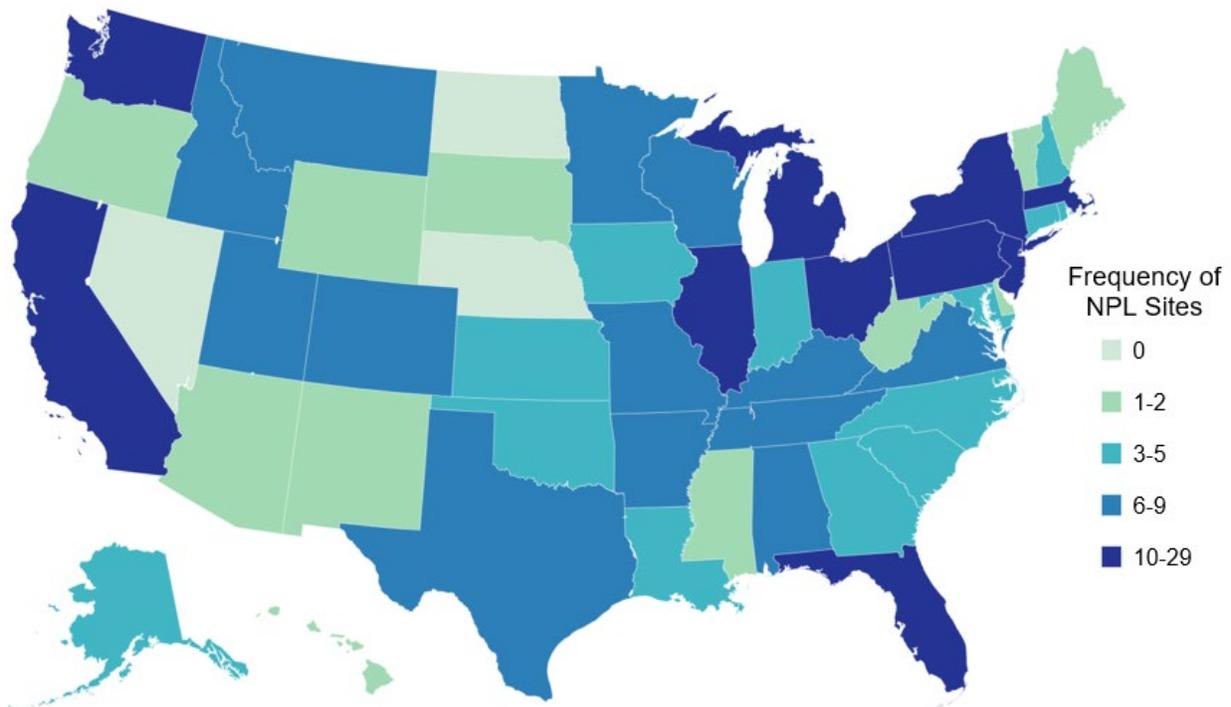


CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Thallium has been identified in at least 346 of the 1,868 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2022). However, the number of sites in which thallium has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, 343 are located within the United States and 3 are located in Puerto Rico (not shown).

Figure 5-1. Number of NPL Sites with Thallium Contamination



Source: ATSDR 2022

- Thallium is released into the environment from both natural and anthropogenic sources. Atmospheric emission and deposition are primarily from mineral smelters and coal-burning facilities.
- Thallium naturally occurs in the Earth's crust, with an estimated concentration of 0.7 ppm.
- Exposure to thallium occurs primarily via consumption of vegetables and fruit.

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- Thallium compounds are mobile in soil, tend to have high water solubility, and may bioaccumulate in living organisms.

Thallium is a trace metal that exists naturally in the environment mainly combined with other elements (primarily oxygen, sulfur, and the halogens) in inorganic compounds. Thallium is quite stable in the environment since it is neither transformed nor biodegraded.

Compounds of thallium are generally soluble in water and the element is found primarily as the monovalent ion (Tl^+). Thallium tends to be sorbed to soils and sediments (Frantz and Carlson 1987; Mathis and Kevern 1975; Wallwork-Barber et al. 1985) and to bioconcentrate in aquatic plants, invertebrates, and fish (Barrows et al. 1978; Lin et al. 2001; Zitko and Carson 1975). Terrestrial plants can also absorb thallium from soil (Ewers 1988; Sharma et al. 1986).

Major releases of thallium to the environment are from processes such as coal-burning and smelting and cement production, in which thallium is a trace contaminant of the raw materials, rather than from facilities producing or using thallium compounds (Karbowska 2016). Humans may be exposed to thallium by ingestion, inhalation, or dermal absorption (EPA 1980, 1988; Ewers 1988). However, the general population is exposed most frequently by ingestion of thallium-containing foods, especially fruits and green vegetables home-grown in thallium-contaminated soil. Inhalation of contaminated air near emission sources or in the workplace may also contribute to thallium exposure of some individuals.

5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.2.1 Production

The domestic production of thallium ceased in 1981 (USGS 2023). Prior to this, thallium had been recovered as a byproduct from the flue dust and residuals that resulted from the smelting of zinc, copper, and lead ores through treatment by electrolysis, precipitation, or reduction (Sax and Lewis 1987; U.S. Bureau of Mines 1983, 1988). Based upon the estimated thallium content of zinc ores, U.S. mine production of thallium was 0.45 metric tons in 1986 and 1987 and 14.06 metric tons in the rest of the world (U.S. Bureau of Mines 1983, 1988). No data were located regarding the production of thallium acetate, thallium nitrate, thallium chloride, thallium sulfate, or thallium oxide.

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Tables 5-1 and 5-2 summarize information on companies that reported the production, import, or use of thallium and thallium compounds, respectively, for the Toxics Release Inventory (TRI) in 2022 (TRI22 2024). TRI data should be used with caution since only certain types of industrial facilities are required to report. This is not an exhaustive list.

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

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
CA	1	1,000	9,999	12
ID	1	10,000	99,999	12
TX	1	1,000	9,999	1, 4

^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: TRI22 2024 (Data are from 2022)

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

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	0	99,999	1, 3, 4, 5, 12, 13, 14
AR	1	1,000	9,999	12
CO	1	10,000	99,999	1, 13
GA	1	1,000	9,999	1, 3, 4, 5, 13, 14
IN	4	1,000	99,999	1, 5, 8, 12, 14
KY	4	10,000	99,999	1, 5, 10, 12, 13
MT	1	10,000	99,999	1, 5, 12, 14
NV	4	1,000	999,999	1, 12, 13, 14
OH	1	100	999	12
PA	1	100	999	1, 5, 12
SC	2	10,000	999,999	1, 5, 12, 13, 14
TN	1	10,000	99,999	1, 5
TX	4	1,000	99,999	1, 2, 3, 4, 5, 9, 12, 13, 14

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

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
UT	3	1,000	99,999	1, 3, 5, 9, 12, 13

^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: TRI22 2024 (Data are from 2022)

Thallium is produced commercially in only a few nations as a byproduct recovered from flue dust in the roasting of copper, lead, and zinc ores. Since most producers withhold thallium production data, global production data are limited. In 2022, the U.S. Geological Survey (USGS) estimated that global production of thallium was approximately 10,000 kg (USGS 2023).

5.2.2 Import/Export

All thallium used in the United States is obtained from thallium reserves or is imported. In a USGS commodity summary from 2022, it was reported that since August of 2021, there were no imports of unwrought thallium metal and powder or thallium waste and scrap (USGS 2023). According to the same survey, no exports of thallium waste and scrap were reported through August 2021, but 359 kg were estimated for the year based on data from the prior year (USGS 2023).

5.2.3 Use

Thallium compounds have a variety of uses. The leading global uses for thallium are gamma radiation detection equipment, high-temperature superconductors, infrared optical materials, low-melting glasses, photoelectric cells, and radioisotopes (USGS 2024). Other thallium uses include as a catalyst in organic compound synthesis, in the manufacture of highly refractive glass, and as a component in high-density liquids for gravity separation of minerals (USGS 2023). Radioactive thallium²⁰¹ is used in the diagnosis of coronary artery disease (Strauss et al. 2008). Intravenously administered radioactive thallium is used to measure blood flow through the heart during exercise and at rest. Thallium and compounds were once

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used as a pesticide for control of rodents and insects, but the use of thallium as a pesticide was banned in 1972 (EPA 1985).

5.2.4 Disposal

Thallium is listed as a hazardous substance; therefore, disposal of waste thallium is controlled by a number of federal regulations, including land disposal restrictions (see Chapter 7). Land disposal restrictions were implemented by EPA in 1987. Prior to this time, disposal of pesticides had been to municipal and industrial landfills. Since thallium is relatively stable in the environment, it is possible that landfills, as well as other Superfund sites, contain thallium or thallium-containing products.

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 2022). 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's North American Industry Classification System (NAICS) codes is covered under EPCRA Section 313 or is a federal facility; and if their facility manufactures (defined to include importing) or processes any TRI chemical in excess of 25,000 pounds, or otherwise uses any TRI chemical in excess of 10,000 pounds, in a calendar year (EPA 2022).

Thallium is released to environmental media from natural and anthropogenic sources. Natural geologic emissions include thallium-bearing, near-surface metal ore deposits or shallow subsurface mineralized rock formations. Anthropogenic sources include atmospheric emissions, solid wastes, and wastewaters derived mostly from sulfide ore and coal mining and processing (sometimes classified as geoanthropogenic sources), metal sulfide ore smelting, industrial and domestic bituminous (hard) coal and lignite combustion, waste incineration, petroleum refining, and cement manufacturing (Migaszewski and Gałuszka 2021).

5.3.1 Air

Estimated releases of 3 pounds (~ 0.001 metric tons) of thallium to the atmosphere from three domestic manufacturing and processing facilities in 2022, accounted for about 0.01% of the estimated total

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environmental releases from facilities required to report to the TRI (TRI22 2024). These releases are summarized in Table 5-3.

