

US EPA ARCHIVE DOCUMENT

BERYLLIUM

A. Commodity Summary

Beryllium (Be) is used as an alloy, oxide or metal in electronic components, electrical components, aerospace applications, defense applications, and other Applications.¹ Beryllium-copper alloys account for about 75 percent of the United States annual consumption of beryllium on a metal equivalent basis. These alloys, most of which contain about two percent beryllium are used because of their high electrical and thermal conductivity, high strength and hardness, good fatigue and corrosion resistance, and non-magnetic properties.²

Beryllium is a recognized constituent in some 40 minerals. Only beryl, an aluminosilicate ($3\text{BeO}\cdot\text{Al}_2\text{O}_3\cdot 6\text{SiO}_2$) containing 5 to 13 percent beryllium oxide (BeO), and bertrandite ($\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$), which occurs as tiny silicate granules containing less than one percent BeO, are commercially available as beryllium ores.³ A BeO content of 10 percent is considered necessary for the economic extraction of beryllium from beryl and bertrandite ores. However, bertrandite ores are still considered a commercially viable source of beryllium because of the large reserves present, open-pit mining, and the fact that beryllium may be extracted by leaching with sulfuric acid. In fact, the majority of beryllium produced is now obtained from bertrandite.⁴

The major deposits of beryllium in the United States are bertrandite deposits in the Spor Mountains of Utah. Brush Wellman, Inc. bought the mineral rights to these deposits and began mining in the 1960's.⁵ Its plant in Delta, Utah, is the only commercial beryllium extraction and production plant operating in the Western world.⁶ The Delta plant uses both beryl and bertrandite ores as inputs for the production of beryllium hydroxide. While the bertrandite ore is mined on-site using open-pit methods, the beryl ore is imported primarily from Brazil. However, beryl deposits also occur in China, Argentina, India, Russia, and some African countries. Beryl is usually obtained as a by-product from mining zoned pegmatite deposits to recover feldspar, spodumene, or mica.⁷ Three other facilities process the beryllium hydroxide to produce beryllium metal, alloy or oxide. Exhibit 1 presents the name, location, the type of processing, input material and product for each of the beryllium processing facilities. Exhibit 2 presents general site information on the Delta, UT facility.

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

² U.S. Bureau of Mines, "Beryllium in 1992," Mineral Industry Surveys, April 1993, p. 3.

³ Brush Wellman, Comments of Brush Wellman Inc. on EPA's Proposed Reinterpretation of the Mining Waste Exclusion, December 30, 1985, p. 1.

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

⁵ "From Mining to Recycling," Metal Bulletin Monthly — MBM Copper Supplement, 270, 1993, p. 27.

⁶ Deborah A. Kramer, January 1995, Op. Cit., p. 28.

⁷ "Beryllium and Beryllium Alloys," 1992, Op. Cit., p. 126.

EXHIBIT 1

SUMMARY OF PRIMARY AND SECONDARY BERYLLIUM ORE PROCESSORS^a

Facility Name	Location	Type of Process	Input Material	Products
Brush Wellman	Delta, UT	Primary	Ores	Be(OH) ₂
Brush Wellman	Elmore, OH	Secondary	Be(OH) ₂	Be Metal and Alloys
NGK Metals	Revere, PA	Secondary	Be(OH) ₂	Be Metal

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

EXHIBIT 2

SITE INFORMATION

Facility Name	Facility Location	Potential Factors Related to Sensitive Environment
Brush Wellman, Inc.	Delta, Utah	<ul style="list-style-type: none">• Brush Wellman facility located 10 miles north of Delta, Utah• Nearest resident lives 5 miles from Brush Wellman facility• Brush Wellman facility is not located in: a 100-year floodplain, area designated as wetland, Karst terrain, fault area, or an endangered species habitat• No public drinking water wells are located within 1 mile of the Brush Wellman facility• Private drinking water wells are located within 1 mile of the Brush Wellman facility

B. Generalized Process Description

1. Discussion of Typical Production Processes

At its mining site in Delta, Utah, Brush Wellman treats bertrandite ore using a counter-current extraction process to produce beryllium sulfate, BeSO₄. A second route, using the Kjellgren-Sawyer process, treats the beryl ore and provides the same beryllium sulfate intermediate. The intermediates from the two ore extraction processes are combined and fed to another extraction process. This extraction process removes impurities solubilized during the processing of the bertrandite and beryl ores and converts the beryllium sulfate to beryllium hydroxide, Be(OH)₂. The beryllium hydroxide is either sold, or sent off-site to either be converted to beryllium fluoride, BeF₂, which is then catalytically reduced to form metallic beryllium, converted to Beryllium oxide, or converted to beryllium alloys.

