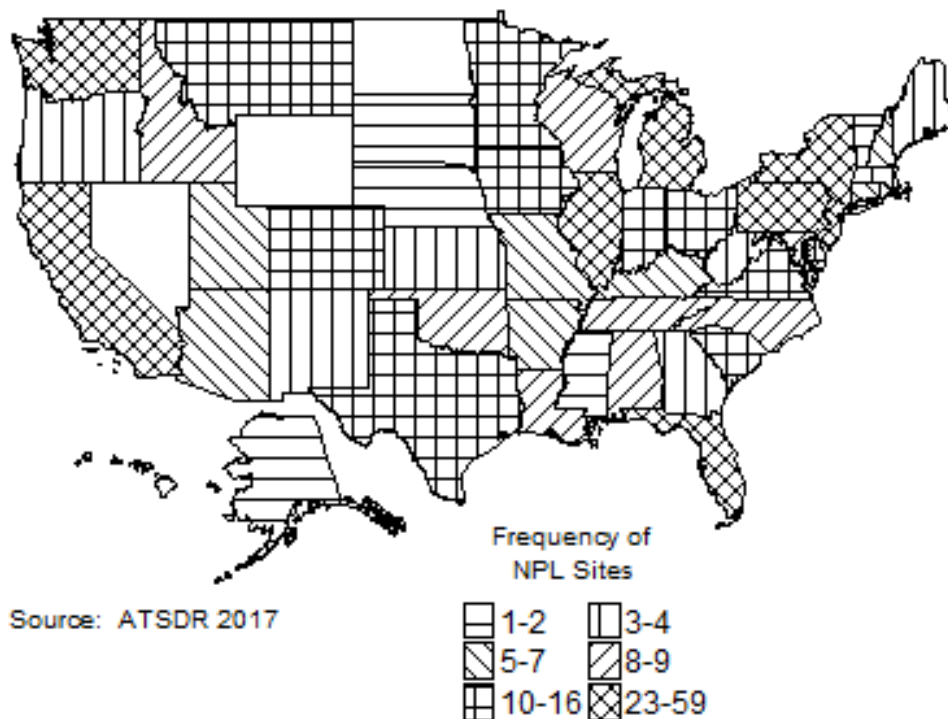


CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Antimony or antimony compounds have been identified in at least 563 of the 1,854 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2017). However, the number of sites in which antimony has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, 556 are located within the United States, 2 are located in the Virgin Islands, 1 is located in Guam, and 4 are located in Puerto Rico (not shown)

Figure 5-1. Number of NPL Sites with Antimony or Antimony Compounds Contamination



- Antimony is a natural constituent of soil and is transported into streams and waterways from natural weathering of soil, as well as from anthropogenic sources (EPA 1979; Mok and Wai 1990). Antimony is naturally present in the earth's crust at levels of about 0.2–0.3 $\mu\text{g/g}$ (ppm), but these levels vary by location (Telford et al. 2008). Studies indicate that antimony is retained in the soil through adsorption and can sorb onto clay minerals, oxides, and hydroxides in the soil and aquatic sediment (Wilson et al. 2010). The general population is exposed to low levels of antimony in ambient air and food. Individuals can be exposed to antimony in polyethylene terephthalate (PET) water bottles (reviewed in Belzile et al. 2011) or from products containing

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antimony flame retardants. Occupationally exposed workers will have the highest levels of exposure to antimony (Quiroz et al. 2011; Smith et al. 1995).

- Background levels of antimony in ambient air are typically $<20 \text{ ng/m}^3$. However, levels of antimony in ambient air can be $>1,000 \text{ ng/m}^3$ near plants that convert antimony ores into metal or manufacture substances such as antimony trioxide (Ragaini et al. 1977).
- Background levels of antimony in groundwater in the United States from 1992 to 2003 were low, with median concentrations of $<1 \text{ } \mu\text{g/L}$ (USGS 2011). Anthropogenic activity such as mining activities, and coal and municipal waste combustion can result in increases in antimony levels in ambient water (Jablonska-Czapla et al. 2014). Most dissolved antimony in natural waters under aerobic conditions is present in the pentavalent oxidation state as antimonate species (Sb(OH)_6^-). Anthropogenic emissions commonly contain antimony in the trivalent oxidation state (e.g., antimony trioxide); however, it is unclear how quickly antimonite oxidizes to antimonate under natural conditions. Under anoxic reducing conditions, trivalent species such as Sb(OH)_3 , Sb(OH)_4^- , and Sb_2S_4^- are the most thermodynamically stable forms of antimony.
- Antimony can be reduced and methylated by microorganisms in anaerobic sediment, releasing volatile methylated antimony compounds into the water. Multiple microorganisms have been found to methylate antimony in the soil and water and some anoxic or poorly oxygenated environments (Bentley and Chasteen 2002).

5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.2.1 Production

Tables 5-1 and 5-2 list the number of facilities in each state that have produced, imported, processed, or used antimony and antimony compounds, respectively, according to reports made to the EPA under requirements of Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 and subsequently published in the Toxic Chemical Release Inventory (TRI17 2018). Only certain types of facilities were required to report; therefore, this is not an exhaustive list. The number of individual facilities and the amount produced on site varied in each state.

Table 5-1. Facilities that Produce, Process, or Use Antimony

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
AL	2	10,000	999,999	1, 5, 7, 8
AR	1	10,000	99,999	7, 8
CA	4	0	99,999	9, 12, 14
CT	1	1,000	9,999	7
FL	1	100,000	999,999	1, 5

5. POTENTIAL FOR HUMAN EXPOSURE

Table 5-1. Facilities that Produce, Process, or Use Antimony

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
IA	2	100	99,999	8
ID	3	1,000	999,999	8, 9, 12
IL	1	10,000	99,999	8, 11
IN	3	1,000	99,999	1, 5, 7, 8, 9
KS	2	10,000	99,999	1, 4, 7, 8
KY	2	10,000	99,999	2, 3, 4, 6, 7, 8, 9
MI	2	100	99,999	7
MN	2	10,000	999,999	7, 8, 14
MO	4	1,000	99,999	1, 6, 8, 9, 12, 13
MS	2	10,000	99,999	8
MT	1	100,000	999,999	1, 2, 3, 4, 5, 7
NC	4	1,000	99,999	7, 8, 14
NE	2	1,000	99,999	7, 8
NJ	2	1,000	999,999	2, 4, 9, 11
NV	2	1,000	99,999	8, 12
NY	4	0	9,999	8, 14
OH	11	100	999,999	1, 2, 3, 7, 8, 9, 10, 11
PA	8	1,000	999,999	2, 3, 4, 7, 8, 9, 10
SC	1	10,000	99,999	1, 5, 7, 14
TN	5	0	99,999	1, 4, 7, 8, 12
TX	2	10,000	99,999	8, 9
VA	1	10,000	99,999	7
WA	2	1,000	99,999	7, 8, 11
WI	1	1,000	9,999	8

^aPost office state abbreviations used.

^bAmounts on site reported by facilities in each state.

^cActivities/Uses:

- | | | |
|----------------------|-----------------------------|--------------------------|
| 1. Produce | 6. Reactant | 11. Manufacture Aid |
| 2. Import | 7. Formulation Component | 12. Ancillary |
| 3. Used Processing | 8. Article Component | 13. Manufacture Impurity |
| 4. Sale/Distribution | 9. Repackaging | 14. Process Impurity |
| 5. Byproduct | 10. Chemical Processing Aid | |

Source: TRI17 2018 (Data are from 2017)

5. POTENTIAL FOR HUMAN EXPOSURE

Table 5-2. Facilities that Produce, Process, or Use Antimony Compounds

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
AK	1	10,000	99,999	1, 5, 12, 13, 14
AL	6	1,000	99,999	7, 8, 10, 11
AR	2	1,000	99,999	1, 5, 8, 9, 12
AZ	3	10,000	999,999	1, 2, 5, 8, 13, 14
CA	15	100	9,999,999	1, 2, 3, 4, 6, 7, 8, 9, 10, 12
CO	2	100,000	999,999	1, 2, 3, 4, 6, 12, 13, 14
CT	4	10,000	99,999	7, 8
DE	2	10,000	99,999	1, 2, 3, 4, 7, 8, 13, 14
FL	2	10,000	999,999	2, 3, 7, 8
GA	22	1,000	999,999	1, 2, 3, 5, 6, 7, 8, 11, 14
IA	1	10,000	99,999	7
ID	4	1,000	99,999	1, 5, 7, 8, 12, 13, 14
IL	16	1,000	999,999	1, 2, 3, 5, 6, 7, 8, 10, 12, 13
IN	29	100	999,999	1, 2, 3, 4, 5, 7, 8, 9, 11, 12, 13, 14
KS	5	1,000	999,999	1, 3, 6, 7, 8
KY	17	100	999,999	1, 2, 3, 4, 6, 7, 8, 10, 11, 13
LA	9	0	99,999	1, 5, 7, 10, 11, 12, 13, 14
MA	17	1,000	999,999	1, 2, 3, 4, 6, 7, 8, 9
MD	1	0	0	0
MI	10	1,000	99,999	1, 2, 3, 4, 5, 7, 8, 9, 14
MN	9	1,000	999,999	7, 8, 9
MO	8	1,000	9,999,999	1, 2, 3, 4, 7, 8
MS	11	1,000	9,999,999	6, 7, 8, 12
MT	2	100,000	999,999	1, 5, 12, 14
NC	22	0	99,999	2, 3, 6, 7, 8, 9, 10, 14
ND	1	100,000	999,999	1, 5, 12, 13, 14
NE	4	1,000	99,999	6, 7, 8, 12
NH	2	10,000	99,999	7, 8
NJ	10	1,000	999,999	2, 5, 7, 8, 10, 11
NV	7	1,000	9,999,999	1, 2, 5, 7, 12, 13, 14
NY	3	1,000	99,999	7, 8, 14
OH	44	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 12
OK	1	1,000	9,999	12
OR	3	10,000	99,999	2, 3, 4, 7, 8
PA	29	100	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
PR	1	10,000	99,999	6, 10
RI	4	1,000	99,999	7, 8, 12
SC	23	0	999,999	1, 2, 3, 6, 7, 8, 10, 12, 13, 14

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Table 5-2. Facilities that Produce, Process, or Use Antimony Compounds

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
TN	21	100	9,999,999	1, 2, 3, 5, 6, 7, 8, 10, 13, 14
TX	41	100	999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	5	10,000	49,999,999	1, 3, 4, 5, 7, 8, 9, 12, 13
VA	7	1,000	999,999	6, 7, 8
VT	2	1,000	99,999	7, 8
WA	1	0	0	0
WI	12	100	999,999	1, 3, 5, 7, 8, 11, 13, 14
WV	5	1,000	99,999	1, 5, 7, 8
WY	1	100,000	999,999	1, 3, 4, 9, 13, 14

^aPost office state abbreviations used.

^bAmounts on site reported by facilities in each state.

^cActivities/Uses:

- | | | |
|----------------------|-----------------------------|--------------------------|
| 1. Produce | 6. Reactant | 11. Manufacture Aid |
| 2. Import | 7. Formulation Component | 12. Ancillary |
| 3. Used Processing | 8. Article Component | 13. Manufacture Impurity |
| 4. Sale/Distribution | 9. Repackaging | 14. Process Impurity |
| 5. Byproduct | 10. Chemical Processing Aid | |

Source: TRI17 2018 (Data are from 2017)

Fifteen countries mine antimony. The world total mine production was 118,000 metric tons in 2000 (USGS 2004). The majority, 85% of the world total, of antimony is mined in China. Between 1977 and 1984, the amount of antimony mined in the United States ranged from 311 to 760 metric tons (Llewellyn 1989; Plunkert 1982). The United States no longer mines antimony. The last domestic mine in the United States closed in 2001. According to the U.S. Bureau of Mines, six companies produced primary antimony metal and metal oxide products in the United States in 1992. These six companies were ASARCO Incorporated, Omaha, Nebraska; Amspec Chemical Corp., Gloucester City, New Jersey; Welcome29 America, Laredo, Texas; Laurel Industries Inc., La Porte, Texas; Sunshine Mining Co., Kellogg, Idaho; and U.S. Antimony Corp, Thompson Falls, Montana (HSDB 2005a).

In 1992, the total U.S. primary antimony consumption was 12,221 metric tons, of which 3,297 metric tons were for metal products, 2,103 metric tons for nonmetal products, and 6,821 metric tons for flame retardants (USGS 2004). Most of the primary antimony generated in the United States was generated as antimony trioxide. Antimony trioxide is produced by oxidizing antimony sulfide ore or antimony metal in air at 600–800°C (Avento and Touval 1980). In 1987 and 1988, 18,758, and 18,226 metric tons of the

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oxide were produced, respectively (U.S. Bureau of Mines 1989). Consumption trends have generally paralleled those of production.

Antimony is also produced as a byproduct of smelting primary lead ores. Primary smelter outputs were 19,675 metric tons in 1992. Almost as much antimony is produced from scrap as from ore. Antimony produced from secondary sources is primarily derived from "old scrap," generally consisting of lead battery plates, type metal, and bearing metal. "New scrap," which is derived from drosses and scrap generated during fabrication, constituted 6% of the secondary antimony in 1992 (HSDB 2005a; Llewellyn 1989). Secondary antimony is chiefly consumed as antimonial lead; a small percentage goes into the production of other lead- and tin-based alloys. Secondary antimony production was 17,736 metric tons in 1992, with 1,043 metric tons originating from new scrap and 16,693 metric tons from old scrap (HSDB 2005a; Llewellyn 1989; Plunkert 1982).

The method of treating antimony ore after mining depends on the type of ore and its antimony content. High-grade (45–60%) sulfide ore that is free from lead and arsenic can be extracted by melting using a technique known as liquation. In this process, the ore is heated to 550–660°C in a crucible or reverberatory furnace in a reducing atmosphere. Also, high-grade sulfide ores can be reduced to the metal by a technique in which the ore is heated with iron scrap, known as iron precipitation. The iron replaces the antimony, forming iron sulfide. Another antimony ore treatment technique takes high-grade oxide ores and reduces them with charcoal in a reverberatory furnace. An alkaline flux is used to reduce volatilization losses; loss of antimony due to volatilization can be as high as 12–20%. The method of choice for low-grade (<20%) sulfide ores is volatilizing roasting. In this process, the ore is heated to about 500°C in a controlled amount of oxygen, so that the antimony trioxide formed is volatilized and then recondensed. Intermediate-grade sulfide or oxide ores are generally handled by smelting (Carapella 1978; Herbst et al. 1985). The impure metal may be refined by pyrometallurgical techniques or electrolysis.

5.2.2 Import/Export

China is the largest exporter of antimony to the United States, most of which is imported as antimony metal. In 2014, total U.S. imports were 365 metric tons for ore and concentrate, 6,210 metric tons for metal, alloys, waste, and scraps, and 17,600 metric tons for antimony oxide. Total U.S. imports were 24,200 metric tons in 2014 and 24,700 metric tons in 2013 (USGS 2015).

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The last domestic antimony producing mine in the United States closed in 2001. In 1988, the United States exported 624 metric tons of antimony metal, alloys, and scrap and 1,227 metric tons of antimony oxide (U.S. Bureau of Mines 1989). Canada was the largest recipient of these exports. The United States also exported 942 metric tons of antimony metal, alloy, waste, and scrap in 1992 (HSDB 2005a).

5.2.3 Use

Pure antimony is a brittle metal and is restricted in its use due to its poor mechanical properties (Grund et al. 2012; HSDB 2005a). As an alloy, it is mixed with other metals to increase their hardness, mechanical strength, corrosion resistance, and electrochemical stability or to decrease their coefficient of friction. Some antimony alloys expand slightly upon cooling, a valuable property for use in type metal and other castings (Carapella 1978). Antimonial lead is used in small arms ammunition, cable sheathing and lead pipe, and the storage-battery grids, grid plates, straps, and terminals of lead-acid batteries (Grund et al. 2012).

