

US EPA ARCHIVE DOCUMENT

ALUMINA & ALUMINUM

A. Commodity Summary

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

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

EXHIBIT 1

SUMMARY OF ALUMINA PROCESSING FACILITIES

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

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

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

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

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

EXHIBIT 2

SUMMARY OF ALUMINUM PROCESSING FACILITIES

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

⁵ Ibid.

B. Generalized Process Description

1. Discussion of Typical Production Processes

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

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

Metallurgical grade alumina is extracted from bauxite by the Bayer process and aluminum is obtained from this purified ore by electrolysis via the Hall-Heroult process. These processes are described below. Exhibits 3 and 4 present process flow diagrams for the Bayer process and the Hall-Heroult process.

2. Generalized Process Flow Diagram

Bayer Process

A process flow diagram of the Bayer process is shown in Exhibit 3. The primary purpose of a Bayer plant is to process bauxite to provide pure alumina for the production of aluminum. All bauxite refineries share five common process steps: (1) ore preparation; (2) bauxite digestion; (3) clarification; (4) aluminum hydroxide precipitation; and (5) calcination to anhydrous alumina. Additional operations include steam and power generation, heat recovery to minimize energy consumption, process liquor evaporation to maintain a water balance, impurity removal from process liquor streams, classification and washing of trihydrate, lime causticization of sodium carbonate to sodium hydroxide, repair and maintenance of equipment, rehabilitation of residue disposal sites, and quality and process control. Each step in the process can be carried out in a variety of ways depending upon bauxite properties and optimum economic tradeoffs. Each step of the Bayer process is discussed in further detail below.⁷

Ore Preparation

Bauxite mining processes depend largely on the nature of the ore body. If the ore is not uniform, contains an excessive amount of kaolin, or is difficult to handle due to the moisture content, blending operations, physical beneficiation, and bauxite drying are used. Grinding is designed to produce feed material small enough to ensure easy alumina extraction, yet coarse enough to avoid clarification problems with bauxite residue. Uniform, consistent, easily digested bauxite slurry is formed by blending properly ground bauxite slurry in slurry storage "surge" tanks prior to digestion.⁸

Bauxite Digestion

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

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

⁷ "Aluminum Compounds," Kirk-Othmer Encyclopedia of Chemical Technology, 4th ed., Vol. II, 1991, pp. 254-261.

⁸ Ibid.

practice of "outside" causticization of dilute pregnant liquors in the residue washing area of the plant, digestion lime additions are still made to control impurities such as phosphorus pentoxide.⁹

Clarification

Clarification is necessary to separate bauxite residue solids from the supersaturated pregnant liquor near its boiling point. Coarse particles, called sand because of their high silica content, are usually removed by cycloning followed by washing on sand classifiers prior to disposal. Iron oxide, silica, and other undigested portions of the ore are also removed in settling, thickening, and filtration units, and sent to treatment and disposal units. These wastes are commonly called red and brown muds; these two wastes are RCRA special wastes and are not subject to regulation.¹⁰ In most plants, the fine fraction of residue is settled in raking thickeners with the addition of flocculants to improve the clarity of thickener overflow. The concentrated thickener underflow is washed before disposal in countercurrent decantation washers, on vacuum drum-type filters, or a combination of both. Thickener overflow is filtered to remove the final traces of solids and ensure product purity. Kelly-type pressure filters are most widely used, but some plants use sand filters in which the liquor is filtered by gravity through a bed of properly sized sand. Filtered solids are removed from filter press cloth by hosing and are elutriated from the sand by backwashing.¹¹

Aluminum Hydroxide Precipitation

Precipitation is the heart of the Bayer process where recovery of the $\text{Al}(\text{OH})_3$ from process liquors occurs in high yield and product quality is controlled. In 1988, practically all of the hydroxide was obtained by Bayer processing and 90% of it was calcined to metallurgical grade alumina (Al_2O_3). The liquor is usually seeded with fine gibbsite seed from previous cycles to initiate precipitation. Precipitation can be continuous or batch. Modern plants use the continuous system. Slurry leaving precipitation is classified into a coarse fraction and one or more fine fractions, usually by elutriation in hydroclassifiers. In smelting grade alumina plants, the coarse fraction, called primary product, is sent to calcination; the fine fractions, called secondary and tertiary seed, are recycled to be grown to product size.¹²

