



2009 Minerals Yearbook

BROMINE

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The United States was the world's leading producer of bromine; however, the U.S. portion of world production has decreased steadily since 1973, when the United States produced 71% of the world supply. World production of bromine for 2009, excluding the United States, was estimated to be 375,000 metric tons (t) compared with 412,000 t in 2008 (tables 1, 6). The world producers of bromine included China, Israel, Jordan, the United States, and seven other countries. In 2009, bromine sold or used in the United States was estimated to have decreased from 243,000 t valued at \$339 million produced in 2006 (table 1); however, data were withheld to avoid disclosing company proprietary data.

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. Primary uses of bromine compounds were in flame retardants (FRs), drilling fluids, water treatment, and brominated pesticides (mostly methyl bromide).

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 (table 2). Albemarle Corp. and Chemtura Corp., both of which responded to the survey, represent 100% of total production. Production data collected by the USGS were withheld to avoid disclosing proprietary information (table 1).

Bromine was recovered from brine wells in Arkansas where brine is found in the Smackover Formation at a depth of about 2,400 meters with concentrations of 4,000 to 5,000 parts per million (ppm) bromine; by comparison, seawater contains 65 ppm bromine.

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).

Recycling

Some bromide solutions were recycled to obtain elemental bromine and to prevent the solutions from being disposed of as hazardous waste. Hydrogen bromide is emitted as a byproduct from many organic reactions. This byproduct waste is recycled with virgin bromine brines and is a major source of bromine production. Plastics containing brominated FRs (BFRs) can be

incinerated as a solid organic waste, and the bromine can be recovered (Frim and Ukeles, 2007).

Consumption

The USGS did not collect consumption data on bromine compounds. Apparent consumption of bromine in the United States, calculated by the USGS from production plus imports minus exports, was estimated to have decreased in 2009 owing to the decline in demand. The major consumption categories, in order of magnitude, were FRs, drilling fluids, water treatment, and pesticides. Other uses included butyl rubber, dyes, mercury emissions, pharmaceuticals, photographic chemicals, and surfactants.

An estimated 50% of bromine consumption was in BFRs, chemicals commonly used in many domestic and industrial appliances and equipment, such as computers, furniture, insulation boards, mattresses, mobile telephones, televisions, and textiles. About 90% of all electrical components contain BFRs.

Albemarle and Chemtura reached an agreement with the EPA for a voluntary phaseout of decabromodiphenyl ether (decaBDE) flame retardant. DecaBDE is used in consumer electronics, furniture, plastic shipping pallets, and textiles. The two companies signed a memorandum of understanding (MOU) with the EPA to end production, importation, and sales of decaBDE for most uses by December 2012 and for all uses by the yearend 2013 (U.S. Environmental Protection Agency, 2009a).

Calcium bromide, sodium bromide, and zinc bromide, collectively referred to as clear brine fluids (CBFs), were 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 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, which is an alternative to using 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 compounds are effective pesticides, used both as soil fumigants in agriculture, particularly fruit growing, and as a fumigant to prevent pests from attacking stored grain and other produce. World trade in agricultural goods depends on the use of bromine compounds to ensure compliance with mandatory quarantine rules. Bromine compounds also are used as intermediates to make other agricultural chemicals. Methyl bromide is the leading bromine-containing pesticide

in the world, but its use is declining owing to the ban imposed by the 1987 Montreal Protocol, which classified it as a class I ozone-depleting substance. As part of the Montreal Protocol, wealthy countries were to stop using the pesticide by 2005; however, the United States has received annual exemptions for crops and other critical uses (for example, cucumbers, melons, orchard replants, peppers, post-harvest uses, squash, strawberries, and tomatoes). In 2009, the EPA authorized use of 4,195 t or 16.4% of the historic 1991 baseline consumption of methyl bromide for approved critical uses (U.S. Environmental Protection Agency, 2009b, p. 16). Methyl bromide is a broad spectrum pesticide used in the control of nematodes, pathogens, pest insects, rodents, and weeds. Domestically, methyl bromide had proven to be difficult to replace because of its low cost and usefulness against a large variety of agricultural pests.

