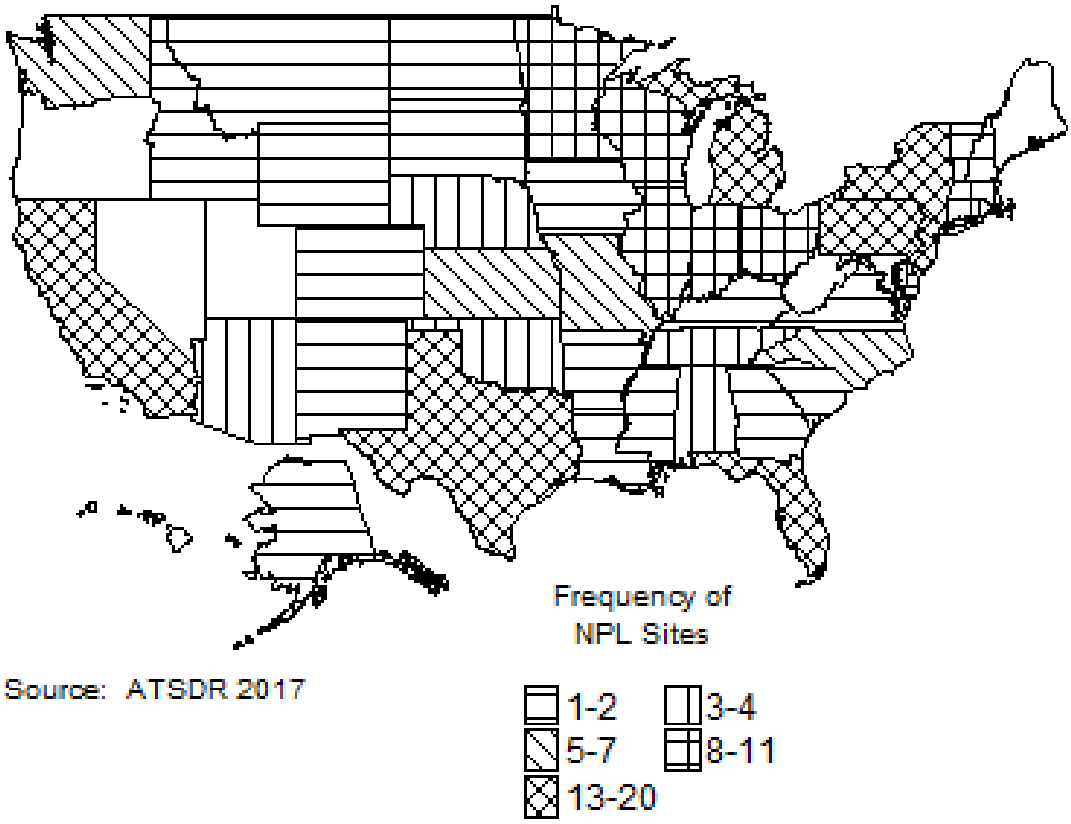
CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Bromodichloromethane has been identified in at least 238 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 bromodichloromethane has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, 233 are located within the United States, 2 are located in the Virgin Islands, and 3 are located in Puerto Rico (not shown).

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



- The most likely route of exposure for the general public to bromodichloromethane is through ingestion, inhalation, and dermal contact of chlorinated drinking water.
- A median bromodichloromethane intake of 2.8–4.2 µg/day from drinking water has been estimated; inhalation and dermal exposure would add to this daily intake.

- Bromodichloromethane is formed as a byproduct of water disinfection methods using chlorination. This is the primary source of bromodichloromethane in the environment.
- Its principal use is as a chemical intermediate for organic synthesis and as a chemical reagent.
- Volatilization is an important fate process. Bromodichloromethane evaporates from sources and enters the environment as a gas, which is slowly broken down in air. Residual bromodichloromethane may be broken down slowly by bacteria.
- In the atmosphere, bromodichloromethane is thought to undergo slow degradation through oxidative pathways, with a half-life of about 2–3 months.

5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.2.1 Production

The principal anthropogenic source of bromodichloromethane is its unintentional formation as a byproduct during the chlorination of water containing organic materials and bromide. It has been reported as the second most frequently detected trihalomethane, following chloroform, in drinking water (Bellar et al. 1974; EPA 2003; Krasner et al. 1989). Bromodichloromethane is formed when chlorine-based chemical disinfectants react with organic matter and bromide present in the system. The reaction is dependent on water quality and the treatment process used for disinfection. Factors such as organic matter concentration, bromide and chlorine concentration, temperature, pH, and contact time affect the production of byproducts during disinfection (WHO 2000).

Synthesis of bromodichloromethane can be achieved by treating a mixture of chloroform and bromoform with triethylbenzylammonium chloride and sodium hydroxide (IARC 1991). Bromodichloromethane is produced commercially by the reaction of dichloromethane with aluminum bromide.