Estimated releases of 3,226 pounds (~1.46 metric tons) of thallium compounds to the atmosphere from 29 domestic manufacturing and processing facilities in 2022, accounted for about 0.24% of the estimated total environmental releases from facilities required to report to the TRI (TRI22 2024). These releases are summarized in Table 5-4.

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

State ^c	RF ^d	Reported amounts released in pounds per year ^b							Total release	
		Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	On-site ^j	Off-site ^k	On- and off-site	
CA	1	1	0	0	27,221	0	27,222	0	27,222	
ID	1	1	0	0	11,661	0	11,662	0	11,662	
TX	1	2	1	0	0	0	3	0	3	
Total	3	3	1	0	38,883	0	38,887	0	38,887	

^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, wastewater 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: TRI22 2024 (Data are from 2022)

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

State ^c	RF ^d	Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Reported amounts released in pounds per year ^b		
							Total release		
							On-site ^j	Off-site ^k	On- and off-site
AL	2	57	0	0	46,600	2,300	31,657	17,300	48,957
AR	1	0	0	0	9,205	0	9,205	0	9,205
CO	1	6	0	0	975	0	980	0	980
GA	1	20	0	0	9,200	0	9,220	0	9,220
IN	4	1,175	15	0	85,703	285	86,894	285	87,179
KY	4	85	7	0	86,502	0	86,594	0	86,594
MT	1	911	0	0	14,800	0	15,711	0	15,711
NV	3	8	0	26	794,017	0	794,051	0	794,051
OH	1	0	0	19,132	38	0	19,132	38	19,170
PA	1	8	0	0	0	0	8	0	8
SC	2	283	0	0	1,600	0	1,884	0	1,884
TN	1	21	0	0	12,000	0	12,021	0	12,021
TX	4	621	1	0	147,650	0	148,270	2	148,272
UT	3	31	500	0	91,011	220	86,599	5,163	91,762
Total	29	3,226	523	19,158	1,299,301	2,805	1,302,225	22,789	1,325,014

^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, wastewater 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: TRI22 2024 (Data are from 2022)

Thallium is a highly volatile element at high temperatures and is released into the atmosphere in the form of fly ash, vapors, and liquids during cement manufacturing, metal sulfide ore smelting, or industrial and domestic coal combustion when facilities lack emission control devices (Migaszewski and Gałuszka 2021). Thallium emissions in the United States were estimated at 140 tons/year each from coal-burning power plants and from iron and steel production (Ewers 1988; Schoer 1984). The global annual release of

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thallium from different pollution sources into the environment is estimated as 2,000–5,000 metric tons (Migaszewski and Gałuszka 2021). Karbowska (2016) also reported annual anthropogenic releases of thallium as 5,000 metric tons.

5.3.2 Water

Estimated releases of 1 pound (~0.0005 metric tons) of thallium to surface water from three domestic manufacturing and processing facilities in 2022, accounted for about 0.003% of the estimated total environmental releases from facilities required to report to the TRI (TRI22 2024). This estimate includes releases to wastewater treatment and publicly owned treatment works (POTWs) (TRI22 2024). These releases are summarized in Table 5-3.

Estimated releases of 523 pounds (~0.24 metric tons) of thallium compounds to surface water from 29 domestic manufacturing and processing facilities in 2022, accounted for about 0.04% of the estimated total environmental releases from facilities required to report to the TRI (TRI22 2024). This estimate includes releases to wastewater treatment and publicly owned treatment works (POTWs) (TRI22 2024). These releases are summarized in Table 5-4.

The major sources of thallium release to water are from the industrial combustion of coal and the cement and mining industries. Past concentrations of thallium in waste waters from these industries contained up to 2,400 µg/L (WHO 1996). In 2014, concentrations of thallium above the recommended reference value were measured in some parts of the drinking water distribution system in Tuscany, Italy, with values as high as 79.5 µg/L. The source of the contamination was a spring adjacent to an abandoned mining site (Nuvolone et al. 2021).

5.3.3 Soil

Estimated releases of 38,883 pounds (~17.64 metric tons) of thallium to soil from three domestic manufacturing and processing facilities in 2022, accounted for about 99% of the estimated total environmental releases from facilities required to report to the TRI (TRI22 2024). No thallium was released via underground injection (TRI22 2024). These releases are summarized in Table 5-3.

Estimated releases of 1,299,301 pounds (~589.35 metric tons) of thallium compounds to soil from 29 domestic manufacturing and processing facilities in 2022, accounted for about 98% of the estimated

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total environmental releases from facilities required to report to the TRI (TRI22 2024). An additional 19,158 pounds (~8.69 metric tons), constituting about 1.4% of the total environmental emissions, were released via underground injection (TRI22 2024). These releases are summarized in Table 5-4.

Thallium releases to soil are mainly solid wastes from coal combustion and smelting operations (Ewers 1988). Although direct soil releases are likely to be small, since thallium-containing wastes are subject to EPA land disposal restrictions, atmospheric thallium pollution may contribute to soil contamination in the vicinity of thallium emission sources (Brockhaus et al. 1981). It should be noted that land disposal restrictions were implemented by EPA in 1987. Prior to this time, disposal of pesticides had been to municipal and industrial landfills. Since thallium is relatively stable in the environment, it is possible that landfills, as well other Superfund sites, contain thallium or thallium-containing products.

5.4 ENVIRONMENTAL FATE

5.4.1 Transport and Partitioning

Air. Thallium is a nonvolatile heavy metal, and if released to the atmosphere by anthropogenic sources, may exist as an oxide (thallium oxide), hydroxide (TlOH), sulfate (thallium sulfate), or as the sulfide Tl₂S (EPA 1988). These thallium compounds are not volatile (EPA 1983; Lide 2005). It has been speculated that thallium sulfate and TlOH will partition into water vapor (such as clouds and raindrops) because they are soluble in water; thus, precipitation may remove these forms of thallium from the atmosphere (EPA 1988). Thallium oxides are less soluble in water and may be subject to only atmospheric dispersion and gravitational settling; no corroborative information was located. The atmospheric half-life of suspended thallium particles is unknown.

Water. Thallium will predominantly exist in water as a monovalent ion (thallium⁺); thallium may be trivalent (Tl³⁺) in very oxidizing water (EPA 1979; Lin and Nriagu 1998). Tl⁺ forms complexes in solution with halogens, oxygen, and sulfur (Lin and Nriagu 1998). Thallium may precipitate from water as solid mineral phases. However, thallium chloride, sulfate, carbonate, bromide, and hydroxide are very soluble in water (Lin and Nriagu 1998). For example, the solubility of thallium sulfate at 20°C is 46 g/L (Lin and Nriagu 1998). In extremely reducing water, thallium may precipitate as a sulfide (Tl₂S), and in oxidizing water, Tl³⁺ may be removed from solution by the formation of Tl(OH)₃ (Lin and Nriagu 1998). Stephenson and Lester (1987a, 1987b) postulated that the partial removal of thallium from water was the result of precipitation of unknown solids during the treatment of sewage sludge.

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Sediment and Soil. Thallium may partition from water to soils and sediments. Mathis and Kevern (1975) presented indirect evidence that thallium was adsorbed by lake sediments. Furthermore, thallium may be adsorbed by micaceous clays in solution (Frantz and Carlson 1987). In a study that evaluated the adsorption of thallium for three soils, K_d values of 768.3, 809.4, and 760.3 were determined (Kim et al. 2016).

Other Media. Partition coefficients such as adsorption constants describe the tendency of a chemical to partition to solid phases from water. Adsorption constants for inorganic ions such as Tl^+ cannot be predicted *a priori* but must be measured for each adsorbent. Thallium adsorption data in Magorian et al. (1974) for a hectorite clay (a rare montmorillonite clay mineral) at pH 8.1 suggest that an adsorption constant for this specific system may be approximately 19 L/g. No other information on the adsorption of thallium by earth materials was located.

Thallium may be bioconcentrated by organisms from water. A bioconcentration factor (BCF) relates the concentration of a chemical in the tissues of aquatic animals or plants to the concentration of the chemical in the water in which they live. Experimentally measured BCF values have been reported: 18.2 for clams and 11.7 for mussels (Zitko and Carson 1975). More recent data from Lin et al. (2001) measured a BCF of 10,000 in lake trout in Lake Michigan, significantly higher than an experimentally determined BCF of 27–1,430 in juvenile Atlantic salmon (Lin et al. 2001; Zitko et al. 1975). The maximum BCF for bluegill sunfish was 34 in the study of Barrows et al. (1978). Thallium is absorbed by plants from soil and thereby enters the terrestrial food chain (Ewers 1988; Sharma et al. 1986). Cataldo and Wildung (1983) demonstrated that thallium could be absorbed by the roots of higher plants from the rhizosphere.

