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Assessment of Solid Waste Management Problems and Practices in the Inorganic Chemicals Industry

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and State Solid Waste Management Agencies*

ASSESSMENT OF SOLID WASTE MANAGEMENT PROBLEMS
AND PRACTICES IN THE INORGANIC CHEMICALS INDUSTRY

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I. EXECUTIVE SUMMARY

Introduction

The disposal of industrial wastes in landfills and permanent lagoons in an environmentally sound manner is an area of increasing concern. The adverse environmental and economic effects of disposal facilities which are improperly located, designed, and managed will continue to increase unless sound control practices are instituted and followed. The severity of the problems associated with industrial solid waste disposal results from several factors. First, more wastes are being disposed of on the land as a result of population increases, economic and industrial growth, and affluence. In addition, new regulations are causing increased generation of solid wastes by requiring more stringent control of air and water pollutants.

To adequately determine the magnitude of these problems of industrial solid waste disposal requires background information with which to identify and define the specific solid waste problems of various industries. This report addresses solid waste generation and management relative to the inorganic chemicals industry. This study is one of a series of assessments of industrial solid waste being conducted for the EPA Office of Solid Waste (OSW) to provide support for implementation of P.L. 94-580, the Resource Conservation and Recovery Act of 1976 (RCRA).

The Resource Conservation and Recovery Act of 1976 is an amendment to a prior statute, the Solid Waste Disposal Act of 1965. The main purpose of this act is to ensure that solid wastes are managed so as to prevent damage to public health and the environment. The act addresses hazardous wastes (Subtitle C) and non-hazardous wastes (Subtitle D). Although this study is concerned with Subtitle D, and emphasizes non-hazardous wastes, it addresses all of the solid wastes associated with the inorganic chemicals industry. Definition of hazardous and non-hazardous wastes for this study is based on proposed lists given in the Federal Register of December 18, 1978. It is important to note that the final regulations and guidelines may be different from those on which the 1978 list is based.

The RCRA requires that EPA provide criteria to be used by the states in identifying practices that constitute the open dumping of solid wastes.

It also requires that EPA provide criteria for determining which solid waste disposal facilities do and which do not "pose a reasonable probability of adverse effects on health or the environment." As part of a broad-based effort undertaken to fulfill these requirements, EPA has commissioned this study of solid waste disposal in the inorganic chemicals industry. The study consisted of the following subtasks:

1. Industry Characterization - discussed in Section II.
2. Selection of Major Waste Sources - discussed in Section III.
3. Analysis of Selected Waste Sources - discussed in Section IV.
4. Treatment and Disposal Practices - discussed in Section V.
5. RCRA Compliance Costs - discussed in Section VI.
6. Identification of Waste Handling Alternatives and Recovery Options - discussed in Section VII.

This report provides (1) a data base on the type and quantity of wastes generated and the treatment and disposal techniques now applied for their control; (2) the background information needed to develop a long-term strategy for Federal policies concerning solid wastes from inorganic chemical industries; (3) information concerning the costs to industry of meeting RCRA requirements, specifically Section 4004. The RCRA induced costs are the additional costs above current costs of solid waste control that will be incurred in bringing existing utilities into compliance with RCRA requirements.

Industry Description

The inorganic chemicals industry is one of a number of sub-industries comprising the broad chemicals industry. In its industrial classification, the Bureau of Census has grouped the inorganic chemicals industry under the Standard Industrial Classification (SIC) 281. The industry manufactures a wide variety of chemicals and chemical products from inorganic compounds. Inorganic compounds are those compounds usually not containing carbon and are derived from atmospheric gases, minerals, water, and other matter that is never, of itself, a part of living organisms.

Types of Industries--

There are four major subcategories under the SIC 281 classification: the chlor-alkali (SIC 2812) manufacturers that produce such commodities as chlorine, caustic soda, potassium hydroxide, and soda ash; the industrial gases (SIC 2813) manufacturers that produce such commodities as oxygen, nitrogen, hydrogen, carbon dioxide and acetylene; the inorganic pigments (SIC 2816) manufacturers that produce such commodities as titanium dioxide, chrome pigments and iron blues; and the manufacturers of the industrial inorganic chemicals not elsewhere classified (SIC 2819) that produce a diversity of commodities such as sulfuric acid, hydrofluoric acid, alum, sodium sulfide, and phosphorus.

The uses of inorganic chemicals are varied, ranging from pigment bases for paints to scouring agents for toothpaste. Sulfuric acid, the largest volume inorganic chemical produced in the United States, is used primarily in the manufacture of phosphoric fertilizers and inorganic pigments.

The companies which produce industrial chemicals range from small independent companies with one or two products to multi-plant corporations employing thousands of people and making thousands of products. The market is dominated by a relatively small number of large, diversified companies. Among the reasons for this dominance by a relatively few companies are economies of scale, growth by acquisition, and the trend toward greater horizontal and vertical integration.

Industry Distribution--

The inorganic chemical production facilities are concentrated in certain areas of the country rather than randomly distributed throughout the nation. Most facilities are generally capital intensive skilled labor operations located in the East Coast (Delaware, New Jersey), Gulf Coast (Texas, Louisiana), or West Coast (California). Inorganic chemical plants are located near coastal areas because raw materials for use in the manufacturing of inorganic chemicals depend to a large extent on water transportation since they are not readily transported by pipeline.

The ages of plants in the inorganic chemicals industry range from five to 30 years. The production process is typically continuous, rather than

batch, and operating levels of 70 to 85 percent of capacity must generally be achieved to assure efficiency and profitability.

Since major technological developments tend to take place infrequently, new facilities are built only when market demand justifies capacity expansions. In sectors of the industry where demand growth is low, virtually all of the plants in the sector may have been built prior to 1970, with a significant number built before 1940. Accordingly, many existing production facilities were built with little regard (by today's standards) for engineering and siting considerations relating to pollution control.

Waste Description--

The inorganic chemicals industry ranks third among U.S. industries in the generation of land destined wastes. Currently, it is estimated that the industry generates about 34 million metric tons of wastes per year (dry basis), of which 8 million are classified as hazardous.

Land destined wastes from the inorganic chemicals industry originates either directly from the manufacturing processes or from air or water effluent treatment.

Waste Volume and Type--

Within the four subcategories under SIC classification 281 (chlor-alkali, gases, pigments, and other inorganic chemicals) there are over 100 individual products. Of these, 31 product areas each generate 1,000 metric tons or more of land-destined waste per year. Twenty-three of the 31 industry segments generate an estimated combined total of 22 million metric tons of non-hazardous waste per year. Fourteen of the 31 industry segments generate about 8 million metric tons of hazardous wastes per year. These figures represent over 80 percent of all solid waste generated by the inorganic chemicals industry. Table 1 lists the 31 industry categories, including number of plants, and type and volume of wastes.

Disposal Practices--

Waste from inorganic chemicals manufacturing is generally disposed of by landfilling, settling in lagoons or ponds, and ocean dumping. Ocean dumping, a common practice at one time, is currently limited to two

TABLE J
AMOUNTS OF WASTE GENERATED BY INDUSTRY CATEGORIES

Product Area	Number of Facilities	Non-hazardous Wastes Generated	Amounts of Non-hazardous Waste Generated (kkq/yr)	Disposal Procedure	Disposal Site Restoration	Disposal Site Monitoring	Notes (* applies only to indicated column for each product area.)	Amounts of Hazardous Waste Generated (kkq/yr)
Chlorine/caustic soda (diaphragm cell process)	12	Brine muds containing calcium carbonate, magnesium hydroxide, barium sulfate and cell rubble.	96,000	Lagooned initially. Landfilled later.	Full	Partial		2,600
Chlorine/caustic soda (mercury cell process)	28	* Brine muds containing calcium carbonate, magnesium hydroxide, barium sulfate and cell rubble.	15,000	Lagooned initially. Landfilled later.	Full	Partial	* Applies to six plants which purify brine separately. Wastes from other plants are considered hazardous due to mercury contamination.	39,000
Potassium chloride	8	Salt tailings, evaporated brine solutions.	12,000,000	* Unlined evaporation ponds.	* None required due to plant locations in desert areas.	* None	All plants are located in desert areas where ground water is naturally highly saline and unfit for human consumption or agricultural purposes.	None
Potassium sulfate	1	Sodium chloride, brine solution.	600,000	* Unlined evaporation ponds (in combination with potassium chloride wastes) in desert areas.	* None required due to plant locations in desert areas.	* None	* Produced at one site where potassium chloride is manufactured.	None
Alumina	10	Red mud containing iron oxides, residual alumina, silica, titanium dioxide and small amounts of alkaline salts.	7,600,000	* Lagooned	None	Partial	* Eight facilities use clay-lined lagoons; two use unlined ponds.	None

TABLE 1 (continued)
AMOUNTS OF WASTE GENERATED BY INDUSTRY CATEGORIES

Product Area	Number of Facilities	Non-hazardous Wastes Generated	Amounts of Non-hazardous Waste Generated (kg/yr)	Disposal Procedure	Disposal Site Restoration	Disposal Site Monitoring	Notes (* applies only to indicated column for each product area.)	Amounts of Hazardous Waste Generated (kg/yr)
Phosphorus	9	Phosphate rock calcination dust	148,000	Landfill	Full	None	* Applies to three plants which have no market for slag as roadbed construction material. Approximately 3.9 million kg/yr sold.	4,560,000*
Natural soda ash	4	Ore residues (alumina, silicates)	1,200,000	Lagoon	* Full	Partial	* In compliance with Wyoming State law.	None
Lime	180	Lime and limestone particulates	1,900,000	Landfill	Full	Partial		None
Hydrofluoric Acid	13	Gypsum	1,300,000	* Landfill * Land storage * Lagoon * Sold or used for construction purposes.	Full None None --	Partial Partial None --	* Six Plants * Two Plants * Two Plants * Three Plants	None
Borax	1	None	--	--	--	--	All wastes considered hazardous.	510,000
Solvay process soda ash	1	Brine muds containing magnesium hydroxide, barium sulfate and cell rubble.	260,000	Lagoon	* Full	* Full	* In compliance with New York State law.	None
Sulfate process Titanium dioxide	4	None	--	--	--	--	All wastes considered hazardous.	1,340,000

TABLE 1 (continued)
AMOUNTS OF WASTE GENERATED BY INDUSTRY CATEGORIES

Product Area	Number of Facilities	Non-Hazardous Wastes Generated	Amounts of Non-Hazardous Waste Generated (kg/yr)	Disposal Procedure	Disposal Site Restoration	Disposal Site Monitoring	Notes (* applies only to indicated column for each product area.)	Amounts of Hazardous Waste Generated (kg/yr)
Sodium dichromate	3	None	--	--	--	--	All wastes considered hazardous.	140,000
Iron oxide	11	Unrecovered iron oxides.	15,000	Landfill	Full	Partial		None
Lithium carbonate	2	Ore residues (silica and alumina), gypsum, calcium carbonate	260,000	Landfill	Partial	Partial		None
Chloride process Titanium dioxide	8	None	--	--	--	--	All wastes considered hazardous.	812,000
Aluminum sulfate	67	Acid insoluble bauxite ore residues (silica, titania, residual alumina)	120,000	Landfill	Full	Partial		None
Zinc oxide	3	Zinc oxide	None	--	--	--	All wastes considered hazardous.	325,000
Antimony oxide	4	Wet scrubber - generated sludges (mainly gypsum) Slag	3,000 --	Landfill Sold to smelters for silver recovery	Full --	None --		3,000 ¹
* Barium sulfate	1	Gypsum, iron oxides, hydroxides	35,000	Landfill in future. Presently waterborne waste.	--	--	* Most barium sulfate processes generate no solid wastes. One plant uses a unique process which generates waterborne wastes. Once plans to neutralize this waste stream go into effect, about 35,000 kg/yr of waste solids will be generated and handled by contractor disposal.	None

TABLE 1 (continued)
AMOUNTS OF WASTE GENERATED BY INDUSTRY CATEGORIES

Product Area	Number of Facilities	Non-hazardous Wastes Generated	Amounts of Non-hazardous Waste Generated (kg/yr)	Disposal Procedure	Disposal Site Restoration	Disposal Site Monitoring	Notes (* applies only to indicated column for each product area.)	Amounts of Hazardous Waste Generated (kg/yr)
Manganese sulfate	1	Sulfuric acid in-soluble ore residues (mainly silica)	32,500	Lagoon	None	None		None
Vanadium pentoxide	1	Iron oxide, iron phosphate, sodium chloride, sodium sulfate, ammonium sulfate.	20,000	Lined evaporation ponds.	None	None		None
Calcium phosphate	13	Calcium phosphate	120,000	Landfill	Full	Partial		None
Sodium hypophosphite	2	Calcium phosphite, calcium carbonate	2,500	Landfill	Full	None		None
Barium carbonate	4	None	--	--	--	--	All wastes considered hazardous.	20,000
* Strontium carbonate	2	--	--	Non-hazardous wastes combined with hazardous barium carbonate wastes prior to disposal.	--	--	* Manufactured at two facilities which also produce barium carbonate.	5,200
Sodium	5	Brine purification muds containing calcium carbonate, magnesium hydroxide, barium sulfate, and cell rubble.	3,500	Landfill	Full	Partial		None
Sodium chlorate	13	Brine muds containing calcium carbonate, magnesium hydroxide, barium sulfate, and cell rubble.	3,800	Landfill, combined with wastes from other chemical categories.	Full	Partial		800

TABLE 1 (continued)
AMOUNTS OF WASTE GENERATED BY INDUSTRY CATEGORIES

Product Area	Number of Facilities	Non-hazardous Wastes Generated	Amounts of Non-hazardous Waste Generated (kg/yr)	Disposal Procedure	Disposal Site Restoration	Disposal Site Monitoring	Notes (* applies only to indicated column for each product area.)	Amounts of Hazardous Waste Generated (kg/yr)
Chrome yellow	9	None	--	--	--	--	All wastes considered hazardous.	2,000
Potassium permanganate	1	Insoluble ore residues (mainly silica and alumina), small amounts of manganese oxides.	1,450	Landfill	Full	Full		None
Calcium carbide	5	Lime	* 450,000	Land storage	None	None	* All currently generated non-hazardous wastes are sold or used internally. One plant has about 450,000 kg of lime land-stored on its premises. This waste is left over from previous acetylene manufacture.	8,000 ²
Rounded Totals	446		26,200,000					7,800,000

¹ All slag wastes from antimony oxide production are considered hazardous. However, three of the four plants sell these materials for recovery of other metals. The fourth plant, due to its unusual raw material generates an unmarketable slag requiring disposal as hazardous waste.

² At one calcium carbide plant only, coal is used in place of coke. This raw material substitution causes generation of a slag which liberates some acetylene on contact with water and can be classified as hazardous. The other four calcium carbide production sites do not generate this waste.

titanium dioxide plants on the East Coast. These two plants are ocean dumping small amounts of ferrous sulfate.

Lagoons are the primary method in which wastes are managed in the inorganic chemical industry. This type of waste storage or disposal lends itself to the industry because of the large amounts of waste slurries that are generated. At one time, numerous chemical industries discharged their waste slurries into bodies of water; however, because of EPA effluent guidelines, this practice has been mostly eliminated. The large volumes of waste that were previously discharged into waterways are now being put into lagoons or ponds.

Impact of Resource Conservation and Recovery Act - Section 4004--

The problems that the inorganic chemicals industry faces with the disposal of their non-hazardous wastes can be related to volume and site location. Generally those industries that manufacture chemicals or chemical products from ores have more severe problems. Of the 23 industry categories generating primarily non-hazardous wastes, only the alumina industry will bear a significant impact from the RCRA Section 4004 regulations proposed on February 6, 1978 (see Table 2). The alumina industry will be affected because of the large volumes of wet waste generated and potential number of sites located near wetland areas. There are 10 alumina plants in the United States, four of which have disposal lagoons located near wetland areas. These sites are Mobile, Alabama; Point Comfort, Texas; Gramercy, Louisiana; and Burnside, Louisiana. Under the proposed wetland provisions of RCRA 4004, these plants would probably have to locate future disposal sites a considerable distance from plant sites to avoid the use of wetland areas for disposal.

Most of the 31 industry segments that were addressed will be affected to some degree by RCRA 4004; however, their projected costs of compliance would be small compared to the projected costs for the alumina and phosphorus industries.

Another industry (acetylene gas) also has the problem of having a large stockpile of non-hazardous waste generated over many years. There are two plants in the United States that produce acetylene from calcium carbide, a

TABLE 2

ESTIMATED COMPLIANCE COSTS FOR NON-HAZARDOUS WASTES*

Chemical	State and other Federal Induced Costs		RCRA 4004 Compliance Costs		Total	
	Capital	Operating	Capital	Operating	Capital	Operating
Diaphragm cell chlorine/caustic soda	\$ 900,000	\$210,000	\$420,000	\$14,000	\$1,320,000	\$224,000
Mercury cell chlorine/caustic soda	180,000	42,000	80,000	---	260,000	42,000
Potassium chloride	210,000	49,000	30,000	7,000	240,000	56,000
Potassium sulfate	270,000	63,000	41,300,000	6,000,000	41,570,000	6,063,000
Alumina	270,000	63,000	none	none	270,000	63,000
Phosphorus	60,000	12,000	none	none	60,000	12,000
Natural soda ash	4,200,000	980,000	300,000	70,000	4,500,000	1,050,000
Lime	300,000	70,000	195,000	108,900	495,000	178,900
Hydrofluoric acid	All wastes from this category are considered hazardous					
Borax	none	none	none	none	---	---
Solvay soda	All wastes from this category are considered hazardous					
Titanium dioxide, sulfate process	270,000	63,000	30,000	7,000	300,000	70,000
Sodium dichromate	30,000	7,000	72,000	8,000	102,000	15,000
Iron oxide	All wastes from this category are considered hazardous					
Lithium carbonate	1,920,000	450,000	90,000	21,000	2,010,000	471,000
Titanium dioxide, chloride process	All wastes from this category are considered hazardous					
Aluminum sulfate	120,000	28,000	none	none	none	none
Zinc oxide	none	none	none	none	none	none
Antimony oxide	30,000	7,000	60,000	5,000	90,000	12,000
Barium sulfate	30,000	7,000	none	3,000	30,000	10,000
Manganese sulfate	360,000	84,000	30,000	7,000	390,000	91,000
Vanadium pentoxide	3,300,000	none	none	none	3,300,000	none
Calcium phosphate	10,000	2,500	none	none	10,000	2,500
Calcium carbide	Wastes from both these processes are normally combined and contain hazardous constituents					
Sodium hypophosphite	120,000	28,000	none	none	120,000	28,000
Barium carbonate	none	none	none	none	none	none
Strontium carbonate	All wastes from this category are considered hazardous					
Sodium	none	none	none	none	---	---
Sodium chlorate	none	none	none	none	---	---
Chrome yellow	none	none	none	none	---	---
Potassium permanganate	none	none	none	none	none	none
Totals	\$6,190,000	\$2,166,000	\$42,607,000	\$6,251,000	\$48,797,000	\$8,417,000

* Capital costs for RCRA compliance include 12 percent interest.

process which produces a calcium waste. Both plants sell all the waste that is generated. However, one plant at Louisville, Kentucky, has an estimated 450,000 metric tons of stockpiled waste. The potential problem associated with this waste is the leaching of materials into the ground water, causing excess hardness in the water. Figure 1 shows the general location of plants in the United States that will be significantly impacted by RCRA 3004 and 4004 regulations.

Impact of Air and Water Regulations on Future Waste Generation--

Generally future waste volumes generated as a result of full implementation of the Clean Air Act and the Clean Water Act will be insignificant compared to volumes presently being generated by the inorganic chemicals industry.

The titanium dioxide industry is the only major inorganic chemical industry which may face a major impact from RCRA because of the Clean Water Act. In 1980, at which time EPA effluent discharge standards are expected to be fully implemented, two titanium plants using the sulfate process will have to neutralize their effluent discharge from disposal lagoons. This action will approximately double the amount of land-destined waste now being generated by the titanium dioxide industry.

Resource Recovery--

The inorganic chemicals industry as a whole generates wastes that have potential market value. However, the amount of waste that is currently being sold or reused is generally small compared to the volumes of waste that are being generated. An exception is the phosphorus industry, which sells over sixty percent of its waste slag. The sales are mostly to the road building industry.

In the titanium dioxide industry, small amounts of ferric chloride and gypsum waste are being sold. A number of titanium dioxide companies are actively looking for markets for their gypsum waste. DuPont and Allied sell some gypsum for hydrofluoric acid production to wallboard manufacturers and construction firms and are currently looking for other markets.

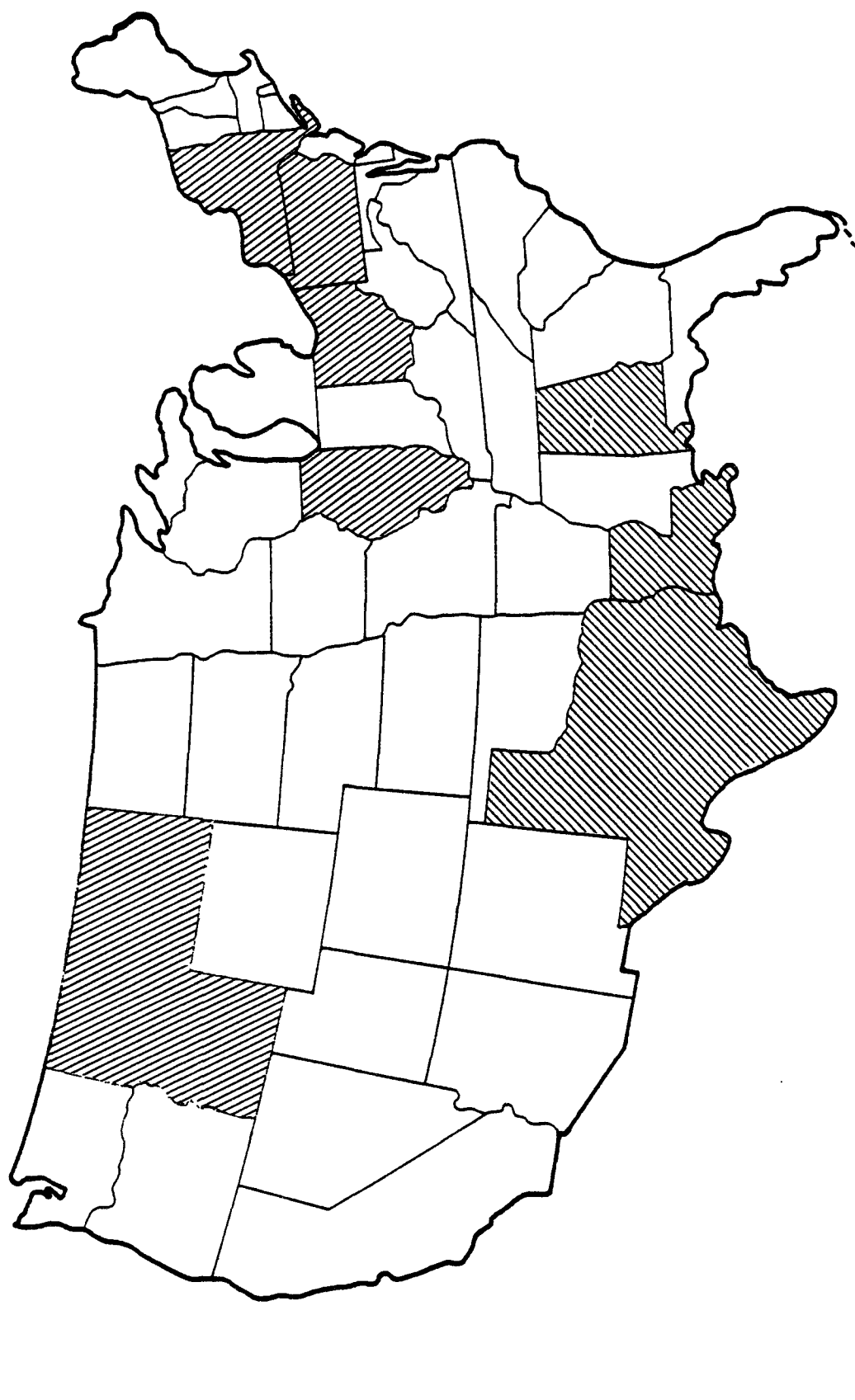


FIGURE 1. STATES CONTAINING PLANTS WITH HIGH RCRA IMPACT

The waste generated by the alumina industry (red muds) contain large quantities of iron oxide which has a potential market value. However, very little of the iron oxide is being utilized because of the small amounts of titanium it contains. The titanium present in the iron oxide interferes with the steel making process. The economics of removing the titanium from the iron oxide does not appear to be an economically feasible alternative at present market conditions.

The waste sodium chloride generated as a result of potassium chloride production can be utilized as a table salt. However, to be sold as table salt, it would have to be further refined to remove impurities. The costs associated with removing the impurities and transportation to markets result in an alternative which is not currently feasible.

In summary, poor economics and the lack of markets are the main factors that impede waste recovery efforts by the inorganic chemicals industry.

Program Methodology

Extensive use was made of contractor files from past studies on the inorganic chemicals industry. All of the data were reviewed to develop an initial industry characterization and to identify those product and process segments requiring special attention. The in-house files also served to identify specific plants likely to be highly impacted by the projected RCRA regulations.

After this review, contacts were established with over 100 individual corporations and three trade associations to determine process changes which have recently occurred, process information not already on file, and projected compliance cost information for the major waste sources selected.

As these data were received, it became obvious that several waste sources could be deleted from this study. Recent process and waste management practice changes have resulted in significant reductions of several waste streams. For the other waste sources, process and cost information was analyzed to determine amounts of waste generated, their current disposition, and the projected economic impacts. Six industry segments were identified as being highly impacted by the proposed RCRA

regulations. Detailed economic analyses were then performed to determine the total compliance costs (1978 dollars) including initial capital outlays, interest charges, and operating expenses, and the effects of these costs on product prices, production, and employment levels.

The data were analyzed on a plant-by-plant basis, because compliance cost estimates varied considerably from site to site. Factors causing this variation were amounts of stored waste inventories, distance from acceptable disposal sites, and the chemical and physical properties of the wastes. To ensure uniformity of industry cost estimates for compliance with RCRA, the following assumptions were used:

Assumption	Waste Stream Type	
	Hazardous	Non-Hazardous
Landfill site covering	yes	yes
Installation of three monitoring wells	yes	yes
Leachate control	yes	no, except where noted
Monitoring frequency	monthly	quarterly
Monitoring duration	20 years after closure	life of site

The averages of various cost estimates provided by the industry and confirmed by Versar were:

Well installation	\$10,000 each
Landfill construction (including land)	\$20,000/acre
Quarterly monitoring	\$4,000/year
Monthly monitoring	\$10,000/year

Finally, based on the data received from the industry and literature sources, waste recovery and reuse options were identified for several current waste streams. Resource recovery and reuse options for specific waste streams were discussed with the industry to determine limitations on the applicability of such options.

II. INDUSTRY CHARACTERIZATION

This section of the report characterizes the inorganic chemicals industry by SIC code with respect to number of plants, plant capacities, location of plants, products, and general economic status.

Information was obtained from the 1977 Directory of Chemical Producers, Stanford Research Institute¹ and the Census of Manufactures and is summarized in Table 3. This table also provides some information on the overall economic outlook of major product segments. More detailed information on specific chemicals, likely to be significantly impacted by solid waste handling regulations, are given in Section V of this report.

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
<u>2812 Chlor-Alkali</u>				
28121 - Chlorine (and Caustic Soda/Caustic Potash)	68	3-2,000	Gulf Coast (60% capacity) Pacific Northwest (7% capacity) Tennessee Valley (5% capacity) Other locations (28% capacity)	4-6% annual growth forecast
28122 - Soda Ash	6	1,000-2,000	Green River, Wyoming (4 plants - Trona) Scars Lake, California (from brine) Syracuse, New York (Solvay Process)	Mixed: Solvay Process has declined, others are growing
28123 - Other Alkalies	10	Not available for all facilities	Syracuse, New York Green River, Wyoming Phillipsburg, New Jersey Muscle Shoals, Alabama South Plainfield, New Jersey Niagara Falls, New York St. Louis, Missouri Concord, New Hampshire	Stable, little growth expected
<u>2813 Industrial Gases</u>				
28132 - Acetylene	10	10-270	Texas (5 plants) Louisville, Kentucky Geismar, Louisiana Taft, Louisiana Ashtabula, Ohio Penuelas, Puerto Rico	Stable, growth parallels national economy

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
28133 - Carbon Dioxide	108	4-3,700	Gulf Coast (31 plants) Plains and Midwest (31 plants) West (34 plants) Tennessee Valley (4 plants) Other locations (18 plants)	3-5% annual growth forecast
28134 - Other Industrial Gases:				
- Carbon monoxide	19	Not available	Gulf Coast (6 plants) West Virginia (4 plants) Other locations (9 plants)	3-5% annual growth forecast
- Helium	24	Not available	Kansas (6 plants) Texas (5 plants) Eastern U.S. (5 plants) Other locations (7 plants)	3-5% annual growth forecast
- Hydrogen	140	Not available for all facilities	Gulf Coast (36 plants) West and Midwest (34 plants) East (23 plants) Tennessee Valley (10 plants) Other locations (37 plants)	3-5% annual growth forecast
- Nitrous oxide	8	Not available	Gulf Coast (2 plants) California (2 plants) Other locations (4 plants)	3-5% annual growth forecast
- Nitrogen, oxygen and argon	171	10-6,600	Gulf Coast (41 plants) Midwest (35 plants) West (31 plants) Other locations (64 plants)	3-5% annual growth forecast

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
2816 Pigments				
28161 - Titanium Dioxide	10	30-210	<p><u>Chloride:</u></p> <p>Ashtabula, Ohio (2 plants)</p> <p>Antioch, California</p> <p>Edge Moor, Delaware</p> <p>New Johnsonville, Tennessee</p> <p>Hamilton, Mississippi</p> <p><u>Sulfate:</u></p> <p>Savannah, Georgia</p> <p>Gloucester City, New Jersey</p> <p>Baltimore, Maryland</p> <p>Sayreville, New Jersey</p>	Moderate growth
28162 - Other White Pigments				
- Antimony oxide	4	Not available	<p>Baltimore, Maryland</p> <p>Texas City, Texas</p> <p>Gloucester City, New Jersey</p> <p>Cleveland, Ohio</p>	
- Barium sulfate	7	Not available	<p><u>Synthetic:</u></p> <p>Steubenville, Ohio</p> <p>St. Louis, Missouri</p> <p>East St. Louis, Illinois</p> <p>Jamaica, New York</p>	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Barium sulfate (continued)			Natural:	
- Lead sulfate	1	Not available	Steuersville, Ohio	
- Zinc oxide	20	Not available	Cartersville, Georgia	
			St. Louis, Missouri	
			Jersey City, New Jersey	
			East (8 plants)	
			Midwest (9 plants)	
			West (3 plants)	
28163 Colored Pigments:				
- Anhydrous chrome oxide pigment	9	Not available	East (5 plants)	Production stable; 4-6% annual growth rate forecast
			Midwest (3 plants)	
			California (1 plant)	
- Cadmium pigments (orange)	2	Not available	Glens Falls, New York	Production stable; 4-6% annual growth rate forecast
			Newark, New Jersey	
- Cadmium pigments (red)	4	Not available	Glens Falls, New York	Production stable; 4-6% annual growth rate forecast
			Newark, New Jersey	
			Baltimore, Maryland	
			Jamaica, New York	
- Cadmium pigments (yellow)	4	Not available	Glens Falls, New York	Production stable; 4-6% annual growth rate forecast
			Newark, New Jersey	
			Baltimore, Maryland	
			Jamaica, New York	
- Chrome green	2	Not available	Glens Falls, New York	Production stable; 4-6% annual growth rate forecast
			Willow Island, West Virginia	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
Colored pigments (continued)				
- Chrome yellow	9	1-10	East (5 plants) Midwest (4 plants)	Production stable; 4-6% annual growth rate forecast
- Hydrated chromic oxide	4	Not available	Bayonne, New Jersey Garland, Texas Santa Fe Springs, California Union, Illinois	Production stable; 4-6% annual growth rate forecast
- Iron blue	2	Not available	Glens Falls, New York Brooklyn, New York	Production stable; 4-6% annual growth rate forecast
- Iron oxide	24	Not available	<u>Synthetic:</u> East (6 plants) Midwest (3 plants) West (1 plant) <u>Natural:</u> East (9 plants) Midwest (5 plants)	Production stable; 4-6% annual growth rate forecast
- Lead monoxide	15	Not available	East (4 plants) West (6 plants) Midwest (5 plants)	Production stable; 4-6% annual growth rate forecast

