USGS
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2010 Minerals Yearbook

ARSENIC

U.S. Department of the Interior
U.S. Geological Survey

October 2012

ARSENIC

By William E. Brooks

Domestic tables were prepared by Samir Hakim, statistical assistant, and the world production table was prepared by Lisa D. Miller, international data coordinator.

In 2010, the United States produced no arsenic and relied mainly on Morocco and China, the leading and second ranked import sources, respectively, for arsenic trioxide and on China and Japan, the leading and second ranked import sources, respectively, for arsenic metal. There has been no domestic production of arsenic trioxide nor arsenic metal since 1985 following the closure of the ASARCO Inc. copper smelter in Tacoma, WA. Arsenic trioxide was used mostly for the production of chromated copper arsenate (CCA), a pesticide and preservative used to pressure treat some wood products, and for production of agricultural chemicals; however, its use as a preservative for outdoor domestic wood products, such as decks, was voluntarily discontinued at yearend 2003. Arsenic metal was used for electronics applications and in nonferrous alloys. In 2010, the United States remained the world's leading consumer of arsenic trioxide and arsenic metal.

Legislation and Government Programs

The Safe Drinking Water Act of 1975 mandated that the U.S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants, such as arsenic, that may have adverse effects on human health. The maximum contaminant level for arsenic was established at 0.05 milligram per liter (mg/L), and in 2001, was revised to 0.01 mg/L.

By yearend 2010, arsenic removal technology, using a variety of methods that included adsorptive media, coagulation/filtration, iron removal, or oxidation/filtration had been tested at locations that included Alvin, TX; Felton, DE; Goshen, IN; Lake Isabella CA; Lead, SD; Nambe Pueblo, NM; Okanogan WA; and Sabin, MN. Reports that discuss the results of these site studies were available at the EPA's arsenic Website (http://www.epa.gov/nrmrl/wswrd/dw/arsenic).

For example, at the Lead, SD, site, an adsorptive media system was evaluated in order to meet the maximum contaminant level of 10 micrograms per liter (µg/L). This project also evaluated the reliability of the arsenic removal system, its operation and maintenance, operator skills, and cost. Total arsenic concentrations in source water ranged from 16.9 to 26.3 µg/L and averaged 21.6 µg/L. The study was for 25 months and was divided into two study periods. After the first study period, arsenic concentrations in the effluent were reduced to 5.8 µg/L, and then circuit revisions were made resulting in arsenic concentration in the effluent being reduced to 0.5 µg/L by the end of the second study period (Wang and others, 2010).

Environmental and Human Health Issues

Arsenic is a naturally occurring element that may be present in drinking water as a result of weathering of arsenic-containing minerals exposed by natural processes or released by mining and smelting; as runoff from arsenic-containing pesticides used in orchards; in wastewater runoff from glass and electronics production; as arsenic released from coal-fired powerplants or from underground coal fires; or from volcanic eruptions. In humans, some of the noncancerous effects of arsenic exposure include blindness, diarrhea, discoloration and thickening of the skin, nausea, stomach pain, and vomiting. Prolonged arsenic exposure has been linked to cancer of the bladder, kidney, liver, lungs, and prostate (Agency for Toxic Substances and Disease Registry, 2007).

Owing to runoff from the Sierra Nevada Mountains, CA, which have high concentrations of natural arsenic, the arsenic concentrations in Mono Lake, CA, are 700 times greater than the EPA considers safe. Research by university, U.S. Geological Survey, and U.S. National Aeronautical and Space Administration scientists indicated that bacteria sampled from those arsenic-laden sediments used arsenic, instead of phosphorus, as a building block for life and for cellular functions. Phosphorus is nearly perfect for building the framework needed for the DNA molecule and is also useful for energy transfer within cells; however, it remained to be established how the bacteria use arsenic as a replacement for phosphorus. Regardless, this research may help redefine what to look for in terms of the chemical architecture necessary to understand extraterrestrial life (Kaufman, 2010; Wolf-Simon and others, 2010).