2. Generalized Process Flow Diagram

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

Part 1: Extraction of Beryllium as Beryllium Sulfate

Processing of bertrandite and imported beryl ores takes place at the Brush Wellman plant in Delta, Utah. Even though beryllium is extracted from both ores as beryllium sulfate, there are significant differences in the two extraction procedures. For example, the beryl extraction procedure requires five 15-foot diameter thickeners, while the bertrandite process uses eight 90-foot diameter thickeners.⁸

Bertrandite Ore. The bertrandite ore is crushed, sized, and wet milled to provide a pumpable slurry of particles below 840 μm .⁹ The slurry is leached with sulfuric acid, H_2SO_4 , at moderate temperatures (about 95°C) to solubilize the beryllium. The resulting beryllium sulfate solution is separated from unreacted solids using thickeners and counter-current decantation (CCD). The solids from the thickener underflow are discarded to a tailings pond.¹⁰

Beryl Ore. In contrast to bertrandite, beryl ore contains beryllium in a tightly bound crystalline structure. Therefore, in order to effectively leach the beryllium with sulfuric acid, it is first necessary to destroy the crystalline structure. The Kjellgren-Sawyer process is used commercially for the extraction of beryllium from beryl. In this process, the ore is crushed, melted at 1650°C, and quenched by pouring the molten ore into water. The resulting noncrystalline glass (frit) is heat treated at 900-950°C to further increase the reactivity of the beryllium component. After grinding to <74 μm , a slurry of the frit powder is reacted with concentrated sulfuric acid at 250-300°C to produce soluble beryllium sulfate and aluminum sulfate, $\text{Al}_2(\text{SO}_4)_3$.¹¹ The spent solid fraction is separated from the beryllium sulfate solution using thickeners and CCD and discarded to a tailings pond. The beryllium sulfate solutions from the two extraction procedures are combined and continue to the next step of the process, the production of beryllium hydroxide.¹²

In the past, the beryllium sulfate solution produced from the extraction of beryl ore was neutralized with ammonia in order to separate the bulk of the aluminum as ammonium alum. The ammonium alum crystals were then removed by centrifugation. Organic chelating agents, such as the sodium salt of ethylenediaminetetraacetic acid and triethanolamine, were added to the alum-free solution in the presence of sodium hydroxide to form a solution of sodium beryllate. Heating the solution to just below its boiling point precipitated a granular beryllium hydroxide which was recovered by continuous centrifugation.¹³

⁸ U.S. Environmental Protection Agency, "Beryllium," 1988 Final Draft Summary Report of Mineral Industrial Processing Wastes, 1988, p. 3-47.

⁹ Crushing, sizing, and wet milling are shown as physical processing in Exhibit 1.

¹⁰ Brush Wellman, Comments of Brush Wellman Inc. on EPA's Proposed Reinterpretation of the Mining Waste Exclusion, Revised November 21, 1988, p. 8.

¹¹ Crushing, melting, quenching, heat treating, and grinding are shown as physical treatment in Exhibit 1.

¹² Brush Wellman, 1988, Op. Cit., pp. 8-9.

¹³ "Beryllium and Beryllium Alloys," Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. IV, 1978, p. 808.

EXHIBIT 3 Graphic Not Available.

PROCESS FLOW DIAGRAM FOR PRODUCTION OF METALLIC BERYLLIUM

Part 2: Production of Beryllium Hydroxide from Beryllium Sulfate

During the extraction processes performed on the bertrandite and beryl ores, elements other than beryllium (e.g., aluminum, iron, and magnesium) are solubilized and must be removed in order to prevent product contamination. Kerosene containing di(2-ethylhexyl)phosphate is used to remove some of the impurities from the beryllium sulfate solution. By repeatedly mixing the aqueous solution and the organic extractant in a counter-current flow pattern at a slightly elevated temperature, all of the beryllium is extracted into the organic phase. The aqueous stream (i.e., raffinate) from the extraction operation contains all of the magnesium (Mg) and most of the aluminum (Al) found in the beryllium sulfate solution. The raffinate is discarded to a tailings pond.¹⁴

