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2019 Minerals Yearbook

BERYLLIUM [ADVANCE RELEASE]

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Beryllium

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On the basis of estimated beryllium content, U.S. mine shipments of beryllium ore in 2019 decreased by 3% to 160 metric tons (t) from 165 t in 2018 and reported consumption of ore for the production of beryllium hydroxide decreased by 6% to 160 t (table 1). U.S. shipments and consumption of beryllium ore were 41% and 43% lower, respectively, than the peak quantities in 2014 (fig. 1), mostly owing to a decrease of beryllium consumption in oil and gas exploration. On the basis of estimated beryllium content, imports of beryllium materials decreased by 29% in 2019 from those in 2018, and exports of beryllium metal increased by 24% (table 3).

In 2019, estimated world beryllium ore production decreased slightly compared with that in 2018 (table 4). The United States accounted for 64% of estimated world production, and China accounted for 28%. Beryl, a principal mineral of beryllium mined outside of the United States, is commonly stockpiled for later processing, and sales or exports may not accurately reflect current production. As a result, world production numbers and the U.S. share of world production have a high degree of uncertainty.

Beryllium is gray in color and one of the lightest metals. It is useful for many applications because of its physical and mechanical properties—outstanding stiffness-to-weight and strength-to-weight ratios, high melting point relative to other light metals, high specific heat, excellent thermal conductivity, outstanding dimensional stability over a wide range of temperatures, high reflectivity, lowest neutron absorption cross section of any metal and high neutron-scattering cross section, and transparency to X-rays. Beryllium was used primarily in beryllium-copper alloys, beryllium oxide ceramics, and as beryllium metal in a wide variety of products, such as bearings and bushings, computer chip heat sinks, contacts and connectors, disc brakes, highly conductive and high-strength wire, mirrors, protective housings, switches and relays, and X-ray windows. Industries that used beryllium products included aerospace, automotive, computer, defense, electronics, energy, marine, medical, nuclear, and telecommunications.

The leading use for beryllium, accounting for about 75% of total world consumption, was in copper-base alloys containing from 0.2% to 2.0% beryllium. Beryllium enhances the strength, stiffness, and hardness of copper alloys while retaining relatively good ductility, machinability, and electrical and thermal conductivity. Beryllium-copper alloys were predominantly formed into strip products used as electrical connectors, contacts, relays, shielding, and switches, and as bulk products in the form of bars, plates, rods, and tubes. Oil and gas exploration equipment relied on beryllium alloy bearings, couplings, and instrument housings to drill under corrosive and high-stress and high-temperature conditions without sparking. The second leading use of beryllium, consuming 20% of total world production, was as 99.5%-pure (or greater) beryllium metal and beryllium-base alloys containing greater than 60% beryllium (primarily alloyed with aluminum). Beryllium metal and alloys were typically used to produce components for high-technology equipment where low weight, low thermal distortion, and good machinability were critical factors. Beryllium oxide ceramics, which accounted for the remaining 5% of beryllium consumption, were used where electrical insulation and heat extraction were essential, such as automotive electrical systems and heat sinks for radar and radio-frequency equipment (Trueman and Sabey, 2014, p. 101–103).

Only two beryllium minerals are of commercial importance for the production of beryllium. Bertrandite, which can contain as much as 15% beryllium, was the principal beryllium mineral mined in the United States. Bertrandite ore mined in the United States contained about 0.25% beryllium by weight. Beryl, which can contain up to 5% beryllium, was the principal beryllium mineral mined in the rest of the world from ores typically grading 4% beryllium or less. Commercial beryl contains approximately 12% beryllium oxide, 19% aluminum oxide, 67% silicon dioxide, and 2% other oxides. Artisanal mining of the gemstone varieties of beryl, most notably aquamarine and emerald, was a primary source of byproduct beryl for beryllium extraction. More information on gem-quality beryl and chrysoberyl can be found in the Gemstones chapter of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs

Because beryllium is toxic, various international, national, and State guidelines and regulations have been established to determine and monitor allowable beryllium content in air, water, and other media. Industry regulations require control of the quantity of beryllium dust, fumes, and mists in the workplace and effluent discharges.