No information is available in the TRI database on facilities that manufacture or process bromodichloro-methane because this chemical is not required to be reported under Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) (EPA 2005a).

5.2.2 Import/Export

No data on imports or exports of bromodichloromethane were located. Little, if any, of either is expected.

5.2.3 Use

In the past, bromodichloromethane has been used as a solvent for fats, waxes, and resins, as a flame retardant, as a heavy liquid for mineral and salt separations, and as a fire extinguisher fluid ingredient (USGS 2006a). At present, the principal use of bromodichloromethane is as a chemical intermediate for organic synthesis and as a chemical laboratory reagent, particularly as a standard in the analysis of drinking water (IARC 1991; O'Neil 2013; Sittig 1985; Verschueren 1983). Bromodichloromethane is not listed as an ingredient in fire extinguishers or solvents as of April 2017, but it is listed as a possible colorant constituent in dyes and pigments as well as a polar organic compound in fragrances of consumer products; it may be used in pesticides or fracking practices, and it is a component of several water standard kits (Dionisio et al. 2015; EPA 2014a).

5.2.4 Disposal

Bromodichloromethane is categorized as a hazardous waste constituent (40 CFR 261 App. VIII) and, therefore, must be disposed of in accordance with Resource Conservation and Recovery Act (RCRA) regulations. Acceptable disposal methods include incineration using liquid injection, rotary kiln, or fluidized bed techniques. At the present time, land disposal of bromodichloromethane is also permitted, although trihalomethanes are being evaluated for land disposal prohibition.

Bromodichloromethane has been detected in the raw and treated waste water of numerous industries (EPA 1983), but no quantitative data on amounts of bromodichloromethane disposed of to the environment were located.

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 2005a). 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 ≥25,000 pounds of any TRI chemical or otherwise uses >10,000 pounds of a TRI chemical in a calendar year (EPA 2005a).

5.3.1 Air

There is no information on releases of bromodichloromethane to the atmosphere from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005a).

No studies were located regarding industrial release of bromodichloromethane into air. Because of the low volume of bromodichloromethane currently in use, it is expected that releases from industrial activities are probably small.

Class et al. (1986) observed trace levels of bromodichloromethane, 0.7–6.7 ng/m^3 (<l ppt), and other bromomethanes in seawater and in the air above the ocean at several locations in the Atlantic between 1982 and 1985. The presence of bromodichloromethane was attributed to biosynthesis and release of bromodichloromethane by macroalgae (Class et al. 1986; Gschwend et al. 1985).

In 1978 through 1986, releases of bromodichloromethane from indoor and outdoor swimming pools were measured from the surface of the pool up to 2 m above the pool surface; air concentrations of bromodichloromethane ranged between 0.2 and 210 µg/m^3 (IARC 1991).

5.3.2 Water

There is no information on releases of bromodichloromethane to water from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005a).

The principal source of bromodichloromethane in the environment is from chlorination of water. EPA (1980) estimated that >800 kkg (1 kkg=1 metric ton) are produced annually in this way. It is presumed that essentially all of this is ultimately released into the environment, mainly through volatilization. This

may occur either indoors (e.g., while showering, washing, cooking, etc.) or outdoors after discharge of the water to the surface.

Bromodichloromethane has been detected in waste water from a number of industrial discharges and municipal wastewater treatment facilities, usually at concentrations between 1 and 100 µg/L (Dunovant et al. 1986; Perry et al. 1979; Staples et al. 1985). These levels of bromodichloromethane are similar to those found in many chlorinated drinking water supplies, and probably most discharges of this sort do not represent a major source of bromodichloromethane release to the environment.

Releases of water containing bromodichloromethane that may enter groundwater include water use techniques such as the recharge of chlorinated waters for lawn and garden irrigation in commercial and residential areas, leaking swimming pools and water lines, leaking chlorinated water distribution and sewer pipes, and unintentional backflow of chlorinate water to supply wells (USGS 2003, 2006a).

5.3.3 Soil

There is no information on releases of bromodichloromethane to soil from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005a).

Water use techniques such as the recharge of chlorinated public waters for lawn and garden irrigation in commercial and residential areas may contribute to bromodichloromethane in the soil environment (USGS 2006a).

Monitoring efforts during the summer and fall of 2008 at the Love Canal in Niagara Falls, New York identified bromodichloromethane as a contaminant in the soil/sediment/water samples (Hauser and Bromberg 1982).

Hoekstra et al. (1998) detected bromodichloromethane at concentrations ranging from 0.03 to 0.31 ng/L (0.0003–0.0031 µg/L) in soil-air samples taken from soil layers, at depths of 10–160 m below the surface, in a Douglas fir forest near Apeldoorn in the Netherlands. Bromodichloromethane was not detected in the ambient air samples taken 5–10 cm above the soil surface. Concentrations of bromodichloromethane in the soil layers were higher in the deeper layers reaching a maximum at a depth of 120 cm.