The most concentrated organic relative to beryllium in the system is referred to as the loaded organic. By contacting the loaded organic stream with a solution of ammonium carbonate, the extraction process is reversed. The beryllium is stripped from the organic phase to the aqueous phase as ammonium beryllium carbonate. Use of a small volume of aqueous ammonium carbonate, in relation to the loaded organic stream, produces an almost 10-fold increase in beryllium concentration.¹⁵ Heating the strip solution to about 70°C causes the iron (Fe) and remaining aluminum to precipitate as hydroxides or carbonates, which are removed by filtration. These precipitates are leached with sulfuric acid to solubilize any additional beryllium sulfate.¹⁶ A portion of the leaching solution is recycled to the beginning of the extraction process, while the balance is discarded as slurry to a tailings pond. The stripped organic phase is treated with sulfuric acid to recover the di(2-ethylhexyl)phosphate. Some of the organic phase is recycled to the beginning of the extraction process, while the remainder is discarded with the raffinate.¹⁷

Heating the ammonium beryllium carbonate solution to 95°C liberates part of the ammonia (NH₃) and carbon dioxide (CO₂) and causes the precipitation of beryllium carbonate, BeCO₃. The beryllium carbonate is separated on a rotary drum filter and may be drummed as an intermediate product. However, the beryllium carbonate may also be reslurried in deionized water and processed to beryllium hydroxide. Heating the beryllium carbonate slurry to 165°C in a pressure vessel liberates the remaining carbon dioxide and the resulting beryllium hydroxide is recovered by filtration.¹⁸ The barren filtrate streams from the two filtration operations are discarded to a tailings pond. The stream from the first filtration operation contains the uranium which was solubilized in the ore extraction processes. Instead of disposing of the uranium-bearing waste in a tailings pond, the stream is sometimes transferred to solar ponds for storage and concentration of the uranium. The uranium is subsequently extracted as uranium oxide, UO₄, and drummed. The wastewater generated in the uranium extraction process is disposed of in a tailings pond.¹⁹

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

Part 3: Production of Beryllium Metal, Oxide and Alloys

Production of Metallic Beryllium. Brush Wellman uses the Schwenzfeier process to prepare a purified, anhydrous beryllium fluoride for reduction to beryllium metal. The first step of this process involves dissolving beryllium hydroxide in ammonium bifluoride to yield a solution of ammonium fluoroberyllate at pH 5.5. The solution is neutralized by adding solid calcium carbonate, CaCO₃, and then heated to 80°C to precipitate any residual aluminum. Lead dioxide, PbO₂, is added to the solution to precipitate manganese as insoluble manganese dioxide, MnO₂, and chromium as insoluble lead chromate, PbCrO₄. After filtration, ammonium sulfide is added to the filtrate to remove any heavy-metal impurities and any solubilized lead from the lead dioxide treatment. Following another filtration step, ammonium fluoroberyllate is crystallized by co-current evaporation under vacuum. The crystals are continuously removed by centrifugation and washed lightly, while the mother liquor and washings are returned to the

¹⁴ "Beryllium and Beryllium Alloys," 1992, Op. Cit., p. 129.

¹⁵ Brush Wellman, 1988, Op. Cit., p. 11.

¹⁶ ICF Incorporated, Brush Wellman: Mineral Processing Waste Sampling Visit — Trip Report, August 1989, p. 2.

¹⁷ "Beryllium and Beryllium Alloys," 1992, Op. Cit., p. 129.

¹⁸ Ibid.

¹⁹ Brush Wellman, December 30, 1985. Op. Cit., p. 6.

evaporator.²⁰ The ammonium fluoroberyllate is charged into inductively heated, graphite-lined furnaces where it is thermally decomposed to beryllium fluoride and ammonium fluoride. The ammonium fluoride is vaporized into fume collectors for recycle to the dissolution operation, whereas the molten beryllium fluoride is removed from the bottom of the furnace and solidified as a glassy product on water-cooled casting wheels.²¹

The beryllium fluoride is then reduced by magnesium metal (Mg) at a stoichiometric ratio of 1 BeF₂ : 0.7 Mg. In this process, magnesium metal and beryllium fluoride are charged into a graphite crucible at a temperature of about 900°C. The excess beryllium fluoride produces a slag of magnesium and beryllium fluorides having a melting point substantially below that of beryllium metal. The excess BeF₂ also dissolves beryllium oxide, which prevents the formation of an oxide film on the beryllium particles and assists in the coalescence of the metal.²²

