



2018 Minerals Yearbook

BROMINE [ADVANCE RELEASE]

BROMINE

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The United States was one of four leading bromine producers in the world, along with China, Israel, and Jordan. World production of bromine in 2018, excluding the United States, was estimated to be 362,000 metric tons (t) compared with 389,000 t (revised) in 2017 (tables 1, 6). In 2018, bromine sold or used in the United States decreased compared with that in 2017, 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 are to make bromine compounds used in the production of brominated flame retardants (BFRs) and intermediates and industrial uses, as drilling fluids, and for 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) (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, 2018).

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 similar to 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. In 2018, the EPA did not approve any critical-use exemptions for methyl bromide. In March 2018, the EPA approved time-limited tolerances for methyl bromide residues on certain agricultural commodities with an expiration date of December 31, 2020. The tolerance is the amount of pesticide chemical residue legally permitted in or on a food. The EPA determined that emergency conditions warranted the post-harvest use of methyl bromide on imported and domestic commodities to prevent the introduction or spread of foreign pest(s) (U.S. Environmental Protection Agency, 2018, p. 8758, 8759).

In April, the U.S. Department of Agriculture allowed lemons to be imported from Chile into the continental United States if they were produced in an area with a low prevalence of the agricultural pest, *Brevipalpus chilensis*, and followed inspection standards allowing for safe importation without the need of methyl bromide fumigation (U.S. Department of Agriculture, 2018, p. 14733).

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.

Bromine contained in plastics, such as BFRs, can be incinerated as 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 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, decreased in 2018. In 2018, the leading global applications of bromine were for the production of BFRs (approximately 40%) and intermediates and industrial applications (approximately 30%), with the remaining consumption attributed to clear brine fluids, water treatment, and other uses (Israel Chemicals Ltd., 2019, p. 133).

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 compounds are widely used in the agricultural, chemical, and pharmaceutical industries. Applications include dyes, perfumes, photographic chemicals, rubber, 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.

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 between underground formations through the wellbore.

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).

Prices

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 as percentages, they do not normally publish actual price data. In October, Lanxess increased prices by up to 11% for all its bromine-based oil field products, which included calcium bromide, sodium bromide, and zinc calcium bromide (Lanxess AG, 2018).

Foreign Trade

In terms of bromine content, exports of bromine and bromine compounds in 2018 (40,500 t) were 7% less than those in 2017 (43,400 t) (table 3). The leading exported bromine compound in 2018 was methyl bromide, a broad-spectrum pesticide whose use in the United States has declined owing to its classification as an ozone-depleting substance. The amount of methyl bromide exported in 2018 (21,900 t) was 12% greater than that in 2017. Mexico was the leading recipient of methyl bromide, receiving 91% of total United States methyl bromide exports in 2018 and 90% of total United States methyl bromide exports in 2017.

Imports of bromine and bromine compounds in 2018 (56,200 t) increased by 7% compared with the amount imported

in 2017 (52,700 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 76% of imported materials in 2018. Israel was the leading supplier of ammonium, calcium, and zinc bromide, accounting for 79% of the total amount imported into the United States in 2018 on a gross-weight basis.

World Review

In 2018, the United States was one of four leading bromine producers in the world, along with China, Israel, and Jordan.

China.—Many bromine facilities in Shandong Province remained closed while rectifications and improvements were completed to meet new environmental regulations initiated by the Government of China in late 2017 (Gulf Resources, Inc., 2018, p. 10; 2019, p. 7). Gulf Resources, Inc., one of the leading bromine producers in China, permanently closed 3 of its 10 bromine production facilities owing to a notice from the local government of Yangkou Town, Shouguang City, that those facilities would not be allowed to resume production. By yearend 2018, Gulf completed the required rectifications and improvements to its remaining seven facilities and was waiting for approval to reopen them (Gulf Resources, Inc., 2019, p. 8). The closures of those facilities led to a decrease in Gulf's production capacity from 42,808 metric tons per year (t/yr) in 2017 to 31,506 t/yr in 2018 (Gulf Resources, Inc., 2019, p. 24).

Israel.—Israel Chemicals Ltd. (ICL) (Tel Aviv) remained a world leader in bromine production with a maximum annual production capacity of 280,000 t at operations on the Dead Sea (table 5). In 2018, ICL produced approximately 175,000 t of elemental bromine compared with 180,000 t produced in 2017 (table 6) (Israel Chemicals Ltd., 2018, p. 60; 2019, p. 52).

Jordan.—Jordan produced an estimated 100,000 t of bromine in 2018 (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 more rigorous fire safety regulations in developing markets and increasing demand for electronics (Israel Chemicals Ltd., 2019, p. 133). However, environmental and toxicological concerns regarding some BFRs continued to be assessed in 2018. Questions of balancing fire safety along with environmental and human health, in relation to BFRs, will likely continue to be examined in coming years.

The amount of clear brine fluids consumed in the oil-well and gas-well drilling industries is expected to mirror global changes in oil and gas prices and the number of active drilling rigs. In 2018, the annual average number of worldwide active drilling rigs increased compared with 2017 (Baker Hughes Inc., 2019).

