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2022 Minerals Yearbook

BERYLLIUM [ADVANCE RELEASE]

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Beryllium

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As measured by beryllium content, U.S. mine shipments of beryllium ore in 2022 remained the same as that in 2021 at 175 metric tons (t) and reported consumption of ore for the production of beryllium hydroxide remained the same as that in 2021 at 170 t (fig. 1, table 1). As measured by estimated beryllium content, imports of beryllium materials decreased by 20% in 2022 from those in 2021 and exports of beryllium metal increased by 99% (table 3). Imports decreased owing primarily to a large reduction of beryllium metal articles imported from Kazakhstan. The large increase in exports was likely due to increased beryllium sales in aerospace, energy, and industrial end markets in 2022. Additionally, increased beryllium hydroxide sales and strong electrical connector demand driven by increased fifth generation (5G) telecommunications applications most likely contributed to increased exports (Materion Corp., 2023a, p. 31, 55; 2023b, p. 8, 15).

In 2022, estimated world beryllium ore production (gross weight) decreased by 9% from that in 2021 (table 4). World beryllium ore production in 2021 was revised owing to updated production information from Brazil. The United States was the leading producer of mined beryllium, accounting for 56% of estimated world production in 2022. China was the second-ranked producer and accounted for 23%. Beryl, a principal mineral of beryllium mined outside of the United States, is commonly stockpiled for later processing and thus sales or exports may not accurately reflect 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 is one of the lightest metals. 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—make it useful for many applications. 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.

In recent years, the leading use for beryllium, which accounted for 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, electromagnetic radiation 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, which consumed 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 used typically to produce components for high-technology equipment where low density, 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 contains 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 in addition to 67% silicon dioxide, 19% aluminum oxide, 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.

Government Actions and Legislation

Because beryllium is toxic, various international, U.S., 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 the 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., 2023a, p. 61).

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 2022, which represented the maximum quantities of beryllium metal that could be upgraded or disposed of from October 1, 2021, through September 30, 2022, was 7 t, the same as that in fiscal year 2021. In calendar year 2022, the NDS sold 9 t of beryllium hot-pressed metal powder. The NDS also upgrades beryllium hot-pressed metal powder into hot isostatic pressing structured metal powder to meet product specifications for many modern DOD applications. NDS calendar yearend inventories of beryllium materials are no longer available (U.S. Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, 2015, p. 5; Defense Logistics Agency Strategic Materials, 2021, 2022).

Production

Domestic production (tables 1, 4) and consumption data (table 1) for beryllium-containing ores were collected by the USGS from two voluntary surveys of U.S. beryllium operations. A small number of unidentified producers may have shipped minimal quantities of byproduct beryl, but these have not been included. In 2022, the only domestic beryllium mine shipped approximately 175 t of beryllium content, the same as that in 2021 (fig. 1).

The United States was 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, UT. Most of the beryllium hydroxide was shipped to Elmore, OH, where Materion converted it into beryllium-copper master alloy (BCMA), metal, or oxide. Historically, some beryllium hydroxide was sold to NGK Insulators, Ltd. of Japan. In 2022, 100% of Materion's beryllium hydroxide was produced from bertrandite (Materion Corp., 2023a, p. 31). Very-high-purity beryllium is 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).

Materion increased its capacity to produce beryllium hydroxide at its Delta, UT, plant in 2013, and in 2015 invested $23 million to further develop its bertrandite pits in the Topaz-Spor Mountain region. In 2022, the capacity utilization of the Delta plant was 53%, 2% less than that in 2021 (Materion Corp., 2014, p. 5; 2016, p. 2; 2023a, p. 31).

Beryllium was recycled from new scrap generated during the manufacture of beryllium-containing components, and from old scrap collected from end users. Detailed data on the quantities of recycled beryllium were not available but recycled beryllium may have accounted for 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).