Defense Production Act.—To ensure current and future availability of high-quality domestic beryllium to meet critical defense needs, in 2008, the U.S. Department of Defense (DOD), under the Defense Production Act Title III Program, invested in a public-private partnership with Materion Corp. (Mayfield Heights, OH) to build a primary beryllium facility in Elmore, OH. The facility was designed to produce high-purity beryllium metal from beryllium hydroxide sourced from Materion's Delta, UT, operation. Approximately two-thirds of the facility's output was to be allocated for defense and Government-related end uses; the remaining output was to go to the private sector. The plant, with a design capacity of 73 metric tons per year (t/yr) of beryllium metal, was placed into service in 2012 (Metal Bulletin, 2010; Materion Corp., 2020a, p. 52).

National Defense Stockpile.—The Defense Logistics Agency Strategic Materials, DOD, offered and sold selected beryllium materials from the National Defense Stockpile (NDS). The Annual Materials Plan for fiscal year 2019, which

represented the maximum quantities of beryllium metal that could be upgraded or disposed of from October 1, 2018, through September 30, 2019, was 5 t, an increase from 2 t in fiscal year 2018. In calendar year 2019, the NDS did not sell any beryllium materials. The NDS upgraded beryllium hot-pressed metal powder into hot isostatic pressing structured metal powder to meet product specification for many modern DOD applications. NDS calendar yearend inventories of beryllium materials are listed in table 2 (U.S. Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, 2015; Defense Logistics Agency Strategic Materials, 2018).

Production

Domestic production (tables 1, 4) and consumption data (table 1) for beryllium-containing ores were collected by the U.S. Geological Survey (USGS) from two voluntary surveys of U.S. beryllium operations. In 2019, both of the canvassed respondents replied to the survey. A small number of unidentified producers may have shipped minimal quantities of byproduct beryl, but these have not been included. In 2019, the only domestic beryllium mine shipped approximately 160 t of beryllium content, 3% less than shipments in 2018.

The United States is one of only three countries known to have processed beryllium ores and concentrates into beryllium products. The two other countries were China and Kazakhstan. Materion converted bertrandite from open pit mines in the Topaz-Spor Mountain region of Juab County, UT, into beryllium hydroxide at its operations near Delta. Most of the beryllium hydroxide was shipped to Elmore, OH, where Materion converted it into beryllium-copper master alloy (BCMA), metal, or oxide, and some was sold to NGK Insulators, Ltd. of Japan. In 2019, 99% of Materion's beryllium hydroxide was produced from bertrandite and 1% was produced from imported beryl (Materion Corp., 2020a, p. 23). Very-high-purity beryllium was produced exclusively from beryl, as beryl typically has fewer impurities (for example, fluorine and uranium) than bertrandite. Beryl-sourced high-purity beryllium was used in nuclear applications, where the absence of uranium in the beryllium allows for safe and timely disposal of nuclear waste containing beryllium, and in foil for use as X-ray windows for medical applications (Keith Smith, Vice President, Technology and Government Business Development, Materion Corp., oral commun., April 4, 2016).

Based on the expectation that worldwide stockpiles of beryllium concentrate were being depleted, Materion increased its capacity to produce beryllium hydroxide at its Delta plant in 2013, and in 2015 invested $23 million to further develop its bertrandite pits in the Topaz-Spor Mountain region. In 2019, the capacity utilization of the Delta plant was 50%, the same as that in 2018 (Materion Corp., 2014, p. 3; 2016, p. 2; 2020a, p. 23).

Consumption

In 2019, U.S. reported consumption of bertrandite ore and beryl for the production of beryllium hydroxide was 160 t of beryllium content, a 6% decrease from that in 2018. U.S. apparent consumption of all beryllium materials in 2019, as calculated from mine shipments, net trade, and changes in Government and industry stocks, was estimated to be 167 t of beryllium content, an 18% decrease from 204 t in 2018. Beryllium mine shipments and net imports decreased in 2019.

Materion produced beryllium hydroxide, beryllium products (including metal, metal-matrix composites, and ceramics), and beryllium strip and bulk products in its Performance Alloys and Composites segment. Materion produced two types of metal-matrix composites—one made from aluminum and beryllium and the other made from beryllium and beryllium oxide (BeO or beryllia). Foil, rod, sheet, tube, and a variety of customized shapes were produced at plants in Elmore, OH, and Fremont, CA. Beryllia ceramic products for aerospace, defense, electronics, medical, semiconductor, telecommunications, and wireless applications were produced at its plant in Tucson, AZ, and copper- and nickel-base alloy products, the majority of which contained beryllium, were produced at plants in Elmore, OH, and Shoemakersville, PA. These included alloy strip products (which were used as connectors, contacts, relays, shielding, and switches) and alloy bulk products (including bar, plate, rod, tube, and customized forms).