5.4.2 Transformation and Degradation

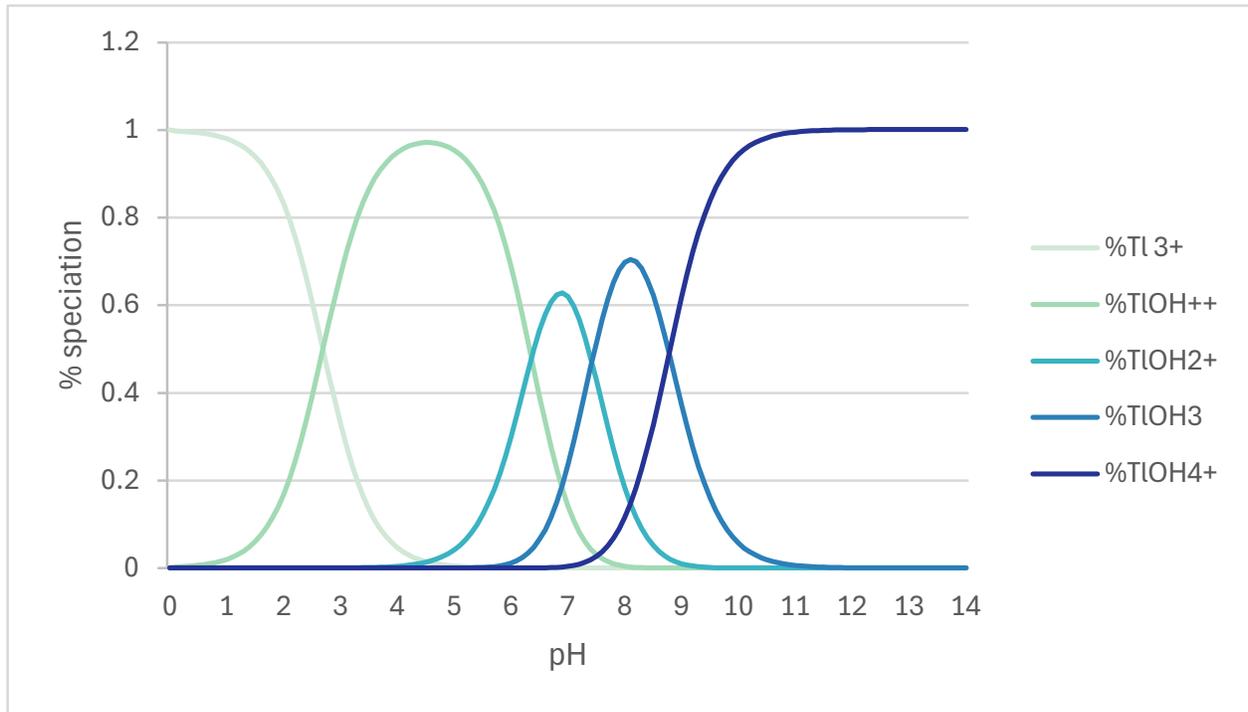
Air. Metallic thallium oxidizes slowly in air (O'Neil 2001), and thallos chloride is photosensitive (Cotton and Wilkinson 1980). However, there was no evidence that thallium is transformed significantly by photochemical reactions in the atmosphere (EPA 1979).

Water. The hydrolysis of thallium is an important acid-base reaction for the generation of hydroxy complexes in the aqueous environment. At pH <7, thallium III was converted to $Tl(OH)^{2+}$, to $Tl(OH)_3$ at pH 7.4–8.8, and $Tl(OH)_4^-$ at pH 8.8 (Lin and Nriagu 1998); see Figure 5-2. The oxidation state of thallium in water is dependent upon the redox potential. In strongly reducing conditions, it is typically in

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the monovalent form; however, it can transform to the trivalent form under oxidizing and alkaline conditions.

Figure 5-2. Thallium III Speciation Curve



Source: Created in Excel using data from Lin and Nriagu (1998).

In natural waters at pH 7, thallium (I) is the predominant species (Kaplan and Mattigod 1998). Speciation calculations for thallium (I) in natural waters are discussed in Kaplan and Mattigod (1998). In seawater, 52% of total thallium (I) would exist in free ionic form, 36% would be complexed with chloride, and 11% would be complexed with sulfate ligands. Under typical pH conditions found in groundwater, river water, and eutrophic lake water, free thallium (I) exists predominantly in free ionic form (90.4% in groundwater, 82.7% in river water, and 76.8% in eutrophic lake water). In highly acidic bog water, only 32.4% of thallium (I) exists in free ionic form, with the remaining 67.6% bound to organic species. Based on these data, bound thallium (I) will predominate in waters with low pH and high levels of dissolved inorganic/organic ligands.

Sediment and Soil. EPA (1979) concluded that there was no evidence that thallium is biotransformed in the environment. No other information was located.

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5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to thallium depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of thallium 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 thallium levels monitored or estimated in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable.

Table 5-5 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 5-6.

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

Media	Detection limit	Reference
Air (nmol/m ³)	0.04	Karbowska 2016
Drinking water (ppb)	0.014	EPA 1994
Surface water and groundwater (ppb)	0.014	EPA 1994
Soil (ppb)	0.014	EPA 1994
Sediment (ppb)	0.014	EPA 1994
Whole blood (ppb)	0.037	Karbowska 2016

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

Table 5-6. Summary of Environmental Levels of Thallium

Media	Low	High	For more information
Outdoor air (ppbv)	0.02	15.4	Section 5.5.1
Indoor air (ppbv)	0.02	22	Section 5.5.1
Surface water (ppb)	0.014	1,100	Section 5.5.2
Ground water (ppb)	0.014	3,810	Section 5.5.2
Drinking water (ppb)	0.014	79.5	Section 5.5.2
Ocean water (pg/L)	0.014	14	Section 5.5.2
Food (ppb)	2	338,000	Section 5.5.4
Soil		171,000	Section 5.5.2

Detections of thallium in air, water, and soil at NPL sites are summarized in Table 5-7.

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Table 5-7. Thallium 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)	11	12.5	10.2	118	70
Soil (ppb)	3,810	5,960	9.33	142	80
Air (ppbv)	0.0065	0.0082	8.95	5	4

^aConcentrations found in ATSDR site documents from 1981 to 2022 for 1,868 NPL sites (ATSDR 2022). 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

There are limited U.S. air monitoring data for thallium. The following data are 30-40 years old and may not be representative of current thallium levels. In six U.S. cities, the thallium concentrations ranged from 0.02 to 0.1 ng/m³, with a typical concentration of 0.04 ng/m³ (EPA 1980, 1988). Concentrations of thallium in Chadron, Nebraska reportedly ranged from 0.04 to 0.48 ng/m³ (EPA 1980, 1988), and geometric mean concentrations measured during 1985–1986 in Genoa, Italy were about 0.015 µg/m³ (Valerio et al. 1988). The estimated thallium concentration near a coal-burning power plant was 0.7 µg/m³ (EPA 1988).

Some more recent monitoring data are available from China. Air particulate thallium was measured in three large cities and four remote locations with values of 2.52–15.4 ppbv (PM_{2.5}), 1.82–14.4 ppbv (PM₁₀) in cities and 1.52–2.12 ppb (PM_{2.5}) and 1.37–2.10 ppbv (PM₁₀) in remote locations (Belzile and Chen 2017).

Thallium levels were measured in workplace air in the past. Marcus (1985) reported maximum thallium levels in workplace air at 0.014 and 0.022 mg/m³ during machining and alloying operations, respectively, of a magnesium alloy used in batteries at a plant in England. Air samples in two cement plants and two foundries in Italy had thallium concentrations of <1 µg/m³ (Apostoli et al. 1988).

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5.5.2 Water

The Water Quality Portal (WQP) is a source of discrete water-quality data in the United States and beyond. This cooperative service integrates publicly available water-quality data from the USGS, EPA, and over 400 state, federal, tribal, and local agencies. Analysis of compiled data from the WQP that spans 4 decades (1981–2023) indicates that thallium is a common surface water pollutant. Of 446,053 samples analyzed, thallium was detected in 115,741 (25.9% of samples). Of those 115,741 samples, only 2312 had values >10 µg/L. The highest value for sediment was 171,000 ppb, the highest value for groundwater was 3810 ppb, and the highest value for surface water was 1,100 ppb (WQP 2024).

Since thallium is a naturally occurring element, it may be present in ambient waters in trace amounts. However, monitoring data indicate elevated thallium concentrations near industrial and commercial sources and hazardous waste sites. The USGS conducted groundwater monitoring studies for radon and trace minerals from 1992 to 2003 on 51 of the nation's river basins and aquifers (USGS 2011). For 867 samples tested, thallium levels were all <1 ppb. Thallium and arsenic levels were monitored in groundwater wells from 1994 to 1999 at the Charleston Naval Complex located in North Charleston, South Carolina (USGS 2002). Mean thallium concentrations in water from all wells were <1.6–32.6 ppb in water samples from the upper surficial aquifer and <1.6–67.7 ppb in water samples from the lower surficial aquifer. Mean thallium concentrations ≥10 ppb were present in water samples from 21 of 604 wells.

The National tap water database indicates that thallium has been detected in tap water in >30 states (EWG 2019). Drinking water concentrations have been reported as high as 7.2 ng/mL (Harrington et al. 2022). Thallium was detected in 10% of urban stormwater runoff samples at concentrations of 1–14 µg/L (Cole et al. 1984). Thallium has been measured in seawater at 10–20 ng/L (Migaszewski and Gałuszka 2021; Sharma et al. 1986). Contaminated waters in Michigan contained 21 and 2,621 ng/L thallium. Levels of dissolved thallium in the Great Lakes ranged from 1.2 to 14.2 ng/L, with the lowest levels detected in Lake Superior and the highest levels detected in Lake Michigan (Cheam 2001).

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5.5.3 Sediment and Soil

Thallium naturally occurs in the Earth's crust and is likely to be present in soils and sediments. The USGS reported thallium levels in U.S. soils (upper 5 cm) ranging of ~0.05–5 ppm, with a median value of about 0.5 ppm (USGS 2024); however, it exists mostly in association with potassium minerals in clays, granites, and soils. Thallium levels in U.S. soils tend to be lowest in the southeast (North Carolina, South Carolina, Georgia, Florida, and Alabama), while the highest levels tend to occur in western Pennsylvania, Ohio, and various locations in the western United States (USGS 2014). The limited data available indicate that soil thallium levels may be increased near thallium-emitting industrial sources and at hazardous waste sites. In the 1980s, measured thallium concentrations in lake sediments ranged from 0.13–0.27 µg/g in four remote Rocky Mountain lakes (Heit et al. 1984) to 2.1–23.1 mg/kg (mean value 13.1 mg/kg) in a Michigan lake reportedly polluted by airborne particulate matter (EPA 1988). Up to 5 mg/kg thallium was reported in stream sediments near metal industry runoff areas (Wallwork-Barber et al. 1985). Thallium concentrations in marine sediments were measured at approximately 0.08–5 mg/kg (Migaszewski and Gałuszka 2021).

