USGS
science for a changing world

2013 Minerals Yearbook

ARSENIC [ADVANCE RELEASE]

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

August 2015

Arsenic

By George M. Bedinger

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

In 2013, the United States produced no arsenic and relied mainly on Morocco and China for arsenic trioxide and arsenic metal, respectively. No arsenic trioxide or commercial-grade arsenic metal has been produced domestically since 1985 following the closure of the ASARCO Inc. copper smelter in Tacoma, WA. Arsenic trioxide was used mostly for the production of arsenic acid used in the formulation of chromated copper arsenate (CCA), a pesticide and preservative used to treat wood products for nonresidential applications such as guard rails, pilings, posts, railroad ties, and utility poles. Arsenic compounds were used in fertilizers, fireworks, herbicides, insecticides, and glassmaking. Arsenic metal was used for electronics applications and in nonferrous alloys. In 2013, estimated world production of arsenic trioxide was 45,200 metric tons (t) (table 3). Production data for arsenic metal were not available.

Legislation and Government Programs

In September 2012, in response to consumer concern over elevated arsenic levels in rice and rice products, the U.S. Food and Drug Administration (FDA) released the analytical results of approximately 1,300 samples of rice and rice products that were analyzed for arsenic content. On the basis of available data and scientific literature, the FDA did not recommend that consumers change their consumption of rice and rice products but advised consumers to eat a well-balanced diet, vary the types of grains consumed, and diversify infant foods (U.S. Food and Drug Administration, 2012).

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 electronics and glass production, as arsenic released from coal-fired powerplants or underground coal fires, or from volcanic eruptions. In humans, some of the noncarcinogenic 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, p. 1–30).

In July, the FDA proposed an "action level" of 10 parts per billion (ppb) for inorganic arsenic in apple juice, the same level set by the U.S. Environmental Protection Agency for arsenic in drinking water. The FDA was establishing the threshold as guidance to industry to help prevent public exposure to occasional lots of apple juice with arsenic above the permissible level for drinking water. The FDA had been monitoring the presence of arsenic in drinking water for 20 years and in 2012, released a study that found that 95% of 94 apple juice samples tested were below 10 ppb total arsenic and 100% of the samples were below 10 ppb organic arsenic, the carcinogenic form of arsenic (U.S. Food and Drug Administration, 2013).

Three U.S. Geological Survey (USGS) Scientific Investigations Reports issued in 2013 addressed the occurrence of arsenic in drinking water. USGS Scientific Investigations Report 2012–5257 outlined a comprehensive analysis of drinking water well samples in Pennsylvania to predict elevated arsenic levels in groundwater. USGS Scientific Investigations Report 2013–5055 reported the results of a pilot study designed to attenuate arsenic in well water in Norman, OK. USGS Scientific Investigations Report 2013–5123 reported on the movement of arsenic in groundwater from landfills at the Auburn Road Landfill Superfund site in Londonderry, NH (Andrews and others, 2013, p. 2, 13; Degnan and Harte, 2013, p. 1; Gross and Low, 2013, p. 1).

Consumption

In 2003, when consumption was estimated to be 21,600 metric tons per year (t/yr), domestic manufacturers of CCA began a voluntary transition from CCA to alternative wood preservatives in residential uses, which resulted in a sharp decrease in domestic consumption of arsenic by about 68% to 6,800 t/yr in 2004. In 2013, domestic apparent consumption of arsenic, based on net imports, was 6,810 metric tons (t), a 3% increase from 6,620 t in 2012. Apparent consumption was revised to be equal to total imports. Prior to 2013, apparent consumption was reported as net imports. However, analysis of trade data indicates that much of the material reported as arsenic metal exports was waste, residues, and alloys containing only limited quantities of arsenic. The estimated value of arsenic compounds and metal consumed domestically in 2013 was approximately $3.6 million. Domestic consumers of arsenic trioxide to produce CCA were Arch Wood Protection, Inc. (Norwalk, CT); Osmose Wood Preserving, Inc. (Buffalo, NY); and Viance LLC (Charlotte, NC).

Arsenic metal was used, along with antimony, to harden ammunition and in solders. 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 was used to produce gallium-arsenide (GaAs), indium-arsenide, and indium-gallium-arsenide semiconductors that were widely used in biomedical, communications, computer, electronics, and photovoltaic applications. Arsenic may be used for germanium-arsenide-

selenide or GaAs specialty optical materials. Based on the reported consumption of gallium, about 34 t of arsenic metal was consumed domestically to produce GaAs integrated circuits in 2013. The value of worldwide GaAs device sales was $5.9 billion in 2013, an increase of 11% from 2012 (Higham, 2014).

