



2017 Minerals Yearbook

BROMINE [ADVANCE RELEASE]

BROMINE

By Emily K. Schnebele

Domestic survey data and tables were prepared by Joanna Goclawska, statistical assistant.

The United States was one of four leading bromine producers in the world along with China, Israel, and Jordan. World production of bromine in 2017, excluding the United States, was estimated to be 388,000 metric tons (t) compared with 367,000 t (revised) in 2016 (tables 1, 6). In 2017, bromine sold or used in the United States increased compared with 2016, 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. In addition, bromine is an essential element for life and is a requirement for tissue development (McCall and others, 2014). The primary uses for bromine compounds are in the production of brominated flame retardants (BFRs) and intermediates and industrial uses, as well as drilling fluids and water treatment.

Production

Domestic production data for bromine were developed by the U.S. Geological Survey (USGS) from a voluntary canvass of the two U.S. producers—Albemarle Corp. (Charlotte, NC) and Lanxess AG (Cologne, Germany), both of which responded to the survey, representing 100% of total production (table 2). Lanxess acquired Chemtura Corp. in April, following regulatory approval (Lanxess AG, 2017). Chemtura was a U.S. company based in Philadelphia, PA, that was founded in 2005 by the merger between Great Lakes Chemical Corp. and Crompton Corp. Production data collected by the USGS were withheld to avoid disclosing proprietary information.

In the United States, bromine was recovered from brine wells in Arkansas, where bromine is found in the Jurassic Smackover Formation at a depth of about 2,400 meters. The brines in Arkansas have bromine concentrations ranging from 3,000 to 5,000 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 spent brine is generally similar to that of the original, 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 has 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. In 2017, the EPA did not approve any critical-use exemptions for methyl bromide. For 2016, the EPA authorized use of 235 t, less than 1% of the historic 1991 baseline consumption of methyl bromide, for approved critical uses (U.S. Environmental Protection Agency, 2015, p. 61988). Although there were no critical-use exemptions for 2017, 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 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 (Weizmann Institute of Science, undated, p. 173). This byproduct can be recycled with virgin bromine brines and used as a source of bromine production.

Bromine contained in plastics, such as BFRs, can be incinerated as a solid organic waste, and the bromine can be recovered (Mills and others, 2015, p. 12). The stability of BFRs may reduce or eliminate the need for incorporating additional flame retardants to new products made from recycled plastics, which had previously contained a BFR (Bromine Science and Environmental Forum, undated). However, this stability may also 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, decreased in 2017. In 2017, the leading global applications of bromine were for the production of BFRs (approximately 40%) and intermediates and industrial uses (approximately 30%), with the remaining consumption attributed to clear brine fluids, water treatment, and other uses (Israel Chemicals Ltd., 2018, p. 148). BFRs are commonly used in many household and industrial appliances; electronic equipment, such as cases for computers, mobile telephones, and

televisions; and other items, such as furniture, insulation boards, mattresses, and textiles. About 90% of all electrical components contain BFRs.

Bromine compounds are widely used in the agricultural, chemical, and pharmaceutical industries. Applications include dyes, perfumes, photographic chemicals, and zinc-bromine batteries. In particular, bromide 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. World trade in agricultural goods depends on the use of bromine compounds to ensure compliance with mandatory quarantine rules.

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

Another major use of bromine is as a water purifier and disinfectant, as an alternative to chlorine. 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 are also 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 mercury liberated during combustion (Fielding, 2012). Southern Research Institute (Birmingham, AL) developed a system that converts calcium bromide to bromine gas. The bromine gas then reacts with mercury in coal-fired powerplant flue gas to form mercuric bromide, which is captured and retained in the powerplant's wet scrubbers (Southern Research Institute, 2010).

Prices

The price for purified, bulk, 99.95% bromine on an ex-works U.S. basis, as reported by Industrial Minerals, ranged from \$2.00 to \$2.45 per pound (about \$4,400 to \$5,400 per metric ton) in 2017, essentially unchanged from the average price range in 2016. Actual prices for bromine are negotiated on long- and short-term contracts between buyers and sellers.

Because the bromine industry has few producers, published price lists of elemental bromine and bromine compounds from producers were not available. Although companies typically announce price increases by percentage increase, they normally do not publish actual price data. At the end of 2016, Albemarle Corp. announced a 5% price increase for selected BFRs and bromine derivatives effective January 1, 2017 (Albemarle Corp., 2016).