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Molybdate - orange	5	Not available	Louisville, Kentucky Beltsville, Maryland Brooklyn, New York Willow Island, West Virginia	Production stable; 4-6% annual growth rate forecast
- Zinc yellow	2	Not available	Beltsville, Maryland Brooklyn, New York	Production stable; 4-6% annual growth rate forecast
28193 - Sulfuric acid	154	5-2,040	Located throughout U.S. (significant concentrations in Florida and Gulf Coast)	4% annual growth rate forecast
28194 - Other Inorganic Acids:				
- Boric acid	3	Not available	Trona, California San Francisco, California Wilmington, California	4-6% annual growth rate forecast
- Chromic acid	5	2-20	Baltimore, Maryland (2 plants) Castle Hayne, North Carolina Kearny, New Jersey Cleveland, Ohio	4-6% annual growth rate forecast
- Chlorosulfuric acid	3	6-30	East Chicago, Indiana Linden, New Jersey Sauget, Illinois	4-6% annual growth rate forecast
- Hydrochloric acid	84	Not available for all facilities	Located throughout U.S.	4-6% annual growth rate forecast
- Hydrocyanic acid	11	1,100-91,000	Texas (6 plants) Louisiana (2 plants) Memphis, Tennessee Glens Falls, New York Lima, Ohio	4-6% annual growth rate forecast

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Hydrofluoric acid	13	5-45	East (4 plants) Midwest and South (8 plants) West (1 plant)	4-6% annual growth rate forecast
- Nitric acid	88	13-550	Located throughout U.S.	4-6% annual growth rate forecast
28195 - Alumina	10	Not available for all facilities	Louisiana (4 plants) Texas (2 plants) Arkansas (2 plants) Mobile, Alabama St. Croix, Virgin Islands	4% annual growth rate forecast
28196 - Aluminum Chemicals				
- Aluminum	6	2-90	Texas (1 plant) New York (3 plants) Elkton, Maryland Phillipsburg, New Jersey	Accelerated growth expected
- Aluminum chloride (hydrous)	8	Not available for all facilities	New Jersey (3 plants) Chicago, Illinois Marcus Hook, Pennsylvania Chattanooga, Tennessee East Chicago, Indiana LaPorte, Texas	Production stable; future growth parallel to national economy
- Aluminum fluoride	5	Not available	Geismar, Louisiana Fort Meade, Florida Point Comfort, Texas Tulsa, Oklahoma Greens Bayou, Texas	Production stable; future growth parallel to national economy

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Aluminum hydroxide	12	Not available	New Jersey (3 plants) Arkansas (2 plants) Texas (2 plants) Mobile, Alabama Lewes, Delaware South San Francisco, California Fairmont, Georgia Glenbrook, Connecticut	Production stable; future growth parallel to national economy
- Aluminum sulfate	77	Not available	Located throughout U.S.	Production stable; future growth parallel to national economy
28197 - Sodium and Potassium Compounds				
- Potassium chlorate	3	Not available	Jersey City, New Jersey Phillipsburg, New Jersey Niagara Falls, New York	Modest growth (<5% annually)
- Potassium chloride	13	60-545	New Mexico (7 plants) Utah (2 plants) South Plainfield, New Jersey Trona, California Solon, Ohio St. Louis, Missouri	Modest growth (<5% annually)
- Potassium iodide	2	Not available	Irvine, California St. Louis, Missouri	Modest growth (<5% annually)

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Potassium nitrate	2	Not available	St. Louis, Missouri Vicksburg, Mississippi	Modest growth (<5% annually)
- Potassium perchlorate	2	Not available	Henderson, Nevada Columbus, Ohio	Modest growth (<5% annually)
- Potassium phosphate	11	Not available for all facilities	New Jersey (3 plants) California (2 plants) Brownfield, Texas Delaware Water Gap, Pennsylvania Fernald, Ohio Carondelet, Missouri Jeffersonville, Indiana Chicago Heights, Illinois	Modest growth (<5% annually)
- Potassium sulfate	7	10-245	Texas (2 plants) New Mexico (2 plants) Johnstown, Colorado Ogden, Utah Trona, California	Modest growth (<5% annually)
- Sodium borohydride	1	Not available	Danvers, Massachusetts	Modest growth (<5% annually)
- Sodium chlorate	12	4-60	Nevada (2 plants) Mississippi (2 plants) Brunswick, Georgia Bellingham, Washington Nacolea, Alabama Riegelwood, North Carolina Niagara Falls, New York Taft, Louisiana Calvert City, Kentucky Portland, Oregon	Healthy growth (>5% annually)

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Sodium fluoride	3	Not available	East St. Louis, Illinois Boyertown, Pennsylvania Joliet, Illinois	Modest growth (<5% annually)
- Sodium hydrosulfide	12	Not available for all facilities	Texas (2 plants) Delaware (2 plants) Arkansas (2 plants) Cartersville, Georgia Linden, New Jersey Natrium, West Virginia Dominguez, California Eighty Four, Pennsylvania Le Moyne, Alabama	Modest growth (<5% annually)
- Sodium hydrosulfite	7	5-15	New Jersey (2 plants) Augusta, Georgia Charleston, Tennessee Bucks, Alabama Leeds, South Carolina Portsmouth, Virginia	Healthy production growth rate (>5 percent)
- Sodium metal	5	20-50	Memphis, Tennessee Niagara Falls, New York Baton Rouge, Louisiana Pasadena, Texas Ashtabula, Ohio	Modest growth (<5% annually)
- Sodium perchlorate	3	Not available	Henderson, Nevada (2 plants) Columbus, Ohio	Modest growth (<5% annually)

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Sodium phosphate	20	<1-190	Pennsylvania (3 plants) New Jersey (3 plants) California (4 plants) Illinois (3 plants) Other locations (7 plants)	Modest growth (<5% annually)
- Sodium silicate	41	Not available for all facilities	Located throughout U.S.	Modest growth (<5% annually)
- Sodium silicofluoride	6	Not available	Florida (2 plants) Illinois (2 plants) Paulsboro, New Jersey Joliet, Illinois	Modest growth (<5% annually)
- Sodium sulfate	29	5-230	Tennessee (3 plants) Pennsylvania (2 plants) Texas (3 plants) Virginia (3 plants) North Carolina (3 plants) California (5 plants) Other locations (10 plants)	Stable
- Sodium sulfide	13	Not available	California (2 plants) Texas (2 plants) Cartersville, Georgia Augusta, Kansas Buffalo, New York Permdale, Washington Joliet, Illinois Paulsboro, New Jersey Natrium, West Virginia Le Moyne, Alabama New Castle, Delaware	Modest growth (<5% annually)

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Sodium sulfite	9	Not available for all facilities	Illinois (2 plants) Pennsylvania (2 plants) Claymont, Delaware St. Louis, Missouri Tuscaloosa, Alabama South Gate, California Longview, Washington	Modest growth (<5% annually)
- Sodium tetraborate (borax)	4	90-640	Trona, California West End, California Death Valley Junction, California Boron, California	Modest growth (<5% annually)
- Sodium thiosulfate	5	<1-30	Chicago, Illinois Claymont, Delaware Baton Rouge, Louisiana Atglen, Pennsylvania South Gate, California	Modest growth (<5% annually)
28199 - Other Inorganic Chemicals:				Overall mixed growth trends
- Barium carbonate	5	Not available for all facilities	Steubenville, Ohio Cartersville, Georgia Modesto, California Coffeyville, Kansas Freeport, Texas	
- Bismuth subcarbonate	5	Not available	New Jersey (2 plants) St. Louis, Missouri Brooklyn, New York Phillipsburg, New Jersey Cincinnati, Ohio	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Bromine	10	2-70	Arkansas (6 plants) Michigan (4 plants)	
- Calcium carbide	5	30-210	Louisville, Kentucky Keokuk, Iowa Pryor, Oklahoma Portland, Oregon Ashtabula, Ohio	
- Calcium carbonate	19	Not available	Missouri (5 plants) Georgia (2 plants) Vermont (2 plants) Alabama (2 plants) Pennsylvania (2 plants) Other locations (6 plants)	
- Calcium chloride	11	Not available for all facilities	Michigan (3 plants) California (2 plants) Washington (2 plants) Syracuse, New York Green S Bayou, Texas St. Louis, Missouri Norco, Louisiana	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Calcium hypochloride	12	Not available for all facilities	Michigan (2 plants) Washington (2 plants) Chicago, Illinois Charlestown, Tennessee Niagara Falls, New York Barberton, Ohio Chester, Pennsylvania Mobile, Alabama Oconto Falls, Wisconsin Winslow, Maine	
- Calcium phosphate (animal feed grade)	6	25-135	Missouri (2 plants) Iowa (2 plants) Weeping Water, Nebraska Plant City, Florida	
- Calcium phosphate (food grade)	3	20-45	Carondelet, Missouri Chicago Heights, Illinois Nashville, Tennessee	
- Activated carbon	8	2-45	Ohio (2 plants) Pennsylvania (2 plants) Romeo, Florida Marshall, Texas Catlettsburg, Kentucky Covington, Virginia	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Sodium chromate	3	Not available	Castle Hayne, North Carolina Baltimore, Maryland Corpus Christi, Texas	
- Sodium dichromate	3	Not available	Baltimore, Maryland Castle Hayne, North Carolina Corpus Christi, Texas	
- Cupric oxide	17	Not available	East (9 plants) Midwest (6 plants) West (2 plants)	
- Copper sulfate	8	Not available	East (2 plants) Midwest (2 plants) West (4 plants)	
- Hydrogen peroxide	7	5-35	Ohio (2 plants) Steubenville, Ohio Memphis, Tennessee South Charleston, West Virginia Norco, Louisiana Vancouver, Washington	
- Iodine	2	Not available	Irvine, California Midland, Michigan	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Ferric chloride	19	Not available for all facilities	Michigan (2 plants) California (4 plants) Texas (2 plants) Illinois (4 plants) New Jersey (2 plants) Indiana (2 plants) St. Louis, Missouri Edge Moor, Delaware Cleveland, Ohio	
- Ferrous sulfate	13	3-90	California (2 plants) Missouri (3 plants) Maryland (2 plants) Illinois (2 plants) Savannah, Georgia Honolulu, Hawaii Sayreville, New Jersey Easton, Pennsylvania	
- Lead nitrate	3	Not available	St. Louis, Missouri Phillipsburg, New Jersey Columbus, Ohio	
- Lithium carbonate	4	Not available	North Carolina (2 plants) Silver Peak, Nevada Trona, California	
- Magnesium sulfate	4	Not available	Midland, Michigan Waynesville, North Carolina Delaware Water Gap, Pennsylvania Berkeley, California	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Manganese sulfate	3	Not available for all facilities	Cedartown, Georgia Galena, Kansas Kingsport, Tennessee	
- Nickel sulfate	11	Not available	California (2 plants) New Jersey (3 plants) Ohio (2 plants) East Chicago, Indiana Texas City, Texas Brooklyn, New York Baltimore, Maryland	
- Phosphorus	9	7-130	Tennessee (3 plants) Florida (3 plants) Idaho (2 plants) Tarpon Springs, Florida	
- Phosphorus oxychloride	6	6-30	West Virginia (2 plants) Charleston, South Carolina Sauget, Illinois Niagara Falls, New York Morrisville, Pennsylvania	
- Phosphorus trichloride	7	9-30	West Virginia (2 plants) Charleston, South Carolina Sauget, Illinois Niagara Falls, New York Cold Creek, Alabama Morrisville, Pennsylvania	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Phosphorus pentasulfide	7	5-30	Tennessee (2 plants) Anniston, Alabama Sauget, Illinois Columbus, Mississippi Niagara Falls, New York Morrisville, Pennsylvania	
- Potassium permanganate	1	Not available	LaSalle, Illinois	
- Silica	24	Not available	East (12 plants) Other locations (12 plants)	
- Silver cyanide	4	Not available	Plainville, Massachusetts Glens Falls, New York Belmont, California St. Louis, Missouri	
- Silver nitrate	4	Not available	Rochester, New York Rockford, Illinois Delaware Water Gap, Pennsylvania Columbus, Ohio	
- Strontium carbonate	2	Not available for all facilities	Cartersville, Georgia Modesto, California	
- Elemental sulfur	161	<1-2,300	Located throughout U.S. (all frash operations in Louisiana and Texas; sulfur from petroleum refining at scattered locations throughout the country)	

TABLE 3. INORGANIC CHEMICALS INDUSTRY CHARACTERIZATION (continued)

SIC/INDUSTRY/PRODUCTS	NUMBER OF PLANTS	PRODUCTION CAPACITY RANGE (THOUSANDS OF METRIC TONS PER YEAR)	PLANT LOCATIONS	ECONOMIC STATUS
- Sulfur dioxide	15	Not available for all facilities	East (6 plants) Midwest (4 plants) West (3 plants) Other locations (2 plants)	
- Tin dioxide	1	Not available	Penn Yan, New York	
- Vanadates	1	Not available	Soda Springs, Idaho	
- Zinc sulfate	21	Not available for all facilities	East (11 plants) Midwest (5 plants) West (3 plants) Honolulu, Hawaii (1 plant)	

III. SELECTION OF MAJOR WASTE SOURCES

The primary objective of this study was to determine the cost of compliance to RCRA, Section 4004, for the inorganic chemicals industry. The logical assumption is that those processes generating the largest volumes of land-destined wastes would be impacted the most.

Table 4, at the end of this chapter, lists the land-destined hazardous and non-hazardous wastes generated by this industry. This table was prepared to aid in the selection of major waste sources. These data were obtained by the following methods:

(1) Production information was obtained from the U.S. Bureau of the Census data,² Minerals Yearbook,³ in-house files on past programs relating to the inorganic chemicals industry and estimates based on producer contacts or contractor knowledge.

(2) The amounts of solid wastes generated for each process per ton of product produced were obtained from previous contractor studies of hazardous solid waste handling practices in the inorganic chemicals industry⁴ and from a recent contractor multi-media assessment of the inorganic chemicals industry.⁵ Where ranges of waste loads are listed, maximum values were usually chosen as the worst case. In cases where process information was unavailable, estimates of waste quantities were made based on raw material purities and process chemistry. It should be noted that, in the manufacture of several chemicals, waste loadings were assumed to exist for all plants, even though only a few producing facilities might have such wastes. Examples of this are heavy metal salts (i.e., nickel sulfate and iron chloride) which can be made from either pure or impure raw materials.

Major waste sources were selected from Table 4 as those processes generating more than 1,000 metric tons of land-destined waste per year. This value was chosen after examination of the data and consultation with the EPA Technical Project Monitors. Based on this rationale, 40 processes were selected as major waste sources. These processes are noted in Table 4.

Additional contacts with industry during this study led to the deletion of ten processes from the major waste source list. The ten processes and the reasons for their deletion are listed below:

(1) Sodium Silicate - Contacts with all producers revealed that about 90 percent of the generated solid wastes are currently recycled to the process. Only about 600 metric tons per year of solid wastes are discarded.

(2) Nickel Sulfate - Of the eight plants producing this chemical, only three use impure materials and generate solid wastes. These three facilities combined generate only 200 metric tons per year of waste.

(3) Iron Blue - Contacts with the industry revealed that there are only two current producers who generate a combined total of only 400 metric tons per year of waste.

(4) Magnesium Carbonate - The process originally evaluated is no longer in use. According to several industry contacts, all current magnesium carbonate production is from soda ash and magnesium chloride. This new process generates no solid waste.

(5) Potassium Nitrate - Industry contacts have revealed that all current production of this chemical is by the Vicksburg process, which generates no solid waste. The old process is no longer used.

(6) Sodium Borohydride - The only U.S. producer of this chemical claimed that hazardous sodium sludge waste is currently reprocessed to recover sodium values. There is no waste requiring disposal.

(7) Ferric Chloride - All U.S. producers revealed that only three facilities have product purification sludge wastes. These three sites generate a combined total of 600 metric tons of waste per year.

(8) Potassium Dichromate - The only U.S. producer claimed that this chemical is produced in batch quantities a few times per year. The amount of solid waste requiring disposal is only about 500 metric tons per year.

(9) Acetylene from Calcium Carbide - At present, only one firm still produces acetylene by this process at two locations. At one, the lime waste is sold to a public utility for use in its wet scrubbers. At the other site, all waste is sold to several local chemical and metallurgical firms for use as a neutralization agent for acidic wastewater. There is, however, a backlog of lime waste at one plant from past years when production rates were higher. This problem is discussed in more detail in the section of this report dealing with calcium carbide wastes.

(10) Sodium Silicofluoride - Except for one plant, the industry combines this process waste with waste from wet process phosphoric acid manufacture. All but one of the production sites are fertilizer plants. Industry suggested that production of this chemical at fertilizer plants be considered as part of that industry. Usually the fertilizer industry does not segregate its waste.

The remaining major waste sources are listed below in the order of decreasing quantities of waste generated:

- | | |
|---|--|
| 1. Potash (potassium chloride and sulfate) from ore | 17. Antimony oxide from ore |
| 2. Alumina | 18. Barium sulfate from ore |
| 3. Phosphorus | 19. Manganese sulfate |
| 4. Natural soda ash | 20. Vanadium pentoxide |
| 5. Hydrated lime | 21. Calcium phosphate (food grade) |
| 6. Hydrofluoric acid | 22. Calcium carbide - open furnace process |
| 7. Borax from ore | 23. Sodium hypophosphite |
| 8. Solvay process soda ash | 24. Barium carbonate |
| 9. Titania - sulfate process | 25. Sodium |
| 10. Sodium chromate and dichromate | 26. Sodium chlorate |
| 11. Iron oxide pigments | 27. Strontium carbonate |
| 12. Lithium carbonate | 28. Chrome yellow |
| 13. Titania - chloride process | 29. Potassium permanganate |
| 14. Aluminum sulfate | |
| 15. Chlor-alkali - diaphragm and mercury cell processes | |
| 16. Zinc oxide from ore | |

These processes and the impact of RCRA Sections 3004 and 4004 on them are discussed in the following sections of this report.

TABLE 4. LAND-DESTINED WASTE CHARACTERIZATION OF THE INORGANIC CHEMICALS INDUSTRY

Industry	Total Land Disposed Waste kg/kg	Total Non-Hazardous Land Disposed Waste kg/kg	Hazardous Waste kg/kg	Total Non-Hazardous Waste Generated kg/year	Total Hazardous Waste Generated kg/year	Information Sources Waste Load
Chlor-Alkali (Diaphragm Cell Process) ϕ	18.1-34	10-33 (15 avg)	0.1-1.0 (0.3 avg)	80,000	19,000	s
(Mercury Cell Process) ϕ	19-71	2-70 (15 avg)	0-50 (30 est avg)	20,000	72,000	s
Sodium/Chlorine (Downs Cell Process) ϕ	4-53	4-40 (30 avg)	13	5,200	1,700	s
Sodium Carbonate (Natural) ϕ	222	222	none	2,000,000	none	s
(Solvay Process) ϕ	185-410	185-410 (260 avg)	none	490,000	none	s
Sodium Bicarbonate	none	none	none	none	none	s
Acetylene ϕ \S	2,850 - carbide process	2,850 - carbide process	none	490,000	none	s
Carbon Dioxide (Permanganate Scrubbing) (Standard Process)	none	none	none	none	none	s
Helium	3-30	3-30 (15 est avg)	none	670	none	s
Carbon Monoxide & Hydrogen	none	none	none	none	none	s
Nitrous Oxide	none	none	none	none	none	s
Titanium (SO ₂ Process) ϕ	2,700 avg	none	2,700 avg	none	1,200,000	s
(Chloride Process) ϕ	130-1,100	none	130-1,100 (300 est avg) (depends on raw material)	none	660,000	s

* Chemical industry only

† At 3 of 4 sulfate process TiO₂ plants, wastes are waterborne, only the other two generate solid wastes via complete wastewater neutralization. ϕ Depending on final form, none or all of this material may also be hazardous but is listed as non-hazardous for computation purposes. \S Selected as major waste sources (information based on previous studies).

* Retracted as a major waste source (based on new information - see text).

** Part of these wastes is sold.

TABLE 4. LAND-DESTINED WASTE CHARACTERIZATION OF THE INORGANIC CHEMICALS INDUSTRY (continued)

Industry	Total Land Disposed Waste kg/kg	Total Non- Hazardous Land Disposed Waste kg/kg	Hazardous Waste kg/kg	Total Non- Hazardous Waste Generated kg/year	Total Hazardous Waste Generated kg/year	Information Sources Waste Load
Lead Sulfate (Wet Process)	none	none	none	none	none	"
(Dry Process)	none	none	none	none	none	"
Zinc Oxide (Thermal Oxidation Process)¶§	450-830	450-830 (700 avg)	none	100,000	none	"
Antimony Oxide¶	2,400	2,400	43	52,000	500	Producer contact
Chrome Yellow¶	69	none	69	none	2,200	"
Molybdate Orange	60	none	60	none	860	"
Zinc Yellow	92	none	92	none	480	"
Anhydrous Chrome Oxide	22	none	22	none	150 est	"
Chrome Green	5	none	5	none	100 est	"
Borax (From Ore)¶	800	800 (but contains traces of natural AsS ₂)	none	560,000	none	"
Sodium Fluoride (From Hydrogen Fluoride) (From Caustic Soda and Sodium Silicofluoride)	none	none	none	none	none	"
Sodium Hydrosulfide	130	none	130	none	650	"
Sodium Hydrosulfite	0.5-14	0.5-14 (10 avg)	none	200	none	"
(Zinc Process)	none	none	none	none	none	"
Sodium Hydrosulfite	none	none	none	none	none	"
Sodium Silicofluoride ¶§	30-61	none	30-61	none	2,600	"
Sodium Silicofluoride (From Impure H ₃ PO ₄)¶§	30-61	none	30-61	none	2,600	"
Sodium Borohydride¶§	100	none	100 (ocean dumped)	none	2,600 (est.)	"

TABLE 4. LAND-DESTINED WASTE CHARACTERIZATION OF THE INORGANIC CHEMICALS INDUSTRY (continued)

Industry	Total Land Disposed Waste kg/kg	Total Non- hazardous Land Disposed Waste kg/kg	Hazardous Waste kg/kg	Total Non- hazardous Waste Generated kg/year	Total hazardous Waste Generated kg/year	Information Sources Waste Load
Sodium Sulfite	1	1	none	150	none	*
Sodium Silicate ^φ §	6	6	none	5,000	none	*
Sodium Chlorate ^φ	43	43	none	8,600	none	*
Potassium Chlorate	none	none	none	none	none	*
Sodium Perchlorate	31	25	6	600	140	*
Potassium Perchlorate	none	none	none	none	none	*
Potassium Nitrate	580	580	none	12,000 (may be sold)	none	*
(From Sodium Nitrate) ^φ §						
Activated Carbon	none	none	none	none	none	*
Barium Carbonate ^φ	100-200	100-200 (150 avg)	none	7,800	none	*
Beryllium Oxide	2.5	2.5	none	50 (est)	none	*
Boron Trichloride	none	none	none	none	none	§
Open Furnace Calcium Carbide ^φ	223-320	223-320 (300 avg)	none	13,000	none	*
Calcium Carbonate	none	none	none	none	none	*
(From Calcium Chloride)						
Hydrated Chromic Oxide	70	none	70	none	440	*
Iron Blue ^φ §	750	none	750	none	2,800	*
Barium Sulfate ^φ	380	380	none	38,000 est	none	*
Cadmium Pigments	11-21	none	11-21	none	150	§
Lead Monoxide	none	none	none	none	none	§
Iron Oxide Pigments	5-10	5-10	none	700	none	§
(Dry Process)						
(Wet Process) ^φ	2,305-2,310	2,305-2,310	none	230,000	none	§
Mercuric Sulfide	2	none	2 (possibly recycled)	none	3 est	Producer contact
Ultramarine Blue	none	none	none	none	none	*
Hydrochloric Acid	none	none	none	none	none	*
(Salt - H ₂ SO ₄ Process)						

TABLE 4. LAND-DESTINED WASTE CHARACTERIZATION OF THE INORGANIC CHEMICALS INDUSTRY (continued)

Industry	Total Land Disposed Waste kg/kg	Total Non-Land Disposed Waste kg/kg	Hazardous Waste kg/kg	Total Non-Hazardous Waste Generated kg/year	Total Hazardous Waste Generated kg/year	Information Sources Waste Load
Boric Acid	0.05	none	0.05	none	6	"
Hydrogen Cyanide (Andrusson Process)	none	none	none	none	none	"
Hydrofluoric Acid ^φ	3,700	none	3,700	none	960,000	"
Chlorosulfonic Acid	none	none	none	none	none	"
Alumina	1,100	1,100	none	7,600,000	none	"
(From Bauxite) ^φ	1	1	none	44	none	"
Aluminum Chloride	180	none	180 (wastes emerge mixed)	none	22,000	"
Aluminum Fluoride ^φ						"
Aluminum Sulfate ^φ	105 (dry basis)	105	none	140,000	none	"
Potassium Sulfate ^φ	2,400-2,500	2,400-2,500	none	1,500,000	none	"
Potassium Iodide	15	15	none	14	none	"
Potassium Chloride						"
(From Sylvite Ore) ^φ	4,000-6,700	4,000-6,700 (5,000 avg)	none	14,000,000	none	"
Mercury Metal	none	none	none	none	none	"
Mercury Oxide	6-12	none	6-12 (recovered)	none	2	"
Mercury Chloride	none	none	none (recycled)	none	none	"
Nickel Sulfate ^φ	0-240	none	0-240 (200 avg - largely recovered)	none	4,900	"
Nickel Hydroxide	none	none	none	none	none	"
Phosphorus ^φ	9,700-10,000	300	9,400-9,900	148,000**	4,560,000	"
Phosphorus Pentoxide	0.4	0.4	none	40 est	none	"
Phosphorus Trichloride	0.1	none	0.1	none	8	"
Phosphorus Oxichloride	none	none	none	none	none	"
Phosphorus Pentasulfide	3	1	2	60	120	"
Potassium Permanganate ^φ	140	140	none	1,500	none	"

TABLE 4. LAND-DESTINED WASTE CHARACTERIZATION OF THE INORGANIC CHEMICALS INDUSTRY (continued)

Industry	Total Land Disposed Waste kg/kg	Total Non-Land Disposed Waste kg/kg	Hazardous Waste kg/kg	Total Non-Hazardous Waste Generated kkg/year	Total Hazardous Waste Generated kkg/year	Information Sources
Selenium	none	none	none	none	none	In-house Files
Tellurium	none	none	none	none	none	In-house Files
Silver Nitrate	20	20 (residue after waste treatment)	none	60	none	"
Strontium Carbonate ^φ	100-200	100-200 (150 avg)	none	4,000	none	"
Sulfur Dioxide	none	none	none	none	none	"
Sulfur Chloride	none	none	none	none	none	"
Sulfur Oxichloride	1	1	none	10	none	"
Thallium Compounds	20	20	none	none	0.2	"
Tin Dioxide	none	none	none	none	none	"
Zinc Sulfate	1-31	1-31 (25 avg)	none	620	none	"
Vanadium Pentoxide ^φ	14,000-28,000	14,000-28,000	none	29,000	none	Contractor Estimate
Molybdates	50-100	50-100	none	100	none	Contractor Estimate
Sodium Thiocyanate	none	none	none	none	none	"
Ammonium Chloride	none	none	none	none	none	"
Ammonium Hydroxide	none	none	none	none	none	"
(From Slaked Lime)	none	none	none	none	none	"
Calcium Oxide	none	none	none	none	none	"
Calcium Hydroxide ^φ	60	60	none	1,300,000 (partly recycled)	none	"
Calcium Chloride	none	none	none	none	none	"
Calcium Phosphate (Animal Feed Grade) ^φ	55	39	16	24,000	9,800	"
(Food Grade)	none	none	none	none	none	"
Cadmium Sulfide	none	none	none	none	none	"
Sodium Dichromate and Chromate ^φ	800-3,500	none	800-3,500 (2,000 est avg)	none	290,000	"

TABLE 4. LAND-DESTINED WASTE CHARACTERIZATION OF THE INORGANIC CHEMICALS INDUSTRY (continued)

Industry	Total Land Disposed Waste kg/kg	Total Non-hazardous Land Disposed Waste kg/kg	hazardous Waste kg/kg	Total Non-hazardous Waste Generated kkg/year	Total Hazardous Waste Generated kkg/year	Information Sources Waste Load
Potassium Dichromate [†]	400	none	400	none	8,000	"
Fluorine	none	none	none	none	none	"
(Fused Salt Electrolysis)	none	none	none	none	none	"
Hydrogen Peroxide	0.2	none	0.2	none	2	"
(Riedl-Pfleiderer)	none	none	none	none	none	"
(Electrolytic Process)	18	18	none	9,600	none	"
Ferric Chloride	none	none	none	none	none	"
(Solution Grade) [†]	none	none	none	none	none	"
Ferrous Sulfate	none	none	none	none	none	"
(From Titania/Sulfate)	none	none	none	none	none	"
Lead Silicate	none	none	none	none	none	"
Lead Nitrate	none	none	none	none	none	"
Lithium Carbonate and Other	11,000	11,000	none	210,000 est	none	"
Lithium Salts [†]	1,200	20	none	24,000 est	none	"
Magnesium Carbonate [†]	none	none	none	none	none	"
Magnesium Oxide	none	none	none	none	none	"
Magnesium Chloride	200-1,700	200-1,700 (1,000 est avg)	none	35,000	none	"
Manganese Sulfate [†]	none	none	none	none	none	"
Manganese Dioxide	none	none	none	none	none	Contractor Estimate
Magnesium Sulfate	none	none	none	none	none	"
Sulfuryl Chloride	1	1	none	10	none	"
Thionyl Chloride	none	none	none	none	none	"
Bromine and Iodine	none	none	none	none	none	"
Arsenic Oxide	none	none	none	none	none	"
Sodium Cyanide	none	none	none	none	none	"
Sodium Bromide	none	none	none	none	none	"

TABLE 4. LAND-DESTINED WASTE CHARACTERIZATION OF THE INORGANIC CHEMICALS INDUSTRY (continued)

Industry	Total Land Disposed Waste kg/kg	Total Non- Hazardous Land Disposed Waste kg/kg	Hazardous Waste kg/kg	Total Non- Hazardous Waste Generated kg/year	Total Hazardous Waste Generated kg/year	Information Sources Waste Load
Sodium Bisulfite	0.75	0.75	none	130	none	"
Oxygen, Nitrogen and rare gases	none	none	none	none	none	"
Sulfuric Acid	none	none	none	none	none	"
Nitric Acid	none	none	none	none	none	"
Potassium Metal	none (solid)	none	none	none	none	"
Chromic Acid	none	none	none	none	none	"
Sodium Thiosulfate	none	none	none	none	none	"
Sodium Phosphates	none	none	none	none	none	"
Stannous Chloride	none	none	none	none	none	"
Sodium Hypophosphite ϕ	2,500-3,000	2,500-3,000	none	9,000	none	"

IV. ANALYSIS OF MAJOR WASTE SOURCES

This section examines the major waste sources selected in Section III. This examination includes a description of the process and a description and quantification of the wastes generated both on an aggregate basis and by locality. The sources are discussed in the order of decreasing waste generation rates.

Potash

The potash industry involves the production of two chemicals - potassium chloride (KCl) and potassium sulfate (K_2SO_4). They are combined because both chemicals are produced at most potash facilities.

Potassium chloride is produced by two methods: (1) recovery from brines and (2) from mined sylvite ore. The first process generates no solid wastes because the spent brines are returned to their source. This process is used at two sites, one in California and the other in Utah. The second process, which is used at seven New Mexico facilities and one plant in Utah is shown in Figure 2. Sylvite ore is crushed, ground and separated from waste clay slimes and salt. These wastes exit the process as a waterborne stream and are sent to evaporation ponds. The upgraded ore is subjected to a flotation operation, where the KCl is separated from any residual salt. The KCl is recovered from the flotation step, dewatered, and dried. The brine and salt tailings wastes are sent to evaporation ponds on-site.

The wastes from this process are as follows:

- (1) Clay and slimes - about 75 kg/kg of product.
- (2) Waste salt - 3,900 - 6,600 kg/kg of product.

Potassium sulfate is also produced by more than one method. Some material is recovered from natural brines at two sites. No solid waste is generated by this process. Some is produced as a co-product of beet sugar production. Again, no solid waste is generated. Some is produced from KCl by the Hargreaves process at two sites with no solid waste generated.