Bromide-base technologies to remove mercury emissions at coal-fired powerplants are an area of potential growth for the industry. Albemarle signed an MOU with MeadWestvaco Corp. to form a partnership to develop a domestic supply of activated carbon to remove mercury from coal-fired plant emissions. The two companies were to continue to develop brominated wood-based activated carbons for use in mercury control (Albemarle Corp., 2009). Chemtura had also developed bromine and brominated derivative products for use in the control of mercury emissions from coal-fired plants (Chemtura Corp., 2009).

Transportation

Bromine in bulk quantities is transported in the United States in 7,570- and 15,140-liter (L) lead-lined pressure tank railcars or 6,435- to 6,813-L nickel-clad pressure tank trailers. The trailers must be filled at least 92% full to prevent inertia effects of the heavy liquid while on the highway. International shipments by The Dead Sea Bromine Group are in 15.2- to 23.3-t lead-lined tank containers (isotanks) with a volume of 5,300 to 8,000 L. For smaller quantities, lead lined tanks (“goslars”) of 3.5 t (four tanks packed on one isoframe) and cylinders of 400 kilograms are used. Dry nitrogen gas is recommended for use in pressure transferring bromine, although dry air may be used. The gas used must be absolutely dry or severe corrosion results. When exposed to a high-humidity atmosphere, the water content of bromine can exceed 300 ppm. If the water content exceeds 70 ppm, the corrosiveness of bromine to many metals increases (Frim and Ukeles, 2007).

Prices

In the beginning of 2009, prices for bromine and bromine compounds were lower as a result of the poor market conditions worldwide. Prices began to rebound in the latter part of 2009 owing to increased demand. The increase in bromine and bromine compound prices reflected the rising market value of bromine and increases in the cost of energy, key raw materials, regulatory compliance, and transportation.

Bromine exports were about 36% lower than those in 2008 (tables 1, 3). The value of exported elemental bromine and bromine compounds decreased by 23% compared with that of 2008. Bromine imports were about 17% lower than

those of 2008. The value of imported elemental bromine and some bromine compounds increased, with the exception of ammonium bromide, potassium bromate, sodium bromate, methyl bromide, tetrabromobisphenol A, decabromodiphenyl oxide, and octabromodiphenyl oxide (tables 1, 4). Overall the import value for elemental bromine and bromine compounds decreased by 14% in 2009.

World Review

The U.S. share of world bromine production has decreased as other countries have strengthened their positions as world producers of elemental bromine. Israel, the United States, Jordan, China, Japan, and Turkmenistan, in descending order, had the leading bromine production capabilities in 2009 (table 5).

Canada.—Environment Canada has issued a performance agreement to control, monitor, and minimize the release of decaBDE from Canadian facilities where decaBDE is used or handled. The proposed agreement aims to manage and reduce releases of decaBDE from its use in plastic and textile manufacturing facilities (Environment Canada, 2009, p. 2)

China.—Shouguang City Haoyuan Chemical Company Ltd. (SCHC) (a subsidiary of Gulf Resources, Inc.) started production of the bromine assets acquired in January. The assets were expected to add an additional 4,000 metric tons per year (t/yr) of bromine production capacity, increasing capacity to 38,700 t/yr (Gulf Resources, Inc., 2009a, b).

Israel.—ICL Industrial Products (a subsidiary of Israel Chemicals Ltd.) began a program designed to accelerate the market’s transition to sustainable flame retardant solutions by developing next-generation polymeric flame retardants and beginning a 3-year phaseout of sales of decaBDE to the U.S. market (ICL Industrial Products, 2009).