Prices

There was little change in the overall arsenic market throughout 2013 compared with that in 2012. According to U.S. Census Bureau data, the value of arsenic trioxide originating from Morocco averaged $0.27 per pound, an increase of 13% from that in 2012. Prices for arsenic metal from China averaged $0.72 per pound, a decrease of 4% from 2012.

Foreign Trade

In 2013, domestic imports of arsenic compounds were estimated to contain about 6,290 t of contained arsenic, an overall increase of approximately 10% compared with the 5,740 t imported in 2012 (table 1). Arsenic trioxide contains about 76% arsenic. In 2013, Morocco was the source of 50% of the arsenic trioxide imported into the United States, China was the source of 32%, and Belgium was the source of 10% (table 2).

In 2013, the United States imported 514 t of arsenic metal, a 42% decrease compared with the 883 t of arsenic metal imported in 2012. China was the leading source of arsenic metal in 2013, accounting for 82% of U.S. metal imports (table 2).

According to U.S. Census Bureau data, exports of arsenic metal from the United States in 2013 increased to 1,630 t from 439 t in 2012. Export destinations included Honduras (54%), Colombia (14%), Guatemala (9%), Jamaica (7%), and France (4%). Because the United States did not produce arsenic metal, it was thought that much of the material reported as metal under the Harmonized Tariff Schedule code 2480.80.0000 was arsenic-containing compounds and waste, as well as nonferrous alloys containing relatively minor quantities of arsenic. The exports also may have included arsenic-containing electronic waste, such as circuit boards and other electronic components destined for reclamation and recycling. Therefore, actual exports of arsenic metal may be significantly less than reported.

World Review

In 2013, commercial-grade arsenic trioxide was thought to have been recovered from the processing of nonferrous ores or concentrates. Reduction of arsenic trioxide to arsenic metal accounted for all world output of commercial-grade (99%-pure) arsenic metal. 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 2013 and may have been stockpiled for future treatment. Production data for most countries were estimated.

In 2013, China produced approximately 25,000 t of arsenic trioxide and remained the world's leading producer followed by Chile (10,000 t) and Morocco (7,500 t). In China, in addition to reclaiming arsenic as a byproduct of nonferrous smelting, arsenic trioxide was recovered 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).

Outlook

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 used in military, solar cells, space, and telecommunications applications. The use of GaAs components in cellular handsets and increased penetration of GaAs-based light-emitting diodes in general and automotive lighting applications are expected to increase arsenic metal consumption.

References Cited

Agency for Toxic Substances and Disease Registry, 2007, Toxicological profile for arsenic: Agency for Toxic Substances and Disease Registry, August, 500 p. (Accessed May 5, 2014, at http://www.atsdr.cdc.gov/toxprofiles/tp2.pdf.)

Andrews, W.J., Masoner, J.R., Rendon, S.H., Smith, K.A., Greer, J.R., and Chatterton, L.A., 2013, Pilot study of natural attenuation of arsenic in well water discharged to the Little River above Lake Thunderbird, Norman, Oklahoma, 2012: U.S. Geological Survey Scientific Investigations Report 2013–5055, 31 p. (Accessed July 9, 2014, at http://pubs.usgs.gov/sir/2013/5055/.)

Degnan, J.R., and Harte, P.T., 2013, Hydrogeologic framework, arsenic distribution, and groundwater geochemistry of the glacial-sediment aquifer at the Auburn Road Landfill Superfund Site, Londonderry, New Hampshire: U.S. Geological Survey Scientific Investigations Report 2013–5123, 58 p. (Accessed May 22, 2014, at http://pubs.usgs.gov/sir/2013/5123/.)

Gross, E.L., and Low, D.J., 2013, Arsenic concentrations, related environmental factors, and the predicted probability of elevated arsenic in groundwater in Pennsylvania: U.S. Geological Survey Scientific Investigations Report 2012–5257, 46 p. (Accessed May 21, 2014, at http://pubs.usgs.gov/sir/2012/5257/.)

Higham, Eric, 2014, Death blow or just a scratch to the GaAs industry?: Strategy Analytics, March 28. (Accessed July 29, 2015, at https://www.strategyanalytics.com/strategy-analytics/blogs/components/advanced-semiconductors/advanced-semiconductors/2014/03/28/death-blow-or-just-a-scratch-to-the-gaas-industry-#.VbkaA7EpDcs.)