At one plant, potassium sulfate is produced from langbeinite ore as shown in Figure 3. After crushing, drying and removing sodium chloride, the ore is reacted in solution with KCl to produce K_2SO_4 . The product is separated

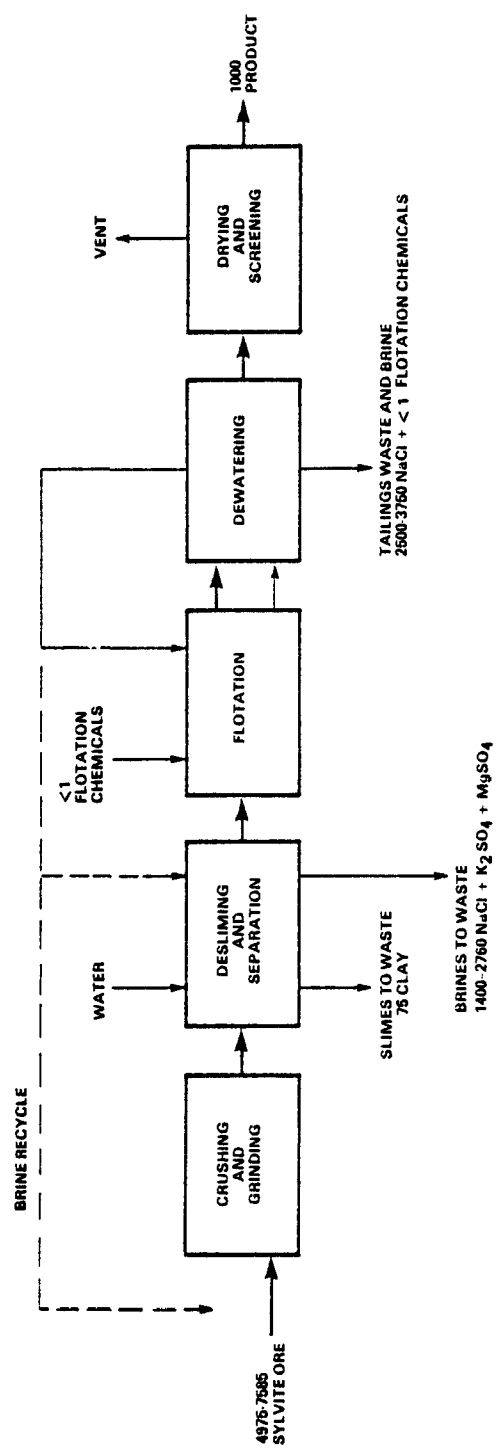


FIGURE 2. POTASSIUM CHLORIDE MANUFACTURE FROM SYLVITE ORE

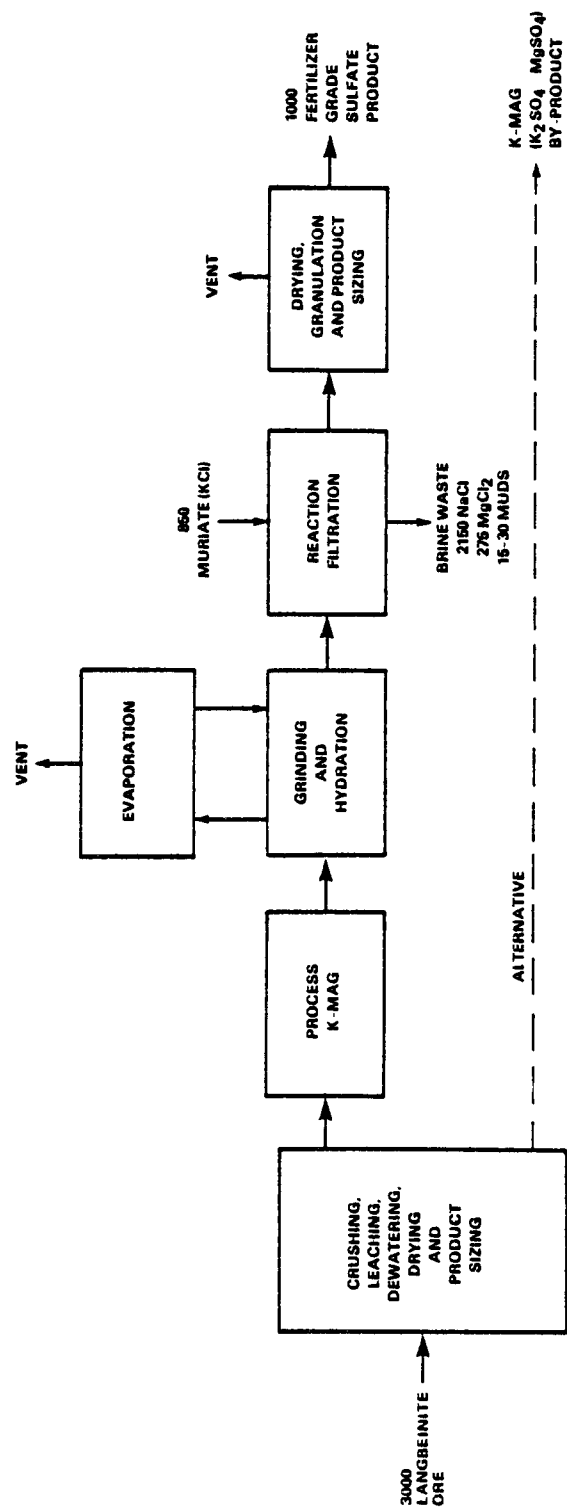


FIGURE 3. POTASSIUM SULFATE MANUFACTURE

by filtration and is dried, sized, and shipped. The waste solutions, containing sodium and magnesium sulfates are discarded in an on-site evaporation pond. The wastes from this process amount to about 2.4 kkg of salt and mud per kkg of product.

The distribution of KCl production wastes is given below:

State	Number of Plants	Capacity (kkg/yr)	Estimated Amount of Solid Waste Generated (kkg/yr)
New Mexico	7	2,315,000	11,575,000
Utah	1	136,000	680,000
Rounded Totals	8	2,500,000	12,000,000

All land destined wastes from K_2SO_4 production are in New Mexico. The generation rate of these wastes averages 600,000 metric tons per year. These wastes are disposed of in the same evaporation ponds used for the potassium chloride production wastes.

Alumina

Alumina is produced from bauxite ore by the Bayer Process as shown in Figure 4. Bauxite ore is ground, mixed with aqueous caustic soda, and the mixture is heated under pressure to dissolve the alumina content of the ore. The heated solution is then cooled, thickened and filtered to remove insoluble material (red mud). After this, the solution of sodium aluminate is further cooled and seeded to precipitate hydrated alumina. This material is recovered by filtration and calcined to alumina. The caustic soda solution separated by filtration is reconcentrated and recycled to the initial digestion step.

Wastes from the process are waterborne and consist mostly of red mud, unrecovered alumina, limestone, other insolubles, and small amounts of caustic soda.

Settling of these wastes in large lagoons generates large quantities of waste muds. The approximate compositions of red muds obtained from three different types of bauxite are listed below:

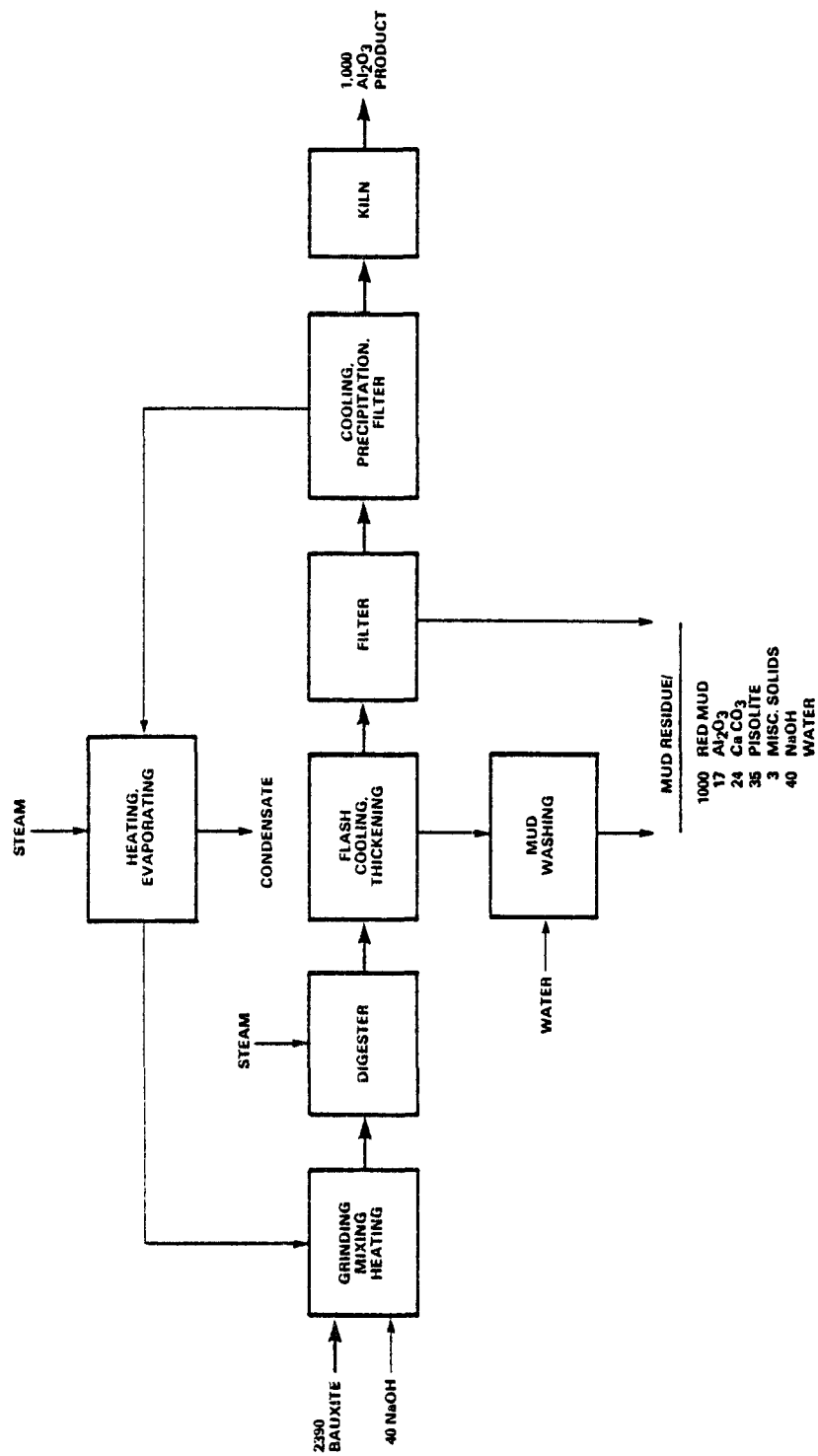


FIGURE 4. ALUMINA MANUFACTURE FROM BAUXITE

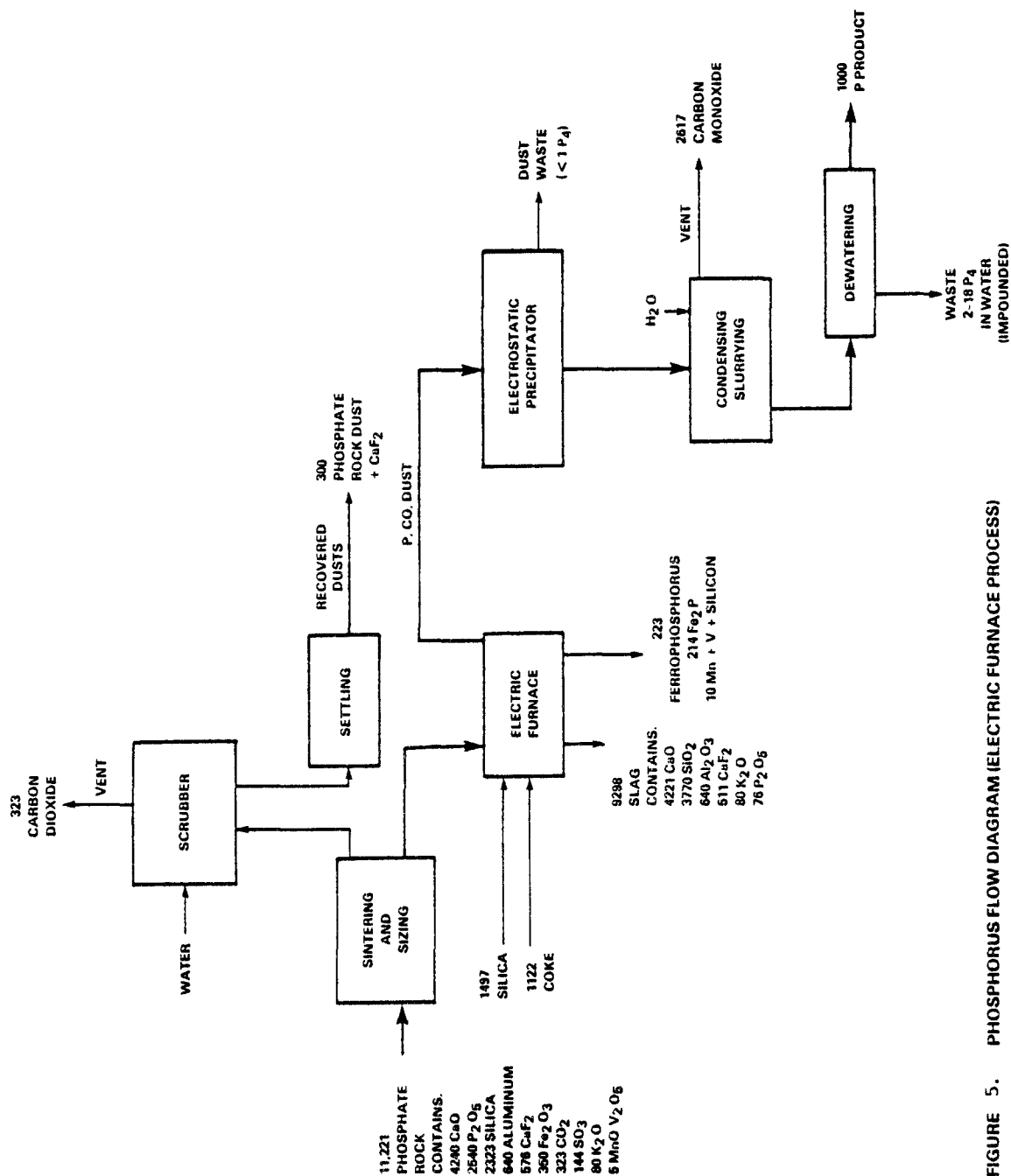


FIGURE 5. PHOSPHORUS FLOW DIAGRAM (ELECTRIC FURNACE PROCESS)

Component	Weight Percent of Component in Red Mud		
	Surinam Bauxite	Arkansas Bauxite	Jamaica Bauxite
Fe ₂ O ₃	30-40	55-60	50-54
Al ₂ O ₃	16-20	12-15	11-13
SiO ₂	11-14	4-5	2.5-6
TiO ₂	10-11	4-5	trace
CaO	5-6	5-10	6.5-8.5
Na ₂ O	6-8	2	1.5-5.0
Loss on Ignition	10.7-11.4	5-10	10-13

The major constituents of red muds from the three most commonly used ores are iron oxides, alumina, silica and titania. Also these muds contain from 1.5 to 8 percent alkaline sodium salts and minor amounts of gallium, nickel, chromium and other trace impurities in the raw ores used.

These wastes dry very slowly and require large amounts of land for their disposal and dewatering.

The distribution of these wastes, on a state-by-state basis, is given below:

State	Alumina Production Capacity (kkg/yr)	Estimated Amount of Solid Waste Generated (kkg/yr)	Number of Plants
Alabama	934,000	1,010,000	1
Arkansas	1,060,000	1,145,000	2
Louisiana	2,230,000	2,410,000	4
Texas	2,490,000	2,690,000	2
Virgin Islands	330,000	360,000	1
Rounded Totals	7,000,000	7,600,000	10

Phosphorus

Elemental phosphorus (P₄) is produced by a thermal process shown in Figure 5. Phosphate rock ore is dried, calcined, blended with coke and silica, and fed to an electric furnace. The three raw materials react to form phosphorus vapors, slag, and ferro phosphorus. The carbon monoxide and phosphorus vapors are passed through electrostatic precipitators to remove furnace dusts

and are condensed in a stream of water. The water-phosphorus mixture is settled to recover the phosphorus. The carbon monoxide is flared prior to release to the atmosphere.

There are several wastes from this process. These are:

(1) Particulate emissions from the initial ore drying and calcination steps. These amount to about 300 kg/kg of product and are removed from vent gases by either dry collection methods or wet scrubbing. Where dry collection is practiced, the particulates are recycled. They are stored at the bottom of settling lagoons where wet scrubbing is employed.

(2) Slag and ferro phosphorus from the furnace. These are removed from the furnace, quenched, and crushed. The ferro-phosphorus is normally sold as a co-product and the slag, amounting to about 9,300 kg per kkg of product, is sometimes sold as a crushed stone substitute when markets are available. If markets are not available, the material is land stored. The slag contains calcium oxide, silica, alumina, phosphate, a small amount of calcium fluoride and traces of heavy metals present in the raw ore, including uranium. This waste has been listed as hazardous by the EPA.

(3) Phossy dusts from the electrostatic precipitators. This is dust that has been in contact with elemental phosphorus. It is periodically recovered and added to phossy water wastes or oxidized to phosphate or retorted to recover elemental phosphorus. Dust waste loads average 1 kg per kkg of phosphorus product. They are considered hazardous because of the toxicity of elemental phosphorus and the high reactivity of phosphorus with oxygen.

(4) Phossy Water. Water used to condense the phosphorus, after recovery and separation of the P_4 product, still contains from 2 to 18 kg per kkg of P_4 product of elemental phosphorus. This water is usually impounded in lined lagoons and reused for the same purpose. It is totally isolated from other plant wastewater streams and never intentionally discharged. With time, elemental phosphorus accumulates in these ponds. This situation is handled by the industry either by the use of flocculants in the process to recover a maximum amount of product and minimize the P_4 con-

tent of the phosphy water, or by use of sodium hypochlorite and lime addition to the ponds to oxidize the phosphorus. This treatment is usually followed by periodically retorting the settled solids in the phosphy water lagoons to recover phosphorus. The first technique is used in at least three plants and at least two plants are using the second technique. Residual solids from the retorting operations are then reused in the process in place of phosphate ore.

The distribution of non-hazardous and hazardous waste generation is:

State	Number of Plants	Production Capacity (kkg/yr)	Estimated Amount of Non-Hazardous Waste Generated* (kkg/yr)	Estimated Amount of Hazardous Waste Generated† (including slag) (kkg/yr)
Florida	3	44,000	13,400	409,480
Idaho	2	210,000	63,000	1,955,300
Montana	1	36,000	11,600	334,390
Tennessee	3	200,000	60,000	1,862,200
Rounded Totals	9	490,000	148,000	4,561,000

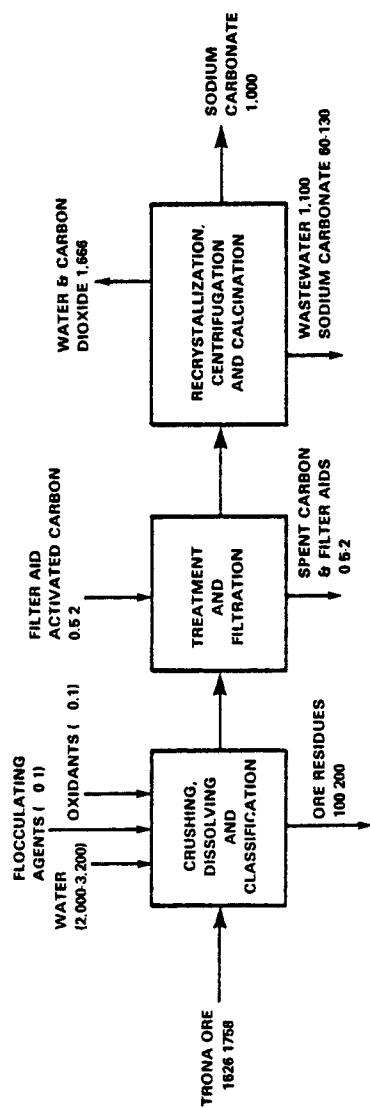
* For the purposes of this study, the fluoride containing calcination dusts were considered non-hazardous.

† All wastes containing elemental phosphorus were considered as hazardous.

Natural Soda Ash

Natural soda ash is produced by two processes, both of which generate about the same waste loads. In the sesquicarbonate process, mineral trona ore is crushed and then dissolved in hot water. The resulting solution is clarified, treated with activated carbon to remove traces of organic materials and then filtered. The clean filtrate is evaporated to recover solid sodium sesquicarbonate which is calcined to soda ash.

In the monohydrate process, mineral trona ore is crushed, calcined, and dissolved in water. The resulting solution is clarified, filtered, and evaporated stepwise to recover a solid material which is then calcined to recover a soda ash product. Process diagrams for these two operations are given in Figure 6. Process wastes, aside from the carbon dioxide liberated to the atmosphere, consist of ore residues, spent carbon, filter aids, and unrecovered soda ash. The amounts of these materials appear in the mass-



MONOHYDRATE PROCESS

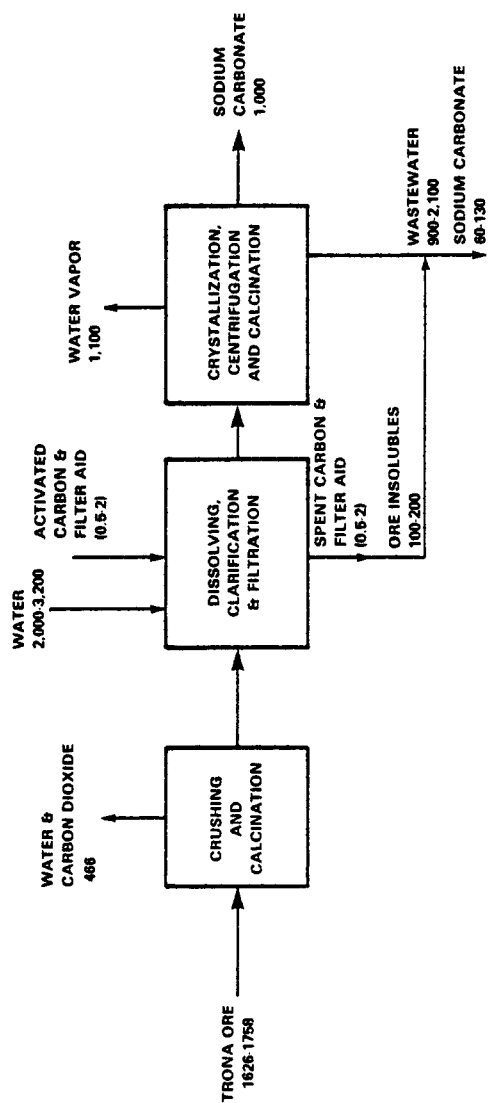


FIGURE 6. SODIUM CARBONATE FROM TRONA ORE
SESQUI-CARBONATE PROCESS

balanced flow diagrams on Figure 6. All solid and waterborne wastes are fed to evaporation ponds. The total production by these processes occurs in Sweetwater County, Wyoming, at four plant sites. The total estimated amount of solid wastes generated per year is 1,200,000 metric tons, based on U.S. Census 1976 production figures for natural soda ash.²

Hydrated Lime

Lime is produced by the calcination of limestone as shown in Figure 7. The limestone is ground, mixed, weighed, and fed to kilns where it is heated. Carbon dioxide gas is liberated during the decomposition. The only process emissions other than carbon dioxide are airborne emissions of lime and limestone particulates. These are removed from process vent gases by either dry collection or wet scrubbing methods. The amount of these particulates is estimated at 90 kg per kkg of product.

The 20,000,000 metric tons of lime produced in the United States in 1977 were generated at 180* facilities located throughout the country. Neither plant capacities nor complete lists of producers of all types of lime are available. Many lime plants are captive to chemical, cement and other industries and are not listed in producer directories. Therefore, a detailed distribution by state of these wastes is not possible. However, an estimated 1.9 million metric tons of lime wastes are generated nationwide.

Hydrofluoric Acid

The process for the production of hydrofluoric acid is shown in Figure 8. After calcium fluoride (fluorspar ore) is dried, it is reacted with dry sulfuric acid to yield hydrogen fluoride (HF) and calcium sulfate. The hydrogen fluoride gas is then cooled and condensed. The crude HF is purified by distillation and is stripped of residual sulfuric acid. The calcium sulfate is sluiced to settling ponds for treatment and eventual disposal.

There are several waste streams from this process:

* Total number of plants estimated by the National Lime Association.

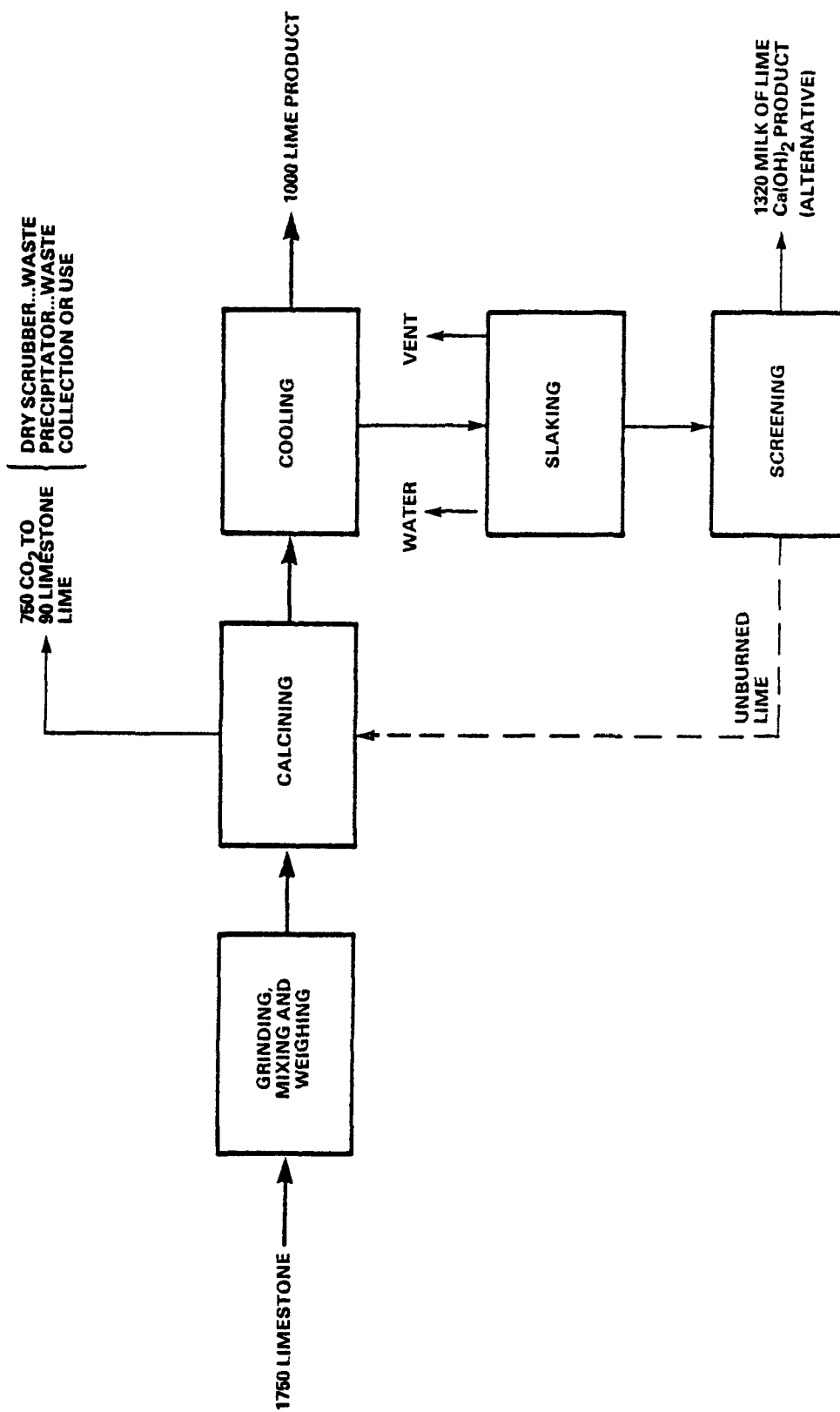


FIGURE 7. CALCIUM OXIDE (LIME) MANUFACTURE

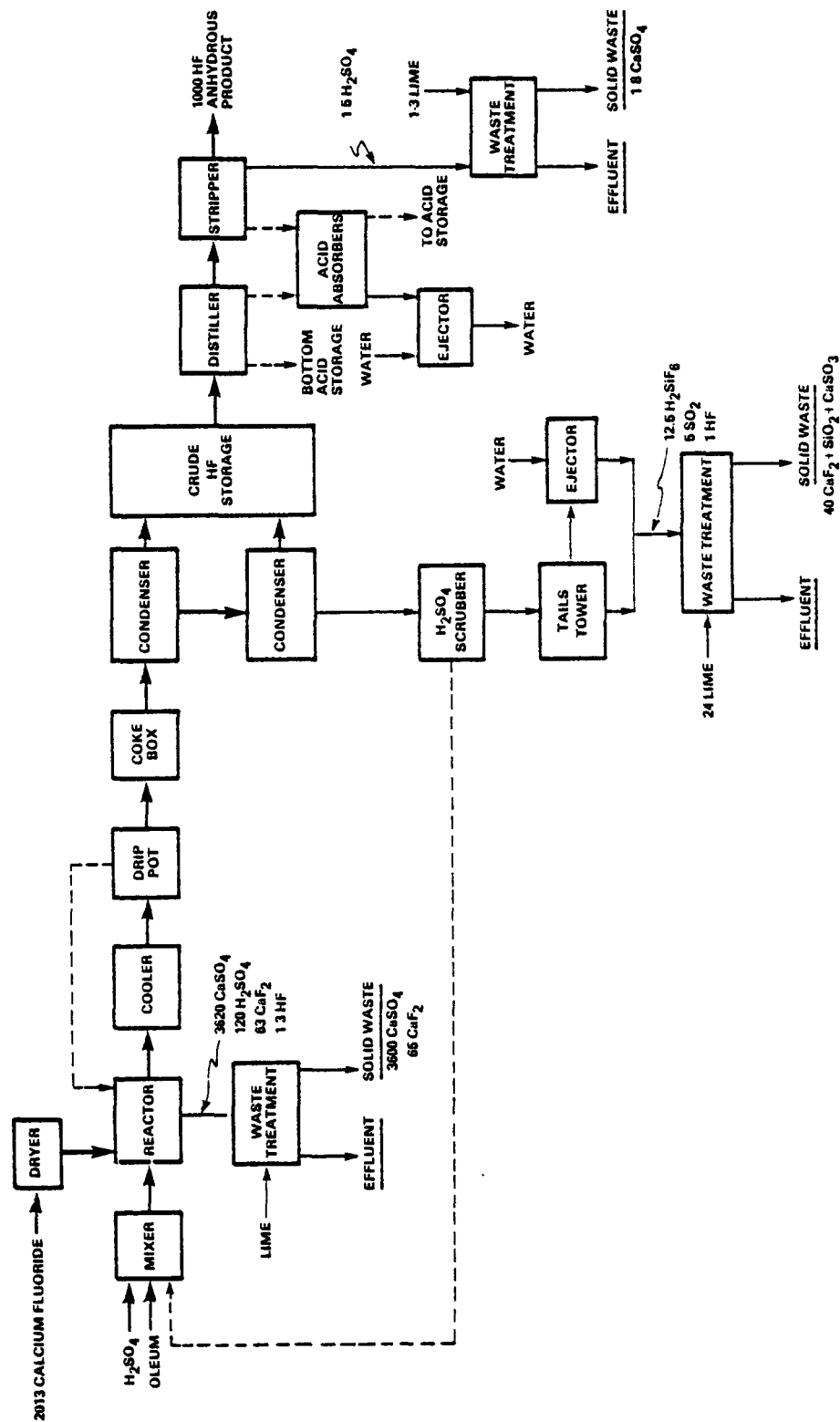


FIGURE 8 . HYDROFLUORIC ACID MANUFACTURE

(1) Calcium sulfate sludge - about 3,600 kg are generated per kkg of product. About 120 kg of unreacted sulfuric acid per kkg and 60 kg of unreacted ore per kkg are also present in the sludge which is sent to treatment ponds where lime is added to neutralize residual acid. The solids are periodically removed from the settling ponds and landfilled.

(2) Tail gases from the initial purification and condensation of crude hydrogen fluoride contain about 12.5 kg per kkg of product of hydrofluosilicic acid (H_2SiF_6) along with lesser amounts of SO_2 and unrecovered HF. These gaseous wastes are passed through a recirculating sulfuric acid scrubber to recover residual acid. The recovered acid is recycled and added to fresh acid at the start of the process.

(3) Scrubber water - After sulfuric acid treatment, the tail gases are wet scrubbed with water which creates a waterborne waste stream. After neutralization with lime, this waste stream generates about 40 kg per kkg of product of waste solids consisting of calcium fluoride, silica and calcium sulfate for landfilling.

(4) Product purification waste - Between 1 and 5 kg of unconverted sulfur acid per kkg of product is removed from the HF and is neutralized with lime which produces more calcium sulfate to be landfilled.

