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ARSENIC

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ARSENIC

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In 2006, the United States produced no arsenic and was import dependent for all its supply of arsenic trioxide (As_2O_3) and arsenic metal, which were sourced mainly from China, the major global supplier. There has been no domestic production of As_2O_3 or arsenic metal since 1985 when the Asarco Inc. copper smelter in Tacoma, WA, closed. However, the United States has remained the world's leading consumer of arsenic, as As_2O_3, mainly for the production of chromated copper arsenate (CCA), which is a pesticide-preservative for pressure-treated wood products. Arsenic metal was used for electronics and nonferrous alloys, and As_2O_3 was used for the production of agricultural chemicals. In 2006, domestic imports of arsenic compounds were 9,330 metric tons (t) contained arsenic, an increase of 12% compared with the 8,330 t contained arsenic in arsenic compounds imported in 2005. Owing to a voluntary phaseout of arsenical wood preservatives for nonindustrial uses at yearend 2003, As_2O_3 imports declined dramatically in 2004, but have trended upward in the past 2 years. In 2006, China was the source of 65% of the As_2O_3 imported into the United States; Morocco, 27%; and Belgium, 3%. The United States imported 1,070 t of arsenic metal in 2006, an increase from 812 t imported in 2005. China was the leading source and provided 944 t, or 88%, up from 718 t in 2005. Arsenic metal was also imported from Japan, 8%; Thailand, 2%; and other countries, 2%.

Legislation and Government Programs

Arsenic is a U.S. Government-approved additive in poultry feed that is used to kill parasites and promote growth. A 2004 U.S. Department of Agriculture study indicated that the increasing domestic annual consumption of chicken, from 13 kilograms (kg) per person in 1960 to 40 kg per person in 2005 indicated an increased per capita intake of arsenic, and therefore, a need to review and possibly revise the 500 parts per billion (ppb) limit for arsenic in commercially available chicken (Burros, 2006).

On January 22, 2001, the U.S. Environmental Protection Agency (EPA) adopted a new standard for arsenic in drinking water at 10 micrograms per liter (µg/l), which replaced the old standard of 50 µg/l. Water systems were required to comply with the new standard, which was named the Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring Final Rule, by January 23, 2006 (U.S. Environmental Protection Agency, 2006).

Environmental Issues

Arsenic is a common, naturally occurring element that may be a drinking water contaminant. It may be found naturally from weathering of arsenic-containing minerals disturbed by mining or other human activities, as runoff from arsenic-containing pesticides used in orchards, in wastewater runoff from glass and electronics production, or released by coal burning. Prolonged arsenic exposure has been linked to cancer of the bladder, kidney, lungs, liver, and prostate. Discoloration and thickening of the skin, nausea, vomiting, stomach pain, blindness, and diarrhea are some of the noncancerous effects of arsenic exposure (Agency for Toxic Substances and Disease Registry, 2007).

An inexpensive ($35 to $40 per unit), maintenance-free, arsenic remediation system that uses brick, charcoal, iron, and sand was developed. The system has been proven in the laboratory and in field tests, and more than 30,000 units have been distributed in Bangladesh, bringing clean water to about 400,000 people (Weiss, 2007).

High levels of arsenic, lead, and cadmium in the blood of children living in mining areas in Peru were the focus of researchers from St. Louis University, MO (La Republica, 2006). Artisanal mining has left high levels of arsenic, mercury, and other contaminants in the ground water in mining areas in northern Peru (Diario Gestion, 2007). Arsenic contamination in rural and urban water supplies in Peru is attributed to runoff from mining waste and pesticide use (Luna, 2005). Arsenic, cadmium, and lead contamination at 90 sites in several western U.S. States may be the result of mining and refining operations (Millman, 2006). In 2004, Indonesia's Environment Ministry said that tailings dumped into Buyat Bay, Indonesia, contained arsenic and mercury that had contaminated the sediment and entered the food chain. An Indonesian court recently indicated that pollution charges against the mining company and its president could not be proven (Wulandari, 2007). Arsenic in drinking water and its impact on human health; arsenic in soils, mine tailings and industrial sites; and arsenic and environmental health in southern Asia are some of the articles included in a special edition of the interdisciplinary journal Elements (Vaughan, 2006).

