5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.1 PRODUCTION

Beryllium is an element that is present in the earth's surface rocks in amounts ranging from <1–15 mg/kg. The beryllium minerals of commercial interest are beryl (i.e., $3BeOCAl_2O_3C6SiO_2$) and bertrandite (i.e., $Be_4Si_2O_7(OH)_2$). In the United States, bertrandite, which contains <1% beryllium, is the principal mineral mined. Outside the United States, beryl is the principal beryllium mineral mined. In 1999, the U.S. Geological Survey (USGS) estimated that United States resources of bertrandite ore in Utah and Texas contained 21,000 metric tons of beryllium (Cunningham 1999). Only one company, Brush Wellman, Inc. of Elmore, Ohio, produced beryllium in the United States in 1998. The bertrandite ore was mined using open-pit methods from deposits near Spor Mountain, Utah. In 1998, 230 metric tons of beryllium were mined in the United States (Cunningham 1999). Beryllium hydroxide is the basic raw material for the production of beryllium metal, alloys, and compounds. Bertrandite ore is wet milled, leached with sulfuric acid, and then extracted from the acid leachate with di(2-diethylhexyl) phosphate in kerosene at elevated temperature. The beryllium is then treated with aqueous ammonium carbonate to form an aqueous ammonium beryllium carbonate complex, which is then heated to precipitate beryllium as carbonate. Continued heating liberates carbon dioxide and beryllium hydroxide (i.e., $Be(OH)_2$). Beryllium hydroxide is then recovered by filtration. Beryllium hydroxide is the feed material for products such as beryllium metal, beryllium alloys, and beryllium oxide (Ballance et al. 1978; Drury et al. 1978).

Beryllium metal is produced by Brush Wellman Inc. in Elmore, Ohio using the Schenzfeier-Pomelee purification process. The hydroxide is initially reacted with ammonium fluoride to form ammonium fluoroberyllate (e.g., $(NH_4)_2BeF_4$), which is then heated to produce an amorphous beryllium fluoride (e.g., BeF_2), which is reduced by magnesium metal at 900–1,300 EC to yield beryllium metal and a beryllium fluoride-magnesium fluoride slag. The slag is removed by leaching with water, leaving 97% pure beryllium metal. Beryllium metal may be further electrorefined to produce a higher purity material (Ballance et al. 1978; Drury et al. 1978). Beryllium oxide (i.e., BeO) is the most important high purity commercial beryllium chemical. It is produced by dissolving technical-grade beryllium hydroxide in sulfuric acid, precipitating out hydrated beryllium sulfate, which is then calcined at 1,150–1,450 EC (Ballance et al. 1978; Drury et al. 1978).

Copper-beryllium alloy is commercially the most important beryllium alloy. Copper-beryllium master alloy is manufactured by an arc-furnace method in which beryllium oxide is reduced by carbon in the presence of molten copper at 1,800–2,000 EC. The resulting master alloy usually contains 4.0–4.25% beryllium by weight. Other copper-beryllium alloys are produced by melting the master alloy together with virgin copper, copper scrap, and possibly other metals (Ballance et al. 1978; Drury et al. 1978).

Brush Wellman, Inc. of Elmore, Ohio is the only processor of beryllium ores in the United States. Brush Wellman, Inc. is also the leading producer and consumer of beryllium metal, alloys, and oxide. NGK Metals Corporation in Reading, Pennsylvania is also a major U.S. manufacturer of beryllium alloys. U.S. mine shipments steadily increased from 173 metric tons in 1994 to 230 metric tons in 1998 of beryllium metal equivalent. Including imports of beryllium ore, stockpiling, and inventory uses, the apparrent U.S. consumption of beryllium from 1994 to 1998 has increased from 198 to 240 metric tons of beryllium equivalent (Cunningham 1999). Tables 5-1 and 5-2 list the number of facilities in each state that manufacture or process beryllium and beryllium compounds, respectively. Included in these tables are the activities and uses of beryllium and beryllium compounds and the range of maximum amounts of beryllium and beryllium compounds that are stored on site (TRI99 2002).

5.2 IMPORT/EXPORT

In 1998, 13% of the beryllium ore and metal consumed in the United States (35 metric tons) was imported from other countries. All imports of beryllium ore originated from Canada. Exports of beryllium metal were 60 metric tons in 1998, up from 29 metric tons in 1994. Japan, France, the United Kingdom, and Germany were the major recipients of beryllium exports during this period (Cunningham 1999).

5.3 USE

In 1998, the use of beryllium (as an alloy, metal, or oxide) in the electronic and electrical components, aerospace, and defense applications accounted for >80% of its consumption (Cunningham 1999).