ICL has developed a bromine compound to remove mercury emission from coal-fired powerplants and, to a lesser degree, emissions by hazardous substance kilns, production of chlorine, and incineration of medical waste products (ICL Industrial Products, 2010).

Outlook

Between 40% and 50% of domestic consumption of bromine is for FRs. In the first half of 2009, demand for FRs, particularly in the construction and electronics industries, declined as a result of the poor market conditions. Although FR usage fluctuates along with overall cycles in the economy, world consumption of FRs is expected to increase, assuming sustained economic growth. Recycling efforts in Europe for BFR plastics in electrical usage, which are easier to recycle than some other FR compounds, may increase the demand for BFR products. BFR products are thought to be more environmentally friendly, especially where recycling is an important concern, such as in Europe and Japan. However, use of BFRs will likely increase at a slower pace owing to legislative mandates and customer demand for more environmentally friendly materials.

The Freedonia Group forecast FR global consumption to rise by 4.7% per year through 2011 (Freedonia Group, The, 2007). The increase would be driven by the use of FRs in developing

countries as they begin to adopt more stringent flammability standards and begin to use more plastic materials. Asia and the Pacific would be the leading consumer of FRs, with consumption rising by 7% per year. More moderate growth in FR use was expected for markets in North America and Western Europe. U.S. demand was forecast to rise by 2.7% per year through 2013 as a result of bromine use in insulated wire and cable and in construction as well as more stringent fire codes and flammability requirements (Freedonia Group, The, 2009a). Above-average gains in the demand for FRs were expected to take place in Africa, Eastern Europe, the Middle East, and Latin America.

Bromine use in CBFs is highly dependent on fluctuations in the oil and natural gas drilling industry. Oil and gas drilling activity in the United States was lower in 2009 than in 2008 as a result of the economic downturn. Production for crude oil and natural gas production was expected to increase as demand for these commodities increases.

Bromine water treatment chemical use was expected to show modest growth during the next several years. Bromine is used in both commercial and residential hot tubs, swimming pools, and whirlpools. In addition, bromine is used to treat industrial cooling water. Bromine has been found to be safer than its substitutes in sanitary preparations because bromine has a higher biocidal activity level for the same volume of product. The use of bromine compounds was expected to continue increasing in the hot tub, spa, and swimming pool sector as a gentler disinfectant than chlorine. Global demand for water treatment products was projected to increase in developing markets, such as China and India, as a result of continued industrial expansion and increased efforts to expand access to safe water supplies (Freedonia Group, The, 2009b).

Bromine use in photography is declining as digital imaging replaces film in consumer and professional photography. Most feature films for movie theater presentation are shot using printed film; however, the use of digital technology was expected to increase and overtake film in these applications during the next decade.

The market potential for bromide-base technologies to remove mercury emissions at coal-fired powerplants is expected to be an area of potential growth for the industry. Using bromide compounds to neutralize mercury emissions appears to be more cost effective compared with other materials like chlorine-, fluorine-, or iodine-base compounds.