In 2019, value-added sales from the Performance Alloys and Composites segment increased slightly from those in 2018 owing mostly to higher value-added sales to the aerospace and defense markets, partially offset by lower value-added sales to the automotive market. In 2019, aerospace and defense, industrial component, automotive, and telecommunications and data center applications accounted for 24%, 23%, 12% and 12%, respectively, of the Performance Alloys and Composites value-added sales. The remaining sales were distributed as follows: consumer electronics, 11%; energy, 9%; semiconductor, 1%; and other, 8% (Materion Corp., 2020a, p. 18; 2020c, p. 9).

IBC Advanced Alloys Corp. (Franklin, IN) manufactured beryllium-aluminum and beryllium-copper alloys and its proprietary Beralcast® alloys, which were castable beryllium-aluminum products, at plants located in Franklin, IN, New Madrid, MO, Royersford, PA, and Wilmington, MA. IBC had multiyear agreements to purchase beryllium metal and BCMA from the Ulba Metallurgical Plant (UMP) in Kazakhstan (IBC Advanced Alloys Corp., 2020, p. 2–8). The UMP was part of Kazatomprom JSC, the national operator for the nuclear industry in Kazakhstan.

Beryllium alloys also were manufactured domestically by Belmont Metals Inc. (Brooklyn, NY) and NGK Metals Corp. (Sweetwater, TN), a subsidiary of Japan's NGK Insulators, Ltd. American Beryllia Inc. (Haskell, NJ) manufactured beryllium oxide ceramic components and compound materials. American Elements (Los Angeles, CA) manufactured beryllium metal and beryllium oxide foil, sheet, and plate.

Recycling

Beryllium was recycled from new scrap generated during the manufacture of beryllium-containing components, as well as from old scrap collected from end users. Detailed data on the quantities of recycled beryllium were not available but may have been as much as 20% to 25% of U.S. consumption. Beryllium products manufactured by Materion from recycled metal required only 20% of the full-cycle (mine through

manufacture) energy as that of beryllium products manufactured from primary material. Materion established a comprehensive recycling program for its beryllium products and indicated a 40%-beryllium recovery rate from processed new and old beryllium scrap (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., August 2, 2012).

Foreign Trade

U.S. foreign trade in beryllium materials, as reported by the U.S. Census Bureau, is summarized in table 3. On the basis of estimated beryllium content, total beryllium imports decreased by 29% compared with that in 2018. The leading suppliers of beryllium materials to the United States were, by beryllium content, Kazakhstan, Japan, and Latvia. By gross weight, the leading suppliers of beryllium materials to the United States were Japan, Kazakhstan, and Germany.

Beryllium exports increased by 24%, based on estimated beryllium content, compared with those in 2018. Canada was the leading recipient of exported beryllium metal, followed by France and Japan. The U.S. Census Bureau, however, only reported exported beryllium metal in its "Schedule B: Statistical Classification of Domestic and Foreign Commodities Exported from the United States." Exported BCMA and beryllium oxide and hydroxide did not have separate dedicated Schedule B numbers. According to Materion, BCMA typically accounted for 85% of domestic beryllium exports, whereas beryllium metal typically accounted for less than 15% of exports (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., January 10, 2013).

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic beryllium production to meet U.S. demand. Net import reliance is defined as imports minus exports plus adjustments for Government and industry stock changes. Included among stock changes are acquisitions or shipments from the NDS, regardless of whether the materials were imported or produced in the United States. Apparent consumption is defined as primary production plus secondary production from old scrap plus net import reliance. For 2019, net import reliance as a percentage of apparent consumption was 4%, a decrease from 18% in 2018. Net import reliance as a percentage of apparent consumption decreased since its peak of 61% in 2010 owing primarily to the startup and operation of a beryllium metal plant in 2012. There has been a commensurate decrease in beryllium imports and Government stockpile shipments.

