ASSESSMENT OF INDUSTRIAL HAZARDOUS WASTE PRACTICES IN THE METAL SMELTING AND REFINING INDUSTRY

Volume I

Executive Summary

Prepublication issue for EPA libraries
and State Solid Waste Management Agencies

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Executive Summary

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ABSTRACT

Investigations of on-land disposal of process and pollution control residuals from the United States metal smelting and refining industry were conducted. Characteristics of each industry sector, including plant locations, production capacities, and smelting and refining processes, have been identified and described.

Land-disposed or stored residuals, including slags, dusts, and sludges have been identified and characterized for physical and chemical properties. State, regional, and national estimates have been made of the total quantities of land-disposed or stored residuals and potentially hazardous constituents thereof.

Current methods employed by the primary metals industry for the disposal or storage of process and pollution control residuals on land are described. Principal methods include lagoon storage of sludges and open dumping of slags. Methods of residual treatment and disposal considered suitable for adequate health and environmental protection have been provided.

Finally, the costs incurred by typical plants in each primary smelting and refining category for current and environmentally sound potentially hazardous residual disposal or storage on land have been estimated.

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The Aluminum Association
National Association of Recycling Industries, Inc.
American Mining Congress
Ferroalloy Association
American Iron and Steel Institute
American Foundrymen's Society
The Aluminum Recycling Association

Appreciation is extended to the many companies who allowed plant visits and interviews and supplied waste samples for chemical analyses.

TABLE OF CONTENTS

LIST OF TABLES

SECTION I

INTRODUCTION

This report is the result of a study commissioned by the U.S. Environmental Protection Agency (EPA) to assess the waste generation, treatment, and disposal practices in the primary metals industry. This study is one of a series of industry studies by the Office of Solid Waste, Hazardous Waste Management Division. The studies were conducted for information purposes only and not in response to a congressional regulatory mandate. As such, these studies serve to provide EPA with: 1) an initial data base concerning the current and projected types and quantities of industrial wastes, applicable treatment and disposal technologies and their associated costs; 2) a data base for technical assistance activities; 3) a background for guidelines development work.

The definition of "potentially hazardous waste" in this study was developed based upon contractor investigations and professional judgment. This definition does not necessarily reflect EPA thinking since such a definition, especially in a regulatory context, must be broadly applicable to widely differing types of waste streams. The presence of a toxic, flammable, explosive, or reactive substance should not be the major determinant of hazardousness if there are data to represent or illustrate actual effects of wastes containing these substances in specific environments. Thus,the reader is cautioned that the data presented in this report consititutes only the contractor's assessment of the hazardous waste management problems in this industry. The primary and secondary* metal smelting and refining categories included in this report are the following:

Primary Copper (SIC 3331)
Primary Lead (SIC 3332)
Primary Zinc (SIC 3333)
Primary Aluminum (SIC 3334)
Primary Antimony (SIC 3339)
Primary Mercury (SIC 3339)
Primary Titanium (SIC 3339)
Primary Tungsten (SIC 3339)
Primary Tin (SIC 3339)
Primary Magnesium (SIC 3339)
Primary Cadmium (SIC 3339)

* The primary metal smelting and refining industries use ore concentrates or other natural resources as raw material,whereas the major raw materials for secondary industries is scrap metal.

Primary Arsenic (SIC 3339)
Primary Selenium and Tellurium (SIC 3339)
Primary Gold and Silver (SIC 3339)
Primary Platinum (SIC 3339)
Primary Bismuth (SIC 3339)
Primary Cobalt (SIC 3339)
Primary Zirconium and Hafnium (SIC 3339)
Secondary Copper (SIC 33412)
Secondary Lead (SIC 33413)
Secondary Aluminum (SIC 33417)
Iron and Steel (SIC 3312)
Iron and Steel Foundries (SIC 332)
Ferroalloys (SIC 3313)
Primary Metal Products Not Elsewhere Classified (SIC 3399)

The larger metal smelting and refining industries, including iron and steel, iron and steel foundries, ferroalloys, primary copper, primary lead, primary zinc, primary aluminum, secondary copper, secondary lead, and secondary aluminum were studied in detail and plant visits made to representative plants in all of these categories. The primary antimony, primary titanium, primary tungsten and primary tin industries are very much smaller than the industries listed previously, but were of significant size to merit detailed study.

The primary magnesium industry is of significant size, but was not studied in detail since most magnesium is produced from sea water with non-hazardous wastes discharged to the ocean. The primary cadmium, arsenic, selenium, tellurium, silver, gold, platinum, bismuth, and cobalt industries were not studied in detail since these metals are produced predominantly as byproducts of the primary copper, zinc or lead industries either at the locations of these smelters or at specialty smelters.

At those primary smelter locations where the above minor metals are recovered from flue dusts, slimes, or other residues, associated wastes will comprise minor quantities of the larger waste streams which have been studied in more detail (i.e., primary copper, zinc and lead).

Where these minor metals are recovered at specialty smelters which process flue dusts and electrolytic slimes from other plants, such as the ASARCO Tacoma, Washington, and Omaha, Nebraska smelters, a number of metals may be recovered in a number of complex operations. Specialty smelters were not visited during the conduct of this program.

The primary mercury industry, although very small, was studied in detail because of the great environmental concern for mercury.

The zirconium and hafnium industries were not studied in detail because of minor production. There was no domestic production of cobalt metal in 1972 or 1973 and therefore cobalt smelting and refining was not studied in detail.

The secondary zinc industry was not studied in detail since it was ascertained that very little land disposed waste is generated in the industry. Secondary antimony metal is almost entirely recovered in conjunction with lead at secondary lead smelters. Production of non-precious metals other than zinc, copper, lead and aluminum from secondary sources is minor and not covered in detail in this report. There is significant recovery of precious metals (i.e., gold, silver, platinum) from secondary sources but associated wastes are negligible since maximum recovery is effected.

Report sections for the metal categories which were studied in detail are organized into four subsections. They are as follows:

Industry Characterization
Waste Characterization
Treatment and Control Technology
Costs of Treatment and Control Technology

For each of the industries characterized, geographic distribution of plants and production capacity are given on state by state, EPA regional, and national levels. Production capacities for the individual states and regions, and nationally, are given separately for distinct production process modes such as electrolytic copper production and pyrometallurgical copper production. The estimated national sales value for the year 1973 is given for each of the metal categories. The smelting and refining processes are briefly described in industry characterization subsections.

Waste characterization sections contain descriptions of production technology at typical plants and the resultant byproducts or wastes which are either recycled directly, shipped to other smelters for further metallics recovery, disposed of on site or handled by contract disposal services. Each waste is characterized with respect to concentrations of potentially hazardous constituents, including heavy metals, fluorides, oil and grease, phenols, and cyanides. Generation factors are given for each residual in kilograms per metric ton of metal product produced.

Based on solubility tests (described in Appendix B of this report) and consideration of physical and chemical characteristics, each waste stream has been evaluated for designation as either potentially hazardous or non-hazardous. It is emphasized that further leachate testing to be carried out by EPA, or other new data, could result in reclassification of wastes from their present designations as either potentially hazardous or non-hazardous.

Total quantities of land disposed wastes, hazardous wastes, and hazardous constituents thereof are given for each metal category for typical plants and on state-by-state, EPA regional, and national levels for each of the years 1974, 1977, and 1983.

Sections on treatment and disposal technologies present the technologies which are employed within each of the smelting and refining industries for treatment of generated wastes and modes for ultimate disposition in the environment. Current methods of treatment and disposal are first presented and environmental adequacy evaluated. For those wastes which are considered potentially hazardous three levels of treatment and disposal technology are presented and discussed. They are:

Level I	Present Treatment and Disposal Technology
Level II	Best Technology Currently Employed
Level III	Technology Necessary To Provide Adequate Health and Environmental Protection

Level I technology represents the predominant practices used by the various industries for treatment and disposal of wastes which are considered potentially hazardous. Level II technology represents the most environmentally adequate practices known to be used by at least one plant in each industrial category. An example would be the use of lined lagoons rather than unlined lagoons. Level III technologies are the treatment and disposal methods for potentially hazardous wastes in each metal category which are considered adequate to protect human health and provide adequate environmental protection.

Sections on the costs of treatment and disposal technologies give the costs for Levels I, II and III treatment and disposal technologies for potentially hazardous wastes. Costs are given for each major type of waste stream (i.e., slags, sludges, dusts, etc.) in each metal category. Costs are expressed as dollars per metric ton of waste produced (dry and wet weight) and dollars per metric ton of product produced. The total costs for treatment and disposal of the potentially hazardous wastes within each metal category are also given.

SECTION II

SUMMARY OF FINDINGS

The primary and secondary metal smelting and refining industries dispose or store large quantities of process and pollution control residues on land. These residuals are predominantly inorganic slags and sludges containing silicates, oxides and sulfates, and chlorides in some industries. Sludges are often residues of water scrubbing of SO_2 or process wastewater treatment with lime. Consequently, they contain calcium sulfates, calcium sulfites, calcium hydroxides, and calcium carbonates. It was found that recycling of dusts from emission controls is a relatively common practice, although some dusts are disposed on land. The high metallic content of dusts often allows their recycle to the production process, an economically attractive and viable alternative to land disposal. Industries which recycle high proportions of generated dusts include primary copper, lead and zinc. The iron and steel industry and the ferroalloy industry do not generally recycle dusts because of trace metal impurities.

The principal potentially hazardous constituents found in iron and steel, ferroalloy, and foundry residuals are heavy metals, including lead, zinc, copper, manganese, nickel and chromium. Phenol and cyanide are found in steel plant residuals as a result of coking operations and carry over into blast furnace dusts and sludges. Phenol is also present in some waste foundry sands when phenolic binders are used. Oils and greases are present in steel plant mill scales and wastewater treatment plant sludges. Fluoride salts are used as fluxing agents in the iron and steel industry, and consequently, fluoride is found in slags, sludges and dusts.

The principal potentially hazardous constituents found in primary and secondary nonferrous smelting residuals are heavy metals, including arsenic, cadmium, lead, zinc, copper, chromium, antimony, and nickel. The primary base metal smelting and refining industries (i.e., lead, copper, zinc, antimony, mercury, tungsten, and tin) produce a wider variety of heavy metals in residues, including arsenic, cadmium, lead, zinc, copper, antimony, nickel and mercury, because of trace amounts in the concentrates and ores from which the metals are recovered.

Bauxite, the ore from which aluminum is recovered, is essentially devoid of toxic heavy metals. However, fluorides and very small amounts of cyanide appear in sludge and potliner residues from aluminum refining because of the fluoride contained in input cryolite (Na_3AlF_6), and cyanide produced in potliner consumption. Magnesium produced from electrolysis of seawater or from dolomitic limestone also uses heavy metal deficient raw materials and will have negligible concentrations of heavy metals in residuals. They are considered non-hazardous.

The predominant practices used in the primary and secondary metal smelting and refining industries for disposal of residuals are lagooning and open dumping. Slags and other solid residues are generally open dumped on site. Scrubwater from wet emissions control and process wastewater with or without lime treatment is generally routed to unlined settling pits or to unlined lagoons. Settled sludge is often dredged from pits or lagoons and stored or disposed of on land. Industries which produce small quantities of sludge will often leave sludges permanently in lagoons. The use of unlined settling pits and lagoons is the predominant practice.