5.4 ENVIRONMENTAL FATE

5.4.1 Transport and Partitioning

Air. Because of the relatively high vapor pressure of bromodichloromethane (50 mm Hg at 20°C), the principal transport process in the environment is volatilization (Class et al. 1986; Gschwend et al. 1985). Over 99% of all bromodichloromethane in the environment is estimated to exist in air (EPA 1980).

Bromodichloromethane may be removed from air by washout in rainfall (Class et al. 1986), but the average rate of this transport process has not been estimated. It is expected that bromodichloromethane removed from air in this way is likely returned to air through volatilization.

Water. Volatilization from surface waters depends on factors such as turbulence and temperature. A measured Henry's Law constant for bromodichloromethane of 2.12×10^{-3} at 25°C indicates that volatilization from water is an important fate process. The volatilization half-life from rivers and streams has been estimated to range from 33 minutes to 12 days, with a typical half-life of 35 hours (Kaczmar et al. 1984). Volatilization rates from surface soils have not been studied in detail, but Wilson et al. (1981) found that about 50% of bromodichloromethane applied to a soil column in the laboratory escaped by volatilization. A fate study in a waste water treatment wetland near Phoenix, Arizona, receiving chlorinated municipal wastewaters, resulted in 83% removal of bromodichloromethane. Volatilization was indicated as the primary removal process, with an atmospheric flux of 2.47 g/day/ha (Keefe et al. 2004).

Bromodichloromethane is moderately soluble in water (3,030 mg/L). Significant transport of bromodichloromethane can occur in water, especially in groundwater where volatilization is restricted. This transport pathway may be important at waste sites or other locations where bromodichloromethane spills lead to groundwater contamination.

Sediment and Soil. An estimated log K_{oc} value of 1.8 (Mabey et al. 1982) indicates that bromodichloromethane is expected to possess high mobility in soil surfaces and has the potential to leach into groundwater. Bromodichloromethane applied to the surface of a sandy soil (92% sand, 5.9% silt, 2.1% clay, <0.1% organic carbon) in a packed column experiment quickly percolated to the bottom of the column (140 cm) when eluted with water (Wilson et al. 1981). Roughly 48% of the initially applied amount was collected in column effluent and about 54% was shown to volatilize from the column.

Other Media. The moderate solubility and low log K_{ow} indicate that bioaccumulation of bromodichloromethane by fish or other aquatic species is likely to be minor, but no estimate of a bioaccumulation factor in aquatic species was located.

5.4.2 Transformation and Degradation

Air. Pathways responsible for bromodichloromethane degradation in the atmosphere are not well studied, but likely involve oxidative reaction with hydroxyl radicals or singlet oxygen (EPA 1980; Mabey et al. 1982). Bromodichloromethane does not contain chromophores that will absorb light at wavelengths >290 nm, and therefore, direct photochemical decomposition is not likely to be significant (EPA 1980). The typical atmospheric lifetime of bromodichloromethane has been estimated to be 2–3 months (EPA 1980). This relatively persistent tropospheric half-life of bromodichloromethane suggests that a small percentage of the bromodichloromethane present in air will eventually diffuse into the stratosphere where it will be destroyed by photolysis. In addition, long-range global transport is possible.

Water. Hydrolysis of bromodichloromethane in aqueous media is very slow, with an estimated rate constant at neutral pH of 5.76×10^{-8} $hour^{-1}$ (Mabey et al. 1982). This corresponds to a half-life of >1,000 years.

Biodegradation in aqueous media may be significant in some cases. For example, Tabak et al. (1981) reported 35% loss of the test substance in a static test after 7 days of incubation in a medium inoculated with sewage at 25°C. Repeated culturing lead to increased losses, up to 59% after 28 days, indicating gradual adaptation of the degradative microbes. Tabak et al. (1981) also examined the volatilization of bromodichloromethane after 10 days at 25°C. The study resulted in 8% loss of test substance due to volatilization, indicating that biodegradation is the prominent degradation process for bromodichloromethane (Tabak et al. 1981).

Under anaerobic aquatic conditions where volatilization cannot occur, biodegradation may be the predominant mechanism for degradation of bromodichloromethane. In a continuous-flow biofilm reactor with a settled sewage inoculum and three zones (aerobic, denitrifying, and sulfate-reducing regions) bromodichloromethane achieved >99% transformation, coinciding with the onset of the sulfate-reducing zone in the column; concentrations were approximately 46 and <0.1 µg/L in the influent and effluent, respectively, after 120 days (Cobb and Bouwer 1991). Bouwer et al. (1981) and Bouwer and McCarty

(1983a) studied the degradation of bromodichloromethane under aerobic and anaerobic conditions in both static and continuous flow systems inoculated with mixed methanogenic bacterial cultures from sewage. Degradation was found to be very limited under aerobic conditions, but essentially complete within 2 days under anaerobic conditions. Minimal to no degradation was observed by Bouwer et al. (1981) under aerobic conditions after a 6-week study using mixed methanogenic bacterial cultures in sterile and seeded conditions. Under anaerobic conditions, rapid degradation (>99% after 2 days) was observed by Bouwer and McCarty (1983a). Slow degradation under anaerobic conditions (50–70% in 16 weeks) occurred in sterile media, indicating that a chemical mechanism (hypothesized to be reductive dehalogenation) was operative in addition to the rapid microbial degradation. Microbial degradation was also observed under anaerobic conditions in media inoculated with denitrifying bacteria (Bouwer and McCarty 1983b).