World Review

China.—Two facilities in China processed beryllium ores and concentrates into beryllium products—Hunan Shuikoushan Nonferrous Metals Group Co., Ltd. in Xinjiang Province and Fuyun Hengsheng Beryllium Industry Co., Ltd. in Guangdong Province. For 2019, Antaike Information Development Co. Ltd. indicated that China produced 70 t of beryllium from domestic beryl ore (1,750 t gross weight), slightly more than 69 t in 2018, and higher than that in 2015, 2016, and 2017, at 52 t, 46 t, and 52 t, respectively (Ying, 2020, p. 7). In 2015, the last year with reported information, China consumed about 95 t of beryllium in the production of beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal. Approximately half of the beryllium content was sourced from domestic ore and half was obtained from Kazakhstan and other foreign sources (China Mining Association, 2016). China was thought to be the world's second leading beryllium-processing country (after the United States), surpassing Kazakhstan (Ron Gilerman, Managing Director, A&R Merchants, Inc., oral commun., August 10, 2017).

Kazakhstan.—The UMP consumed 94.5 t of beryllium in the production of beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal in 2017 and in 2018; consumption was probably about the same in 2019 (Kazatomprom JSC, 2018, p. 61–62). Since the early 1990s, the UMP's production was sourced from beryllium concentrate stockpiled in Kazakhstan, which had accumulated prior to the breakup of the Soviet Union. The beryllium concentrate stockpile in Kazakhstan was still present in 2019 but thought to be nearly depleted. The UMP's current primary source of beryllium concentrate was from a Soviet-era stockpile located in Russia. The Russian stockpile would support about 20 years of production, based on the UMP's current rate of consumption (Ron Gilerman, Managing Director, A&R Merchants, Inc., oral commun., August 10, 2017).

In 2017, the last year with reported information, Ulba-China Co., Ltd., a Shanghai, China-based-subsidiary of the UMP, accounted for 63% of Kazatomprom's sales of beryllium products by volume. The beryllium products were sold to customers in China, Japan, the Republic of Korea, and Malaysia. In addition, Germany's Tropag Oscar H. Ritter Nachf, GmbH; Japan's NGK Insulators, Ltd.; and IBC Advanced Alloys in the United States accounted for 18%, 10%, and 5%, respectively, of Kazatomprom's sales of beryllium products by volume (Kazatomprom JSC, 2018, p. 105).

Russia.—In an effort to augment the beryllium metal imported by Russia, Mariinsky Priisk JSC, an enterprise located at the Malyshevskoye emerald-beryllium deposit in the Sverdlovsk region, announced plans in 2019 to produce beryllium metal by 2025. Gemstone beryl ore has historically been mined from this deposit. Mariinsky Priisk planned to reconstruct the underground mine at the deposit and build beryllium-concentration and metal-production operations presumably in the town of Krasnoturinsk (ITAR-TASS News Agency, 2019).

Russia's Industry and Trade Ministry financed research on beryllium metal production. Tomsk Polytechnic University and the Rare Metals of Siberia Research and Production Association jointly produced a total of 1 kilogram of beryllium metal at yearend 2015. The Priargunsky Industrial Mining and Chemical Union in Krasnokamensk, Trans-Baikal Territory, was being considered for a concentrator, and the Siberian Chemical Combine in Seversk, Tomsk Region, was being considered for the beryllium hydrometallurgical plant. Bertrandite ore from the Ermakovskoe deposit in Buryatiya was being considered for this project. As of 2015, the last year with reported information, planned production capacity was expected to be 30 t/yr of beryllium metal (Dragomanovich, 2015; ITAR-TASS News Agency, 2015; Tomsk Polytechnic University, 2017).

Russia's reopening of the Ermakovskoe bertrandite operation in the Siberian Republic of Buryatiya has been reported to be on hold owing to a 2014 financial downturn in Russia. Kazakhstan's UMP was expected to continue supplying Russia with beryllium products (Ron Gilerman, Managing Director, A&R Merchants, Inc., oral commun., August 10, 2017). Ermakovskoe was thought to be the largest identified beryllium deposit in Russia, with reported reserves at 1.4 million metric tons (MBC Corp., 2009, 2011; Rusnano Corp., 2012).