5.5.4 Other Media

In the latest U.S. Food and Drug Administration (FDA) Total Diet Study (TDS) (fiscal years 2018–2020), thallium was only tested for in bottled water/spring water and it was not detected in any of the 27 samples tested (FDA 2022). The TDS monitors levels of chemicals such as pesticides, contaminants, and nutrients in foods consumed by the U.S. general population. The TDS collects commercially available regional foods in each of six U.S. regions (West, North Central, Northeast, Mid-Atlantic, Southeast, and Southwest).

Thallium has been found to accumulate by food crops, including green cabbage, rapeseed, and brassicaceous plants. In an experiment in which 12 commonly grown food crops were grown in soil containing 0.7 mg thallium/kg, the following thallium levels were detected: beetroot 8.75 mg/kg; green cabbage 7.85 mg/kg; *Iberis intermedia* 60.9 mg/kg; lettuce 3.1 mg/kg; onion 1.42 mg/kg; pea 1.82 mg/kg; radish 10.4 mg/kg; spinach 15.9 mg/kg; tomato 0.53 mg/kg; turnip 7.8 mg/kg; and watercress 84.4 mg/kg (LaCoste et al. 2001).

A study of lake trout from Lake Michigan reported thallium levels ranging from 9.8 to 496.9 ng/g, with an average concentration of 140.8 ng/g (Lin et al. 2001).

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In a survey of Italian populations, thallium levels were measured in different foods with values as follows: cereals and cereal products, 0.055 mg/kg; legumes, 0.256 mg/kg; potatoes 0.002 mg/kg; fresh fruits; 0.046 mg/kg; and dry fruits, nuts, and seeds, 0.648 mg/kg (Doulgeridou et al. 2020). In a thallium-rich sulfide mineralization area in China, the following levels were found: green cabbage, 338 mg/kg; carrot, 22.1 mg/kg; and shelled rice, 2.4 mg/kg (Doulgeridou et al. 2020).

Data on thallium content of specific foods grown and consumed in the United States were not located. A 1980s study of the thallium content of food in the United Kingdom reported levels of thallium in meat, fish, fats, and green vegetables (Sherlock and Smart 1986).

5.6 GENERAL POPULATION EXPOSURE

Human exposure to thallium may occur by inhalation, ingestion, or dermal absorption. Recent data on the potential for general population exposure to thallium are limited. In the 1980s, the frequent source of exposure for the general population was ingestion of thallium-containing foods (EPA 1980, 1988; Ewers 1988). From the very limited data available, EPA estimated daily intakes for the general adult population from drinking water, air, and food of ≤ 6 $\mu\text{g}/\text{day}$ (EPA 1980). A study from the United Kingdom also suggested that dietary intake from foods, particularly green vegetables, is the primary route of human exposure (Sherlock and Smart 1986). The same study from 1986 estimated 2 μg intake from water, 3.4 ng intake from air, and 5 μg intake from food. A more recent study estimated a daily intake in Northern Italy of 0.53 μg thallium/day, mostly derived from vegetables (mainly cabbage and root vegetables), meat, cereals, and fruit (particularly citrus fruits) (Filippini et al. 2020).

Urinary thallium levels are considered the most reliable indicator of thallium exposure. The geometric mean and selected percentiles of urinary levels of thallium for the general U.S. general population for select age and demographic groups from the NHANES are presented in Tables 5-8 and 5-9 (CDC 2023). The urinary thallium geometric mean levels for the most recent survey year (2017–2018) ranged from 0.154 to 0.180 $\mu\text{g}/\text{L}$ for the different sex, age, and ethnicity groups and the 95th percentile levels rarely exceeded 0.5 $\mu\text{g}/\text{L}$ (CDC 2023). The urinary thallium levels have remained fairly stable over time (1999–2000 to 2017–2018).

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Table 5-8. Urinary Thallium Concentrations (in µg/L) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval) ^a	Percentiles (95% confidence interval) ^a				Sample size
		50th	75th	90th	95th	
Total						
1999–2000	0.176 (0.162–0.192)	0.200 (0.180–0.220)	0.290 (0.270–0.330)	0.400 (0.370–0.420)	0.450 (0.430–0.480)	2,413
2001–2002	0.165 (0.154–0.177)	0.190 (0.180–0.200)	0.280 (0.260–0.290)	0.370 (0.350–0.390)	0.440 (0.410–0.470)	2,653
2003–2004	0.155 (0.145–0.165)	0.170 (0.160–0.180)	0.270 (0.250–0.290)	0.370 (0.340–0.400)	0.440 (0.410–0.490)	2,558
2005–2006	0.158 (0.151–0.165)	0.180 (0.170–0.190)	0.270 (0.260–0.280)	0.360 (0.350–0.390)	0.430 (0.410–0.460)	2,576
2007–2008	0.146 (0.139–0.153)	0.160 (0.150–0.170)	0.250 (0.230–0.260)	0.330 (0.320–0.360)	0.400 (0.390–0.420)	2,627
2009–2010	0.144 (0.137–0.152)	0.160 (0.150–0.170)	0.240 (0.230–0.250)	0.340 (0.310–0.360)	0.410 (0.380–0.440)	2,848
2011–2012	0.149 (0.138–0.160)	0.157 (0.144–0.169)	0.255 (0.232–0.278)	0.361 (0.334–0.377)	0.434 (0.379–0.521)	2,504
2013–2014	0.141 (0.132–0.150)	0.154 (0.139–0.163)	0.248 (0.228–0.266)	0.349 (0.338–0.370)	0.421 (0.414–0.438)	2,664
2015–2016	0.153 (0.143–0.163)	0.161 (0.149–0.177)	0.255 (0.234–0.275)	0.362 (0.330–0.385)	0.435 (0.403–0.466)	3,061
2017–2018	0.164 (0.155–0.174)	0.177 (0.165–0.187)	0.271 (0.254–0.287)	0.393 (0.366–0.421)	0.473 (0.436–0.509)	2,808
Age group^b						
3–5 years						
2015–2016	0.150 (0.137–0.163)	0.159 (0.142–0.178)	0.251 (0.218–0.275)	0.347 (0.315–0.388)	0.432 (0.353–0.500)	486
2017–2018	0.174 (0.154–0.198)	0.183 (0.153–0.220)	0.289 (0.251–0.324)	0.389 (0.353–0.430)	0.463 (0.398–0.483)	403
6–11 years						
1999–2000	0.201 (0.167–0.243)	0.210 (0.150–0.280)	0.310 (0.250–0.350)	0.410 (0.330–0.450)	0.450 (0.350–0.590)	336
2001–2002	0.172 (0.147–0.202)	0.200 (0.160–0.220)	0.290 (0.230–0.330)	0.350 (0.340–0.370)	0.390 (0.360–0.430)	362
2003–2004	0.191 (0.170–0.215)	0.190 (0.170–0.230)	0.300 (0.250–0.370)	0.430 (0.360–0.500)	0.510 (0.430–0.690)	290
2005–2006	0.174 (0.158–0.192)	0.190 (0.170–0.210)	0.280 (0.250–0.300)	0.380 (0.320–0.430)	0.430 (0.400–0.480)	355
2007–2008	0.166 (0.150–0.185)	0.170 (0.150–0.200)	0.250 (0.230–0.270)	0.350 (0.310–0.410)	0.420 (0.360–0.470)	394
2009–2010	0.161 (0.147–0.176)	0.170 (0.150–0.200)	0.280 (0.230–0.310)	0.360 (0.330–0.410)	0.440 (0.400–0.460)	378
2011–2012	0.157 (0.143–0.172)	0.157 (0.136–0.195)	0.272 (0.232–0.308)	0.365 (0.330–0.474)	0.509 (0.372–0.629)	399
2013–2014	0.149 (0.131–0.170)	0.163 (0.146–0.173)	0.259 (0.221–0.282)	0.364 (0.331–0.400)	0.438 (0.367–0.577)	402
2015–2016	0.168 (0.151–0.186)	0.172 (0.150–0.209)	0.276 (0.234–0.306)	0.363 (0.314–0.420)	0.452 (0.369–0.574)	379
2017–2018	0.172 (0.154–0.193)	0.178 (0.158–0.202)	0.299 (0.256–0.322)	0.394 (0.361–0.493)	0.497 (0.405–0.522)	333