The distribution of all waste generated is given below:

State	Total Capacity (kkg/yr)	Estimated amount of Waste Generated at 100% Capacity (kkg/yr)	Number of Plants
California	10,900	40,000	1
Delaware	22,500	82,800	1
Kentucky	22,500	82,800	1
Louisiana	104,700	385,300	3
New Jersey	10,000	36,800	1
Ohio	16,400	60,300	1
Pennsylvania	4,400	16,200	1
Texas	157,000	577,800	3
West Virginia	13,500	49,700	1
Rounded Totals	350,000	1,300,000	13

Borax from Ore

Borax is produced by two methods in the United States: (1) by extraction from Searles Lake brines and (2) by extraction from ore.

The first of these methods generates no solid waste. In the second process, as shown in Figure 9, ore is crushed and dissolved in water. The ore insolubles are separated by filtration and the solution is evaporated to recover the product, sodium tetraborate pentahydrate. The only process waste from these operations is about 800 kg per kkg of product of ore residues. At the only site using this process, the waste is stored in lined ponds. This waste is considered to be potentially hazardous because it contains a small amount of natural arsenic sulfide "realgar" (AsS_2) that was present in the ore before mining. The amount of arsenic present in the residues is about 0.08 percent.

All this waste is generated in California. The generation rate of ore residue waste is estimated at 510,000 metric tons per year.

Solvay Process Soda Ash

Soda ash is produced by two methods - from salt and limestone by the Solvay Process and by refining of natural trona ores. In the Solvay Process, sodium chloride brine is purified to remove calcium and magnesium salts as calcium carbonate and magnesium hydroxide. The purified brine is reacted with ammonia and carbon dioxide which is produced on-site by limestone calcination. Sodium bicarbonate precipitates from the brine and is recovered and calcined to produce soda ash. The spent brine is then reacted with the lime generated from the limestone calcination to recover ammonia values. The ammonia is recycled and the waste brine, now containing mostly calcium chloride, is discharged as a waterborne waste. A mass-balanced process diagram appears as Figure 10.

The wastes from these operations are generally combined before treatment, which consists of suspended solids settling and neutralization of wastewater. The average compositions of the effluent and solid wastes from these operations are listed below⁵:

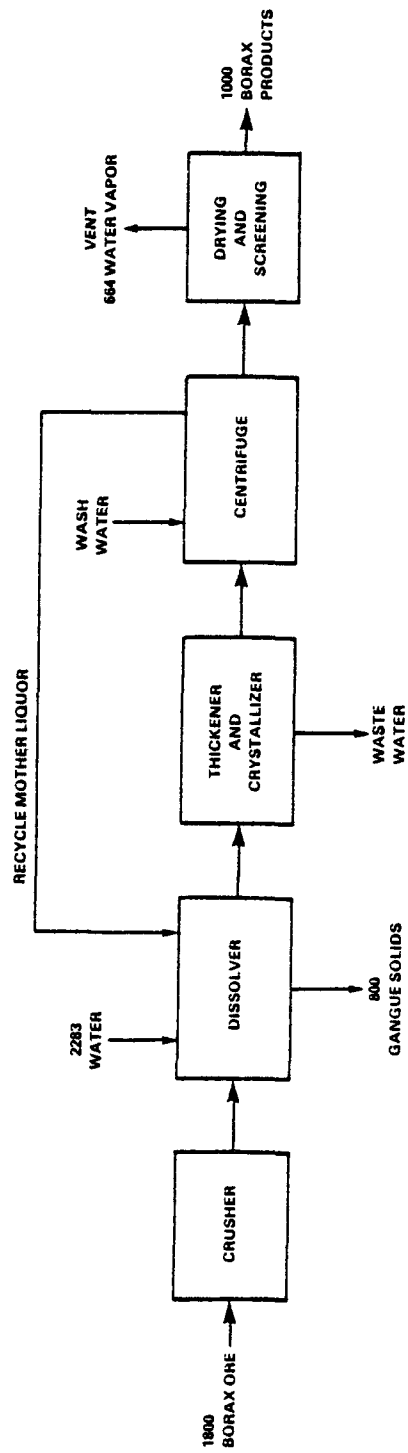


FIGURE 9. BORAX MANUFACTURE FROM ORE

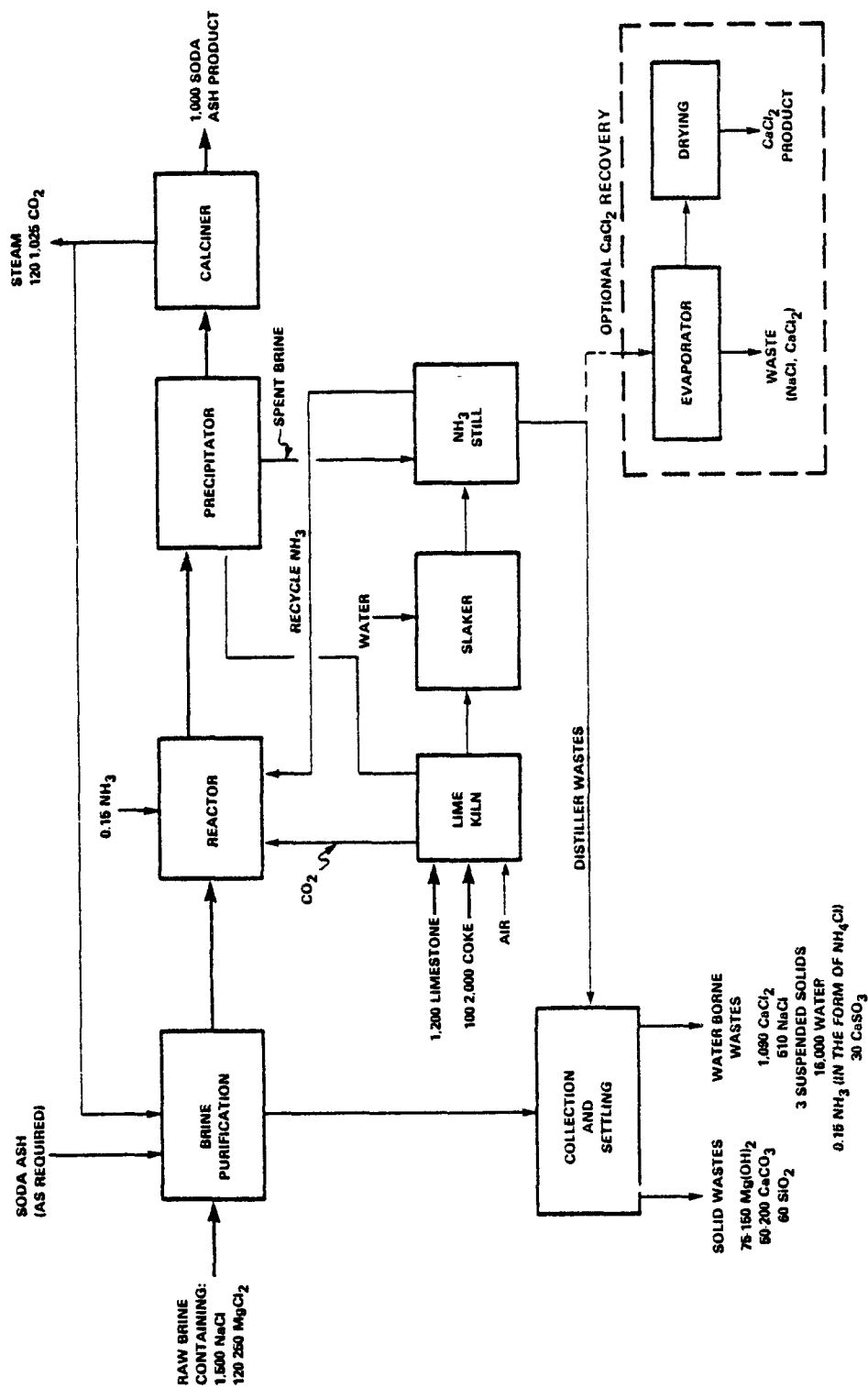


FIGURE 10. SODIUM CARBONATE MANUFACTURE BY THE SOLVAY PROCESS

Amount Discharged (kg/kkg
of soda ash produced)

Waterborne

Calcium chloride	1,100
Sodium chloride	510
Suspended solids	3
Calcium sulfite	30
Ammonia (as NH_4Cl)	0.15

Amount Discharged (kg/kkg
of soda ash produced)

Solid Wastes

Magnesium hydroxide	75-150
Calcium carbonate	50-200
Silica (from impure limestone)	60

Generally, the solid wastes are allowed to remain in settling lagoons. As the lagoons are filled, new ones are dug and the old sites are drained and restored. There are no hazardous constituents in these solid wastes. The amounts of these wastes are expected to decrease in the future. The number of Solvay plants since 1969 have decreased from 7 to 1. Effective January 1, 1979, the only Solvay plant still operating was in Syracuse, New York. This plant generates about 260,000 metric tons per year of land-destined wastes.

Titania - Sulfate Process

Titanium dioxide is produced by two methods - the sulfate and chloride processes. In the sulfate process, as shown in Figure 11, ilmenite ore, scrap iron, and sulfuric acid are mixed and reacted to yield ferrous sulfate and titanyl sulfate. After reaction, the resulting liquor is filtered to remove undigested ore residues and cooled to crystallized ferrous sulfate. This material is recovered by centrifugation and is either sold or disposed of as a waste.

The purified titanyl sulfate solution is hydrolyzed to titania and recovered by filtration. The spent liquor from the filtration step is discarded as a waterborne waste. The recovered titania is repulped, washed, recovered again by filtration, calcined and then wet or dry treated and ground to produce a finished product.

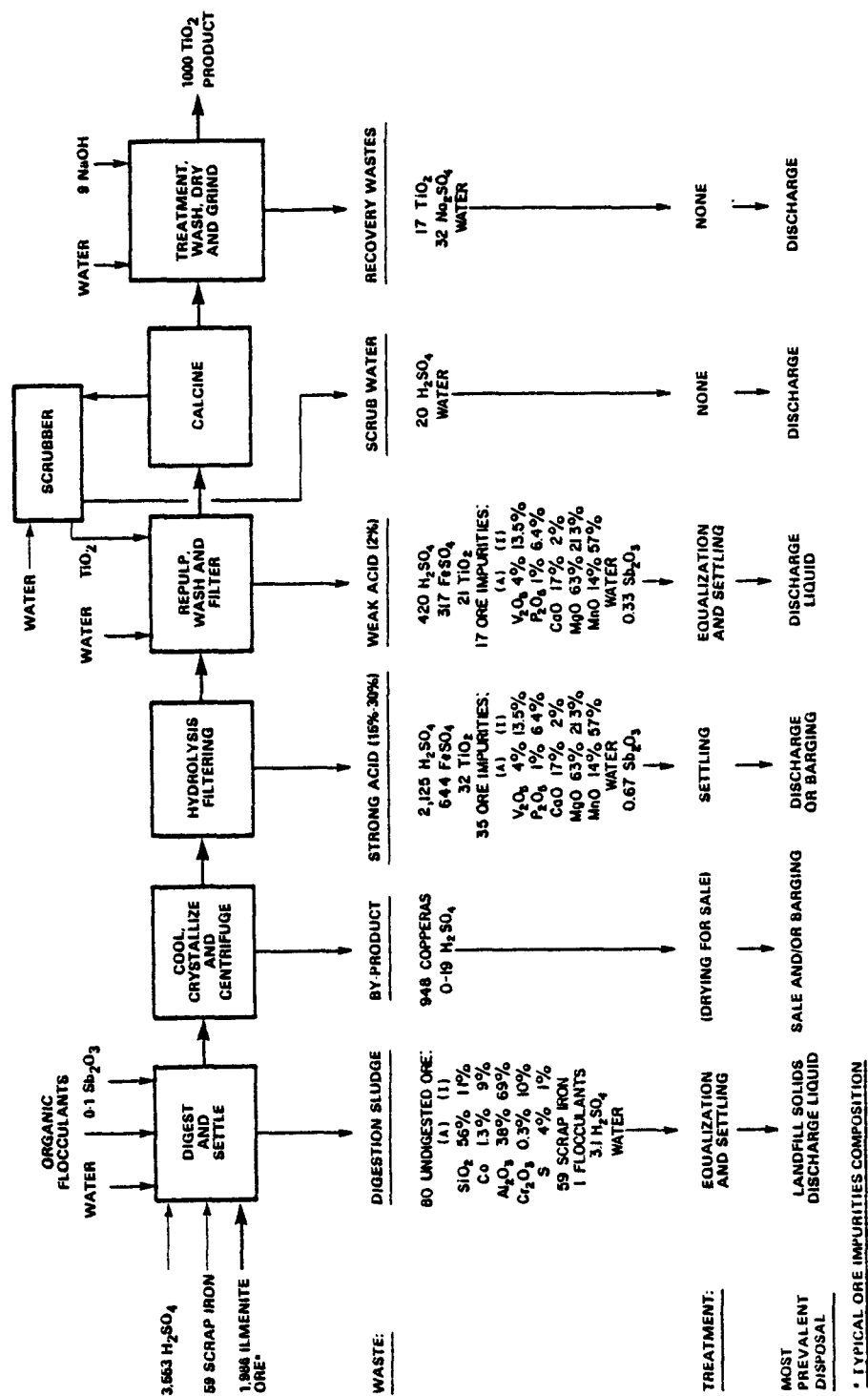


FIGURE 11. TITANIUM DIOXIDE MANUFACTURE BY THE SULFATE PROCESS

The mass-balanced process flow diagram shows the major wastes generated by the sulfate process as follows:

(1) Undigested ore residues. The composition of these residues varies slightly with the ilmenite ore used. A typical composition is listed on the process flow diagram. The residues usually contain silica, alumina, unreacted scrap iron, and minor amounts of cobalt, chromium, and other heavy metal oxides and silicates. These wastes are normally landfilled.

(2) Ferrous sulfate. This material is either sold, if markets are available, or is discharged or ocean dumped at 3 of 4 operating plants. Only one plant currently produces complete neutralization of all wastes to gypsum and metal oxides/hydroxides.

(3) Strong acid wastes from the titanyl sulfate hydrolysis and crude titania recovery steps. At two plants, these wastes are discharged to the environment. At another site, partial neutralization is currently used and at a fourth site, complete neutralization is practiced. These wastes consist of 15-30 percent sulfuric acid solutions containing dissolved ferrous sulfate and the sulfates of magnesium, manganese, vanadium and other heavy metals. Minor amounts of dissolved phosphates from the ores may also be present.

(4) Weak acid waste. This originates from washing the recovered titania and consists of about two percent sulfuric acid solution containing small amounts of the same heavy metal sulfates present in the strong acid waste. This waste stream is usually neutralized prior to discharge and the sludges generated are landfilled.

(5) Other wastewater. Additional process wastes include scrubber water from product calcining and wash water from finishing operations. These contain small amounts of sodium sulfate, sulfuric acid and unrecovered titania. These waterborne wastes are usually neutralized and settled prior to discharge.

Disposal methods for the wastes produced by this process are undergoing rapid changes because of the phasing out of ocean disposal and enforcement of water pollution regulations. At present, one plant is fully neutralizing its wastes and another is using partial neutralization. However, contacts with the industry have revealed that within 5 years all plants will be using full neutralization. A distribution of wastes generated on a state-by-state basis is given below. Also listed are the estimated amounts of ferrous

sulfate currently sold. Assuming full neutralization by the industry, over 1.2 million tons of solid waste will be generated by this process per year.

State	Waste Generated and Unsold (kkg/yr)	Amount currently sold (as FeSO_4)*	Number of Plants
Georgia	290,000	25,000	1
Maryland	295,000	0	1
New Jersey	629,000	100,000	2
Totals	1,214,000	125,000	4

* Based on plant capacities for FeSO_4 production.¹

Sodium Chromate and Dichromate

This product is produced at three plants using the process shown in Figure 12. Chromite ore is dried, ground, mixed with limestone and soda ash, and placed in a kiln. The reacted solid mixture is then leached with hot water and the resulting solution is filtered to remove insoluble ore residues. The filtrate is acidified with sulfuric acid and refiltered to remove any calcium sulfate that may have precipitated. Soda ash is added and the solution is filtered again to recover a sodium sulfate co-product. The filtrate is reacidified, evaporated, and centrifuged to recover sodium dichromate crystals which are dried and packaged.

The wastes from this process are ore residues and insoluble calcium salts. They are removed from the process and slurried to wastewater treatment ponds. After treatment to reduce hexavalent chromium to trivalent chromium, the solids are landfilled. These wastes contain ore residuals (iron, aluminum and calcium salts, and small amounts of chromium).

The distribution of waste generation for this process is:

State	Estimated Dichromate Production Capacity (kkg/yr)	Estimated Amount of Solid Waste Generated (kkg/yr)
Maryland	70,000	56,700
North Carolina	70,000	56,700
Texas	30,000	24,300
Rounded Totals	170,000	140,000

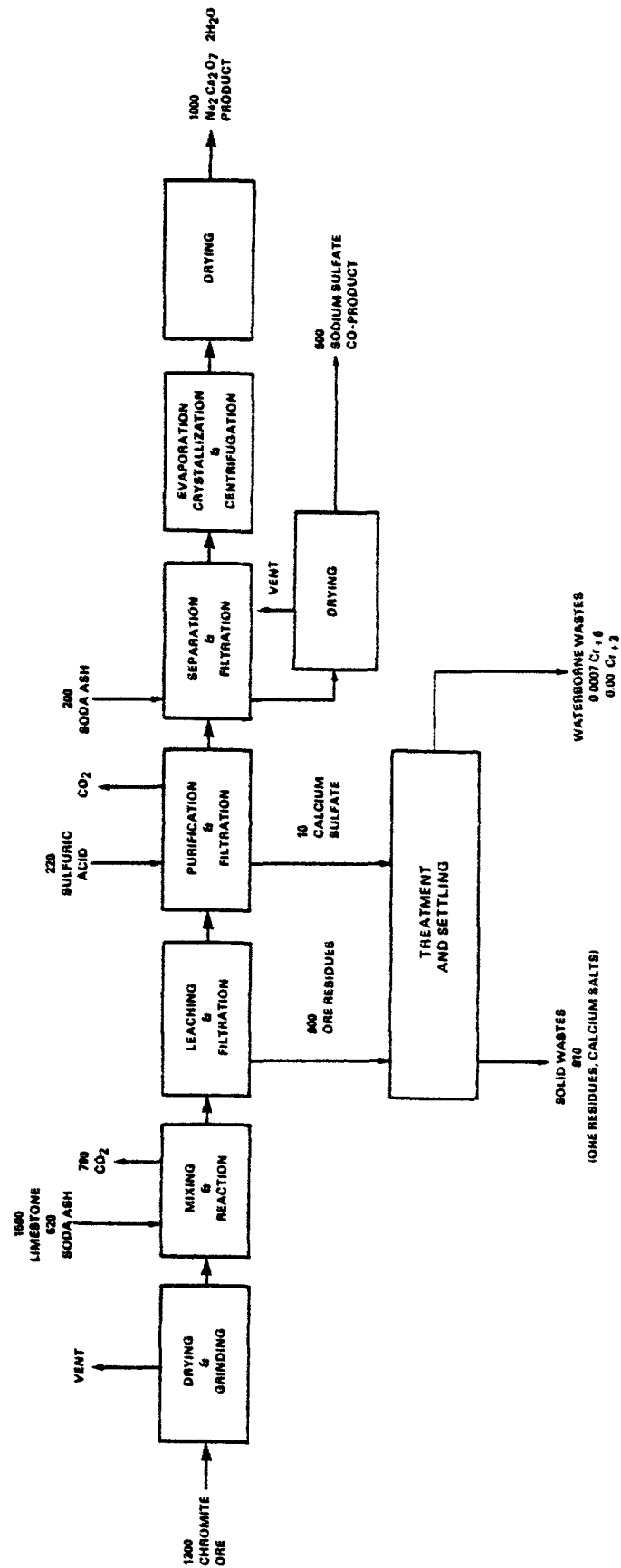


FIGURE 12 . SODIUM DICHROMATE MANUFACTURE

Iron Oxide Pigments

Pigment grade iron oxides are produced by two processes, both of which are generally employed at the same production sites (see Figure 13). In the dry process, ferrous sulfate is decomposed and oxidized by heating in air to yield ferric oxide, sulfur dioxide and sulfur trioxide. The gases are either reacted with caustic soda creating a waterborne waste or, at a few sites, are converted to sulfuric acid.

In the wet process, sulfuric acid is reacted with pickle liquor or upgraded iron ore. After reaction, the residues are separated by filtration and the resulting ferrous sulfate solution is neutralized with caustic soda to yield a hydrated ferrous oxide. This material is oxidized to ferric oxide, recovered by filtration, dried, and calcined to the final product.

Wastes from the two processes are as follows:

Dry Process--

(1) Sulfur dioxide and sulfur trioxide. About 1,000 kg per kkg of product are generated from ferrous sulfate calcination. The gases are either converted to sulfuric acid on-site or wet scrubbed with a caustic solution.

(2) Scrubbing creates a waterborne waste containing about 1,800 kg of sodium sulfate per kkg of product. Small amounts (5-10 kg per kkg of product) of iron oxides are separated from this wastewater stream by settling prior to discharge and landfilled.

Wet Process--

(1) Ore or pickle liquor residues of about 250 kg per kkg of product are generated. These are washed and landfilled.

(2) Wastewater containing about 2,400 kg per kkg of product of sodium sulfate and about 5-10 kg per kkg of product of unrecovered iron oxides is settled prior to discharge and the solids are landfilled along with the ore residues.

At present, there are eleven facilities producing iron oxide pigments in the United States. These are listed as follows:

<u>Plant Location</u>	<u>Comments</u>
Eastern Pennsylvania	At this plant waste SO_2 from dry process is converted to H_2SO_4
East St. Louis, Illinois	} SO_2 generated is converted to H_2SO_4
Emeryville, California	
Wyandotte, Michigan	
Trenton, New Jersey	
Monmouth Junction, New Jersey	
St. Louis, Missouri	
Huntington, West Virginia	
Newark, New Jersey	
Pulaski, Virginia	
Valparaiso, Indiana	

Plant capacity information has not been published and this information is regarded as confidential by the industry. Based on the waste load information provided by several plants and the total annual production of 77,000 metric tons,³ we estimate the amount of land-destined waste from this industry to be about 15,000 kkg per year.

Lithium Carbonate

This chemical is produced from two types of raw materials: (1) natural brines and (2) spodumene ore.⁴ Brine extraction operations, conducted in Nevada and California, return depleted brine to their sources and generate little or no solid waste. The spodumene ore process, however, generates large amounts of waste solids as shown in Figure 14. Spodumene ore is milled and then roasted with sulfuric acid to convert many of the materials present to their corresponding sulfates. The reacted ore is leached with water, and the leachate is filtered to remove ore residues. The solution is then reacted with calcium carbonate and filtered again to remove waste gypsum. After this, the filtrate is reacidified, refiltered with carbon and partially evaporated. The concentrated solution is reneutralized with soda ash and further evaporated to form lithium carbonate crystals which are recovered by filtration, dried, and packaged. The spent solution is then evaporated to dryness to recover a sodium sulfate co-product.

Wastes from this process include the following:

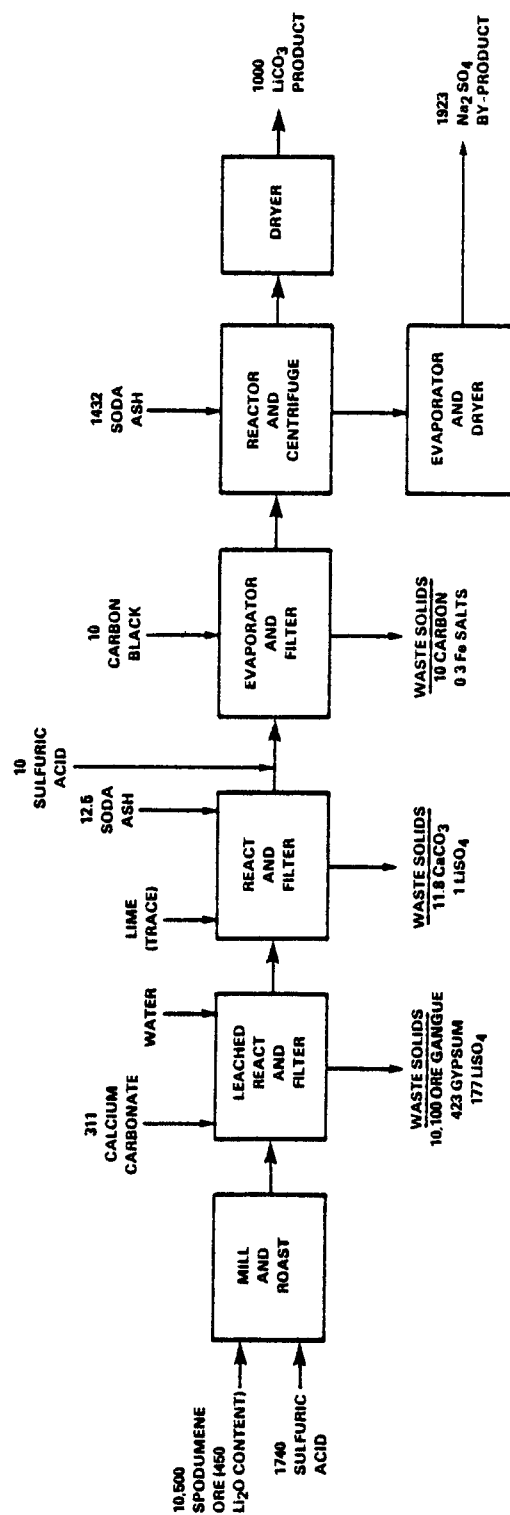


FIGURE 14. LITHIUM CARBONATE MANUFACTURE

(1) Waste ore residues. About 10 kkg of these are produced per metric ton of product. These consist of mostly alumina, silica, and other acid insoluble materials.

(2) Waste gypsum and calcium carbonate from various process neutralization steps. These amount to about 440 kg per kkg of product.

(3) Waste carbon from solution filtration, about 10 kg per kkg of product.

(4) Waterborne wastes containing about 180 kg per kkg of product of lithium sulfate and small amounts of sodium sulfate.

All the above exit the process in wastewater streams. The first three are usually settled from the wastewater prior to discharge.

Lithium carbonate produced from spodumene ore is manufactured by two facilities in North Carolina. Total production is estimated at about 25,000 metric tons per year and the rate of solid waste generation is estimated at 260,000 metric tons per year.

Titania - Chloride Process

Titanium dioxide (TiO_2) is also produced by the chloride process which is shown in Figure 15. Coke, chlorine and either rutile or ilmenite ore are reacted to yield titanium tetrachloride (TiCl_4) and a variety of other metal chlorides. This mixture of chlorides is separated by fractional distillation and condensation. The waste from these purification operations consists of small amounts of unreacted ore and coke and variable amounts of iron and other metal oxides and chlorides, depending on the ore quality used. When high grade ore (rutile) is used, these waterborne wastes are usually neutralized prior to discharge and the sludges are landfilled. When low grade ore (ilmenite) is used, the waterborne purification wastes currently are either disposed of by deep well injection or ocean dumping.

After purification, the TiCl_4 intermediate is reacted with oxygen to generate TiO_2 . The chlorine produced by this operation is recycled to the chlorination step in the process. The TiO_2 is washed, treated, milled, and packaged.

• PARENTHEetical VALUES

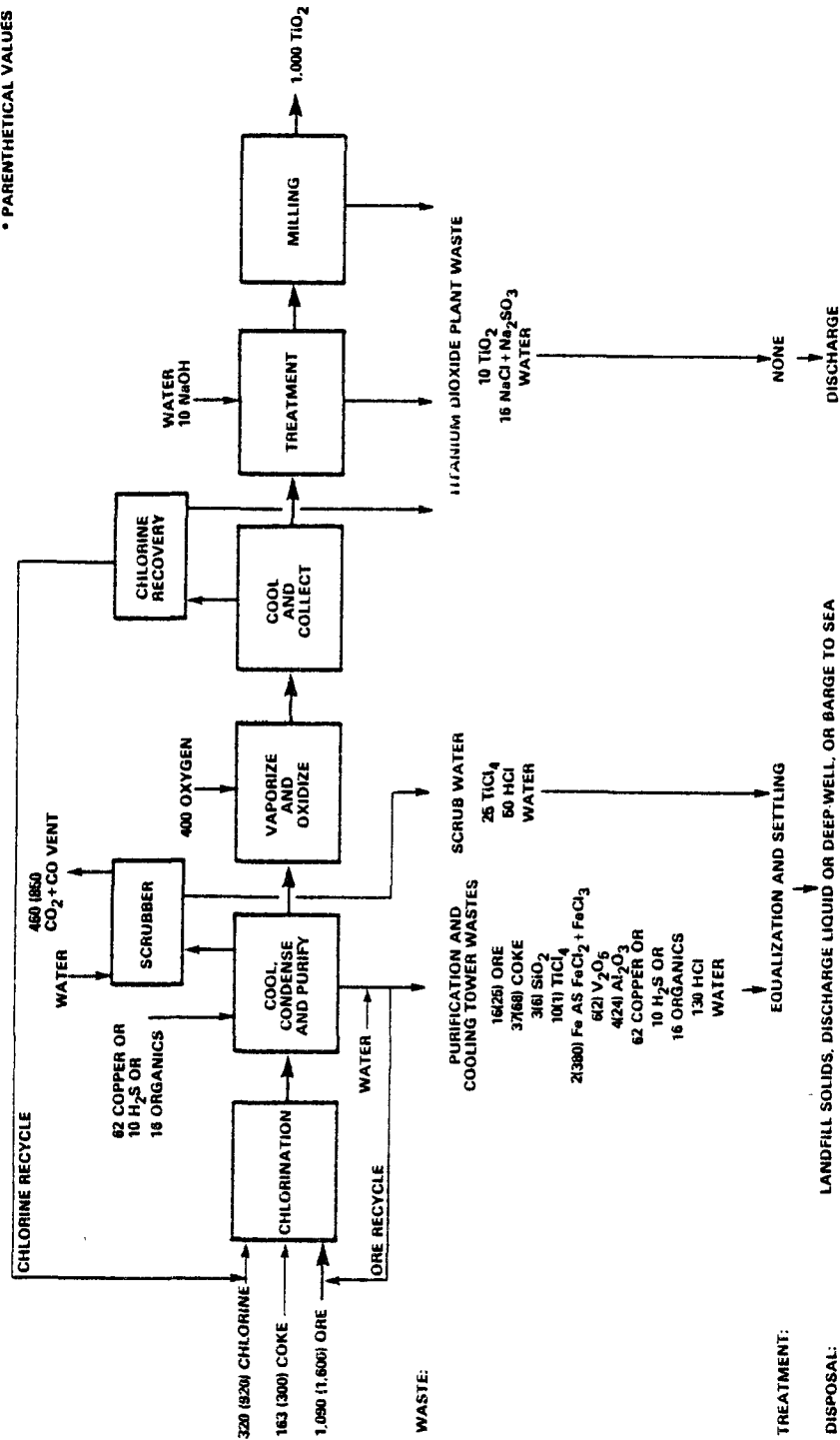


FIGURE 15. TITANIUM DIOXIDE MANUFACTURE BY THE CHLORIDE PROCESS USING 95% ORE OR 65% ORE*

Wastes from the process consist of the following:

(1) Purification wastes from the TiCl_4 intermediate purification. These wastes initially leave the process in waterborne form. Neutralization of these waterborne wastes generates sludge which is landfilled. The amounts are shown in Figure 15.

(2) Vent gases from the TiCl_4 purification. These consist of CO and CO_2 and are vented after being wet scrubbed to remove traces of free chlorine.

(3) Scrubber water normally contains small amounts of TiCl_4 and hydrogen chloride as shown in Figure 15.

(4) Other waterborne wastes - small amounts from the TiO_2 finishing operation. They contain unrecovered TiO_2 and small amounts of dissolved salt and sodium sulfite. These wastes are settled and the solids are landfilled.

Some changes in waste loads are expected where low grade ore is used. One facility, currently using ocean disposal, is converting to partial sale of a recovered 30 percent ferric chloride solution and neutralization and landfilling of the remaining wastes. The other plant using low grade ore disposes of all wastes by deep well injection.

The estimated amounts of land-destined wastes projected from this process on a state-by-state basis are shown below. Apparently, about 800,000 metric tons of waste per year are expected if full neutralization is adopted by all facilities.

State	Ore Used	Total Amount of Wastes Generated (kkg/yr)*	Number of Plants
California	Rutile	1,500	1
Delaware	Ilmenite	337,000†	1
Georgia	Rutile	2,000	1
Maryland	Rutile	1,800	1
Mississippi	Rutile	2,500	1
Ohio	Rutile	9,700	2
Tennessee	Ilmenite	461,000	1
Totals		811,500	8

* Based on plant capacity data.¹

† Of this quantity, as much as 150,000 tons per year may be sold as FeCl_3 .