Consumption

In 2022, U.S. reported consumption of bertrandite ore and beryl for the production of beryllium hydroxide was 170 t of beryllium content, the same as that in 2021 (fig. 1, table 1). U.S. apparent consumption of all beryllium materials in 2022, as calculated from mine shipments, net trade, and changes in Government and industry stocks, was estimated to be 187 t of beryllium content, a 5% decrease from 196 t in 2021.

Materion produced beryllium hydroxide, beryllium products (including ceramics, metal, and metal-matrix composites), 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 2022, net sales from the Performance Alloys and Composites segment increased by 31% from those in 2021 owing to higher sales in most major end markets, with the largest increases in the aerospace and defense, energy, and industrial end markets. In 2022, the Performance Alloys and Composites value-added sales were distributed by application as follows: industrial, 25%; aerospace and defense, 17%; automotive, 14%; telecommunications and data center, 10%; consumer electronics, 7%; energy applications, 7; semiconductor, 1%; and other, 19% (Materion Corp., 2023a, p. 55).

IBC Advanced Alloys Corp. (Franklin, IN) manufactured beryllium-aluminum and beryllium-copper alloys. In 2022, IBC launched a copper alloy casting operation at its copper alloy foundry in Franklin, IN, effectively relocating it from the company's previously owned Royersford, PA, facility. IBC also had a facility in Wilmington, MA. IBC purchased beryllium from Materion and the NDS. IBC also had an agreement to purchase beryllium metal and BCMA from the Ulba Metallurgical Plant (UMP) in Kazakhstan lasting through 2023

(IBC Advanced Alloys Corp., 2022; 2023, p. 4, 17–18). 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.

Prices

There are no reported beryllium prices. Based on foreign trade in beryllium materials, as reported by the U.S. Census Bureau, exports of all beryllium materials had an annual average unit value of $416 per kilogram (beryllium content basis) and imports of all beryllium materials has an annual average value of $509 per kilogram (beryllium content basis) (table 3).

Foreign Trade

U.S. foreign trade in beryllium materials, as reported by the U.S. Census Bureau, is summarized in table 3. As measured by estimated beryllium content, total beryllium imports decreased by 20% from that in 2021. The leading suppliers of beryllium materials to the United States, by beryllium content, were Latvia (39%), Kazakhstan (23%), and Japan (21%). By gross weight, the leading suppliers of beryllium materials to the United States were Japan (81%) and Kazakhstan (12%).

As measured by estimated beryllium content, beryllium exports increased by 99% from that in 2021 (table 3). The leading recipient of exported beryllium metal was Canada (37%), followed by Germany (21%) and France (16%). 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. consumption. 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 imports minus exports plus adjustments for Government and industry stock changes. For 2022, net import reliance as a percentage of apparent consumption for all forms of beryllium was 6%, a decrease from 11% in 2021. 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 (Jaskula, 2015). There has been a commensurate decrease in beryllium imports.

World Review

China.—Two facilities in China processed beryllium ores and concentrates into beryllium products—Hunan Shuikoushan Nonferrous Metals Group Co., Ltd. in Xinjiang Uyghur Autonomous Region and Fuyun Hengsheng Beryllium Industry Co., Ltd. in Guangdong Province. In 2020, Antaike Information Development Co., Ltd. estimated that China produced 70 t of beryllium from domestic beryl ore (1,750 t gross weight). Antaike also reported that China's apparent beryllium consumption for 2020 was 115 t of beryllium in the production of beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal (Ying, 2020, p. 10, 15). For 2022, the USGS estimated that China's beryllium production and apparent beryllium consumption were about the same as in 2020. China, on average, sources one-half of its beryllium from domestic ore and one-half from Kazakhstan and other foreign sources (China Mining Association, 2016). China was estimated to be the world's second ranked beryllium-processing country (after the United States), greater than 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, the last year with reported beryllium consumption data (Kazatomprom JSC, 2018, p. 61–62). The USGS estimated that UMP beryllium consumption was about 96 t in 2021 (revised from 92 t), and about 94 t in 2022 owing to an 8% decrease in Kazatomprom's production of beryllium-containing products in 2022, the majority of which typically contain 0.2% to 2.0% beryllium (Kazatomprom JSC, 2023, p. 10). 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 may have still been present in 2022 but was thought to be depleted or nearly depleted. The UMP's primary source of beryllium concentrate in 2022 was from a Soviet-era stockpile located in Russia. In 2017, the Russian stockpile was forecast to support about 20 years of production, based on the UMP's annual 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, JSC Mariinsky Mine, an enterprise located at the Malyshevskoye and Aulskoye emerald-beryllium deposits in Sverdlovsk Province, announced plans in 2019 to produce beryllium metal by 2025. Gemstone beryl ore has historically been mined from these deposits. The company

