



2008 Minerals Yearbook

ARSENIC

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In 2008, the United States produced no arsenic and relied mostly 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 or arsenic metal since 1985 following the closure of the ASARCO Inc. copper smelter in Tacoma, WA. Arsenic trioxide has been used mainly 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. Arsenic metal was used for electronics applications and in nonferrous alloys. The United States remained the world's leading consumer of arsenic trioxide and arsenic metal.

Legislation and Government Programs

The U.S. Food and Drug Administration (FDA) urged caution with Ayurvedic products and indicated that these products do not undergo FDA review. Ayurvedic medicine is a traditional system of healing that originated in India and includes preparations that combine herbs with minerals and metals such as arsenic, lead, mercury, and zinc. These products are available on the Internet and typically come from South Asia (Saper and others, 2008; U.S. Food and Drug Administration, 2008).

Environmental Issues

Some of the noncancerous effects of arsenic exposure in humans 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, lungs, liver, and prostate (Agency for Toxic Substances and Disease Registry, 2007). 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 disturbed by mining or other anthropogenic activities; as runoff from arsenic-containing pesticides used in orchards; in wastewater runoff from glass and electronics production; or arsenic released by coal burning.

High exposure to arsenic in drinking water has been linked to the development of diabetes. University researchers have found that the risk of diabetes for Americans with the highest arsenic content in their urine is more than three times the risk of those with the lowest arsenic levels. Their findings were consistent with results from similar studies in Bangladesh, Mexico, and Taiwan (Navas-Acien and others, 2008; Voiland, 2008).

Arsenic contamination of the Mekong River in Southeast Asia is reportedly putting millions at risk of severe illness. Approximately 21% of the Vietnamese population is exposed to arsenic levels above the World Health Organization's acceptable level of 10 parts per billion (ppb). Arsenic was also found in bottled water, tap water, and fish. The precise number of people

who were exposed in Cambodia and Laos was not known (IRIN News, 2008).

Researchers in the United Kingdom indicated that one-third of baby-food rice for sale in the United Kingdom contained high levels of arsenic; seventeen samples of three common brands of baby-food rice were tested. There are no regulations on the amount of arsenic in food products; however, drinking water standards for arsenic are in place in the European Union and in the United States (Agence France-Presse, 2008; Crowley, 2008).

Environmental arsenic exposure through contaminated drinking water was found to be a significant risk factor. When laboratory mice were exposed to arsenic at federally approved levels for drinking water, pores in liver blood vessels closed, which may lead to cardiovascular disease (Straub and others, 2008).

The U.S. Environmental Protection Agency (EPA) indicated that arsenic levels in water near the site of a massive coal ash spill in eastern Tennessee were more than 100 times the legally acceptable amount. The arsenic content of water sampled at a nearby water treatment plant upstream from the spill site was within Federal limits (Washington Post, The, 2008).

Hong Kong intercepted and turned away shipping containers that carried tons of electronic waste (e-waste) from the United States. Reports indicated that the e-waste may have been unsafely disposed of in China or India after it was turned away from Hong Kong. The e-waste contains arsenic, beryllium, cadmium, copper, gold, lead, mercury, and silver that may be recycled. However, the recovery of the metals poses an environmental hazard and risk to human health (Schmit, 2008). Mobile phones and other electronic waste from Southeast Asia have been exported to Japan for extraction and recycling of nonferrous metals, such as arsenic, copper, gold, and lead (Daily Yomiuri, 2007).

Consumption

The major domestic consumers of arsenic, as CCA for pressure-treated wood, include Arch Wood Protection, Inc., Norwalk, CT; Osmose Wood Preserving, Inc., Buffalo, NY; and Viance, a joint venture between Rohm and Haas Co. and Chemical Specialties, Inc., Charlotte, NC. Domestic manufacturers of wood preservatives voluntarily reduced their use of CCA in response to concerns about the effects of arsenic exposure on human health. The phaseout applied to wood used for boardwalks, decks, fencing, gazebos, picnic tables, and play structures. 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 (PR Newswire, 2002). Beginning in 2004, the global arsenic market and domestic imports of arsenic declined significantly in response to this voluntary ban.