Sediment and Soil. Biodegradation of bromodichloromethane in soil has not been studied, but studies in aqueous media indicate that biodegradation might occur under anaerobic conditions (Bouwer et al. 1981; Bouwer and McCarty 1983a, 1983b; Tabak et al. 1981). This suggests that, in regions of soil where volatilization is restricted, biodegradation could be a major removal process.

5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to bromodichloromethane depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of bromodichloromethane 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 bromodichloromethane 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 5-1 shows the lowest limit of detections that are achieved by analytical analysis in environmental media. Bromodichloromethane has been detected in indoor and outdoor air, water sources, and in soil; an overview summary of the range of concentrations detected in environmental media is presented in Table 5-2.

Table 5-1. Lowest Limit of Detection Based on Standards[a]

Media	Detection Limit	Reference
Air	0.019 ppbv	EPA 1999
Drinking water	0.003 µg/L	EPA 1990
Surface water and groundwater	0.049 µg/L	USGS 1998
Soil	0.02 µg/L	EPA 2014d, 2002, 1996a, 1996b, 1996c
Sediment	0.02 µg/L	EPA 2014d, 2002, 1996a, 1996b, 1996c
Whole blood	0.29 ng/L; 0.36 ng/L	Bonin et al. 2005

[a]Detection limits based on using appropriate preparation and analytics. These limits may not be possible in all situations.

Table 5-2. Summary of Environmental Levels of Bromodichloromethane

Media	Low	High	For more information
Outdoor air (ppbv)	0.00076	0.180	Table 5-6
Indoor air (ppbv)	0.01	0.49	Table 5-7
Surface water (ppb)	0.3	1.1	Table 5-9
Ground water (ppb)	0.02	23	Table 5-10
Drinking water (ppb)	Range of mean levels 1.0–20.3		Table 5-11
Food (ppb)	Trace	37	Tables 5-13 and 5-14
Soil	No monitoring data were located		

Detections of bromodichloromethane in air, water, and soil at NPL sites are summarized in Table 5-3.

Table 5-3. Bromodichloromethane Levels in Water, Soil, and Air of National Priorities List (NPL) Sites

Medium	Median[a]	Geometric mean[a]	Geometric standard deviation[a]	Number of concentrations	NPL sites
Water (ppb)	6	8.01	7,560	100	64
Soil (ppb)	9.35	7.26	2,190	6	6
Air (ppbv)	0.10	0.13	228	3	3

[a]Concentrations 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

Data from the EPA Air Quality System (AQS) database were used to calculate the annual mean percentile distributions of bromodichloromethane from multiple monitoring locations across the nation for the years 2010–2018 (EPA 2019). The results of these data are summarized in Table 5-4. The AQS database is EPA's source of criteria air pollutant and hazardous air pollutant (HAP) monitoring data. Monitoring data for other years may be obtained directly from the EPA AQS website.

Table 5-4. Percentile Distribution of Annual Mean Bromodichloromethane Concentrations (ppbv) Measured in Ambient Air at Locations Across the United States

Year	Number of U.S. locations	25th	50th	75th	95th	Maximum
2010	151	0.0089	0.010	0.033	0.10	0.47
2011	127	0.0079	0.012	0.029	0.099	0.47
2012	124	0.0072	0.010	0.050	0.075	0.23
2013	117	0.0095	0.0097	0.050	0.052	0.24
2014	116	0.0090	0.012	0.050	0.067	0.12
2015	52	0.0090	0.0090	0.050	0.11	0.23
2016	101	0.0000	0.0000	0.000328	0.0023	0.35
2017	87	0.0000	0.0000	0.0000	0.0020	0.12
2018	83	0.0000	0.0000	0.0005	0.0019	0.033

Source: EPA 2019

The 2012 and 2013 National Monitoring Program sponsored by the EPA compiled 24-hour air sample data from 64 and 66 monitoring sites, respectively, located in 26 states across the United States (EPA 2015a, 2014b). Samples from 34 sites were assessed for volatile organic compounds, including bromodichloromethane, in 2013 and samples from 30 sites were obtained for 2012. The percent of detections at each site ranged from about 0 to 15%, with the exception of the site in Northbrook, Illinois at which bromodichloromethane was detected in 93% of the 61 samples at that site in 2013 and 100% of the samples in 2012 (EPA 2015b, 2014c). The results of these data are summarized in Table 5-5.