British scientists reported that the Deepwater Horizon oil spill in the Gulf of Mexico in 2010 increased the levels of arsenic in the world's oceans. Arsenic is normally filtered out of the ocean's waters and combines with sediments; however, oil spills stop the normal process by combining with the sediment, which then leads to an accumulation of arsenic in the water. This results in bioaccumulation of arsenic in the food chain and may eventually impact humans (New York Post, 2010).

Near Anstead, WV, well water and streams were tested for metal content. Tests indicated that antimony, arsenic, barium, lead, and manganese, which may be related to coal-mining and coal occurrences in the area, were at unacceptable levels. However, since some of the water tested came from wells on private property, EPA regulations did not apply. Recommendations for residents that get their drinking water from wells included getting wells tested, the use of bottled water, or get connected to the public water supply (Lannom, 2010).

Electronic waste (e-waste) may contain arsenic, beryllium, cadmium, copper, gold, lead, mercury, and silver that may be recycled. However, the small-scale recovery of the metals may pose an environmental hazard and risk to human health (Schmit, 2008). Vermont solid waste districts took in 725 metric tons (t) of electronic waste in 2008, and the State passed legislation in 2010 addressing disposal of most electronic devices, including

cellular telephones, computers, electronic devices, and televisions. The legislation makes disposal of e-waste illegal in landfills as of January 1, 2011 (Metal-Pages, 2010d).

Consumption

Arsenic is one of the components of CCA, a widely used wood preservative used in pressure-treated wood. The major domestic consumers of arsenic, as CCA, include Arch Wood Protection, Inc., Norwalk, CT; Osmose Wood Preserving, Inc., Buffalo, NY; and Viance LLC, Charlotte, NC. In response to concerns about the effects of arsenic exposure on human health, domestic manufacturers of wood preservatives voluntarily reduced their use of CCA at yearend 2003. The phaseout applied to wood used for boardwalks, decks, fencing, gazebos, picnic tables, and play structures. However, wood treated with CCA prior to December 31, 2003, could still be used, and glue-laminated beams, marine timbers, plywood flooring and roofing, and utility poles could still be treated with CCA.

The United States remained the world's leading consumer of arsenic, mainly for the production of CCA. Apparent domestic consumption for arsenic was about 4,820 metric tons (t) in 2010, a slight increase from 4,740 t in 2009. The estimated value of arsenic compounds and metal consumed domestically in 2010 was approximately $4.9 million.

In 2010, slightly more than 50% of the arsenic, as arsenic trioxide, was used in the wood preservative industry for nonresidential use. The remainder of the arsenic trioxide was used in agricultural chemicals (either directly or after conversion to arsenic acid) or in glass manufacturing applications. Arsenic acid also was used in glassmaking as a bubble dispersant or decoloring agent. No data were available on the percentages of arsenic used in these traditional use categories.

Some arsenic may be found as an impurity in copper, and alloys containing arsenic have been used to produce hardened copper tools since ancient times (Petersen, 1970, p. 61). Arsenic metal is used, along with antimony, to harden ammunition, in solders, and in other applications. Grids and posts in lead-acid storage batteries are strengthened by the addition of arsenic metal. Arsenic is one of several metals used as an antifriction additive in babbitt metals (alloys that are used for bearings).

High-purity (99.9999%) arsenic metal is used for gallium-arsenide (GaAs), indium-arsenide (InAs), and indium-gallium-arsenide semiconductors that are widely used in computer, biomedical, communications, electronics, and photovoltaic applications. Arsenic may be used for germanium-arsenide-selenide or GaAs specialty optical materials. Arsenic sulfide is one of several substrate materials that are used for optical thin films and interference coatings for applications in data recording media, optical communications systems, and sensors. A cellular telephone typically contains GaAs in its circuitry, of which the arsenic content is less than 1 milligram; however, since 2007, there are more GaAs components in the newer 3G and 4G cell phones. Based on reported consumption of 40 t of gallium in 2010, U.S. consumption of arsenic metal in GaAs semiconductors was also approximately 40 t in 2010, which was equal to a peak of about 40 t of arsenic metal used in 2000.