The application of antimony in lead-acid batteries has decreased, and most of the use of antimony in the batteries is in recycling. Historically, antimony improves fluidity and electrical stability, and increases the fatigue strength and creep resistance of the lead in the batteries (Carapella 1978). Alloys of tin and antimony are utilized in electrical equipment, such as the end and side seams of cans, car radiators, and plumbing. Alloys of tin, copper, and antimony are utilized to produce Britannia metal and pewter. Metal products utilize 20% of primary antimony produced (Grund et al. 2012), and 50% of primary antimony is used in plastics to impart flame retardancy. Antimony trioxide is utilized as a flame retardant when combined with a halogen (van Velzen et al. 1998). Antimony is used in the manufacture of chromate pigments, as an opacifer for ceramic glaze, as a gas bubble and color remover in lead crystal glass and glass for television tubes, and as a polymerization catalyst to manufacture polyester fibers (Grund et al. 2012).

Antimony compounds have also been used for the treatment of parasitic diseases such as leishmaniasis. Other antimony salts are used in certain pesticides, ammunition primers, flares, tracer shells, and fireworks, and in the manufacture of disk-brake pads and cutting disks (Grund et al. 2012).

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5.2.4 Disposal

Much of the antimony used in antimonial lead is recycled. This is evident from the large amount of secondary antimony production. Most antimonial lead comes from auto batteries. Little information concerning the disposal of antimony and its compounds has been found in the literature. Wastes from mining and smelting are generally disposed of in landfills. This is evident from the amounts of releases to land from companies that produce antimony and its compounds (Section 5.3.1). In addition, many companies transfer their antimony waste to publicly-owned treatment works or to off-site facilities for disposal. Plastics and articles of clothing that contain small amounts of antimony oxide flame retardants will generally be placed in landfills or undergo incineration along with normal industrial or municipal trash.

Antimony and its compounds have been designated as priority pollutants by EPA (1988). As such, persons who generate, transport, treat, store, or dispose of antimony-containing material must comply with regulations of the federal Resource Conservation and Recovery Act (RCRA). No limitations on the disposal of antimony ore from mines and mills have been promulgated in the Code of Federal Regulations (EPA 1988).

5.3 RELEASES TO THE ENVIRONMENT

The Toxics Release Inventory (TRI) data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ ≥ 10 full-time employees; if their facility is included in Standard Industrial Classification (SIC) Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20–39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under RCRA Subtitle C, 42 U.S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis); and if their facility produces, imports, or processes $\geq 25,000$ pounds of any TRI chemical or otherwise uses $>10,000$ pounds of a TRI chemical in a calendar year (EPA 2005).

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5.3.1 Air

Estimated releases of 6,779 pounds (~3.07 metric tons) of antimony to the atmosphere from 77 domestic manufacturing and processing facilities in 2017, accounted for about 0.79% of the estimated total environmental releases from facilities required to report to the TRI (TRI17 2018). These releases are summarized in Table 5-3. Estimated releases of 16,901 pounds (~7.66 metric tons) of antimony compounds to the atmosphere from 441 domestic manufacturing and processing facilities in 2017, accounted for about 0.11% of the estimated total environmental releases from facilities required to report to the TRI (TRI17 2018). These releases are summarized in Table 5-4.

Table 5-3. Releases to the Environment from Facilities that Produce, Process, or Use Antimony^a

State ^c	RF ^d	Reported amounts released in pounds per year ^b							On- and off-site
		Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Total release		
							On-site ^j	Off-site ^k	
AL	2	108	83	0	513,764	2	513,931	26	513,957
AR	1	54	166	0	5,297	No data	220	5,297	5,517
CA	4	1	No data	0	90,051	7	89,573	486	90,059
FL	1	9	1,961	0	No data	9,549	9	11,510	11,519
IA	2	2	1	0	12,331	No data	12,334	1	12,334
ID	3	3	0	0	No data	No data	3	0	3
IL	1	257	255	0	15,001	14,105	262	29,356	29,618
IN	3	No data	No data	0	0	No data	0	No data	0
KS	2	34	1	0	No data	No data	34	1	35
KY	2	2	0	0	No data	0	2	0	2
MI	2	0	0	0	9,722	No data	1	9,722	9,723
MN	2	3	446	0	81,381	No data	3	81,826	81,829
MO	4	6	42	0	1,463	3,781	1,452	3,840	5,292
MS	2	1	12	0	No data	246	1	258	259
MT	1	5,346	No data	0	No data	No data	5,346	No data	5,346
NC	4	21	No data	0	3,773	No data	3,114	680	3,794
NE	2	59	5	0	No data	31	59	36	95
NJ	2	No data	No data	0	No data	No data	No data	No data	No data
NV	2	1	No data	0	10,035	No data	10,031	5	10,036
NY	4	35	942	0	31	2,035	40	3,003	3,043
OH	11	62	No data	0	634	5,296	62	5,930	5,992
PA	8	68	324	0	15	4,052	78	4,381	4,460

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Table 5-3. Releases to the Environment from Facilities that Produce, Process, or Use Antimony^a

State ^c	RF ^d	Reported amounts released in pounds per year ^b							
		Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Total release		On- and off-site
							On-site ^j	Off-site ^k	
SC	1	2	4	0	26,739	No data	2	26,743	26,745
TN	5	505	255	0	1,419	35,773	1,929	36,023	37,952
TX	2	2	No data	0	No data	No data	2	No data	2
VA	1	181	No data	0	No data	384	181	384	565
WA	2	20	No data	0	211	No data	20	211	231
WI	1	0	No data	0	No data	No data	0	No data	0
Total	77	6,779	4,497	0	771,868	75,261	638,686	219,720	858,406

^aThe TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.

^bData in TRI are maximum amounts released by each facility.

^cPost office state abbreviations are used.

^dNumber of reporting facilities.

^eThe sum of fugitive and point source releases are included in releases to air by a given facility.

^fSurface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).

^gClass I wells, Class II-V wells, and underground injection.

^hResource Conservation and Recovery Act (RCRA) subtitle C landfills; other onsite landfills, land treatment, surface impoundments, other land disposal, other landfills.

ⁱStorage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown

^jThe sum of all releases of the chemical to air, land, water, and underground injection wells.

^kTotal amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI17 2018 (Data are from 2017)

Table 5-4. Releases to the Environment from Facilities that Produce, Process, or Use Antimony Compounds^a

State ^c	RF ^d	Reported amounts released in pounds per year ^b							
		Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Total release		On- and off-site
							On-site ^j	Off-site ^k	
AK	1	No data	20	No data	8,500	No data	8,520	No data	8,520
AL	6	10	5	No data	6,327	1,034	15	7,361	7,376
AR	2	1	5	No data	43,198	No data	43,184	20	43,204
AZ	3	548	10	No data	468,233	No data	468,784	7	468,791
CA	14	21	597	No data	321,857	7,261	405	329,331	329,736
CO	2	12	No data	No data	2,635	No data	12	2,635	2,647

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Table 5-4. Releases to the Environment from Facilities that Produce, Process, or Use Antimony Compounds^a

State ^c	RF ^d	Reported amounts released in pounds per year ^b							
		Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Total release		On- and off-site
							On-site ^j	Off-site ^k	
CT	4	10	173	No data	4,443	27,255	10	31,871	31,881
DE	2	0	No data	No data	No data	23	0	23	24
FL	2	No data	No data	No data	1,534	No data	No data	1,534	1,534
GA	22	562	161	No data	33,095	18,005	574	51,249	51,823
IA	1	1	No data	No data	No data	No data	1	No data	1
ID	4	462	803	No data	131,730	496	132,255	1,236	133,491
IL	16	255	439	No data	39,741	4,369	36,024	8,779	44,803
IN	29	2,084	7,410	No data	1,110,798	73,297	77,170	1,116,419	1,193,589
KS	5	371	0	No data	5,326	476	371	5,802	6,173
KY	17	1,434	151	No data	33,173	5,844	7,648	32,955	40,603
LA	9	561	3,565	No data	27	558	4,126	585	4,711
MA	17	No data	No data	No data	No data	No data	No data	No data	No data
MD	1	681	585	No data	6,888	37,928	684	45,398	46,082
MI	10	290	84	No data	6,369	269	290	6,722	7,012
MN	9	69	12	No data	3,789	2,124	69	5,925	5,994
MO	9	5	246	No data	201,000	65	191,639	9,677	201,316
MS	11	2,067	112	No data	2,664	38,965	2,068	41,740	43,808
MT	2	140	No data	No data	9,660	4	9,800	4	9,804
NC	19	115	149	No data	13,295	6,851	514	19,896	20,410
ND	1	1,201	No data	No data	77,300	No data	78,501	No data	78,501
NE	4	10	5	No data	39,309	338	28,061	11,601	39,662
NH	2	No data	No data	No data	1,286	No data	No data	1,286	1,286
NJ	10	120	15	No data	3,429	10,328	125	13,767	13,892
NM	7	28	No data	No data	96,868	No data	28	96,868	96,896
NV	3	67	72	No data	10,664,735	No data	10,664,045	829	10,664,874
OH	43	792	15,172	526	40,611	11,210	1,071	66,715	67,785
OK	1	No data	No data	No data	20,627	No data	20,627	No data	20,627
OR	3	29	No data	No data	No data	1,216	29	1,216	1,245
PA	29	205	1,636	No data	94,723	47,621	6,893	137,292	144,185
PR	1	10	No data	No data	65,993	No data	10	65,993	66,003
RI	4	3	2	No data	5,817	5,502	3	11,321	11,324
SC	23	498	4,754	1	8,944	2,370	2,622	13,944	16,566
TN	20	371	1,191	No data	65,270	434	38,927	28,339	67,265
TX	41	1,640	1,173	19,412	430,283	90,242	365,172	158,165	523,337
UT	5	161	1,000	No data	410,695	14,112	194,388	231,579	425,967

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Table 5-4. Releases to the Environment from Facilities that Produce, Process, or Use Antimony Compounds^a

State ^c	RF ^d	Reported amounts released in pounds per year ^b							
		Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Total release		On- and off-site
							On-site ^j	Off-site ^k	
VA	7	111	274	No data	4,162	133	136	4,544	4,680
VT	2	No data	No data	No data	No data	No data	No data	No data	No data
WA	1	No data	No data	No data	No data	No data	No data	No data	No data
WI	11	1,850	9	No data	80,561	6,703	1,853	87,270	89,124
WV	5	62	No data	No data	2,238	No data	623	1,677	2,300
WY	1	46	No data	No data	791	No data	837	No data	837
Total	441	16,901	39,831	19,938	14,567,922	415,035	12,388,114	2,651,577	15,039,691

^aThe TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.

^bData in TRI are maximum amounts released by each facility.

^cPost office state abbreviations are used.

^dNumber of reporting facilities.

^eThe sum of fugitive and point source releases are included in releases to air by a given facility.

^fSurface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).

^gClass I wells, Class II-V wells, and underground injection.

^hResource Conservation and Recovery Act (RCRA) subtitle C landfills; other onsite landfills, land treatment, surface impoundments, other land disposal, other landfills.

ⁱStorage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown

^jThe sum of all releases of the chemical to air, land, water, and underground injection wells.

^kTotal amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI17 2018 (Data are from 2017)

Section 112 of the Clean Air Act (CAA) lists antimony as one of 188 hazardous air pollutants (HAPs) known to cause or suspected of causing cancer or other serious human health effects or ecosystem damage (EPA 2000). EPA's National Emission Inventory (NEI) database contains data regarding sources that emit criteria air pollutants and their precursors, and HAPs for the 50 United States, Washington DC, Puerto Rico, and the U.S. Virgin Islands (prior to 1999, criteria pollutant emission estimates were maintained in the National Emission Trends [NET] database and HAP emission estimates were maintained in the National Toxics Inventory [NTI] database). The NEI database derives emission data from multiple sources, including state and local environmental agencies; the TRI database; computer models for on-road and off-road emissions; and databases related to EPA's Maximum Achievable Control Technology (MACT) programs to reduce emissions of HAPs. Using composite data from the NTI database from 1990 to 1993, it was estimated that the annual emissions of antimony in the United States

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were approximately 103 tons per year during that time frame (EPA 2000). Data downloaded from the 2011 NEI (see Table 5-5) indicated that the total emission of antimony was approximately 5,210,763 pounds, with the biggest contribution arising from electric generation by coal (EPA 2016a).

Table 5-5. 2011 National Emission Inventory (NEI) Total National Emissions

Name	Annual emissions (lb)
Bulk gasoline terminals	2.5134
Commercial cooking	264.183
Dust, construction dust	5.26327
Fires, agricultural field burning	330.6032
Fuel combustion, commercial/institutional, biomass	67.40831
Fuel combustion, commercial/institutional, coal	40.24683
Fuel combustion, commercial/institutional, natural gas	0.09
Fuel combustion, commercial/institutional, oil	143.801
Fuel combustion, commercial/institutional, other	1.411491
Fuel combustion, electric generation, biomass	188.6612
Fuel combustion, electric generation, biomass coal	13,020.77
Fuel combustion, electric generation, biomass natural gas	78.23796
Fuel combustion, electric generation, biomass oil	5,978.314
Fuel combustion, electric generation, biomass other	25.92661
Fuel combustion, industrial boilers, internal combustion engines, biomass	2,206.582
Fuel combustion, industrial boilers, internal combustion engines, coal	2,513.459
Fuel combustion, industrial boilers, internal combustion engines, natural gas	1,682.659
Fuel combustion, industrial boilers, internal combustion engines, oil	311.0068
Fuel combustion, industrial boilers, internal combustion engines, other	801.3158
Fuel combustion, residential, natural gas	0
Fuel combustion, residential, oil	0.00051
Fuel combustion, residential, other	0.647524
Industrial processes, cement manufacturing	78.64444
Industrial processes, chemical manufacturing	1,502.073
Industrial processes, ferrous metals	1,071.269
Industrial processes, mining	94.03349
Industrial processes, not elsewhere classified	25,172.5
Industrial processes, nonferrous metals	11,997.31
Industrial processes, oil and gas production	220.7644
Industrial processes, petroleum refineries	2,073.725
Industrial processes, pulp and paper	1,857.656
Industrial processes, storage and transfer	597.7857
Miscellaneous non-industrial, not elsewhere classified	20.64527
Mobile, commercial marine vessels	69.72685
Mobile, locomotives	314.1618

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Table 5-5. 2011 National Emission Inventory (NEI) Total National Emissions

Name	Annual emissions (lb)
Solvent, degreasing	416.547
Solvent, graphic arts	19.95
Solvent, industrial surface coating and solvent use	6,836.025
Waste disposal	407.8158
Total	5,210,763

Source: EPA 2016a

Releases of antimony to the atmosphere result from natural and anthropogenic sources. Total emissions from both sources were reported to be 6,100 tons/year in the 1980s; anthropogenic sources such as coal combustion, smelting, and refining were the major sources (Belzile et al. 2011). It was also estimated that 41% of antimony emissions to the air were from natural sources in the 1980s. The natural sources and their median percentage contribution were: wind-borne soil particles, 32.5%; volcanos, 29.6%; sea salt spray, 23.3%; forest fires, 9.2%; and biogenic sources, 12.1% (Nriagu 1989).

Total mid-1990 atmospheric emissions of antimony were reported to be 1,561 tonnes/year total from anthropogenic sources. Emissions from the combustion of fuels, lead production, zinc production, copper production, nonferrous production, pig iron and steel production, municipal waste, and sewage sludge were found to be 319, 134, 95, 547, 7, 235, 34, and 730 tonnes, respectively (Pacyna and Pacyna 2001).