planned to reconstruct the underground Mariinsky Mine at the Malyshevskoye deposit and build beryllium-concentration and metal-production operations presumably in the town of Krasnoturinsk (ITAR-TASS News Agency, 2019).

An economic assessment of the Malyshevskoye and Aulskoye deposits, completed in September 2022, reported an estimated 13,400 t of emerald-beryllium proven ore reserves and 17,300 t of beryllium oxide reserves. A new flotation factory was to be built within 3 years, which was expected to process up to 250,000 t/yr of emerald-beryllium ore and produce up to 50 t/yr of beryllium metal (Russia's News, 2023).

Outlook

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. At yearend 2022, Materion reported proven reserves in Juab County, UT, of 7 Mt of bertrandite having an average grade of 0.245% beryllium and containing 17,000 t of beryllium, representing a minimum of 75 years of future production. The company's proven and probable reserves totaled more than 19,000 t of beryllium. Materion reported indicated resources of almost 1.4 Mt of bertrandite having an average grade of 0.128% beryllium and containing more than 1,700 t of beryllium. The company's indicated and inferred resources totaled 10,000 t of beryllium and are exclusive of mineral reserves (Materion Corp., 2023a, p. 30–31).

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS[1]

(Metric tons, beryllium content)

	2018	2019	2020	2021	2022
United States, beryllium-containing ores:					
Mine shipments[2]	165	160	165	175	175
Imports for consumption, beryl[3]	2	(4)	--	(4)	--
Consumption, reported[5]	170	160	170	170	170
Stocks, December 31:					
Industry[2]	30	35	30	35	10
U.S. Government, beryl[3, 6]	(4)	(4)	(4)	(4)	(4)
World, production[3, 7]	255 r	234 r	248 r	341 r	313

rRevised. -- Zero.
[1]Table includes data available through May 8, 2023.
[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]Source: Defense Logistics Agency Strategic Materials.
[7]May include estimated data.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE BERYLLIUM STATISTICS IN 2022[1]

(Metric tons, beryllium content)