Calcination to Anhydrous Alumina

Calcination, the final operation in the Bayer process for production of metallurgical grade alumina, is done either in rotary kilns or fluid bed stationary calciners. Prior to calcination, the process liquor is washed from the $\text{Al}(\text{OH})_3$ using storage tanks and horizontal vacuum filters. During heating, the trihydroxide undergoes a series of changes in composition and crystal structure but essentially no change in particle shape. The product is a white powder and consists of aggregates of differing sizes.¹³

Evaporation and Impurity Removal

Evaporation over and above that obtained in the cooling areas from flashed steam is usually required to maintain a water balance by accounting for the dilution arising from residue and $\text{Al}(\text{OH})_3$ washing, free moisture in the ore, injected steam, purge water, and uncontrolled dilutions. Evaporation also serves to concentrate impurities in the liquor stream such as sodium oxalate (a product of organics degradation) facilitating the removal of impurities.¹⁴

Hall-Heroult Process

Reduction

⁹ Ibid.

¹⁰ U.S. Environmental Protection Agency, "Aluminum Production," from Report to Congress on Special Wastes from Mineral Processing, Vol. II, Office of Solid Waste, July 1990, pp. 3-1 - 3-15.

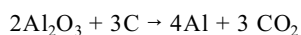
¹¹ "Aluminum Compounds," Op.Cit., pp. 254-261.

¹² Ibid.

¹³ Ibid.

¹⁴ Ibid.

Since the development of the Hall-Heroult process, nearly all aluminum has been produced by electrolysis of alumina dissolved in a molten cryolite based bath. Molten aluminum is deposited on a carbon cathode, which serves also as the melt container. Simultaneously, oxygen is deposited on and consumes the cell's carbon anodes. The overall reaction is¹⁵:



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

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

¹⁵ Ibid.

EXHIBIT 3
THE BAYER PROCESS

EXHIBIT 3 (continued)

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Source: Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume 2, 1989.

EXHIBIT 4
THE HALL-HEROULT PROCESS

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Source: Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Volume II, 1989.

Fluxing and Degassing

The molten aluminum collected in the bottom of the electrolytic pots is tapped and conveyed to holding furnaces for subsequent refining and alloying. Refining consists of fluxing to remove impurities and degassing to reduce entrapped hydrogen gas in the molten aluminum. These two operations are often performed prior to casting. Degassing is performed by injecting chlorine, nitrogen, argon, helium, and mixtures of chlorine and inert gases into the molten aluminum. Hydrogen desorbs into the chlorine bubble due to the partial pressure difference between the elements. The addition of a gas to the melt also mixes the aluminum to assure that all materials added concurrently for alloying are distributed evenly in the molten aluminum. Chlorine gas reacts with trace element impurities to form insoluble salt particles. These salt particles and the metal oxide impurities rise to the surface of the molten bath through specific gravity differences and flotation, respectively. The impurities collect at the surface of the molten metal and are skimmed and removed from the furnace.¹⁶

Casting

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

Stationary casting is used to cast *pigs and sows* (ingots). In this method of casting, the molds are stationary and the contact cooling water (if used) generally evaporates.¹⁷

There are two methods of *direct chill casting*, vertical and horizontal. Vertical direct chill casting is characterized by continuous solidification of the metal while it is being poured. The length of the ingot or billet cast using this method is determined by the vertical distance it is allowed to drop rather than by mold dimensions. Molten aluminum is tapped from the smelting furnace and flows through a distributor channel into a shallow mold. Noncontact cooling water circulates within this mold, causing solidification of the aluminum. As the solidified aluminum leaves the mold, it is sprayed with contact cooling water to reduce the temperature of the forming ingot or billet. The cylinder descends into a tank of water, causing further cooling of aluminum as it is immersed. When the cylinder reaches its lowest position, pouring stops, the ingot is removed, and the process is repeated to create another ingot. Horizontal chill casting is performed in much the same manner as vertical chill casting. The main difference is that the cast aluminum is conveyed from the mold in the horizontal direction rather than vertically.¹⁸