Atmospheric particulate matter was found to be enriched with antimony in Japan; brake abrasion dust from automobiles and waste fly ash were found to be the predominant sources of antimony emissions. Emissions were estimated to be 21 tonnes/year from brake pads (Iijima et al. 2009). Antimony levels in high-density traffic areas are likely due to abrasion of tires, brake lining, and other automotive components that use of antimony alloys (Belzile et al. 2011). In Gottingen, Germany, 176 kg/year of antimony is emitted from brakes, tires, street surfaces, and vehicle exhaust (WHO 2003).

Increased emissions from fly ash were also reported in Japan. Fly ash is produced in waste incineration (Iijima et al. 2009). Antimony concentrations in fly ash were reported to be 4.7 $\mu\text{g/g}$ total in Japan, 1–3.9 $\mu\text{g/g}$ in various countries, and 1.99 $\mu\text{g/g}$ total in Spain (Smichowski 2008).

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5.3.2 Water

Estimated releases of 4,497 pounds (~2.04 metric tons) of antimony to surface water from 77 domestic manufacturing and processing facilities in 2017, accounted for about 0.52% of the estimated total environmental releases from facilities required to report to the TRI (TRI17 2018). This estimate includes releases to waste water treatment and publicly owned treatment works (POTWs). These releases are summarized in Table 5-3. Estimated releases of 39,831 pounds (~18.07 metric tons) of antimony compounds to surface water from 441 domestic manufacturing and processing facilities in 2017, accounted for about 0.26% of the estimated total environmental releases from facilities required to report to the TRI (TRI17 2018). These releases are summarized in Table 5-4.

Antimony is a natural constituent of soil and is transported into streams and waterways in runoff either due to natural weathering or disturbed soil (Cole et al. 1984).

Antimony is also found in water due to contamination from mining and smelter, shooting ranges, and road sides that contain dust from brake pads and tires.

5.3.3 Soil

Estimated releases of 771,868 pounds (~350.11 metric tons) of antimony to soil from 77 domestic manufacturing and processing facilities in 2017, accounted for about 89.92% of the estimated total environmental releases from facilities required to report to the TRI (TRI17 2018). These releases are summarized in Table 5-3. Estimated releases of 14,567,922 pounds (~6,607.89 metric tons) of antimony compounds to soil from 441 domestic manufacturing and processing facilities in 2017, accounted for about 96.86% of the estimated total environmental releases from facilities required to report to the TRI (TRI17 2018). An additional 19,938 pounds (~9.04 metric tons), accounted for about 0.13% of the total environmental emissions were released via underground injection (TRI17 2018). These releases are summarized in Table 5-4.

Antimony is a natural constituent of soil and is produced from the weathering of soil parent materials (Wilson et al. 2010). Contamination of the soil leads to increased concentrations of antimony. Most of the antimony released to the environment is released to land. The industries that release the largest amount of antimony are smelters that produce antimony and antimony trioxide. Much of this release is slag, which is the residue from smelting operations. Other releases to land include sludge from publicly

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owned treatment works (POTWs) and municipal refuse (Eckel and Langley 1988). Munitions may also be a source of antimony soil contamination (Hockmann et al. 2014; Mariussen et al. 2017).

Antimony was reported to be in 166 of the 1,397 soil samples at the Lawrence Berkeley National Laboratory. The samples were obtained from soil boring sites from the construction of 71 groundwater monitoring wells. A 12% occurrence of antimony was reported, and levels found in the sample site (0.7–22 mg/kg) exceeded the background levels of antimony normally found in the soil (DOE 2009a).

5.4 ENVIRONMENTAL FATE

5.4.1 Transport and Partitioning

The oxidized form of antimony, Sb(V), is expected to be the more stable form in the environment; however, Sb(III) is formed under certain environmental conditions (Mitsunobu et al. 2006). Similarly, inorganic species are expected to be more present than organic species of antimony in most environmental systems (Wilson et al. 2010).

Sb(V) corresponds to the octahedral antimonite ion, Sb(OH)_6^- , while Sb(III) corresponds to the uncharged antimonous acid, Sb(OH)_3 in antimony water systems. In the soil, antimony oxidation state and environmental reactions are largely dependent on the pH, redox conditions, and concentrations of co-occurring reduction agents and oxidants in the system (Wilson et al. 2010).

Antimony can be retained in the soil primarily through adsorption. Antimony can sorb to clay minerals, or to oxides and hydroxides in the soil. Sb(III) sorbs more strongly to manganese (III) oxyhydroxide (MnOOH) than to aluminum hydroxide (Al(OH)_3) or iron(III) oxide-hydroxide (FeOOH) (Wilson et al. 2010). Antimony K_d values ranged from 1 to 2,065 L/kg in a sorption study investigating plant uptake of antimony (Nakamaru and Sekine 2008).

Antimony behavior in soil-water systems was found to be dependent on redox conditions in a study evaluating soil collected at different depths at the Ichinokawa mine pit in Ehime, Japan. Decreased antimony concentrations were observed in the soil as the water saturation increased. Sb(V) was found to be stable under reducing conditions. Antimony was found to have a positive correlation with iron and manganese in the soil (Mitsunobu et al. 2006).

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Sb(III) was found to bind more strongly to solids than Sb(V) in a study evaluating antimony solubility in soil from shooting ranges. Sorption of antimony was highly dependent on pH. At pH levels <7, Sb(V) was found to be almost completely sorbed. At pH levels of at least 10, Sb(III) was found to be sorbed. The total release of antimony was found to be much higher than the releases from nickel, copper, bismuth, thallium, and mercury in the soil at the seven Swiss shooting ranges (Johnson et al. 2005).

Miravet et al. (2006) examined the mobility of antimony from coal fly ash. Fly ash, from coal fired power plants, contains a mixture of chemicals that may be distributed to soils, freshwater, seawater, or groundwater. Some portions of fly ash are not extractable or are unavailable under environmental conditions; however, the leachable portion of fly ash has the potential to accumulate in organisms. Antimony was found to leach out of fly ash solution at pH 1–12. Sb(V) was the major antimony species in the leachate. Antimony was partially soluble at pH 5, and more soluble at acidic pH values.

Leaching experiments performed with river sediment samples from a mining district in Idaho also indicated that Sb(V) was the major species released during leaching (Mok and Wai 1990). The fraction of antimony leached from sediment with deionized water after 10 days was highly correlated with the free iron and manganese oxide content of the sediment (correlation coefficients of 0.90 and 0.75, respectively). Experiments on the pH dependence of leaching showed marked differences between trivalent and pentavalent antimony (Mok and Wai 1990). The release of trivalent antimony from the sediment increased at low pH; in contrast, the release of pentavalent antimony from sediment increased sharply at high pH (pH 11.4). At pH 4.3, the concentrations of tri- and pentavalent antimony were comparable. Antimony does not appear to bioconcentrate appreciably in fish and aquatic organisms. No detectable bioconcentration occurred during a 28-day test in bluegills (EPA 1980). Only low levels of antimony have been reported in fish and aquatic organisms collected off the coast of Africa, Australia, and the Danube River in Austria (EPA 1979; Maher 1986). Bioconcentration factors for antimony ranged from 0.15 to 390 (Acquire 1989; EPA 1979).

Antimony sorption was studied in relation to its plant uptake. Antimony K_d values ranged from 1 to 2,065 L/kg. The K_d values were significantly decreased with increasing phosphate concentrations, indicating that the addition of phosphate fertilizer may increase the potential for antimony uptake in plants. No difference in antimony sorption to soil occurred when sulfates were added to the soil in this study (Nakamaru and Sekine 2008).

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Antimony can be taken up by plants through the roots and via surface deposition from aerosols. Surface deposition is the major pathway for soil-to-plant transfer of antimony in field conditions (Tschan et al. 2009).

The *Viola* species were found to accumulate antimony in their roots, stems, leaves, flowers, and seeds. Mean antimony concentrations in *Viola allcharensis* were 0.46 mg/kg in the root, 0.34 mg/kg in the stem, 0.46 mg/kg in the leaf, 0.25 mg/kg in the flower, and 0.40 mg/kg in the seed. Mean antimony concentrations for the root, stem, leaves, flowers, and seeds of *Viola arsenica* were reported as 1.06, 0.25, 0.72, 0.47, and 0.91 mg/kg, respectively. Mean antimony concentrations for *Viola macedonica* were 0.25 mg/kg for each root, stem, leaves, and flowers (Baceva et al. 2014).

Certain plants may be used in phytoremediation because they are able to accumulate metals in their tissues and have a high tolerance for those metals in contaminated soils. In the Sao Domingos copper mine, several plant species were found to accumulate antimony in their systems. Concentrations of antimony in the mine tailings ranged from 203 to 2,513 mg/kg. Concentrations in plant species were 6.67 mg/kg for *Erica andevalensis*, 4.09 mg/kg for *Erica australis*, 3.59 mg/kg for *Corrigiola telephypholia*, 2.8 mg/kg for *Echium plantagium*, 2.02 mg/kg for *Eritrae pulcheria*, and 0.60 mg/kg for *Daphne gnidium* and other plants (Anawar et al. 2011).

Root tissues of Maize (*Zea mays*) contained 0.35, 2.5, 3.98, 22.01, and 26.5–68.42 mg/kg of antimony, when exposed to 10, 50, 100, 500 and 1,000 mg/kg of antimony, respectively. Concentrations of antimony at 10, 50, 100, 500, and 1,000 mg/kg corresponded to 0.82, 6.32, 13.76, 45.1, and 68.42 mg/kg in the shoot tissues. Higher concentrations of antimony resulted in higher antimony accumulation in the plants in this study (Pan et al. 2010).

In a similar study, antimony uptake was measured in maize (*Z. mays*) and sunflowers (*Helianthus annuus*). No significant differences in uptake between the two plant species were observed. The bioaccumulation coefficient was reported as 0.93 for maize and 1.33 for sunflower (Tschan et al. 2008).

The mechanism of Baker yeast cell (*Saccharomyces cerevisiae*) antimony biosorption has also been investigated. Sb(III) was removed from contaminated aqueous samples and accumulated in the Baker yeast cells. Accumulation increased with increasing pH, incubation time, temperature, and amount of yeast. Sb(V) was undisturbed under the conditions of the test, indicating selective accumulation of Sb(III) (Perez-Corona et al. 1997).

5.4.2 Transformation and Degradation

Air. Little is known about the chemical forms and physical and chemical transformations of trace elements in the atmosphere. This is primarily because analytical methods provide information concerning the metal content rather than the specific compounds or species. In the absence of specific information, it is generally assumed that elements of anthropogenic origin, especially those emanating from combustion sources, are present as the oxide. Windblown dust particles may contain antimony in mineral species, such as sulfides and oxides, and are associated with silicates. When released into the atmosphere as an aerosol, antimony is believed to be oxidized to antimony trioxide by reaction with atmospheric oxidants.

Water. Most of the dissolved antimony in natural waters is present in the pentavalent oxidation state as the antimonate species ($\text{Sb}(\text{OH})_6^-$) under aerobic conditions (Filella et al. 2002). Anthropogenic emissions commonly contain antimony in the trivalent oxidation state (antimonite; e.g., antimony trioxide); however, it is not certain how quickly antimonite oxidizes to antimonate under natural conditions. Under anoxic reducing conditions, trivalent species, such as $\text{Sb}(\text{OH})_3$, $\text{Sb}(\text{OH})_4^-$ and Sb_2S_4^- , are the most thermodynamically stable forms.

The pentavalent form was reported to be the predominant species in a study examining the behavior of antimony in oxic systems (Filella et al. 2002). The trivalent form was also found to be sometimes present in oxic systems; however, >10% of the total dissolved amount of antimony was rarely found to be in the trivalent form (Filella et al. 2009a). Antimony speciation in various types of natural waters was analyzed in a study conducted in Warsaw Poland. Of the 12 samples obtained from the different rivers, lakes, and ponds, the majority of the total antimony, or 96–99%, was in the pentavalent form (Garbos et al. 2000).

Han-Wen et al. (1982) estimated the rate of oxidation of the trivalent form to the pentavalent form by adding known quantities of each into lake water and waste water samples and studying the change in concentration with respect to time. The trivalent form of antimony in lake water and waste water appeared to be unstable since none could be detected after 6 hours; it is presumed that there were oxidants in the water samples. The addition of tartaric acid (1% w/v) into the water samples had a stabilizing effect (no changes in Sb(III) levels) after 5 days due to the fact that the rate of conversion of Sb(III) into Sb(V) decreases with increasing acidity.

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Cutter (1992) estimated a much slower oxidation rate of trivalent antimony in seawater by measuring the depth profiles for antimony species in the upper 100 m of the Black sea. No Sb(III) was detected in the upper surface levels, but a gradual increase of Sb(III) concentration with a gradual decrease in Sb(V) levels was observed with increasing depth beyond 60 m. The maximum concentration of Sb(III) was observed in the largely anaerobic region (90–100 m). At this depth, no pentavalent antimony was detectable. An estimated pseudo first-order oxidation rate constant of 0.008 day^{-1} was calculated from these data, corresponding to a residence time (1/rate constant) of about 125 days. This rate included all forms of removal since Sb(III) may also be scavenged by suspended particulate matter in the water column. It is presumed that the presence of the thermodynamically unstable trivalent species in aerobic waters may, in part, be due to biotic processes involving the uptake of antimonate and the subsequent biological conversion to the trivalent species. These unstable species were reported to be able to persist due to the low rates of conversion (Cutter 1992). Likewise, as the trivalent species may be present in thermodynamically unfavorable (aerobic) environments, the pentavalent species has also been detected in anoxic settings. As reported by Cutter (1992), the presence of pentavalent antimony in anoxic waters of the Baltic Sea, the Black Sea, and the Saanich Inlet has been observed, and is due to the transport of Sb(V) on sinking detritus from aerobic waters, formation of thioantimonate species, and advection of surface waters containing high levels of pentavalent antimony. All of these potential transport processes also assume a slow reduction rate of pentavalent conversion to the trivalent form. The rate constant for this reaction was estimated as $1.1 \times 10^{-6} \text{ days}^{-1}$ (Cutter 1992).

Antimony can be reduced and methylated by microorganisms in the aquatic environment, similar to arsenic, and become mobilized (Andreae et al. 1983; Austin and Millward 1988). This reaction is most likely to occur in reducing environments, such as in bed sediment.

Pseudomonas fluorescens K27, isolated from the Kesterson reservoir in California, was found to reduce trimethyldibromoantimony to trimethylstibine (Bentley and Chasteeen 2002). Sb(III) and methylated antimony species were converted to stibine at approximately pH 7; however, Sb(V) was not converted. Sb(III) was found to be oxidized in an *Agrobacterium tumefaciens* isolate. The algal strain 5508, found at the Yellowstone National Park in the geothermal environment of Dragon Spring, was also found to have the capability to oxidize Sb(III) (Lehr et al. 2007).

The oxidation rate of As(III) and Sb(III) was studied using circumneutral pH (pH 5.5–6.5) and acidic conditions similar to those in mine tailings under both abiotic and biotic conditions. Under acidic conditions, both antimony and arsenic were slowly oxidized, but more rapid oxidation was observed in

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aerated abiotic solutions containing Fe(III) as opposed to solutions containing microbes; this process was accelerated by natural sunlight and increasing chloride ion concentration (Asta et al. 2012). In unfiltered (microbially active) circumneutral water, antimony was oxidized at a similar rate as in the acidic solutions; however, the rate of arsenic oxidation was enhanced and was several orders of magnitude greater than the rate of antimony oxidation.