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TABLE 1
SALIENT BROMINE STATISTICS¹

(Metric tons and thousand dollars)

	2014	2015	2016	2017	2018
United States:					
Bromine sold or used: ²					
Quantity	W	W	W	W	W
Value	W	W	W	W	W
Exports: ³					
Quantity (Br equivalent)	31,500	29,600	28,300 ^r	43,400	40,500
Value	93,800	90,400	87,400 ^r	120,000	120,000
Imports for consumption: ⁴					
Quantity (Br equivalent)	59,400	61,200	58,400 ^r	52,700	56,200
Value	134,000	139,000	128,000	121,000	124,000
Apparent consumption	W	W	W	W	W
World, production ^{6, 5}	376,000 ^r	329,000 ^r	368,000 ^r	389,000 ^r	362,000

⁶Estimated. ^rRevised. W Withheld to avoid disclosing company proprietary data.

¹Table includes data available through July 17, 2019. Data are rounded to no more than three significant digits.

²Elemental bromine sold as such to nonproducers, including exports, or used by primary U.S. producers in preparing bromine compounds.

³Export values are free alongside ship.

⁴Import values are cost, insurance, and freight.

⁵Does not include U.S. production.

TABLE 2
ELEMENTAL-BROMINE-PRODUCING PLANTS IN THE UNITED STATES IN 2018¹

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.

¹Table includes data available through July 17, 2019.

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

Compound	HTS ² code	2017			2018			Principal recipients in 2018 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	5,680	5,680	\$10,000	2,560	2,560	\$6,740	Canada, 35%; Belgium 26%; China 26%.
Inorganic bromine compounds:								
Sodium or potassium bromide	2827.51.0000	5,810 ^r	4,210 ^r	8,730 ^r	4,930	3,570	8,320	Ghana, 39%; United Kingdom, 20%.
Other bromides and bromide oxides ⁵	2827.59.0000	17,400	13,500	32,000	14,500	11,300	22,700	Saudi Arabia, 27%; United Arab Emirates, 19%; United Kingdom, 15%.
Organic bromine compounds:								
Ethylene dibromide	2903.31.0000	596	507	3,600	1,430	1,220	9,010	Belgium, 77%; India, 16%.
Methyl bromide	2903.39.1520	23,200	19,500	65,200	26,000	21,900	73,300	Mexico, 91%.
Total		52,700	43,400	120,000	49,500	40,500	120,000	

^rRevised.

¹Table includes data available through July 17, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States.

³Declared cost, insurance, and freight valuation exports are free alongside ship.

⁴Calculations based on gross weight.

⁵Includes ammonium, calcium, and zinc bromides.

Source: U.S. Census Bureau.

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

Compound	HTS ² code	2017			2018			Principal sources in 2018 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	2,710	2,710	\$9,290	1,890	1,890	\$5,660 Israel, 89%.	
Inorganic bromine compounds:								
Ammonium, calcium, or zinc bromide	2827.59.2500	50,900	41,500	72,900	52,300	42,600	67,100 Israel, 79%; Jordan, 18%.	
Potassium bromate	2829.90.0500	38	18	189	(⁵)	(⁵)	6 Spain, 100%.	
Sodium bromate	2829.90.2500	609	322	2,390	477	253	2,260 China, >99%.	
Sodium or potassium bromide	2827.51.0000	7,660	5,550	19,400	12,000	8,700	32,200 Israel, 73%; China, 22%.	
Organic bromine compounds:								
Decabromodiphenyl oxide and								
octabromodiphenyl oxide	2909.30.0700	446	357	2,260	230	184	1,520 China, 100%.	
Dibromoneopentyl glycol	2905.59.3000	681	388	3,770	801	457	4,940 Israel, 86%; China, 14%.	
Ethylene dibromide	2903.31.0000	11	10	184	4	4	74 India, 89%; Canada, 11%.	
Hydrobromic acid	2811.19.3000	1,050	1,040	4,460 ^r	1,590	1,570	6,030 Israel, 92%.	
Methyl bromide	2903.39.1520	200	169	1,270	242	204	1,600 Israel, 93%.	
Tetrabromobisphenol A	2908.19.2500	1,060	620	5,000	542	319	3,070 China, 78%; Jordan, 15%.	
Total		65,300	52,700	121,000	70,100	56,200	124,000	

^rRevised.¹Table includes data available through July 17, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.²Harmonized Tariff Schedule of the United States.³Import values are cost, insurance, and freight.⁴Calculations based on gross weight.⁵Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
SELECTED WORLD BROMINE ANNUAL PLANT CAPACITIES AND SOURCES AS OF DECEMBER 31, 2018¹

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.
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 July 17, 2019. Data are rounded to no more than three significant digits.

TABLE 6
BROMINE: WORLD PRODUCTION, BY COUNTRY OR LOCALITY¹

(Metric tons)

Country or locality ²	2014	2015	2016	2017	2018
China	75,500 ^e	86,400	77,800 ^e	81,700 ^e	60,000 ^e
Germany ^e	NA	--	--	--	--
India ^e	2,200 ^r	2,400 ^r	2,700 ^r	2,400 ^r	2,300
Israel	173,796	115,583	161,986	180,000	175,000
Japan ^e	20,000	20,000	20,000	20,000	20,000
Jordan ^e	100,000	100,000	100,000	100,000	100,000
Turkmenistan ^e	500	500	500	NA	NA
Ukraine	3,549 ^r	4,060 ^r	4,866 ^r	4,500 ^{r,e}	4,500 ^e
United States	W	W	W	W	W
Total ^{e,3}	376,000 ^r	329,000 ^r	368,000 ^r	389,000 ^r	362,000

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

¹Table includes data available through April 22, 2019. 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.

²In addition to the countries and (or) localities listed, several 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.