Peters, S.G., Jiazhan, Huang, and Chenggui, Jing, 2002, Geology and geochemistry of sedimentary-rock-hosted Au deposits of the Qinling fold belt (Chuan-Shan-Gan) area, Shaanxi, Sichuan, and Gansu Provinces, P.R. China, chap. 4 *of* Peters, S.G., ed., Geology, geochemistry, and geophysics of sedimentary rock-hosted Au deposits in P.R. China: U.S. Geological Survey Open-File Report 02–131, p. 168–254.

U.S. Food and Drug Administration, 2012, FDA looks for answers on arsenic in rice: U.S. Food and Drug Administration, September 19. (Accessed January 8, 2015, at http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm319827.htm.)

U.S. Food and Drug Administration, 2013, FDA proposes "action level" for arsenic in apple juice: U.S. Food and Drug Administration news release, July 12. (Accessed July 27, 2015, at http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm360466.htm.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Arsenic. Ch. in Mineral Commodity Summaries, annual.

Arsenic. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Arsenic (As). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.

Gallium. Ch. in Minerals Yearbook, annual.

Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.

Other

American Wood Protection Association.
Arsenic. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Arsenic (8th ed.). Roskill Information Services Ltd., 1992.
Arsenic and Old Waste, A Report of the U.S. Interagency Working Group on Industrial Ecology, Material and Energy Flows. U.S. Environmental Protection Agency, 1998.
Gallium and Gallium Arsenide—Supply, Technology, and Uses. U.S. Bureau of Mines Information Circular 9208, 1988.
Materials Flow of Arsenic in the United States. U.S. Bureau of Mines Information Circular 9382, 1994.

TABLE 1
SALIENT ARSENIC STATISTICS[1]

(Metric tons of arsenic content)

	2009	2010	2011	2012	2013
Imports:					
Metal[2]	438	769	628	883	514
Compounds	4,660	4,530	4,990	5,740	6,290
Total	5,100	5,300	5,620	6,620	6,810
Exports, metal[2]	354	481	705	439	1,630
Apparent consumption[3]	5,100	5,300	5,620	6,620	6,810
Price, cents per pound, average:[4]					
Metal (China)	121	72	74	75	72
Trioxide (Morocco)	20	20	22	24	27

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Listed as metal only, but may include alloys, waste, and compounds.
[3]Estimated to be the same as imports. Prior to 2013, reported to be equal to net imports.
[4]Landed duty-paid unit based on U.S. imports for consumption.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ARSENIC PRODUCTS[1]

Class and country	2012 Quantity (metric tons)	2012 Value (thousands)	2013 Quantity (metric tons)	2013 Value (thousands)
Arsenic trioxide:				
Belgium	731	$489	858	$499
China	1,900	855	2,700	1,220
Germany	--	--	--	--
Hong Kong	240	108	580	261
Japan	--	--	(2)	4
Liechtenstein	--	--	(2)	4
Morocco	4,680	2,460	4,170	2,490
Spain	(2)	2	(2)	2
Total	7,550	3,910	8,310	4,470
Arsenic acid, Japan	4	40	2	16
Arsenic sulfide, Russia	(2)	30	--	--
Arsenic metal:				
China	758	1,260	424	674
Finland	--	--	--	--
France	(2)	4	--	--
Germany	6	454	6	448
Hong Kong	--	--	19	24
Japan	112	804	64	719
Mexico	--	--	(2)	3
United Kingdom	7	28	(2)	15
Total	883	2,550	514	1,880

-- 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	2009	2010	2011	2012	2013
Belgium	1,000	1,000	1,000	1,000	1,000
Bolivia	115 [4]	155 [4]	99 [4]	104 [r, 4]	100
Chile	11,000	11,000	11,000 [r]	10,000	10,000
China	25,000	25,000	25,000	26,000	25,000
Japan	40	40	45 [r]	45 [r]	50
Morocco	8,655 [4]	13,731 [4]	8,154 [4]	7,000 [r, 4]	7,500
Peru[5]	301 [4]	-- [4]	-- [4]	-- [4]	--
Portugal	15	15	15	15	--
Russia	1,500	1,500	1,500	1,500	1,500
Total	47,600 [r]	52,400 [r]	46,800 [r]	45,700 [r]	45,200

[r]Revised. -- Zero.
[1]Includes calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide; 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]Includes data available through April 30, 2014.
[4]Reported figure.
[5]Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energía y Minas.