Aluminum Sulfate

Aluminum sulfate (alum) is produced from sulfuric acid and bauxite by the process shown in Figure 16. Bauxite ore, sulfuric acid and water are mixed and reacted in a digestion tank. The resulting solution is settled and filtered to remove insoluble materials. The solution is either marketed as such or evaporated to yield a solid product.

The waste from the process consists of ore insolubles which are sluiced from the reaction tank. Settling of this waste generates 105 kg per kkg of product of muds requiring land disposal. The primary constituents of the muds are alumina, titania, silica, and iron oxide.

A state-by-state distribution of the amounts of wastes generated from this process could not be developed. There are insufficient published data on alum plant capacities. The number of alum plants by state, according to the 1976 Census Bureau report² is as follows:

<u>State</u>	<u>Number of Plants</u>	<u>State</u>	<u>Number of Plants</u>
Alabama	4	Minnesota	2
Arkansas	1	Mississippi	2
California	6	New Jersey	3
Colorado	1	North Carolina	1
Delaware	1	Ohio	4
Florida	2	Oregon	1
Georgia	5	Pennsylvania	2
Illinois	2	South Carolina	1
Louisiana	8	Tennessee	4
Maine	1	Texas	1
Maryland	1	Virginia	3
Massachusetts	1	Washington	4
Michigan	4	Wisconsin	<u>2</u>
		Total	67 plants

Based on a total production of 1.12 million metric tons in 1976, the estimated amount of solid waste generated by this process per year is 120,000 metric tons.

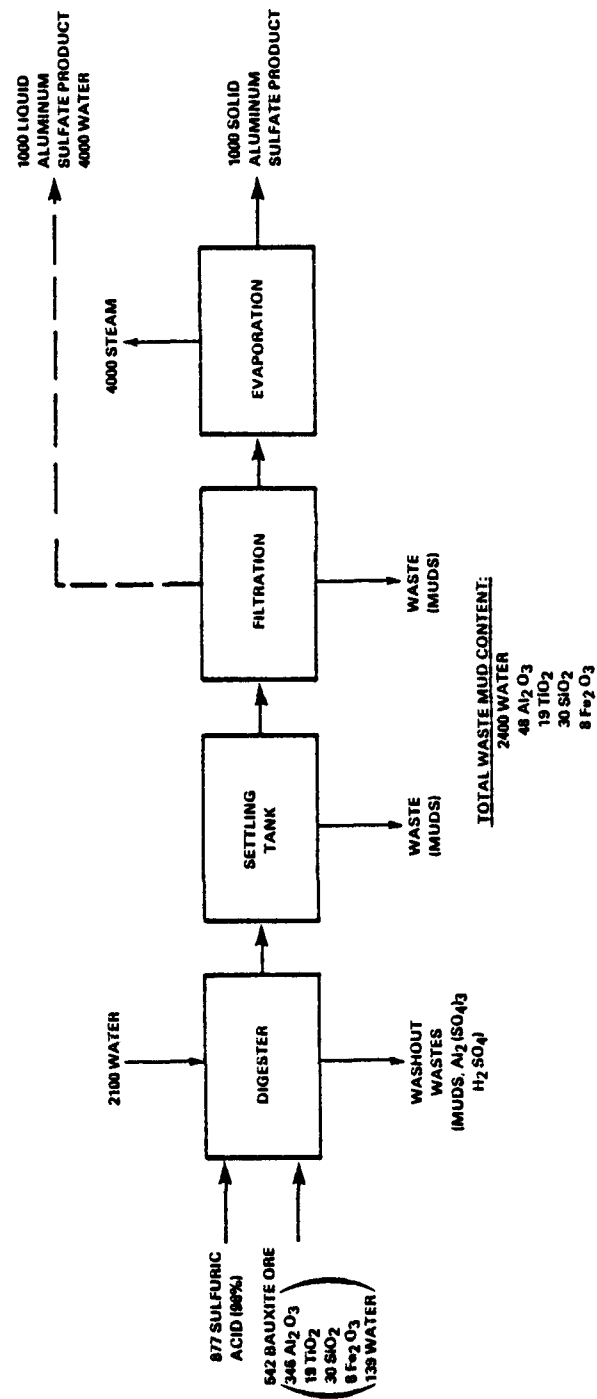


FIGURE 16. ALUMINUM SULFATE MANUFACTURE

Chlor-Alkali - Diaphragm Cell Process

Chlorine and sodium hydroxide are produced by two electrolytic processes: the diaphragm cell and the mercury cell. In the diaphragm cell shown in Figure 17, saturated sodium chloride brine, containing minor amounts of dissolved magnesium and calcium salts, is treated with sodium hydroxide and/or soda ash to remove these impurities by precipitating calcium carbonate and magnesium hydroxide. When the sulfate content of the brine exceeds 600 ppm, barium chloride is also added to remove sulfate as barium sulfate. This sulfate removal process is usually required only for brine obtained from the Texas-Louisiana coastal salt dome. On the other hand, removal of calcium and magnesium ions is universally required.

The brine muds resulting from this chemical treatment average about 15 kg per kkg of chlorine produced and are disposed of either on site in settling lagoons or off site in landfills.

The purified brine is first acidified with hydrochloric acid and then pumped to the electrolytic cells where the anode and cathode are separated by asbestos diaphragms. Chlorine is liberated at the anode and hydrogen gas and sodium hydroxide (caustic soda) are formed at the cathode. The hydrogen is usually compressed, cooled, dried and either used on the plant site or sold. The chlorine is cooled, dried with 98 percent sulfuric acid and then purified to remove traces of chlorinated organics and nitrogen trichloride (formed from traces of ammonium salts in the brine). After purification, the chlorine is compressed and sold.

The caustic soda exits the electrolytic cells with unconverted brine. This material is evaporated to 50 percent caustic soda to precipitate unconverted sodium chloride, which is either recovered and reused or discarded as a waterborne waste. Most caustic soda is sold as a 50 percent solution; however, solutions can be further evaporated to produce a solid sodium hydroxide co-product.

The diaphragm cell is also used to produce potassium hydroxide (caustic potash). In such cases, potassium chloride is used as a feed material instead of sodium chloride. However, the process and wastes are very similar.

Figure 17 shows the diaphragm cell process diagram and mass balance. The wastes from the process are as follows:

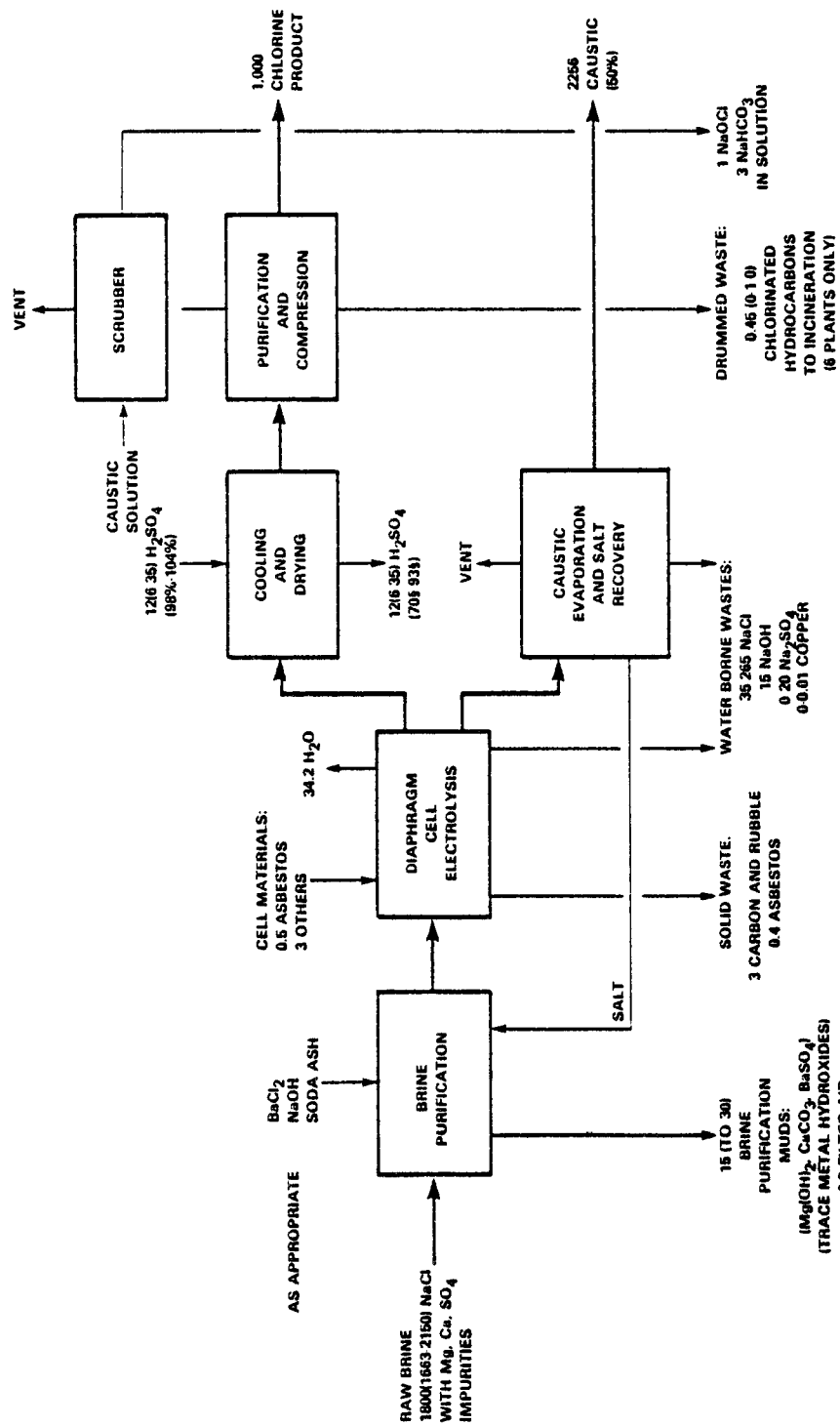


FIGURE 17. CHLOR-ALKALI MANUFACTURE
DIAPHRAGM CELL PROCESS

(1) Brine muds are generated in amounts of up to 30 kg per kkg of product. These muds contain magnesium hydroxide, calcium carbonate, and in some cases, barium sulfate. The amounts of these precipitates are dependent on the purity of the salt used. For plants using pre-purified (i.e., chemical grade, evaporated salt) the amounts are very small (i.e., about 0.7 kg per kkg). Most, if not all, western plants use pre-purified salt. For plants using salt from the Texas-Louisiana salt dome, which accounts for over 55 percent of the total U.S. production, the amounts are about 10 kg per kkg of product. Barium is used in several of these plants for sulfate removal and these muds will contain over 40 percent calcium carbonate and magnesium hydroxide and up to 60 percent barium sulfate. For other salt sources, the average values are about 30 kg per kkg of product and these muds contain primarily calcium carbonate and magnesium hydroxide.^{6, 29}

(2) Carbon and rubble - the amounts range up to 3 kg per kkg of product. Waste carbon is present only at six facilities where they use carbon anodes. The other plants use dimensionally stable metal anodes (DSA).

(3) Waterborne wastes containing 35-265 kg per kkg of salt, 15 kg per kkg of caustic soda, small amounts of suspended solids and sulfates. Lead salts are also present in these wastes at six plants. Waterborne wastes are due to purges to eliminate sulfates from the system in plants not using barium salts.

(4) Spent sulfuric acid - about 12 kg per kkg of chlorine product. This waste is generated from the drying of chlorine.

(5) Chlorinated hydrocarbons - Purification wastes contain up to 1 kg per kkg of chlorine product. This waste no longer occurs at most plants in the United States. Most plants now use DSA or cobalt oxide based electrodes which do not yield lead or chlorinated hydrocarbon wastes. Nitrogen trichloride, removed from the chlorine during purification, is converted to nitrogen and chlorine, and the chlorine is added to the product.⁸

(6) Scrubbing wastes created by wet scrubbing of process tail gases to reduce chlorine emissions. These amount to 1 kg per kkg of product and are waterborne. They contain dissolved sodium hypochlorite and sodium carbonate or bicarbonate. At one site, this wastewater stream is processed to decompose catalytically the hypochlorite to sodium chloride and oxygen.⁷

(7) Asbestos - waste asbestos is generated in rebuilding of the electrolytic cells. For newer cells, the asbestos diaphragm and its holders are removed from the cells and containerized for burial. For some older cells, such as those using the graphite electrodes, the asbestos is washed from the diaphragm, recovered from the water and then containerized and buried. This latter approach can lead to wastewater containing asbestos.

The amounts and types of land-destined wastes are unlikely to undergo radical changes in the next few years because capacity expansion is expected to be only a few percent per year. The formation of chlorinated hydrocarbon, lead, and graphite wastes, however, is expected to fall to negligible values in the next few years as the remaining lead-graphite anodes are replaced by metal anodes. One major corporation, which until recently used graphite electrodes, has released R&D studies on the use of alternate types of metal electrodes and has recently installed them.⁹ Six small plants still using carbon electrodes are considering possible changeovers. They handle electrode wastes as follows: at least four do not remove the chlorinated hydrocarbons from the product, one plant disposes of all wastes by deep well injection; the fate of these wastes at the sixth site is unknown. These six plants account for less than 10 percent of production of chlorine by diaphragm cells.

Table 5 shows the estimated amounts of land-destined waste generated on a state-by-state and national basis from diaphragm cell operations. These numbers were derived from current plant capacity data¹ using a production to capacity ratio of 0.9. Cumulative solid wastes for this process are:

brine muds	78,158 kkg/yr	}	95,665 kkg/yr
carbon and cell rubble	17,507 kkg/yr		non-hazardous waste
asbestos	2,641 kkg/yr		potentially hazardous waste

Chlor-Alkali - Mercury Cell Process

In the mercury cell process, chlorine and caustic soda or caustic potash are produced by the electrolysis of sodium or potassium chloride solutions. The raw salt (or brine) is pre-purified by addition of caustic soda, soda ash, and at one plant, barium chloride. Calcium carbonate,

TABLE 5. DISTRIBUTION OF ESTIMATED AMOUNTS OF LAND-DESTINED
WASTES GENERATED BY THE DIAPHRAGM CELL PROCESS (KKG/YR)

State	Brine Muds (Non-Hazardous)	Carbon and Rubble (Non-Hazardous)	Asbestos (Poten- tially Hazardous)
Alabama	1,500	161	20
California	157	78	80
Georgia	810	81	10
Indiana	800	75	9
Kansas	3,780	378	40
Louisiana	18,160	6,000	720
Michigan	11,670	117	160
New York	2,190	219	28
Nevada	76	300	32
North Carolina	540	54	7
Ohio	3,000	300	40
Oregon	70	300	280
Tennessee	750	75	10
Texas	25,800	7,800	1,000
Virginia	840	84	11
Washington	175	700	90
West Virginia	7,800	780	103
Wisconsin	50	5	1
Actual Totals	78,158 kkg/yr	17,507 kkg/yr	2,641 kkg/yr
Rounded Totals	78,000 kkg/yr	18,000 kkg/yr	2,600 kkg/yr

magnesium hydroxide and barium sulfate are precipitated from the brine and removed as solid waste. The mass-balanced process diagram is shown in Figure 18. Chlorine is formed at the anode and a sodium- (or potassium-) mercury amalgam is formed at the cathode. The chlorine is cooled, dried with sulfuric acid, purified, compressed and marketed. The sodium-mercury amalgam is reacted with water to yield a 50 percent caustic solution and to regenerate the mercury. The mercury is returned to the electrolytic cells and the 50 percent caustic is either sold as such or evaporated to recover a solid product. Spent brines from the electrolysis step are usually recycled to the salt saturation step (if brine is not used) or brine purification step in the process.

The wastes from the process are as follows:

(1) Brine purification muds - The amount of these, as was discussed for the diaphragm cell, is dependent on the purity of salt used, but they average about 15 kg per kkg of chlorine for this process. These muds normally contain calcium carbonate, magnesium hydroxide and barium sulfate. However, treatment of recycled brines to remove mercury or contact with other mercury-bearing waste results in brine muds which are contaminated with minor amounts of mercury sulfide and elemental mercury. Thus, for plants where salt purification is segregated from mercury containing streams, brine muds are non-hazardous. On the other hand, where no segregation of waste streams is practiced, brine muds are hazardous. About 3/4 of the brine muds generated do contain some mercury.

(2) Cell rubble, filter aids, and mercury sulfide from treatment of cell area drainages. These average 2 kg per kkg of product.

(3) Waterborne wastes from chlorine drying and purification and from scrubbing of process tail gases. These wastes, containing spent sodium chloride and sodium sulfate, are also treated to remove mercury. The amounts of these wastes average 88 kg per kkg of product chlorine.

(4) Chlorinated hydrocarbon wastes generated by chlorine purification are negligible because of the almost universal adoption of dimensionally stable anodes. No mercury cell plants were found that still use graphite anodes.

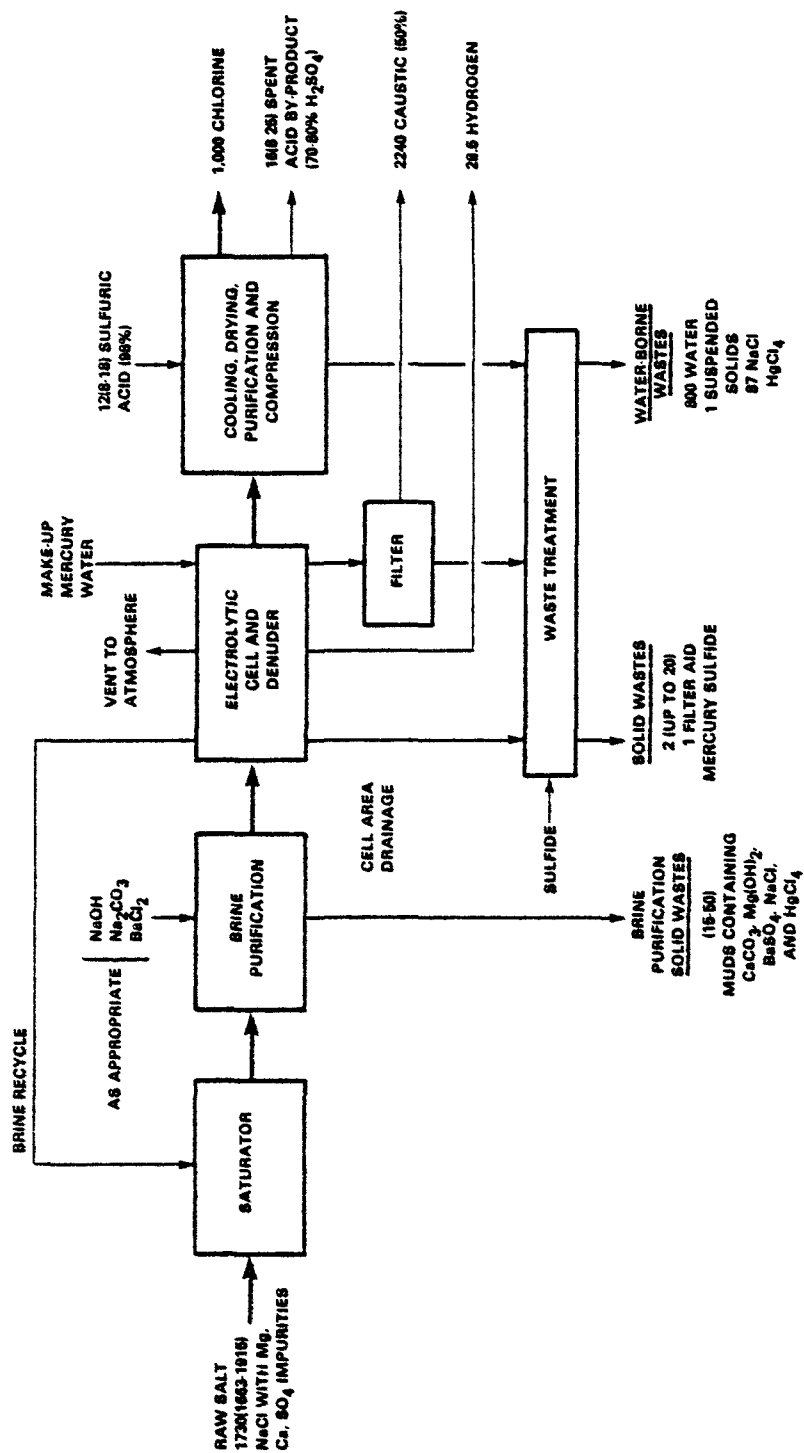


FIGURE 18. CHLOR-ALKALI MANUFACTURE
MERCURY CELL PROCESS

For the land-destined wastes generated by this process, few major changes are expected over the next few years. However, high costs for wastewater treatment and compliance with OSHA regulations may cause some changeover to the diaphragm cell process at a few sites. The state-by-state distribution of wastes generated by the mercury cell process is given in Table 6. The estimated amounts of hazardous and non-hazardous wastes generated are:

39,000 kkg/yr potentially hazardous mercury containing wastes
15,000 kkg/yr non-hazardous brine muds (from six mixed cell plants
that segregate their wastes)

Comparison of these figures with those from the diaphragm cell shows that:

(1) Although the mercury cell and diaphragm cell processes produce 23 and 72 percent, respectively, of the total U.S. chlorine production, the amounts of brine waste differ by only a factor of two. This reflects greater use of the diaphragm cell process in Gulf Coast and West Coast areas where relatively high purity salt is available locally. According to the U.S. Census,² 61 percent of total U.S. production in 1976 was from Louisiana and Texas. Most of this production came from diaphragm cell operations.

(2) There is a need for segregation of mercury containing waste streams, particularly if lower purity salt is used, to minimize the amount of brine mud contaminated by mercury.

Zinc Oxide

This material is produced by four methods:

- (1) By the French process from zinc metal and oxygen;
- (2) As a by-product of sodium hydrosulfite production;
- (3) By up-grading crude zinc oxide recovered by smelters; and
- (4) By the American process.

The first three of these processes generate insignificant amounts of land-destined wastes. In the American process, as shown in Figure 19, zinc ore is wet milled to remove gangue wastes. The upgraded ore is then roasted to convert zinc sulfide to zinc oxide and sulfur dioxide. The zinc oxide

TABLE 6. DISTRIBUTION OF ESTIMATED LAND-DESTINED WASTES
GENERATED BY THE MERCURY CELL PROCESS

State	Brine Muds (kkg/yr) *	Concentrated Mercury Bearing Wastes (kkg/yr)	Number of Plants	Number of Plants Known to Segregate Brine Muds or Use Upgraded Salt
Alabama	4,100	500	4	4
Delaware	2,150	200	1	
Georgia	1,700	400	2	2
Illinois	1,050	70	1	
Kentucky	3,650	360	2	
Louisiana	8,560	1,720	3	2
Maine	400	128	1	1
New Jersey	2,320	230	1	
New York	4,950	330	3	
No. Carolina	40	120	1	1
Ohio	400	80	1	
Tennessee	5,520	370	1	
Texas	4,420	880	2	
Washington	60	140	1	1
West Virginia	9,500	630	2	1
Wisconsin	150	10	1	1
Puerto Rico	148	300	1	1
Actual Totals	49,118 kkg/yr	6,468 kkg/yr	28	14
Rounded Totals	49,000 kkg/yr	6,500 kkg/yr		

* The majority of these wastes are hazardous because of non-segregation of brine purification facilities at 22 mercury cell plants. The other six mixed cell plants usually segregate their brine muds.

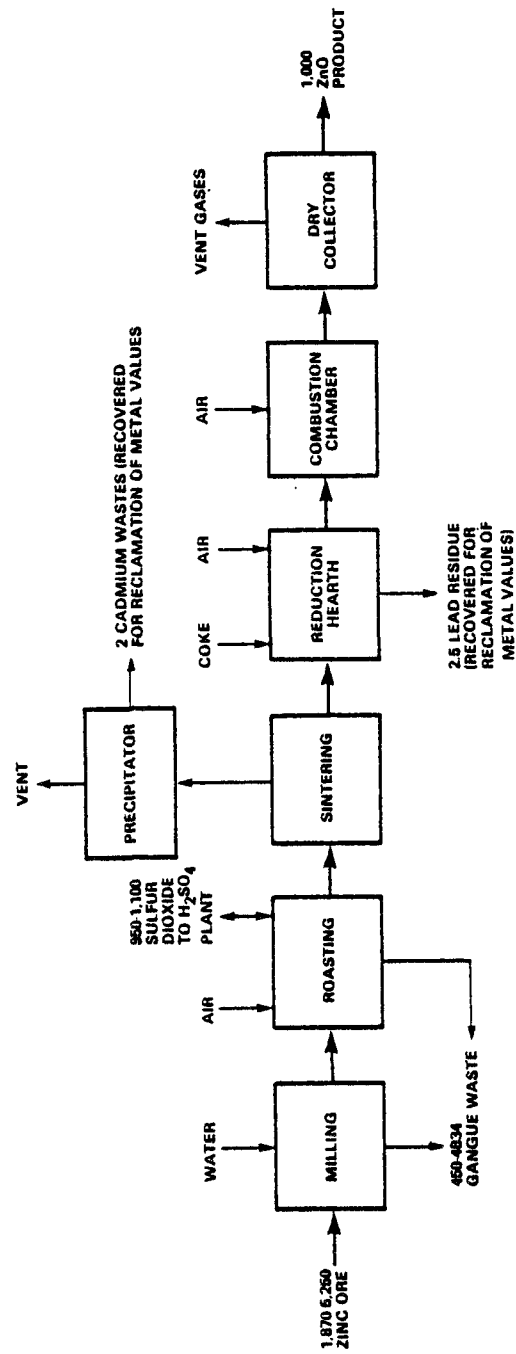


FIGURE 19. ZINC OXIDE MANUFACTURE BY THE AMERICAN PROCESS

and sulfur dioxide exit the roaster in the gas phase. The gas stream is cooled and dry bag collectors are used to recover the zinc oxide. The sulfur dioxide is fed to a sulfuric acid plant on-site. The recovered zinc oxide is then sintered, mixed with coke and fed to hearth reduction furnaces where the oxide is reduced to elemental zinc. The elemental zinc vapors, emerging from the furnace, are reacted with air to form a purified zinc oxide. This material is recovered by dry collection methods and packaged.

The following are the wastes from the American process:

- (1) Ore residues from the milling and roasting operations. These amount to 450-4,800 kg per kkg of product and are land disposed. The wide variations in amounts of residue are due to different compositions of ore used.
- (2) Sulfur dioxide from ore roasting - at the three plants using this process, the sulfur dioxide is used as feed for on-site sulfuric acid plants.
- (3) Dusts from the sintering operation amount to 2 kg per kkg of product and are recovered by dry collection methods to recover cadmium values.
- (4) Residue from the hearth reduction step which consists of lead compounds. The amount of residue averages 2.5 kg per kkg of product and is recovered for its lead value.

The three facilities using this process are located in Ohio, Illinois, and Pennsylvania.

According to the industry, about 125,000 metric tons per year of zinc oxide are produced by the American process. The unpublished capacities of these plants are estimated to be approximately the same. On the basis of this production rate, the total amount of waste generated is 325,000 kkg per year.

Antimony Oxide

This pigment product is produced from ore as shown in Figure 20. Crude antimony ore, containing about 25 percent antimony sulfide, is roasted with oxygen. Antimony oxide is formed in the vapor state and is condensed

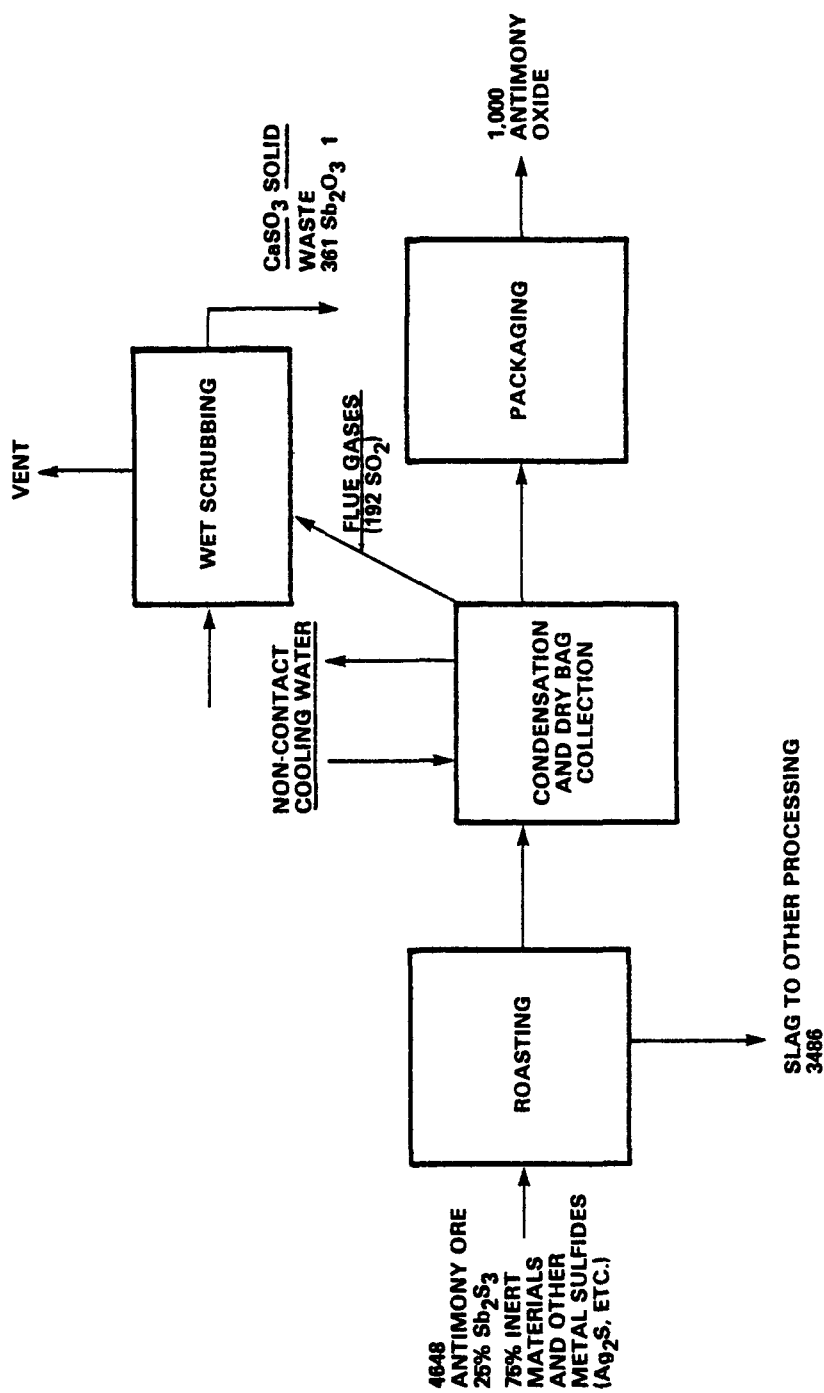


FIGURE 20. ANTIMONY OXIDE MANUFACTURE

and collected in a dry bag collector. Wastes from this process consist of the following:

(1) Slag from the roasting operation - This material contains other heavy metal values (including silver) and is generally not discarded. Most plants sell this material to other processors for silver and other metals recovery. About 3,500 kg of slag are generated per kkg of product.

(2) Flue gases from ore roasting contain considerable amounts of SO₂ which is either used for sulfuric acid production on-site or neutralized by wet lime scrubbing.

(3) The waterborne waste stream from scrubbing is settled prior to discharge and the recovered sludge is generally landfilled. About 360 kg of sludge is generated per kkg of product. This sludge can contain small amounts of unrecovered antimony oxide.