Arsenic is one of several hazardous elements contained in discarded electronic waste or "e-waste" (Kessler, 2004). It may be found in circuit boards, relays, and switches (Ohio Department of Natural Resources, 2005). These electronics, which include used computers and televisions, were exported and may have become part of an uncontrolled hazardous stream in other countries and many of the people who disassemble them may be exposed to arsenic or other toxic metals (Grossman, 2005).

Consumption

Because of concern for human exposure to arsenic, and after consulting with the EPA, domestic manufacturers of wood preservatives began a voluntary cutback of those containing arsenic as chromated copper arsenate (CCA) at yearend 2003. The phaseout applied to wood used for boardwalks, decks, fencing, gazebos, picnic tables, and play structures. However,

wood treated 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). In response to this voluntary ban, the global arsenic market declined sharply. In the United States, the major producers of CCA included Arch Wood Protection, Inc., Smyrna, GA; Chemical Specialties, Inc., Charlotte, NC; and Osmose Wood Preserving, Inc., Buffalo, NY.

In 2006, the United States remained the world's leading consumer of arsenic, mainly for the production of CCA. Apparent domestic consumption for arsenic was about 7,300 t in 2006, a 17% decline from about 8,800 t in 2005, and far less than the apparent consumption of 21,600 t in 2003. The estimated value of arsenic compounds and metal consumed domestically was approximately $7.5 million.

In 2006, more than 50% of the arsenic, as As_2O_3, was used in the wood preservative industry for nonresidential use, down from about 90% prior to 2004. The remainder of As_2O_3 was used in agricultural chemicals (either directly or after conversion to arsenic acid) or in glass manufacturing applications. Arsenic acid is also used in glassmaking as a bubble dispersant or decoloring agent. There are no data available on the percentages of arsenic used in these traditional use categories.

When alloyed with lead and antimony, arsenic metal is used as a hardener for ammunition, solders, and 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 to babbitt metals 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 (Los Angeles Silhouette Club, undated).

Gallium arsenide (GaAs) semiconductors are used in lasers and solar cells, and GaAs is an important component in light emitting diodes, which has contributed to stronger sales of GaAs (Metal-Pages Ltd., 2006a). Gallium-arsenide and indium-arsenide semiconductors used in computers and electronic devices require high-purity (99.9999%) arsenic metal. GaAs wafers are used for electronics applications. A mobile phone typically contains GaAs in its microelectronic circuitry, of which the arsenic content is less than one milligram (International Precious Metals Institute, 2003). Arsenic may be used for germanium-arsenide-selenide or GaAs specialty optical materials (Harrick Scientific Products, Inc., 2006).

U.S. demand for arsenic and gallium in wafer production declined significantly in 2002 owing to a buildup of domestic GaAs inventory, closure of several U.S. plants, and increased wafer manufacturing in China. Based on reported consumption of gallium, U.S. consumption of arsenic metal in GaAs semiconductors was approximately 20 t in 2006, which was a decrease from a peak of about 40 t in 2000 (D.A. Kramer, U.S. Geological Survey gallium commodity specialist, written commun., April 24, 2007). A Japanese company developed technology to recover arsenic and gallium from used semiconductors and they plan to recycle the arsenic to meet Japanese requirements for environmental protection (Metal-Pages Ltd., 2006b).

Indium-gallium-arsenide is used for short wave infrared technology (Metal-Pages Ltd., 2005). Arsenic sulfide is one of several substrate materials that are used for optical thin films and interference coatings (JK Consulting, 2007).

World Trade

Imports into the United States of As_2O_3 from China rose to 8,110 t in 2006 and were 44% higher than the 5,620 t imported in 2005. However, the total amount of As_2O_3 imported in 2006 was still less than one-half of the 20,600 t of As_2O_3 imported in 2003.

Exports of arsenic metal appear to have increased dramatically in 2005 and 2006, and the main export destinations in 2006 included the Republic of Korea (1,700 t), Tawain (873 t), Japan (193 t), and Chile (182 t). A possible explanation for this increase might be that the exports in this category include arsenic alloyed with another metal or metals.