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Table 5-8. Urinary Thallium Concentrations (in µg/L) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval) ^a	Percentiles (95% confidence interval) ^a				Sample size
		50th	75th	90th	95th	
12–19 years						
1999–2000	0.202 (0.181–0.225)	0.220 (0.200–0.240)	0.300 (0.270–0.340)	0.410 (0.390–0.430)	0.470 (0.430–0.510)	697
2001–2002	0.200 (0.182–0.220)	0.220 (0.190–0.250)	0.310 (0.290–0.320)	0.370 (0.350–0.420)	0.470 (0.400–0.500)	746
2003–2004	0.201 (0.185–0.218)	0.220 (0.210–0.240)	0.310 (0.290–0.320)	0.410 (0.360–0.470)	0.500 (0.420–0.560)	725
2005–2006	0.182 (0.165–0.200)	0.210 (0.190–0.230)	0.290 (0.270–0.310)	0.370 (0.350–0.400)	0.430 (0.390–0.480)	701
2007–2008	0.172 (0.155–0.190)	0.180 (0.160–0.210)	0.270 (0.230–0.300)	0.330 (0.310–0.350)	0.390 (0.340–0.420)	376
2009–2010	0.150 (0.137–0.163)	0.160 (0.150–0.180)	0.250 (0.240–0.270)	0.340 (0.290–0.380)	0.400 (0.350–0.430)	451
2011–2012	0.155 (0.131–0.184)	0.169 (0.141–0.196)	0.288 (0.240–0.301)	0.376 (0.320–0.403)	0.447 (0.387–0.545)	390
2013–2014	0.160 (0.136–0.188)	0.170 (0.154–0.191)	0.274 (0.224–0.334)	0.400 (0.324–0.507)	0.495 (0.384–0.562)	451
2015–2016	0.168 (0.150–0.187)	0.186 (0.163–0.203)	0.248 (0.221–0.300)	0.368 (0.295–0.428)	0.437 (0.368–0.515)	402
2017–2018	0.176 (0.160–0.194)	0.192 (0.169–0.221)	0.289 (0.253–0.315)	0.388 (0.332–0.428)	0.442 (0.383–0.551)	364
≥20 years						
1999–2000	0.170 (0.157–0.183)	0.190 (0.180–0.210)	0.290 (0.260–0.320)	0.400 (0.370–0.420)	0.450 (0.420–0.480)	1,380
2001–2002	0.159 (0.147–0.173)	0.190 (0.170–0.200)	0.270 (0.250–0.290)	0.380 (0.350–0.400)	0.440 (0.410–0.490)	1,545
2003–2004	0.145 (0.134–0.156)	0.160 (0.150–0.170)	0.250 (0.240–0.270)	0.360 (0.330–0.390)	0.420 (0.390–0.460)	1,543
2005–2006	0.152 (0.144–0.161)	0.170 (0.160–0.180)	0.260 (0.240–0.270)	0.360 (0.340–0.390)	0.440 (0.400–0.470)	1,520
2007–2008	0.140 (0.133–0.148)	0.150 (0.140–0.160)	0.240 (0.230–0.250)	0.330 (0.310–0.360)	0.400 (0.380–0.440)	1,857
2009–2010	0.142 (0.133–0.150)	0.160 (0.150–0.170)	0.240 (0.220–0.250)	0.330 (0.310–0.360)	0.410 (0.370–0.440)	2,019
2011–2012	0.147 (0.136–0.159)	0.155 (0.142–0.167)	0.247 (0.223–0.274)	0.356 (0.324–0.377)	0.431 (0.375–0.520)	1,715
2013–2014	0.137 (0.129–0.146)	0.150 (0.136–0.161)	0.241 (0.222–0.262)	0.340 (0.326–0.364)	0.417 (0.398–0.426)	1,811
2015–2016	0.149 (0.140–0.160)	0.157 (0.144–0.173)	0.255 (0.234–0.268)	0.358 (0.328–0.379)	0.433 (0.395–0.464)	1,794
2017–2018	0.161 (0.151–0.172)	0.174 (0.162–0.185)	0.263 (0.247–0.280)	0.395 (0.364–0.421)	0.473 (0.434–0.510)	1,708
Gender						
Males						
1999–2000	0.197 (0.179–0.217)	0.220 (0.200–0.240)	0.320 (0.280–0.350)	0.400 (0.370–0.440)	0.450 (0.420–0.520)	1,200
2001–2002	0.184 (0.173–0.196)	0.210 (0.200–0.230)	0.290 (0.280–0.300)	0.380 (0.360–0.400)	0.430 (0.400–0.470)	1,313
2003–2004	0.167 (0.156–0.178)	0.190 (0.180–0.200)	0.280 (0.260–0.300)	0.370 (0.340–0.400)	0.430 (0.400–0.480)	1,281
2005–2006	0.171 (0.163–0.179)	0.190 (0.180–0.200)	0.270 (0.260–0.280)	0.370 (0.360–0.390)	0.430 (0.410–0.470)	1,271

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Table 5-8. Urinary Thallium Concentrations (in µg/L) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval) ^a	Percentiles (95% confidence interval) ^a				Sample size
		50th	75th	90th	95th	
2007–2008	0.154 (0.148–0.161)	0.170 (0.160–0.180)	0.250 (0.240–0.270)	0.340 (0.320–0.360)	0.390 (0.380–0.440)	1,327
2009–2010	0.152 (0.140–0.164)	0.170 (0.150–0.180)	0.250 (0.240–0.270)	0.330 (0.310–0.360)	0.410 (0.360–0.440)	1,398
2011–2012	0.165 (0.150–0.181)	0.173 (0.151–0.195)	0.272 (0.239–0.301)	0.369 (0.343–0.387)	0.431 (0.381–0.524)	1,262
2013–2014	0.147 (0.136–0.159)	0.161 (0.151–0.171)	0.258 (0.231–0.274)	0.356 (0.325–0.381)	0.422 (0.400–0.455)	1,318
2015–2016	0.163 (0.155–0.172)	0.181 (0.168–0.195)	0.267 (0.248–0.288)	0.366 (0.334–0.394)	0.440 (0.394–0.477)	1,524
2017–2018	0.175 (0.164–0.187)	0.185 (0.172–0.198)	0.271 (0.253–0.283)	0.387 (0.328–0.427)	0.465 (0.406–0.545)	1,381
Females						
1999–2000	0.159 (0.145–0.175)	0.180 (0.150–0.200)	0.270 (0.250–0.300)	0.390 (0.350–0.420)	0.460 (0.410–0.490)	1,213
2001–2002	0.149 (0.137–0.163)	0.160 (0.150–0.180)	0.260 (0.230–0.290)	0.370 (0.330–0.400)	0.440 (0.400–0.500)	1,340
2003–2004	0.144 (0.133–0.156)	0.160 (0.140–0.170)	0.250 (0.230–0.280)	0.370 (0.330–0.410)	0.450 (0.410–0.510)	1,277
2005–2006	0.146 (0.138–0.155)	0.160 (0.150–0.180)	0.260 (0.240–0.270)	0.360 (0.350–0.380)	0.440 (0.400–0.460)	1,305
2007–2008	0.139 (0.129–0.148)	0.150 (0.130–0.160)	0.240 (0.220–0.260)	0.330 (0.300–0.390)	0.410 (0.380–0.430)	1,300
2009–2010	0.137 (0.129–0.146)	0.150 (0.140–0.160)	0.230 (0.210–0.250)	0.340 (0.310–0.360)	0.410 (0.380–0.450)	1,450
2011–2012	0.135 (0.122–0.148)	0.141 (0.131–0.155)	0.237 (0.208–0.260)	0.348 (0.304–0.376)	0.434 (0.367–0.522)	1,242
2013–2014	0.135 (0.125–0.145)	0.143 (0.127–0.160)	0.241 (0.214–0.262)	0.348 (0.328–0.373)	0.421 (0.398–0.443)	1,346
2015–2016	0.143 (0.131–0.156)	0.146 (0.132–0.163)	0.236 (0.208–0.262)	0.352 (0.311–0.385)	0.432 (0.388–0.470)	1,537
2017–2018	0.154 (0.139–0.170)	0.165 (0.148–0.184)	0.272 (0.245–0.302)	0.398 (0.364–0.447)	0.486 (0.428–0.521)	1,427
Race						
Mexican American						
1999–2000	0.172 (0.150–0.196)	0.200 (0.160–0.230)	0.270 (0.250–0.300)	0.370 (0.320–0.420)	0.450 (0.370–0.520)	861
2001–2002	0.160 (0.148–0.173)	0.180 (0.160–0.200)	0.260 (0.240–0.270)	0.340 (0.310–0.360)	0.400 (0.350–0.440)	675
2003–2004	0.171 (0.160–0.183)	0.200 (0.170–0.220)	0.280 (0.260–0.310)	0.360 (0.340–0.420)	0.450 (0.390–0.480)	618
2005–2006	0.158 (0.149–0.167)	0.180 (0.170–0.190)	0.250 (0.240–0.270)	0.330 (0.300–0.360)	0.400 (0.360–0.440)	652
2007–2008	0.151 (0.140–0.164)	0.170 (0.150–0.180)	0.250 (0.220–0.270)	0.330 (0.310–0.360)	0.380 (0.350–0.390)	515
2009–2010	0.147 (0.139–0.155)	0.160 (0.150–0.180)	0.240 (0.210–0.260)	0.310 (0.290–0.320)	0.390 (0.320–0.430)	613
2011–2012	0.142 (0.135–0.150)	0.162 (0.143–0.174)	0.231 (0.210–0.248)	0.298 (0.268–0.321)	0.344 (0.306–0.381)	317
2013–2014	0.139 (0.127–0.154)	0.157 (0.137–0.175)	0.247 (0.206–0.274)	0.324 (0.285–0.387)	0.414 (0.324–0.511)	453
2015–2016	0.162 (0.145–0.181)	0.180 (0.150–0.210)	0.270 (0.247–0.288)	0.349 (0.309–0.406)	0.419 (0.349–0.492)	585