Prices

China was the world's leading producer of arsenic trioxide and arsenic metal; however, there was little change in the overall arsenic market, and sales continued to be low through July 2010. Suppliers complained that because of a lack of consumer buying, only a few small transactions took place in early 2010. In July, the price in Beijing, China, for arsenic trioxide (minimum 99%) was $0.51 per kilogram, an increase from the $0.39- to $0.41-per-kilogram price at midyear 2009 (Metal-Pages, 2010c).

In July, the price for 99%-pure arsenic metal was $1,230 per metric ton, a slight decrease from the November 2009 prices (Metal-Pages, 2010a). However, by December 2010, the price had risen to approximately $1,500 per metric ton (Metal-Pages, 2010b).

Foreign Trade

In 2010, domestic imports of arsenic compounds were 4,530 t contained arsenic, an overall decrease of approximately 3% compared with the 4,660 t contained arsenic in arsenic compounds imported in 2009. Arsenic trioxide contains 76% arsenic. In 2010, Morocco was the source of 62% of the arsenic trioxide imported into the United States, China was the source of 21%, and Belgium was the source of 16%. Imports of arsenic trioxide into the United States in 2010 from Morocco decreased by 19%; increased from China by 17%; and increased from Belgium by 89%.

In 2010, the United States imported 769 t of arsenic metal, a 75% increase compared with the 438 t of arsenic metal imported in 2009. China was the leading source of arsenic metal in 2010 and provided 639 t of arsenic metal, or 83%; however, this was an increase of 73% compared with the 370 t of arsenic metal that was imported from China in 2009. Arsenic metal was also imported from Japan (16%) and other countries.

Exports of arsenic metal from the United States in 2010 increased to 481 t from 354 t in 2009. Export destinations included Honduras (41%), Morocco (18%), Chile (11%), and Canada (10%). In the Harmonized Tariff Schedule, exported materials are classified only by number and may or may not be inspected so as to confirm the contents of the shipping container. This may have resulted in misclassification of the exported material, and therefore, exports of material classified as arsenic metal may vary from year to year. This classification may also include arsenic-containing "e-waste," such as computers and other electronics destined for reclamation and recycling (Mayo, 2008; Schmit, 2008), transshipped arsenic metal used for production of small-arms ammunition (Agence France-Presse, 2005; Chicago Tribune, The, 2005), and arsenic alloyed with lead or another metal.

World Review

In 2010, commercial-grade arsenic trioxide was recovered from processing of nonferrous ores or concentrates in 11 countries. Reduction of arsenic trioxide to arsenic metal accounted for all world output of commercial-grade (99%-pure) arsenic metal.

In 2010, China produced approximately 25,000 t of arsenic trioxide and remained the world's leading producer followed by Chile (11,000 t), Morocco (8,000 t), and Peru (4,500 t). Arsenic was also produced in China as a byproduct of gold mining from orpiment (As_2S_3) and realgar (AsS), the more common ore minerals of arsenic (Peters and others, 2002, p. 182). Arsenic trioxide was also produced in Mexico at the San Luis Potosi copper smelter.

Arsenic-containing residues and smelter dusts recovered from nonferrous metals plants in several countries may not have been processed to recover commercial-grade arsenic trioxide in 2010 and may have been stockpiled for future treatment. Production data for most countries were estimated and subject to revision.