References Cited

- Albemarle Corp., 2009, Albemarle announces strategic alliance with MeadWestvaco to expand mercury removal product and services line: Baton Rouge, LA, Albemarle Corp. press release, September 8, 1 p.
- Chemtura Corp., 2009, GeoBrom™ bromine and brominated derivatives remove mercury from coal fired power plant emissions: Middleburg, CT, Chemtura Corp. press release, September 14, 1 p.
- Environment Canada, 2009, Performance agreement to control, monitor and minimize the release of decabromodiphenyl ether commercial mixture (decaBDE) from Canadian facilities where decaBDE is used and handled: Environment Canada, March 28, 19 p. (Accessed June 16, 2010, at <http://www.ec.gc.ca/epe-epa/F21F03B2-CF46-43F3-8CCF-891FB2ABEB31/decaEN.pdf>.)
- Freedonia Group, The, 2007, World flame retardants—Industry study with forecasts for 2011 & 2016: Cleveland, OH, The Freedonia Group, December, 8 p. (Accessed May 29, 2009, at <http://www.freedoniagroup.com/brochure/22xx/2277smwe.pdf>.)
- Freedonia Group, The, 2009a, Flame retardants—US industry study with forecasts for 2013 & 2018: Cleveland, OH, The Freedonia Group, December, 8 p. (Accessed May 11, 2010, at <http://www.freedoniagroup.com/brochure/25xx/2557smwe.pdf>.)
- Freedonia Group, The, 2009b, World water treatment products—Industry study with forecasts for 2013 & 2018: Cleveland, OH, The Freedonia Group, November, 8 p. (Accessed May 11, 2010, at <http://www.freedoniagroup.com/brochure/24xx/2412smwe.pdf>.)
- Frim, R., and Ukeles, S.D., 2007, Bromine: Mining Engineering, v. 59, no. 6, June, p. 22–23.
- Gulf Resources, Inc., 2009a, Gulf Resources begins formal production of new bromine and crude salt assets: Shouguang City, China, Gulf Resources Inc. press release, December 14, 1 p.
- Gulf Resources, Inc., 2009b, Gulf Resources provides expected net income contribution of acquired manufacturing assets: Shouguang City, China, Gulf Resources Inc. press release, September 25, 1 p.
- ICL Industrial Products, 2009, ICL-IP announces next-generation flame retardant strategy: Be'er Sheva, Israel, ICL Industrial Products press release, December 18, 2 p.
- ICL Industrial Products, 2010, ICL to boost sales by making coal-fueled plants friendlier: Be'er Sheva, Israel, ICL Industrial Products press release, February 3, 3 p.
- U.S. Environmental Protection Agency, 1999, The class V underground injection control study—Spent brine flow wells: U.S. Environmental Protection Agency EPA/816-R-99-014i, 27 p.
- U.S. Environmental Protection Agency, 2009a, DecaBDE phase-out initiative: U.S. Environmental Protection Agency, December 17, 1 p. (Accessed June 3, 2010, at <http://www.epa.gov/oppt/existingchemicals/pubs/actionplans/deccadbe.html>.)
- U.S. Environmental Protection Agency, 2009b, Protection of stratospheric ozone—The 2009 critical use exemption from the phaseout of methyl bromide: U.S. Environmental Protection Agency EPA/74 FR19878, 23 p.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

- Bromine. Ch. in Mineral Commodity Summaries, annual.
- Evaporites and Brines. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

- Bromine. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
- Bromine Science and Environmental Forum.

TABLE 1
SALIENT BROMINE STATISTICS¹

(Metric tons and thousand dollars)

	2005	2006	2007	2008	2009
United States:					
Bromine sold or used: ²					
Quantity	226,000	243,000	W	W	W
Value	168,000	339,000	W	W	W
Exports: ³					
Quantity	9,740	12,400	8,560 ^r	9,640 ^r	6,120
Value	16,800	23,000	15,200 ^r	16,200 ^r	12,400
Imports for consumption: ⁴					
Quantity	59,100	43,100	32,200 ^r	41,200 ^r	34,200
Value ⁵	55,800	78,100	817,000 ^r	97,300 ^r	83,300
Apparent consumption	277,000	275,000	W	W	W
World, production ^c	654,000 ^r	669,000	408,000 ^{r,6}	412,000 ^{r,6}	375,000 ⁶

^cEstimated. ^rRevised. W Withheld to avoid disclosing company proprietary data.

¹Data 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.

⁴Source: U.S. Census Bureau or United Business Media Global Trade Port Import/Export Reporting Service (see table 4).

⁵Import values are cost, insurance, and freight.

⁶Excludes U.S. production.