Sediment and Soil. Transformation of antimony in the soil is dependent on the microbial population (Luo et al. 2014). Anaerobic microbial methylation occurs in the soil, producing trimethylstibine. Trimethylstibine was produced by the pure cultures of *Clostridium collagenovorans* and *Desulfovibrio vulgaris* under anaerobic conditions in sewage sludge. Anaerobic digestion of sewage sludge by *Methanobacterium formicicum* formed stibine, monomethylstibine, dimethylstibine, and trimethylstibine (Michalke et al. 2000). Under aerobic conditions, *Scopulariopsis brevicaulis* was found to methylate antimony through a dimethylantimony species intermediate in the trimethylstibine pathway (Bentley and Chasteen 2002).

Five soil samples were collected in an antimony and arsenic mine field in the Hunan Province of China. It was determined that *Gemmatimonadetes* and *Actinobacteria* aid in the bioremediation of antimony in the mine field soil (Luo et al. 2014).

Other Media. A 1998 study detected antimony in infant cot mattress covers that contained polyvinyl chloride (PVC). Antimony leached into extraction fluids from mattress samples (Jenkins et al. 1998). In the mid-1990s, it was hypothesized that microbial growth on the cot mattress could generate stibines from the antimony trioxide in the flame retardants. It was also hypothesized that the stibine could result in sudden infant death syndrome (SIDS) (Richardson 1994). However, increases in liver and brain antimony levels have not been found in infants dying from SIDS, as compared to infants dying from other causes (Boex et al. 1998; Cullen et al. 2000).

5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to antimony depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of antimony in unpolluted atmospheres and in pristine surface waters are often so low as to be near the limits of current analytical methods. In reviewing data on antimony levels monitored or estimated in the

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environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable.

Table 5-6 shows the lowest limit of detections that are achieved by analytical analysis in environmental media. An overview summary of the range of concentrations detected in environmental media is presented in Table 5-7.

Table 5-6. Lowest Limit of Detection Based on Standards^a

Media	Detection limit	Reference
Air	0.004 µg	De Doncker et al. 1983
Drinking water	0.5 µg/L Sb(V), 0.9 µg/L Sb(III)	Vinas et al. 2006
Surface water and groundwater	0.00001 µg	de la Calle-Guntinas et al. 1991
Soil and sediment	0.03 µg/g	Lopez-Garcia et al. 1997
Whole blood, tissue, or hair	No data	NIOSH 1985
Urine	0.01 µg/L	Quiroz et al. 2011

^aDetection limits based on using appropriate preparation and analytics. These limits may not be possible in all situations.

Table 5-7. Summary of Environmental Levels of Antimony

Media	Low	High	For more information
Ambient air (ppbv)	0	24.917 (median)	Table 5-9
Ground water (ppb)	<1	12 (geometric mean)	Section 5.5.2
Soil (ppm)	<1	8.8	Section 5.5.3

Detections of antimony in air, water, and soil at NPL sites are summarized in Table 5-8.

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Table 5-8. Antimony Levels in Water, Soil, and Air of National Priorities List (NPL) Sites

Medium	Median ^a	Geometric mean ^a	Geometric standard deviation ^a	Number of quantitative measurements	NPL sites
Water (ppb)	60.5	87.1	5.81	158	104
Soil (ppb)	53,200	75,700	9.05	278	161
Air (ppbv)	0.00623	0.0237	22.3	12	10

^aConcentrations found in ATSDR site documents from 1981 to 2017 for 1,854 NPL sites (ATSDR 2017). Maximum concentrations were abstracted for types of environmental media for which exposure is likely. Pathways do not necessarily involve exposure or levels of concern.

5.5.1 Air

Background levels of antimony in ambient air are usually on the order of about 1 ng/m³, but can be higher in urban environments. In the vicinity of plants that convert antimony ores into metal (smelting operations), or other point sources, levels can be >1,000 ng/m³.

The Air Quality System (AQS) database is EPA's repository of criteria air pollutant and HAPs monitoring data. Detailed air monitoring data for antimony in various cities in the United States for 2014 are shown in Table 5-9. Data for other years are available and may be accessed directly from the EPA website.

Daily mean concentrations ranged from 0.37 to 2 ng/m³ for antimony (total suspended particulate; TSP) standard temperature and pressure (STP); 0.13–20.6 ng/m³ for antimony PM₁₀ LC (local conditions); 0.56–2.18 ng/m³ for antimony PM₁₀ STP; and 1.9–22 ng/m³ for antimony PM_{2.5} LC (EPA 2015).

Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
Antimony (TSP) STP	Rosemount, Minnesota	27	0
	Eagan, Minnesota	26	1.429
	Eagan, Minnesota	28	2
	Apple Valley, Minnesota	25	0.417
	Minneapolis, Minnesota	24	1.6
	Minneapolis, Minnesota	25	0.385
	Minneapolis, Minnesota	26	0.37
	Minneapolis, Minnesota	27	0
	St. Paul, Minnesota	27	0

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Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
	Virginia, Minnesota	27	0
	Duluth, Minnesota	22	0.4
	Duluth, Minnesota	25	0.4
	Newport, Minnesota	25	0
	Bayport, Minnesota	27	0
	Yukon, Oklahoma	28	0.425
	Oklahoma City, Oklahoma	40	0.5
	Tulsa, Oklahoma	40	0.667
	Tulsa, Oklahoma	39	0.59
	Tulsa, Oklahoma	39	0.789
	Tulsa, Oklahoma	38	0.784
Antimony PM ₁₀ LC	Phoenix, Arizona	44	2.450909
	Middletown, California	45	4.511111
	Cobb, California	45	4.444444
	Banning, California	10	1.05
	San Jose, California	45	2.463111
	Valrico, Florida	15	1.46
	Valrico, Florida	15	1.58
	Boston, Massachusetts	39	1.51
	Boston, Massachusetts	23	1.49087
	St. Louis, Missouri	3,705	20.64183
	St. Louis, Missouri	40	1.74975
	St. Louis, Missouri	40	1.7335
	Underhill (Town of), Vermont	14	0.133571
	Underhill (Town of), Vermont	3	0.25
	Seattle, Washington	40	1.0185
Antimony PM ₁₀ STP	Orlando, Florida	22	0.754545
	Saint Petersburg, Florida	43	0.635349
	Pinellas Park, Florida	45	0.697556
	Northbrook, Illinois	27	0.681111
	Ashland, Kentucky	34	2.182353
	Ashland, Kentucky	2	1.3
	Kentucky	33	0.562727
	Kentucky	15	1.012667
	Lexington-Fayette (corporate name for Lexington), Kentucky	33	1.047879
	Kentucky	34	0.754118
	Calvert City (RR name Calvert), Kentucky	32	0.59375
	Providence, Rhode Island	50	0.6466

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Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
	Providence, Rhode Island	24	0.631667
	Houston, Texas	88	0.647727
Antimony PM _{2.5} LC	Birmingham, Alabama	80	19.213
	Birmingham, Alabama	76	18.539
	Huntsville, Alabama	39	20.115
	Montgomery, Alabama	41	17.768
	Phenix City, Alabama	41	20.732
	Fairbanks, Alaska	82	19.854
	Fairbanks, Alaska	70	20.95
	Alaska	30	24.15
	Phoenix, Arizona	83	20.729
	Tucson, Arizona	71	21.092
	North Little Rock, Arkansas	81	20.259
	Chico, California	47	10.383
	Fresno, California	80	20.344
	Calexico, California	39	15.897
	Los Angeles, California	81	19.722
	Portola, California	45	11.044
	Rubidoux, California	79	19.241
	Rubidoux, California	41	18.683
	Arden-Arcade, California	84	19.929
	Sacramento, California	46	12.109
	El Cajon, California	17	19.529
	Escondido, California	47	10.723
	San Jose, California	72	19.326
	Modesto, California	47	12.213
	Visalia, California	47	11.106
	Commerce City, Colorado	38	18.579
	Colorado	69	20.457
	Platteville, Colorado	35	17.529
	New Haven, Connecticut	68	18.904
	Dover, Delaware	13	19.615
	Wilmington, Delaware	62	18.468
	Washington, District Of Columbia	78	22.045
Davie, Florida	45	18.944	
Valrico, Florida	79	20.101	
Tallahassee, Florida	39	18.923	
Pinellas Park, Florida	39	20.244	
Macon, Georgia	42	18.429	

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Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
	Athens (corporation name Athens-Clarke County), Georgia	42	22.083
	Georgia	42	21.643
	Georgia	68	19.478
	Georgia	40	20.05
	Columbus (Remainder), Georgia	41	22.695
	Augusta-Richmond County (Remainder), Georgia	34	21.382
	Georgia	41	19.805
	Hawaii	66	19.712
	Idaho	80	20.438
	Chicago, Illinois	42	22.405
	Chicago, Illinois	75	20.907
	Northbrook, Illinois	74	18.507
	Naperville, Illinois	38	18.013
	Granite City, Illinois	22	20.75
	Roxana, Illinois	39	19.692
	Belleville, Illinois	38	20.605
	Jeffersonville, Indiana	41	19.22
	Jasper, Indiana	41	20.232
	Elkhart, Indiana	41	18.963
	Middletown, Indiana	41	19.402
	Gary, Indiana	39	19.372
	Indianapolis (Remainder), Indiana	60	20.192
	Evansville, Indiana	42	18.774
	Cedar Rapids, Iowa	41	18.159
	Des Moines, Iowa	41	18.11
	Davenport, Iowa	81	20.302
	Wichita, Kansas	42	19
	Kansas City, Kansas	69	20.645
	Ashland, Kentucky	42	20.571
	Kentucky	41	17.5
	Lexington-Fayette (corporate name for Lexington), Kentucky	42	19.726
	Louisville, Kentucky	81	20.951
	Shreveport, Louisiana	39	18.205
	Baton Rouge, Louisiana	76	18.941
	Essex, Maryland	75	19.687
	Beltsville, Maryland	82	21.451
	Chicopee, Massachusetts	80	20.819

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Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
	Boston, Massachusetts	84	20.077
	Boston, Massachusetts	42	18.333
	Grand Rapids, Michigan	82	20.951
	Tecumseh, Michigan	42	19.583
	Michigan	42	20.952
	Michigan	42	19.512
	Port Huron, Michigan	42	20.298
	Allen Park, Michigan	81	20.062
	Detroit, Michigan	41	18.402
	Dearborn, Michigan	42	18.607
	Blaine, Minnesota	82	20.043
	Minneapolis, Minnesota	83	20.596
	Rochester, Minnesota	42	19.738
	Jackson, Mississippi	66	20.818
	Missouri	82	22.079
	Arnold, Missouri	82	20.152
	Missouri	78	21.269
	St. Louis, Missouri	81	20.16
	Montana	68	19.096
	Butte-Silver Bow (Remainder), Montana	53	19.519
	Omaha, Nebraska	71	19.873
	Sunrise Manor, Nevada	70	19.514
	Reno, Nevada	66	19.955
	Camden, New Jersey	68	19.831
	Newark, New Jersey	68	20.368
	North Brunswick Township, New Jersey	66	20.515
	North Brunswick Township, New Jersey	38	18.842
	Chester, New Jersey	68	19.625
	Elizabeth, New Jersey	69	18.725
	Albuquerque, New Mexico	84	19.5
	Albany, New York	79	18.025
	New York, New York	72	18.535
	Buffalo, New York	38	18.526
	New York	42	19.274
	Rochester, New York	80	22.65
	New York, New York	82	19.024
	New York, New York	84	19.964
	New York	80	20.556
	Asheville, North Carolina	29	17.534

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Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
	Hickory, North Carolina	12	24.917
	Lexington, North Carolina	40	18.838
	Winston-Salem, North Carolina	38	19.842
	Charlotte, North Carolina	84	19.143
	Rockwell, North Carolina	42	18.202
	Raleigh, North Carolina	78	19.391
	North Dakota	84	19.048
	Cleveland, Ohio	38	22.013
	Cleveland, Ohio	66	21.356
	Cleveland, Ohio	36	20.75
	Columbus, Ohio	42	18.75
	Cincinnati, Ohio	83	19.88
	Steubenville, Ohio	36	19.944
	Ironton, Ohio	42	19.048
	Sheffield, Ohio	41	22.61
	Toledo, Ohio	37	18.432
	Youngstown, Ohio	30	19.333
	Dayton, Ohio	36	18.819
	New Paris, Ohio	83	20.524
	Canton, Ohio	41	19.341
	Akron, Ohio	35	19.243
	Oklahoma City, Oklahoma	40	18.538
	Tulsa, Oklahoma	81	19.914
	Altamont, Oregon	26	13.596
	Altamont, Oregon	3	11.6
	Lakeview, Oregon	30	13.482
	Lakeview, Oregon	3	11.6
	Eugene, Oregon	30	12.715
	Eugene, Oregon	3	11.583
	Portland, Oregon	71	19.993
	Pennsylvania	41	20.378
	Pittsburgh, Pennsylvania	70	19.164
	Liberty, Pennsylvania	42	20.024
	Pennsylvania	42	19.369
	Johnstown, Pennsylvania	42	17.119
	State College, Pennsylvania	37	20.378
	Pennsylvania	28	17.732
	Pennsylvania	40	18.8
	Erie, Pennsylvania	40	20.2

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Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
	Scranton, Pennsylvania	22	18.25
	Lancaster, Pennsylvania	42	20.75
	Freemansburg, Pennsylvania	37	18.541
	Philadelphia, Pennsylvania	79	21.285
	Philadelphia, Pennsylvania	42	19.607
	Pennsylvania	39	18.128
	Greensburg, Pennsylvania	38	18.684
	York, Pennsylvania	41	21.561
	East Providence, Rhode Island	80	19.894
	South Carolina	36	17.597
	Greenville, South Carolina	39	19.936
	Dentsville (Dents), South Carolina	83	19.602
	Sioux Falls, South Dakota	74	19.818
	Nashville, Tennessee	41	21.988
	Chattanooga, Tennessee	42	19.512
	Knoxville, Tennessee	40	20.3
	Loretto, Tennessee	41	20.988
	Memphis, Tennessee	79	18.899
	Dallas, Texas	86	2.033
	Dallas, Texas	82	20.683
	Midlothian, Texas	44	2.002
	El Paso, Texas	75	21.407
	Texas	46	1.972
	Deer Park, Texas	83	19.813
	Deer Park, Texas	42	18.595
	Texas	41	18.817
	Corpus Christi, Texas	42	1.993
	Bountiful, Utah	41	18.512
	Salt Lake City, Utah	74	21.378
	Lindon, Utah	41	22.854
	Burlington, Vermont	56	20.813
	East Highland Park, Virginia	62	19.435
	Vancouver, Washington	42	19.488
	Seattle, Washington	77	20.052
	Tacoma, Washington	39	17.731
	Marysville, Washington	38	20.763
	Yakima, Washington	42	19.952
	West Virginia	70	19.636
	South Charleston, West Virginia	13	18.846

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Table 5-9. Median Antimony Levels in Ambient Air

Antimony type	Sampling location	Number of samples	Daily mean concentration (ng/m ³)
	Moundsville, West Virginia	27	18.185
	Green Bay, Wisconsin	41	18.951
	Horicon, Wisconsin	84	19.75
	Milwaukee, Wisconsin	79	19.101
	Wisconsin	42	18.881
	Waukesha, Wisconsin	41	20.061
	Wyoming	82	19.384

LC = local conditions; PM = particulate matter; STP = standard temperature and pressure; TSP = total suspended particulate

Source: EPA 2015

Antimony concentrations over the North Atlantic and North Pacific were 0.086 and 0.0037 ng/m³, respectively (Arimoto and Duce 1987; Austin and Millward 1988). Two values reported for antimony in aerosols in clean continental and marine environments were 0.2 ng/m³ at the Jungfrauoch in the Swiss Alps and 0.00045 ng/m³ at American Samoa (Austin and Millward 1988). The MMAD of antimony-containing aerosols from a range of areas remote from anthropogenic sources was 0.86 μm (Milford and Davidson 1985). The mass size distribution is bimodal, with the larger peak at about 0.6 μm and a smaller one at about 3 μm. An example of the size distribution of antimony-containing particles removed from anthropogenic sources was obtained in an 8-week study on an island in the German Bight. The concentration of antimony in a size fraction increased as the size decreased. The antimony concentration ranged from 0.03 ng/m³ for particles >7.2 μm to 0.3 ng/m³ for particles <0.5 μm (Stoessel and Michaelis 1986).