Outlook

The voluntary decision by the wood preservative industry to eliminate CCA as a wood preservative for certain wood products has led to a decline in U.S. consumption and a decline in arsenic trioxide production in China. The use of alternative wood preservatives and wood alternatives, such as concrete, plastic, or wood composites, will continue to substitute for CCA wood preservatives. Borate-treated wood is resistant to insects and fungal decay, but its use is recommended only for interior or weather-shielded applications. Specific industrial applications, such as marine timber, plywood roofing, and utility poles, are expected to continue to use CCA-treated wood. High-purity arsenic is expected to continue to be used by the electronics industry for GaAs semiconductors. The GaAs slowdown in the first half of 2009 resulted in year-on-year growth for the industry. GaAs technology will be central to supporting the "smartphone" cellular handset. Industry research projected a 5-year average annual growth rate of up to 12% (Anwar, 2010; Higham, 2010). World sources of arsenic, as arsenic trioxide and arsenic metal from nonferrous metal processing, are expected to be sufficient to meet projected needs.

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TABLE 1

ARSENIC SUPPLY-DEMAND RELATIONSHIPS[1]

(Metric tons of arsenic content)

	2006	2007	2008	2009	2010
U.S. supply, imports:					
Metal	1,070	759	376	438	769
Compounds	9,430	7,010	4,810	4,660	4,530
Total	10,500	7,770	5,180	5,100	5,300
Distribution of U.S. supply:					
Exports[2]	3,060	2,490	1,050	354	481
Apparent consumption	7,450	5,280	4,130	4,740	4,820

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

[2]Metal only.

TABLE 2

U.S. IMPORTS FOR CONSUMPTION OF ARSENIC PRODUCTS[1]

	2009		2010	
Class and country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:				
Belgium	514	$297	973	$603
China	1,080	440	1,260	561
Germany	--	--	4	29
Morocco	4,530	1,970	3,690	1,640
Spain	10	36	--	--
Total	6,130	2,740	5,920	2,830
Arsenic acid:				
Indonesia	--	--	20	8
Japan	3	11	(2)	3
Taiwan	--	--	40	32
Total	3	11	60	43
Arsenic sulfide:				
Italy	77	334	--	--
Russia	--	--	13	35
Total	77	334	13	35
Arsenic metal:				
China	370	993	639	1,020
Germany	1	276	1	297
Japan	67	613	125	1,100
Korea, Republic of	--	--	4	11
United Kingdom	(2)	5	(2)	7
Total	438	1,890	769	2,440

-- Zero.

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

[2]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 3
ARSENIC TRIOXIDE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Metric tons)

Country[4]	2006	2007	2008	2009	2010
Belgium	1,000	1,000	1,000	1,000	1,000
Bolivia	120 [r, 5]	--	74 [5]	115 [r, 5]	155 [6]
Canada	-- [r]	-- [r]	-- [r]	-- [r]	--
Chile	11,700	11,400	10,000	11,000	11,000
China	30,000	25,000	25,000	25,000	25,000
Iran	100	100	100	100	100
Japan	40	40	40	40	40
Kazakhstan	1,500	1,500	1,500	1,500	1,500
Mexico	1,595 [5]	1,600	513	500	--
Morocco	8,900 [5]	8,950 [5]	8,800	8,500	8,000
Peru[7]	4,399 [5]	4,321 [5]	4,822 [5]	4,850	4,500 [e]
Portugal	15	15	15	15	15
Russia	1,500	1,500	1,500	1,500	1,500
Total	60,900 [r]	55,400 [r]	53,400 [r]	54,100 [r]	52,800

[r]Revised. -- Zero.

[1]Including calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide where inclusion of such materials would not duplicate reported arsenic trioxide production.

[2]World totals and estimated data have been rounded to no more than three significant digits; may not add to totals shown.

[3]Table includes data available through April 20, 2011.

[4]Austria, Hungary, the Republic of Korea, Serbia and Montenegro, South Africa, Ukraine, the United Kingdom, and Zimbabwe have produced arsenic and (or) arsenic compounds in previous years, but information is inadequate to make estimates of output levels, if any.

[5]Reported figure.

[6]Estimated exports of arsenic trioxide reported by Bolivia's Ministry of Mines and Metallurgy (in 2009).

[7]Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energía y Minas.