The distribution of waste generation is as follows:

State	Estimated Capacity (kkg/yr)	Amount of Solid Waste Generated (kkg/yr)	Number of Plants
Maryland	360	130 -slag sold	1
New Jersey	4,500	1,620 -slag sold	1
Ohio	2,250	810 -slag sold	1
Texas	900	3,500 -including slag	1
Total	8,010	6,060	4

Barium Sulfate

Most of the chemical grade barium sulfate produced is manufactured by reaction of barium carbonate with sulfuric acid. This process produces no land-destined wastes. One plant, however, uses a process which involves upgrading of 95 percent barite ore by a wet leaching method. This process is shown in Figure 21. At that plant, 95 percent barite ore is ground and leached with 20 percent sulfuric acid to dissolve iron and other metallic salt impurities present. After leaching, the purified barium sulfate is recovered by filtration, washed free of sulfuric acid and then further ground and packaged. The wastewater from sulfuric acid leaching and

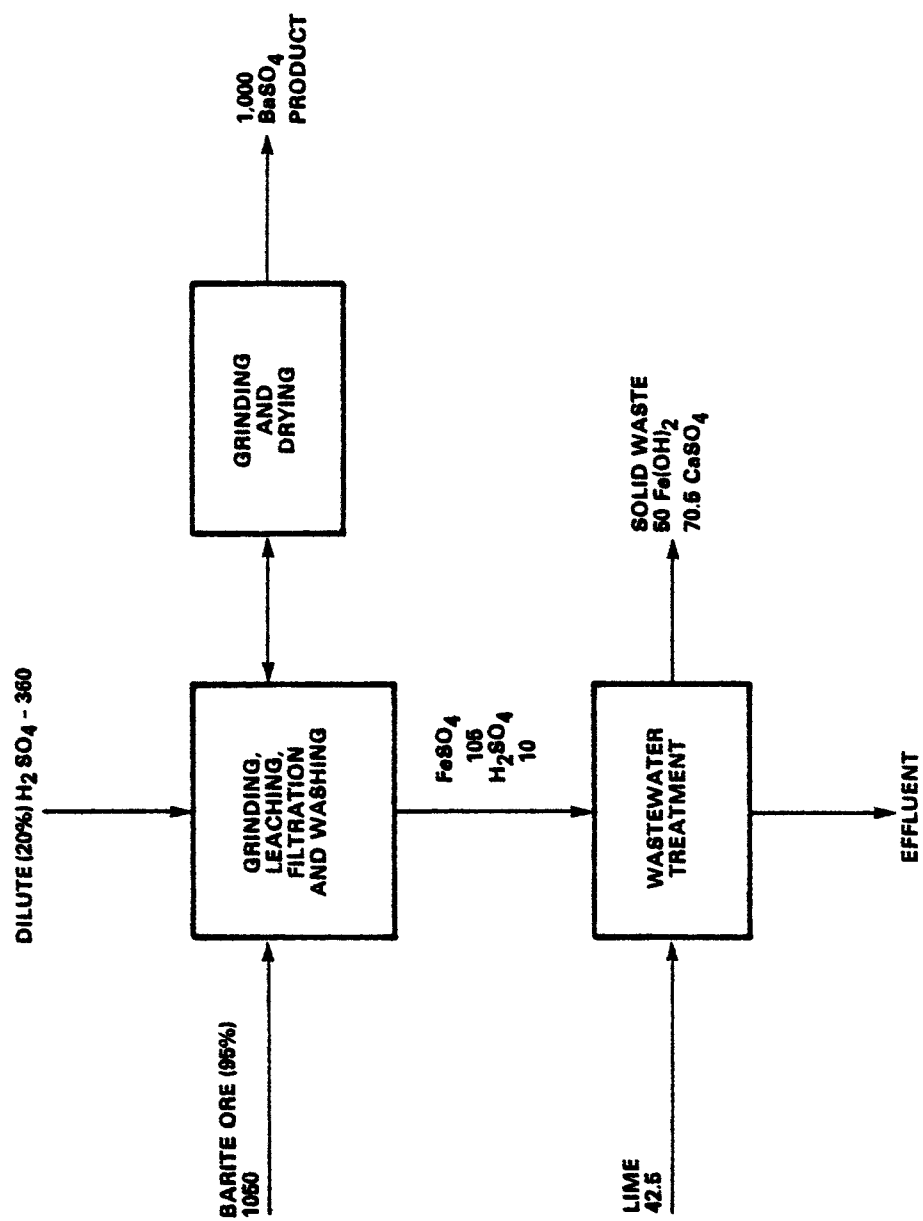


FIGURE 21. BARIUM SULFATE MANUFACTURE FROM BARITE ORE

product washing is neutralized with lime prior to discharge. This generates about 120 kg per kkg of product of sludge containing iron oxide and calcium sulfate. This plant is located in St. Louis, Missouri, and it is estimated that the amount of waste generated by the process is less than 35,000 kkg per year. Plant capacity is not available.

Manganese Sulfate

Manganese sulfate (MnSO_4) is produced by two processes at three locations. At two sites, manganese ore, coke and sulfuric acid are reacted to form a low grade product containing 27 percent MnSO_4 . All solid wastes at the two locations are sold with the product for agricultural purposes.

At the one remaining site, the process shown in Figure 22 is used. Manganese ore, aniline and sulfuric acid are reacted to form hydroquinone, ammonium sulfate, and manganese sulfate. The hydroquinone is recovered by steam distillation and the remaining solution is filtered to remove ore residues. The filtrate is partially evaporated to crystallize MnSO_4 which is recovered by centrifugation and dried.

There are two waste streams from this process:

(1) Ore residues consisting of acid insoluble materials such as silica. These range from 130 to 1,000 kg per kkg of product and are landfilled after washing.

(2) Waste process solutions from the final centrifugation step. These contain 30–600 kg of ammonium sulfate per kkg of product along with smaller amounts of unrecovered manganese sulfate. Treatment of this wastewater generates from 100 to 660 kg per kkg of product of waste solids consisting of manganese oxides and calcium sulfate. These wastes are also landfilled.

These wastes are generated only in Tennessee. The estimated solid waste generation rate for this process is 32,500 kkg per year.

Vanadium Pentoxide

Vanadium pentoxide (V_2O_5) is produced in the United States either by reprocessing of spent catalysts or from ferrophosphorus produced from Idaho phosphate rock. Production of V_2O_5 from spent catalysts generates little solid waste and is practiced at only two sites with minor combined production.

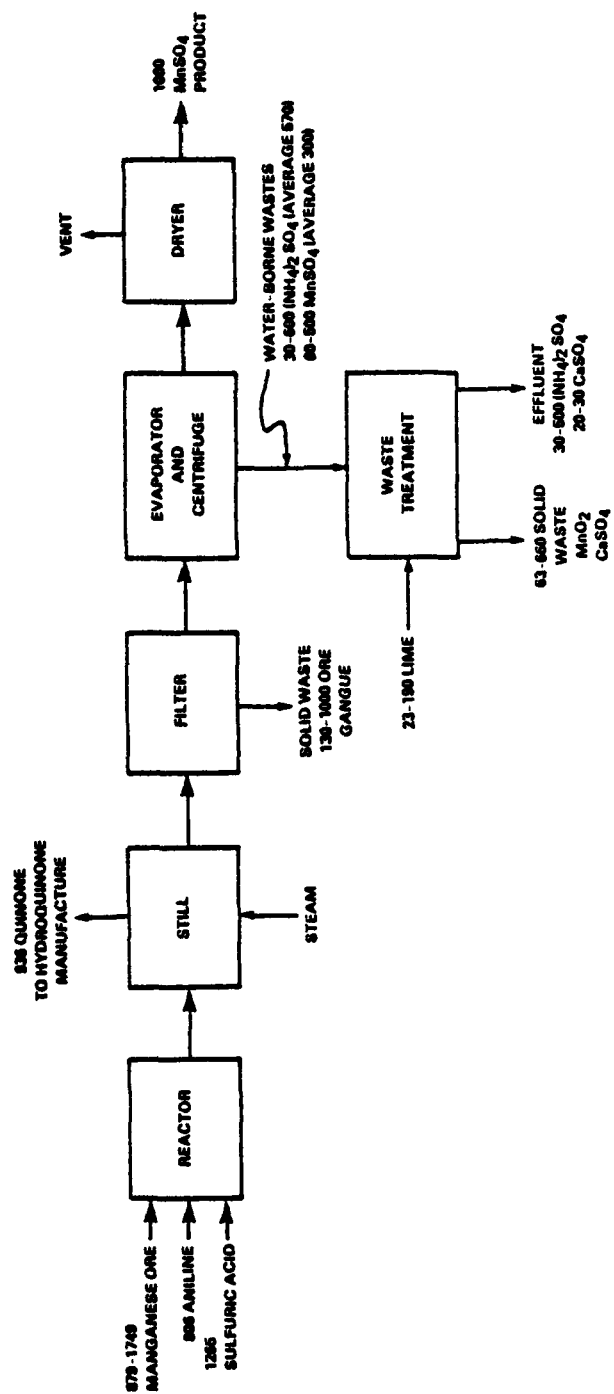


FIGURE 22. MANGANESE SULFATE MANUFACTURE

V_2O_5 is produced from Idaho ferrophosphorus by the process shown in Figure 23. The ferrophosphorus, containing six to 8 percent vanadium, is ground, mixed with soda ash and sodium chloride, and then calcined in air. This procedure converts the ferrophosphorus alloy to a mixture of iron oxide, iron phosphate and sodium metavanadate. The mixture is removed from the kilns and leached with water to recover the salt and sodium metavanadate. The iron oxides and phosphates are separated by filtration and discarded.

The filtrate is acidified with sulfuric acid to precipitate V_2O_5 . The precipitate is recovered by filtration and redissolved in an ammonium hydroxide solution. This solution is then mixed with a proprietary alkyl-amine solvent which extracts the ammonium metavanadate from the aqueous phase. This solvent is evaporated, to recover a purified ammonium metavanadate, and condensed for reuse.

The pure vanadate is redissolved in water and the solution is reacted with sulfuric acid to precipitate V_2O_5 which is recovered, dried, and packaged.

There are several waste streams from this process as follows:

Waste	Process Source	Type Waste	Estimated Amount Generated (kg/kkg)
Iron oxides and phosphates	leaching of calcined raw material	solid	11,800
Sodium chloride and sodium sulfate	second filtration	waterborne	10,700
Ammonium hydroxide	extraction	waterborne	0 - 2
Ammonium sulfate	final purification	waterborne	730

At the one plant producing V_2O_5 by this method, all wastes are fed to a lined evaporation pond. All production occurs in Idaho and the waste generation rate is estimated at 29,000 kkg per year.

Calcium Phosphate (Food Grade)

Food grade calcium phosphates are made by the neutralization of furnace phosphoric acid with hydrated lime. The processes for manufacturing the different calcium phosphates differ from one another principally in the

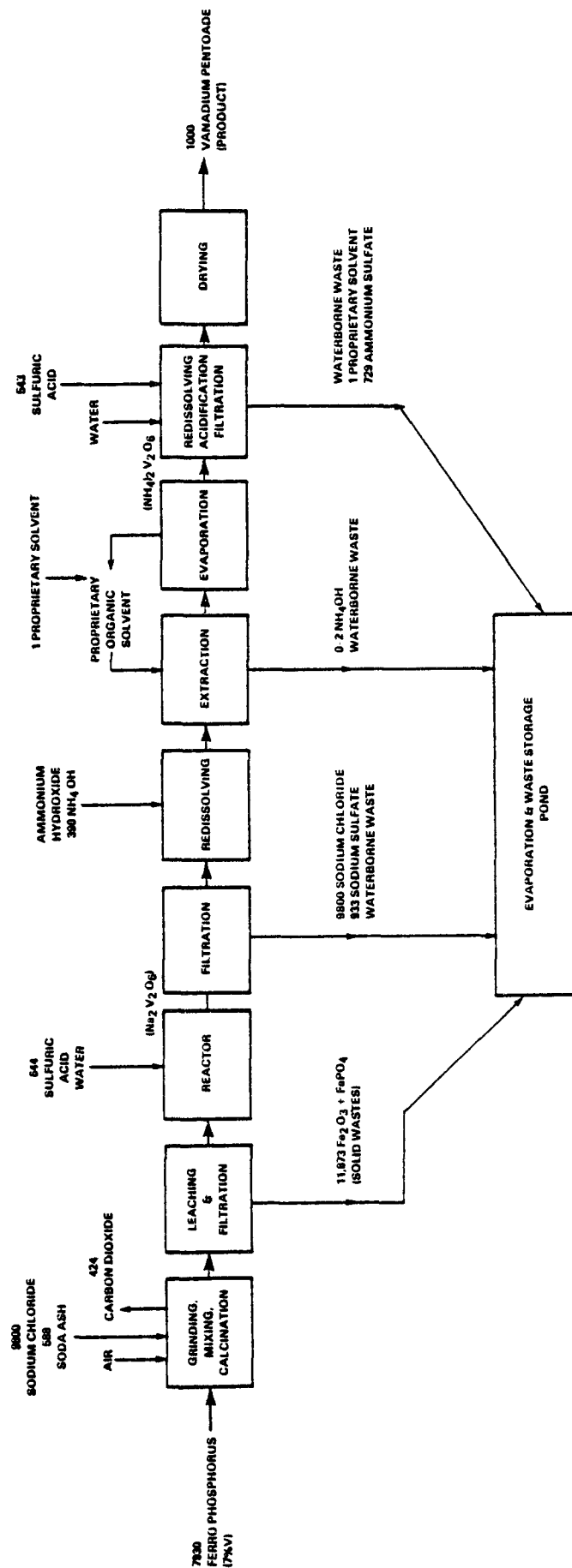


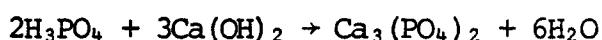
FIGURE 23. VANADATES MANUFACTURE FROM IDAHO FERRO PHOSPHORUS

amount and type of lime used and the amount of process water used. A schematic process flow diagram for the manufacture of mono-, di- and tri-calcium phosphates, respectively, is shown in Figure 24. The reaction to form monocalcium phosphate (MCP) is:



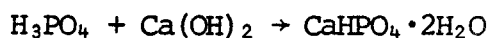
An excess of phosphoric acid maintained during the batch addition cycle inhibits the formation of dicalcium phosphate. A minimum quantity of process water is used. The heat of the reaction liberates some water as steam in the reactor, and the remaining water is evaporated in a vacuum drier, a steam heated drum drier, or a spray drier. The anhydrous MCP is produced by using CaO (quicklime) and in carrying out the reaction at 140°C (310°F) so that water is driven off as it is produced. Drying at higher temperatures than 140°C results in product degradation.

Relatively pure food grade tricalcium phosphate (TCP) is made in a similar manner to MCP, except that an excess of lime slurry, maintained during the batch addition cycle, inhibits formation of dicalcium phosphate:



Like MCP, the TCP is dried in equipment designed to prevent excessive product temperatures from developing.

Relatively pure, food grade dicalcium phosphate (DCP) is made in batch stirred reactors, but with much more process water than for either MCP or TCP:



The stoichiometry for DCP manufacture is critical; any excess H_3PO_4 during the batch addition cycle would result in some MCP and any excess $\text{Ca}(\text{OH})_2$ would result in some TCP. The excess water in the DCP reactor is to ensure homogeneity so that the local stoichiometry is as balanced as the overall reactor stoichiometry (see Figure 25).

As a result of the excess water used, the reaction mixture is a pumpable slurry as opposed to the pasty consistency of MCP and TCP. The DCP is mechanically dewatered before drying.

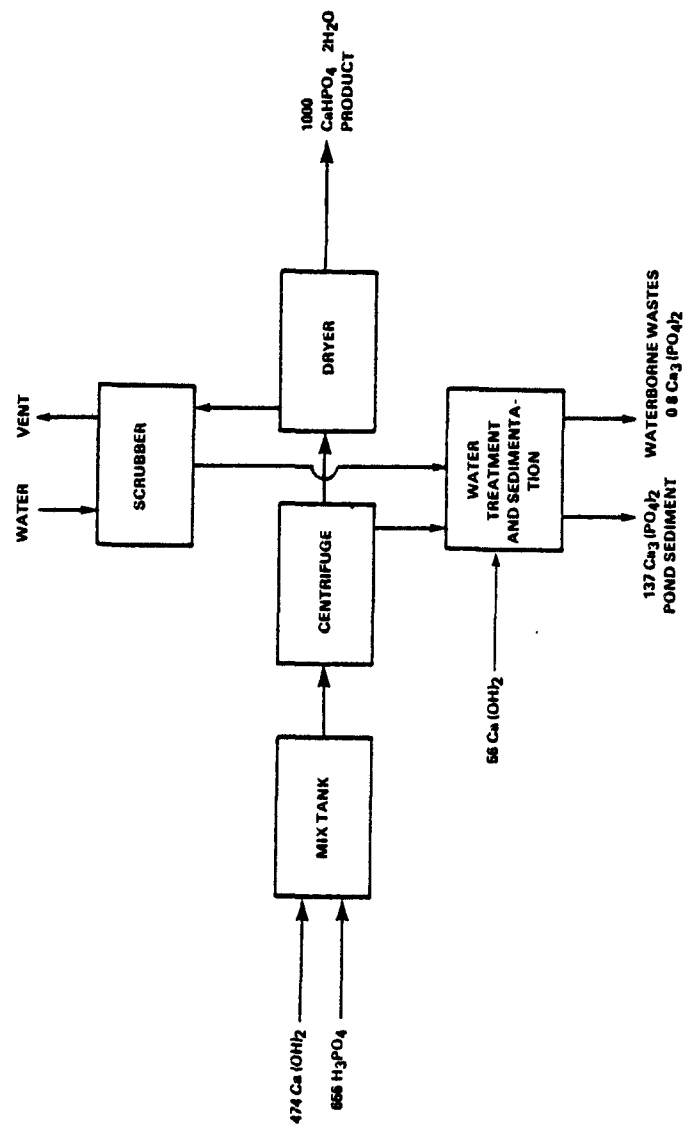
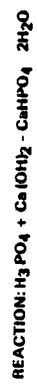


FIGURE 25. MANUFACTURE OF FOOD GRADE DICALCIUM PHOSPHATE

Wastes from all three product lines consist initially of waterborne phosphates. Treatment of these wastes with lime generates calcium phosphate sludges requiring land disposal. The average amount of these varies slightly with product. All plants produce at least two of the three product lines. Average waste load of wastewater treatment sludge from all three product areas is estimated at 135 kg per kkg of product.

The distribution of waste generation is as follows:

State	Production Capacity (kkg/yr)	Estimated Amount of Solid Waste Generated (kkg/yr)
Florida	430,000	58,000
Illinois	45,000	6,100
Iowa	170,000	23,000
Massachusetts	4,500	600
Missouri	180,000	24,300
Nebraska	69,000	9,300
New Jersey	6,200	800
Tennessee	18,000	2,400
Rounded Totals	820,000	120,000

Calcium Carbide

The open furnace process for calcium carbide is shown in Figure 26. Coke is dried and fed to a furnace along with lime and then the mixture is heated to form calcium carbide. The product is recovered from the furnace, cooled, crushed, screened, and packaged. There are several waste sources in this process. These are:

(1) Particulate emissions from the coke drying. These amount to about 50 kg per kkg of product. Dry collection methods are generally used to recover these materials for reuse.

(2) Particulate emissions from the electric furnace. These consist mostly of unreacted lime and coke and are collected primarily by dry methods and reused. About 440 kg per kkg of product of carbon monoxide is also vented from this source.

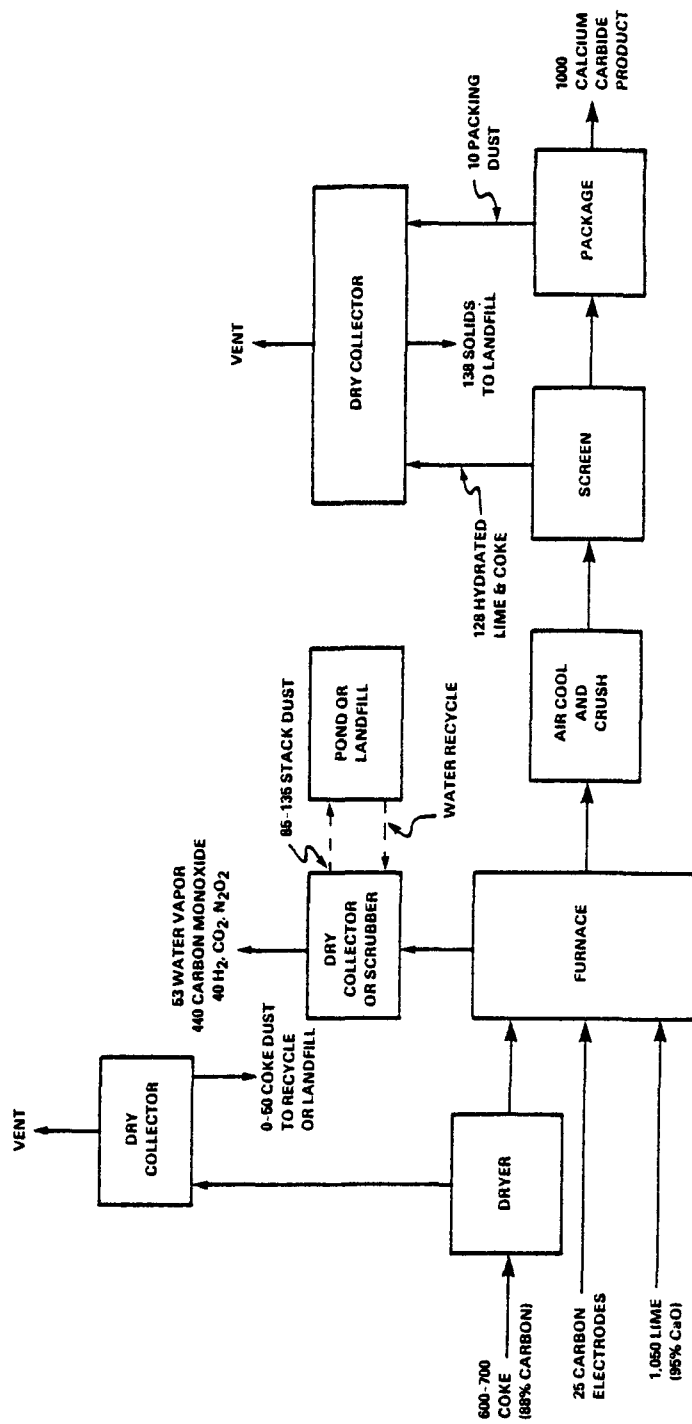


FIGURE 26. OPEN FURNACE CALCIUM CARBIDE MANUFACTURE

(3) Particulate emissions from product screening and packaging. These consist of mostly lime and coke and are either recycled or landfilled.

The distribution of waste generation from calcium carbide production is:

State	Production Capacity (kkg/yr)	Estimated Amounts of Solid Waste Generated (kkg/yr)
Kentucky	136,000	36,700
Iowa	27,000	7,300
Ohio	207,000	55,900
Oklahoma	45,500	12,200
Oregon	32,000	8,600
Rounded Totals	450,000	120,000

Not all 120,000 kkg per year is destined for land disposal. An estimate of the percentage of the total going to landfills is eight percent.

Sodium Hypophosphite

Sodium hypophosphite is produced at two plants in the United States using the process shown in Figure 27. Caustic soda, lime and elemental phosphorus are reacted in a hot aqueous solution to yield calcium and sodium hypophosphites, calcium phosphite and phosphine (PH_3). The phosphine liberated is burned to phosphorus pentoxide which is absorbed in water to produce phosphoric acid for other plant uses. The solution of sodium and calcium hypophosphites is filtered to remove the solid calcium phosphate, and then is reacted with sodium bicarbonate to convert the calcium hypophosphite to the sodium salt and calcium carbonate. The solution is filtered again to remove calcium carbonate and then evaporated to recover the sodium hypophosphite product.

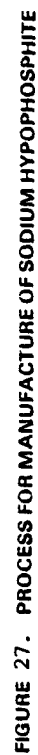
There are two waste streams generated by this process. These are as follows:

(1) Phosphine emissions - about 200 kg per kkg of product. This air-borne emission is normally converted to phosphoric acid for on-site use.

REACTOR: $3\text{P}_4 + 4\text{NaOH} + 4\text{Ca(OH)}_2 + 9\text{H}_2\text{O} \rightarrow 4\text{NaH}_2\text{PO}_2 + \text{Ca(H}_2\text{PO}_2)_2 + 3\text{CaHPO}_3 \downarrow + 3\text{PH}_3\uparrow + 3\text{H}_2\uparrow$

PURIFICATION. $\text{Ca}(\text{H}_2\text{PO}_4)_2 + 2\text{NaHCO}_3 \rightarrow 2\text{NaH}_2\text{PO}_4 + \text{CaCO}_3 \downarrow + \text{CO}_2 + \text{H}_2\text{O}$

INCINERATOR: $\text{PH}_3 + 2\text{O}_2(\text{AIR}) \rightarrow \text{H}_3\text{PO}_4$

$$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$$


(2) Product purification wastes - about 630 kg of calcium phosphite and 190 kg of calcium carbonate are generated per kkg of product. These non-hazardous solid wastes are combined before landfilling.

Sodium hypophosphite is produced at only two sites in two states: Tennessee and New York. Total estimated capacity for the two operations is 3,000 metric tons per year and the total amount of land-destined waste generated is estimated at 2,500 metric tons per year.

Barium Carbonate and Strontium Carbonate

Barium and strontium carbonates (BaCO_3 and SrCO_3) are combined because both chemicals are produced at the same sites using similar processes. Figure 28 shows the process for barium carbonate.

Barite ore and coke are reacted in a kiln. Barium sulfide is produced along with carbon dioxide (CO_2) and some sulfur dioxide (SO_2). The reaction product from the kiln is leached with water to recover barium sulfide. The insoluble ore residues are then discarded and the barium sulfide solution is reacted with soda ash to precipitate barium carbonate. This product is recovered by filtration, washed, and dried. The solution, after removal of barium carbonate, is then generally filtered to recover a sodium sulfide (Na_2S) co-product.

Sometimes carbon dioxide is used in place of soda ash. This results in a hydrogen sulfide (H_2S) co-product which is either recovered for sale or used on-site to manufacture other sulfide chemicals.

The wastes from barium carbonate manufacture are the following:

Waste	Process Source	Type Emission	Amount (kg/kkg of BaCO_3)
Ore residue	reaction kilns	solid	100-200
CO_2 and SO_2	reaction kilns	gaseous	450 CO_2 , 0-12 SO_2
H_2S	reactor (if CO_2 used)	co-product	170
Na_2S	reactor (if soda ash used)	co-product	390
Sulfides and barium	filtration and washing	waterborne	12-47

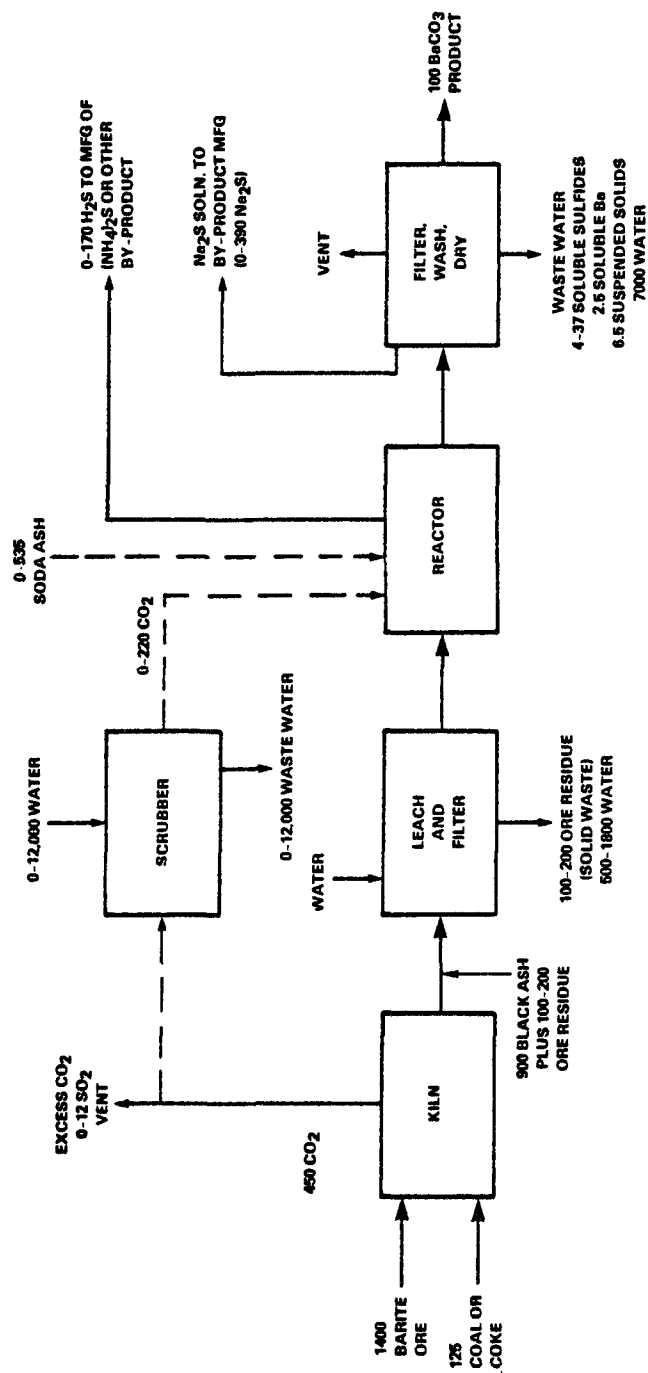


FIGURE 28. BARIUM CARBONATE MANUFACTURE

The ore residue is the principal land-destined waste. Some additional wastes are generated by wastewater treatment and they are combined with the ore residue before disposal.

Figure 29 shows the process for strontium carbonate manufacture. The ore (Celestite) is reacted with coke to yield strontium sulfide which is separated from the ore residues by leaching with water and filtration. The ore residues are discarded and the strontium sulfide solution is reacted with soda ash to precipitate strontium carbonate. This product is collected by filtration, washed, and dried. The solution is further processed to recover a sodium sulfide co-product.

As with barium carbonate manufacture, CO_2 is sometimes used in place of soda ash. Again, H_2S is generated in the reactor as a co-product and is used on-site to produce other sulfide chemicals. The rest of the process is the same as for BaCO_3 .

The wastes generated from SrCO_3 production are listed below:

Waste	Process Source	Type Emission	Amount (kg/ kkg SrCO_3)
Ore residue	kiln	solid	100-200
CO_2 and SO_2	kiln	gaseous	600 CO_2 0-18 SO_2
H_2S	reactor	co-product	0-230
Na_2S	reactor	co-product	0-530
Wash water	final filtration and washing	waterborne	5-31

The ore residue is land disposed along with an additional amount (up to 30 kg per kkg of SrCO_3) of barium and strontium containing solids which are generated after wastewater treatment.

For barium carbonate production, the distribution of waste generation is:

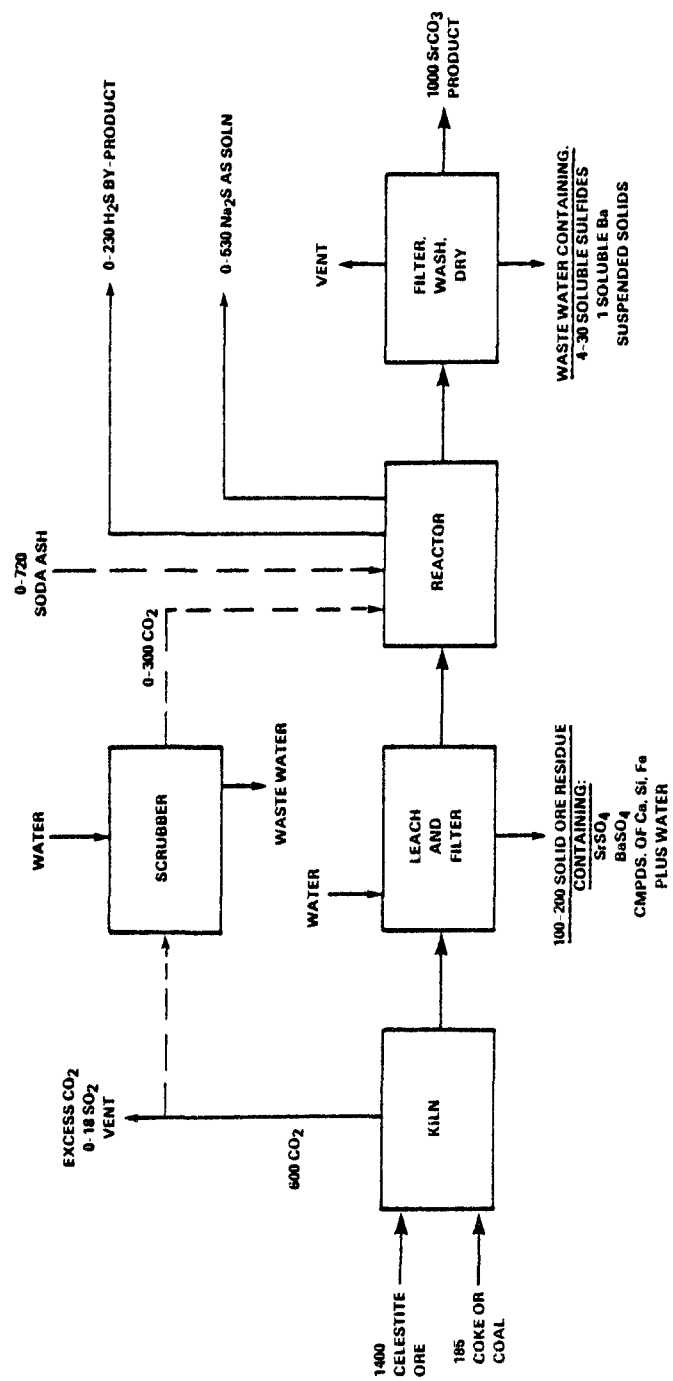


FIGURE 29. STRONTIUM CARBONATE MANUFACTURE

State	Number of Plants	Published Capacity (kkg/yr) ¹	Amount of Land-Destined Waste (kkg/yr)
California	1	27,300	16,000**
Georgia	1	13,500	2,000
Kansas	1	10,800	1,600
Texas	1	5,000*	500*
Rounded Totals	4	57,000	20,000

* Contractor estimates.

