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2019 Minerals Yearbook

BROMINE [ADVANCE RELEASE]

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Bromine

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The United States was one of the four leading bromine producers in the world, along with China, Israel, and Jordan. World production of bromine in 2019, excluding the United States, was estimated to be 429,000 metric tons (t) compared with 362,000 t in 2018 (tables 1, 6). In 2019, bromine sold or used in the United States increased slightly compared with 2018, but data were withheld to avoid disclosing company proprietary information.

Bromine is one of two elements that are liquid at room temperature and is found principally as a dissolved species in seawater, evaporitic (salt) lakes, and underground brines associated with petroleum deposits. Bromine is an essential element for life and is a requirement for tissue development (McCall and others, 2014). In 2019, the leading global applications of bromine were in the production of brominated flame retardants (BFRs) (approximately 40%) and intermediates and industrial applications (approximately 30%), and the remaining consumption was attributed to clear brine fluids, water treatment, and other uses (Israel Chemicals Ltd., 2020, p. 118).

Production

Domestic production data for bromine were developed by the U.S. Geological Survey (USGS) from a voluntary canvass of the two United States producers—Albemarle Corp. (Charlotte, NC) and Lanxess AG (Germany) (table 2). Production data collected by the USGS were withheld to avoid disclosing company proprietary information.

In the United States, bromine was recovered from brine wells in Arkansas, where bromine is found in the Jurassic Smackover Formation. The brines in Arkansas have bromine concentrations ranging from 4,000 to 4,600 parts per million (ppm) bromine; by comparison, seawater contains about 65 ppm bromine (Mills and others, 2015, p. 2; Arkansas Geological Survey, undated).

After bromine processing, the spent brine is returned underground into the production formation by class V injection wells that are regulated by the U.S. Environmental Protection Agency (EPA). The chemical composition of the post-processed brine is similar to that of the pre-processed brine, except that the concentration of the target elements (such as bromine and magnesium) is reduced, and the concentration of other elements (such as calcium) may have increased through substitution (U.S. Environmental Protection Agency, 1999, p. 1–2, 5).

Environment

Methyl bromide, a broad-spectrum pesticide used in the control of nematodes, pathogens, pest insects, rodents, and weeds, is the leading bromine-containing pesticide in the world, but its use has been declining owing to the ban imposed by the Montreal Protocol, which classified it as a class I ozone-depleting substance. As part of the Montreal Protocol, developed countries were to stop using the pesticide by 2005; however, the United States received annual exemptions for crops and other critical uses. The critical-use exemption is for applications where no technically or economically feasible alternatives to methyl bromide exist. Since 2017, the EPA had not approved any critical-use exemptions for methyl bromide. Although there were no critical-use exemptions in 2019, future exemptions could be granted if a need arose that met the criteria. A separate exemption under the Montreal Protocol does allow for the use of methyl bromide for the quarantine and preshipment applications of agricultural commodities and lumber to prevent the spread of pests in trade (United Nations, 2000, p. 19).

Recycling

Some bromide solutions were recycled to obtain elemental bromine and to prevent the solutions from being disposed of as hazardous waste. For example, hydrogen bromide is emitted as a byproduct of many organic reactions, such as the reaction between an alkane and bromine (Kesner, 1999, p. 173). This byproduct can be recycled with virgin bromine brines and used as a source of bromine production. About 45% of Albemarle Corp.'s production is from recycled or byproduct bromides (Albemarle Corp., 2019, p. 33).

Bromine contained in plastics, such as BFRs, can be incinerated as solid organic waste and the bromine recovered (Mills and others, 2015, p. 12). The stability of BFRs may reduce or eliminate the need for incorporating additional flame retardants into new products made from recycled plastic that contain a BFR (Bromine Science and Environmental Forum, undated). However, this stability may lead to the unintentional reintroduction of bromine or BFRs into new plastic product cycles (Pivnenko and others, 2017; Turner and Filella, 2017).

Consumption

The USGS did not collect consumption data on bromine compounds. Apparent consumption of bromine in the United States, calculated by the USGS as production plus imports minus exports, was essentially unchanged from that in 2018. In 2019, the leading global applications of bromine were in the production of BFRs (approximately 40%) and intermediates and industrial applications (approximately 30%), and the remaining consumption was attributed to clear brine fluids, water treatment, and other uses (Israel Chemicals Ltd., 2020, p. 118).