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Table 5-8. Urinary Thallium Concentrations (in µg/L) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval) ^a	Percentiles (95% confidence interval) ^a				Sample size
		50th	75th	90th	95th	
2017–2018	0.165 (0.157–0.173)	0.178 (0.170–0.193)	0.261 (0.246–0.276)	0.374 (0.345–0.398)	0.466 (0.391–0.521)	435
Non-Hispanic Black						
1999–2000	0.217 (0.197–0.239)	0.230 (0.220–0.260)	0.350 (0.300–0.390)	0.450 (0.400–0.520)	0.550 (0.460–0.630)	561
2001–2002	0.202 (0.187–0.218)	0.220 (0.200–0.230)	0.300 (0.270–0.340)	0.410 (0.380–0.440)	0.520 (0.440–0.590)	657
2003–2004	0.185 (0.167–0.206)	0.190 (0.170–0.220)	0.290 (0.250–0.330)	0.410 (0.330–0.490)	0.490 (0.410–0.640)	723
2005–2006	0.188 (0.169–0.210)	0.210 (0.180–0.230)	0.300 (0.270–0.320)	0.390 (0.360–0.440)	0.500 (0.430–0.530)	692
2007–2008	0.171 (0.160–0.182)	0.180 (0.170–0.190)	0.270 (0.250–0.290)	0.350 (0.330–0.390)	0.430 (0.390–0.460)	589
2009–2010	0.162 (0.148–0.177)	0.180 (0.160–0.200)	0.270 (0.250–0.280)	0.350 (0.330–0.400)	0.450 (0.390–0.510)	544
2011–2012	0.176 (0.150–0.206)	0.184 (0.158–0.214)	0.294 (0.244–0.364)	0.431 (0.370–0.503)	0.524 (0.429–0.657)	669
2013–2014	0.172 (0.156–0.189)	0.190 (0.170–0.213)	0.271 (0.241–0.301)	0.356 (0.325–0.380)	0.415 (0.375–0.433)	581
2015–2016	0.170 (0.156–0.186)	0.183 (0.171–0.197)	0.279 (0.260–0.296)	0.364 (0.338–0.393)	0.443 (0.414–0.494)	671
2017–2018	0.179 (0.169–0.191)	0.201 (0.178–0.213)	0.280 (0.259–0.297)	0.378 (0.338–0.399)	0.438 (0.406–0.501)	639
Non-Hispanic White						
1999–2000	0.170 (0.153–0.188)	0.200 (0.170–0.220)	0.290 (0.260–0.330)	0.400 (0.360–0.420)	0.450 (0.420–0.480)	801
2001–2002	0.159 (0.147–0.172)	0.180 (0.170–0.200)	0.270 (0.250–0.290)	0.360 (0.330–0.390)	0.430 (0.390–0.460)	1,114
2003–2004	0.146 (0.135–0.158)	0.160 (0.150–0.170)	0.260 (0.240–0.280)	0.360 (0.330–0.380)	0.410 (0.380–0.460)	1,074
2005–2006	0.150 (0.140–0.160)	0.170 (0.160–0.180)	0.260 (0.240–0.270)	0.350 (0.320–0.380)	0.420 (0.390–0.450)	1,041
2007–2008	0.138 (0.130–0.147)	0.150 (0.130–0.160)	0.240 (0.220–0.260)	0.320 (0.300–0.360)	0.390 (0.350–0.440)	1,095
2009–2010	0.139 (0.130–0.149)	0.150 (0.140–0.170)	0.240 (0.210–0.250)	0.330 (0.300–0.360)	0.400 (0.360–0.430)	1,225
2011–2012	0.143 (0.133–0.155)	0.149 (0.135–0.166)	0.245 (0.218–0.277)	0.353 (0.322–0.372)	0.412 (0.367–0.522)	820
2013–2014	0.132 (0.120–0.145)	0.139 (0.121–0.161)	0.235 (0.203–0.265)	0.340 (0.318–0.370)	0.419 (0.392–0.440)	985
2015–2016	0.143 (0.132–0.155)	0.151 (0.139–0.166)	0.236 (0.209–0.259)	0.336 (0.298–0.379)	0.414 (0.369–0.459)	924
2017–2018	0.160 (0.146–0.175)	0.172 (0.159–0.186)	0.270 (0.238–0.295)	0.398 (0.338–0.456)	0.484 (0.412–0.551)	918

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Table 5-8. Urinary Thallium Concentrations (in µg/L) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval) ^a	Percentiles (95% confidence interval) ^a				Sample size
		50th	75th	90th	95th	
All Hispanic						
2011–2012	0.145 (0.134–0.157)	0.158 (0.148–0.169)	0.237 (0.219–0.257)	0.305 (0.289–0.340)	0.381 (0.326–0.438)	573
2013–2014	0.144 (0.130–0.160)	0.160 (0.138–0.178)	0.251 (0.220–0.272)	0.340 (0.291–0.382)	0.417 (0.365–0.473)	701
2015–2016	0.159 (0.148–0.170)	0.174 (0.157–0.197)	0.263 (0.248–0.280)	0.351 (0.319–0.394)	0.419 (0.388–0.466)	982
2017–2018	0.169 (0.161–0.178)	0.181 (0.171–0.194)	0.264 (0.252–0.282)	0.393 (0.372–0.441)	0.469 (0.436–0.556)	676
Non-Hispanic Asian						
2011–2012	0.177 (0.160–0.197)	0.183 (0.163–0.214)	0.292 (0.255–0.319)	0.417 (0.372–0.489)	0.541 (0.431–0.664)	353
2013–2014	0.154 (0.140–0.169)	0.159 (0.134–0.184)	0.268 (0.239–0.310)	0.414 (0.368–0.438)	0.502 (0.421–0.662)	292
2015–2016	0.190 (0.175–0.206)	0.213 (0.189–0.241)	0.348 (0.306–0.371)	0.483 (0.413–0.543)	0.551 (0.514–0.595)	332
2017–2018	0.180 (0.166–0.196)	0.198 (0.178–0.207)	0.299 (0.260–0.323)	0.438 (0.379–0.467)	0.511 (0.460–0.583)	365

^aLimits of detection in µg/L (survey years) were: 0.020 (1999–2000), 0.020 (2001–2002), 0.020 (2003–2004), 0.015 (2005–2006), 0.015 (2007–2008), 0.015 (2009–2010), 0.020 (2011–2012), 0.018 (2013–2014), 0.018 (2015–2016), and 0.018 (2017–2018).

^bParticipants were ≥6 years old in survey years through 2014; beginning with survey years 2015–2016, participants included those ≥3 years old.

Source: CDC 2023

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Table 5-9. Creatinine-Corrected Urinary Thallium Concentrations (in $\mu\text{g/g}$ of Creatinine) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval)	Percentiles (95% confidence interval)				Sample size
		50th	75th	90th	95th	
Total						
1999–2000	0.166 (0.159–0.173)	0.168 (0.162–0.176)	0.224 (0.217–0.233)	0.297 (0.273–0.319)	0.366 (0.338–0.387)	2,413
2001–2002	0.156 (0.151–0.162)	0.156 (0.148–0.164)	0.215 (0.208–0.222)	0.287 (0.278–0.300)	0.349 (0.337–0.365)	2,652
2003–2004	0.154 (0.149–0.158)	0.153 (0.146–0.160)	0.214 (0.203–0.222)	0.286 (0.274–0.304)	0.350 (0.328–0.369)	2,558
2005–2006	0.155 (0.149–0.162)	0.150 (0.140–0.160)	0.210 (0.200–0.220)	0.300 (0.290–0.320)	0.370 (0.350–0.390)	2,576
2007–2008	0.152 (0.147–0.158)	0.150 (0.140–0.160)	0.210 (0.200–0.220)	0.290 (0.280–0.310)	0.370 (0.350–0.380)	2,627
2009–2010	0.153 (0.145–0.162)	0.150 (0.140–0.160)	0.220 (0.200–0.230)	0.300 (0.280–0.320)	0.370 (0.350–0.400)	2,848
2011–2012	0.168 (0.157–0.180)	0.167 (0.156–0.178)	0.235 (0.216–0.253)	0.337 (0.310–0.365)	0.425 (0.369–0.497)	2,502
2013–2014	0.162 (0.155–0.171)	0.161 (0.151–0.169)	0.236 (0.228–0.245)	0.338 (0.321–0.351)	0.429 (0.405–0.444)	2,663
2015–2016	0.171 (0.163–0.181)	0.169 (0.158–0.180)	0.243 (0.226–0.270)	0.348 (0.321–0.384)	0.432 (0.402–0.471)	3,058
2017–2018	0.179 (0.170–0.189)	0.174 (0.167–0.183)	0.251 (0.238–0.266)	0.380 (0.339–0.407)	0.472 (0.445–0.521)	2,806
Age group^a						
3–5 years						
2015–2016	0.344 (0.330–0.358)	0.342 (0.328–0.358)	0.474 (0.436–0.507)	0.643 (0.587–0.717)	0.850 (0.682–0.972)	485
2017–2018	0.360 (0.333–0.389)	0.368 (0.335–0.397)	0.500 (0.465–0.559)	0.660 (0.564–0.777)	0.793 (0.687–0.914)	403
6–11 years						
1999–2000	0.221 (0.197–0.248)	0.222 (0.196–0.236)	0.297 (0.229–0.356)	0.375 (0.318–0.469)	0.424 (0.356–0.600)	336
2001–2002	0.211 (0.198–0.226)	0.207 (0.198–0.221)	0.286 (0.260–0.321)	0.370 (0.333–0.402)	0.412 (0.389–0.456)	362
2003–2004	0.223 (0.208–0.238)	0.216 (0.198–0.229)	0.306 (0.280–0.346)	0.412 (0.346–0.458)	0.458 (0.400–0.532)	290
2005–2006	0.215 (0.200–0.231)	0.210 (0.190–0.250)	0.310 (0.270–0.320)	0.360 (0.320–0.410)	0.430 (0.360–0.510)	355
2007–2008	0.217 (0.201–0.234)	0.220 (0.210–0.240)	0.310 (0.270–0.340)	0.410 (0.370–0.440)	0.470 (0.410–0.540)	394
2009–2010	0.219 (0.199–0.241)	0.220 (0.200–0.260)	0.300 (0.280–0.340)	0.400 (0.350–0.440)	0.500 (0.390–0.600)	378
2011–2012	0.223 (0.209–0.238)	0.216 (0.200–0.241)	0.301 (0.275–0.336)	0.395 (0.371–0.440)	0.486 (0.422–0.568)	398
2013–2014	0.222 (0.199–0.249)	0.227 (0.215–0.255)	0.318 (0.279–0.360)	0.429 (0.386–0.458)	0.502 (0.457–0.537)	402
2015–2016	0.238 (0.223–0.253)	0.232 (0.216–0.257)	0.335 (0.312–0.359)	0.450 (0.418–0.496)	0.524 (0.485–0.593)	379
2017–2018	0.240 (0.223–0.259)	0.243 (0.227–0.268)	0.328 (0.293–0.363)	0.435 (0.391–0.459)	0.621 (0.446–0.645)	332