Beryllium metal is used in aircraft disc brakes, x-ray transmission windows, space vehicles optics and instruments, aircraft/satellite structures, missile guidance systems, nuclear reactor neutron reflectors, nuclear warhead triggering devices, fuel containers, precision instruments, rocket propellants,

Table 5-1. Facilities that Produce, Process, or Use Beryllium

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
CA	2	0	999	8, 10
IN	2	100	999,999	9, 12
LA	1	0	99	1, 5, 9, 13
MO	1	1,000	9,999	8, 10
NC	1	100,000	999,999	10, 13
OH	1	10,000	99,999	1, 4
OK	2	100	99,999	1, 5, 9
PA	1	10,000	99,999	10
SC	1	100	999	9
UT	1	1,000	9,999	8
WI	1	10,000	99,999	8

Source: TRI99 2002

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses

Table 5-2. Facilities that Produce, Process, or Use Beryllium Compounds

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	4	1,000	99,999	1, 3, 4, 5, 6, 9, 1, 13
AR	1	1,000	9,999	1, 5
AZ	3	10,000	9,999,999	1, 3, 4, 5, 6, 9, 1
FL	2	0	9,999	1, 3, 4, 5, 6, 1
GA	3	10,000	99,999	1, 3, 4, 5, 6, 1, 13
IL	1	1,000	9,999	1, 5, 1
IN	3	100	99,999	1, 5, 6, 9, 1, 13
KY	5	0	99,999	1, 2, 3, 5, 6, 9, 1, 13
MI	2	10,000	99,999	1, 5, 9, 1
MO	1	1,000	9,999	9
MS	1	100	999	1, 5
MT	1	10,000	99,999	1, 3, 5, 6, 13
NC	2	10,000	99,999	1, 3, 4, 5, 6, 1
NM	3	100	99,999	1, 3, 4, 5, 6, 1, 13
NY	1	100	999	1, 5
OH	4	1,000	99,999	1, 3, 4, 5, 6, 8, 1, 13
PA	4	100	999,999	1, 2, 3, 4, 5, 6, 7, 9, 1
TN	2	10,000	99,999	1, 5, 8, 9
TX	1	10,000	99,999	1, 3, 4, 5, 6, 1, 13
UT	4	1,000	49,999,999	1, 4, 7, 8, 13
WI	1	1,000	9,999	9
WV	3	1,000	99,999	1, 3, 4, 5, 6, 1, 13
WY	1	0	99	1, 5, 6

Source: TRI99 2002

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses

navigational systems, heat shields, mirrors, high speed computer, and audio components, as well as other uses (Ballance et al. 1978; Cunningham 1998).

Beryllium oxide is used in high technology ceramics, electronic heat sinks, electrical insulators, microwave oven components, gyroscopes, military vehicle armor, rocket nozzles crucibles, thermocouple tubing, laser structural components, substrates for high-density electrical circuits, automotive ignition systems, and radar electronic countermeasure systems (Ballance et al. 1978, Cunningham 1998).

Beryllium-copper alloys are used in a wide variety of applications because of their electrical and thermal conductivity, high strength and hardness, good corrosion and fatigue resistance, and nonmagnetic properties. Beryllium-copper alloys are manufactured into: springs; electrical connectors and relays; precision instruments; bushings and bearings in aircraft and heavy machinery; nonsparking tools; submarine cable housing and pivots; wheels and pinions; switches in automobiles; molds for injection molded plastics; radar; telecommunications; factory automation; computers; home appliances; instrumentation and control systems; tubing in oil and drilling equipment; connectors for fiber optics; and integrated circuits, as well as many other uses (Ballance et al. 1978; Cunningham 1998).

5.4 DISPOSAL

The most significant amount of beryllium waste results from pollution control methods such as solid particulates scrubbers. Since beryllium is a valuable element, the most desirable method of handling beryllium wastes is to recycle them to the producers. Metal scrap, aqueous suspensions, and particulates are routinely recycled by Brush Wellman, Inc. at their production facility in Ohio (Brush Wellman 2000a).

The EPA has classified beryllium powder as a hazardous waste material (40 CFR Section 261.33). Under the Resource Conservation and Recovery Act (RCRA), compliance with labeling and disposal procedures as well as obtaining permits for discharges into air and water are required for beryllium powder. EPA standards require that atmospheric emissions from stationary sources be <10 g of beryllium over a 24-hour period, and that the ambient concentration of beryllium near the stationary source be <0.01 $\mu g/m^3$. Beryllium solid waste should be placed into impermeable, sealed bags or containers (e.g., drums) that are labeled in accordance with the requirements of EPA regulations (Fishbein 1981). The EPA has also issued final regulations under the Clean Water Act for specific nonferrous metal manufacturing operations including beryllium processing facilities. These regulations limit the discharge of beryllium containing pollutants into navigable waters and into publically-owned treatment works (POTWs). Waste waters containing beryllium may therefore require treatment to reduce the concentration of beryllium. A typical treatment method for beryllium involves steps such as chemical precipitation, settling clarification, neutralization, filtration, and sludge dewatering (EPA 1982, 1988a). Waste waters that contain permissible levels of beryllium may be discharged into streams and POTW facilities (EPA 1982, 1988a).

A significant amount of beryllium waste results from pollution control methods such as containment of solid particulates or aqueous suspensions resulting from air-scrubbing processes. According to the TRI99 (TRI99 2002), a total of 54,097 and 838,373 pounds of beryllium and beryllium compound wastes, respectively, were released to the environment by various industries in 1999 (see Chapter 6). Of the total release of beryllium, 98.5% was disposed on land (on-site), 1.4% was released to air, and 0.1% was released to surface water. Likewise, of the total release of beryllium compounds, 98.2% was disposed on land (on-site), 0.9% was released to air, 0.4% was released to surface water, and 0.5% was injected underground. An additional 20,081 and 72,118 pounds of beryllium and beryllium compound wastes, respectively, were transferred to off-site locations within the United States. Data regarding the trend in disposal practices for beryllium wastes in recent years were not located.