BFRs are commonly used in many household and industrial appliances; electronic equipment, such as computers, telephones, televisions, and wires and cables; building materials such as insulation foams; and other items, such as furniture, mattresses, and textiles (National Institute of Environmental Health Sciences, 2016).

Bromine and bromine compounds are widely used in the agricultural, chemical, and pharmaceutical industries. Applications include dyes, perfumes, photographic chemicals, rubber, and zinc-bromine batteries. Bromine compounds are especially effective pesticides, used as soil fumigants in agriculture, particularly in fruit growing, and as fumigants to prevent pests from attacking stored grain and fresh produce.

Calcium bromide, sodium bromide, and zinc bromide, collectively referred to as clear brine fluids, are used in the oil- and gas-well-drilling industry for high-density, solids-free completion, packer, and workover fluids to reduce the likelihood of damage to the wellbore and productive zone. These high-density fluids also help to prevent the migration of fluids from one underground formation to another through the wellbore.

Another major use of bromine is as an alternative to chlorine in water purification and disinfection. Brominated compounds are used for water treatment in hot tubs and swimming pools and to control algae and bacterial growth in industrial processes.

Bromine and bromine compounds also are used to remove mercury from flue gas emissions at coal-fired electric powerplants (Vosteen and others, 2005). Inorganic bromine compounds, such as calcium bromide, when mixed with coal at powerplants, react with mercury in combustion zones, forming mercury compounds that are captured in scrubbers, removing up to 90% of the mercury liberated during combustion (Fielding, 2012).

Foreign Trade

In terms of bromine content, exports of bromine and bromine compounds in 2019 (41,500 t) were slightly more than those in 2018 (40,600 t) (table 3). The average value of exported elemental bromine in 2019 was $2.56 per kilogram, slightly less than the average value in 2018 ($2.63 per kilogram). The leading exported bromine compound in 2019 was methyl bromide, a broad-spectrum pesticide whose use in the United States had declined owing to its classification as an ozone-depleting substance. The amount of methyl bromide exported in 2019 (16,000 t) was 27% less than that in 2018. Mexico was the leading recipient of methyl bromide, receiving 89% of total United States methyl bromide exports in 2019, on a gross weight basis.

In terms of bromine content, imports of bromine and bromine compounds in 2019 (56,300 t) increased slightly compared with the amount imported in 2018 (56,200 t) (table 4). The average value of imported elemental bromine in 2019 was $3.78 per kilogram, almost 26% greater than the average value in 2018 ($3.00 per kilogram). Based on bromine content, the category of ammonium, calcium, and zinc bromide accounted for 75% of imported materials in 2019, in terms of quantity. Israel was the leading supplier of ammonium, calcium, and zinc bromide, accounting for 76% of the total amount imported into the United States in 2019, on a gross-weight basis.

World Review

In 2019, the United States was one of the four leading bromine producers in the world, along with China, Israel, and Jordan.

China.—In China, bromine operations were located in Shandong Province. In 2017, the Government of China closed many chemical production facilities so they could complete modifications to meet new safety and environmental regulations. Subsequently, Gulf Resources, Inc., one of the leading bromine producers in China, received notice from the local government of Yangkou Town, Shouguang City, that three of their facilities would not be allowed to resume production, thus permanently closing them. By 2019, Gulf Resources had completed all the required improvements on the remaining facilities and was waiting for further notices and approvals from the Government of China. However, many of the smaller producers may have been unable to afford the required modifications (Gulf Resources, Inc., 2020, p. 4). It is unknown if the closed facilities will be able to reopen in the future.

Israel.—Israel Chemicals Ltd. (ICL) remained a world leader in bromine production with a maximum annual production capacity of 280,000 t at their Dead Sea operations (table 5). In November 2019, the International Trade Administration of the U.S. Department of Commerce determined that magnesium from Israel was sold in the United States at less than fair value following a period of investigation from October 1, 2017, through September 30, 2018 (International Trade Administration, 2019). The investigation resulted in decreased magnesium production by ICL, which in turn adversely affected its elemental bromine production. However, bromine production was slightly higher in 2019 (180,000 t) compared with that in 2018 (175,000 t) (table 6) (Israel Chemicals Ltd., 2020, p. 48).

