM1063	Ms. Laura Furtman

Commenter List, May 12, 1997 (Continued)

Commenter #	Commenter Name
COMM1064	Mr. Gregory Furtman
COMM1065	Ms. Jennifer Pierce
COMM1066	Cement Kiln Recycling Coalition
COMM1067	Institute for Interconnecting and Packaging Electronic Circuits
COMM1068	Horsehead Resource Development Company, Inc.
COMM1069	Macalloy Corporation
COMM1070	Ms. Dori Gilels
COMM1071	Kenneth and Linda Pierce
COMM1072	Ms. Ellen Wertheimer
COMM1073	Mr. Earl Meyer
COMM1074	New York State Department of Environmental Conservation
COMM1075	United States Department of Defense (DoD)
COMM1076	Clean Water Action Council of Northeast Wisconsin, Inc.
COMM1077	Air Products and Chemicals, Inc.
COMM1078	EnviroSource Treatment and Disposal Services, Inc. (TDS)
COMM1079	Independence Mining Company Inc. (IMCI)
COMM1080	Uniroyal Chemical Company, Inc.
COMM1081	Eastman Chemical Company
COMM1082	Nevada Mining Association (NvMA)
COMM1083	Kerr-McGee Corporation
COMM1084	Elf Atochem North America Inc.
COMM1085	New Mexico Mining Association
COMM1086	DuPont
COMM1087	Waste Management
COMM1088	FMC Corporation
COMM1089	Phelps Dodge Corporation
COMM1090	Arizona Mining Association
COMM1091	Beazer East, Inc.
COMM1092	AlliedSignal Inc.
COMM1093	Placer Dome U.S., Inc.
COMM1094	Phosphorus Producers Environmental Council
COMM1095	U.S. Borax, Inc.
COMM1096	Appalachian Producers
COMM1097	Aluminum Company of America; Kaiser Aluminum & Chemical Corporation; Ormet Corporation; and Reynolds Metals Company.
COMM1098	AMAX Metal Recovery, Inc.

Commenter List, May 12, 1997 (Continued)

Commenter #	Commenter Name
COMM1099	Barrick Resources, Inc.
COMM1100	Koppers Industries, Inc.
COMM1101	IMC-Agrico Company
COMM1102	Echo Bay Mines
COMM1103	Mining Impact Coalition of Wisconsin Inc.
COMM1104	Precious Metals Producers (PMP)
COMM1105	California Mining Association
COMM1106	Freeport-McMoRan
COMM1107	Shoshone-Bannock Tribe Land Use Department
COMM1108	Texaco
COMM1109	Occidental Chemical Corporation (OxyChem)
COMML1001	Photographic & Imaging Manufacturers Association, Inc.
COMML1002	Phosphorus Producers Environmental Council
COMML1003	Environmental Technology Council