Foreign Trade

In terms of bromine content, exports of bromine and bromine compounds in 2017 (43,400 t) were almost double those in 2016

(28,200 t) (table 3). The leading exported bromine compound in 2017 was methyl bromide, a broad-spectrum pesticide, whose use has been declining owing to its classification as an ozone-depleting substance. The amount of methyl bromide exported in 2017 (19,500 t) was 44% greater than that in 2016. Mexico was the leading recipient of methyl bromide, receiving 90% of the total amount of methyl bromide exported by the United States in 2017 and 82% of the total amount of methyl bromide exported by the United States in 2016. Because the number of critical-use exemptions for methyl bromide have been declining in recent years, and none were approved for 2017, the exports and imports of methyl bromide are believed to be for the quarantine and preshipment of agricultural commodities and lumber, an approved exemption to prevent the spread of pests.

Imports of bromine and bromine compounds in 2017 (52,700 t) decreased by 10% compared with the amount imported in 2016 (58,400 t) (table 4). Based on bromine content, the combined category of ammonium, calcium, and zinc bromide remained the dominant imported bromine product, in terms of quantity, accounting for 79% of imported materials in 2017. Israel was the leading supplier of ammonium, calcium, and zinc bromide, accounting for 76% of the total amount imported into the United States in 2017 on a gross-weight basis.

World Review

In 2017, The United States was one of four leading bromine producers in the world along with China, Israel, and Jordan.

China.—In China, bromine operations were located in Shandong Province. Although the Shandong Provincial government and the Government of China require companies to purchase licenses for the extraction of bromine, many small unlicensed facilities continued to operate (Gulf Resources, Inc., 2018, p. 17).

Because bromine production capacity was available for only one company, estimated production listed in table 6 is higher than the capacity listed in table 5. Gulf Resources, Inc., one of the leading bromine producers in China, had a combined production capacity of about 42,800 metric tons per year (t/yr) (table 5). This was a decrease compared to its 2016 capacity (47,300 t/yr) owing to the closure of one of its factories. In 2017, Gulf Resources produced approximately 18,000 t of bromine, about a 5% increase compared with 2016 production of approximately 17,000 t (Gulf Resources, Inc., 2018, p. 26).

Israel.—Israel Chemicals Ltd. (ICL) (Tel Aviv) remained a world leader in bromine production with a maximum production capacity of 280,000 t/yr at operations on the Dead Sea (table 5). In 2017, ICL produced approximately 180,000 t of elemental bromine compared with 162,000 t produced in 2016 (table 6) (Israel Chemicals Ltd., 2017, p. 80; 2018, p. 60).

Jordan.—Jordan produced an estimated 100,000 t of bromine in 2016 (table 6). Jordan Bromine Co. Ltd. (a joint venture between Albemarle and Arab Potash Co.) processed brines from the Dead Sea in Safi, Jordan.

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. The demand for BFRs will likely remain strong owing to the possibility of more rigorous fire safety regulations in developing markets along with improvements in global standards of living as well as increasing demand for electronics (Albemarle Corp., 2018, p. 30). However, environmental and toxicological concerns regarding some BFRs continued to be assessed in 2017. Questions of balancing fire safety with environmental and human health, in relation to BFRs, will likely continue to be examined in coming years.

Bromine use in clear brine drilling fluids is dependent on fluctuations in the business cycle for the oil- and gas-well-drilling industries. In 2017, demand for clear brine fluids used in drilling was greater than in 2016 but remained low compared to pre-2016 demand and was reflected in the average number of active drilling rigs worldwide (Baker Hughes Inc., 2018; Israel Chemicals Ltd., 2018, p. 148). Future bromine use in clear brine drilling fluids will continue to be dependent on fluctuations in the oil- and gas-well-drilling industries. However, long-term growth in offshore natural-gas and oil drilling is expected and therefore in demand for clear brine fluids (Albemarle Corp., 2018, p. 30).