** Includes ore beneficiation wastes.

The Texas operation is considerably different from the others. At that plant, the barium carbonate is produced for captive use for brine purification at three chlor-alkali plants. The barium sulfate from brine purification is apparently returned to the plant for reconversion to the carbonate. This would account for the relatively low waste loads in Texas.

For strontium carbonate production, the distribution of waste generation is:

State	Number of Plants	Published Capacity (kkg/yr) ¹	Estimated Amount of Land-Destined Waste (kkg/yr)
California	1	9,100	4,900
Georgia	1	900	300
Totals	2	10,000	5,200

Sodium

Metallic sodium is produced by the Downs cell process as shown in Figure 30. Raw sodium chloride brine is treated with soda ash and barium chloride to precipitate magnesium hydroxide, calcium carbonate and barium sulfate. These wastes are removed by filtration and the purified brine is evaporated to recover dry salt. The salt is blended with calcium chloride to form a low melting eutectic and the mixture is melted and electrolyzed to produce sodium and chlorine. The sodium leaves the cell as a liquid and is cooled,

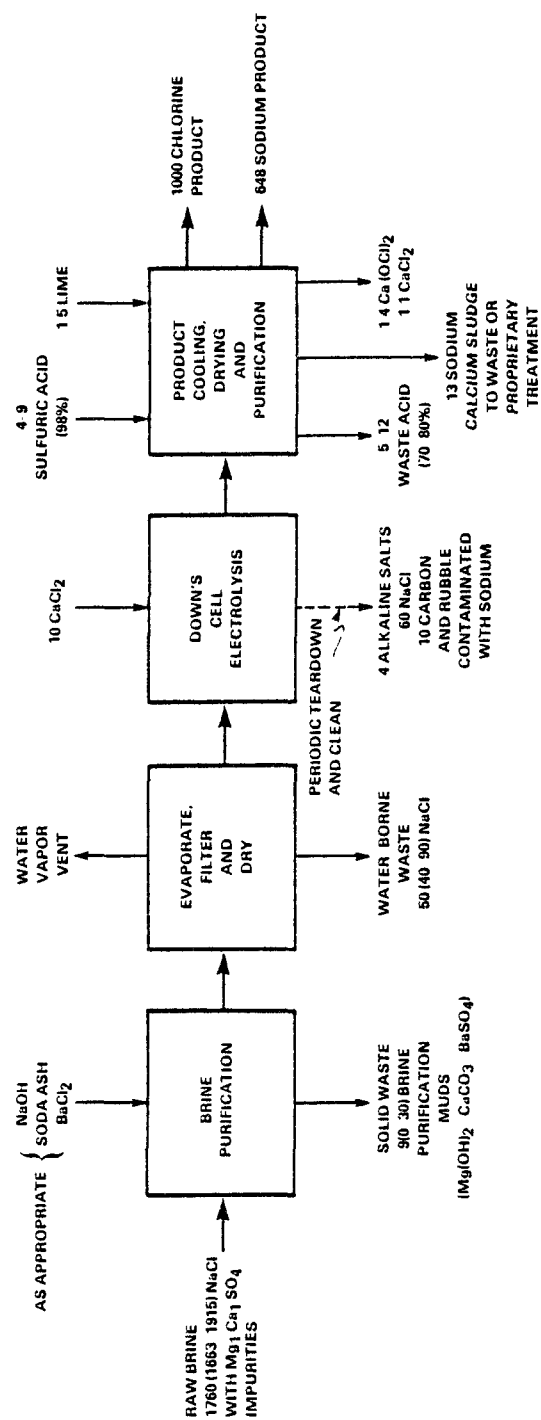


FIGURE 30. SODIUM AND CHLORINE MANUFACTURE DOWN'S CELL PROCESS

filtered to remove a sodium calcium sludge, and is prepared for shipment. The chlorine is dried with sulfuric acid and then compressed, further purified if required, and readied for market.

The wastes from these operations are as follows:

(1) Brine purification sludge - this averages about 9 kg per kkg of product and consists of barium sulfate, magnesium hydroxide and calcium carbonate. It is usually landfilled.

(2) Waterborne wastes from brine purification - contains 40-90 kg per kkg of product of sodium chloride.

(3) Cell wastes - primarily waste salt, carbon and cell rubble contaminated with traces of sodium. These materials are weathered to oxidize the sodium present prior to disposal. The amount of this waste averages about 10 kg per kkg of product.

(4) Sodium-calcium sludges from sodium purification - All three manufacturers process these wastes to convert them to sodium and calcium chlorides for recycle to the process.

(5) Waste sulfuric acid from chlorine drying - about 5 to 12 kg are generated per kkg of product. It is neutralized prior to discharge.

(6) Scrubber waste - Tail gases are wet scrubbed with lime or caustic soda solution which creates a waterborne waste. About 2.5 kg per kkg of product of chlorides and hypochlorites are formed by the scrubbing of tail gases.

The geographical distribution of sodium production wastes is as follows:

State	Published Capacity (kkg/yr) ¹	Estimated Amount of Land-Destined Waste Generated (kkg/yr)
Louisiana	41,000	820
New York	51,400	1,030
Ohio	33,600	670
Tennessee	20,000	400
Texas	27,000	540
Totals	173,000	3,460

These land-destined wastes should be non-hazardous. The hazardous wastes (sodium-calcium sludges) are reprocessed on-site by all the producers.

Sodium Chlorate

The manufacture of sodium chlorate starts with the purification of sodium chloride solution by the addition of soda ash as shown in Figure 31. Magnesium hydroxide and calcium carbonate are precipitated and removed by filtration. The sodium chloride solution is acidified by addition of hydrochloric acid. In some plants, sodium dichromate is added prior to electrolysis. The brine is then electrolyzed to produce a sodium chlorate solution. In five plants, barium chlorate is added to recover chromates as barium chromate. The purified sodium chlorate solution is partially evaporated and fed to crystallizers where the product is recovered by filtration and dried. The liquor is recycled to the brine purification step of the process. The use of chromates and barium salts in this process is dependent on the electrodes used in the electrolytic cells. When platinum electrodes are employed, chromates are never used. When graphite electrodes are employed, chromates are generally used.

The wastes from this process are the following:

(1) Salt purification muds - these consist of calcium carbonate and magnesium hydroxide and are generated only if impure salt is used as a feed material. The amounts of these range from 0-15 kg per kkg of product.

(2) Spent graphite electrodes and barium dichromate wastes are present only if graphite electrodes are used. The amounts generated average 25 and 6 kg per kkg of product, respectively. The chromate wastes are potentially hazardous.

Of the 12 plants in the industry, seven currently use platinum electrodes and five still employ the older graphite electrode technology. Three of these five are currently converting step-wise to the newer technology.

A distribution of wastes generated on a state-by-state basis is given in Table 7.

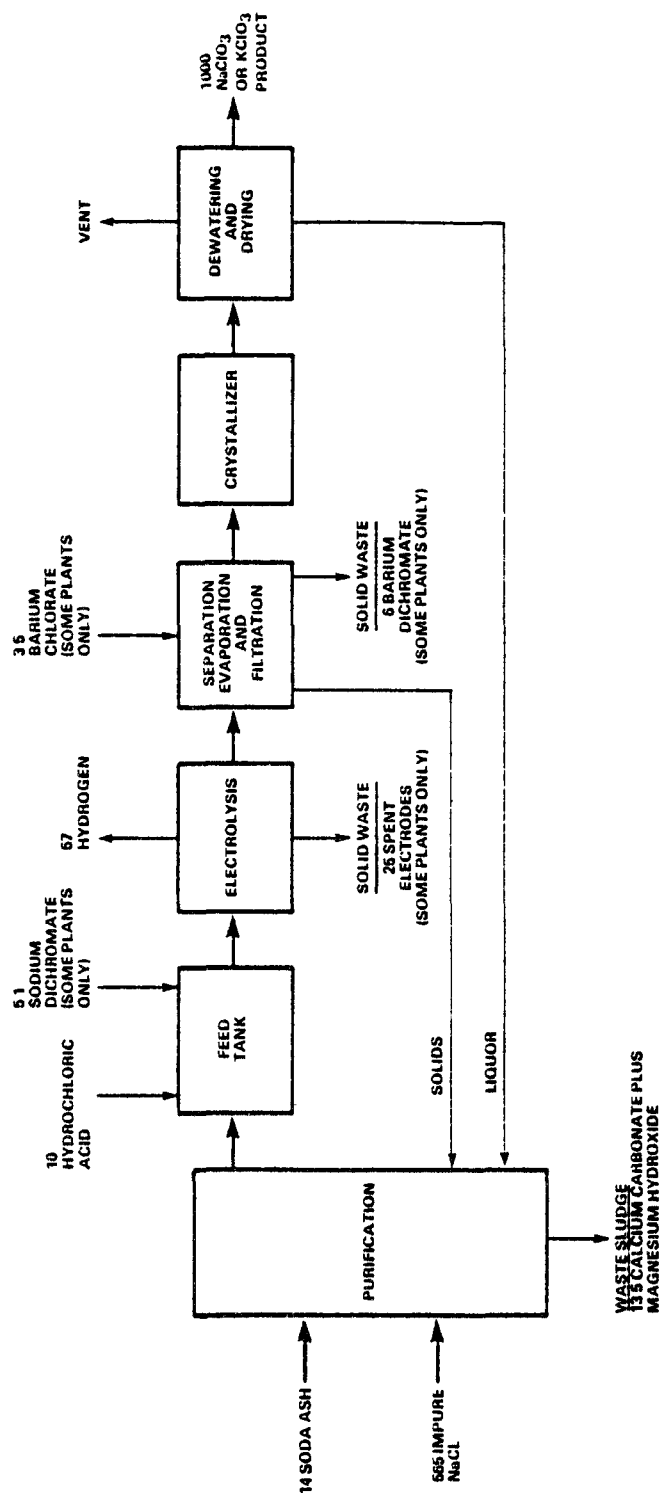


FIGURE 31. SODIUM CHLORATE MANUFACTURE

TABLE 7. DISTRIBUTION OF ESTIMATED WASTES GENERATED BY SODIUM CHLORATE MANUFACTURE*

State	Production Capacity (kkg/yr)	Number of Plants	Amount of Non-Hazardous Waste Generated (kkg/yr)	Amount of Hazardous Waste Generated (kkg/yr)
Alabama	3,600	1	None	None
Georgia	7,300	1	200	None
Kentucky	38,000	1	1,000	None
Louisiana	40,500	1	600	270
Mississippi	90,000	2	725	400
Nevada	34,500	2	640	None
New York	12,000	1	125	80
North Carolina	6,400	1	None	None
Oregon	18,000	1	None	None
Washington	3,600	1	100	24
Rounded Totals	254,000	12	3,800	800

* Waste information for this table was obtained from data provided by all seven producers.

Chrome Yellow

This pigment, as shown in Figure 32 is produced in batches. Lead nitrate or acetate and sodium chromate solutions are prepared. These solutions are mixed and the product lead chromate (chrome yellow) precipitates from solution. It is then recovered by filtration, washed, dried, milled and packaged. The processing solutions, containing unreacted lead, chromates, and unrecovered pigments are usually treated prior to discharge. This generates sludges containing lead chromate and chromium and lead oxides and hydroxides which are landfilled. The amounts of these sludges average 50-70 kg per kkg of product and their approximate compositions are listed in Figure 32.

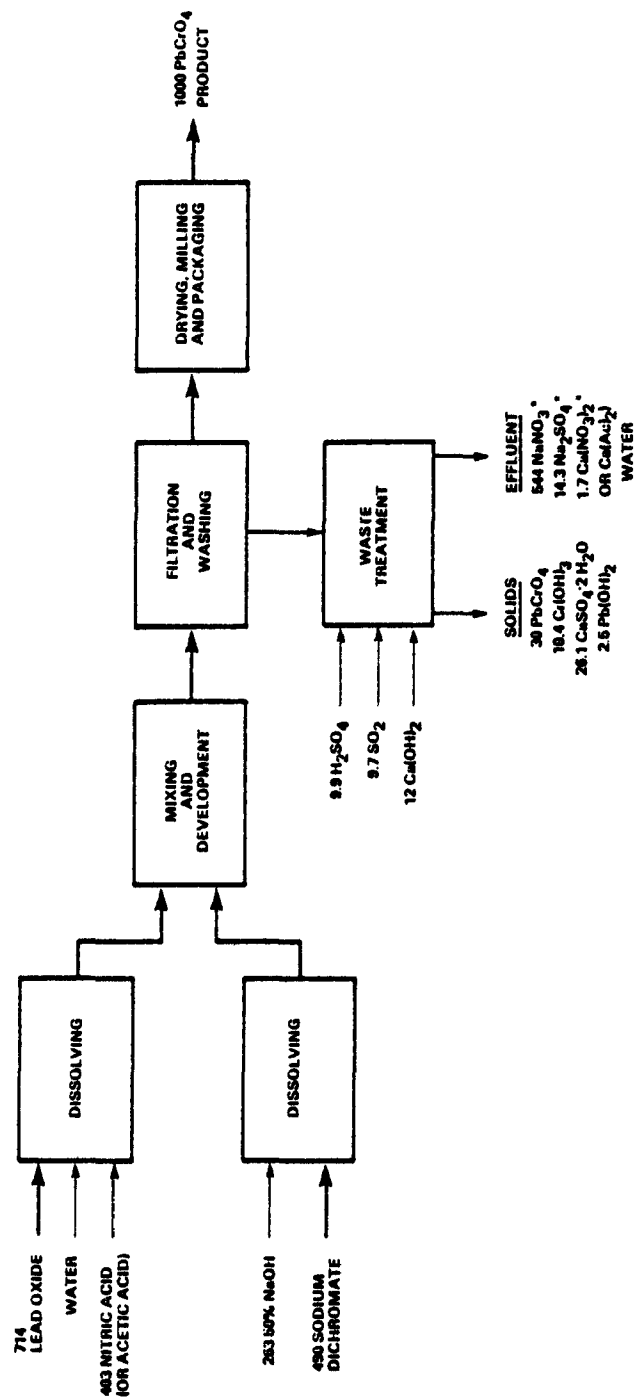
The distribution of waste generators is as follows:

Plant Location	Capacity (kkg/yr)	Estimated Amount of Sludges Generated (kkg/yr)	Number of Plants
New York	>19,000	1,280	3
New Jersey	not available	140	1
West Virginia	2,500	300	1
Kentucky	2,500	300	1
Ohio	700	42	1
Illinois	not available	140	1
Wisconsin	not available	140	1
Totals	33,000	2,340	9

These wastes are potentially hazardous because of their lead and chromate contents.

Potassium Permanganate

Potassium permanganate is made by the process shown in Figure 33. Manganese ore, water and potassium hydroxide are reacted in a kiln with oxygen to yield potassium manganate. This material is then leached from the ore with water. The resulting solution/ore mixture is separated by filtration and the ore residue is discarded. The filtrate is electrolyzed to convert the manganate to permanganate. The permanganate solution is



* VALUES WILL DIFFER DUE TO DIFFERENT
REACTANTS USED TO MAKE DIFFERENT
SHADES OF CHROME YELLOW

FIGURE 32. CHROME YELLOW MANUFACTURE

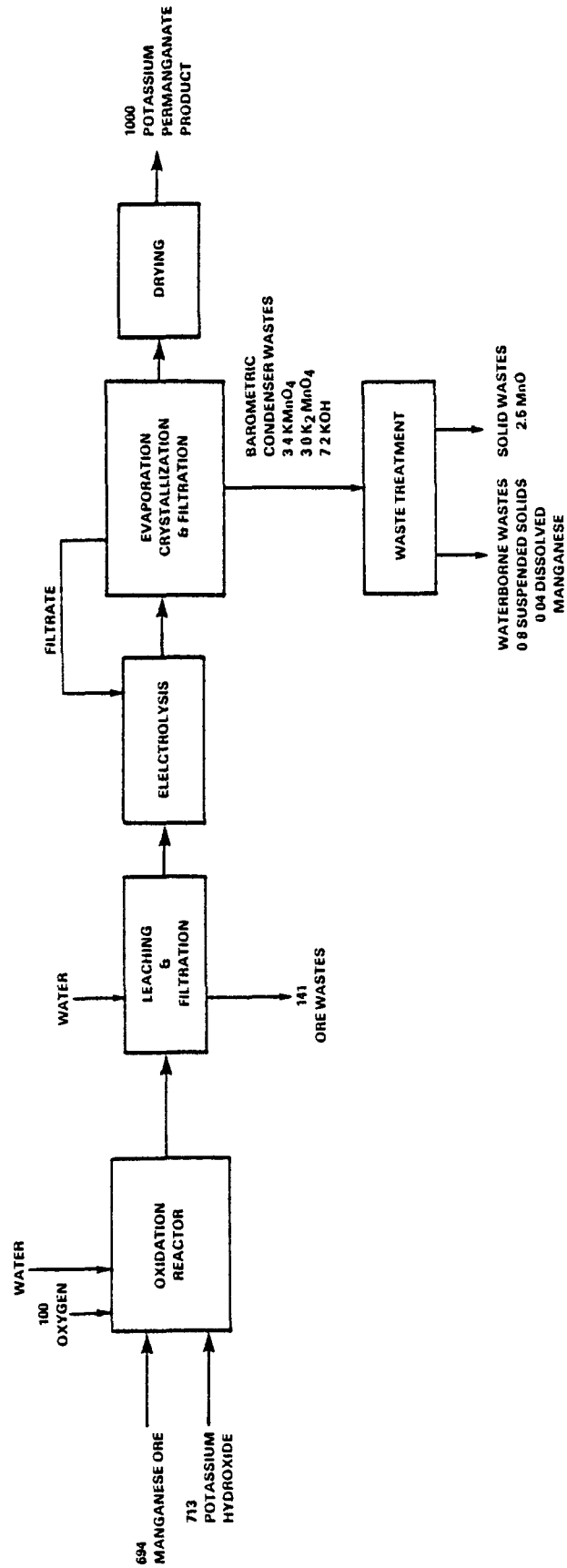


FIGURE 33. POTASSIUM PERMANGANATE PRODUCTION

partially evaporated which causes crystallization of potassium permanganate. The crystals are recovered by filtration and dried. The filtrate is recycled to the electrolysis cells.

There are two sources of wastes from this process:

(1) Ore residues from the leaching and filtration step. These amount to 140 kg per kkg of product and consist of silica, alumina and other insoluble materials. These are landfilled.

(2) Waterborne wastes from the barometric condensers used on the evaporators - this waste stream contains potassium manganate and permanganate and small amounts of KOH in solution. Treatment of this waste stream generates about 2.5 kg per kkg of product of manganese oxides which are combined with the ore residue wastes for disposal.

The only plant producing this chemical is in Illinois. The rate of solid waste generation at this site is estimated at 1,450 metric tons per year.

V. CURRENT DISPOSAL PRACTICES

This section is a discussion of the present disposal practices employed by the major waste sources identified and characterized in previous sections.

Current Disposal Practices by Industry Group

Chlor-Alkali - Diaphragm Cell--

The wastes from diaphragm cell operations are brine muds, cell rubble, spent electrodes, and asbestos.

The brine muds are usually disposed of by lagooning. As lagoons are filled, new lagoons are dug if space is available, and the old ones are then drained, covered and restored. If space is unavailable, the muds are periodically removed from the lagoons and trucked to off-site disposal sites. We estimate that at least half the plants will eventually use off-site disposal for these muds. At a few sites, the brine muds from the process are sent directly to off-site disposal sites. Four of the 32 plants are located in areas where space is limited. At least one plant disposes of its brine mud by deep well injection.³⁰

Apparently one plant alone separates its brine purification process into steps so that the recovery of barium sulfate is isolated. This is an area where a waste material could be recovered for processing into other barium chemicals.

Cell rubble and spent electrodes are usually landfilled on-site. The asbestos wastes produced by the industry are normally handled wet and buried in sealed, marked containers. At least 50 percent of the burial sites are estimated to be on plant property. Lined sites for asbestos burial are not generally used because the industry feels there is no danger of leachate from the sealed containers.

Six plants still using lead graphite anodes also dispose of their lead-bearing wastes in the plant lagoons. At most of these sites, these wastes are mixed with brine mud wastes prior to storage.

Most of the 26 plants using the newer metal anodes, however, no longer have any lead-bearing wastes on their premises. These wastes were either correctly land disposed in the past or have already been removed by contractors.

Three of the 32 diaphragm cell plants are located in Louisiana near wetlands areas. Another plant in Georgia may also be in a wetlands region. At least one of these plants uses off-site disposal for its wastes.

Chlor-Alkali - Mercury Cell--

The mercury cell process industry generates about 15,000 kkg per year of non-contaminated brine muds and 40,000 kkg per year of mercury-containing wastes. Percentages of mercury in the brine muds prior to treatment range from 5×10^{-4} up to 0.10.

The non-hazardous brine muds are disposed of in the same manner as described for the diaphragm cell plants (i.e., lagoon storage and off-site burial). About half the plants dispose of these wastes off-site.

The wastes contaminated with mercury are handled as follows:

- 12 plants store muds in lagoons
- 1 plant uses a lined lagoon
- 12 plants use off-site landfills
- 1 plant uses deep well injection (monitored)
- 4 retort brine muds before disposal to recover mercury
- 2 treat muds with hypochlorite
- 11 plants retort or chemically treat concentrated wastes
- 6 plants pond concentrated wastes after treating
- 15 plants dispose of concentrated wastes in secure, monitored landfills

Five mercury cell plants are located near wetlands areas. These include two in Louisiana and one each in Delaware, Georgia and Texas. Three plants are in urban areas where additional land is unavailable.

Solvay Soda Ash--

About 260,000 metric tons per year of brine muds are generated by the one plant still using the Solvay process. These wastes are currently lagooned on-site and as the lagoons are filled new ones are constructed. The used lagoons are drained and the land is restored. The plant expects to continue this on-site disposal practice and already has monitoring wells on-site to comply with current state regulations. However, the corporation also operates a mercury cell chlor-alkali facility on the plant site and the brine muds from the Solvay process may be contaminated with mercury

from earlier years of operation. Therefore, leachate control and treatment systems may have to be installed at about 10 restored pond areas.

Natural Soda Ash--

It was estimated that about 1,200,000 metric tons per year of ore residues and unrecovered trona are being land disposed at four sites in Wyoming. These plants currently use evaporation ponds for waste disposal. Reclamation of the disposal areas is already required by Wyoming law. At least two sites currently have and use monitoring wells.

Titanium Dioxide - Sulfate Process--

The four sulfate process plants currently dispose of their wastes as follows:

- One plant practices full neutralization with on-site storage of generated gypsum. A small amount of ferrous sulfate is recovered for sale.
- One plant ocean barges most of its wastes and recovers about 25 percent of the generated ferrous sulfate for sale. This plant expects that it will have to install neutralization facilities in the next few years because of the phasing out of ocean barging.
- One plant discharges its wastes directly to a river, but is installing neutralization facilities.
- One site partially neutralizes its wastes, landfills the generated gypsum off-site, discharges part of the remaining waterborne waste, and landfills some ferrous sulfate off-site. This plant probably will have to install full neutralization facilities.

No plants are located in environmentally sensitive areas, but three are located in urban areas where land for on-site disposal is unavailable.

Titanium Dioxide - Chloride Process--

The current practices for waste treatment and disposal in this industry are as follows:

- One plant disposes of neutralization wastes on-site and uses monitoring wells (lined site).
- Two plants share a common off-site disposal area which has no monitoring wells (unlined site).

- One facility disposes of most wastes by deep well injection with monitoring of the disposal site.
- One facility sells some waste ferric chloride and disposes of the remaining wastes by ocean barging.
- One plant uses an unlined off-site landfill.
- Two facilities combine their wastewater with that from titanium dioxide, sulfate process operations. One neutralizes all wastewater prior to discharge and uses on-site disposal of solids. The other plant neutralizes only part of its wastewater.

These plants are not in environmentally sensitive areas.

Antimony Oxide--

The production of this chemical generates 6,000 metric tons per year of land-destined wastes. Approximately 3,000 kkg per year are scrubber wastes and an equal volume is slag. Three of the four plants sell their slag for reclamation of silver and other metals. The other plant obtains its raw material from a uranium producer who has already extracted other metal values. Because the spent slag at this site contains low levels of radioactivity, it is land disposed at a special hazardous waste disposal area off-site. The slag generated by the other producers is not radioactive. All four plants use off-site disposal for the scrubber wastes.

Three plants are in urban areas and none is in an environmentally sensitive region.

Barium Sulfate--

Only one plant will be generating land-destined wastes because of water pollution regulations that will require neutralization of its waste stream. Once this occurs, off-site disposal of the iron oxide and gypsum wastes generated will be required. There is no room for on-site disposal at this plant.

Zinc Oxide--

The current disposal method at all three American process plants is on-site storage of slag wastes. This practice over the years has resulted in slag piles containing over 1.8 million metric tons of waste at one site alone. The other two sites are about the same age and their slag piles are estimated to contain similar quantities of material.

These slags contain small amounts of unsmelted material and some free carbon. At one site, zinc and cadmium were detected in the leachate from the waste piles. These materials are potentially hazardous.

These plants are not in environmentally sensitive areas.

Chrome Yellow--

Chrome yellow is produced at nine locations in the United States. The solid wastes are produced from wastewater treatment to remove lead and chromates.

Two plants use their own disposal facilities, one on site and the other off site. Both sites are lined and equipped with leachate control systems and monitoring wells. These sites are already in compliance with projected hazardous waste disposal regulations.

The remaining seven plants use off-site contractor disposal. At least three plants currently use acceptable disposal sites. The remaining four facilities are uncertain as to the adequacy of present disposal areas.

Two plants have reported some recovery of materials from wastewater treatment and subsequent sale as offgrade products.

None of the plants is located in an environmentally sensitive area and seven of the plants are in urban locations.

Iron Oxide--

Ten plants currently produce iron oxide products. The 15,000 metric tons of waste which they generate annually are landfilled. Seven facilities employ contractors who dispose of wastes off site, at locations which may or may not have monitoring wells.

None of the facilities is in an environmentally sensitive area and seven are located in urban or suburban locations.

Hydrofluoric Acid--

Production of hydrofluoric acid generates a gypsum co-product which is contaminated with small amounts of unreacted calcium fluoride. At the 13 plants producing this chemical, the current practices are as follows:

(1) Two plants, with a combined production capacity of 36,000 kkg per year, sell all their wastes for use as construction material or soil stabilizer. Neither of these plants is in an urban location nor in an environmentally sensitive area.

(2) One plant, with a capacity of 45,000 kkg per year, uses all waste for on-site construction purposes. At that site, which is near a wetlands area, local construction material is not easily available. The waste is used for levee construction and maintenance.

(3) Five plants use off-site landfill disposal and one plant landfills on site.

(4) Four plants currently store all wastes on site in piles or lagoons. Three of these plants combine these wastes with those from aluminum fluoride production prior to storage.

One plant is unusual in that the waste gypsum produced is slightly acidic because of only partial neutralization of the recycled solid wastewater transport system used. All other facilities fully neutralize their wastes prior to disposal. The gypsum precipitated from acid waters at this plant is $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$ instead of the dihydrate $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ normally produced by full neutralization. Runoff water from these waste gypsum piles is weakly acidic. However, this water is collected on site and either reused or neutralized prior to discharge. This plant mixes wastes from an on-site aluminum fluoride process with the hydrofluoric acid gypsum wastes.

Of the 13 plants, three are located near but not in wetlands areas and two of these are presently using on-site storage.

Lime--

The wastes from the 180 plants in this industry consist of underburned lime dusts which are collected by wet or dry methods from process vent gases. About 30 plants either reprocess this material or sell it as off-grade

material. The remaining 150 plants landfill these wastes either at the plant or at the limestone mining site. The amounts landfilled on- or off-site are about equal. None of these landfill sites is known to have monitoring wells. Fewer than six lime plants are located near wetlands areas.

Alumina--

This product is manufactured from bauxite at ten facilities in the United States. The waste muds from the process are pumped to settling lagoons where they are allowed to accumulate. As the lagoons are filled, new ones are dug. The old lagoons are allowed to slowly drain. All other miscellaneous wastes are disposed of at the plant sites.

Large areas of land are required for mud storage. Current industry practice does not include restoration of filled mud lagoons. At eight of the ten sites, the mud lagoons are adjacent to the plant site. At two locations, however, the muds are pumped several miles to disposal lagoons. The muds leaving the process average 10 percent solids content. After deposition in the lagoons and proper drainage, however, their solids content increases to approximately 50 percent. Removal of additional water occurs very slowly and several years may be required for significant increases in solids content. Only at this time can proper land reclamation be practiced. The residual alkali content of the muds makes restoration of the lagooning areas more expensive. Eight of the 10 plants use clay-lined lagoons for mud storage.

Eight plants are located on the Gulf Coast. The other two are in Arkansas, near bauxite deposits. The Gulf Coast plants were originally located there for two reasons: (1) most of the bauxite used is transported by ship from Jamaica, Surinam, West Africa or South America and (2) caustic soda and natural gas (for fuel) are both readily available on the Gulf Coast. One plant in Louisiana and one plant in Alabama are near but not in wetlands areas. In addition, two other sites in Texas are near wetlands and could also be impacted by wetlands regulations in future times as more land is required.

Aluminum Sulfate--

According to Census data,² there are 67 plants manufacturing this product. Most plants are located in rural areas where land is readily available. The general waste disposal practice is for periodic removal of the mud wastes from settling lagoons and landfill on-site. A few plants near urban areas may employ off-site disposal. The number of such plants is estimated at less than ten.

Only two or three of these plants in Southern Alabama and Southern Louisiana are in wetlands areas.

Sodium--

The production of sodium generates two waste streams requiring land disposal. These are brine purification muds containing CaCO_3 , Mg(OH)_2 , and BaSO_4 ; and cell rubble and spent graphite electrodes.

The general industry disposal practice is to landfill these wastes on site. Only one plant uses an off-site disposal area. None of the five plants is in an environmentally sensitive area.

Sodium Chlorate--

This product is produced at 12 locations in the United States using technology which is undergoing rapid change. The seven plants using the latest technology have only brine purification muds as wastes, if impure salt is used. The five plants using old technology, however, have wastes consisting of barium chromate and spent graphite anodes. The barium chromate wastes are potentially hazardous.

Five of the seven modern technology plants reported no wastes requiring disposal. The other two plants landfill their brine muds. One uses a lined evaporation pond with on-site monitoring. The other combines these wastes with gypsum and other non-hazardous process wastes prior to off-site landfilling.

Two of the five plants using older technology landfill their wastes off site. The other three landfill on site. One plant recovers and reuses its barium chromate and land disposes only the graphite anodes along with non-hazardous diaphragm cell chlor-alkali wastes.

At least three plants use hazardous waste disposal sites that are in compliance with projected RCRA regulations. The status of one wetlands area plant is uncertain.

Sodium Hypophosphite--

Sodium hypophosphite is produced at only two locations, neither of which is in an environmentally sensitive area. The solid wastes generated at both plants are recovered and buried off site with other non-hazardous wastes generated from other processes.

Potash--

The wastes from production of KCl and K_2SO_4 from ore are initially waterborne. These wastes are all fed to evaporation ponds at the eight sites. Over the years, the amount of waste salt and clay deposited in these ponds has grown to an estimated 450 million metric tons. All production occurs in New Mexico and Utah. Both areas are arid regions where the disturbed land has no agricultural value. Both areas are situated atop salt domes so that the local ground water is saturated with salt. The evaporation ponds are located sufficiently far from rivers and streams to preclude the chance of salt contamination. Thus, the environmental effects on these eight sites are minimal.

Potassium Permanganate--

Potassium permanganate is produced at only one site. The ore residues and wastewater treatment sludges are combined and landfilled in an off-site disposal area. The site is monitored and the wastes are considered non-hazardous. The disposal site and plant are not in environmentally sensitive areas.

Barium and Strontium Carbonates--

These two chemicals are produced by similar processes in the same plants. The wastes from the two operations are generally combined prior to disposal. Both processes generate ore residues, containing small amounts of potentially soluble barium or strontium and sulfides, and wet scrubber residues containing mostly calcium sulfate. These two wastes are combined prior to landfilling.

There are four plants manufacturing one or both of these chemicals. None of these is in an environmentally sensitive area.