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Table 5-9. Creatinine-Corrected Urinary Thallium Concentrations (in $\mu\text{g/g}$ of Creatinine) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval)	Percentiles (95% confidence interval)				Sample size
		50th	75th	90th	95th	
12–19 years						
1999–2000	0.153 (0.146–0.160)	0.154 (0.146–0.162)	0.205 (0.191–0.219)	0.258 (0.231–0.278)	0.321 (0.265–0.364)	697
2001–2002	0.143 (0.137–0.150)	0.145 (0.135–0.152)	0.196 (0.184–0.207)	0.272 (0.250–0.289)	0.312 (0.299–0.333)	746
2003–2004	0.143 (0.135–0.152)	0.146 (0.131–0.155)	0.194 (0.179–0.208)	0.254 (0.234–0.280)	0.304 (0.271–0.327)	725
2005–2006	0.140 (0.133–0.147)	0.140 (0.130–0.150)	0.190 (0.170–0.200)	0.240 (0.220–0.270)	0.290 (0.250–0.310)	701
2007–2008	0.134 (0.124–0.145)	0.140 (0.120–0.150)	0.190 (0.180–0.220)	0.260 (0.220–0.300)	0.300 (0.250–0.370)	376
2009–2010	0.140 (0.127–0.155)	0.140 (0.120–0.160)	0.190 (0.170–0.220)	0.260 (0.220–0.310)	0.310 (0.260–0.370)	451
2011–2012	0.149 (0.134–0.165)	0.147 (0.130–0.169)	0.200 (0.180–0.218)	0.276 (0.235–0.321)	0.339 (0.268–0.500)	390
2013–2014	0.145 (0.133–0.158)	0.141 (0.131–0.160)	0.213 (0.182–0.231)	0.276 (0.237–0.301)	0.315 (0.283–0.361)	451
2015–2016	0.157 (0.145–0.169)	0.161 (0.144–0.175)	0.222 (0.191–0.244)	0.290 (0.262–0.329)	0.351 (0.289–0.410)	402
2017–2018	0.159 (0.151–0.167)	0.158 (0.153–0.174)	0.221 (0.195–0.241)	0.282 (0.252–0.304)	0.312 (0.282–0.354)	364
≥20 years						
1999–2000	0.162 (0.153–0.171)	0.167 (0.155–0.176)	0.218 (0.207–0.230)	0.286 (0.271–0.300)	0.364 (0.325–0.389)	1,380
2001–2002	0.153 (0.147–0.159)	0.153 (0.144–0.161)	0.210 (0.200–0.217)	0.278 (0.263–0.293)	0.343 (0.313–0.362)	1,544
2003–2004	0.148 (0.144–0.153)	0.149 (0.141–0.156)	0.206 (0.192–0.215)	0.273 (0.258–0.289)	0.333 (0.306–0.353)	1,543
2005–2006	0.152 (0.145–0.159)	0.150 (0.140–0.160)	0.210 (0.200–0.210)	0.290 (0.270–0.310)	0.370 (0.350–0.400)	1,520
2007–2008	0.149 (0.143–0.156)	0.150 (0.140–0.160)	0.210 (0.200–0.220)	0.280 (0.270–0.300)	0.350 (0.330–0.380)	1,857
2009–2010	0.150 (0.142–0.157)	0.150 (0.140–0.160)	0.210 (0.200–0.220)	0.290 (0.270–0.320)	0.370 (0.330–0.400)	2,019
2011–2012	0.166 (0.155–0.179)	0.164 (0.154–0.175)	0.233 (0.212–0.250)	0.333 (0.298–0.367)	0.436 (0.365–0.510)	1,714
2013–2014	0.160 (0.153–0.168)	0.157 (0.148–0.165)	0.229 (0.222–0.241)	0.333 (0.313–0.352)	0.429 (0.394–0.457)	1,810
2015–2016	0.163 (0.153–0.174)	0.159 (0.148–0.173)	0.231 (0.207–0.256)	0.323 (0.288–0.362)	0.400 (0.358–0.444)	1,792
2017–2018	0.171 (0.160–0.182)	0.168 (0.159–0.178)	0.235 (0.218–0.254)	0.348 (0.314–0.388)	0.456 (0.386–0.516)	1,707
Gender						
Males						
1999–2000	0.154 (0.147–0.161)	0.156 (0.149–0.164)	0.202 (0.192–0.214)	0.269 (0.254–0.297)	0.338 (0.300–0.364)	1,200
2001–2002	0.146 (0.140–0.153)	0.148 (0.142–0.157)	0.192 (0.184–0.204)	0.260 (0.246–0.278)	0.307 (0.291–0.342)	1,312
2003–2004	0.140 (0.135–0.146)	0.142 (0.134–0.149)	0.188 (0.180–0.198)	0.264 (0.235–0.286)	0.317 (0.287–0.350)	1,281
2005–2006	0.140 (0.134–0.147)	0.140 (0.130–0.140)	0.190 (0.180–0.200)	0.270 (0.240–0.300)	0.320 (0.300–0.340)	1,271

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Table 5-9. Creatinine-Corrected Urinary Thallium Concentrations (in $\mu\text{g/g}$ of Creatinine) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval)	Percentiles (95% confidence interval)				Sample size
		50th	75th	90th	95th	
2007–2008	0.138 (0.131–0.145)	0.130 (0.130–0.140)	0.190 (0.180–0.210)	0.270 (0.250–0.290)	0.330 (0.300–0.360)	1,327
2009–2010	0.138 (0.129–0.148)	0.130 (0.130–0.150)	0.190 (0.170–0.210)	0.270 (0.240–0.300)	0.330 (0.290–0.360)	1,398
2011–2012	0.154 (0.142–0.167)	0.155 (0.144–0.165)	0.211 (0.197–0.233)	0.292 (0.258–0.326)	0.353 (0.312–0.385)	1,261
2013–2014	0.147 (0.137–0.158)	0.141 (0.133–0.150)	0.206 (0.194–0.222)	0.295 (0.272–0.315)	0.368 (0.341–0.414)	1,317
2015–2016	0.155 (0.145–0.166)	0.150 (0.138–0.167)	0.220 (0.199–0.247)	0.322 (0.298–0.348)	0.396 (0.358–0.449)	1,524
2017–2018	0.163 (0.154–0.173)	0.157 (0.145–0.168)	0.230 (0.212–0.244)	0.353 (0.310–0.391)	0.433 (0.380–0.542)	1,380
Females						
1999–2000	0.178 (0.167–0.189)	0.182 (0.169–0.197)	0.244 (0.226–0.259)	0.317 (0.281–0.366)	0.380 (0.333–0.462)	1,213
2001–2002	0.167 (0.158–0.176)	0.167 (0.153–0.180)	0.233 (0.217–0.250)	0.313 (0.282–0.348)	0.378 (0.348–0.402)	1,340
2003–2004	0.167 (0.162–0.173)	0.166 (0.157–0.177)	0.235 (0.222–0.243)	0.313 (0.286–0.333)	0.368 (0.340–0.412)	1,277
2005–2006	0.171 (0.162–0.181)	0.170 (0.160–0.180)	0.230 (0.220–0.250)	0.330 (0.300–0.360)	0.430 (0.370–0.490)	1,305
2007–2008	0.167 (0.163–0.173)	0.170 (0.160–0.180)	0.230 (0.230–0.240)	0.320 (0.300–0.340)	0.390 (0.360–0.430)	1,300
2009–2010	0.170 (0.161–0.178)	0.170 (0.160–0.180)	0.230 (0.220–0.250)	0.340 (0.310–0.370)	0.420 (0.370–0.470)	1,450
2011–2012	0.183 (0.172–0.195)	0.180 (0.168–0.193)	0.261 (0.240–0.286)	0.382 (0.349–0.420)	0.480 (0.422–0.510)	1,241
2013–2014	0.179 (0.172–0.187)	0.180 (0.171–0.190)	0.264 (0.248–0.274)	0.374 (0.352–0.402)	0.439 (0.416–0.482)	1,346
2015–2016	0.188 (0.179–0.199)	0.187 (0.175–0.199)	0.265 (0.243–0.283)	0.379 (0.339–0.408)	0.458 (0.418–0.517)	1,534
2017–2018	0.195 (0.185–0.207)	0.191 (0.177–0.206)	0.268 (0.252–0.289)	0.400 (0.365–0.455)	0.504 (0.465–0.571)	1,426
Race						
Mexican American						
1999–2000	0.158 (0.147–0.170)	0.160 (0.148–0.176)	0.213 (0.200–0.237)	0.282 (0.266–0.304)	0.343 (0.306–0.389)	861
2001–2002	0.156 (0.145–0.169)	0.155 (0.145–0.167)	0.204 (0.191–0.221)	0.286 (0.250–0.317)	0.361 (0.301–0.424)	674
2003–2004	0.159 (0.148–0.170)	0.157 (0.143–0.172)	0.211 (0.187–0.241)	0.293 (0.273–0.324)	0.369 (0.326–0.422)	618
2005–2006	0.149 (0.139–0.158)	0.150 (0.140–0.160)	0.200 (0.180–0.210)	0.270 (0.240–0.290)	0.320 (0.280–0.370)	652
2007–2008	0.151 (0.143–0.160)	0.160 (0.130–0.170)	0.200 (0.190–0.220)	0.270 (0.250–0.280)	0.320 (0.290–0.370)	515
2009–2010	0.154 (0.141–0.167)	0.150 (0.140–0.170)	0.210 (0.180–0.230)	0.280 (0.250–0.330)	0.360 (0.310–0.430)	613
2011–2012	0.160 (0.150–0.170)	0.163 (0.141–0.175)	0.222 (0.198–0.245)	0.295 (0.276–0.326)	0.359 (0.302–0.440)	317
2013–2014	0.159 (0.151–0.168)	0.151 (0.142–0.162)	0.218 (0.194–0.230)	0.313 (0.282–0.350)	0.409 (0.350–0.457)	453
2015–2016	0.178 (0.165–0.192)	0.178 (0.158–0.199)	0.241 (0.217–0.278)	0.369 (0.316–0.403)	0.455 (0.406–0.513)	584