When the exothermic reaction is completed, the reaction products are heated to about 1300°C to allow molten beryllium to separate and float on top of the slag. The molten beryllium and slag are then poured into a graphite receiving pot where both solidify. The reaction product is then crushed and water-leached in a ball mill. The excess beryllium fluoride quickly dissolves, causing disintegration of the reaction mass and liberation of the beryllium metal as spherical pebbles. The leach liquor in this step is continuously passed through the ball mill in order to remove the fine, insoluble magnesium fluoride (MgF₂) particles formed during the reduction reaction. The magnesium fluoride is ultimately separated from the leach liquor and discarded. The leach liquor, which includes the excess beryllium fluoride, is then recycled as part of the input for making ammonium fluoroberyllate. The beryllium metal pebbles contain 97 percent beryllium along with entrapped reduction slag and unreacted magnesium. To remove these impurities, the metal is melted in induction furnaces under a vacuum. The excess magnesium and beryllium fluoride from the slag vaporize and are collected in suitable filters. Nonvolatiles, such as beryllium carbide (Be₂C), beryllium oxide, and magnesium fluoride, separate from the molten metal as a dross that adheres to the bottom of the crucibles. The purified beryllium metal is poured and cast into ingots of 150-200 kilograms.²³

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

²⁰ Evaporation, centrifugation, and washing are shown as processing in Exhibit 1.

²¹ "Beryllium and Beryllium Alloys", 1992, Op. Cit., pp. 129-130.

²² Ibid., p. 130.

²³ "Beryllium and Beryllium Alloys," 1978, Op. Cit., p. 810.

EXHIBIT 4 Graphic Not Available.

PROCESS FLOW DIAGRAM FOR PRODUCTION OF BERYLLIUM OXIDE

and the mother liquor is recycled to the beryllium hydroxide dissolver. The beryllium sulfate is calcined in gas fired furnaces at about 1100°C to beryllium oxide. The exhaust gas from the calcining furnace is scrubbed in caustic scrubbers to remove sulfur dioxide. The scrubber water is sent to treatment.²⁴

Production of Beryllium-copper alloys. Beryllium hydroxide, electrolytic copper and carbon are combined in an electric arc furnace to make beryllium-copper master alloy. The resultant melt, containing about four percent beryllium is cast into ingots. Remelting master alloy ingots with additional copper and other alloying elements yields the desired beryllium-copper alloy, which is then cast into slabs or billets. Slabs of beryllium copper alloys are processed further into strip or plate, and billets are extruded into tube, rod, bar, and wire products.²⁵

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

The Fluoride process, an alternative to the Kjellgren-Sawyer process, converts the beryllium oxide found in beryl ore to a water-soluble form by roasting with fluxes. In this process, pulverized beryl ore is roasted with sodium fluorosilicate at approximately 750°C to form slightly soluble sodium fluoroberyllate. The reaction products are extruded as wet briquettes and ground in a wet pebble mill. The sodium fluoroberyllate is then leached out with water at room temperature. The filtered solution is treated with sodium hydroxide to form sodium beryllate, from which a filterable beryllium hydroxide is precipitated by boiling. The beryllium hydroxide can then be processed to metallic beryllium using the process discussed in Part 3.²⁶

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.

Bertrandite Ore Process

EPA determined that for the production of beryllium via the bertrandite ore process, mineral processing occurs when the bertrandite ore is leached (acidified) with sulfuric acid due to the chemical substitution reaction that

²⁴ U.S. Environmental Protection Agency, Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, Vol. VII, Office of Water Regulation Standards, May 1989, p. 3643.

²⁵ Deborah A. Kramer, "Beryllium Minerals," from Industrial Rocks and Minerals, 6th Ed., Society for Mining, Metallurgy, and Exploration, 1994, p. 152.

²⁶ "Beryllium and Beryllium Alloys," 1978, Op. Cit., pp. 808-809.

occurs. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Beryl Ore Process

EPA determined that for the production of beryllium through the beryl ore process, the beneficiation/processing line occurs between grinding and reacting with sulfuric acid due to the chemical substitution that occurs here. Therefore, because EPA has determined that all operations following the initial "processing" step in the production sequence are also considered processing operations, irrespective of whether they involve only techniques otherwise defined as beneficiation, all solid wastes arising from any such operation(s) after the initial mineral processing operation are considered mineral processing wastes, rather than beneficiation wastes. EPA presents below the mineral processing waste streams generated after the beneficiation/processing line, along with associated information on waste generation rates, characteristics, and management practices for each of these waste streams.