In *continuous rod casting*, a ring mold is fitted into the edge of a rotating casting wheel. Molten aluminum is then poured into the mold and cools as the mold assembly rotates. After the wheel has rotated about 160 degrees, the pliable aluminum bar is released. Immediately following release from casting, the rod is transported on conveyers to a rolling mill where the diameter of the rod is reduced.¹⁹

In *shot casting*, aluminum shot is used as a deoxidant. Molten metal is poured into a vibrating feeder, where droplets of molten metal are formed through perforated openings. The droplets are cooled in a quench tank.²⁰

Anode Paste Plant

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

¹⁶ U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Vol II, Office of Water Regulations Standards, May 1989.

¹⁷ Ibid.

¹⁸ Ibid.

¹⁹ Ibid.

²⁰ Ibid.

Anode Bake Plant

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

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

In the tunnel kiln, a controlled atmosphere is maintained to prevent oxidation of the carbon anodes. Green anode blocks are loaded on transporter units that enter the kiln through an air lock, pass successively through a preheating zone, a baking zone, and a cooling zone, and leave the kiln through a second air lock. The refractory beds of the cars are sealed mechanically to the kiln walls to form the muffle chamber and permit movement of the units through the kiln. The muffle chamber is externally heated by combustion gases and the products of combustion are discharged through an independent stack system. Effluent gases from the baking anodes may be introduced into the fire box so as to recover the fuel value of hydrocarbons and reduce the quantity of unburned hydrocarbons. Baked anodes are delivered to air blast cleaning machines using fine coke as blasting grit. Fins, scrafs, and adherent packing are removed by this treatment, and the baked anodes are then transferred to the rod shop where the electrodes are attached.²¹

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

Spent potliner wastes (SPL) from aluminum reduction have become one of the aluminum industry's biggest environmental concerns. Reynolds developed a process for detoxifying SPL in which the SPL was blended with limestone and an antiagglomeration agent and thermally treated in a rotary kiln. The process is successful in destroying cyanides and reduced the concentration of soluble fluorides in the kiln residue. The cyanides are destroyed by oxidation and the majority of soluble fluoride salts are converted to stable, insoluble calcium fluoride by reaction with limestone. The process was developed and utilized for more than 2 years on an industrial scale at Reynolds' idled Hurricane Creek Alumina Plant in Bauxite, AR. More than 300,000 tons of SPL reportedly were treated successfully during this period.²² In fact, Reynolds received a RCRA delisting variance for this waste stream.

An alternative treatment known as the COMTOR process was developed at Comalco's Research Center in Melbourne, Australia. The process has three stages--feed preparation, calcination, and fluoride recovery. Crushing the SPL before treatment reportedly improved the rate and quality of the detoxification process. The COMTOR process utilized a new type of calciner, known as a Torbed. Calcination reportedly was the most effective method for reducing the leachable cyanide content of the SPL. Ash treatment recovered the fluoride values for recycling directly to the electrolytic cell. Once the cyanide was destroyed and the fluorides either recovered or stabilized, the residue reportedly passed the standard leach tests and was no longer considered toxic.²³

The Florida Institute of Phosphate Research (FIPR) reportedly has developed a dewatering process that may achieve promising results on red mud waste streams from the Bayer process operations. The FIPR process consists of adding pulp fibers with a polyacrylamide flocculent. The fibers assist in the formation of large flocs that have the physical stability to withstand normal industrial dewatering techniques.²⁴

Biological methods of converting sodium oxalate, generated from the Bayer process production of alumina, have been tested. The use of micro-organisms to dispose of sodium oxalate was said to be far simpler and cheaper than the currently employed burning and landfilling methods of disposal.²⁵

Research on carbon removal from Bayer liquors has also been studied. Manganese dioxide treatment also was

²¹ Ibid.