Unlike other smelting and refining industries, the iron and steel industry generates considerable oily waste and acid pickle liquor. These are usually removed from the plant sites by contract disposers.

In the event of demonstrated significant leaching of potentially hazardous constituents, the use of lined lagoons for the storage or permanent disposal of sludges is considered environmentally adequate. Leachable sludges which are dredged or pumped from lagoons or settling pits and dumped on land can be chemically fixed so that leaching of heavy metals may be prevented. Alternatively, sealing of soil in disposal areas with bentonite or other low permeability material should prevent leachate percolation.

For those slags or other land-disposed or stored solid residues which have been shown to leach significantly in solubility tests, soil treatment at disposal or storage areas would be needed. Collection of run-off from disposal dumps containing slags, sludges or dusts with leachable heavy metals or other potentially hazardous constituents is advisable. Collected runoff would require treatment before discharge, or retention and evaporation in lagoons.

In a number of industry sectors, including primary copper, zinc, lead and aluminum, it was found that some sludges, dusts, or other residues are stored on open ground for periods ranging from months to years before processing for further metallic recovery. In such cases, immediate recycle or storage in concrete pits before reprocessing will preclude leaching of potentially hazardous constituents.

In some industries, the use of dry air pollution control systems can greatly reduce or eliminate the quantity of land-disposed waste. Examples are the use of dry alumina absorption beds in the primary aluminum industry and silica-impregnated baghouses or dry emissions control in the secondary aluminum smelting sector (e.g., "Derham Process").

Future air and water pollution controls are expected to increase the quantities of land-disposed sludges, particularly sulfite and sulfate sludge residues from control of SO_2 emissions from primary copper and secondary lead smelters.

SECTION III

METHODOLOGY

This section describes the methods which were used for collection and analysis of data for industry characterization, waste characterization and treatment and disposal technologies. Methodology used to estimate total quantities of land disposed wastes and potentially hazardous constituents thereof is described. Basic assumptions and methodologies for estimating the costs of treatment and disposal technologies are given.

Industry Characterization

At the outset,it was necessary to identify the sizes and geographical distribution of the various U.S. smelting and refining industries. It was also highly desirable to inform the various industries of the nature and purposes of the study and to encourage industry cooperation and inputs. To this end,arrangements were made to visit and brief the major trade associations involved in primary and secondary metal smelting and refining industries. The following Trade Associations were contacted and visited by Calspan and EPA personnel and asked to inform member companies of the solid and hazardous waste study:

The Aluminum Association
Lead Industries Association, Inc.
Lead-Zinc Producers Committee
International Lead Zinc Research Organization, Inc.
The Aluminum Recycling Association
National Association of Recycling Industries, Inc.
American Mining Congress
Ferroalloy Association
American Iron and Steel Institute
Copper Development Association
International Copper Research Assoc., Inc.
Cast Metals Federation
American Foundrymen's Society

Trade associations generally provided lists of member companies and provided data on production or capacities of individual plants in those instances where this data was allowed to be published by member companies. In some industries, notably the secondary smelting and refining sectors, individual plant data is considered proprietary and was not provided. The Aluminum Recycling Association did, however, provide EPA regional plant capacity data without revealing production of individual plants.

Other sources of information on production, plant capacities, locations, and production processes were the U.S. Bureau of Mines, Minerals Yearbook, The Engineering and Mining Journal Directory, and Effluent Guidelines development documents for the primary aluminum sector, the primary iron and steel industry, the ferroalloy industry, the primary lead, copper and zinc smelting and refining sectors,and the secondary copper, lead and aluminum sectors. Specialists in various metal categories from the U.S. Bureau of Mines supplied state production capacity information in some categories where individual plant data could not be published due to proprietary reasons.

A decision was made to incorporate production capacity data into tabular presentations wherever possible since actual production data is seen to fluctuate rather widely in some industries due to such factors as depressed markets, work stoppages and other economic factors. Consequently, state, EPA regional, and national estimates of total process waste which are based on production capacity estimates generally represent upper limits of waste generation. In the primary tin and mercury industries, where it is clear that production in recent years is known to be substantially less than capacity, actual average production was used in estimating land destined total and hazardous waste.

Tables showing geographical distributions of production capacities in each smelting and refining sector have been subcategorized,where necessary, according to process variations which result in distinctly different types or quantities of land disposed and potentially hazardous wastes. Examples are fire refining vs electrolytic refining of copper, pyrometallurgical vs electrolytic refining of zinc, and blast furnace vs electrolytic refining of antimony.

Waste Characterization

The principal approach used to characterize the land disposed wastes from the primary and secondary smelting and refining industry was to identify, describe and quantify as well as possible the process and pollution control residuals associated with production and pollution control processes in each industry category. In this way the processes and associated waste data acquired from representative plants in each category could be reasonably well extrapolated to other plants using similar procedures. Although the effluent guidelines documents previously referred to provided valuable insight as to the nature of land disposed residuals, the nature of the data did not enable direct calculations of waste quantities.

The most reliable data on quantities of land disposed or stored residuals was found to be that supplied by the industry during plant visits. Additionally, chemical analyses of waste samples from the plants visited were considered most reliable since the exact sequences of production and pollution control processes resulting in the residuals were identified. Additional information was obtained from published and unpublished Bureau of Mines data.

Except for the iron and steel industry individual plants were visited and sampled only once. As a result of cooperative efforts of the American Iron and Steel Institute and member companies, a program which enabled the acquisition and analysis of weekly composited samples was implemented. Under this arrangement, steel company personnel obtained daily samples of various residuals over a one month period which were then composited into 4 weekly samples and analyzed by Calspan.

The numbers of plants in each smelting and refining category which were visited during the study are summarized in Table 1. Samples of land disposed or stored wastes were obtained from these plants.

After visiting plants in the various smelting and refining categories and a review of available process and pollution control literature in these categories, it was possible to assign residual factors for given configurations of production processes and air and water pollution control technologies. The waste residual factors were generally averages of industry supplied data on waste quantities. For industries which provided no individual plant data, best estimates were made by data from the literature or materials balance calculations. These residual generation factors were expressed in kilograms of residuals per metric ton of metal output and are tabularized for each of the metal categories studied in detail. The predominant residuals from the metal smelting and refining industries are slags, sludges and dusts. Thus, residuals are generally expressed in kilograms of slag, dust or sludge per metric ton of product. Residual generation factors are shown in production and pollution control flow diagrams for various smelting and refining categories.

The residual generation factors comprised the major input for estimating quantities of state, EPA Regional and national land disposed or stored residuals. Chemical analyses of waste samples collected by Calspan Corporation, supplemented by analyses provided by industry and the U.S. Bureau of Mines, were the basis for estimating the concentrations of hazardous constituents contained in land disposed or stored residuals.

<u>Treatment and Disposal Technology</u>

Identification of predominant and exemplary treatment and disposal technologies and reclamation or recycling technologies were obtained mainly from plant visits and discussions with industry representatives. The predominant practices consisted of open land dumping of nonrecyclable slags, dusts and dredged sludges, and lagoon storage or permanent retention of water slurried wastes. Careful attention was given to identification of industries in which at least one plant used lined lagoons, thus qualifying this practice as exemplary technology (Best Technology Currently Employed). In addition, attention was given to identifying plants which further processed or in some other way recycled residuals which other plants discarded on land. In a number of industries (e.g., primary lead, copper, and zinc), it was noted that

TABLE 1

SUMMARY OF PLANT VISITS

SIC Category	Metal Category	No. of Plants Visited	No. of Plants in Category
3312	Iron and Steel	10	158
3313	Ferroalloy	7	50
332	Iron and Steel Foundry	5	2000
3331	Primary Copper	5	22
3332	Primary Lead	3	7
3333	Primary Zinc	3	7
3334	Primary Aluminum	4	31
3339*	Primary Antimony	2	3
3339*	Primary Mercury	1	5
3339*	Primary Tungsten	1	15
3399	Metal Powders	1	161
33412	Secondary Copper	3	40
33413	Secondary Lead	5	82
33417	Secondary Aluminum	3	109
	Total:	53	2690

*These plants are all included under one SIC category #3339, Primary Metals, Not Elsewhere Classified (NEC) immediate recycle of residuals or storage on concrete pads rather than storage on ground offers a means by which possible leaching would be precluded.

For those wastes which are considered potentially hazardous and for which current treatment and disposal technologies were considered inadequate for human health and environmental protection, alternative treatments for environmental and health protection were identified. Identified practices included the use of lined lagoons, sludge chemical fixation, sealing of disposal areas, and collection of runoff.

Cost Analysis

The costs presented in this report are for present and environmentally adequate treatment and disposal of only those residuals considered potentially hazardous. The basic methods (i.e., lagooning, open dumping) for disposing of potentially hazardous wastes by the metal smelting industries considered in this study entail many common practices such as land grading, draglining, berm construction, waste hauling, and lagoon construction and lining. The cost factors and costing methodology employed to derive the capital and annual costs of these practices are documented in Appendix C to this report. The industry costs presented in Vols. II and III are computed as described in Appendix C unless specifically noted otherwise. All costs are in 4th quarter 1973 dollars.

There is no sharp, distinguishing line in a number of instances between activities which can be characterized as water treatment vs. those designed to dispose of wastes. For the purpose of this study, it is assumed that waste disposal starts at the point the waste stream enters a settling pit, lagoon or tailings pond. The costs associated with the construction, operation and maintenance of such facilities are charged to industrial waste disposal.

Prior activities such as treatment of an effluent stream by lime neutralization and the pumps and piping necessary to transport the waste stream to the lagoon or tailings pond are considered water treatment and the costs for these functions are not included.

SECTION IV

INDUSTRY CHARACTERIZATION

The primary and secondary metal smelting and refining categories included in this study have been identified in Section I, Introduction. Table 2 summarizes the number of plants in each category, the estimated 1973 production capacity of each industry, and estimated 1973 national sales.

The iron and steel industry produces the largest tonnage of metal (i.e., approximately 141,000,000 MT production capacity), and accounts for the largest dollar sales volume of the U.S. smelting and refining industries. Plants are typically large integrated complexes. The iron and steel foundry industry is extensive, with some 2,000 plants. Production capacity of this industry (approximately 18,000,000 MT capacity) is second only to iron and steel. Of the ferrous metal smelting and refining industries (i.e., iron and steel, iron and steel foundries, ferroalloys), the ferroalloy industry is the smallest and most diversified. Principal ferroalloys produced are ferrosilicon, ferromanganese, ferrochrome and ferronickel. The iron and steel industry consumes most ferroalloys which are produced.

The larger primary nonferrous smelting and refining industries are typified by a relatively small number of plants with large production capacities. The largest primary nonferrous industry is the primary aluminum industry with approximately 4,400,000 MT/yr production capacity, followed by primary copper with approximately 2,900,000 MT/yr capacity. The primary lead and zinc industries have only 7 plants apiece with production capacities of approximately 800,000 MT/yr for each of the two industries. The production capacity of the primary magnesium industry is approximately 200,000 MT/yr, with most of this produced at one plant in Freeport, Texas.

The remaining primary industries are small. A number of these industries (cadmium, arsenic, selenium and tellurium, gold and silver, platinum, bismuth) process the residuals (i.e., slimes, dusts, sludges) from the primary copper, zinc or lead industries to recover minor metals. Recovery of these metals is done either at the primary lead, zinc, or copper smelters or at specialty smelters which process only electrolytic slimes, dusts or other residues.