Antimony is enriched in coal and vaporized in fossil fuel combustion, resulting in the release of increased levels of antimony to the atmosphere. After condensation, antimony is primarily found in fly ash (Miravet et al. 2006). Antimony levels in coal fly ash leachates from two different samples obtained from the Escucha coal-fired power station in Teruel, Spain were reported to be 0.01–0.07 μg/g for Sb(III) and 0.17–0.41 μg/g for Sb(V) in the first sample. Levels were slightly higher in the second sample: Sb(III) levels were 0.02–0.09 μg/g and Sb(V) levels were 0.16–0.56 μg/g. The data indicate that Sb(V) was the predominant species found in the leachate, and while the antimony was found to bind strongly to the matrix, the study demonstrated that significant amounts of antimony can leach out of coal fly ash particles (Miravet et al. 2006). Likewise, in Taipei, Taiwan, the total antimony content in fly ash was 4.7 μg/g,

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while in Barcelona, Spain, the Sb(III) content was 0.07–0.36 $\mu\text{g/g}$ and the Sb(V) content was 1.63 $\mu\text{g/g}$. Antimony content (predominantly Sb(III)) in fly ash from various countries ranged from 1 to 3.9 $\mu\text{g/g}$ (Smichowski 2008). Antimony emissions may have increased in Japan over the years due to the fact that part of the process in the incineration of household wastes containing plastics occurs in Japan; thus, fly ash originating from waste incineration may be an important source of antimony (Iijima et al. 2009).

Several older studies show that antimony can travel long distances, and that ambient levels may reflect the origin of the air masses. The geometric mean antimony concentrations in aerosols at three rural/remote locations in New York State were 1.0, 0.72, and 0.33 ng/m^3 (Dutkiewicz et al. 1987), and the enrichment over crustal abundance ranged from 920 to 1,650. The enrichment factor is smaller but similar to the mean enrichment factor of 1,880 for antimony in 29 cities (Gladney et al. 1984). The high enrichment indicates that the antimony is of anthropogenic origin. An analysis of the New York State data using backward-in-time air trajectories is consistent for the Midwest being the dominant source of antimony. An analysis of European sources and wind trajectories further illustrate that antimony may be transmitted over long distances. The average concentrations at a city in southern Norway were 0.54 ng/m^3 when the air masses came from the United Kingdom and 0.07 ng/m^3 when they came from over the Atlantic (Hillamo et al. 1988).

Twenty-four-hour samples collected at 10 locations in Washington, DC yielded average antimony concentrations ranging from 1.1 to 3.0 ng/m^3 (Kowalczyk et al. 1982). As a result of a chemical element balance analysis, the three major contributing sources in order of decreasing significance are believed to be refuse incineration, motor vehicles, and coal combustion. In a Houston study, the range of antimony concentrations in fine (0.1–2.5 μm) aerosols was 0–12 ng/m^3 , whereas in particles $>2.5 \mu\text{m}$, the range was 0–4 ng/m^3 (Johnson et al. 1984). Median, mean, and maximum concentrations of antimony in aerosols at three sites in Quebec, Ontario, and Nova Scotia were 0.05–0.10, 0.11–0.23, and 0.37–2.17 ng/m^3 , respectively (Hopper and Barrie 1988). According to the Texas Air Control Board, the first- and second-highest annual average antimony concentrations in Texas between 1978 and 1982 were 452 and 50 ng/m^3 at Laredo and Dallas, respectively. The statewide 1978–1982 average was below the minimum detectible mean of 90 ng/m^3 (Wiersema et al. 1984).

Concentrations of antimony in 24-hour air samples at Kellogg, Idaho, an area with a large number of operating mines, ranged from 5.21 to 1,210 ng/m^3 , with a mean of 146 ng/m^3 (Ragaini et al. 1977). The 6-month average concentration of antimony in air in an industrial area of England where a number of ferrous and nonferrous metal smelting and manufacturing works were concentrated was 40 ng/m^3 . This is

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a factor of 50 higher than that found in rural areas (Pattenden et al. 1982). The maximum concentration at the industrial site was 69 ng/m³.

The mean monthly concentration of antimony in precipitation at Birkenes in southern Norway ranged from 0.2 to 2.3 µg/L, with a mean of 0.6 µg/L (Pacyna et al. 1984). During the same period, the respective air concentrations were 0.19–0.80 and 0.43 ng/m³. Rain samples were collected during two storms upwind and downwind of a copper smelter in Tacoma, Washington. Antimony in rainwater originated primarily from the smelter. The mean total antimony concentration in rainwater downwind from the smelter was 1.3 µg/L; the concentration upwind was 0.03 µg/L (Vong et al. 1988). Eighty percent of the antimony in rainwater was dissolved (i.e., passed through a 0.45-µm filter).

Antimony is almost entirely found in the particulate, as opposed to the dissolved fraction of snow (Landsberger et al. 1983). The antimony content of snow particulate matter in samples from Montreal, Canada, ranged from 4 to 145 ppm. Another sampling of snow around Montreal found total antimony concentrations of 1–8.7 ppb and enrichment factors of 39–590 (Zikovsky and Badillo 1987).

Antimony is a component of ammunition, and studies have been performed to ascertain the elemental concentrations of antimony in the air of indoor shooting ranges. Antimony might be expected in such situations because it is alloyed with lead in bullets, and lead stibnite and antimony sulfides are used as primers (Dams et al. 1988). After an intensive 3-hour shooting exercise, levels of antimony reached 119 µg/m³ (190,000 ng/m³), or 4 orders of magnitude over ambient levels (Vandecasteele et al. 1988). An instructor at the shooting range had a time-weighted average (TWA) inhalable antimony concentration of 12.0 µg/m³ (1,200 ng/m³) compared with the threshold limit value (TLV) of 500 µg/m³ (500,000 ng/m³). An American study conducted at the National Guard Armory in Washington, DC, during routine daytime and gun club use, found indoor antimony concentrations ranging from 57 to 216 µg/m³ (57,000–216,000 ng/m³) versus background air ranging from 1.5 to 2.3 µg/m³ (1,500–2,300 ng/m³), an enrichment of 9,900 over District of Columbia air (Olmez et al. 1985). More than 60% of the antimony was associated with respirable particles with an aerodynamic diameter <3.5 µm (<3,500 ppb).

5.5.2 Water

The National Water-Quality Assessment (NAWQA) program surveyed groundwater across the United States from 1992 to 2003 and generally found low concentrations of antimony in the water. Median concentrations were reported as <1 µg/L (ppb) (USGS 2011). Other studies also reported low

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concentrations of antimony in water. Eckel and Jacob (1989) gathered water monitoring data from the Water Resources Division of the U.S. Geological Survey (USGS) covering the period from about 1960 to September, 1988, and found that all but 70 of 1,077 entries for dissolved antimony were below 5 µg/L. The geometric mean and standard deviation of the 70 values >5 µg/L were 12 and 1.93 µg/L, respectively. The concentrations of dissolved antimony were 1.62 nM (0.197 µg/L) in the St. Lawrence River at Massena, New York and 2.73 nM (0.332 µg/L) in the Yukon River. European rivers had dissolved antimony at concentrations ranging from <0.03 to 4.43 nM (0.004–0.539 µg/L) (Andreae and Froelich 1984).

Geothermal waters often have naturally elevated levels of trace metals such as arsenic, mercury, and antimony. The speciation of these compounds is complex and can change during sampling, storage, and analysis; therefore, results are usually reported as the total amount present in the geothermal water. Analysis of 268 thermal springs in Yellowstone National Park showed total antimony levels ranging from 9 to 166 µg/L for sampling conducted from 1966 to 1975 (Stauffer and Thompson 1984). USGS (2010) analyzed water samples from streams, tributaries, drainage channels, and other water bodies at 104 locations in the Yellowstone National Park, Wyoming from 2006 to 2008. The results of this study are summarized in Table 5-10.

Table 5-10. Total Antimony Levels in Water Samples Collected at Yellowstone National Park

Sampling location	Antimony (µg/L)
Norris-Mammoth Corridor and West Nymph Creek	<1–6
Norris Geyser Basin	<1–180
Gibbon Canyon and Geyser Springs Group	3–95
Crater Hills area	1–150
Ojo Caliente Spring and its discharge channel, Lower Geyser Basin	10–94
Porcupine Hills area	62–123
Midway Geyser Basin and the Rabbit Creek area	0–82
Mud Volcano area	<0.5–6
Washburn Hot Springs	<0.5

Source: USGS 2010

These data are consistent with antimony levels in geothermal waters in other parts of the world. For example, antimony levels ranged from 0.05 to 244 µg/L (n=75), with a mean value of 35 µg/L for geothermal waters sampled in various locations of Japan.

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Anthropogenic activity can result in elevated levels of antimony in nearby water systems. A study in Luxembourg found higher concentrations of antimony in samples close to an ore site as compared to concentrations further from the site (Filella et al. 2009b). Similarly, a study in Corsica found higher levels of antimony in the water after crossing the mining soils, with concentrations decreasing further downstream (Migon and Mori 1999).

Sb(V) was the most prevalent species of antimony found in drinking water. Sb(V) is expected to predominate due to the oxidative treatments used in water disinfection processes (Belzile et al. 2011). Sb(V) was also the predominant species in oceans at mean concentrations of 200 ng/L. Sb(V) is predominant in oxic and mildly reducing environments. Sb(III) is predominant in anoxic waters and porewaters, and in reducing conditions. The presence of thermodynamically unfavorable Sb(III) in oxygenated surface waters has been attributed largely to phytoplankton activity (Chen et al. 2003).

The major antimony mining area in the United States was the Kellogg district in northern Idaho, and mining and smelting wastes have been dumped into the South Fork of the Coeur d'Alene River for over 80 years (Mok and Wai 1990). The South Fork joins with the North Fork of the river to form the Main Stem of the Coeur d'Alene River somewhat below Kellogg. Mean and maximum total dissolved antimony concentrations at two sites on the South Fork were 4.3 and 8.2 $\mu\text{g/L}$, respectively. Mean and maximum concentrations at six stations on the Main Stem ranged from 0.6 to 1.0 and from 0.8 to 1.9 $\mu\text{g/L}$, respectively. Those at a station on the unpolluted North Fork were 0.09 and 0.2 $\mu\text{g/L}$, respectively.

Since antimony is used in solder, there has been interest as to whether antimony will leach from pipes soldered with antimony-containing solder into drinking water. Leaching of antimony from tin/antimony (Sn/Sb) solder when it comes in contact with water with pH of 5.2–8.6 was evaluated using loops of pipe containing 20 solder joints (Murrell 1987). Antimony was undetectable (<4 ppb) in the water at first, but rose to 10 ppb after 4 days and 68 ppb (at pH 7.4) after 4 weeks. A study was conducted at the University of Washington to evaluate the potential for leaching of metals into drinking water from 95/5 Sn/Sb solder (EPA 1982). After a series of static and continuous-flow laboratory tests and evaluation of field samples from university buildings, it was concluded that increases in antimony concentration as a result of corrosion and leaching were minimal and would not contribute significantly to dietary antimony intake. Only one of the field samples of standing water from university buildings containing Sn/Sb solder joints was above the detection limit of 0.6 ppb. The sample contained 2 ppb of antimony, one-half of which

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was dissolved. Examination of the solder joints indicated that a double passivation film of tin monoxide (SnO) and tin dioxide (SnO₂) forms and inhibits leaching.

5.5.3 Sediment and Soil

Antimony is naturally present in the earth's crust at levels of about 0.2–0.3 µg/g (ppm), but these levels vary by location (Telford et al. 2008). A survey of soils throughout the conterminous United States conducted by the USGS showed that antimony concentrations ranged from <1 to 8.8 ppm (µg/g) with an average concentration of 0.48 ppm (µg/g). This was the third lowest concentration of the 50 elements surveyed (DOI 1984). In this survey, samples were taken at a depth of 20 cm at 1,318 sampling sites. Soils not derived from ore-bearing rock or close to industrial sources do not generally contain more than 1 ppm (µg/g) of antimony. Background concentrations for antimony in soil ranged from 0.06 to 0.79 µg/g in seven Florida soil orders. Concentrations were dependent on the location, mineralization, parent material differences, varying degrees of anthropogenic influence, and different sampling strategies (Wilson et al. 2010). Elevated levels of antimony in soil samples are commonly associated with anthropogenic activities such as mining, fossil fuel combustion, smelting, and other activities. Samples of soil were collected from the decommissioned Hanford Site along the Columbia River in 2008. The Hanford site was utilized to produce plutonium. Antimony was detected in 27 out of 158 samples at a mean concentration of 0.113 µg/g. Antimony and selenium were not able to be detected in the majority of the samples (DOE 2009b). The distribution of antimony at two sites in Austria, with close proximity to traffic routes, was evaluated by Amereih et al. (2005) at two sampling depths (0–5 and 5–10 cm from the soil surface) and three distances (0.2, 2, and 10 m) from the edge of the road. In addition to roadside soil, samples were also obtained from Lungau, an alpine region with negligible traffic. Table 5-11 summarizes the results from this study during two sampling periods (2002 and 2005).

Table 5-11. Antimony Levels at Three Locations With Different Vehicular Traffic

Location ^a	Distance from road (m)	Sample depth (cm)	Total Sb µg/g (2002)	Total Sb µg/g (2005)
Lungau	Not applicable	0–5	0.64	Not available
	Not applicable	5–10	0.81	Not available
Knittelfeld	0.2	0–5	6.30	8.68
	0.2	5–10	3.80	4.78
	2	0–5	1.75	1.99
	2	5–10	1.51	1.96
	10	0–5	1.21	1.16
	10	5–10	1.13	1.13

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Table 5-11. Antimony Levels at Three Locations With Different Vehicular Traffic

Location ^a	Distance from road (m)	Sample depth (cm)	Total Sb $\mu\text{g/g}$ (2002)	Total Sb $\mu\text{g/g}$ (2005)
Rankweil	0.2	0–5	2.74	Not available
	0.2	5–10	1.83	Not available
	2	0–5	1.52	Not available
	2	5–10	1.21	Not available
	10	0–5	0.91	Not available
	10	5–10	0.82	Not available

^aVehicular traffic at the Knittelfeld and Rankweil sampling locations exceeds 20,000 vehicles per day, while there is no vehicular traffic at the Lungau location.

Source: Amereih et al. 2005

Examining the monitoring data from this study shows clear trends in the antimony levels in the soils reflective of anthropogenic contributions due to the presence of motor vehicles at the Knittelfeld and Rankweil locations as compared to the site with negligible vehicular traffic. Moreover, greater antimony levels are observed at both sampling depths the nearer to the road the soil samples were obtained (0.2 versus 2 versus 10 m). Levels of antimony decreased to near background levels within a few meters from the edge of the road.