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

NA Not available. -- Zero.
[1]Table includes data available through May 8, 2023. Data were converted from gross weight reported in short tons; may not add to total shown.
[2]Based on a beryllium content of 4%.
[3]Less than ½ unit.
[4]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	HTS codes Schedule B numbers[2]	2021 Gross weight (kilograms)	2021 Be content[3] (kilograms)	2021 Value (thousands)	2022 Gross weight (kilograms)	2022 Be content[3] (kilograms)	2022 Value (thousands)	Principal destinations or sources, by gross weight, 2022
Exports:								
Beryllium, unwrought[4]	8112.12.0000	5,700	5,700	$243	26,500	26,500	$1,080	Germany, 39%; France, 31%; Mexico, 18%; China, 6%.
Beryllium waste and scrap	8112.13.0000	--	--	--	13,500	13,500	387	Canada, 99%.
Beryllium, other[6]	8112.19.0000	24,700	24,700	26,600	20,600	20,600	23,700	Canada, 44%; Japan, 13%; Germany, 12%; Republic of Korea, 5%; Singapore, 4%; China, 4%.
Total		30,400	30,400	26,800	60,600	60,600	25,200	Canada, 37%; Germany, 21%; France, 16%; Mexico, 8%; Japan, 5%; China, 4%.
Imports for consumption:								
Beryllium ores and concentrates[4]	2617.90.0030	6,090	244	6	--	--	--	--
Beryllium oxide and hydroxide	2825.90.1000	6,990	2,520	73	6,850	2,470	92	Estonia, 100%.
Beryllium, unwrought[5]	8112.12.0000	--	--	--	396	396	194	Canada, 100%.
Beryllium waste and scrap	8112.13.0000	66	66	5	449	449	17	Canada, 100%.
Beryllium, other[6]	8112.19.0000	38,000	38,000	5,320	24,800	24,800	5,370	Latvia, 62%; Kazakhstan, 25%; Canada, 5%; Ukraine, 5%.
Beryllium-copper master alloy	7405.00.6030	60,500	2,420	1,640	76,700	3,070	2,020	Kazakhstan, 90%.
Beryllium-copper plates, sheets, and strip	7409.90.1030, 7409.90.5030, 7409.90.9030	366,000	5,480	7,690	528,000	7,920	12,200	Japan, 98%.
Total		477,000	48,800	14,700	637,000	39,100	19,900	Japan, 81%; Kazakhstan, 12%.

-- Zero.

[1]Table includes data available through April 5, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States are imports and Schedule B of the United States are exports.

[3]Estimated from gross weight.

[4]Includes powders.

[5]Data verified by U.S. Census Bureau.

[6]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]	2018	2019	2020	2021	2022
Brazil	39 r	9 r	10 r, e	2,000 r	1,000 e
China	1,725	1,750	1,750 e	1,750 e	1,750 e
Madagascar[e, 4]	16	16	14 r	16	16
Mozambique	381	45	80	330	629
Nigeria	35	1 r	2 r	-- r	-- e
Rwanda[e]	20	20	18 r	20	20
Uganda	24	15	190	35 r	35 e
United States[5]	4,130	3,990	4,150	4,370	4,330
Total	6,370 r	5,850 r	6,210 r	8,520 r	7,780 e

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

[1]Table includes data available through September 20, 2023. All data are reported unless otherwise noted: totals may include estimated data. 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 may also 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.

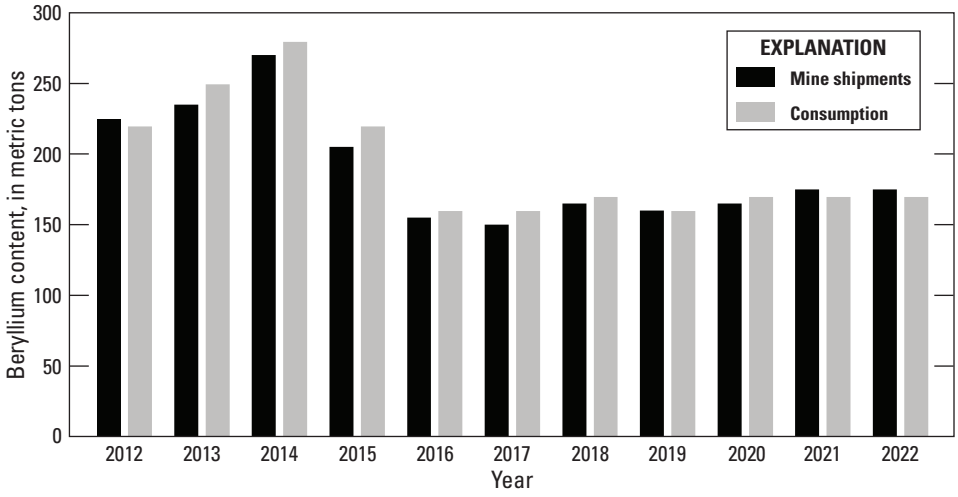

Figure 1. U.S. mine shipments and consumption of beryllium from 2012 through 2022.