TABLE 2
ELEMENTAL-BROMINE-PRODUCING PLANTS IN THE UNITED STATES IN 2009

State and company	County	Plant	Production source	Capacity ¹ (thousand metric tons)
Arkansas:				
Albemarle Corp.	Columbia	Magnolia South	Well brines	NA
Do.	do.	Magnolia West	do.	NA
Do.	Union	Satellite plants	do.	NA
Total				148 ²
Chemtura Corp.	do.	El Dorado Central and El Dorado South	do.	71 ³
Do.	do.	Marysville West	do.	36
Do.	do.	Newell	do.	23
Total				59
Grand total				278

Do., do. Ditto. NA Not available.

¹Actual production capacity is limited by brine availability.

²Cumulative capacity of Magnolia South, Magnolia West, and Satellite plants.

³Cumulative capacity of El Dorado Central and El Dorado South plants.

TABLE 3
U.S. EXPORTS OF BROMINE AND BROMINE COMPOUNDS^{1,2}

Compound	HTS ³ number	2008			2009		
		(metric tons)		Value ⁴ (thousands)	(metric tons)		Value ⁴ (thousands)
		Gross weight	Br equivalent		Gross weight	Br equivalent	
Elemental bromine	2801.30.2000	6,140	6,140	\$7,100	3,810	3,810	\$5,930
Other compounds:							
Ethylene dibromide	2903.31.0000	2,750 ^r	2,340 ^r	5,840 ^r	1,760	1,500	4,320
Methyl bromide	2903.39.1520	1,380 ^r	1,160 ^r	3,280 ^r	968	815	2,190
Grand total		10,300 ^r	9,640 ^r	16,200 ^r	6,540	6,120	12,400

^rRevised.

¹These data detail the information included in table 1 under "Exports."

²Data are rounded to no more than three significant digits; may not add to totals shown.

³Harmonized Tariff Schedule of the United States.

⁴Declared cost, insurance, and freight valuation.

Source: U.S. Census Bureau.

TABLE 4

U.S. IMPORTS OF BROMINE AND BROMINE COMPOUNDS^{1,2}

Compound	HTS ³ number	2008			2009			Principal sources in 2009
		(metric tons)		Value ⁴	(metric tons)		Value ⁴	
		Gross weight	Br equivalent	(thousands)	Gross weight	Br equivalent	(thousands)	
Elemental bromine	2801.30.2000	1,950	1,950	\$2,280	1,390	1,390	\$3,020 Israel, 95%.	
Bromine compounds:								
Ammonium bromide	2827.59.2500	37,000	30,200	56,500	25,600	20,900	39,200 Israel, 85%; Germany, 11%.	
Calcium bromide ⁵	2827.59.2500	684	547	595 ^e	1,760	1,410	1,690 ^e China, 64%; Israel, 30%.	
Potassium bromate	2829.90.0500	84	40	349	54	26	203 China, 100%.	
Potassium bromide ^{5,6}	2827.51.0000	272	182	1,030 ^e	279	187	1,170 ^e Israel, 78%; China, 16%.	
Sodium bromate	2829.90.2500	686	363	1,810	223	118	547 China, 99%.	
Sodium bromide ^{5,6}	2827.51.0000	4,320	3,350	7,050 ^{r,e}	6,490	5,040	11,900 ^e Israel, 57%; China, 30%; Belgium, 13%.	
Other compounds:								
Hydrobromic acid	2811.19.3000	422	417	483	970	958	1,520 Israel, 52%; France, 33%; United Kingdom, 14%.	
Ethylene dibromide	2903.31.0000	84 ^r	71 ^r	53 ^r	105	89	178 Israel, 85%; Japan, 13%.	
Methyl bromide	2903.39.1520	647 ^r	545 ^r	4,850 ^r	565	476	4,260 Israel, 98%.	
Dibromoneopentyl glycol ⁵	2905.50.3000	536	306	NA	606	345	NA China, 90%; Israel, 10%.	
Tetrabromobisphenol A	2908.19.2500	1,140 ^r	675 ^r	7,760 ^r	1,860	1,100	7,250 Israel, 63%; Jordan, 35%.	
Decabromodiphenyl oxide and octabromodiphenyl oxide	2909.30.0700	4,480	2,580	14,500	3,810	2,190	12,400 Israel, 92%.	
Grand total		52,300 ^r	41,200 ^r	97,300 ^r	43,700	34,200	83,300	