²² Patricia Plunkert, 1992, Op. Cit., pp. 183-203.

²³ Ibid.

²⁴ Ibid.

²⁵ Ibid.

found to cause a beneficial decrease in the soda content of the alumina and that a small reduction in the total organic carbon levels with this treatment also may be significant in improving the viscosity of the liquor.²⁶

4. Beneficiation/Processing Boundaries

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

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

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

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

C. Process Waste Streams

Cooling tower blowdown was generated at a rate of 8,000 metric tons per year in 1991.²⁷ Since this waste stream is non-uniquely associated, the Agency did not evaluate it further.

1. Extraction/Beneficiation Wastes

Water softener sludge. The 1991 total waste volume generation rate for this waste stream was 2,000 metric tons per year.²⁸ Since this waste is not a mineral processing waste, the Agency did not evaluate it further.

2. Mineral Processing Wastes

Alumina Production

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

²⁶ Ibid.

²⁷ Ibid.

²⁸ U.S. Environmental Protection Agency, Newly Identified Mineral Processing Wastes Characterization Data Set, Vol. I, Office of Solid Waste, August 1992, pp. I-2 - I-8.

Evaporator salt waste. The 1991 total waste volume generation rate for this waste stream was 2,000 metric tons per year.²⁹

Bauxite residue. The 1991 total waste volume generation rate for this waste stream was 137,000 metric tons per year.³⁰ Lagooning behind retaining dikes built around clay-lined ground is commonly used for disposal of bauxite residue. Leaks into aquifers have motivated installation of underdrains between the residue and a clay-sealed, plastic-lined lake bottom. Another method of disposal is called semidry disposal, dry-stacking, or the drying field method. This method takes advantage of the thixotropic nature of the residue. The residue is concentrated by vacuum filtration or other means to 35-50% solids. Using agitation and/or additives, the viscosity of the concentrated slurry is reduced so it can be pumped to the disposal area where it flows like lava. The slurry is called nonsegregating because neither water nor sand separate from it. As viscosity increases, the flow stops. There is no free water on the surface of the impoundment, so the deposited residue dries and cracks whenever it is not raining. When the percent solids approaches 70-75%, bulldozers can work on the deposit.³¹

Waste alumina. The 1991 total waste volume generation rate for this waste stream was 7,000 metric tons per year.³²

Spent cleaning residue. The 1991 total waste volume generation rate for this waste stream was 3,000 metric tons per year.³³

Pisolites. Kaiser, in Gramercy, LA reported generating 72,920 metric tons of this waste in 1988. Reportedly, this waste was either sold for construction of farm roads or sent to a pisolite storage pile which is lined with an in-situ clay barrier.³⁴

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

Red and brown muds result from the clarification step of the Bayer process and are RCRA special wastes. The 1991 total waste volume generation rate for this waste stream was 2,800,000 metric tons per year.³⁵ The red and brown muds are routed to large on-site surface impoundments known as red and brown mud lakes. In these lakes, the red and brown muds settle to the bottom and the water is removed, treated, and either discharged or reused. The muds are not removed, but are accumulated and disposed in place. The muds dry to a solid with a very fine particle size. The impoundments that receive the muds typically have a surface area of between 44.6 and 105.3 hectares. The depth of the impoundments ranges from 1 to 16 meters and averages 7 meters. As of 1988, the quantity of muds accumulated on-site ranged from 500,000 to 22 million metric tons per facility, with an average of 9.7 million metric tons per facility.³⁶

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

Aluminum Production

²⁹ Ibid.

³⁰ Ibid.

³¹ "Aluminum Compounds," Op. Cit., pp. 254-261.

³² U.S. Environmental Protection Agency, 1992, Op. Cit., pp. I-2 - I-8.

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

³⁴ RTI Survey, Kaiser, Gramercy, LA, 1988, ID# 100339.

³⁵ Ibid.

³⁶ U.S. Environmental Protection Agency, Op. Cit., 1990, 3-1 - 3-15.