The United States remained the world's leading consumer of arsenic, mainly for the production of CCA. Apparent domestic

consumption for arsenic was about 4,130 metric tons (t) in 2008, a 22% decline from about 5,280 t in 2007 and 81% less than the apparent consumption of 21,600 t in 2003. The estimated value of arsenic compounds and metal consumed domestically in 2008 was approximately \$4.2 million.

More than 50% of the arsenic, as arsenic trioxide, was used in the wood preservative industry for nonresidential use, down from about 90% prior to 2004. 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.

Arsenical copper, a naturally occurring alloy, has been used to produce hardened copper knives and other tools since ancient times. When alloyed with lead and antimony, arsenic metal was used to harden ammunition and 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). Arsenic is also used in lead shot, and minor amounts may be added to lead and antimony for use in clip-on wheel weights.

High-purity (99.9999%) arsenic metal is used for gallium-arsenide (GaAs) and indium-arsenide (InAs) semiconductors that are used in computers, electronic devices, light-emitting diodes, and solar cells. A mobile phone typically contains GaAs in its microelectronic circuitry, of which the arsenic content is less than 1 milligram (International Precious Metals Institute, 2003). Arsenic may be used for germanium-arsenide-selenide or GaAs specialty optical materials. Other applications of GaAs semiconductors include laser tracking for weapons and short-wave infrared technology. Arsenic sulfide is one of several substrate materials that are used for optical thin films and interference coatings.

Based on reported consumption of gallium, U.S. consumption of arsenic metal in GaAs semiconductors was approximately 30 t in 2008, which was a 25% decrease from a peak of about 40 t in 2000. The global GaAs industry continued to see application of its products in the automotive, defense optoelectronics, integrated circuits, switches, and wireless handset markets.

Prices

Arsenic prices generally remained low and demand continued to be weak throughout most of 2008. In January, prices in Beijing, China, for arsenic metal (minimum 99%) were \$0.96 to \$1.10 per kilogram, a decrease from the \$1.51 per kilogram at yearend 2007, but buyers were not interested in purchasing (Metal-Pages Ltd., 2007a, 2008a).

In China, arsenic trioxide prices at the beginning of 2008 ranged between \$439 and \$469 per metric ton (Metal-Pages Ltd., 2008b). In general, the arsenic trioxide export market was sluggish, with export prices for arsenic trioxide lower than the \$450 per ton reported at yearend 2007 (Metal-Pages Ltd., 2007b).

By midyear, there had been no substantial increase in arsenic prices. This was mainly because arsenic remained in oversupply. Arsenic metal prices were \$1.17 per kilogram, and arsenic trioxide prices were \$454 to \$483 per ton (Metal-Pages Ltd., 2008c). However, by September, several smelters reported sales at

relatively higher prices. Arsenic metal prices were approximately \$1.25 per kilogram, and one company offered arsenic metal as high as \$1.40 per kilogram (Metal-Pages Ltd., 2008d).

Foreign Trade

In 2008, domestic imports of arsenic compounds were 4,800 t contained arsenic, a decrease of approximately 32% compared with the 7,010 t contained arsenic in arsenic compounds imported in 2007. Arsenic trioxide contains 76% arsenic. In 2008, Morocco was the source of 70% of the arsenic trioxide imported into the United States, and China was the source of 19%. In 2008, the United States imported 376 t of arsenic metal, a 50% decrease compared with the 759 t of arsenic metal imported in 2007. China was the leading source of arsenic metal in 2008 and provided 288 t of arsenic metal, or 77%; however, this was a decrease of 55% compared with the 646 t of arsenic metal that was imported from China in 2007. Arsenic metal was also imported from Japan (22%) and Germany (1%).

Imports of arsenic trioxide from China into the United States decreased by 64% to 1,180 t from 3,260 t in 2007. Because of the voluntary reduction in the use of CCA at yearend 2003, the 6,320 t of arsenic trioxide imported by the United States in 2008 was 68% less than the 20,600 t of arsenic trioxide imported in 2003 (table 2).