Table 5-5. Statistical Summary of Bromodichloromethane Concentrations from the 2012 and 2013 National Monitoring Program

Non detects[a]	Measured detects[a]	Measured detects <MDL	Minimum (ppbv)[b]	Maximum (ppbv)	Arithmetic mean (ppbv)	Median (ppbv)	25th (ppbv)	75th (ppb)	Standard deviation (ppbv)
2013									
1,728	155	113	0.005	8.36	0.009	0	0	0	0.205
2012									
1,350	116	NR	0.006	4.10	0.010	0	0	0	0.152

[a]Out of 1,883 valid samples in 2013 and 1,466 valid samples in 2012.
[b]Excludes zeros for non-detects.
MDL = method detection limit
Source: EPA 2014b, 2015a

Ambient air monitoring data for bromodichloromethane, including data for concentrations detected during water-related activities, are compiled in Tables 5-6, 5-7, and 5-8.

Table 5-6. Outdoor Air Monitoring Data for Bromodichloromethane

Location(s)	Geographic type	Date(s)	Range	Mean concentration	Notes	Reference
Texas, North Carolina, Arkansas	Suburban, urban, source dominated	Not specified (1983 or earlier)	0.00076–0.180 ppbv	0.0011 ppbv	Not detected in two of the rural, remote sites monitored in Arkansas	Brodzinsky and Singh 1983
California	Urban, industrial	1982/1983		0.01–0.10 ppbv	Detected above 0.01 ppbv in 35% of the samples	Shikiya et al. 1984
Atlantic Ocean	Open ocean	1982/1984/1985	0.001–0.007 ppbv		Air samples at several locations; attributed to releases from macroalgae	Class et al. 1986
Texas, Louisiana, North Carolina, Arkansas	Suburban, urban, source dominated	Not specified (2005 or earlier)		0.74 µg/m^3 (0.11 ppbv)	Outdoor air	EPA 2005b
Germany	Surface air above swimming pools	1995–1999	0.03–2.0 µg/m^3 (0.0045–0.3 ppbv)	0.1–0.4 µg/m^3 (0.02–0.06 ppbv)	Measured 20 or 150 cm above the water surface of outdoor pools	WHO 2006

Table 5-6. Outdoor Air Monitoring Data for Bromodichloromethane

Location(s)	Geographic type	Date(s)	Range	Mean concentration	Notes	Reference
United States	Surface air above swimming pools	1986	<0.1 µg/m^3 (<0.02 ppbv)	Not reported	Measured 200 cm above the water surface outdoor pools	WHO 2006

Table 5-7. Indoor Air Monitoring Data for Bromodichloromethane

Location(s)	Geographic type	Date(s)	Mean concentration	Notes	Reference
New Jersey	Suburban	Not specified (1999 or earlier)	0.38–0.75 µg/m^3 (0.056–0.11 ppbv)	Indoor air of 48 households	EPA 2005b
Southwestern United States	Urban living space air	August 1997	0.01–0.49 ppbv	Indoor air concentrations from 24-hour integrated samples 0.2–0.9 µg/m^3 (0.03–0.13 ppbv); air exchange rates in the home influenced concentrations	Kerger et al. 2005
Italy	Surface air above indoor swimming pools	1993–1998	17.4–20 µg/m^3 (2.61–3 ppbv)	Measured 20 cm above water surface of indoor pool	WHO 2006
Germany	Surface air above swimming pools	1995–1999	4.1–9.2 µg/m^3 (0.62–1.38 ppbv)	Measured 20 or 150 cm above the water surface of indoor pools	WHO 2006
United States	Surface air above swimming pools	1986	Range of <0.1–10 µg/m^3 (0.02–2 ppbv)	Measured 200 cm above the water surface of indoor pools	WHO 2006

Table 5-8. Water-Related Activities and Indoor Air Monitoring Data for Bromodichloromethane

Activity	Range	
Showering[a,b]	Prior:	0.3–20.9 µg/m^3 (0.04–3.12 ppbv)
	During:	33.1–141.5 µg/m^3 (4.94–21.1 ppbv)
	After:	14.8–96 µg/m^3 (2.21–14.3 ppbv)
Bathing[a,c]	Prior:	0.4–2.1 µg/m^3 (0.06–0.31 ppbv)
	During:	7.0–65.1 µg/m^3 (1.0–9.71 ppbv)
	After:	5.9–29.0 µg/m^3 (0.88–4.33 ppbv)

[a]The average concentration of bromodichloromethane in the household water samples was reported as 42.0 µg/L.
[b]Durations of showers were 6.8–20 minutes; ventilated and non-ventilated scenarios were assessed.
[c]Durations of bath were 6.8–20 minutes.