World Review

In 2006, commercial grade As_2O_3 was recovered from the processing of nonferrous ores or concentrates in 14 countries. Reduction of As_2O_3 to arsenic metal accounted for all world output of commercial-grade (99%-pure) arsenic metal.

China remained the world's leading producer of As_2O_3 in 2006 followed by Chile and Peru. China continued to be the leading world producer of commercial-grade arsenic metal and supplied the United States with 944 t in 2006. In addition to production from nonferrous ores, arsenic was also obtained as a byproduct of gold mining in China. The more common ore minerals of arsenic, orpiment and realgar, are routinely stockpiled near the Qiaoqiaoshang gold mine, northern Sichuan Province, for transport and processing in Guizhou Province (Peters and others, 2002, p. 182).

Arsenic-containing residues and smelter dusts recovered from nonferrous plants in several countries may not have been processed to recover commercial grade As_2O_3 in 2006 and may have been stockpiled for future treatment. Country production data are estimated and subject to revision because As_2O_3 production may not be reported accurately.

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 resulted in a decline in As_2O_3 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 however 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. World sources of arsenic, as As_2O_3 and arsenic metal available from nonferrous metal processing, are expected to be sufficient to meet projected needs.

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TABLE 1
ARSENIC SUPPLY-DEMAND RELATIONS[1]

(Metric tons of arsenic content)

	2002	2003	2004	2005	2006
U.S. supply:					
Imports:					
Metal	879	990	872	812	1,070
Compounds	18,800	20,800	6,150	8,330	9,330
Total	19,700	21,700	7,020	9,150	10,400
Distribution of U.S. supply:					
Exports[2]	100	173	220	3,273 r	3,060
Apparent consumption	19,600	21,600	6,800	8,820	7,340
Estimated U.S. use:					
Agricultural chemicals	750	860	850	NA	NA
Glass	700	660	650	NA	NA
Wood preservatives	17,300	19,200	4,450	NA	NA
Nonferrous alloys and electronics	650	660	650	NA	NA
Other	200	200	200	NA	NA
Total	19,600	21,600	6,800	8,820	7,340

rRevised. NA Not available.

[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]

	2005		2006	
Class and country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:				
Belgium	307	$209	369	$268
Bolivia	120	64	90	45
Chile	78	33	110	40
China	5,620	2,680	8,110	3,830
Germany	(2)	4	64	241
Hong Kong	1,140	606	329	178
Mexico	344	234	--	--
Morocco	3,350	1,450	3,320	1,370
Spain	(2)	3	--	3
United Kingdom	--	--	14	53
Total	11,000	5,280	12,400	6,020
Arsenic acid:				
China	--	--	16	16
France	9	50	6	33
Mexico	--	--	2	3
Total	9	50	24	52
Arsenic sulfide, China	--	--	75	179
Arsenic metal:				
China	718	1,790	944	1,290
Germany	5	758	6	846
Hong Kong	--	--	16	12
Japan	90	860	84	1,470
Thailand	--	--	19	15
United Kingdom	--	--	4	11
Total	812	3,410	1,070	3,640

-- 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]	2002	2003	2004	2005	2006
Belgium	1,000	1,000	1,000	1,000	1,000
Bolivia	237 [5]	276 [5]	168 [5]	120 [r, 5]	200
Canada	250	250	250	250	250
Chile	11,400	11,600	11,500 [r]	11,700 [r]	11,800
China	40,000	40,000	30,000	30,000	30,000
France	1,000	1,000	1,000	1,000	1,000
Germany	100 [r]	-- [r]	-- [r]	-- [r]	--
Iran	400	275 [5]	89 [5]	100	100
Japan	40	40	40	40	40
Kazakhstan	1,500	1,500	1,500	1,500	1,500
Mexico	1,946 [5]	1,729 [5]	1,829 [5]	1,664 [r, 5]	1,750
Peru[6]	2,970 [5]	3,000 [5]	3,500	3,600	3,500 [p]
Portugal	50	50	50	50	50
Russia	1,500	1,500	1,500	1,500	1,500
Total	62,400 [r]	62,200 [r]	52,400 [r]	52,500	52,700

[p]Preliminary. [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 1, 2007.

[4]Austria, Hungary, the Republic of Korea, Serbia and Montenegro (union dissolved in 2006), South Africa, Spain, 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]Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energía y Minas.