Jordan.—Jordan Bromine Co. Ltd. (JBC) (a joint venture between Albemarle and Arab Potash Co.) processed brines from the Dead Sea in Safi, Jordan. In 2019, JBC concluded a $50 million expansion project to increase production capacity to meet rising global demand (Arab Potash Co., 2019, p. 13; 2020, p. 87). The expanded capacity was estimated to have increased 2019 bromine production to 150,000 t, compared with 100,000 t in 2018 (table 6).

Outlook

Because of domestic and international fire safety standards regulating the flammability of construction, home furnishing, and electronic products, BFRs account for the largest consumption of bromine worldwide. Over the next 4 years, the global BFR market is forecast to grow at a compound annual growth rate (CAGR) of almost 4%, and the Asia Pacific region is forecast to have the highest CAGR of 6.4% from 2019 through 2027 (Business Wire, 2019; GlobeNewswire, 2020). Environmental and toxicological concerns regarding some BFRs continued to be assessed in 2019. Questions of balancing fire safety and environmental and human health with regard to BFRs will likely continue to be examined in coming years.

The amount of clear brine fluids consumed in the oil- and gas-well drilling industry is expected to mirror global changes in oil and gas prices and the number of active drilling rigs. In 2019, the annual average number of worldwide active drilling rigs decreased compared to 2018 (Baker Hughes Inc., 2020).

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TABLE 1
SALIENT BROMINE STATISTICS[1]

(Metric tons and thousand dollars)

	2015	2016	2017	2018	2019
United States:					
Bromine sold or used:[2]					
Quantity	W	W	W	W	W
Value	W	W	W	W	W
Exports:					
Quantity (Br content)	29,600	28,300	43,400	40,600 r	41,500
Value[3]	90,400	87,400	120,000	120,000	118,000
Imports for consumption:					
Quantity (Br content)	61,200	58,400	52,700	56,200	56,300
Value[4]	139,000	128,000	121,000	125,000 r	130,000
Apparent consumption	W	W	W	W	W
World, production[e, 5]	329,000	367,000 r	383,000 r	362,000	429,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through May 12, 2020. Data are rounded to no more than three significant digits.
[2]Elemental bromine sold as such to nonproducers, including exports, or used by primary U.S. producers in preparing bromine compounds.
[3]Export values are free alongside ship.
[4]Import values are cost, insurance, and freight.
[5]Does not include U.S. production.

TABLE 2
ELEMENTAL-BROMINE-PRODUCING PLANTS IN THE UNITED STATES IN 2019[1]

State and company	County	Plant	Production source
Arkansas:			
Albemarle Corp.	Columbia	South Field plant	Well brines
Do.	do.	West Field plant	Do.
Lanxess AG	Union	Central plant	Do.
Do.	do.	South plant	Do.
Do.	do.	West plant	Do.

Do., do. Ditto.
[1]Table includes data available through May 12, 2020.

TABLE 3
U.S. EXPORTS OF BROMINE AND BROMINE COMPOUNDS[1]

Compound	HTS[2] code	2018 Gross weight (metric tons)	2018 Br content (metric tons)	2018 Value[3] (thousands)	2019 Gross weight (metric tons)	2019 Br content (metric tons)	2019 Value[3] (thousands)	Principal recipients in 2019[4]
Elemental bromine	2801.30.2000	2,620 r	2,620 r	$6,900 r	4,290	4,290	$11,000	Canada, 43%; Belgium, 28%; China, 15%.
Inorganic bromine compounds:								
Sodium or potassium bromide	2827.51.0000	4,940 r	3,580 r	8,330 r	7,500	5,430	14,700	Guyana, 35%; United Kingdom, 19%; Netherlands, 13%.
Other bromides and bromide oxides[5]	2827.59.0000	14,500	11,300	22,700	19,000	14,700	31,400	Saudi Arabia, 22%; United Arab Emirates, 18%; Brazil, 16%; Trinidad and Tobago, 12%.
Organic bromine compounds:								
Ethylene dibromide	2903.31.0000	1,430	1,220	9,010	1,230	1,050	5,960	United Kingdom, 40%; Belgium, 32%; India, 16%.
Methyl bromide	2903.39.1520	26,000	21,900	73,200 r	19,000	16,000	55,400	Mexico, 89%.
Total		49,500	40,600 r	120,000	51,000	41,500	118,000	

rRevised.
[1]Table includes data available through April 24, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Declared cost, insurance, and freight valuation exports are free alongside ship.
[4]Calculations based on gross weight.
[5]Includes ammonium, calcium, and zinc bromides.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS OF BROMINE AND BROMINE COMPOUNDS[1]