Source: Kerger et al. 2000

5.5.2 Water

Bromodichloromethane occurs in water primarily as a byproduct of the chlorination process used for disinfection, but it also can be found in surface waters from biosynthesis by macroalgae.

The concentration of bromodichloromethane in chlorinated water depends on reaction conditions during the chlorination process. Important parameters include temperature, pH, bromide ion concentration in the source water, fulvic and humic substance concentration in the water, and chlorination treatment practices (EPA 1985). The amount of bromodichloromethane tends to increase as a function of increasing organic content and bromide ion in the source water (Arguello et al. 1979; Bellar et al. 1974).

Concentrations of bromodichloromethane in swimming pool waters are affected by several factors including the frequency and number of swimmers in the pool, the chlorine dose used for disinfection, the bromide content, and the source water used (Kim et al. 2002).

Water monitoring data for bromodichloromethane are compiled in Tables 5-9, 5-10, 5-11, and 5-12.

Table 5-9. Surface Water Monitoring Data for Bromodichloromethane

Location(s)	Geographic type	Date(s)	Range	Mean concentration	Notes	Reference
California, Utah, Florida	Monitoring sites	January–December 2012	Not detected–140 µg/L	Mean: 11.07 µg/L; median: 0.0 µg/L	EPA STORET data: Routine monitoring samples from: California Department of Water Resources; Hopland Band of Pomo Indians Tribal EPA; Dade Environmental Resource Management (Florida); Utah Department of Environmental Quality; water depths 0–1 m	WQP 2017
California, Utah, Florida	Monitoring sites	January–December 2013	Not detected–25.0 µg/L	Mean: 0.74 µg/L; median: 0.0 µg/L	EPA STORET data: Routine monitoring samples from: California Department of Water Resources; Hopland Band of Pomo Indians Tribal EPA; Dade Environmental Resource Management (Florida); Utah Department of Environmental Quality; water depths 0–1 m	WQP 2017
California; Utah, Florida	Monitoring sites	January–December 2014	Not detected–51.90 µg/L	Mean: 1.93 µg/L; median: 1.2 µg/L	EPA STORET data: Routine monitoring samples from: California Department of Water Resources; Hopland Band of Pomo Indians Tribal EPA; Dade Environmental Resource Management (Florida); Utah Department of Environmental Quality; water depths 0–12 m	WQP 2017

Table 5-9. Surface Water Monitoring Data for Bromodichloromethane

Location(s)	Geographic type	Date(s)	Range	Mean concentration	Notes	Reference
California; Minnesota	Monitoring sites	January–October 2015	Not detected–13.00 µg/L	Mean: 1.99 µg/L; median: 0.0 µg/L	EPA STORET data: Routine monitoring samples from: California Department of Water Resources; Minnesota Pollution Control Agency-Ambient Surface Water; water depths 0–1 m	WQP 2017
Atlantic Ocean	Open ocean; African coast, West Africa, Porto Santo, Sao Miguel, Bermuda Islands, Tenerife	1982/1984/1985	0.0001–0.001 µg/L (seawater); 0.0004 µg/L (rain)	Not reported	Surface water concentrations attributed to releases from macroalgae	Class et al. 1986
Gila River Phoenix, Arizona	River surface water	1997–1998	Not detected	Not reported		Rostad et al. 2000
The Rhine, Meuse, northern delta area, and Westerscheld	Surface water	1992–1997	<100 µg/L	Not reported		Miermans et al. 2000

Table 5-10. Groundwater Monitoring Data for Bromodichloromethane

Location(s)	Type	Date(s)	Range	Mean concentration	Notes	Reference
Salt Lake Valley, Utah	Well	1999	0.02–0.51 µg/L	Not reported	Detected in 17 of 30 wells sampled; attributed to the recharge of chlorinated public supply waters used to irrigate lawns and gardens in residential areas	USGS 2003
United States	Shallow groundwater	1996 and 2002	Trace: ≤0.2 µg/L	Not reported	Detected in 14% of samples; ≥0.2 in 1.7% of the samples	Squillace et al. 2004
United States	Domestic wells	1986–2001	0.2–7.0 µg/L	Not reported	Detected in 124 of 2,400 wells sampled	USGS 2006b
United States	Public wells	1986–2001	0.2–21 µg/L	Not reported	Detected in 46 of 1,095 wells sampled	USGS 2006b
United States	Untreated Ground and source water	1985–2002	0.02–23 µg/L	Not reported	Detected in 1–3% of the aquifers samples; 0.1–1.7% shallow groundwaters; more frequently detected in groundwater samples collected from urban areas as compared to agricultural areas	USGS 2006b
United States	Untreated Ground; public and domestic wells	1997–2007	0.08–0.09 µg/L (median values)	Not reported	10% (66 out of 631) of the public well samples; 1.7% (33 out of 1,861) of the domestic well samples; detected at a higher frequency in wells surrounded by urban areas compared with undeveloped, mixed, and agricultural surroundings	Carter et al. 2012
United States	Public wells	1993–2007		Not reported	Detected in 11% of the samples (932 wells)	USGS 2010b
United States	Principal aquifers	1991–2010	>0.2 µg/L	Not reported	0.93% frequency of detection of bromodichloromethane in 40 aquifers in the United States used for drinking water; 1.67% frequency of detection of bromodichloromethane in 22 aquifers beneath urban areas	USGS 2015
Taiwan	Groundwater	Not specified (2000 or prior)		Not reported	Detected in less than 5% of 214 sample taken at 30 industrial sites	Kuo 2000
Tampa Bay, Florida	Groundwater in an aquifer	October 2002–January 2003; August–September 2004	0.040 µg/L	Not reported	Detected 3 times in 30 source-water samples collected from 30 community water system wells during the first phase, concentration not reported; 1 time in 11 source-water samples collected during the second phase	USGS 2007