One plant already disposes of the potentially hazardous waste at a secure off-site landfill site in accordance with state hazardous regulations.

Another plant stores these wastes at the plant site and has land available on site.

A third plant has been landfilling these wastes off-site in an unlined landfill for the past ten years.

The fourth plant is captive to a chlor-alkali complex and supplies the barium carbonate solely for use in brine purification. Much of this plant's feed material is probably the barium sulfate formed by brine purification with the result that the amount of ore residues generated is minimal. This plant landfills its wastes off site in a secure area.

Borax--

Borax is produced from ore at only one site in the United States. The spent ore residues are permanently stored in lined lagoons with the surrounding area being monitored for leachate. As these ore residues contain small amounts of natural arsenic minerals, they are potentially hazardous. The production site is located in the Mojave Desert area of California.

Calcium Carbide--

The wastes from calcium carbide manufacture at five plants are handled as follows:

Four plants either sell or reuse all solid wastes. Three facilities sell the material as a low grade neutralization agent. One plant, located in a ferroalloy complex, uses this material for neutralization of acidic waterborne wastes from other operations.

One facility reported an unusual situation in that coal is used in their process in place of high grade coke, generating a furnace slag not present as a waste at the other plants. About 8,300 kkg per year of slag and other wastes are generated which are currently land stored at the plant site.

One facility which currently sells its wastes, has over 450,000 metric tons of stored lime on the premises. This lime is from previous years of acetylene production and the plant feels it may be salable over a period of years. The salability of this material is questionable.

None of these plants is in an environmentally sensitive area.

Calcium Phosphate--

For the solid wastes from calcium phosphate manufacture, landfilling is the only reported method of disposal. At least three facilities use off-site disposal. Most of the other plants are located in rural areas and it would be expected that their waste disposal would be on-site. None of the landfill sites had monitoring wells. There are no plants in environmentally sensitive areas.

Sodium Dichromate--

The solid wastes, usually consisting of ore residues and wastewater treatment generated muds, are landfilled. Chemical treatment with ferrous chloride or sodium sulfide is used at two plants to reduce hexavalent chromium to the trivalent form prior to disposal. The third plant thoroughly washes its waste solids to remove soluble chromates before disposal.

One plant uses a lined on-site disposal area which is projected to meet all RCRA hazardous waste disposal criteria. Another plant currently disposes of its wastes in an unlined quarry near the plant site. Wastes have been deposited in this quarry for the last six years.

The third plant has used outside contractors for waste disposal, but is presently having problems finding suitable locations for its wastes.

None of the plants is in an environmentally sensitive area.

Lithium Carbonate--

There are two plants producing lithium carbonate. One plant stores its solid wastes in a 60-acre ravine. The second facility also land stores some of its wastes, however, it has landfilled most on site and has restored the disturbed area. Neither plant is in an environmentally sensitive area and one already has monitoring wells.

Manganese Sulfate--

The one plant manufacturing manganese sulfate by the hydroquinone process currently stores its wastes in an on-site lagoon. The plant is not in an environmentally sensitive area and has the area for future lagoon construction.

Phosphorus--

The handling practices for the wastes generated by phosphorus production are as follows:

Slag is entirely sold at the six eastern plants for use as a crushed stone substitute in roadbed construction. Only 60 percent of this material is sold at the three western plants. The rest is stockpiled. Inventory stockpiles from past years of production total about 18,000,000 metric tons for the three western sites.

Particulates recovered from ore drying and preparation by dry collection methods are generally landfilled on-site. Seven plants, however, do not have monitoring wells at the landfill sites.

Phosphy dusts, recovered by dry collection methods from phosphorus-containing gas streams, are combined with the phosphy water at most plants; retorted to recover phosphorus at one plant which landfills the residues on-site in a lined and monitored area; and collected, drummed, and stored by another plant for future off-site disposal at a hazardous waste disposal site. The phosphy water is fed to lined lagoons for settling of suspended phosphorus and is then reused in the process to condense and collect phosphorus. At some sites, waste phosphorus accumulates at the bottom of these ponds. Two plants currently recover the phosphorus periodically by retorting and then landfill the residues in a lined and monitored area. Two other plants have used in-process control technology to reduce the amounts of phosphorus going to the ponds. One of these two plants also uses a proprietary scheme for phosphorus recovery from these wastes.

None of these plants is located in either urban or environmentally sensitive areas.

Sodium Silicofluoride--

At the one plant studied in this program, all waterborne wastes are disposed of by deep well injection. The plant is not located in an environmentally sensitive area.

Vanadium Pentoxide--

At the only plant producing vanadium pentoxide, all solid and waterborne wastes are fed to a lined evaporation pond. Space is available on site for additional pond construction and corporate plans call for covering and restoration of the original pond site, once the pond is filled. The plant is located in an arid area in eastern Idaho.

VI. RCRA 4004 COMPLIANCE COSTS

This chapter provides an estimate of the additional capital and operating costs the inorganic chemicals industry is likely to incur in complying with section 4004 of RCRA. Cost estimates for recent State and other Federal regulations are also presented. The scope has been limited to the manufacture of 31 inorganic chemicals whose processes generate over 1,000 metric tons per year of land-destined wastes. Other inorganic chemicals manufacturing processes generate less significant quantities of land-destined waste which are generally contractor hauled. The impact of RCRA 4004 on these producers will be minimal and therefore, is not discussed.

Table 1 in the Executive Summary of this report gives a comprehensive overview of the 31 inorganic chemical product areas, indicating amounts of non-hazardous wastes generated by each and the current status of disposal methods, monitoring and reclamation. Table 2 summarizes the estimated compliance costs for non-hazardous wastes.

The costing methodology section of this chapter describes the sources of data and assumptions made to arrive at the estimated costs. The inorganic chemicals industry is both complex and highly diversified; therefore, cost information has to be obtained on a plant-by-plant and product-by-product basis through contacts with corporation offices and on-site visits. Figures used represent the most accurate averaging of costs on an industry-wide basis, except where noted.

The compliance costs section of this chapter discusses disposal control mechanisms which must be implemented to achieve compliance with RCRA 4004 criteria and with other overlapping Federal and State regulations, and provides estimates of the costs associated with compliance. These costs are based on Versar's estimates of what is needed to upgrade current practices. These estimates have not been endorsed by EPA and other control mechanisms not discussed here may also be required or used. Non-RCRA Federal regulations apply to such statutes as the Clean Water Act of 1977, which covers surface waters and wetlands when an NPDES permit is denied. State regulations refer to recent State ground-water regulations. All RCRA 4004-induced costs must be considered supplemental to other compliance costs incurred.

COST METHODOLOGY

Data Sources

Compliance cost information was obtained directly from the inorganic chemicals industry on a site-by-site and product-by-product basis. This approach was necessitated by the complexity of the industry and the diversity of products involved. Industry-furnished costs were subjected to an in-depth review and, when costs varied excessively from published data, they were examined to determine if unusual factors were present. Follow-up visits to several plants and corporation headquarters were then made to verify information received.

Presentation of Costs

Compliance costs are divided into capital costs and annual operating/maintenance costs and are expressed in 1978 dollars. Capital costs are then amortized and combined with operating/maintenance costs to determine the total annualized costs associated with compliance requirements. When it appeared that compliance would have a significant economic impact on an industry segment, costs were further broken down to derive estimates per ton of product and to project possible price increases.

Cost Assumptions

Capital Costs

For most segments of the industry, the major capital cost expenditure is the installation of three monitoring wells for each site. Industry estimates for geological studies, equipment purchases, cost of borrowed capital at 12 percent interest, and actual installation ranged from \$5,000 to \$20,000 per well. We averaged industry projections and assumed a cost of \$10,000.

Several segments of the industry will incur capital costs for purchasing or upgrading waste disposal areas. Following are industry estimates and the figures we have derived as the most accurate averages:

- Cost of land
Industry estimates : \$1,000 - \$10,000 per acre
Our estimate: \$5,000 per acre

- Unlined landfill construction costs
Industry estimates: \$10,000 - \$25,000 per acre
Our estimate: \$20,000 per acre
- Amount of waste buried per acre
Industry estimates: 8,000 - 30,000 tons
Our estimate: 10,000 tons (including area for active landfill operation, perimeter construction, fencing, monitoring sites, etc.)

Annual Operating/Maintenance Costs

- Monitoring--These costs averaged \$4,000 per year industry-wide for quarterly monitoring. We also assume that each well will depreciate by \$1,000 or 10 percent annually.

- Site closure costs--For most segments of this industry, closure costs are merely those for monitoring during the site closure period. Monitoring costs are assessed, as explained above, at \$4,000 per site per year.

Land reclamation costs

Projections were uniformly about \$1,500 per acre except for alumina. These costs include those for site covering with topsoil and revegetation. Because of the alkaline nature of alumina wastes, disposal sites must be specially treated and will thus be more expensive. Costs for reclamation of already disturbed areas are treated as capital costs. Costs for future reclamation are treated on an annualized basis.

Current waste disposal costs are not emphasized because the objective of this study is to determine incremental costs for compliance with RCRA. The industry has reported that costs for on-site landfilling of non-hazardous solid wastes range from \$1.35 to \$2.00 per ton. Off-site disposal costs are as high as \$8.00 per ton, depending on the distance to be transported.

Price Impacts

The projected compliance costs for many of the chemical products were not significant (i.e., amounted to less than one percent of the product selling price on a per tonnage basis). For two of the chemical products (alumina and hydrofluoric acid) compliance costs were large enough to

justify a more detailed assessment. For each of these products, estimated compliance costs per metric ton were developed. Capital cost estimates include 12 percent interest charges and, in those cases where compliance costs per ton of product exceeded one percent of the product selling price, the capital costs were allocated over a 10-year capital recovery period. (One exception where costs exceeded one percent but were not allocated over a ten-year period was one hydrofluoric acid plant that will incur environmental costs of approximately 1.8 percent of the product price in the first year. This cost was not spread out over a ten year period to allow comparison with other similar hydrofluoric acid plants).

It must be emphasized that within each product category, compliance costs will vary from site to site and will also vary over time as waste inventory problems are eliminated. To give a realistic picture of compliance costs, plants in each product area were grouped according to the level of impact. Actual price increases will, of course, depend on actual compliance costs at each site. To give an estimate of the magnitude of these price increases, compliance costs per metric ton of product were estimated as a percentage of the selling price of the chemical products. It is assumed that all compliance costs will be passed on to consumers. Following are ranges of potential increases for the most heavily impacted products:

<u>Product</u>	<u>Range of potential price increase (as a percent of present product selling price)</u>
Alumina	0.3 % - 1.6 %
Hydrofluoric acid	0.0 % - 1.8 %

COMPLIANCE COSTS

In this section the estimated compliance costs presented in Table 2 are disaggregated and attributed on a chemical-by-chemical basis to three criteria:

- State ground water protection regulations
- RCRA 4004 (relating to ground water protection)
- State surface water regulations

These criteria and associated costs will be discussed in detail. Other RCRA criteria listed below, do not have a cost impact on the inorganic chemicals industry.

- Floodplains and wetlands regulations - No inorganic chemical plants are located in swamps or marsh areas. In addition, those that are situated near rivers are already adequately protected from potential flooding by levees.
- Critical habitat regulations - No plants are located near critical habitats.
- Air regulations - No hazardous gases result from the burial of non-hazardous wastes. Fugitive dusts, however, could result from open land storage of wastes and will be discussed for relevant cases.
- Disease vector regulations - No bacterial wastes are involved.
- Safety regulations - No explosive gas, toxic gas, bird sanctuary, access, or fire-related problems are involved.

In the following discussion, the criteria that result in compliance costs will be addressed on a chemical-by-chemical basis. As shown in Table 2, these costs are divided between "State and other Federal-induced costs" and "RCRA 4004 compliance costs". The State and other Federal-induced costs are attributable to State regulations concerning ground water protection. Within this category, the capital costs are for construction of monitoring wells (three per site at \$10,000 each), and the annual operating costs are for well depreciation, quarterly monitoring, and analysis. The only other costs incurred under this category are for compliance with State surface water

regulations in the case of calcium carbide (see calcium carbide discussion below).

The RCRA 4004 compliance costs are for ground water protection. Specifically, this category covers landfill, burial, and reclamation costs as well as monitoring wells for facilities in states which do not have ground water related criteria.

Chlorine/Caustic Soda (Diaphragm Cell)

The major costs involve installation of monitoring wells for ground water protection. Most wells are required by recently enacted State regulations. The remainder are required by RCRA ground water criteria for plants in 13 States which do not have ground water regulations comparable to RCRA. In addition to ground water protection, some additional site improvements will be required to conform to RCRA closure requirements and surface water protection.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$900,000 for 90 monitoring wells at 30 plants.

Operating: \$210,000 annual cost, including \$4,000 for monitoring and \$3,000 for well depreciation at each of the 30 plants.

RCRA 4004-induced costs:

Capital: \$420,000. Most of this cost (\$360,000) is for disposal of brine mud and rubble inventories and for land reclamation at a few sites. The remainder (\$60,000) is for six monitoring wells at two sites in States which do not have ground water regulations.

Operating: \$14,000, including \$4,000 for monitoring and \$3,000 for well depreciation for each of two plants mentioned above.

Chlorine/Caustic Soda (Mercury Cell)

The major improvement required is installation of monitoring wells for ground water protection to meet State regulations. Non-hazardous wastes are generated at only six plants. All wastes from the remaining plants are hazardous.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$180,000 is for 18 monitoring wells at six plants.

Operating: \$42,000 annual cost including \$4,000 for monitoring
and \$3,000 for well depreciation at each of the six plants.

RCRA 4004-induced costs:

Capital: \$80,000 for closure expenses at six plants reclamation of
lagoon disposal areas.

Operating: No costs.

Potassium Chloride

Only monitoring wells for ground water protection will be required.
At seven of the eight sites, these are required by recent State regulations.
The costs at the remaining site are directly attributable to the RCRA ground
water criteria.

State and other Federal-induced costs:

Capital: \$210,000 is for 21 monitoring wells at seven plants.

Operating: \$49,000 including \$4,000 for monitoring and \$3,000 for well
depreciation at each of the seven plants.

RCRA 4004-induced costs:

Capital: \$30,000 is for three monitoring wells at one site.

Operating: \$7,000, including \$4,000 for monitoring and \$3,000 for well
depreciation at the one site mentioned above.

Potassium Sulfate

Potassium sulfate is produced at one facility which also produces
potassium chloride. Wastes are combined prior to disposal. Compliance costs

for potassium chloride, given above, therefore include those for potassium sulfate.

Alumina

Significant upgrading of waste handling and disposal procedures will be required to meet both RCRA criteria and State and other Federal regulations. Recently enacted State ground water protection regulations will necessitate monitoring well installation and use at several facilities. In addition, major site changes may be required at two locations to replace unlined waste disposal ponds to conform with RCRA-specified criteria for ground and surface water protection. This may require construction of new lined lagoon facilities and draining and restoration of the current lagoon systems. No plants reclaim waste disposal ponds when filled. Reclamation of these areas will be required to fulfill the site closure requirements specified by RCRA. No disposal site areas currently have leachate control systems intact under the disposal pond areas; however, eight of the 10 plants do have pond linings of sufficient thickness to preclude any leachate problems.

Compliance Costs---

State and other Federal-induced costs:

Capital: \$270,000 for 27 monitoring wells at nine plants. (One plant already has monitoring wells).

Operating: \$63,000 including \$4,000 for monitoring and \$3,000 for well depreciation at each of the nine plants.

RCRA 4004-induced costs:

Capital: \$41,300,000 for restoration of existing unlined ponds, construction of new ponds, and closure expenses. Specifically, this cost represents what is needed to reclaim 7,000 acres of lagoon area in present use at 10 sites and for construction of new lined lagoon facilities at two locations. Eight locations presently use clay-lined lagoons; the other two do not.

Operating: \$6,000,000 for site restoration at all 10 plant locations and for lining expenses at two plants.

Phosphorus

This is another product category where significant upgrading of current disposal practices may be required to meet RCRA and other State and Federal regulations. At most plants, monitoring wells will be required at disposal sites to meet recent State ground water regulations.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$270,000 for 27 monitoring wells at nine plants.

Operating: \$63,000, including \$4,000 for monitoring and \$3,000 for well depreciation for each of the nine plants.

RCRA 4004-induced costs:

Capital: No cost.

Operating: No cost.

Natural Soda Ash

Installation of monitoring wells to meet recent State ground water regulations at two locations is the only disposal site upgrading required for this industry category. All plants are located in Wyoming, which has had land reclamation laws in effect for many years.

Compliance Costs

State and other Federal-induced costs:

Capital: \$60,000 for six monitoring wells at two plants.

(Two other plants already have monitoring wells).

Operating: \$12,000, including \$4,000 for monitoring and \$3,000 for well depreciation at each of two sites.

RCRA 4004-induced costs:

Capital: No cost.

Operating: No cost.

Lime

Many sites will be required to install monitoring wells to comply with State ground water regulations. In addition, a few plants in States without ground water regulations will also require these wells to meet RCRA ground water criteria.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$4,200,000 for 420 monitoring wells at 140 plants. (About 30 plants either reprocess lime dust or sell it as off-grade material.)

Operating: \$980,000 including \$4,000 for monitoring and \$3,000 for well depreciation at each of the 140 plants noted above.

RCRA 4004-induced costs:

Capital: \$300,000 for 30 monitoring wells at 10 sites in the States which do not have ground water regulations.

Operating: \$70,000, including \$4,000 for monitoring and \$3,000 for well depreciation at each of the 10 sites mentioned above.

Hydrofluoric Acid

The costs for this category will be presented differently because of special considerations involved for some sites. The estimated compliance costs can be disaggregated as follows:

- Three plants which sell all of their waste gypsum will have no capital or operating costs.
- The remaining ten plants will each require three monitoring wells to meet recent state ground water regulations. These requirements will cost the industry \$300,000 in capital expenses and \$70,000 in annual operating costs for monitoring and 10 percent well depreciation expenses. Four of these plants will also incur the following added expenses:

- Two facilities will incur a combined annual expense of \$48,900 for reclamation of lagoon storage areas to comply with RCRA site closure requirements.
- One facility will incur similar closure costs distributed as follows:
 - \$60,000 to cover 40 acres of waste gypsum piles already located on the premises and,
 - Up to \$30,000 annual land reclamation expense to cover land-stored gypsum piles to be created during future years of operation
- One facility which land stores its wastes will also incur site closure expense. About \$135,000 will be needed for covering and seeding of stored waste piles from earlier years of operation and \$30,000 annual land reclamation expenses will be incurred to cover land-stored gypsum piles in future years of operation.

This last plant is unusual in that the gypsum is recovered from the process wastewater as anhydrite instead of dihydrate material. This novel recovery system was installed by the plant as part of an effort to develop a marketable gypsum co-product. Runoff waters from the recent waste piles at the site are weakly acidic, unlike other sites. However, the waste piles are located on top of a clay base, and all runoff from the piles goes to the plant wastewater treatment system before release. If the system has to be modified to eliminate runoff water acidity, additional capital costs of \$40,000 to \$6 million will be incurred. The former figure represents the cost of additional lime feeding equipment alone and the latter the cost of reworking the entire plant lagoon system. Increased annual operating expenses for the latter situation would involve \$360,000 for lime, plus as much as \$1.2 million for increased maintenance, pumping costs, and interest charges. As all runoff and drainage water from the waste piles is already treated and as the entire waste handling system is already clay-lined, these additional expenses would buy little environmental improvement and it is doubtful that they will be required.

In summary, aside from costs to meet state ground water monitoring requirements, the only added expenses likely to be required by this industry segment are:

\$48,900 annualized expenses for lagoon reclamation at two locations, and \$195,000 capital costs for inventory coverage and \$60,000 annual expense for waste covering at another two locations.

Borax

No costs. All wastes from this category are considered hazardous.

Solvay Process Soda Ash

No costs. The sole facility in this category already meets all of the RCRA and other State and Federal regulations for its non-hazardous wastes.

Titanium Dioxide (Sulfate Process)

No costs. All wastes from this category are considered hazardous.

Sodium Dichromate

No costs. All wastes from this category are considered hazardous.

Iron Oxide

Monitoring wells will have to be installed at most disposal sites. At all but one site, wells are required by recent State regulations. The remaining site will also require the monitoring wells to comply with RCRA ground water regulations.

Compliance Costs---

State and other Federal-induced costs:

Capital: \$270,000 for 27 monitoring wells at nine plants.

Operating: \$63,000, including \$4,000 for monitoring and \$3,000 for well depreciation at each of the nine plants.

RCRA 4004-induced costs:

Capital: \$30,000 for three monitoring wells at one site where the State does not have ground water regulations.

Operating: \$7,000 including \$4,000 for monitoring and \$3,000 for well depreciation at the one site mentioned above.

Lithium Carbonate

There are two facilities in this production category. One will require monitoring wells to meet recent State ground water regulations. Both plant disposal areas will require land reclamation to conform with RCRA closure criteria.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$30,000 for three monitoring wells at one plant.

Operating: \$7,000 including \$4,000 for monitoring and \$3,000 for well depreciation at one plant.

RCRA 4004-induced costs:

Capital: \$72,000, for land reclamation of existing stored waste areas at two plants.

Operating: \$8,000, annualized cost for land reclamation of future waste disposal sites.

Titanium Dioxide (Chloride Process)

No costs. All wastes from this category are considered hazardous.

Aluminum Sulfate

Monitoring wells will have to be installed at most active disposal sites. Most of these are required to meet recent State ground water regulations. A few will be required to meet RCRA criteria in States with no ground water regulations.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$1,920,000 for 192 monitoring wells at 64 plants.

Operating: \$450,000, including \$4,000 for monitoring and \$3,000 for well depreciation at 64 plants.

RCRA 4004-induced costs:

Capital: \$90,000 for nine monitoring wells at three plants in a State with no ground water regulations.

Operating: \$21,000, including \$4,000 for monitoring and \$3,000 for well depreciation at the three plant sites noted above.

Zinc Oxide

No costs. All wastes from this category are considered hazardous.

Antimony Oxide

Monitoring wells will have to be installed at four disposal sites to meet recent State ground water regulations.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$120,000 for 12 monitoring wells at four plant sites.

Operating: \$28,000 including \$4,000 for monitoring and \$3,000 for well depreciation at each of the four plant sites.

RCRA 4004-induced costs:

No costs.

Barium Sulfate

The one facility which will generate solid wastes in this production category plans to use commercial contractors to handle all waste disposal. It is assumed that the waste disposal site chosen already meets all regulations and that no additional costs will result. The plant presently discharges its wastes in waterborne form.

Manganese Sulfate

The one facility generating land-destined wastes in this category will require monitoring wells to comply with recent State ground water regulations. Lagoon restoration will also be required to meet RCRA closure criteria.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$30,000 for three monitoring wells at one plant.

Operating \$7,000. This cost includes \$4,000 for monitoring and \$3,000 for well depreciation at one plant.

RCRA 4004-induced costs:

Capital: \$60,000 for pond area reclamation at one plant.

Operating: \$5,000. Annualized cost for reclamation at one site.

Vanadium Pentoxide

The one facility producing this material from Idaho ferro-phosphorus will require monitoring wells to meet recent State ground water regulations. Reclamation of the currently used disposal lagoons will also be needed to meet RCRA closure requirements.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$30,000 for three monitoring wells at one plant.

Operating: \$7,000 including \$4,000 for monitoring and \$3,000 for well depreciation at one plant site.

RCRA 4004-induced costs:

Capital: No Costs.

Operating: \$3,000 for annual site restoration.

Calcium Phosphate

Most disposal sites will require monitoring wells to meet recent State ground water regulations. One disposal location is located in a State without such requirements and will need wells to meet RCRA ground water criteria.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$360,000 for 36 monitoring wells at 12 plants.

Operating: \$84,000 including \$4,000 for monitoring and \$3,000 for well depreciation at 12 plants.

RCRA 4004-induced costs:

Capital \$30,000 for three monitoring wells at one plant.

Operating: \$7,000 including \$4,000 for monitoring and \$3,000 for well depreciation at one plant.

Sodium Hypophosphite

There are two disposal sites used for the wastes from this product category. Both sites are already in compliance with all RCRA criteria, including closure requirements.

Compliance Costs—

State and other Federal-induced costs:

Capital: \$10,000. The solid wastes generated at the two plants that produce sodium hypophosphite are received and buried off site with other non-hazardous wastes generated from other processes. It is assumed that about 17 percent of the well and monitoring costs will be borne by this category. (The \$10,000 cost is approximately 17 percent of the total \$60,000 cost for six monitoring wells at the two plants involved.)

Operating: \$2,500. This represents approximately 17 percent of the total \$15,000 monitoring and well depreciation expenses at the two plants.

RCRA 4004-induced costs:

No costs.

Barium Carbonate

No costs. All wastes from this category are considered hazardous.

Strontium Carbonate

No costs. The wastes from this production category are in all cases mixed with those from barium carbonate production prior to disposal. As a result, the mixed wastes can be considered hazardous.

Sodium

Four of the five landfill locations used for burial of these wastes will require monitoring wells to meet recent State ground water regulations. All sites are already in compliance with the other RCRA related regulations.

Compliance Costs--

State and other Federal-induced costs:

Capital: \$120,000 for 12 monitoring wells at four plants. (The waste at the fifth plant is combined with the waste from a diaphragm cell chlor-alkali plant, and its cost is attributed to the chlorine plant.)

Operating: \$28,000 including \$4,000 for monitoring and \$3,000 for well depreciation at each of the four plants.

RCRA 4004-induced costs:

No costs.

Sodium Chlorate

No additional disposal site upgrading is necessary for the non-hazardous wastes from this production category. All non-hazardous wastes are currently landfilled at locations which were examined under other product categories (mostly chlorine/caustic soda diaphragm cell).

Chrome Yellow

No costs. All wastes from this category are considered hazardous.

Potassium Permanganate

No costs. The one landfill used for wastes from this production category is already in compliance with all RCRA and other Federal and State regulations.

Calcium Carbide

There is only one site in this production category which may have non-hazardous wastes requiring disposal. This plant has about 450,000 metric tons of by-product lime from earlier years of acetylene manufacture land-stored on its premises. Contacts with the plant have established that some or all

of this material may be salable over an unspecified period of time. For this material, there are two options:

Option 1: \$3,300,000. This option assumes that the lime inventory cannot be sold and that the producer will use a private contractor for disposing wastes at a landfill several miles from the plant. It can be viewed as a one-time capital expense since the producer is able to sell all wastes from current production. The cost (\$4.45/metric ton of waste) includes loading, transportation, waste burial, contingencies and a 12 percent cost of capital.

Option 2: \$3,000,000 This option assumes that the waste inventory can be sold over a period of time. The \$3.0 million is estimated as the cost for construction of an enclosure, including loading facilities and 12 percent cost of capital, to prevent rainwater contact with the waste lime piles. It is presumed that loading facilities will be required if the lime is marketed. (The \$3.0 million cost was derived from that received from a Kansas salt facility for construction of a similar structure for storage of about the same quantity of material to prevent runoff problems. Figures were provided in 1976 dollars and updated to 1978 dollars.) No credit is assumed for sale of the lime.

This cost can be viewed as a capital expenditure. Operating costs cannot be estimated because it is uncertain how long the inventory will have to be stored. Under either option, the costs are attributable to State surface water regulations; there are no RCRA 4004-induced costs.

VII. WASTE HANDLING ALTERNATIVES AND RECOVERY OPTIONS

One of the objectives of this study was to identify waste handling alternatives and resource recovery options that are being used or could be used by the inorganic chemicals industry. This includes process changes which would reduce the volume of wastes generated and/or alter its form so as to reduce adverse impacts on the environment, and enhance resource conservation and resource recovery. During our industry contacts, we solicited information about industry's plans or existing practices for waste handling alternatives and resource recovery options. The following were identified:

Potash

Small amounts of the wastes from potash have been sold locally for road salt and cattle salt applications. However, significant sales of the salt wastes are not practical because large markets are too far away from the plants and transportation costs would be prohibitive.

Alumina

Kaiser Aluminum has had an in-house program to develop methods for recovery of iron and residual alumina from the red mud wastes. To date, none of the methods has shown promise.

Kaiser also noted that more widespread use of high quality Surinam bauxite would reduce the volume of wastes generated. Use of the alternative raw material would be costly, though, and involve several million dollars in plant modifications.

Phosphorus

The phosphorus plants in the east have been able to sell all their slag wastes for use as a crushed stone substitute in roadbed construction. Because of limited markets, the western plants can sell only about two-thirds of the slag they generate. The rest is stockpiled. Transportation costs limit more widespread sale of these materials.

Over the last several years, recovery of elemental phosphorus from phosphy waste has been practiced at two of the plants. Significant amounts

of phosphorus may be available for recovery from phosphy water ponds at the seven other plants. Industry plans call for increased use of this technology in the near future. At least three other facilities are installing recovery systems.

Lime

About 25 percent of the lime dusts are recycled in the production process or sold as an off-grade product. Product applications include the following:

- Raw materials usage (in cement manufacturing).
- Agricultural lime.
- Waste acid neutralization.
- Flue gas desulfurization.

The sale of lime dusts for such uses is limited by local demand and requires further study.

Hydrofluoric Acid

Approximately 25 percent of the gypsum wastes are sold for use as a soil conditioner or construction material. The market for these applications is limited by local demand.

Titanium Dioxide

Sulfate Process--

Two plants sell a fraction of their waste ferrous sulfate; one sells 25 percent and the other, 10 percent. The demand for ferrous sulfate is limited and whatever is sold competes with that generated as a steel industry waste.

A possible market exists for the waste gypsum; however, it would have to compete with the gypsum generated as a waste in many other chemical processes.

Another possibility is the sale of iron oxides for use in colored cement; the market for this application is very limited.

Chloride Process--

Some of the ferric chloride wastes are sold. One plant already has 40 percent of this market, though, and expanded sales are not expected. The very limited market for iron oxide as a cement color also applies here.

Chlor-Alkali

Diaphragm Cell--

The use of barium for sulfate removal as a separate step in brine purification could allow for barium sulfate recovery and reuse. One plant in Texas is already doing this and uses the barium sulfate as a raw material for its on-site barium carbonate plant.

A possible use of the alkaline brine mud waste would be as a neutralization agent for acid wastes at nearby plants.

Use of metal anodes at the six plants still using lead graphite electrodes would eliminate the remaining lead wastes from the industry. This change is expected to occur for energy related reasons.

Mercury Cell--

One waste handling alternative is a process change involving the segregation of brine purification from the rest of the process; this would reduce the quantity of mercury bearing wastes and the costs of disposal. However, an energy penalty of 5×10^5 kcal (2×10^6 BTU) or \$3.30 per kkg (\$3.00 per ton) of chlorine product would be incurred because of this change. The energy is required to evaporate the brine for recovery of salt for process use.

Another waste handling alternative is a major process change requiring conversion to diaphragm cells. One plant in Louisiana, with a published capacity of 500,000 kkg (548,000 tons) per year, is currently undergoing this type of conversion.

Sodium

The option to recover barium sulfate in a separate brine purification step is also available for this industry as it was for diaphragm cell chlor-alkali plants. This material could then be sold as a feed for barium carbonate plants. Another possible option is to use the alkaline brine mud wastes as a neutralization agent for other acidic wastes.

Calcium Carbide

At four of the five calcium carbide plants, the solid wastes are sold as a low-grade lime. There is no market for the wastes from the fifth plant

at the present time because of the special problems associated with the type of furnace in use. However, the installation of a new furnace would allow it to market its wastes.

Chlorates

The chlorate wastes can be eliminated by using platinum electrodes in the production process. Seven of the twelve plants are already using platinum electrodes.

Chrome Yellow

More efficient recovery of the product in the manufacturing process would reduce the amount of wastes generated. One plant is currently accomplishing this by using an improved filtration system.

NEW TRENDS IN THE INDUSTRY

Although most process technology used in the inorganic chemicals industry is undergoing little change, an exception has been noted with respect to the electrolytic industries. In the chlor-alkali area, coated metal anodes have mostly replaced the old lead-graphite electrodes, eliminating all of the lead and most of the chlorinated hydrocarbon wastes. These metal anodes were utilized mainly because of their improved electrochemical characteristics which result in significant reductions in power consumption by the industry. At present, two types of coated metal anodes are known to be in use. The dimensionally stable anode (DSA) employs a ruthenium dioxide coated titanium electrode. The other anode, in use by one company, uses cobalt oxide coated titanium.

In the chlorates manufacturing industry, platinum coated electrodes have largely replaced lead-graphite electrodes. Again, this results in substantial power savings and waste reduction.

The electrolytic industries are undergoing rapid change as newer cell designs and electrode materials are coming into widespread use. New processes for the chlor-alkali industry, such as the membrane cell, are currently undergoing development and may be commercialized within the next decade. If this occurs, further declines in hazardous waste generation will be experienced and the chlor-alkali area may cease to be an area of major environmental concern.

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