High concentrations of antimony were observed in soil at a shooting range. Antimony concentrations (only Sb(V)) were 4,000 $\mu\text{g/g}$ in soil samples collected at a depth of 1 cm, 1,600–17,500 $\mu\text{g/g}$ in soil samples collected at 0–5 cm, 3,400 mg/kg at 5–15 cm, 1,300 $\mu\text{g/g}$ at 16 cm, and 8,600 $\mu\text{g/g}$ at 25–45 cm at different sites at the shooting range (Scheinost et al. 2006). In a study of small arms ranges at military sites in eight U.S. states, antimony levels ranged from 7 to 91 $\mu\text{g/g}$ in composite samples of the top few inches of soil (Bannon et al. 2009).

Levels of mean antimony, Sb(III), and Sb(V) in contaminated soils from the Hillgrove mine located in New South Wales, Australia were measured in six samples. This facility mines for gold and antimony and has been in operation for over 100 years. There were higher levels of Sb(V) than Sb(III) in the soil samples, ranging from 12 to 27 $\mu\text{g/g}$ for Sb(III) and from 211 to 384 $\mu\text{g/g}$ for Sb(V). Total mean antimony levels ranged from 470 to 849 $\mu\text{g/g}$ (Telford et al. 2008). Concentrations of antimony were also high in the sediment around mining sites in Corsica. The levels of antimony decreased with increasing distance downstream from the site. Concentrations ranged from 8 to 1,108 $\mu\text{g/g}$ in January 1993 and from 10 to 1,005 $\mu\text{g/g}$ in March 1993 depending upon the sampling location (Migon and Mori 1999).

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The greatest concentrations occurred at a sampling location on the Presa River nearby the mine and gradually decreased at sampling locations 10 km away where the Presa River runs into the Bravona River.

Levels of Sb(III), Sb(V), and total antimony were monitored at three locations in sediment from the Plawniowice reservoir in Poland nearby metallurgy and coal mining operations (Jablonska-Czapla et al. 2014). Levels of Sb(III) varied between approximately 20–45 $\mu\text{g/g}$ in the upper (0–5 cm) sediment profile and approximately 20–35 $\mu\text{g/g}$ in sediment collected from a depth of 15–20 cm. Sb(V) levels were similar in both the upper sediment samples and the lower sediment samples with levels ranging from approximately 5 to 25 $\mu\text{g/g}$.

5.5.4 Other Media

Antimony trioxide (Sb_2O_3) is used in the production of PET. The antimony content in PET has been reported to be as high as 190–300 mg/kg. Leaching of antimony into PET water bottles has been reported in several studies of water bottles and food storage containers produced in the United States, Mexico, and Europe (Belzile et al. 2011; Chapa-Martinez et al. 2016; Westerhoff et al. 2008). These studies have shown that increased temperature and length of time stored may contribute to more antimony being released from the containers. Belzile et al. (2011) reported that the levels of antimony increased from 200 to 7,800–9,700 ng/L in heated water bottles (at 80°C for 48 hours). Heated PET packing materials had antimony concentrations ranging from 50 to 285 mg/kg and non-heated containers had levels <0.1–24 $\mu\text{g/kg}$. Concentrations of antimony in food has been reported to be <1.0 $\mu\text{g/g}$ (Belzile et al. 2011). At room temperature, only a small amount of antimony was detected in U.S. bottled water (average concentration of 0.195 ppb) (Westerhoff et al. 2008).

Antimony has been detected in commercial juices. Juices of blackcurrant, mixed fruit, strawberry, raspberry, sour cherry, mint, and synthetic caramel purchased from Greece, Denmark, and Scotland were analyzed for antimony content. The highest concentration of antimony from the 42 samples was 13.6 $\mu\text{g/L}$, reported in sour cherry juice packaged in glass (Hansen et al. 2010).

5.6 GENERAL POPULATION EXPOSURE

The general population may be exposed to antimony through ingestion of food and drinking water, inhalation of particulates from ambient air, or ingestion of contaminated soil or dust. Occupational

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exposures of antimony may occur at smelters, coal-fired plants, and refuse incinerators that process or release antimony.

In discussing exposure to antimony, it is important to consider what form of antimony a person is exposed to and its availability. High concentrations of antimony may be found in the contaminated soil and sediment. In water, the pentavalent state is predominant, although significant levels of trivalent antimony and methylated antimony compounds exist. People who live or work near sources of antimony such as smelters, coal-fired power plants, and refuse incinerators may be exposed to high levels of antimony in airborne dust, soil, and vegetation. People who live near or work at waste sites that receive slag from smelters or fly ash from power plants and refuse incinerators may also be exposed to higher than background levels. Exposure routes would include either inhalation of contaminated air or ingestion of contaminated soil or vegetation. Similarly, people who are exposed to soot and smoke in fires, such as firefighters, may be exposed to high levels of antimony. Occupational exposure to antimony appears to be highest for those involved in the production and processing of antimony and antimony oxide. Workers in battery-forming areas of lead-storage battery plants may be exposed to high levels of stibine.

In the Fourth National Report on Human Exposures to Environmental Chemicals reported by the Centers for Disease Control and Prevention (CDC 2019) results from the NHANES updated tables 1999–2016 were provided for antimony. Antimony levels in unadjusted urine (see Table 5-12), and creatinine corrected urine (see Table 5-13) were evaluated for a variety of age groups and ethnicities. Urinary samples reflect recent exposure to antimony (CDC 2019). The geometric mean and median concentrations of urinary antimony have dramatically decreased from 1999–2000 to 2005–2006 (40–50%); thereafter, the urinary antimony levels have only changed slightly (increased or decreased). These differences may be due to decreases in exposure or methodological differences.

Gebel et al. (1998b) investigated urine, blood, and scalp hair for antimony biomonitoring. No association between elevated soil levels and urinary antimony levels were found in this study of >200 German residents. A high proportion of blood samples had antimony levels below the limit of detection. Antimony was detected in hair samples from individuals in Rio de Janeiro at concentrations that ranged from <0.03 to <1.8 µg/g. The samples were for both men and women and were collected from the scalp in the occipital area (back of the head) (Miekeley et al. 1998). In an analogous study, the mean concentration of antimony in hair samples from 55 men and women from Scranton, Pennsylvania contained 0.096 ppm of antimony. The hair samples of populations from cities in four other countries contained mean antimony levels between 0.11 and 0.86 ppm (Takagi et al. 1986). A Japanese national

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Table 5-12. Geometric Mean and Selected Percentiles of Urinary Antimony (in $\mu\text{g/L}$) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
Total	1999–2000	0.132 (0.120–0.145)	0.130 (0.120–0.150)	0.220 (0.200–0.230)	0.330 (0.300–0.350)	0.430 (0.390–0.470)	2,276
	2001–2002	0.134 (0.126–0.142)	0.130 (0.130–0.140)	0.190 (0.180–0.200)	0.270 (0.250–0.310)	0.350 (0.320–0.400)	2,690
	2003–2004	*	0.080 (<LOD–0.090)	0.130 (0.120–0.150)	0.200 (0.190–0.220)	0.280 (0.250–0.320)	2,558
	2005–2006	0.073 (0.066–0.081)	0.070 (0.070–0.080)	0.120 (0.110–0.140)	0.220 (0.180–0.250)	0.300 (0.270–0.360)	2,576
	2007–2008	0.061 (0.057–0.066)	0.060 (0.060–0.060)	0.100 (0.090–0.110)	0.170 (0.140–0.200)	0.240 (0.220–0.260)	2,627
	2009–2010	0.056 (0.053–0.059)	0.050 (0.050–0.060)	0.090 (0.090–0.100)	0.170 (0.140–0.180)	0.230 (0.200–0.280)	2,847
	2011–2012	*	0.047 (0.042–0.052)	0.083 (0.075–0.091)	0.144 (0.125–0.158)	0.188 (0.169–0.222)	2,504
	2013–2014	0.043 (0.039–0.048)	0.041 (0.036–0.046)	0.076 (0.069–0.086)	0.130 (0.120–0.144)	0.189 (0.170–0.214)	2,664
	2015–2016	0.047 (0.044–0.051)	0.046 (0.043–0.051)	0.080 (0.077–0.085)	0.137 (0.126–0.150)	0.201 (0.171–0.218)	3,061
Age group							
3–5 years	2015–2016	0.049 (0.044–0.055)	0.049 (0.042–0.054)	0.087 (0.075–0.096)	0.138 (0.118–0.164)	0.188 (0.152–0.212)	486
6–11 years	1999–2000	0.176 (0.154–0.200)	0.190 (0.160–0.210)	0.260 (0.230–0.280)	0.350 (0.300–0.400)	0.440 (0.320–0.600)	316
	2001–2002	0.146 (0.134–0.160)	0.150 (0.130–0.160)	0.200 (0.180–0.210)	0.270 (0.240–0.330)	0.340 (0.280–0.440)	368
	2003–2004	0.099 (0.087–0.114)	0.100 (0.070–0.120)	0.160 (0.120–0.200)	0.240 (0.190–0.310)	0.310 (0.230–0.330)	290
	2005–2006	0.075 (0.063–0.088)	0.080 (0.060–0.090)	0.110 (0.090–0.130)	0.190 (0.120–0.260)	0.240 (0.170–0.340)	355
	2007–2008	0.068 (0.061–0.077)	0.070 (0.060–0.080)	0.110 (0.090–0.130)	0.170 (0.150–0.210)	0.230 (0.180–0.280)	394
	2009–2010	0.069 (0.061–0.079)	0.070 (0.060–0.080)	0.120 (0.100–0.150)	0.220 (0.150–0.260)	0.260 (0.230–0.350)	378
	2011–2012	0.064 (0.059–0.069)	0.059 (0.049–0.072)	0.108 (0.094–0.124)	0.169 (0.152–0.188)	0.206 (0.182–0.257)	399
	2013–2014	0.052 (0.045–0.060)	0.053 (0.046–0.065)	0.096 (0.089–0.105)	0.151 (0.128–0.172)	0.228 (0.168–0.254)	402
	2015–2016	0.061 (0.054–0.068)	0.063 (0.064–0.067)	0.102 (0.089–0.115)	0.159 (0.134–0.176)	0.207 (0.168–0.244)	379
12–19 years	1999–2000	0.158 (0.141–0.178)	0.170 (0.150–0.180)	0.240 (0.210–0.270)	0.350 (0.290–0.420)	0.460 (0.350–0.510)	663
	2001–2002	0.169 (0.156–0.184)	0.160 (0.150–0.180)	0.240 (0.220–0.260)	0.350 (0.320–0.410)	0.460 (0.400–0.500)	762
	2003–2004	0.105 (0.095–0.115)	0.100 (0.090–0.120)	0.150 (0.140–0.160)	0.230 (0.200–0.270)	0.290 (0.250–0.370)	725
	2005–2006	0.092 (0.083–0.101)	0.090 (0.080–0.100)	0.140 (0.130–0.160)	0.240 (0.200–0.270)	0.280 (0.250–0.320)	701
	2007–2008	0.079 (0.069–0.091)	0.080 (0.070–0.090)	0.130 (0.110–0.140)	0.210 (0.150–0.230)	0.230 (0.210–0.340)	376
	2009–2010	0.063 (0.056–0.071)	0.060 (0.050–0.070)	0.100 (0.090–0.120)	0.180 (0.150–0.210)	0.270 (0.180–0.370)	451
	2011–2012	0.065 (0.057–0.073)	0.065 (0.048–0.081)	0.106 (0.098–0.126)	0.173 (0.137–0.202)	0.218 (0.166–0.283)	390
	2013–2014	0.051 (0.043–0.061)	0.051 (0.041–0.062)	0.088 (0.070–0.112)	0.138 (0.121–0.166)	0.203 (0.152–0.235)	451
	2015–2016	0.059 (0.051–0.068)	0.060 (0.047–0.069)	0.094 (0.080–0.118)	0.160 (0.129–0.207)	0.259 (0.178–0.292)	402

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Table 5-12. Geometric Mean and Selected Percentiles of Urinary Antimony (in $\mu\text{g/L}$) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
≥20 years	1999–2000	0.123 (0.112–0.137)	0.120 (0.110–0.130)	0.200 (0.180–0.220)	0.310 (0.290–0.350)	0.430 (0.390–0.470)	1,297
	2001–2002	0.128 (0.119–0.136)	0.130 (0.120–0.130)	0.180 (0.170–0.190)	0.250 (0.220–0.300)	0.330 (0.280–0.390)	1,560
	2003–2004	*	0.070 (<LOD–0.080)	0.120 (0.100–0.140)	0.190 (0.170–0.210)	0.270 (0.220–0.320)	1,543
	2005–2006	0.070 (0.064–0.078)	0.070 (0.060–0.080)	0.120 (0.110–0.140)	0.220 (0.180–0.270)	0.320 (0.260–0.420)	1,520
	2007–2008	0.058 (0.054–0.062)	0.060 (0.050–0.060)	0.090 (0.090–0.100)	0.160 (0.130–0.190)	0.240 (0.210–0.270)	1,857
	2009–2010	0.054 (0.051–0.057)	0.050 (0.050–0.050)	0.090 (0.080–0.090)	0.150 (0.140–0.180)	0.220 (0.190–0.270)	2,018
	2011–2012	*	0.044 (<LOD–0.051)	0.076 (0.066–0.087)	0.129 (0.112–0.152)	0.171 (0.158–0.228)	1,715
	2013–2014	0.042 (0.038–0.045)	0.039 (0.033–0.043)	0.071 (0.065–0.079)	0.128 (0.116–0.137)	0.184 (0.161–0.215)	1,811
2015–2016	0.045 (0.042–0.047)	0.044 (0.040–0.048)	0.077 (0.073–0.080)	0.131 (0.113–0.147)	0.191 (0.161–0.209)	1,794	
Gender							
Males	1999–2000	0.143 (0.131–0.157)	0.150 (0.130–0.160)	0.240 (0.220–0.260)	0.350 (0.330–0.390)	0.470 (0.390–0.570)	1,132
	2001–2002	0.145 (0.136–0.154)	0.140 (0.130–0.150)	0.200 (0.190–0.210)	0.310 (0.280–0.330)	0.390 (0.350–0.440)	1,335
	2003–2004	0.095 (0.088–0.103)	0.090 (0.080–0.100)	0.140 (0.130–0.160)	0.220 (0.200–0.250)	0.320 (0.270–0.350)	1,281
	2005–2006	0.085 (0.076–0.095)	0.080 (0.080–0.090)	0.140 (0.120–0.160)	0.250 (0.210–0.290)	0.350 (0.260–0.460)	1,271
	2007–2008	0.068 (0.062–0.076)	0.070 (0.060–0.070)	0.110 (0.100–0.120)	0.210 (0.170–0.230)	0.280 (0.230–0.340)	1,327
	2009–2010	0.060 (0.055–0.065)	0.060 (0.050–0.070)	0.100 (0.090–0.110)	0.170 (0.150–0.200)	0.250 (0.200–0.290)	1,397
	2011–2012	0.057 (0.052–0.063)	0.052 (0.044–0.061)	0.089 (0.080–0.100)	0.152 (0.124–0.169)	0.196 (0.169–0.259)	1,262
	2013–2014	0.048 (0.044–0.052)	0.046 (0.041–0.051)	0.082 (0.072–0.094)	0.145 (0.129–0.161)	0.213 (0.182–0.230)	1,318
2015–2016	0.053 (0.049–0.058)	0.053 (0.047–0.058)	0.090 (0.080–0.103)	0.156 (0.137–0.162)	0.209 (0.175–0.248)	1,524	
Females	1999–2000	0.122 (0.109–0.137)	0.120 (0.110–0.140)	0.200 (0.180–0.220)	0.300 (0.280–0.340)	0.400 (0.350–0.460)	1,144
	2001–2002	0.125 (0.117–0.133)	0.120 (0.120–0.130)	0.180 (0.160–0.190)	0.240 (0.220–0.280)	0.320 (0.260–0.360)	1,355
	2003–2004	*	<LOD	0.120 (0.090–0.140)	0.180 (0.150–0.220)	0.230 (0.190–0.330)	1,277
	2005–2006	0.063 (0.057–0.071)	0.060 (0.050–0.070)	0.100 (0.090–0.120)	0.180 (0.150–0.230)	0.270 (0.200–0.330)	1,305
	2007–2008	0.055 (0.052–0.058)	0.050 (0.050–0.060)	0.090 (0.080–0.100)	0.130 (0.120–0.150)	0.200 (0.170–0.230)	1,300
	2009–2010	0.052 (0.049–0.056)	0.050 (0.040–0.050)	0.090 (0.080–0.090)	0.150 (0.130–0.170)	0.220 (0.190–0.270)	1,450
	2011–2012	*	0.043 (<LOD–0.049)	0.074 (0.068–0.082)	0.131 (0.122–0.149)	0.182 (0.166–0.218)	1,242
	2013–2014	0.040 (0.036–0.044)	0.036 (0.030–0.043)	0.070 (0.062–0.078)	0.122 (0.105–0.132)	0.169 (0.146–0.200)	1,346
2015–2016	0.042 (0.039–0.045)	0.042 (0.037–0.045)	0.072 (0.067–0.078)	0.117 (0.107–0.131)	0.178 (0.150–0.205)	1,537	