Table 5-11. Drinking Water Monitoring Data for Bromodichloromethane

Location(s)	Type	Date(s)	Range	Mean concentration	Notes	Reference
United States	Finished water	August 1973–February 1974	1.1–20.8 µg/L	Not reported	Sampling sites not reported	Bellar et al. 1974
Tampa Bay, Florida	Finished water	August–September of 2004	0.053–7.48 µg/L	Not reported	Detected in 10 of 10 finished water samples	USGS 2007
United States	Drinking water	2000–2004		1.0, 15.0, and 20.3 µg/L	Three locations were sampled weekly; it was found that all trihalomethanes were removed after heating the drinking water; faucet filters completely removed trihalomethanes and pitcher filters removed on average 40% of the trihalomethanes.	Savitz et al. 2006
India	Finished water	March 2009–June 2009		0.03–315 µg/L (median 12.40 µg/L)	Samples collected from water treatment plant endpoints at 11 locations	Basu et al. 2011
United States	Drinking/finished water	1991–2003		1.62 µg/L	Detected in 3 out of 34 tap water samples	FDA 2006
Italy	Italian tap water	Not specified (2005 or prior)	0.249 µg/L	Not reported	Not detected in Italian mineral water, contaminated mineral water, Italian superficial snow, or Antarctic superficial snow	Zoccolillo et al. 2005
Korea	Tap water	2009	Maximum 10.7 µg/L	6.1 µg/L (median 6.3 µg/L)	Detected in 100% of 770 tap water samples from six municipal water treatment plants using chlorination disinfection methods; highest concentrations were observed in the summer samples	Lee et al. 2013

Table 5-11. Drinking Water Monitoring Data for Bromodichloromethane

Location(s)	Type	Date(s)	Range	Mean concentration	Notes	Reference
United States	Drinking water	1988–1989	Seasonal medians 4.1–10 µg/L	Not reported	35 water utilities; 25 across the United States and 10 in California	Krasner et al. 1989
Canada	Drinking water	1976–1977	2.9 µg/L	Not reported	Reported concentration in winter samples from water supplies serving 38% of the population in 70 communities	WHO 2000
United States, Florida, Washington, Pennsylvania, Ohio, Michigan	Drinking water	1974–1986	Not detected–73 µg/L	1–20 µg/L		Coleman et al. 1975; EPA 1979; Furlong and D'itri 1986; Symons et al. 1975

Table 5-12. Swimming Pool Water Monitoring Data for Bromodichloromethane

Location(s)	Type	Date(s)	Range	Mean concentration	Notes	Reference
Miami, Florida	Saltwater and freshwater swimming pools	Not specified (1980 or prior)		13–34 µg/L		Beech et al. 1980
Poland, Italy, United States, Germany, Hungary, and the United Kingdom	Swimming pools	1981–2002	<0.1–150 µg/L	1.3–22.6 µg/L		WHO 2006
Not reported	Laboratory study of pool water		7.9 µg/L	Not reported	Concentration in groundwater control 4.4 µg/L	Kim et al. 2002
Portugal	Indoor swimming pools	April–November 2011	1–21.5 µg/L	Not reported	Detected in 99% of the pool water samples	Silva et al. 2012
Not reported	Swimming pools	February–August 2008	Specific concentrations of bromodichloro-methane were not reported, it was noted that its occurrence was sporadic compared with the other disinfection byproducts that appeared regularly in the samples	Not reported	Water was sampled 20–30 cm below pool surface	Weaver et al. 2009

5.5.3 Sediment and Soil

Little information was located regarding concentrations of bromodichloromethane in ambient soils. Because of its volatility, it is likely that bromodichloromethane would be present only at low levels in most soils.

Bromodichloromethane was detected in <1% of 705 soil samples taken from 30 industrial sites investigated in Taiwan. Sites included chemical and petrochemical industrial districts, technology industrial parks, general industrial districts, metal processing areas, oil refinery plants, pesticide manufacturing facilities, and landfills. Samples were collected via purge-and-trap techniques using EPA method 5035 (Kuo 2000).