Bromine and bromine compounds are highly effective at removing mercury from flue-gas emissions at coal-fired electric powerplants, and this is an area of potential growth for the industry. Using bromide compounds for abatement of mercury emissions appears to be more cost effective compared with other materials, such as chlorine-, fluorine-, or iodine-based compounds. The EPA's findings on its Mercury and Air Toxics Standards (MATS), which finalized standards for the reduction of air pollution from coal- and oil-fired powerplants, will likely initiate a growing market for bromine compounds as companies comply with these regulations (U.S. Environmental Protection Agency, 2016).

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TABLE 1
SALIENT BROMINE STATISTICS¹

(Metric tons and thousand dollars)

	2013	2014	2015	2016	2017
United States:					
Bromine sold or used:²					
Quantity	W	W	W	W	W
Value	W	W	W	W	W
Exports:^{3,4}					
Quantity (Br equivalent)	28,800 ^r	31,500 ^r	29,600 ^r	28,200 ^r	43,400
Value ⁵	77,700 ^r	93,800 ^r	90,400 ^r	87,300 ^r	120,000
Imports for consumption:³					
Quantity (Br equivalent)	37,100 ^r	59,400 ^r	61,200 ^r	58,400 ^r	52,700
Value ⁶	97,800 ^r	134,000 ^r	139,000 ^r	128,000 ^r	121,000
Apparent consumption	W	W	W	W	W
World, production ⁷	389,000	375,000	328,000 ^r	367,000 ^r	388,000

¹Revised. W Withheld to avoid disclosing company proprietary data.

²Table includes data available through June 14, 2019. Data are rounded to no more than three significant digits.

³Elemental bromine sold as such to nonproducers, including exports, or used by primary U.S. producers in preparing bromine compounds.

⁴Includes changes to trade sources and reporting methods that are different from the 2016 Minerals Yearbook.

⁵Includes bromine compounds that were not included in the 2016 Minerals Yearbook and earlier editions.

⁶Free alongside ship value.

⁷Cost, insurance, and freight value.

⁷Does not include U.S. production.

TABLE 2
ELEMENTAL-BROMINE-PRODUCING PLANTS IN THE UNITED STATES IN 2017¹

State and company	County	Plant	Production source
Arkansas:			
Albemarle Corp.	Columbia	South Field plant	Well brines
Do.	do.	West Field plant	Do.
Do.	Union	Satellite plants	Do.
Lanxess AG ²	do.	Central and South plants	Do.
Do.	do.	West plant	Do.

Do., do. Ditto.

¹Table includes data available through June 14, 2019.

²Previously Chemtura Corp., was acquired by Lanxess AG effective April 21, 2017.

TABLE 3
U.S. EXPORTS OF BROMINE AND BROMINE COMPOUNDS¹

Compound	HTS ² code	2016			2017			Principal recipients in 2017 ⁴
		Gross weight (metric tons)	Br equivalent (metric tons)	Value ³ (thousands)	Gross weight (metric tons)	Br equivalent (metric tons)	Value ³ (thousands)	
Elemental bromine	2801.30.2000	5,370 ^r	5,370 ^r	\$13,600 ^r	5,680	5,680	\$10,000	China, 75%; Canada, 13%.
Inorganic bromine compounds:								
Sodium or potassium bromide ⁵	2827.51.0000	5,100 ^r	3,690 ^r	7,140 ^r	5,800	4,200	8,720	Netherlands, 39%; United Kingdom, 35%; Canada, 12%.
Other bromides and bromide oxides ⁶	2827.59.0000	6,540 ^r	5,070 ^r	13,800 ^r	17,400	13,500	32,000	Saudi Arabia, 30%; Trinidad and Tobago, 22%; United Arab Emirates, 16%.
Organic bromine compounds:								
Ethylene dibromide	2903.31.0000	628	534	4,260	596	507	3,600	Belgium, >79%; India, 20%.
Methyl bromide	2903.39.1520	16,100	13,600	48,500	23,200	19,500	65,200	Mexico, 90%.
Total		33,800 ^r	28,200 ^r	87,300 ^r	52,700	43,400	120,000	

^rRevised.

¹Table includes data available through June 14, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States.

³Free alongside ship value.

⁴Calculations based on gross weight.

⁵Compounds previously reported separately.