The only secondary smelting and refining industries of appreciable capacity are the secondary copper, lead, zinc, and aluminum industries. Capacities of these industries range from approximately 400,000 MT/yr for secondary zinc to approximately 800,000 MT/yr for secondary aluminum. Although there are many more secondary plants than primary plants producing lead, zinc, aluminum and copper, they have very much smaller capacities. Secondary plants are generally located in urban areas where the scrap raw material is plentiful. The primary industries are generally located in rural areas near the mine-mill complexes.

TABLE 2

Characteristics of U. S. Metal Smelting and Refining Industries (SIC 33)

Industry Category	No. of Plants	Estimated U.S. Capacity (MT) 1973	Estimated 1973 Nat'l. Sales (thousands of dollars)
Iron and Steel (SIC 3312)	158	140,616,000	26,435,808
Ferroalloys (SIC 3313)	50	2,300,000	720,542
Iron and Steel Foundries (SIC 3321)	2000	18,118,000	5,685,400*
Primary Copper (SIC 3331)	22	2,874,000	2,223,500
Primary Lead (SIC 3332)	7	844,000	224,065
Primary Zinc (SIC 3333)	7	709,000	259,814
Primary Aluminum (SIC 3334)	31	4,418,000	2,206,440
Primary Antimony (SIC 3339)	3	3,800	4,528
Primary Mercury (SIC 3339)	5	80	1,601
Primary Titanium (SIC 3339)	2	15,230	47,800
Primary Tungsten (SIC 3339)	15	4,690	61,974
Primary Tin (SIC 3339)	1	4,500	22,572
Primary Magnesium (SIC 3339)	3	213,000	105,017
Primary Cadmium (SIC 3339)	7	4,500	23,891

* Estimate for 1972

TABLE 2 (cont'd.)

Characteristics of U. S. Metal Smelting and Refining Industries (SIC 33)

Industry Category	No. of Plants	Estimated U.S. Capacity (MT) 1973	Estimated 1973 Nat'l. Sales (thousands of dollars)
Primary Arsenic (SIC 3339)	1	10,000	554
Primary Selenium and Tellurium (SIC 3339)	5	600	8,186
Primary Gold and Silver (SIC 3339)	not known	38,000,000 (troy oz.)	222,657
Primary Platinum (SIC 3339)	5	21,000 (troy oz.)	834
Primary Bismuth (SIC 3339)	1	173	1,875
Primary Cobalt (SIC 3339)	1	150	not produced
Primary Zirconium and Hafnium (SIC 3339)	2	3,550	49,850
Secondary Copper (SIC 33412)	40	449,800	350,083
Secondary Lead (SIC 33413)	82	600,000	213,166
Secondary Zinc (SIC 33413)	not known	400,000	123,990
Secondary Aluminum (SIC 33417)	109	825,440	601,834

SECTION V

WASTE CHARACTERIZATION

The principal types of wastes from the metal smelting and refining industries include furnace slags, dusts, and sludges. Dusts and sludges generally result from emissions controls on smelting and refining furnaces. Some sludges, however, result from treatment of effluents from production process related activities. These include sludges from treatment of spent electrolyte in the primary and secondary electrolytic copper industries, the electrolytic primary zinc industry, and the electrolytic antimony industry. It is estimated that 10% of the land disposed waste from the U.S. smelting and refining industry results from control of air and water pollution with about equal percentages (5%) coming from each. The remaining 90% is comprised of manufacturing process residuals, including furnace slags, furnace linings and refractories, sands and miscellaneous sludges.

Table 3 gives waste generation factors for the metal smelting and refining categories studied in detail. Waste factors are given in kg/MT of metal product produced. These factors were generally estimated by averaging waste generation data provided by plants during plant visits or on plant data forms. For a few industries, including primary tin, primary titanium, and primary mercury, generation factors were calculated from waste quantity and associated production data from available literature.

Table 3 also summarizes Calspan's hazard assessment of the waste streams from each metal category. Residuals are rated either as non-hazardous or potentially hazardous. Hazard ratings were made using a number of criteria including the following:

- Types and concentrations of potentially hazardous constituents
- Physical characteristics of residuals
- Susceptibility to leaching of potentially hazardous constituents as indicated in solubility tests described in Appendix B of this report.

The mere presence of toxic constituents in significant concentrations in a waste did not automatically result in a hazardous rating. The most important criteria was the tendency of toxic constituents to be leached from residuals at significant concentrations.

If lead, cadmium, mercury, cyanide, phenol or other highly toxic materials leached at greater than 1 ppm in solubility tests, the waste was designated as potentially hazardous at this time. Although proposed interim drinking water standards for these species are less

TABLE 3

RESIDUAL GENERATION FACTORS FOR METAL SMELTING AND REFINING [1]

Metal Category	Type of Residual	Residual Factor (kg/MT of Product)	Hazard Rating: Non-Hazardous	Hazard Rating: Potentially Hazardous
Primary Copper, Smelting and Fire Refining	Reverbatory slag	3,000	X	
	Acid plant sludges	2.7		X
	Dusts	17		X
	Miscellaneous slurries	17		X
Primary Copper Electrolytic Refining	Miscellaneous slurries	2.4		X
Primary Lead	Blast furnace slag	410	X	
	Slag fines	30	X	
	Acid plant sludge	40		X
	Sinter scrubber sludge [2]	19		X
Primary Zinc, Electrolytic	Acid plant sludge [2]	17		X
	Miscellaneous sludges [2]	9.1		X
Primary Zinc, Pyrometallurgical	Retort residue	1,050	X	
	Acid plant sludge [2]	122		X
	Retort residue ("blue powder") [2]	10		X
	Cadmium plant residue	1.8		X
Primary Aluminum	Shot blast dust	5	X	
	Pot line scrubber sludge [2]	29.3		X
	Pot line skimmings [2]	5.5		X
	Spent potliners [2]	53		X
	Cast house dust	2.5		X
Primary Antimony, Pyrometallurgical	Blast furnace slag	2,800		X

TABLE 3 (Cont.)

RESIDUAL GENERATION FACTORS FOR METAL SMELTING AND REFINING [1)]

Metal Category	Type of Residual	Residual Factor (kg/MT of Product)	Hazard Rating: Non-Hazardous	Hazard Rating: Potentially Hazardous
Primary Antimony, Electrolytic	Anolyte sludge	210		X
Primary Mercury	Kiln or retort residue	207,000	X	
Primary Titanium	Chlorination sludge	330		X
Primary Tungsten	Digestion residue	50		X
Primary Tin	Smelting slag	915		X
Iron and Steel	Coke oven sludge	2.6		X
	Waste ammonia liquor	190		X
	Blast furnace slag	250	X	
	Blast furnace dust	11.7	X	
	Blast furnace sludge	17.6	X	
	Basic oxygen furnace slag	145	X	
	Basic oxygen furnace dust	16	X	
	Basic oxygen furnace kish	0.14	X	
	Basic oxygen furnace sludge	17.3	X	
	Open hearth furnace slag	243	X	
	Open hearth furnace dust	13.7	X	
	Electric furnace slag	120	X	
	Electric furnace dust	12.8		X
	Electric furnace sludge	8.7		X
	Soaking pit slag	35.2	X	
	Primary mill sludge	1.87		X
	Primary mill scale	44.9		X
	Continuous caster sludge	0.104		X
	Continuous caster scale	8.7		X

TABLE 3 (Cont.)

RESIDUAL GENERATION FACTORS FOR METAL SMELTING AND REFINING [1)]

Metal Category	Type of Residual	Residual Factor (kg/MT of Product)	Hazard Rating: Non-Hazardous	Hazard Rating: Potentially Hazardous
Iron and Steel (Cont.)	Hot rolling mill sludge	1.74		X
	Hot rolling mill scale	18.3		X
	Cold rolling mill sludge	0.16		X
	Cold rolling mill scale	0.052		X
	Cold rolling mill pickle liquor	22.8 [3)]		X
	Tin plating mill sludge	5.32		X
	Galvanizing mill sludge	10.8		X
	Galvanizing mill pickle liquor	5.17 [3)]		X
Gray and Ductile Iron Foundries	Slag	62.9	X	
	Sludge	32.8	X	
	Dust	65.6	X	
	Sand	600	X	
	Refractories	13.8	X	
Malleable Iron Foundries	Slag	55.5	X	
	Sludge	31.9	X	
	Dust	64.7	X	
	Sand	600	X	
	Refractories	13.2	X	
Steel Foundries	Slag	122	X	
	Sludge	36.4	X	
	Dust	186	X	
	Sand	780	X	
	Refractories	53	x	
Ferromanganese	Slag	240	X	
	Sludge	165		X

TABLE 3 (Cont.)

RESIDUAL GENERATION FACTORS FOR METAL SMELTING AND REFINING [1)]

Metal Category	Type of Residual	Residual Factor (kg/MT of Product)	Hazard Rating: Non-Hazardous	Hazard Rating: Potentially Hazardous
Silicomanganese	Slag	1,100	X	
	Sludge	98.5		X
Ferrosilicon	Dust	338	X	
Ferrochrome	Slag	1,750	X	
	Dust	151		X
Ferronickel	Slag	31,000	X	
	Skull plant tailings	5,300		X
	Dust	84	X	
	Sludge	576		X

1) Residuals immediately recycled to process (e.g., dusts) are not included.

2) May be recycled after storage periods of months to years.

3) Wet weight generation factor.

than 1 ppm (Ref. 2) allowance is given for some attentuation of leachate concentration before it reaches ground or surface water used as a drinking water source.

Some leeway was allowed depending on the physical nature of the waste material and the constituents found to solubilize. Thus, many materials solubilized manganese in the range of a few to 50 or 100 ppm. Leaching of manganese alone was not considered sufficient reason to designate a waste as potentially hazardous since manganese is relatively non-toxic. Manganese is highly abundant in soils and rocks and is present to an average extent of 850 ppm in soils, with ranges of 100 to 4,000 ppm (Ref. 1)

Fluoride is beneficial to teeth at low concentrations as evidenced by the use of fluoridated toothpastes and fluoridated water supplies. The average concentration of fluorine in soils is 200 ppm, with a range of 30 to 300 ppm (Ref. 1). Leaching of fluoride of up to 20 ppm in iron and steel making slags, sludges, and dusts was not considered sufficient to designate these wastes as potentially hazardous if there was less than 1 ppm leaching of other potentially hazardous constituents.

Although leaching of sodium, potassium and chloride from wastes would not ordinarily constitute a hazardous waste problem in the metal smelting and refining industry, the extremely high concentration of these constituents in "high salt slag" from the secondary aluminum industry and their high solubility pose a definite threat to groundwater quality. High salt slag is therefore considered potentially hazardous.

The only residual which leached a heavy metal at significant concentration and was not considered potentially hazardous at this time was retort residue from primary zinc smelting. This slag residue leached zinc at 230 ppm in a solubility test. Zinc is required in human diets at 10-40 ppm and has low toxicity. Further testing of the leachability of zinc and other metals from zinc retort residue is needed for further evalation of toxicity.

The limitations of the solubility tests conducted must be recognized. Only one solubility test was conducted on each residual. Replications are desirable to establish statistical significance of test results. The leaching solution in all cases was distilled water at pH 5.5. Thus, no information is available from these tests on the quality of leachate at lower or higher pH's.