Other Beryllium Processing

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

C. **Process Waste Streams**

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

Parts 1 and 2: Extraction of Ore and Processing to Beryllium Hydroxide

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

Bertrandite thickener slurry. Approximately 370,000 metric tons of bertrandite thickener slurry were discarded to a tailings pond in 1992.²⁷ The pH of the bertrandite thickener slurry has been reported between 2.5 and 3.5.²⁸ Therefore, this waste may exhibit the hazardous characteristic of toxicity. We used best engineering judgement to determine that this waste stream may be recycled to extraction/beneficiation units. Bertrandite thickener slurry is classified as a by-product. This waste stream is combined with approximately 250,000 metric tons of miscellaneous water streams prior to disposal.²⁹ The miscellaneous water streams are generated during the bertrandite ore extraction process, but the origin of these streams is unknown. See Attachment 1 for waste characterization data.

²⁷ U.S. Environmental Protection Agency, Newly Identified Mineral Processing Waste Characterization Data Set, Office of Solid Waste, Volume I, August, 1992, p. I-2.

²⁸ Brush Wellman, 1988, Op. Cit., p. 8.

²⁹ RTI Survey 101006, National Survey of Solid Wastes From Mineral Processing Facilities, Brush Wellman Co., Delta, UT, 1989, p. 2-4.

Beryl thickener slurry. In 1992, beryl thickener slurry was discarded to a tailings pond at a rate of 3,000 metric tons/yr.³⁰ The beryl thickener slurry has a pH of 2.³¹ Therefore, this waste exhibits the hazardous characteristic of toxicity. We used best engineering judgement to determine that this waste stream may be recycled to extraction beneficiation units. Beryl thickener slurry is classified as a by-product. This waste stream is combined with about 21,000 metric tons of sluice water prior to disposal.³² The sluice water is used to transport the beryl ore to the start of the ore extraction processes. See Attachment 1 for waste characterization data.

Spent raffinate. Approximately 380,000 metric tons of spent raffinate were discarded to a tailings pond in 1992. This waste exhibits the hazardous characteristics of toxicity (for selenium) and corrosivity.³³ The raffinate has a pH of 1.4.³⁴ This aqueous waste stream also contains magnesium and aluminum,³⁵ and may contain treatable concentrations of beryllium, other metal impurities, total suspended solids, and low levels of organics.³⁶ We used best engineering judgement to determine that this waste stream may be partially recycled. Spent raffinate is classified as a spent material. This waste stream is combined with approximately 82,000 metric tons of **sump water** and roughly 33,000 metric tons of an **acid conversion stream** prior to disposal.³⁷ See Attachment 1 for waste characterization data.

Sump water. This waste is generated during the solvent extraction process which removes metal impurities from the beryllium sulfate solution. 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.

Acid conversion stream. This waste is the portion of the stripped organic phase which is not recycled to the beginning of the solvent extraction process. 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.

Separation slurry. In 1992, the separation slurry was discarded to a tailings pond at a rate of 2,000 metric tons/yr.³⁸ The separation slurry has a pH of 3.³⁹ The slurry contains iron and aluminum which have been precipitated as hydroxides and carbonates from the aqueous ammonium beryllium carbonate stream.⁴⁰ This waste stream is combined with about 39,000 metric tons of scrubber water prior to disposal.⁴¹ The scrubber water is probably basic because it is used to scrub the ammonia and carbon dioxide stream released during the heating of the ammonium beryllium carbonate. See Attachment 1 for waste characterization data.

³⁰ U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-2.

³¹ Ibid., p. 6-61.

³² RTI Survey 101006, 1989, Op. Cit., p. 2-4.

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

³⁴ Brush Wellman, 1988, Op. Cit., p. 11.

³⁵ "Beryllium and Beryllium Alloys", 1992, Op. Cit., p. 129.

³⁶ U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3569.

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

³⁸ U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-2.

³⁹ Brush Wellman, 1988, Op. Cit., p. 9.

⁴⁰ "Beryllium and Beryllium Alloys," 1978, Op. Cit., p. 807.