Compound	HTS[2] code	2018 Gross weight (metric tons)	2018 Br content (metric tons)	2018 Value[3] (thousands)	2019 Gross weight (metric tons)	2019 Br content (metric tons)	2019 Value[3] (thousands)	Principal sources in 2019[4]
Elemental bromine	2801.30.2000	1,890	1,890	$5,660	753	753	$2,850	Israel, 79%; China, 21%.
Inorganic bromine compounds:								
Ammonium, calcium, or zinc bromide	2827.59.2500	52,300	42,600	67,100	51,800	42,300	74,300	Israel, 76%; Jordan, 21%.
Hydrobromic acid	2811.19.3000	1,590	1,570	6,030	1,020	1,010	4,330	Israel, 87%; Republic of Korea, 9%.
Potassium bromate	2829.90.0500	(5)	(5)	6	(5)	(5)	11	Spain, 100%.
Sodium bromate	2829.90.2500	477	253	2,250 r	419	222	2,000	China, 99%.
Sodium or potassium bromide	2827.51.0000	12,000	8,700	32,200	15,600	11,300	39,300	Israel, 90%.
Organic bromine compounds:								
Decabromodiphenyl oxide and octabromodiphenyl oxide	2909.30.0700	230	184	1,520	289	232	2,160	China, 100%.
Dibromoneopentylglycol	2905.59.3000	816 r	465 r	5,080 r	450	256	2,810	Israel, 96%.
Ethylene dibromide	2903.31.0000	4	4	74	3	2	46	India, 68%; China, 27%.
Methyl bromide	2903.39.1520	242	204	1,600	266	224	1,770	Israel, 88%; India, 11%.
Tetrabromobisphenol A	2908.19.2500	537 r	316 r	3,010 r	100	59	504	China, 60%; Israel, 17%; Jordan, 15%.
Total		70,100	56,200	125,000 r	70,700	56,300	130,000	

rRevised.
[1]Table includes data available through April 24, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Import values are cost, insurance, and freight.
[4]Calculations based on gross weight.
[5]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
SELECTED WORLD BROMINE ANNUAL PLANT CAPACITIES AND SOURCES AS OF DECEMBER 31, 2019[1]

Country or locality and company or plant	Location	Capacity (metric tons)	Source
China, Gulf Resources, Inc.	Shandong Province	31,500	Underground brines.
India:			
Hindustan Salts Ltd.	Kharaghoda	900	Seawater bitterns from salt production.
Satyesh Brinechem Pvt. Ltd.	Hajipir	15,000	Do.
Solaris ChemTech Industries Ltd.	Khavda	NA	Do.
Tata Chemicals Ltd.	Mithapur	150	Do.
Israel, Israel Chemicals Ltd. (ICL)	Sodom	280,000	Bitterns of potash production from surface brines.
Japan, Tosoh Corp.	Shunan	24,000	Seawater.
Jordan, Jordan Bromine Co. Ltd.	Safi	150,000	Bitterns of potash production from surface brines.
Ukraine, Perekop Bromine Plant (JSC Brom)	Krasnoperekopsk	NA	Underground brines.

Do. ditto. NA Not available.
[1]Table includes data available through May 12, 2020. Does not include U.S. production capacity.

TABLE 6
BROMINE: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons)

Country or locality[2]	2015	2016	2017	2018	2019
China	86,400	77,000 r	76,000 r	60,000 e	64,000 e
India[e]	2,400	2,700	2,400	2,300	10,000
Israel	115,583	161,986	180,000	175,000	180,000
Japan[e]	20,000	20,000	20,000	20,000	20,000
Jordan[e]	100,000	100,000	100,000	100,000	150,000
Turkmenistan	500 e	500 e	NA	NA	NA
Ukraine	4,060	4,866	4,500 e	4,500 e	4,500 e
United States	W	W	W	W	W
Total[e]	329,000	367,000 r	383,000 r	362,000	429,000

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in total.
[1]Table includes data available through May 4, 2020. All data are reported unless otherwise noted. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]In addition to the countries and (or) localities listed, several other countries and (or) localities, including Iran, may have produced bromine, but available information was inadequate to make reliable estimates of output.