For the solubility tests 2 parts distilled water to 1 part test sample by weight were gently agitated for a period of 72 hours. The mixtures were filtered through very fine (i.e., 0.45 micron micropore) filters to remove solids, and the liquid filtrates analyzed. The degree to which comminution of larger separates of slag occurred and exposed surfaces to leaching action could not be ascertained.

Using the industry by industry waste generation factors given previously in Table 3 and production capacities for the various metal categories, total wastes generated from each metal category on state-by-state, regional and national levels were estimated. In the main volumes of the report, quantities of slags, sludges, dusts, potliners and other residuals are given individually. Tables 4 through 6 gives national totals of wastes generated by each metal category during 1974, 1977 and 1983. These tables also give the quantities of potentially hazardous wastes generated in each metal category and total hazardous constituents. Table 4 also lists the types of principal hazardous constituents.

Because of the great variety of trace metals found in copper, zinc, and lead ores and concentrates, a considerable number of heavy metals, including As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Se, and Zn, are found in residuals from smelting and refining. On the other hand, aluminum and iron ores are trace metal deficient. The presence of trace metals in residuals from these industries generally result from addition of alloying metals during metal processing operations. The presence of trace metals in secondary smelting wastes results from the input of metal alloy scrap.

Phenol and cyanide present in some steel plant residuals result from the byproduct recovery of coking gases, or the further release of these materials from coke in blast furnace operations. Phenol may also be found in waste foundry sands although recent trends show less use of phenolic binders in foundry sands. Traces of cyanide are also found in primary aluminum plant spent potliners. Fluorides in primary aluminum plant dusts, sludges, and potliners are derived from the use of fluoride rich cryolyte (Na_3AlF_6). Similarily, the use of fluorides as fluxing agents in the iron and steel industry result in appreciable concentrations of fluorides in slags, sludges and dusts from furnacing operations.

Table 7 indicates trends in the total quantities of residuals generated over the 1974 to 1983 time frame. Future estimates were prepared on the basis of predicted changes in production capacities and pollution control over the 1974 to 1983 time period. There are no predicted significant changes in generated wastes from the primary lead, antimony, mercury, and titanium industries or the secondary copper industry.

The greatest estimated change as shown in Table 7 will be in the primary zinc industry. Because of closings of pyrometallurgical zinc facilities and replacement by electrolytic zinc facilities which are more efficient, it is estimated that there will be an increase of electrolytic waste (as sludge) of 279% by 1983. Concurrently there will be an estimated 35% decrease in pyrometallurgical zinc waste (mainly as retort residue). The overall result will be an estimated 30% reduction of land disposed waste from the primary zinc industry by 1983.

Table 4

ESTIMATES OF GENERATED AND POTENTIALLY HAZARDOUS WASTES FROM UNITED STATES SMELTING AND REFINING INDUSTRY, 1974 (METRIC TONS)

INDUSTRY CATEGORY	TOTAL GENERATED		TOTAL POTENTIALLY HAZARDOUS		TOTAL HAZARDOUS CONSTITUENTS	PRINCIPAL HAZARDOUS CONSTITUENTS
	DRY	WET	DRY	WET	DRY WEIGHT	
IRON AND STEEL (SIC 3312)	73,792,200	80,696,800	2,764,400	4,991,300	85,850	HEAVY METALS (Cr, Cu, Ni, Pb, Zn) FLUORINE, CYANIDE, PHENOL OIL & GREASE
FERROALLOYS (SIC 3313)	1,925,200	2,244,300	287,800	606,900	7,390	HEAVY METALS (Cd, Co, Cr, Cu, Ni, Pb, Zn)
IRON AND STEEL FOUNDRIES (SIC 332)	16,598,500	17,612,800	0	0	0	HEAVY METALS (Cd, Cu, Cr, Ni, Pb, An)
PRIMARY COPPER, SMELTING AND FIRE REFINING (SIC 3331)	6,083,700	6,531,900	335,800	783,930	24,180	HEAVY METALS (As, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, Zn)
PRIMARY COPPER ELECTROLYTIC REFINING (SIC 3331)	5,600	14,000	5,600	14,000	210	HEAVY METALS (As, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, Zn)
PRIMARY LEAD SMELTING AND REFINING (SIC 3332)	542,400	579,200	18,400	55,200	4,400	HEAVY METALS (As, Cd, Cr, Cu, Hg, Pb, Sb, Zn)
PRIMARY ELECTROLYTIC ZINC SMELTING AND REFINING (SIC 3333)	18,300	54,900	18,300	54,900	4,600	HEAVY METALS (As, Cd, Cr, Cu, Hg, Pb, Se, Zn)
PRIMARY PYROMETALLURGICAL ZINC SMELTING AND REFINING (SIC 3333)	287,800	431,400	71,800	215,400	22,340	HEAVY METALS (As, Cd, Cr, Cu, Hg, Pb, Se, Zn)
PRIMARY ALUMINUM (SIC 3334)	405,600	804,200	405,600	804,200	62,580	FLUORIDE, CYANIDE HEAVY METALS (Cu, Pb)
PRIMARY TIN	3,700	3,700	3,700	3,700	40	
PRIMARY ANTIMONY (SIC 3339)	8,300	8,700	8,300	8,700	160	HEAVY METALS (Cu, Pb, Sb, Zn)
PRIMARY MERCURY (SIC 3339)	21,400	21,400	0	0	0	HEAVY METALS (Cr, Cu, Hg, Ni, Pb, Sb, Zn)
PRIMARY TITANIUM (SIC 3339)	5,100	12,800	5,100	12,800	2,170	CHLORINE, HEAVY METALS (Cr, Ti, V)
PRIMARY TUNGSTEN (SIC 3339)	2,500	5,900	2,500	5,900	250	HEAVY METALS (As, Cu, Pb, Zn)
SECONDARY COPPER (SIC 33412)	153,400	153,500	153,400	153,500	6,640	HEAVY METALS (Cu, Ni, Pb, Sn, Zn)
SECONDARY LEAD (SIC 33413)	151,300	157,300	3,000	9,000	180	HEAVY METALS (Cu, Cr, Pb, Sb, Sn, Zn)
SECONDARY ALUMINUM (SIC 33417)	346,100	548,300	346,100	548,300	1,040	HEAVY METALS (Cu, Cr, Pb, Zn)
NATIONAL TOTAL	100,351,000	109,881,000	4,429,800	8,267,800	215,240	

Table 5

ESTIMATES OF GENERATED AND POTENTIALLY HAZARDOUS WASTES FROM UNITED STATES SMELTING AND REFINING INDUSTRY, 1977 (METRIC TONS)

INDUSTRY CATEGORY	TOTAL GENERATED		TOTAL POTENTIALLY HAZARDOUS		TOTAL HAZARDOUS CONSTITUENTS
	DRY	WET	DRY	WET	DRY WEIGHT
IRON AND STEEL (SIC 3312)	78,220,000	85,539,000	2,956,700	5,356,900	93,100
FERROALLOYS (SIC 3313)	1,925,200	2,244,300	287,800	606,900	7,390
IRON AND STEEL FOUNDRIES (SIC 332)	18,365,000	19,496,000	0	0	0
PRIMARY COPPER, SMELTING AND FIRE REFINING (SIC 3331)	6,333,900	6,800,900	349,300	971,900	25,130
PRIMARY COPPER, ELECTROLYTIC REFINING (SIC 3331)	6,700	16,700	6,700	16,700	250
PRIMARY LEAD, SMELTING AND REFINING (SIC 3332)	542,400	579,200	18,400	55,200	4,400
PRIMARY ELECTROLYTIC ZINC SMELTING AND REFINING (SIC 3333)	22,900	68,800	22,900	68,800	5,760
PRIMARY PYROMETALLURGICAL ZINC SMELTING AND REFINING (SIC 3333)	185,400	314,100	64,400	193,100	20,900
PRIMARY ALUMINUM (SIC 3334)	435,200	812,600	435,200	812,600	69,700
PRIMARY TIN	3,700	3,700	3,700	3,700	40
PRIMARY ANTIMONY (SIC 3339)	8,300	8,700	8,300	8,700	160
PRIMARY MERCURY (SIC 3339)	21,400	21,400	0	0	0
PRIMARY TITANIUM (SIC 3339)	5,100	12,800	5,100	12,800	2,170
PRIMARY TUNGSTEN (SIC 3339)	2,500	5,900	2,500	5,900	250
SECONDARY COPPER (SIC 33412)	153,400	153,500	153,400	153,500	6,640
SECONDARY LEAD (SIC 33413)	164,500	196,900	16,200	48,600	880
SECONDARY ALUMINUM (SIC 33417)	415,300	658,000	415,300	658,000	1,250
NATIONAL TOTAL	106,811,000	116,935,000	4,745,900	8,973,100	235,840

Table 6

ESTIMATES OF GENERATED AND POTENTIALLY HAZARDOUS WASTES FROM UNITED STATES SMELTING AND REFINING INDUSTRY, 1983 (METRIC TONS)

INDUSTRY CATEGORY	TOTAL GENERATED		TOTAL POTENTIALLY HAZARDOUS		TOTAL HAZARDOUS CONSTITUENTS
	DRY	WET	DRY	WET	DRY WEIGHT
IRON AND STEEL (SIC 3312)	90,764,000	99,257,000	3,408,000	6,154,000	108,000
FERROALLOYS (SIC 3313)	1,925,200	2,244,300	287,800	606,900	7,390
IRON AND STEEL FOUNDRIES (SIC 332)	22,365,000	23,763,000	0	0	0
PRIMARY COPPER, SMELTING AND FIRE REFINING (SIC 3331)	6,415,000	7,004,000	430,000	1,215,000	28,500
PRIMARY COPPER, ELECTROLYTIC REFINING (SIC 3331)	6,900	17,300	6,900	17,300	260
PRIMARY LEAD, SMELTING AND REFINING (SIC 3332)	542,400	579,200	18,400	55,200	4,400
PRIMARY ELECTROLYTIC ZINC SMELTING AND REFINING (SIC 3333)	51,100	153,300	51,100	153,300	12,660
PRIMARY PYROMETALLURGICAL ZINC SMELTING AND REFINING (SIC 3333)	185,400	314,100	64,400	193,100	20,900
PRIMARY ALUMINUM (SIC 3334)	502,800	880,200	502,800	880,200	78,600
PRIMARY TIN	3,700	3,700	3,700	3,700	40
PRIMARY ANTIMONY (SIC 3339)	8,300	8,700	8,300	8,700	160
PRIMARY MERCURY (SIC 3339)	21,400	21,400	0	0	0
PRIMARY TITANIUM (SIC 3339)	5,100	12,800	5,100	12,800	2,170
PRIMARY TUNGSTEN (SIC 3339)	2,500	5,900	2,500	5,900	250
SECONDARY COPPER (SIC 33412)	153,400	153,500	153,400	153,500	6,640
SECONDARY LEAD (SIC 33413)	164,500	196,900	16,200	48,600	880
SECONDARY ALUMINUM (SIC 33417)	588,900	932,600	588,900	932,800	1,770
NATIONAL TOTAL	123,706,000	135,548,000	5,545,500	10,440,800	272,820