Outlook

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. At yearend 2019, Materion reported proven reserves in Juab County, UT, of 7.1 million metric tons of bertrandite having an average grade of 0.246% beryllium and containing nearly 18,000 t of beryllium, representing a minimum of 75 years of future production. The company's proven and probable reserves totaled nearly 20,000 t of beryllium. Materion owned approximately 90% of its proven mineral reserves and leased the remainder from the State (Materion Corp., 2020a, p. 23; 2020c, p. 9).

In the first quarter of 2020, net sales for Materion's beryllium-rich Performance Alloys and Composites segment were 22% lower than those in the first quarter of 2019 owing to reduced demand in all major markets from the impact of the COVID-19 pandemic (Materion Corp., 2020b, p. 19, 22).

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS[1]

(Metric tons, beryllium content)

	2015	2016	2017	2018	2019
United States, beryllium ore:					
Mine shipments[2]	205	155	150	165	160
Imports for consumption, beryl[3]	18	12	5	2	(4)
Consumption, reported[5]	220	160	160	170	160
Stocks, December 31:					
Industry[2]	25	35	30	30	35
U.S. Government, beryl[3, 6]	(4)	(4)	(4)	(4)	(4)
World, production[e, 3]	263 [r]	215 [r]	210 [r]	255 [r]	251

[e]Estimated. [r]Revised.
[1]Table includes data available through August 20, 2020.
[2]Data are rounded to the nearest 5 metric tons.
[3]Based on a beryllium content of 4%.
[4]Less than ½ unit.
[5]Data are rounded to the nearest 10 metric tons.
[6]Data from Defense Logistics Agency Strategic Materials.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
BERYLLIUM STATISTICS IN 2019[1]

(Metric tons, beryllium content)

Material	Annual Materials Plan[2]	Inventory, December 31
Beryl ore	--	(3)
Beryllium metal:		
Hot-pressed powder	(4)	60
Rods	--	(3)
Structural powder	--	7
Vacuum-cast	(4)	6
Total	5	75
Grand total	5	75

-- Zero.
[1]Table includes data available through August 20, 2020. Data were converted from gross weight reported in short tons; may not add to totals shown.
[2]Maximum quantity of material that can be upgraded or disposed during the 12-month period ending September 30, 2019. Disposals are defined in U.S.C. 50 as any disposal or sale of National Defense Stockpile stock.
[3]Less than ½ unit.
[4]Stockpile goal and Annual Materials Plan for beryllium metal included under "Total."

Source: Defense Logistics Agency Strategic Materials.

TABLE 3
U.S. FOREIGN TRADE OF BERYLLIUM MATERIALS, BY TYPE[1]

Type and material	2018 Gross weight (kilograms)	2018 Content[2] (kilograms)	2018 Value (thousands)	2019 Gross weight (kilograms)	2019 Content[2] (kilograms)	2019 Value (thousands)	Principal destinations or sources based on gross weight data, 2019
Exports:							
Beryllium, unwrought[3]	6,100	6,100	$258	3,170	3,170	$120	Guatemala, 44%; France, 16%; Japan, 15%; Czechia, 14%; Taiwan, 6%.
Beryllium waste and scrap	3,490	3,490	259	9,410	9,410	282	Canada, 64%; Jordan, 22%; Hong Kong, 14%.
Beryllium, other	20,100	20,100	26,300	24,200	24,200	26,700	Canada, 48%; France, 9%; Japan, 8%; Germany, 7%; Spain, 5%; Republic of Korea, 5%.
Total	29,700	29,700	26,800	36,700	36,700	27,100	Canada, 48%; France, 7%; Japan, 7%; Jordan, 6%; Hong Kong, 5%.
Imports for consumption:							
Beryllium ores and concentrates[4]	39,800	1,590	87	139	6	7	Germany, 100%.
Beryllium oxide and hydroxide	1,700	613	38	2,620	944	80	Canada, 81%; China, 19%.
Beryllium, unwrought[3]	--	--	--	9	9	6	Germany, 100%.
Beryllium waste and scrap	22,200 r	22,200 r	112 r	--	--	--	XX.
Beryllium, other[5]	29,500	29,500	2,500	33,700	33,700	2,750	Kazakhstan, 62%; Latvia, 20%; Canada, 8%; Sweden, 8%; Germany, 2%.
Beryllium-copper master alloy	99,100	3,960	2,340	83,700	3,350	2,070	Kazakhstan, 88%; Germany, 7%; Japan, 4%.
Beryllium-copper plates, sheets, and strip	740,000	11,100	12,400	711,000	10,700	12,500	Japan, 91%; Germany, 8%.
Total	933,000 r	69,000 r	17,500 r	831,000	48,600	17,400	Japan, 78%; Kazakhstan, 11%; Germany, 8%.