⁴¹ RTI Survey 101006, 1989, Op. Cit., p. 2-4.

Spent barren filtrate streams. The barren filtrate streams are produced during the filtration of beryllium carbonate and beryllium hydroxide. Approximately 88,000 metric tons of barren filtrate were discarded to a tailings pond in 1992. This waste exhibits the hazardous characteristic of toxicity for selenium.⁴² The barren filtrate streams have a pH of 9.8.⁴³ We used best engineering judgement to determine that this waste stream may be partially recycled. The streams are classified as spent material. The barren filtrate stream from the filtration of beryllium carbonate operation contains uranium which was solubilized in the ore extraction processes. See Attachment 1 for waste characterization data.

Beryllium hydroxide supernatant. When beryllium is recovered from recycled customer material, internally generated residues, scrap, and recycled mother liquor from the beryllium oxide crystallization operations, the raw material is dissolved in sulfuric acid and beryllium and then precipitated with caustic as beryllium hydroxide. After gravity separation, the supernatant is discharged as a wastewater stream.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. See Attachment 1 for waste characterization data.

Part 3: Production of Beryllium Metal, Oxide and Alloys

Production of Metallic Beryllium

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

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

Precipitation discard. This waste stream contains precipitated manganese dioxide and lead chromate. 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.

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

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

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

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

Process Wastewater. Process condensates are generated from the ammonium beryllium fluoride crystallizer and the ammonium fluoride sludge filtrate evaporator. The condensed water is used as makeup for the fluoride furnace scrubbing system, for the beryllium pebble plant scrubbing system, for sludge washing, and general plant water usage

⁴² U.S. Environmental Protection Agency, 1992, Op. Cit., p. I-2.

⁴³ Brush Wellman, 1988, Op. Cit., p. 10.

⁴⁴ U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3660.

such as floor washing. Periodic discharge from the process water pit is necessary to prevent dissolved solids build-up. The process wastewater has a neutral pH, and treatable concentrations of beryllium and fluoride. Ammonia and cyanide are also reported as present above treatable concentrations.⁴⁵

Pebble Plant Area Vent Scrubber Water. The beryllium pebble plant contains a ventilation system for air circulation. A wet scrubber is employed to clean the used air prior to venting to the atmosphere. Although the scrubber is recycled extensively, a blowdown stream is periodically discharged to the process water pit. Makeup water for the scrubber is obtained from the process water pit. This scrubber water has a slightly acidic pH, and treatable concentrations of beryllium and fluoride.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. See Attachment 1 for waste characterization data.

Chip treatment wastewater. Pure beryllium metal scrap in the form of chips is treated with nitric acid and rinsed prior to being vacuum cast along with beryllium pebbles into a beryllium metal billet. The spent acid and rinse water are discharged. This operation combines refining beryllium from secondary as well as primary sources.⁴⁷ Although no published information regarding waste generation rate or characteristics was found, we used the methodology outlined in Appendix A of this report to estimate a low, medium, and high annual waste generation rate of 100 metric tons/yr, 50,000 metric tons/yr, and 1,000,000 metric tons/yr, respectively. We used best engineering judgement to determine that this waste may exhibit the characteristics of toxicity for chromium. See Attachment 1 for waste characterization data. We also used best engineering judgement to determine that this waste stream may be partially recycled and classified as a spent material.

Production of Beryllium Oxide

Scrubber liquor. This waste contains the sulfur dioxide that was removed from the furnace exhaust gas, and is sent to treatment. While over 90 percent of this stream is recycled, the rest is discharged as a wastewater stream. Scrubber liquor has a neutral pH, very high concentrations of dissolved solids (primarily sodium sulfate), and treatable concentrations of beryllium, fluoride and suspended solids.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.

Waste Solids. This waste stream contains the impurities filtered from beryllium sulfate solution. 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.

Production of Beryllium-copper alloys

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

D. 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, tank cleaning wastes, and polychlorinated biphenyls from electrical transformers and capacitors. Non-hazardous wastes may include tires from trucks and large machinery, sanitary sewage, and waste oil and other lubricants.

⁴⁵ U.S. Environmental Protection Agency, 1989, Op. Cit., p. 3661.

⁴⁶ Ibid., p. 3662.

⁴⁷ Ibid., p. 3661.

⁴⁸ Ibid., p. 3660.

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