Exports of arsenic metal from the United States in 2008 have generally increased since 2004. The export destinations for the 1,050 t of arsenic metal shipped from the United States in 2008 included Honduras (38%), the Republic of Korea (24%), France (15%), Guatemala (14%), and the United Kingdom (3%). Exported materials are classified by number in the Harmonized Tariff Schedule and this may have possibly resulted in misclassification of exports. Exports classified as arsenic metal may include arsenic-containing "e-waste," such as computers and other electronics destined for reclamation and recycling (Grossman, 2005; 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 2008, commercial-grade arsenic trioxide was recovered from processing of nonferrous ores or concentrates in 13 countries. Reduction of arsenic trioxide to arsenic metal accounted for all world output of commercial-grade (99%-pure) arsenic metal.

In 2008, China produced approximately 25,000 t of arsenic trioxide and remained the world's leading producer followed by Chile (10,000 t), Morocco (8,800 t), and Peru (4,000 t). The overall Chinese arsenic market had improved by the third quarter of 2008 (Metal-Pages Ltd., 2008d). 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 2008

and may have been stockpiled for future treatment. Production data for most countries are 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 at yearend 2003 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 for automotive uses, military and space applications, solar cells, and telecommunications equipment. The GaAs industry was expected to exceed the \$5 billion mark in 2011 (Metal-Pages Ltd., 2008d). 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 RELATIONSHIPS¹

(Metric tons of arsenic content)

	2004	2005	2006	2007	2008
U.S. supply, imports:					
Metal	872	812	1,070	759	376
Compounds	6,150	8,330	9,430	7,010	4,810
Total	7,020	9,150	10,500	7,770	5,180
Distribution of U.S. supply:					
Exports ²	220	3,270	3,060	2,490	1,050
Apparent demand ³	6,800	5,870	7,450	5,280	4,130

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

²Metal only.

³Estimated use in the United States in 2004 (the last time for which data are broken down by category) of arsenic was 4,450 metric tons (t) for wood preservatives, 850 t for agricultural chemicals, 650 t for glass, 650 t for nonferrous alloys and electronics, and 200 t for other uses.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ARSENIC PRODUCTS¹

Class and country	2007		2008	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:				
Belgium	267	\$178	654	\$413
Bolivia	120	60	30	15
China	3,260	1,680	1,180	599
Germany	--	--	5	17
Morocco	5,580	2,220	4,460	1,860
Spain	--	--	(2)	16
United Kingdom	(2)	4	--	--
Total	9,220	4,140	6,320	2,920
Arsenic acid:				
France	--	--	89	639
Germany	5	14	(2)	2
Indonesia	--	--	19	22
Japan	--	--	4	11
Taiwan	7	14	3	7
Total	12	28	115	682
Arsenic sulfide:				
China	103	241	(2)	5
France	--	--	(2)	6
Total	103	241	(2)	11
Arsenic metal:				
China	646	1,750	288	792
Germany	4	689	5	761
Hong Kong	32	42	--	--
Japan	77	927	84	1,050
Thailand	--	--	--	--
Total	759	3,410	376	2,610

-- Zero.

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

²Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 3
ARSENIC TRIOXIDE: ESTIMATED WORLD PRODUCTION, BY COUNTRY^{1, 2, 3}

(Metric tons)

Country ⁴	2004	2005	2006	2007	2008
Belgium	1,000	1,000	1,000	1,000	1,000
Bolivia	168 ⁵	120 ⁵	90 ^{r, 5}	-- ^r	--
Canada	250	250	250	250	250
Chile	11,500	11,700	11,700	11,400	10,000
China	30,000	30,000	30,000	25,000	25,000
Iran	89 ⁵	100	100	100	100
Japan	40	40	40	40	40
Kazakhstan	1,500	1,500	1,500	1,500	1,500
Mexico	1,829 ⁵	1,664 ⁵	1,595 ⁵	1,600	513
Morocco	6,866 ⁵	8,939 ⁵	8,900 ⁵	8,950 ⁵	8,800
Peru ⁶	3,037 ⁵	3,150 ⁵	4,399 ⁵	4,320 ^{r, 5}	4,000 ^p
Portugal	15	15	15	15	15
Russia	1,500	1,500	1,500	1,500	1,500
Total	57,800	60,000	61,100 ^r	55,700 ^r	52,700

^pPreliminary. ^rRevised. -- Zero.

¹Including 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.

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

³Table includes data available through March 24, 2009.

⁴Austria, Hungary, the Republic of Korea, Serbia and Montenegro (listed as an individual entity but dissolved their union in June 2006), 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.

⁵Reported figure.

⁶Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energía y Minas.