TABLE 7

SUMMARY OF GENERATED WASTES
1974, 1977, 1983
(metric tons) dry weights

Industry Category	YEAR 1974	1977	1983
Iron and Steel (SIC 3312)	73,792,200	78,220,000 (+6%)	90,764,000 (+23%)
Ferroalloys (SIC 3313)	1,925,200	1,925,200 (Unchanged)	1,925,200 (Unchanged)
Iron and Steel Foundries (SIC 332)	16,598,500	18,365,000 (+11%)	22,365,000 (+34%)
Primary Copper, Smelting and Fire Refining (SIC 3331)	6,083,700	6,333,900 (+4%)	6,415,000 (+5%)
Primary Copper, Electrolytic Refining (SIC 3331)	5,600	6,700 (+19%)	6,900 (+24%)
Primary Lead (SIC 3332)	542,400	542,000 (Unchanged)	542,000 (Unchanged)
Primary Zinc, Electrolytic (SIC 3333)	18,300	22,900 (+25%)	51,100 (+279%)
Primary Zinc, Pyrometallurgical (SIC 3333)	287,800	185,400 (-35%)	185,400 (-35%)
Primary Aluminum (SIC 3334)	405,600	435,200 (+7%)	502,800 (+24%)
Primary Antimony (SIC 3339)	8,300	8,300 (Unchanged)	8,300 (Unchanged)
Primary Mercury (SIC 3339)	21,400	21,400 (Unchanged)	21,400 (Unchanged)
Primary Titanium (SIC 3339)	5,100	5,100 (Unchanged)	5,100 (Unchanged)
Primary Tungsten (SIC 3339	2,500	2,500 (Unchanged)	2,500 (Unchanged)
Secondary Copper (SIC 33412)	153,400	153,400 (Unchanged)	153,400 (Unchanged)
Secondary Lead (SIC 33413	151,300	164,500 (+9%)	164,500 (+9%)
Secondary Aluminum (SIC 33417)	346,100	415,300 (+20%)	588,900 (+70%)
National Total:	100,347,000	106,807,000 (+6%)	123,702,000 (+19%)

The estimated increases in land disposed or stored residuals from the primary copper industry results from a combination of estimated plant expansion and lime treatment of wastewaters, resulting in increased quantities of sludge. The projected higher percentage increase in electrolytic copper refinery waste (as sludge) is due to the much greater projected expansion in electrolytic copper as opposed to fire refined copper.

Projected increases in residuals from the primary aluminum industry result entirely from projected increases in plant capacities. Growth in production capacity is estimated as 4% per year through 1983. The amount of waste generated in the primary aluminum industry is not estimated to increase at an equal rate as capacity growth because the increased use of alumina dry bed absorption systems for potline emissions control, rather than wet systems, will result in more recycling of collected emissions, rather than land disposal.

The projected increase of waste from the secondary lead industry by 1977 is based entirely on the premise that treatment of SO_2 scrubwater from SO_2 air pollution control will result in significant quantities of sulfite-sulfate sludge. Projected increases of wastes generated from the secondary aluminum industry are based on an estimated increase in production of 20% by 1977 and 70% by 1983.

Primary electrolytic zinc and primary titanium residues (both sludges) are seen to be comparatively high in potentially hazardous heavy metals.

It is observed that the quantities of potentially hazardous wastes and hazardous constituents thereof from electrolytic zinc refineries are much less than those from pyrometallurgical refiners. This is because the bulk of the residues from electrolytic zinc refiners are sent to lead smelters for recovery of lead value. Virtually all planned expansion in the zinc refining industry is expected to be electrolytic plants, which is reflected in 30% lower residuals estimates for 1977 and 1983 on an industry wide basis.

With respect to the primary copper industry, it is noticed that the copper smelting and fire refining category produces a much larger quantity of wastes than electrolytic refining. This must not be construed to mean that conversion to electrolytic refining can greatly reduce the quantity of waste from the primary copper industry. Smelting is an essential operation before either fire refined or electrorefined copper can be produced. The predominant waste from copper smelting is a hard siliceous slag, three metric tons of which are produced for every metric ton of copper produced. This waste is not considered hazardous at this time.

The quantities given in Tables 4 to 6 include aggregated totals of slags, sludges, dusts, and miscellaneous solid residues. Table 8 gives the percentage compositions of sludge, slag, and dusts for

Table 8

PERCENT COMPOSITION OF GENERATED RESIDUALS
METAL SMELTING AND REFINING INDUSTRIES (SIC 33)

INDUSTRY CATEGORY	SLUDGE			SLAG			DUST			MISCELLANEOUS RESIDUES		
	1974	1977	1983	1974	1977	1983	1974	1977	1983	1974	1977	1983
IRON AND STEEL (SIC 3312)	5.6	5.6	5.6	82	82	82	3.6	3.6	3.6	8.8 (SCALE AND PICKLE LIQUOR)	8.8	8.8
FERROALLOYS (SIC 3313)	11.2	11.2	11.2	73	73	73	15.8	15.8	15.8	-	-	-
IRON AND STEEL FOUNDRIES (SI 332)	4.1	4.1	4.1	8.4	8.4	8.4	9.5	9.5	9.5	78 (SAND + REFRACTORIES)	78	78
PRIMARY COPPER SMELTING AND FIRE REFINING (SIC 3331)	4.9	4.9	6.1	94.5	94.5	93.3	0.6	0.6	0.6	-	-	-
PRIMARY COPPER, ELECTROLYTIC REFINING (SIC 3331)	100	100	100	-	-	-	-	-	-	-	-	-
PRIMARY LEAD SMELTING AND REFINERY (SIC 3332)	3.4	3.4	3.4	96.6	96.6	96.6	-	-	-	-	-	-
PRIMARY ZINC, ELECTROLYTIC REFINING (SIC 3333)	100	100	100	-	-	-	-	-	-	-	-	-
PRIMARY ZINC, PYROMETALLURGICAL SMELTING AND REFINING (SIC 3333)	24.9	34.7	34.7	-	-	-	-	-	-	75.1 (RETORT RESIDUE)	65.3	65.3
PRIMARY ALUMINUM (SIC 3334)	49.1	43.3	37.6	-	-	-	7.3	7.9	8.8	43.6 (POT LINERS AND SKIMMINGS)	48.8	53.6
PRIMARY ANTIMONY (SIC 3339)	2.3	2.3	2.3	97.7	97.7	97.7	-	-	-	-	-	-
PRIMARY MERCURY (SIC 3339)	-	-	-	-	-	-	-	-	-	100 (RETORT OR FURNACE RESIDUE)	100	100
PRIMARY TITANIUM (SIC 3339)	100	100	100	-	-	-	-	-	-	-	-	-
PRIMARY TUNGSTEN	100	100	100	-	-	-	-	-	-	-	-	-
SECONDARY COPPER (SIC 33410)	-	-	-	100	100	100	-	-	-	-	-	-
SECONDARY LEAD (SIC 33413)	2.0	9.8	9.8	98.0	90.2	90.2	-	-	-	-	-	-
SECONDARY ALUMINUM (SIC 33417)	29.2	29.2	29.2	70.8	70.8	70.8	-	-	-	-	-	-

the three time frames. It becomes apparent from Table 8 that only a small percentage of the disposed waste stream from smelting and refining operations is dust. This is because the high metallic content of dusts makes it economical to recycle them for further metallic recovery.

It is also clear that industries which use pyrometallurgical processes, such as blast furnaces, reverbatory furnaces, electric furnaces or retorts produce copious amounts of slag. Over 95% of land disposed residuals from primary copper smelting and fire refining, primary lead smelting, primary antimony smelting, primary mercury smelting secondary copper smelting, and secondary lead smelting are slags or retort residues. Seventy to eighty-five percent of total residues from iron and steel, ferroalloys, primary pyrometallurgical zinc smelting and refining, and secondary aluminum smelting and refining are slags.

On the other hand, processes employing electrowinning of metals produce predominantly sludge residues as the result of treating spent electrolyte solution. These include electrolytic copper (100% sludge), electrolytic zinc (100% sludge), and electrolytic antimony (100% sludge). Chlorination processes used for recovery of titanium also produce 100% sludge residues.

With the exception of the primary aluminum and secondary lead industries, the relative proportions of generated sludges, slags and other residuals is expected to remain the same as in 1974 through 1983. Examination of Table 8 shows that the relative amounts of sludge from the primary aluminum industry is estimated to decrease from 49% of land disposed residuals in 1974 to 38% in 1983. This is a result of expected increase in usage of dry alumina bed absorption rather than wet scrubbing for emissions control.

The expected implementation of SO_2 scrubbing in the secondary lead industry is expected to increase the proportion of sludges in land disposed wastes from 2% to 10% of total in this industry waste. Although there is an expected 25% increase in sludge generation from primary copper smelting by 1983 due to lime treatment of scrubwater, the relative proportion of sludge is only expected to increase from 5% to 6% of the total waste in this industry.

Tables 9 through 11 give the aggregated estimated quantities of total generated and potentially hazardous wastes from the United States Smelting and Refining Industry (SIC 33) on state-by-state, EPA regional and national levels for the years 1974, 1977, and 1983. The totals do not include dusts from primary copper, lead, and zinc smelting and refining categories which are immediately recycled. It is estimated that the total quantity of waste generated in 1977 will increase 6% over that generated in 1974 and that a 23% increase over 1974 levels will be experienced in 1983.