⁶Includes ammonium, calcium, and zinc bromides. Previously reported calcium bromide separately.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS OF BROMINE AND BROMINE COMPOUNDS¹

Compound	HTS ² code	2016			2017			Principal sources in 2017 ⁴
		Gross weight (metric tons)	Br equivalent (metric tons)	Value ³ (thousands)	Gross weight (metric tons)	Br equivalent (metric tons)	Value ³ (thousands)	
Elemental bromine	2801.30.2000	2,690	2,690	\$8,090	2,710	2,710	Israel, >99%	
Inorganic bromine compounds:								
Ammonium, calcium, or zinc bromide	2827.59.2500	51,800 r	42,200 r	74,300 r	50,900	41,500	Israel, 76%; Jordan 17%.	
Potassium bromate	2829.90.0500	37	18	146	38	18	China, 54%; India, 37%.	
Sodium bromate	2829.90.2500	338	179	1,170	609	322	China, 100%.	
Sodium or potassium bromide ⁵	2827.51.0000	15,400 r	11,200 r	30,500 r	7,660	5,550	Israel 65%; China 22%; France 13%.	
Organic bromine compounds:								
Decabromodiphenyl oxide and								
octabromodiphenyl oxide	2909.30.0700	445	356	2,400	446	357	China, >99%.	
Dibromoneopentyl glycol	2905.59.3000	527	300	2,950	681	388	Israel, 95%.	
Ethylene dibromide	2903.31.0000	--	--	--	11	10	China, 89%.	
Hydrobromic acid	2811.19.3000	856	846	3,370	1,050	1,040	Israel, 89%.	
Methyl bromide	2903.39.1520	157 r	132 r	926 r	200	169	Israel, 100%.	
Tetrabromobisphenol A	2908.19.2500	884	519	3,920	1,060	620	China, 51%; Israel, 49%.	
Total		73,100 r	58,400 r	128,000 r	65,300	52,700		

¹Revised. -- Zero.

²Table includes data available through June 14, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

³Harmonized Tariff Schedule of the United States.

⁴Cost, insurance, and freight value.

⁵Calculations based on gross weight.

⁶Compounds previously reported separately.

Source: U.S. Census Bureau.

TABLE 5
SELECTED WORLD BROMINE ANNUAL PLANT CAPACITIES AND SOURCES AS OF DECEMBER 31, 2017¹

Country and company or plant	Location	Capacity (metric tons)	Source
China, Gulf Resources, Inc.	Shandong Province	42,800	Underground brines.
India:			
Hindustan Salts Ltd.	Kharaghoda	900	Seawater bitterns from salt production.
Solaris ChemTech Industries Ltd.	Khavda	NA	Do.
Tata Chemicals Ltd.	Mithapur	150	Do.
Israel, ICL Industrial Products	Sodom	280,000	Bitterns of potash production from surface brines.
Japan, Tosoh Corp.	Shunan	24,000	Seawater.
Jordan, Jordan Bromine Co. Ltd.	Safi	100,000	Bitterns of potash production from surface brines.
Ukraine, Perekop Bromine Plant (JSC Brom)	Krasnoperekopsk	NA	Underground brines.

Do. Ditto. NA Not available.

¹Table includes data available through June 14, 2019. Does not include U.S. production capacity.

TABLE 6
BROMINE: WORLD PRODUCTION, BY COUNTRY OR LOCALITY¹

(Metric tons)

Country or locality ²	2013	2014	2015	2016	2017
China	110,000 ^e	75,500 ^e	86,400 ^r	77,800 ^{r,e}	81,700 ^{r,e}
Germany ^c	NA	NA	--	--	--
India ^c	1,700	1,700	1,700	1,700	1,700
Israel	172,341	173,796	115,583	161,986 ^r	180,000 ^e
Japan ^c	20,000	20,000	20,000	20,000	20,000
Jordan ^c	80,000	100,000	100,000	100,000	100,000
Turkmenistan ^c	500	500	500	500	NA
Ukraine	4,100 ^e	3,200 ^e	4,100 ^{r,e}	4,900 ^r	4,900 ^e
United States	W	W	W	W	W
Total ³	389,000	375,000	328,000 ^r	367,000 ^r	388,000

^cEstimated. ^rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

¹Table includes data available through May 9, 2018. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

²In addition to the countries and (or) localities listed, other nations, including Iran, may have produced bromine, but available information was inadequate to make reliable estimates of output.

³Does not include U.S. production.