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Table 5-9. Creatinine-Corrected Urinary Thallium Concentrations (in $\mu\text{g/g}$ of Creatinine) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval)	Percentiles (95% confidence interval)				Sample size
		50th	75th	90th	95th	
2017–2018	0.178 (0.165–0.192)	0.178 (0.164–0.194)	0.242 (0.221–0.264)	0.343 (0.306–0.389)	0.435 (0.377–0.486)	433
Non-Hispanic Black						
1999–2000	0.142 (0.133–0.152)	0.140 (0.129–0.151)	0.200 (0.184–0.214)	0.278 (0.244–0.307)	0.383 (0.286–0.462)	561
2001–2002	0.138 (0.128–0.150)	0.136 (0.125–0.146)	0.194 (0.170–0.212)	0.256 (0.238–0.278)	0.328 (0.271–0.387)	657
2003–2004	0.133 (0.122–0.145)	0.128 (0.119–0.143)	0.185 (0.171–0.200)	0.255 (0.237–0.269)	0.323 (0.267–0.377)	723
2005–2006	0.137 (0.128–0.145)	0.130 (0.130–0.140)	0.190 (0.180–0.200)	0.240 (0.220–0.290)	0.320 (0.270–0.370)	692
2007–2008	0.125 (0.118–0.132)	0.130 (0.120–0.130)	0.170 (0.160–0.180)	0.230 (0.210–0.260)	0.280 (0.250–0.330)	589
2009–2010	0.128 (0.120–0.137)	0.120 (0.110–0.130)	0.180 (0.160–0.210)	0.250 (0.230–0.280)	0.310 (0.270–0.350)	544
2011–2012	0.137 (0.119–0.157)	0.137 (0.113–0.159)	0.208 (0.174–0.244)	0.284 (0.248–0.334)	0.348 (0.293–0.406)	669
2013–2014	0.131 (0.125–0.137)	0.126 (0.117–0.138)	0.181 (0.171–0.189)	0.254 (0.232–0.276)	0.324 (0.265–0.421)	581
2015–2016	0.135 (0.126–0.145)	0.130 (0.119–0.138)	0.194 (0.181–0.212)	0.304 (0.270–0.339)	0.369 (0.333–0.412)	669
2017–2018	0.135 (0.127–0.145)	0.135 (0.128–0.144)	0.190 (0.179–0.206)	0.267 (0.245–0.308)	0.335 (0.300–0.368)	639
Non-Hispanic White						
1999–2000	0.169 (0.160–0.179)	0.173 (0.167–0.181)	0.227 (0.215–0.240)	0.300 (0.272–0.329)	0.364 (0.333–0.377)	801
2001–2002	0.161 (0.155–0.167)	0.161 (0.153–0.171)	0.222 (0.214–0.231)	0.292 (0.278–0.304)	0.348 (0.330–0.383)	1,114
2003–2004	0.154 (0.148–0.160)	0.153 (0.143–0.162)	0.214 (0.200–0.223)	0.283 (0.271–0.304)	0.333 (0.313–0.363)	1,074
2005–2006	0.156 (0.148–0.164)	0.150 (0.140–0.160)	0.210 (0.200–0.230)	0.300 (0.280–0.320)	0.360 (0.330–0.400)	1,041
2007–2008	0.154 (0.146–0.164)	0.160 (0.140–0.170)	0.220 (0.210–0.230)	0.300 (0.280–0.320)	0.370 (0.340–0.390)	1,095
2009–2010	0.155 (0.145–0.166)	0.150 (0.140–0.170)	0.220 (0.200–0.240)	0.310 (0.280–0.330)	0.380 (0.340–0.410)	1,225
2011–2012	0.173 (0.161–0.186)	0.171 (0.161–0.181)	0.235 (0.213–0.261)	0.337 (0.309–0.373)	0.453 (0.357–0.521)	818
2013–2014	0.163 (0.151–0.176)	0.163 (0.149–0.176)	0.242 (0.226–0.255)	0.338 (0.309–0.362)	0.430 (0.390–0.482)	984
2015–2016	0.169 (0.157–0.182)	0.168 (0.154–0.180)	0.239 (0.213–0.276)	0.336 (0.300–0.369)	0.404 (0.371–0.450)	924
2017–2018	0.185 (0.172–0.198)	0.179 (0.168–0.191)	0.254 (0.236–0.280)	0.386 (0.338–0.433)	0.477 (0.420–0.559)	918

5. POTENTIAL FOR HUMAN EXPOSURE

Table 5-9. Creatinine-Corrected Urinary Thallium Concentrations (in $\mu\text{g/g}$ of Creatinine) in the U.S. Population from the National Health and Nutrition Examination Survey (NHANES)

Survey years	Geometric mean (95% confidence interval)	Percentiles (95% confidence interval)				Sample size
		50th	75th	90th	95th	
All Hispanic						
2011–2012	0.162 (0.150–0.176)	0.158 (0.142–0.174)	0.221 (0.198–0.250)	0.304 (0.278–0.347)	0.370 (0.316–0.440)	573
2013–2014	0.161 (0.153–0.170)	0.154 (0.145–0.164)	0.222 (0.208–0.238)	0.318 (0.294–0.344)	0.386 (0.350–0.432)	701
2015–2016	0.180 (0.170–0.190)	0.178 (0.167–0.190)	0.241 (0.225–0.266)	0.366 (0.332–0.389)	0.444 (0.424–0.509)	981
2017–2018	0.183 (0.171–0.195)	0.178 (0.164–0.189)	0.249 (0.229–0.280)	0.377 (0.333–0.435)	0.498 (0.454–0.622)	674
Non-Hispanic Asian						
2011–2012	0.237 (0.219–0.256)	0.228 (0.206–0.250)	0.337 (0.297–0.367)	0.526 (0.442–0.586)	0.663 (0.557–0.830)	353
2013–2014	0.242 (0.221–0.264)	0.237 (0.216–0.268)	0.352 (0.304–0.382)	0.456 (0.417–0.529)	0.570 (0.460–0.857)	292
2015–2016	0.259 (0.242–0.278)	0.254 (0.234–0.279)	0.368 (0.333–0.406)	0.536 (0.492–0.603)	0.663 (0.572–0.742)	332
2017–2018	0.236 (0.221–0.252)	0.229 (0.203–0.252)	0.330 (0.309–0.355)	0.453 (0.392–0.520)	0.595 (0.507–0.707)	365

^aParticipants were ≥ 6 years old in survey years through 2014; beginning with survey years 2015–2016, participants included those ≥ 3 years old.

Source: CDC 2023

5. POTENTIAL FOR HUMAN EXPOSURE

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Occupational exposure to thallium may be significant for workers in smelters, power plants, cement factories, and other industries that produce or use thallium compounds or alloys. Exposure may occur by dermal absorption from handling thallium-containing compounds, ores, limestone, or cement or by inhalation of workplace air (Ewers 1988; Marcus 1985; Schaller et al. 1980).

No recent data were located for U.S. workplaces. Although data on exposure levels in workplace air are rare, studies associating workplace exposure and elevated urinary thallium confirm the occurrence of industrial exposures in Europe (Apostoli et al. 1988; Marcus 1985; Schaller et al. 1980; Staff et al. 2014). A 2014 study of workers in the United Kingdom reported a median urinary thallium level of 0.41 µg/L (Staff et al. 2014). The urinary thallium levels were higher than levels measured in general workers (0.20 µg/L) or non-occupational exposed people (0.11 µg/L) (Staff et al. 2014).

Populations with potentially high exposures are those living near coal-burning power plants, metal smelters, or cement plants (Sharma et al. 1986). The airborne particulate emissions from these plants may have high thallium levels, especially on the small-diameter, respirable particles (Davison et al. 1974; Ewers 1988). Human populations living in the vicinity of these plants may be exposed by inhalation or by ingestion of fruits and vegetables home-grown in contaminated soils (Brockhaus et al. 1980, 1981; EPA 1988; Sharma et al. 1986).

Limited data suggest that smokers may have potentially higher exposure to thallium than nonsmokers. Although authoritative evaluations of cigarette smoke constituents do not include thallium, thallium was detected at 0.057–0.170 µg/g in cigar stubs and 0.024 µg/g in cigarette tobacco (EPA 1980). A more recent study reported an average thallium concentration of 0.0089 µg/g in tobacco samples collected from a commercial cigarette brand in Poland (Karbowska and Zembrzuski 2016). One study indicates that the urinary excretion of thallium in smokers is about twice that of nonsmokers (EPA 1980). A recent study showed that illicit opioid users were a high-risk group for thallium toxicity. In the studied group, the median (interquartile range) concentrations of thallium in urine, blood, and hair were 54.8, 14.5, and 5.4 µg/g, respectively, as compared to respective levels 4.8, 2.4, and 1.4 µg/g in the control group (Molavi et al. 2020).