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Table 5-12. Geometric Mean and Selected Percentiles of Urinary Antimony (in µg/L) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
Race/ethnicity							
Mexican Americans	1999–2000	0.132 (0.108–0.161)	0.140 (0.120–0.170)	0.210 (0.180–0.240)	0.300 (0.260–0.390)	0.430 (0.330–0.560)	787
	2001–2002	0.142 (0.130–0.154)	0.130 (0.130–0.150)	0.200 (0.170–0.230)	0.260 (0.240–0.320)	0.360 (0.300–0.400)	683
	2003–2004	0.093 (0.079–0.110)	0.090 (<LOD–0.120)	0.140 (0.120–0.160)	0.190 (0.160–0.260)	0.270 (0.210–0.330)	618
	2005–2006	0.093 (0.082–0.105)	0.090 (0.080–0.100)	0.150 (0.140–0.170)	0.250 (0.210–0.340)	0.470 (0.270–0.850)	652
	2007–2008	0.069 (0.060–0.079)	0.070 (0.060–0.080)	0.110 (0.100–0.120)	0.190 (0.150–0.250)	0.270 (0.220–0.390)	515
	2009–2010	0.063 (0.060–0.067)	0.060 (0.060–0.070)	0.110 (0.090–0.120)	0.170 (0.150–0.200)	0.250 (0.200–0.270)	613
	2011–2012	0.056 (0.051–0.062)	0.053 (0.044–0.062)	0.086 (0.075–0.091)	0.134 (0.110–0.164)	0.174 (0.149–0.261)	317
	2013–2014	0.048 (0.038–0.060)	0.047 (0.033–0.057)	0.082 (0.066–0.106)	0.172 (0.109–0.248)	0.252 (0.170–0.432)	453
2015–2016	0.057 (0.052–0.062)	0.057 (0.053–0.063)	0.090 (0.084–0.098)	0.139 (0.121–0.165)	0.194 (0.167–0.284)	585	
Non-Hispanic blacks	1999–2000	0.175 (0.148–0.207)	0.180 (0.150–0.200)	0.260 (0.230–0.300)	0.400 (0.310–0.490)	0.490 (0.410–0.710)	554
	2001–2002	0.180 (0.164–0.197)	0.170 (0.160–0.190)	0.250 (0.220–0.280)	0.360 (0.320–0.410)	0.460 (0.370–0.530)	667
	2003–2004	0.108 (0.098–0.119)	0.110 (0.100–0.120)	0.160 (0.150–0.190)	0.230 (0.200–0.280)	0.310 (0.250–0.360)	723
	2005–2006	0.088 (0.077–0.100)	0.090 (0.080–0.100)	0.140 (0.130–0.170)	0.210 (0.190–0.250)	0.280 (0.240–0.320)	692
	2007–2008	0.085 (0.079–0.092)	0.080 (0.080–0.090)	0.130 (0.120–0.140)	0.210 (0.180–0.250)	0.290 (0.250–0.370)	589
	2009–2010	0.073 (0.065–0.081)	0.070 (0.060–0.080)	0.120 (0.110–0.140)	0.190 (0.160–0.250)	0.280 (0.220–0.350)	544
	2011–2012	0.070 (0.063–0.079)	0.068 (0.062–0.074)	0.110 (0.096–0.125)	0.182 (0.148–0.229)	0.254 (0.200–0.354)	669
	2013–2014	0.065 (0.056–0.075)	0.066 (0.060–0.070)	0.111 (0.097–0.128)	0.189 (0.146–0.225)	0.245 (0.218–0.303)	581
2015–2016	0.068 (0.062–0.075)	0.066 (0.057–0.073)	0.110 (0.097–0.127)	0.192 (0.166–0.219)	0.265 (0.211–0.319)	671	
Non-Hispanic whites	1999–2000	0.128 (0.115–0.144)	0.130 (0.110–0.140)	0.210 (0.190–0.230)	0.330 (0.280–0.350)	0.400 (0.360–0.500)	768
	2001–2002	0.126 (0.117–0.135)	0.130 (0.120–0.130)	0.180 (0.170–0.190)	0.250 (0.230–0.300)	0.340 (0.310–0.390)	1,132
	2003–2004	*	0.070 (<LOD–0.080)	0.130 (0.110–0.140)	0.190 (0.170–0.210)	0.280 (0.230–0.320)	1,074
	2005–2006	0.069 (0.062–0.077)	0.070 (0.060–0.080)	0.110 (0.100–0.130)	0.210 (0.170–0.260)	0.300 (0.240–0.380)	1,041
	2007–2008	0.057 (0.052–0.063)	0.060 (0.050–0.060)	0.090 (0.080–0.110)	0.150 (0.130–0.200)	0.230 (0.190–0.260)	1,095
	2009–2010	0.053 (0.050–0.057)	0.050 (0.040–0.050)	0.090 (0.080–0.090)	0.160 (0.130–0.190)	0.230 (0.190–0.280)	1,225
	2011–2012	*	0.044 (<LOD–0.049)	0.081 (0.069–0.095)	0.143 (0.118–0.159)	0.180 (0.159–0.231)	820
	2013–2014	0.041 (0.037–0.045)	0.037 (0.032–0.043)	0.071 (0.063–0.079)	0.118 (0.104–0.130)	0.167 (0.143–0.184)	985
2015–2016	0.044 (0.041–0.047)	0.043 (0.039–0.047)	0.075 (0.068–0.081)	0.129 (0.112–0.144)	0.178 (0.155–0.208)	924	
All Hispanics	2011–2012	*	0.046 (<LOD–0.053)	0.079 (0.066–0.088)	0.128 (0.110–0.149)	0.174 (0.149–0.208)	573
	2013–2014	0.047 (0.040–0.055)	0.045 (0.038–0.052)	0.079 (0.069–0.096)	0.155 (0.116–0.218)	0.231 (0.178–0.318)	701
	2015–2016	0.054 (0.050–0.058)	0.053 (0.048–0.058)	0.086 (0.080–0.094)	0.136 (0.117–0.161)	0.205 (0.167–0.264)	982

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Table 5-12. Geometric Mean and Selected Percentiles of Urinary Antimony (in $\mu\text{g/L}$) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
Asians	2011–2012	*	<LOD	0.066 (0.054–0.075)	0.103 (0.075–0.145)	0.145 (0.100–0.194)	353
	2013–2014	*	0.027 (<LOD–0.052)	0.052 (0.045–0.061)	0.080 (0.065–0.098)	0.099 (0.083–0.169)	292
	2015–2016	0.033 (0.028–0.038)	0.053 (0.022–0.039)	0.051 (0.042–0.061)	0.092 (0.062–0.134)	0.139 (0.095–0.208)	332

<LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample.

*Not calculated: proportion of results below limit of detection was too high to provide a valid result.

CI = confidence interval

Source: CDC 2019

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Table 5-13. Geometric Mean and Selected Percentiles of Urinary Antimony (Creatinine Corrected) (in µg/g of Creatinine) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
Total	1999–2000	0.124 (0.108–0.143)	0.119 (0.102–0.143)	0.185 (0.164–0.214)	0.276 (0.233–0.333)	0.385 (0.333–0.430)	2,276
	2001–2002	0.126 (0.119–0.134)	0.120 (0.115–0.126)	0.173 (0.162–0.188)	0.267 (0.242–0.300)	0.364 (0.320–0.414)	2,689
	2003–2004	*	0.080 (<LOD–0.086)	0.135 (0.119–0.143)	0.208 (0.192–0.230)	0.277 (0.250–0.294)	2,558
	2005–2006	0.072 (0.068–0.077)	0.070 (0.060–0.070)	0.100 (0.100–0.110)	0.160 (0.150–0.190)	0.230 (0.190–0.290)	2,576
	2007–2008	0.064 (0.060–0.068)	0.060 (0.060–0.060)	0.090 (0.080–0.100)	0.140 (0.140–0.160)	0.200 (0.170–0.230)	2,627
	2009–2010	0.060 (0.056–0.064)	0.060 (0.050–0.060)	0.090 (0.080–0.090)	0.140 (0.120–0.160)	0.200 (0.180–0.230)	2,847
	2011–2012	*	0.059 (0.055–0.063)	0.092 (0.085–0.100)	0.152 (0.135–0.171)	0.223 (0.181–0.261)	2,502
	2013–2014	0.050 (0.046–0.055)	0.047 (0.044–0.051)	0.073 (0.068–0.079)	0.114 (0.103–0.127)	0.160 (0.145–0.172)	2,663
	2015–2016	0.053 (0.050–0.056)	0.049 (0.047–0.052)	0.079 (0.071–0.087)	0.124 (0.115–0.137)	0.176 (0.152–0.190)	3,058
Age group							
3–5 years	2015–2016	0.113 (0.103–0.124)	0.108 (0.91–0.117)	0.163 (0.149–0.181)	0.255 (0.220–0.291)	0.328 (0.274–0.425)	485
6–11 years	1999–2000	0.191 (0.147–0.248)	0.185 (0.156–0.220)	0.250 (0.200–0.417)	0.447 (0.271–0.741)	0.741 (0.333–10.30)	316
	2001–2002	0.178 (0.159–0.200)	0.173 (0.150–0.193)	0.228 (0.200–0.272)	0.338 (0.265–0.480)	0.471 (0.313–0.727)	368
	2003–2004	0.116 (0.103–0.130)	0.118 (0.098–0.136)	0.167 (0.146–0.187)	0.256 (0.194–0.317)	0.333 (0.250–0.500)	290
	2005–2006	0.092 (0.081–0.104)	0.090 (0.080–0.110)	0.130 (0.110–0.150)	0.180 (0.150–0.210)	0.220 (0.180–0.270)	355
	2007–2008	0.089 (0.079–0.100)	0.090 (0.070–0.100)	0.120 (0.110–0.140)	0.200 (0.150–0.240)	0.300 (0.200–0.370)	394
	2009–2010	0.094 (0.084–0.106)	0.090 (0.080–0.100)	0.140 (0.120–0.160)	0.200 (0.170–0.250)	0.280 (0.220–0.320)	378
	2011–2012	0.091 (0.081–0.102)	0.091 (0.078–0.100)	0.130 (0.116–0.147)	0.206 (0.153–0.283)	0.308 (0.218–0.340)	398
	2013–2014	0.077 (0.068–0.088)	0.076 (0.067–0.084)	0.114 (0.098–0.133)	0.177 (0.154–0.193)	0.225 (0.191–0.238)	402
	2015–2016	0.086 (0.077–0.096)	0.084 (0.073–0.096)	0.125 (0.114–0.137)	0.183 (0.155–0.210)	0.250 (0.196–0.300)	379
12–19 years	1999–2000	0.121 (0.104–0.140)	0.120 (0.095–0.146)	0.176 (0.146–0.207)	0.259 (0.206–0.310)	0.310 (0.228–0.421)	663
	2001–2002	0.121 (0.112–0.131)	0.115 (0.106–0.127)	0.160 (0.138–0.186)	0.224 (0.199–0.245)	0.266 (0.244–0.310)	762
	2003–2004	0.075 (0.068–0.082)	0.068 (0.061–0.077)	0.100 (0.092–0.113)	0.156 (0.126–0.173)	0.193 (0.172–0.255)	725
	2005–2006	0.070 (0.065–0.076)	0.070 (0.060–0.080)	0.100 (0.090–0.110)	0.140 (0.120–0.150)	0.170 (0.150–0.250)	701
	2007–2008	0.062 (0.054–0.070)	0.060 (0.050–0.070)	0.090 (0.070–0.100)	0.120 (0.100–0.160)	0.160 (0.110–0.240)	376
	2009–2010	0.059 (0.053–0.066)	0.060 (0.050–0.060)	0.090 (0.070–0.100)	0.130 (0.110–0.170)	0.180 (0.150–0.220)	451
	2011–2012	0.062 (0.055–0.069)	0.058 (0.051–0.067)	0.085 (0.070–0.106)	0.147 (0.115–0.181)	0.222 (0.122–0.373)	390
	2013–2014	0.046 (0.041–0.053)	0.047 (0.039–0.052)	0.064 (0.057–0.071)	0.103 (0.084–0.115)	0.144 (0.109–0.172)	451
	2015–2016	0.055 (0.049–0.062)	0.050 (0.045–0.059)	0.075 (0.065–0.085)	0.114 (0.096–0.133)	0.148 (0.128–0.200)	402