Table 9

STATE, REGIONAL AND NATIONAL WASTE GENERATION U.S. SMELTING AND REFINING INDUSTRY (SIC 33)*, METRIC TONS 1974

STATE	TOTAL GENERATED (WET. WT.)	TOTAL GENERATED (DRY WT.)	TOTAL POTENTIALLY HAZARDOUS (WET WT.)	TOTAL POTENTIALLY HAZARDOUS (DRY WT.)	TOTAL HAZARDOUS CONSTITUENTS (DRY WT.)
ALABAMA	5,160,000	4,864,000	395,300	190,900	7,910
ARIZONA	3,330,000	3,116,000	357,400	140,900	11,080
ARKANSAS	25,000	19,000	15,900	10,500	1,280
CALIFORNIA	2,767,000	2,557,000	192,700	118,800	2,910
COLORADO	871,000	721,000	42,800	25,300	750
CONNECTICUT	108,000	91,000	14,900	6,200	140
DELAWARE	116,000	113,000	5,400	4,800	240
FLORIDA	68,000	65,000	1,700	1,300	100
GEORGIA	128,000	124,000	42,200	41,600	1,800
HAWAII	4,000	3,000	200	200	10
IDAHO	190,000	165,000	37,000	12,300	2,960
ILLINOIS	7,861,000	7,208,000	457,300	261,200	9,240
INDIANA	14,382,000	13,022,000	1,042,500	567,800	17,980
IOWA	410,000	372,000	27,200	10,900	NA
KANSAS	98,000	91,000	6,100	3,700	120
KENTUCKY	1,631,000	1,500,000	173,900	106,800	8,650
LOUISIANA	62,000	47,000	36,200	22,400	3,580
MASSACHUSETTS	57,000	54,000	0	0	0
MARYLAND	3,815,000	3,617,000	156,500	85,400	4,290
MICHIGAN	9,180,000	8,414,000	425,300	220,900	8,730
MINNESOTA	235,000	223,000	1,800	1,400	90
MISSISSIPPI	13,000	12,000	900	600	30
MISSOURI	530,000	491,000	39,400	28,600	4,340
MONTANA	767,000	703,000	114,700	50,200	7,710
NEBRASKA	36,000	34,000	0	0	0
NEVADA	148,000	132,000	25,500	10,000	1,830
NEW JERSEY	1,002,000	935,000	96,200	50,200	2,860
NEW MEXICO	32,000	14,000	32,400	13,800	950
NEW YORK	4,524,000	4,069,000	314,600	153,900	4,470
N. CAROLINA	138,000	132,000	8,000	7,800	1,200
OHIO	17,893,000	16,412,000	1,313,600	789,600	24,580
OKLAHOMA	167,000	148,000	24,400	9,200	2,020
OREGON	3,115,000	2,890,000	379,200	157,400	2,790
PENNSYLVANIA	20,915,000	19,180,000	1,312,800	715,900	40,780
RHODE ISLAND	31,000	28,000	800	200	<1
S. CAROLINA	302,000	289,000	29,000	17,700	620
S. DAKOTA	4,000	3,000	0	0	0
TENNESSEE	624,000	581,000	67,100	47,400	7,300
TEXAS	2,512,000	2,308,000	291,300	156,700	18,470
UTAH	2,562,000	2,343,000	170,000	85,500	4,410
VERMONT	10,000	9,000	0	0	0
VIRGINIA	176,000	166,000	900	800	40
WASHINGTON	639,000	473,000	304,100	141,800	12,860
W. VIRGINIA	2,613,000	2,303,000	310,300	181,200	4,400
WISCONSIN	651,000	611,000	7,500	2,500	20
EPA REGION					
I	206,000	182,000	15,700	6,400	140
II	5,526,000	5,004,000	410,900	204,100	7,330
III	27,635,000	25,379,000	1,785,900	988,000	49,840
IV	8,064,000	7,257,000	778,000	414,000	27,610
V	50,202,000	45,890,000	3,247,700	1,843,400	60,600
VI	2,798,000	2,536,000	400,200	212,600	26,280
VII	1,074,000	988,000	72,800	43,200	4,460
VIII	4,204,000	3,770,000	327,300	161,000	12,870
IX	6,249,000	5,808,000	575,900	269,900	15,830
X	3,944,000	3,528,000	720,300	311,800	18,610
NATIONAL TOTALS	109,902,000	100,342,000	8,334,700	4,464,200	223,570

*DOES NOT INCLUDE SOME DUSTS FROM NONFERROUS SMELTING AND REFINING INDUSTRIES WHICH ARE IMMEDIATELY RECYCLED.

Table 10

STATE, REGIONAL AND NATIONAL WASTE GENERATION U.S. SMELTING AND REFINING INDUSTRY (SIC 33)*, METRIC TONS 1977

STATE	TOTAL GENERATED (WET. WT.)	TOTAL GENERATED (DRY WT.)	TOTAL POTENTIALLY HAZARDOUS (WET WT.)	TOTAL POTENTIALLY HAZARDOUS (DRY WT.)	TOTAL HAZARDOUS CONSTITUENTS (DRY WT.)
ALABAMA	5,514,000	4,965,000	394,900	202,900	10,540
ARIZONA	3,306,000	3,085,000	327,600	141,000	11,080
ARKANSAS	27,000	20,000	17,500	11,000	1,270
CALIFORNIA	2,970,000	2,737,000	221,500	134,300	3,250
COLORADO	888,000	811,000	45,200	26,800	800
CONNECTICUT	114,000	100,000	16,800	6,300	150
DELAWARE	116,000	113,000	5,700	5,000	260
FLORIDA	76,000	71,000	4,500	2,200	150
GEORGIA	134,000	130,000	42,500	4,200	1,800
HAWAII	4,000	3,000	200	200	10
IDAHO	190,000	165,000	37,000	12,300	2,960
ILLINOIS	8,383,000	7,683,000	458,900	277,600	9,710
INDIANA	15,284,000	13,833,000	1,100,800	618,000	17,450
IOWA	451,000	410,000	27,200	10,900	NA
KANSAS	108,000	101,000	6,800	3,900	120
LOUISIANA	65,000	50,000	36,200	22,400	3,580
MARYLAND	4,462,000	3,914,000	204,000	118,700	4,560
MASSACHUSETTS	63,000	60,000	0	0	0
MICHIGAN	9,812,000	8,993,000	421,000	234,600	9,110
MINNESOTA	258,000	244,000	1,700	1,500	90
MISSISSIPPI	13,000	12,000	1,000	600	30
MISSOURI	560,000	520,000	44,300	33,400	2,890
MONTANA	767,000	703,000	695,000	50,200	7,710
NEBRAKSA	39,000	39,000	0	0	0
NEVADA	148,000	132,000	25,500	10,000	1,830
NEW JERSEY	1,046,000	975,000	98,000	51,000	2,870
NEW MEXICO	538,000	501,000	64,700	27,500	1,900
NEW YORK	4,801,000	4,334,000	266,800	158,200	6,280
N. CAROLINA	155,000	147,000	11,900	11,700	1,840
OHIO	19,060,000	17,476,000	1,380,300	848,500	25,650
OKLAHOMA	107,000	94,000	16,000	6,400	1,250
OREGON	3,138,000	2,912,000	392,700	170,900	6,710
PENNSYLVANIA	22,254,000	20,403,000	1,372,000	762,700	44,140
RHODE ISLAND	34,000	31,000	900	200	<1
S. DAKOTA	4,000	4,000	0	0	0
S. CAROLINA	309,000	296,000	30,700	18,400	630
KENTUCKY	1,965,000	1,749,000	179,100	109,500	8,720
TENNESSEE	668,000	622,000	67,200	47,400	7,300
TEXAS	2,595,000	2,387,000	291,700	158,900	17,250
UTAH	2,627,000	2,455,000	187,400	88,400	4,520
VERMONT	11,000	10,000	0	0	0
VIRGINIA	194,000	183,000	1,000	900	40
WASHINGTON	651,000	484,000	305,300	142,400	12,880
W. VIRGINIA	2,734,000	2,405,000	294,500	187,600	4,560
WISCONSIN	721,000	676,000	9,000	3,000	20
EPA REGION					
I	222,000	201,000	17,700	6,500	150
II	5,847,000	5,309,000	364,800	209,200	9,150
III	29,580,000	27,018,000	1,877,400	1,074,900	53,550
IV	8,834,000	7,992,000	731,700	406,900	31,030
V	53,518,000	48,905,000	3,370,900	1,983,800	62,040
VI	3,332,000	3,052,000	426,100	226,200	25,240
VII	1,158,000	1,070,000	78,300	48,200	3,010
VIII	4,288,000	3,973,000	927,600	186,400	13,030
IX	6,428,000	5,957,000	574,800	286,500	16,190
X	3,979,000	3,561,000	735,000	325,600	22,550
NATIONAL TOTALS	117,184,000	107,038,000	9,104,300	4,732,200	235,930

*DOES NOT INCLUDE SOME DUSTS FROM NONFERROUS SMELTING AND REFINING INDUSTRIES WHICH ARE IMMEDIATELY RECYCLED.

Table 11

STATE, REGIONAL AND NATIONAL WASTE GENERATION U.S. SMELTING AND REFINING INDUSTRY (SIC 33)*, METRIC TONS 1983

STATE	TOTAL GENERATED (WET WT.)	TOTAL GENERATED (DRY WT.)	TOTAL POTENTIALLY HAZARDOUS (WET WT.)	TOTAL POTENTIALLY HAZARDOUS (DRY WT.)	TOTAL HAZARDOUS CONSTITUENTS (DRY WT.)
ALABAMA	6,526,000	5,894,000	482,300	229,400	12,070
ARIZONA	3,423,000	3,146,000	461,400	168,700	12,660
ARKANSAS	34,000	25,000	23,300	14,400	1,600
CALIFORNIA	3,433,000	3,156,000	346,100	239,700	3,720
COLORADO	1,037,000	947,000	52,400	31,100	920
CONNECTICUT	139,000	120,000	21,800	8,800	180
DELAWARE	135,000	131,000	6,600	5,900	300
FLORIDA	88,000	83,000	4,800	2,500	170
GEORGIA	150,000	148,000	43,200	42,400	1,830
HAWAII	5,000	4,000	300	200	20
IDAHO	190,000	165,000	37,000	12,300	2,960
ILLINOIS	9,900,000	9,073,000	585,800	313,000	11,000
INDIANA	17,887,000	16,191,000	1,364,500	734,200	20,550
IOWA	550,000	503,000	27,200	10,900	NA
KANSAS	134,000	124,000	8,600	4,500	120
KENTUCKY	2,062,000	1,840,000	243,300	7,000	13,380
LOUISIANA	76,000	60,000	40,900	27,000	4,340
MARYLAND	4,938,000	4,479,000	212,200	106,100	5,270
MASSACHUSETTS	78,000	74,000	0	0	0
MICHIGAN	11,604,000	10,635,000	544,100	267,700	10,380
MINNESOTA	314,000	298,000	2,000	1,800	110
MISSISSIPPI	15,000	14,000	1,100	700	40
MISSOURI	632,000	589,000	48,700	37,500	5,480
MONTANA	789,000	713,000	136,100	60,500	8,490
NEBRASKA	46,000	44,000	0	0	0
NEVADA	152,000	134,000	29,500	11,600	1,900
NEW JERSEY	1,165,000	1,164,000	117,000	56,800	2,320
NEW MEXICO	554,000	507,000	80,800	34,000	2,170
NEW YORK	5,649,000	5,102,000	871,200	172,000	7,080
S. CAROLINA	188,000	179,000	14,900	14,700	2,320
OHIO	22,346,000	20,489,000	1,677,000	998,600	29,230
OKLAHOMA	126,000	113,000	16,300	6,700	1,270
OREGON	3,169,000	2,941,000	398,500	176,700	5,850
PENNSYLVANIA	25,977,000	23,838,000	1,606,700	865,400	47,540
RHODE ISLAND	42,000	38,000	1,000	200	< 1
S. DAKOTA	5,000	5,000	0	0	0
S. CAROLINA	329,000	311,000	34,900	20,000	660
TENNESSEE	823,000	743,000	115,200	68,000	11,670
TEXAS	2,978,000	2,746,000	323,700	180,400	19,000
UTAH	2,978,000	2,773,000	210,600	105,300	5,200
VERMONT	14,000	13,000	0	0	0
VIRGINIA	237,000	224,000	1,100	1,000	40
WASHINGTON	703,000	528,000	326,200	156,500	14,370
W. VIRGINIA	3,190,000	2,806,000	377,200	198,400	5,400
WISCONSIN	891,000	833,000	12,800	4,300	30
EPA REGION					
I	273,000	246,000	22,800	9,000	180
II	6,814,000	6,266,000	488,200	228,800	9,380
III	34,297,000	31,478,000	2,213,800	1,176,700	58,560
IV	10,171,000	9,210,000	939,800	514,800	42,140
V	62,942,000	57,519,000	4,186,000	2,329,500	71,310
VI	3,768,000	3,450,000	486,000	262,400	28,380
VII	1,362,000	1,260,000	84,600	62,900	5,610
VIII	4,809,000	4,438,000	399,100	196,900	14,600
IX	7,013,000	6,439,000	837,200	420,100	18,300
X	4,062,000	3,634,000	761,700	345,500	23,180
NATIONAL TOTALS	135,511,000	123,939,000	10,418,200	5,536,400	271,640

*DOES NOT INCLUDE SOME DUSTS FROM NONFERROUS SMELTING AND REFINING INDUSTRIES WHICH ARE IMMEDIATELY RECYCLED.