⁴Estimated. ^rRevised. NA Not available.¹These data detail the information included in table 1 under "Imports for consumption."²Data are rounded to no more than three significant digits; may not add to totals shown.³Harmonized Tariff Schedule of the United States.⁴Declared cost, insurance, and freight valuation.⁵Source: United Business Media Global Trade Port Import/Export Reporting Service.⁶Potassium bromide and sodium bromide import data are reported under a common HTS number, 2827.51.0000.

Source: U.S. Census Bureau.

TABLE 5
WORLD BROMINE ANNUAL PLANT CAPACITIES AND SOURCES AS OF DECEMBER 31, 2009¹

Country and company or plant	Location	Capacity (metric tons)	Source
Azerbaijan, Neftechala Bromine Plant	Baku	4,000	Underground brines.
China, Laizhou Bromine Works	Shandong	43,000	Do.
India:			
Hindustan Salts Ltd.	Jaipur	NA	Seawater bitterns from salt production.
Mettur Chemicals Ltd.	Mettur Dam	NA	Do.
Tata Chemicals Ltd.	Mithapur	NA	Do.
Total		1,500	
Israel, ICL Industrial Products	Sdom	280,000	Bitterns of potash production from surface brines.
Japan, Toyo Soda Manufacturing Co. Ltd.	Tokuyama	20,000	Seawater.
Jordan, Jordan Bromine Co. Ltd.	Safi	50,000	Bitterns of potash production from surface brines.
Spain, Derivados del Etilo S.A.	Villaricos	900	Seawater.
Turkmenistan:			
Cheleken Chemical Plant	Cheleken Region	4,740	Do.
Nebitdag Iodine Plant	Vyshka	2,370	Underground brines.
Ukraine, Perekop Bromine Plant	Krasnoperekopsk	3,000	Do.

Do. ditto. NA Not available.

¹Excludes U.S. production capacity, which is detailed in table 2.

TABLE 6
BROMINE: ESTIMATED WORLD REFINERY PRODUCTION, BY COUNTRY^{1,2}

(Metric tons)

Country ³	2005	2006	2007	2008	2009
Azerbaijan	2,000	2,000	2,000	3,500	3,500
China	104,500 ⁵	124,000	137,000 ^r	135,000	140,000
Germany ⁴	274 ⁵	431 ⁵	1,612 ⁵	1,680 ^r	1,400
India	1,500	1,500	1,500	1,500	1,500
Israel	207,048 ⁵	179,493 ⁵	159,395 ^{r,5}	164,042 ^{r,5}	128,000 ⁵
Japan	20,000	20,000	20,000	20,000	20,000
Jordan	89,785 ⁵	94,500 ⁵	85,105 ⁵	85,000	80,000
Spain	100	100	100	100	100
Turkmenistan	150	150	150	150	150
Ukraine	1,878 ^{r,5}	3,138 ^{r,5}	700 ^r	700 ^r	700
United States ⁶	226,000 ⁵	243,000 ⁵	W	W	W
Total	654,000 ^r	669,000	408,000 ^{r,7}	412,000 ^{r,7}	375,000 ⁷

^rRevised. W Withheld to avoid disclosing company proprietary data; not included in total.

¹World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through May 13, 2010.

³In addition to the countries listed, several other nations, including Iran, produced bromine, but output data were not reported; available general information is inadequate to formulate reliable estimates of output levels.

⁴Includes bromides and oxides.

⁵Reported figure.

⁶Sold or used by producers.

⁷Excludes U.S. production.