rRevised. XX Not applicable. -- Zero.
[1]Table includes data available through August 19, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Estimated from gross weight.
[3]Includes powders.
[4]The low 2019 beryllium ores and concentrates weight and value data was verified by the U.S. Census Bureau.
[5]Includes articles not elsewhere specified.

Source: U.S. Census Bureau.

TABLE 4
BERYL: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Metric tons, gross weight)

Country or locality[3]	2015	2016	2017	2018	2019
Brazil[e]	100	120	80	80	80
China	1,275 [r]	1,150 [r]	1,300 [r]	1,725 [r]	1,750
Madagascar[e, 4]	16 [r]	16 [r]	16 [r]	16 [r]	16
Mozambique	35	181	53	381 [r]	380 [e]
Nigeria	26 [e]	--	18 [r, e]	35 [r]	35 [e]
Rwanda	23	20	20 [e]	20 [e]	20 [e]
Uganda	--	14	--	-- [e]	-- [e]
United States[5]	5,100	3,870	3,760	4,130	3,990
Total	6,580 [r]	5,370 [r]	5,240 [r]	6,390 [r]	6,270

[e]Estimated. [r]Revised. -- Zero.

[1]Table includes data available through August 12, 2020. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Unless otherwise noted, figures represent beryl ore for the production of beryllium and exclude gem-quality beryl.

[3]In addition to the countries and (or) localities listed, Kazakhstan, Portugal, and Russia may have produced beryl ore, but available information was inadequate to make reliable estimates of output. Other nations that produced gemstone beryl ore also may have produced some industrial beryl ore.

[4]Beryl in quartz concentrates.

[5]Includes raw bertrandite ore, calculated as equivalent to beryl containing 11% beryllium oxide.

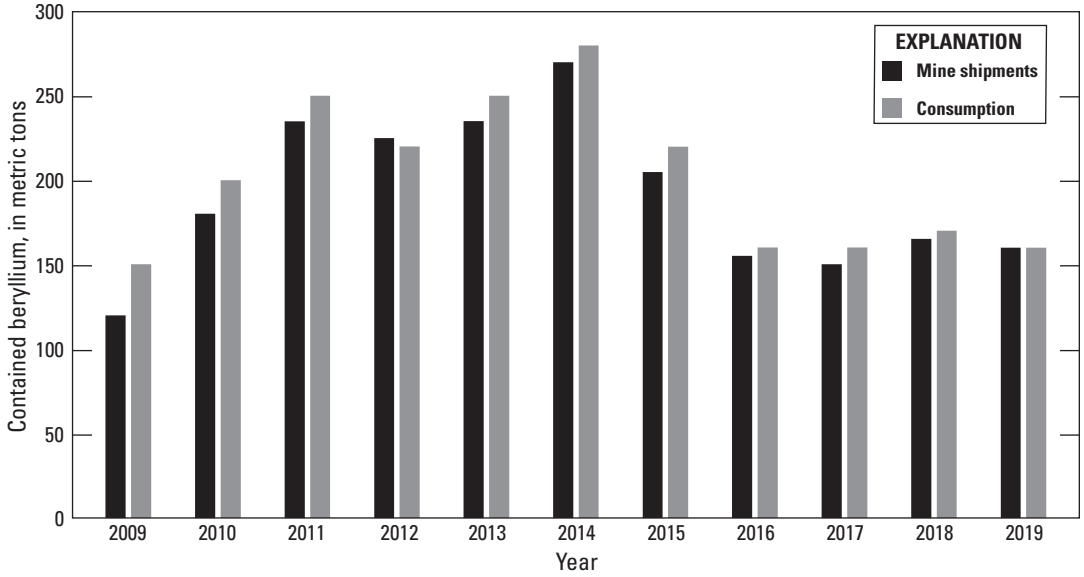

Figure 1. U.S. mine shipments and consumption of beryllium from 2009 through 2019.