SECTION VI

TREATMENT AND DISPOSAL TECHNOLOGY

Within the context of Volumes II and III of this report, dealing with nonferrous and ferrous metals, respectively, technologies have been identified and discussed for treatment and disposal of land disposed or stored residuals.

For specific waste streams from each metal category, current methods of treatment and disposal are identified and discussed. This was done for all waste streams, whether or not they were considered potentially hazardous.

For those waste streams considered potentially hazardous, three levels of technology were identified and described. Level I, or Present Treatment and Disposal Technology, comprises the average treatment and disposal practices for the potentially hazardous wastes. Level II, or Best Technology Currently Employed, comprises those practices now employed within each metal category and considered to be the most environmentally sound practices now employed.

Level III, or Technology Necessary to Provide Adequate Health and Environmental Protection, are those practices believed necessary to provide adequate environmental protection from disposal of potentially hazardous wastes within each metal category. These practices may or may not be currently employed by the industry.

Table 12 summarizes the Levels I, II and III treatment and disposal technologies for potentially hazardous wastes generated in the metal smelting and refining industries. This table also gives the relative amounts of each of the potentially hazardous wastes as percentages of total wastes generated in each category.

Present Treatment and Disposal Technology (Level 1)

The predominant practices used in the metal smelting and refining industry (SIC 33) for the storage or disposal of process or pollution control residuals on land were found to be open dumping and lagooning. Slags and dusts which are not recycled are generally open dumped on land.

Waste slurries containing appreciable solids content are put into lagoons or clarifiers for solids settling before discharge of supernatant to receiving streams or water recycle. For the larger industries such as primary copper, lead, and zinc, lagoons must be periodically dredged to maintain adequate lagoon volume. Dredged lagoon sediments are generally stored or disposed on land adjacent to the lagoons or added to slag dumps. Where the solids content of waste slurries are not high or discharge volumes are low, the sludge may be left in

TABLE 12

TREATMENT AND DISPOSAL TECHNOLOGIES FOR POTENTIALLY HAZARDOUS WASTES, METAL SMELTING AND REFINING INDUSTRY (SIC 33)

(Potentially Hazardous Wastes As A Percentage of Total Generated)

Metal Category and Waste	Level I Present Treatment and Disposal	Level II Best Technology Currently Employed	Level III Adequate Health and Environmental Protection
Primary Copper (SIC 3331) Dust (0.6%)	Land storage before recycle	Immediate recycle	Immediate recycle
Sludge (5%)	Unlined lagoons; land storage or open dumping of dredged sludge	Same as I	Lined lagoons; immediate recyle; storage in concrete pits or disposal in sealed soil areas.
Primary Lead (SIC 3332) Sludge (3.4%)	Unlined settling pits and lagoons; open land storage or disposal	Immediate recycle to sinter	Immediate recycle to sinter or concrete settling pits, lined lagoons and chemical fixation, if land disposed sludge.
Primary Zinc, Electrolytic (SIC 3333) Sludge (100%)	Unlined lagoons--dredged sludge stored on ground or open dumped	Same as I	Lined lagoons and storage of dredged sludge in concrete pits, or immediate shipment to lead smelters
Primary Zinc, Pyrometallurgical (SIC 3333) Sludge (25%)	Unlined lagoons with dredged sludge stored or dumped on land	Unlined lagoons; immediate recycle of retort scrubber sludge; storage or dumping of dredged acid plant sludge on land	Lined lagoons; immediate recycle of retort scrubber sludge; chemical fixation of acid plant sludge before land dumping.

TABLE 12 (Cont.)

Metal Category and Waste	Level I Present Treatment and Disposal	Level II Best Technology Currently Employed	Level III Adequate Health and Environmental Protection
Iron Press Residue (0.2%)	Open dumping	Immediate shipment to lead smelter	Immediate shipment to lead smelter
Primary Aluminum (SIC 3334) Sludge (49%)	Unlined lagoons	Cryolite recovery	Cryolite recovery or lined lagoons with sealing of sludge disposal areas
Potliners and Skimmings (44%)	Ground storage	Immediate recycle for cryolite and carbon recovery	Same as II
Dust (&.3%)	Open dump	Open dump	Sealed soil areas for dumping
Primary Antimony (SIC 3339) Slag (98%)	Open dump	Open dump	Sealing of soil at disposal areas; collection and treatment of runoff
Sludge (2%)	Tailings pond	Tailings pond	Separate lined lagoon for sludge impoundment
Primary Mercury (SIC 3339) Condenser Water (<1%)	Unlined lagoon or spread on calcine dump	Unlined lagoon	Lined lagoon
Primary Titanium (SIC 3339) Chlorinator Sludge (100%)	Daily covered landfill or unlined lagoon	Same as Level I	Lined lagoon

TABLE 12 (Cont.)

Metal Category and Waste	Level I Present Treatment and Disposal	Level II Best Technology Currently Employed	Level III Adequate Health and Environmental Protection
Primary Tungsten (SIC 3339)			
Digestion Residue (10%)	Land Storage	Stored in drums	Stored in drums
Sludge (90%)	Unlined lagoons for settling; open dumping of dredged sludge	Unlined settling lagoons; chemical fixation before open dumping	Lined settling lagoons; chemical fixation before open dumping
Primary Tin (SIC 3339) Slag (10%)	Open dump	Open dump	Ground sealing; collection of runoff
Secondary Copper (SIC 33412)			
Slag (>99%)	Open dump	Open dump	Ground sealing; collection of runoff
Sludge (<1%)	Unlined lagoon	Unlined lagoon	Lined lagoon
Secondary Lead (SIC 33413) Sludge (2%)	Unlined lagoon	Unlined lagoon	Lined lagoon
Secondary Aluminum (SIC 33417) Sludge (29%)	Unlined lagoon	Lined lagoon	Lined lagoon
Iron and Steel (SIC 3312) Ammonia Liquor (15.8%)	Biological treatment	Biological treatment	Biological treatment

TABLE 12 (Cont.)

Metal Category and Waste	Level I Present Treatment and Disposal	Level II Best Technology Currently Employed	Level III Adequate Health and Environmental Protection
Iron and Steel (Cont.)			
Lime Sludge-Coke Plant (0.2%)	Open dump	Open dump	Ground sealing
Decanter Tank Tar-Coke Plant (0.2%)	Open dump	Open dump	Ground sealing
Electric Furnace Dust (1.1%)	Open dump	Open dump	Ground sealing
Electric Furnace Sludge (0.7%)	Open dump	Open dump	Chemical fixation
Pickle Liquor (0.2%)	Neutralization by contract disposer	Acid regeneration and reuse	Acid regeneration and reuse or neutralization in lined lagoons
Mill Sludges (2.6%)	Open dump	Metal reclamation	Metal reclamation or chemical fixation prior to open dumping
Mill Scales (8.5%)	Mostly recycled for iron recovery (∿80%); remainder open dumped	Same as I	Recycle for iron recovery or ground sealing if open dumped
Ferroalloys (SIC 3313) Sludge (11%)	Unlined lagoons; dredged sludge open dumped	Same as I	Lined lagoons; chemical fixation of sludge prior to open dumping
Dust (16%)	Open dumped	Open dumped	Sealed ground at disposal area; collection and treatment of runoff
Skull Plant Tailings (ferronickel) (6.5%)	Open dumped	Open dumped	Ground sealing; collection and treatment of runoff

lagoons permanently. The use of unlined lagoons was found to be almost universally employed. The only industry found to employ lined lagoons was secondary aluminum. The above practices, therefore, generally comprised technology currently employed (Level I).

Best Technology Currently Employed (Level II)

As discussed previously, potentially hazardous constituents, principally heavy metals, were found in slags, sludges and dusts from all of the industries studied. A number of practices have been observed as best technology currently employed. These generally consisted of immediate recycle of some residuals rather than storage on ground for periods of months to years before recycle, the use of lined lagoons, and chemical fixation of sludge.

Industries able to immediately recycle some land stored residuals back to smelting operations as Level II practice include primary copper (dusts), primary lead (sinter and acid plant scrubber sludge), and pyrometallurgical primary zinc (retort scrubwater sludge). In addition, shipment of iron press residues to lead smelters from pyrometallurgical zinc smelters without lengthy ground storage has been observed. Shipment of electrolytic zinc sludge to lead smelters without lengthy periods of ground storage is considered an alternative Level II practice.

The iron and steel industry presently recycles an estimated 80% of mill scales which it generates back to the sinter for agglomeration, and then to blast furnaces for iron production. In recent years the iron and steel industry has developed technology for reclaiming acid and iron from pickle liquor, although this practice is not yet widely used in the industry.

Immediate recovery of cryolite (sodium aluminum fluoride) from scrubber sludges and spent potliners generated in the primary aluminum industry is an observed Level II practice. The demand for cryolite will, however, be less than the amount which could be generated in the industry. Similarly, at least one primary zinc producer recovers zinc, lead, carbon and ferrosilicon.

The use of lined lagoons as Level II practice is evident only for the secondary aluminum industry and certain sectors of the ferroalloy industry, since lined lagoons were not found to be in use by other smelting and refining industries.

The only industry category which is known to employ chemical fixation of sludge (1 plant) before land disposal, thus precluding leachate generation, is primary tungsten. Chemical fixation of sludge is a Level II practice, therefore, only for the primary tungsten industry.

Technology Necessary To Provide Adequate Health and Environmental Protection (Level III)

A number of methods have been advanced for insuring health and environmental protection in the event of demonstrated leaching of hazardous constituents. These methods include immediate recycling or shipment of residuals as discussed under Level II technology, the use of lined lagoons and concrete settling pits to prevent leachate percolation, chemical fixation of sludges prior to land disposal, and sealing of soil at slag, dust and sludge disposal areas to prevent leachate percolation.

As discussed previously, the use of lined lagoons, concrete settling pits, or chemical fixation of sludges is practiced by only a few plants. This is believed to be primarily a result of the absence or lack of regulations regarding the ultimate disposal of residuals on land. Sealing of the soil at disposal areas with bentonite or other sealants is not known to be practiced by any primary or secondary metal smelting plant, but is practiced by other industries (e.g., petroleum refineries).

A final available practice is the collection of runoff from land dump perimeters, with its diversion to lagoons or other treatment prior to discharge, if runoff is significantly contaminated with heavy metals or other toxic constituents.

SECTION VII

COSTS OF TREATMENT AND DISPOSAL

Technologies comprising Levels I (present), Levels II (best practiced), and Levels III (adequate health and environmental protection) were summarized in the previous section for residuals considered potentially hazardous at this time. The capital and annual costs associated with each of these levels were estimated for the potentially hazardous wastes in each metal category. Table 13 summarizes Levels I, II, and III treatment and disposal technology costs. Costs are expressed as dollars per metric ton of product, and dollars per metric ton of dry waste. Details of cost estimates are provided in sections on individual metal categories.