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Table 5-13. Geometric Mean and Selected Percentiles of Urinary Antimony (Creatinine Corrected) (in $\mu\text{g/g}$ of Creatinine) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
≥20 years	1999–2000	0.118 (0.104–0.135)	0.111 (0.097–0.135)	0.175 (0.149–0.209)	0.263 (0.227–0.320)	0.352 (0.320–0.391)	1,297
	2001–2002	0.122 (0.115–0.129)	0.115 (0.108–0.121)	0.167 (0.153–0.181)	0.265 (0.241–0.300)	0.364 (0.318–0.405)	1,559
	2003–2004	*	0.079 (<LOD–0.087)	0.135 (0.116–0.145)	0.209 (0.195–0.233)	0.278 (0.250–0.294)	1,543
	2005–2006	0.070 (0.066–0.075)	0.060 (0.060–0.070)	0.100 (0.090–0.110)	0.170 (0.150–0.190)	0.250 (0.190–0.300)	1,520
	2007–2008	0.062 (0.058–0.066)	0.060 (0.050–0.060)	0.090 (0.080–0.100)	0.140 (0.130–0.160)	0.200 (0.160–0.240)	1,857
	2009–2010	0.057 (0.053–0.061)	0.050 (0.050–0.060)	0.080 (0.080–0.090)	0.130 (0.120–0.140)	0.190 (0.160–0.220)	2,018
	2011–2012	*	0.056 (<LOD–0.060)	0.088 (0.078–0.097)	0.145 (0.127–0.171)	0.215 (0.179–0.240)	1,714
	2013–2014	0.049 (0.044–0.053)	0.046 (0.043–0.049)	0.070 (0.064–0.076)	0.104 (0.095–0.115)	0.151 (0.130–0.170)	1,810
2015–2016	0.049 (0.046–0.051)	0.046 (0.043–0.048)	0.070 (0.064–0.078)	0.113 (0.103–0.122)	0.151 (0.130–0.177)	1,792	
Gender							
Males	1999–2000	0.112 (0.099–0.127)	0.109 (0.095–0.127)	0.164 (0.146–0.181)	0.226 (0.204–0.268)	0.320 (0.235–0.391)	1,132
	2001–2002	0.114 (0.107–0.123)	0.108 (0.103–0.115)	0.153 (0.138–0.171)	0.228 (0.205–0.250)	0.333 (0.281–0.438)	1,334
	2003–2004	0.080 (0.076–0.084)	0.075 (0.069–0.081)	0.122 (0.111–0.132)	0.192 (0.173–0.209)	0.253 (0.230–0.278)	1,281
	2005–2006	0.070 (0.064–0.077)	0.060 (0.060–0.070)	0.100 (0.090–0.120)	0.160 (0.130–0.220)	0.250 (0.170–0.310)	1,271
	2007–2008	0.061 (0.057–0.066)	0.060 (0.050–0.060)	0.090 (0.080–0.100)	0.140 (0.130–0.160)	0.210 (0.160–0.260)	1,327
	2009–2010	0.055 (0.050–0.060)	0.050 (0.050–0.060)	0.080 (0.070–0.100)	0.130 (0.120–0.150)	0.190 (0.160–0.210)	1,397
	2011–2012	0.054 (0.050–0.058)	0.051 (0.048–0.057)	0.078 (0.071–0.089)	0.132 (0.120–0.151)	0.186 (0.161–0.224)	1,261
	2013–2014	0.048 (0.043–0.053)	0.045 (0.040–0.049)	0.068 (0.061–0.076)	0.114 (0.099–0.123)	0.163 (0.145–0.177)	1,317
2015–2016	0.051 (0.047–0.055)	0.047 (0.043–0.048)	0.076 (0.067–0.089)	0.125 (0.112–0.140)	0.178 (0.151–0.211)	1,524	
Females	1999–2000	0.137 (0.117–0.161)	0.131 (0.108–0.164)	0.213 (0.176–0.247)	0.320 (0.263–0.417)	0.429 (0.357–0.485)	1,144
	2001–2002	0.139 (0.131–0.148)	0.132 (0.124–0.140)	0.196 (0.178–0.211)	0.295 (0.267–0.317)	0.371 (0.333–0.444)	1,355
	2003–2004	*	<LOD	0.143 (0.125–0.161)	0.225 (0.188–0.261)	0.288 (0.250–0.333)	1,277
	2005–2006	0.074 (0.070–0.078)	0.070 (0.070–0.070)	0.110 (0.100–0.110)	0.170 (0.150–0.190)	0.220 (0.180–0.300)	1,305
	2007–2008	0.067 (0.062–0.071)	0.060 (0.060–0.070)	0.100 (0.090–0.100)	0.140 (0.130–0.160)	0.200 (0.160–0.230)	1,300
	2009–2010	0.064 (0.060–0.069)	0.060 (0.060–0.070)	0.090 (0.090–0.100)	0.150 (0.130–0.170)	0.220 (0.180–0.260)	1,450
	2011–2012	*	0.066 (<LOD–0.071)	0.104 (0.094–0.112)	0.165 (0.145–0.193)	0.226 (0.183–0.303)	1,241
	2013–2014	0.053 (0.048–0.057)	0.050 (0.046–0.055)	0.077 (0.071–0.084)	0.114 (0.104–0.133)	0.156 (0.145–0.171)	1,346
2015–2016	0.055 (0.052–0.059)	0.051 (0.048–0.055)	0.081 (0.073–0.090)	0.123 (0.114–0.139)	0.172 (0.144–0.196)	1,534	

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Table 5-13. Geometric Mean and Selected Percentiles of Urinary Antimony (Creatinine Corrected) (in µg/g of Creatinine) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
Race/ethnicity							
Mexican Americans	1999–2000	0.120 (0.107–0.135)	0.114 (0.105–0.129)	0.167 (0.148–0.203)	0.250 (0.209–0.315)	0.333 (0.280–0.357)	787
	2001–2002	0.138 (0.128–0.149)	0.130 (0.117–0.143)	0.182 (0.159–0.203)	0.269 (0.229–0.308)	0.338 (0.308–0.429)	682
	2003–2004	0.086 (0.076–0.098)	0.082 (<LOD–0.092)	0.129 (0.107–0.151)	0.189 (0.154–0.238)	0.238 (0.185–0.321)	618
	2005–2006	0.087 (0.076–0.099)	0.080 (0.070–0.080)	0.120 (0.110–0.130)	0.190 (0.150–0.310)	0.370 (0.200–0.800)	652
	2007–2008	0.069 (0.059–0.081)	0.060 (0.050–0.080)	0.100 (0.080–0.120)	0.160 (0.130–0.180)	0.200 (0.160–0.360)	515
	2009–2010	0.066 (0.063–0.071)	0.060 (0.060–0.060)	0.100 (0.080–0.110)	0.160 (0.130–0.190)	0.240 (0.190–0.280)	613
	2011–2012	0.063 (0.059–0.067)	0.061 (0.057–0.064)	0.089 (0.079–0.100)	0.133 (0.121–0.153)	0.183 (0.150–0.246)	317
	2013–2014	0.055 (0.046–0.066)	0.049 (0.043–0.057)	0.076 (0.063–0.099)	0.138 (0.107–0.172)	0.196 (0.137–0.381)	453
2015–2016	0.062 (0.057–0.069)	0.056 (0.051–0.062)	0.094 (0.084–0.101)	0.140 (0.126–0.166)	0.224 (0.166–0.275)	584	
Non-Hispanic blacks	1999–2000	0.114 (0.099–0.133)	0.112 (0.098–0.130)	0.163 (0.144–0.183)	0.236 (0.195–0.338)	0.343 (0.255–0.425)	554
	2001–2002	0.123 (0.113–0.134)	0.115 (0.106–0.127)	0.163 (0.150–0.181)	0.233 (0.208–0.267)	0.300 (0.248–0.373)	667
	2003–2004	0.078 (0.071–0.085)	0.074 (0.069–0.082)	0.109 (0.096–0.124)	0.170 (0.148–0.192)	0.222 (0.179–0.257)	723
	2005–2006	0.064 (0.058–0.071)	0.060 (0.050–0.070)	0.090 (0.080–0.090)	0.130 (0.120–0.150)	0.190 (0.150–0.220)	692
	2007–2008	0.062 (0.059–0.066)	0.060 (0.050–0.070)	0.090 (0.080–0.090)	0.140 (0.120–0.160)	0.180 (0.160–0.220)	589
	2009–2010	0.058 (0.053–0.063)	0.060 (0.050–0.060)	0.080 (0.070–0.090)	0.130 (0.110–0.160)	0.170 (0.150–0.190)	544
	2011–2012	0.055 (0.049–0.060)	0.052 (0.047–0.058)	0.077 (0.069–0.088)	0.121 (0.104–0.147)	0.175 (0.140–0.232)	669
	2013–2014	0.049 (0.046–0.053)	0.048 (0.044–0.052)	0.068 (0.064–0.073)	0.110 (0.095–0.122)	0.164 (0.133–0.221)	581
2015–2016	0.054 (0.049–0.060)	0.048 (0.045–0.052)	0.080 (0.068–0.088)	0.136 (0.113–0.179)	0.226 (0.167–0.280)	669	
Non-Hispanic whites	1999–2000	0.129 (0.109–0.152)	0.125 (0.102–0.152)	0.195 (0.167–0.225)	0.298 (0.239–0.352)	0.400 (0.333–0.444)	768
	2001–2002	0.127 (0.117–0.138)	0.120 (0.113–0.130)	0.176 (0.159–0.198)	0.280 (0.241–0.317)	0.380 (0.318–0.471)	1,132
	2003–2004	*	0.081 (<LOD–0.089)	0.139 (0.124–0.147)	0.217 (0.200–0.238)	0.286 (0.253–0.333)	1,074
	2005–2006	0.072 (0.068–0.077)	0.070 (0.060–0.070)	0.110 (0.100–0.110)	0.170 (0.150–0.190)	0.230 (0.190–0.280)	1,041
	2007–2008	0.064 (0.060–0.069)	0.060 (0.050–0.070)	0.090 (0.080–0.100)	0.140 (0.140–0.160)	0.210 (0.170–0.230)	1,095
	2009–2010	0.060 (0.055–0.065)	0.060 (0.050–0.060)	0.090 (0.080–0.100)	0.140 (0.120–0.170)	0.200 (0.170–0.250)	1,225
	2011–2012	*	0.060 (<LOD–0.067)	0.097 (0.088–0.108)	0.161 (0.135–0.183)	0.224 (0.181–0.273)	818
	2013–2014	0.050 (0.044–0.056)	0.047 (0.042–0.053)	0.075 (0.068–0.081)	0.110 (0.098–0.127)	0.156 (0.133–0.171)	984
2015–2016	0.052 (0.048–0.055)	0.049 (0.046–0.053)	0.077 (0.068–0.089)	0.136 (0.106–0.132)	0.160 (0.138–0.180)	924	
All Hispanics	2011–2012	*	0.058 (<LOD–0.065)	0.085 (0.073–0.097)	0.132 (0.113–0.161)	0.181 (0.153–0.214)	573
	2013–2014	0.052 (0.044–0.056)	0.047 (0.043–0.054)	0.076 (0.065–0.089)	0.137 (0.107–0.164)	0.196 (0.143–0.326)	701
	2015–2016	0.061 (0.048–0.055)	0.055 (0.049–0.060)	0.092 (0.085–0.100)	0.143 (0.132–0.162)	0.246 (0.183–0.300)	981

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Table 5-13. Geometric Mean and Selected Percentiles of Urinary Antimony (Creatinine Corrected) (in $\mu\text{g/g}$ of Creatinine) for the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

	Survey years	Geometric mean (95% CI)	Selected percentiles (95% CI)				Sample size
			50 th	75 th	90 th	95 th	
Asians	2011–2012	*	<LOD	0.087 (0.072–0.107)	0.153 (0.132–0.177)	0.215 (0.171–0.290)	353
	2013–2014	*	0.047 (<LOD–0.050)	0.067 (0.060–0.077)	0.114 (0.087–0.145)	0.160 (0.133–0.201)	292
	2015–2016	0.045 (0.039–0.051)	0.041 (0.037–0.047)	0.067 (0.065–0.080)	0.114 (0.087–0.144)	0.167 (0.125–0.223)	332

<LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample.

*Not calculated: proportion of results below limit of detection was too high to provide a valid result.

CI = confidence interval

Source: CDC 2019

study analyzing antimony concentrations in washed hair samples from 234 healthy individuals reported a geometric mean concentration and standard deviation of 0.078 and 2.5 ppm, respectively. No significant differences between different sexes or age groups were noted (Ohmori et al. 1981).

In another Japanese study, hair and nail samples taken from workers at an antimony refinery, nearby residents, and a control group were analyzed before and after washing with a nonionic, surface-active agent in an ultrasonic cleaner (Katayama and Ishide 1987). The respective concentrations of antimony in the nails of the three groups were 730, 2.46, and 0.19 ppm before washing and 230, 0.63, and 0.09 ppm after washing. The concentrations of antimony in the hair of workers before and after washing were 222 and 196 ppm, respectively. The concentrations of antimony in the hair of control subjects before and after washing were 0.21 and 0.15 ppm, respectively. Nail samples from 71 Americans contained an average of 0.41 ppm of antimony. Averages for residents of four other countries ranged from 0.28 to 0.70 ppm (Takagi et al. 1988).

The NHANES 1999–2016 reported antimony levels in urine (see Tables 5-12 and 5-13) for children in different age groups (CDC 2019). Infant urinary antimony levels reported in the scientific literature are similar to those reported for young children in Fourth National Report on Human Exposures to Environmental Chemicals (CDC 2019). Antimony levels $>1 \mu\text{g/L}$ were found in 4% of 126 term infants; 7% had levels $<0.02 \mu\text{g/L}$ and 90.5% had levels $<0.5 \mu\text{g/L}$ (Dezateux et al. 1997). Higher levels of antimony were found in postmortem liver and serum samples from infants who died as a result of sudden infant death syndrome (Cullen et al. 1998; Jenkins et al. 1998). Mean serum antimony concentrations ranged from 0.16 to 0.18 $\mu\text{g/L}$ for 100 healthy infants, 2–56 weeks old. Urinary antimony concentrations were not detected in 5% of the infants, the median urinary antimony concentrations were 0.42 ng/mg creatinine, and 95% of the infants had antimony concentrations $<2.6 \text{ ng/mg creatinine}$.

Several studies have evaluated the factors that contribute to antimony body burden. A study of Norwegian never-pregnant women found that increasing age (25–40 versus 18–24 years), an omnivore diet (compared to a vegetarian diet), and tobacco use were associated with higher serum antimony levels (Fløtre et al. 2017). A comparison of serum antimony levels in professional athletes and sedentary males found significantly higher serum antimony levels among the athletes (Maynar et al. 2017). When the athletes were divided into groups on whether they participated in aerobic (long distance runners), anaerobic (judo and speed athletes), or aerobic-anaerobic (soccer players) sports, serum antimony levels in the aerobic athlete group did not differ from the sedentary group. The investigators suggested that the difference between the findings in aerobic athletes and anaerobic athletes may be due to the high levels of

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antimony in muscles and because anaerobic athletes have a greater muscle volume. A study of French children 3–6 years of age found that the diet accounted for more 77% of total antimony exposure (Glorennec et al 2016).

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Elevated urinary antimony levels were reported in workers exposed to airborne antimony (Bailly et al. 1991; Iavicoli et al. 2002; Kentner et al. 1995; Liao et al. 2004; Ludersdorf et al. 1987). A National Occupational Exposure Survey (NOES) conducted by NIOSH from 1981 to 1983 estimated that 373,460 workers were potentially exposed to antimony (molecular formula unknown) in the United States in 1981–1983 (NIOSH 1989). An estimated 226,645 workers were exposed to antimony trioxide, antimony sulfide, antimony oxide, antimony pentoxide, antimony dialkyldithiocarbamate, and other antimony compounds. The total estimated number of workers exposed to antimony and all of its compounds was 486,347. These estimates are preliminary since all of the data for trade-name products that may contain antimony were not analyzed. The NOES was based on field surveys of 4,490 facilities. It was designed as a nationwide survey based on a statistical sample of virtually all workplace environments in the United States where eight or more persons are employed in all standard industrial codes (SIC) except mining and agriculture. The NOES database does not contain information on the frequency, concentration, or duration of exposure of workers to any of the chemicals listed therein. These surveys provide only estimates of the number of workers potentially exposed to chemicals in the workplace. EPA states that the NOES figures substantially overestimate occupational exposure to antimony and compounds (EPA 1983).

Reported urinary levels of antimony were high in occupationally exposed individuals compared to levels in control subjects ranging from 0.18–2.16 µg/L. Levels ranged from 0.08 to 32.6 µg/L in the urine of refinery workers, from 0.1 to 36.1 µg/L in chemical manufacturers, and from 1.5 to 149.2 µg/L in battery manufacturers. The authors specified that the levels of antimony were 5 times higher from battery workers than other workers. Battery manufacturers were likely exposed to stibine (SbH₃) during the charging process of batteries (Smith et al. 1995).

Concentrations of antimony were examined in the urine of workers at the Puchancavi site in Chile. Concentrations of total antimony and Sb(V) were 6–6.3 and 2.4–6.2 µg/L, respectively. Urine sample analysis determined that most samples had concentrations of total antimony and Sb(V) that were below the limit of detection. No Sb(III) was found in the samples (Quiroz et al. 2011).

5. POTENTIAL FOR HUMAN EXPOSURE

A study of residents living near an electronic waste recycling facility in China found significantly higher hair antimony levels, as compared to residents in another area of China (160.78 ng/g compared to 61.74 ng/g) (Huang et al. 2015). The highest levels were found in the residents that participated in electronic waste recycling activities.