APC dust/sludge is a possible waste stream from aluminum production operations including electrolysis, fluxing, degassing, and anode production. Emissions may consist of unreacted chlorine and aluminum chloride gas, aluminum oxide, sulfur, fluoride, hydrocarbons, and organics.³⁷ Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Flue dust. The 1991 waste generation rate was 39,000 metric tons per year.³⁸ Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Sweepings. The 1991 waste generation rate was 23,000 metric tons per year.³⁹ Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Electrolysis waste. Electrolysis wastes include fluoride emissions and hydrocarbon fumes. Both sodium tetrafluoroaluminate gas and entrained liquid solidify to form fluoride particulates. Treatment consists of dry scrubbers that catch particulates and sorb HF on alumina that is subsequently fed to the cells. Nearly all the fluoride evolved is fed back into the cell.⁴⁰ Hydrocarbon fumes are generally disposed of by burning. This waste is generated at a rate of 58,000 metric tons per year (adjusted from a 1991 reported value to reflect recent changes in the sector) and may be toxic for lead.⁴¹ This waste is classified as a sludge.

Baghouse bags and spent plant filters. The 1991 waste generation rate was 19,000 metric tons per year.⁴² Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Skims. The 1991 waste generation rate was 20,000 metric tons per year. This waste may contain traces of sodium, calcium, lithium, and aluminum oxide.⁴³ Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

Discarded Dross. The 1991 waste generation rate was 126,000 metric tons per year. This waste may contain traces of sodium, calcium, lithium, and aluminum oxide.⁴⁴ Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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

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

³⁷ U.S. Environmental Protection Agency, 1989. Op. Cit., Vol. II.

³⁸ Ibid.

³⁹ Ibid.

⁴⁰ "Aluminum Alloys," 1992, Op. Cit., pp. 190-212.

⁴¹ U.S. Environmental Protection Agency, 1992, Op. Cit., pp. I-2 - I-8.

⁴² Ibid.

⁴³ Ibid.

⁴⁴ Ibid.

⁴⁵ Ibid.

⁴⁶ Ibid.

Cryolite recovery residue. The 1991 waste generation rate was 30,000 metric tons per year.⁴⁷ This waste may contain high levels of lead. Management of this waste includes disposal in an unlined surface impoundment.⁴⁸ Existing data and engineering judgement suggest that this material does not exhibit any characteristics of hazardous waste. Therefore, the Agency did not evaluate this material further.

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

Spent potliners. The 1991 waste generation rate was 118,000 metric tons per year.⁵⁰ This waste stream may contain toxic levels of arsenic and selenium as well as detectable levels of cadmium, chromium, barium, lead, mercury, silver, sulfates, and cyanide. This waste is generally managed through landfilling, indefinite "storage," or cathode reprocessing. Cathode reprocessing serves a hazardous waste treatment function by reducing waste volume, and incidentally recovering cryolite. Cathode reprocessing consists of grinding the spent potliners in a ball mill and then leaching with caustic to solubilize fluoride. Undigested cathode material is separated from the leachate using sedimentation and then sent to lagoons. Sodium aluminate is then added to the leachate to initiate the precipitation of cryolite and a second solid-liquid separation is performed to recover cryolite, which can be reused in the electrolytic cell. Lime is added to the supernatant to precipitate calcium fluoride and a third solid-liquid separation is performed. The resulting supernatant is then routed back to the front of the process and used for leaching. Blowdown from the system varies from plant to plant but it is universally used as potline scrubber liquor make-up when wet potline scrubbers are used. It is also common to route potline scrubber liquor through the cathode reprocessing circuit. In this way, fluoride concentrations of the scrubber liquor are controlled and recycling is possible. Spent potliners are listed wastes, KO88.

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

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

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

D. Ancillary Hazardous Wastes

Ancillary hazardous wastes may be generated at on-site laboratories, and may include used chemicals and liquid samples. Other hazardous wastes may include spent solvents (e.g., petroleum naphtha), acidic tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, waste oil (which may or may not be hazardous), and other lubricants.

⁴⁷ Ibid.

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

⁴⁹ U.S. Environmental Protection Agency, 1992, Op.Cit., pp. 1-2 - 1-8.

⁵⁰ Ibid.

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

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