Examination of this data shows that, for the larger industries, costs of the three levels generally range from $0.10 or less to 2 to 3 dollars per metric ton of product, with the higher costs attributable to Level III (adequate health and environmental protection). The costs of treatment and disposal technologies in the smaller primary metals industries (antimony, mercury, titanium, tungsten, ferronickel) are significantly higher when expressed in terms of dollars per metric ton of product. This results from the fact that production from these plants is very much less than that from the larger primary industries, such as iron and steel, primary aluminum, primary copper, primary lead and primary zinc. The costs of treatment and disposal in the primary mercury industry are high as a result of very small production for the large quantity of raw material processed. Production at the typical mercury retort smelter is only about 0.12 MT per day.

It is observed from Table 13 that, in advancing from Level I to Level II treatment and disposal technologies, costs are either the same or only modestly increased. This is because the treatment and disposal technology levels are generally the same for both levels. For example, only one industry (secondary aluminum) was observed to employ lined lagoons for at least one plant, and only one industry (primary tungsten) employs sludge chemical fixation at one or more plants.

Costs increase significantly when comparing Level III technologies to Level I or II technologies, generally by a factor of 1.5 to 3.0. Exceptions include the ferromanganese and silicomanganese and ferrochrome sectors of the ferroalloy industry, the primary zinc pyrometallurgical zinc sector, the primary copper smelting and fire refining sector, the primary electrolytic antimony sector, the primary mercury sector, and the primary titanium sector.

The relatively large increase in cost for the Level III treatment and disposal of primary copper smelter and fire refining wastes (31 times Level I and II costs) are a result of the necessity for using

TABLE 13

SUMMARY OF ANNUAL TREATMENT AND DISPOSAL TECHNOLOGY COSTS
FOR POTENTIALLY HAZARDOUS WASTES, METAL SMELTING
AND REFINING (SIC 33)

(Dollars per Metric Ton of Product and Dry Waste)

Metal Category	Level I Cost (Present)		Level II Cost (Best Practiced)		Level III Cost (Adequate Health & Environmental Protection)	
	$/MT Product	$/MT Waste	$/MT Product	$/MT Waste	$/MT Product	$/MT Waste
Iron and Steel (SIC 3312)	0.08	13.95	0.09	16.40	0.13	23.00
Ferroalloys (SIC 3313)						
Ferromanganese & Silicamanganese	0.32	2.15	0.32	2.15	1.66	11.06
Ferrochrome	0.26	3.15	0.26	3.15	1.32	15.70
Ferronickel	2.56	3.35	2.56	3.35	6.90	9.13
Primary Copper, Smelting and Fire Refining (SIC 3331)	0.12	6.18	0.12	6.18	3.78	19.36
Primary Copper, Electrolytic Refining (SIC)3331	0.03	68.97	0.03	68.97	0.08	172.52
Primary Lead (SIC 3332)	0.29	1.50	0.29	1.50	0.92	4.83
Primary Zinc, Electrolytic (SIC 3333)	0.14	0.94	0.14	0.94	0.27	1.87
Primary Zinc, Pyrometallurgical	0.52	2.76	0.53	2.81	2.63	13.96
Primary Aluminum (SIC 3334)	0.62	4.63	0.62	4.63	1.39	7.63

TABLE 13 (Cont.)

SUMMARY OF ANNUAL TREATMENT AND DISPOSAL TECHNOLOGY COSTS
FOR POTENTIALLY HAZARDOUS WASTES

Metal Category	Level I Cost (Prevalent)		Level II Cost (Best Practiced)		Level III Cost (Adequate Health & Environmental Protection)	
	$/MT Product	$/MT Waste	$/MT Product	$/MT Waste	$/MT Product	$/MT Waste
Primary Antimony Pyrometallurgical (SIC 3339)	4.42	1.59	4.42	1.59	6.38	2.30
Primary Antimony Electrolytic (SIC 3339)	.01	.01	.01	.01	3.71	17.31
Primary Mercury (SIC 3339)	57.25	1.30*	57.25	1.30*	123.69	2.81*
Primary Titanium (SIC 3339)	4.95	3.01	4.95	3.01	16.73	10.17
Primary Tungsten (SIC 3339)	16.67	34.59	73.79	76.56	86.97	93.82
Primary Tin (SIC 3339)	1.58	1.73	1.58	1.73	2.47	2.70
Secondary Copper, Pyrometallurgical (SIC 33412)	0.68	1.93	0.68	1.93	0.99	2.83
Secondary Copper, Electrolytic (SIC 33412)	0.86	18.02	0.86	18.02	1.10	35.93
Secondary Lead	0.58	7.71	0.58	7.71	0.98	13.06
Secondary Aluminum Reverbatory Smelting (SIC 33417)	0.82	3.29	1.65	6.62	1.65	6.62
Secondary Aluminum, Dross Smelting (SIC 33417)	2.50	3.57	2.50	3.57	3.57	5.09

*This is wet weight cost since solids content of wastewater is insignificant.

concrete lined pits and lined lagoons for a large volume of wastes. The primary electrolytic antimony industry at present treats its refinery waste in conjunction with a much larger volume of mill wastewater. The refinery wastewater comprises less than 1% of the total volume; therefore, the Level I and II costs attributable to the refinery are negligible. For Level III, the refinery wastewater is segregated from mill water and put in a lined lagoon, resulting in a cost of $6.38/MT product.

The cost of Level III treatment of chlorination sludge from primary titanium production is 3.4 times Levels I and II as a result of using lined lagoons, as opposed to unlined lagoons, for a relatively large volume of sludge per unit of production (330 kg/MT product).

The costs of Level III treatment and disposal technologies for ferrochrome and ferromanganese and silicomanganese are 5 times Levels I and II technology as a result of the requirements for lined lagoons, chemical fixation of sludges, and soil sealing at dust disposal areas.

Table 14 summarizes the estimated annual costs of Levels I, II, and III treatment and disposal technology for the potentially hazardous wastes in each metal category as percentages of 1973 metal selling price. An impact of 1.5% on mercury selling price for Level III technology is the largest observed. Tables 15 and 16 summarize the capital and annual cumulative industry costs for the primary and secondary metal smelting and refining industries, respectively.

TABLE 14

ANNUAL POTENTIALLY HAZARDOUS WASTE TREATMENT AND DISPOSAL COSTS AS PERCENTAGES OF 1973 METAL SELLING PRICES

Industry Category	Treatment and Disposal Technology Levels		
	Level I	Level II	Level III
Iron and Steel (SIC 3312)	0.09	0.10	0.15
Ferromanganese & Silicomanganese (SIC 3313)	0.2	0.2	0.80
Ferrochrome (SIC 3313)	0.07	0.07	0.36
Ferronickel (SIC 3313)	0.18	0.18	0.48
Primary Copper Smelting & Fire Refining (SIC 3331)	0.01	0.01	0.29
Primary Copper, Electrolytic Refining (SIC 3331)	0.002	0.002	0.006
Primary Lead (SIC 3332)	0.08	0.08	0.26
Primary Zinc, Electrolytic (SIC 3333)	0.03	0.03	0.06
Primary Zinc, Pyrometallurgical (SIC 3333)	0.11	0.12	0.58
Primary Aluminum (SIC 3334)	0.09	0.09	0.21
Primary Antimony, Pyrometallurgical (SIC 3339)	0.29	0.29	0.42
Primary Antimony, Electrolytic (SIC 3339	Negligible	Negligible	0.25
Primary Mercury (SIC 3339)	0.7	0.7	1.5
Primary Titanium (SIC 3339)	0.16	0.16	0.54
Primary Tungsten (SIC 3339)	0.13	0.57	0.68
Primary Tin (SIC 3339)	0.03	0.03	0.05

TABLE 14 (Cont.)

ANNUAL POTENTIALLY HAZARDOUS WASTE TREATMENT AND DISPOSAL COSTS AS PERCENTAGES OF 1973 METAL SELLING PRICES

Industry Category	Treatment and Disposal Technology Levels		
	Level I	Level II	Level III
Secondary Copper, Pyrometallurgical (SIC 33412)	0.05	0.05	0.08
Secondary Copper, Electrolytic (SIC 33412)	0.06	0.06	0.08
Secondary Lead (SIC 33413)	0.16	0.16	0.27
Secondary Aluminum, Reverbatory Smelting (SIC 33417)	0.13	0.26	0.26
Secondary Aluminum, Dross Smelting (SIC 33417)	0.39	0.39	0.56

TABLE 15

CUMULATIVE WASTE TREATMENT AND DISPOSAL TECHNOLOGY COSTS
PRIMARY METAL SMELTING AND REFINING INDUSTRIES
($ Million)

Industry	LEVEL I Capital	LEVEL I Annual	LEVEL II Capital	LEVEL II Annual	LEVEL III Capital	LEVEL III Annual
Copper: Smelt & Fire Refining	$ 1.15	$ 0.19	$ 1.15	$ 0.19	$ 3.66	$ 6.13
Copper: Electrolytic Refining	0.32	0.05	0.32	0.05	0.79	0.12
Lead	0.24	0.18	0.24	0.18	0.34	0.56
Zinc: Electrolytic	0.08	0.03	0.08	0.03	0.20	0.05
Zinc: Pyrometallurgical	0.27	0.16	0.29	0.16	0.34	0.80
Aluminum	7.41	2.55	7.45	2.55	27.34	5.72
Antimony: Pyrometallurgical	0.01	0.01	0.01	0.01	0.30	0.01
Antimony: Electrolytic	(1)	(1)	(1)	(1)	.01	(1)
Mercury	0.03	0.004	0.03	0.004	0.06	0.009
Titanium	0.01	0.07	0.01	0.07	0.01	0.23
Tungsten	0.56	0.33	0.58	1.28	0.89	1.33
Tin	0.01	0.01	0.01	0.01	0.03	0.01
Iron and Steel	3.53	7.57	3.53	7.57	8.08	12.93
Ferroalloys						
FeMn & SiMn	0.47	0.25	0.47	0.25	0.63	1.31
FeCr	0.35	0.11	0.35	0.11	0.73	0.56
FeSi	1.19	1.07	1.19	1.07	1.19	1.07
FeNi	0.17	0.07	0.17	0.07	0.83	0.17
Total:	$15.80	$12.65	$15.88	$13.60	$45.43	$31.01

(1) Less than $5,000

TABLE 16

CUMULATIVE WASTE TREATMENT AND DISPOSAL TECHNOLOGY COSTS
SECONDARY METAL SMELTING AND REFINING INDUSTRIES

($ Million)

Industry	LEVEL I Capital	LEVEL I Annual	LEVEL II Capital	LEVEL II Annual	LEVEL III Capital	LEVEL III Annual
Copper - Pyromet. Refining	$ 0.20	$ 0.21	$ 0.20	$ 0.21	$ 0.71	$ 0.31
Copper - Electrolytic Refining	0.14	0.12	0.14	0.12	0.35	0.17
Lead - Hard & Soft Smelting	0.37	0.10	0.37	0.10	0.81	0.17
Aluminum - Reverbatory Smelting	4.08	0.62	8.11	1.25	8.11	1.25
Aluminum - Dross Smelting	N/A	0.47	N/A	0.47	N/A	0.67
Total	$ 4.79	$ 1.52	$ 8.82	$ 2.15	$ 9.98	$ 2.57

N/A - Not Applicable

REFERENCES

1. "Agronomic Controls Over Environmental Cycling of Trace Elements," W. H. Alloway in Advances in Agronomy, V. 20: 235-274, 1968.

2. National Interim Primary Drinking Water Regulations (40CFR 141), December 24, 1975.

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