5.5.4 Other Media

Bromodichloromethane is not a common contaminant of food, occurring only in trace quantities in some samples (trace quantities are concentrations above the method detection limit but below the method quantification limit).

A market basket study conducted by the U.S. Food and Drug Administration (FDA) in 1991–2003 evaluated over 400 food products (FDA 2006). Bromodichloromethane was detected in about 10% of the foods, mostly at trace levels. Data are provided in Table 5-13.

Table 5-13. Bromodichloromethane Detections in Food from the U.S. Food and Drug Administration (FDA) 1991–2003 Market Basket Survey

Food	Number of detections	Number of samples	Mean concentration (ppb)
Processed American cheese	1	44	0.07
Boiled beef/pork frankfurters	4	44	0.39
Beef/pork bolognas	2	44	0.43
Salami lunch meats	1	44	0.09
Popcorn popped in oil	1	40	0.13
Raw/frozen strawberry samples	1	43	0.07
Regular carbonated colas	4	44	0.43
Diet carbonated colas	4	44	0.36
Plain milk chocolate candy bars	1	44	0.09

Table 5-13. Bromodichloromethane Detections in Food from the U.S. Food and Drug Administration (FDA) 1991–2003 Market Basket Survey

Food	Number of detections	Number of samples	Mean concentration (ppb)
Light vanilla ice creams	3	44	0.16
Salted margarines	3	44	0.30
Salted butters	1	44	0.14
Baby food beef and gravy	1	44	0.07
Swiss cheeses	3	44	0.36
Cream cheese	1	44	0.09
Fast food chicken nuggets	3	44	0.23
Graham crackers	1	44	0.07
Fast food french fries	1	44	0.07
Fast food tacos with beef and cheese	1	44	0.09
Take out pizzas	1	44	0.11
Vanilla ice creams	5	44	0.34
Fruit sherbets	3	44	0.32
Fruit popsicles	6	44	0.50
Sour creams	4	44	0.30
Carbonated fruit drinks	3	44	0.43
Fast food chicken legs	1	4	0.75
Pan cooked catfish	1	4	0.75
Salted and roasted sunflower seeds	1	4	1.0
Bottled cranberry juice cocktails	1	4	1.75
Orange juices	1	4	0.75
Prepared potato salads	1	4	1.0
Prepared coleslaws	1	4	0.75
Fried eggs with added fat	1	40	0.33
Canned pork and bean samples	1	44	0.25
Creamy peanut butter	1	44	0.23
Homemade cornbread	1	44	0.30
Raw orange	1	44	0.32
Canned pineapple	1	44	0.32
Bottled apple juice	1	44	0.75
Fresh/frozen, boiled collards	1	44	0.32
Tomatoes	1	44	0.25
Green peppers	1	44	0.32
Fast food quarter-pound hamburgers on a bun	1	44	0.84

Table 5-13. Bromodichloromethane Detections in Food from the U.S. Food and Drug Administration (FDA) 1991–2003 Market Basket Survey

Food	Number of detections	Number of samples	Mean concentration (ppb)
Creamy low calorie salad dressing	1	4	2.5

Source: FDA 2006

A 5-year study of 70 foods was conducted from 1996 to 2000 using purge-and-trap methods (Fleming-Jones and Smith 2003). Forty-one of the foods had at least one detection of a volatile organic compound over 100 ppb. Bromodichloromethane was detected in 10 of these 41 foods at concentrations ranging from 3 to 5 ppb, with the expectation of the highest concentration found in 1 sample of cooked hamburger at 37 ppb. Data are provided in Table 5-14.

Table 5-14. Bromodichloromethane in Food

Food	Number of detections	Concentration ppb
American cheese	1	3
Fruit-flavored sherbet	1	3
Popsicle	1	3
Fast food french fries	1	3
Fast food chicken nuggets	1	3
Carbonated cola	2	3
Sour cream	1	4
Beef frankfurters	2	4–5
Popcorn popped in oil	1	5
Cooked hamburger	1	37

Source: Fleming-Jones and Smith 2003

Hiatt and Pia (2004) screened 35 milk samples from eight grocery stores in Las Vegas, Nevada in January and February 2002. Concentrations of bromodichloromethane were 0.02–0.30 µg/L in whole milk, 0.03–0.37 µg/L in 2% milk, and 0.04–0.14 µg/L in 1% milk.

A market basket study of 39 food items detected bromodichloromethane in one dairy composite at 1.2 ppb and in butter at 7 ppb (Entz et al. 1982). A study of bromodichloromethane in food processing water and processed foods revealed no detectable levels except in ice cream at one processing plant (0.6–2.3 ppt) (Uhler and Diachenko 1987). Soft drinks have been found to contain bromodichloromethane

(Abdel-Rahman 1982; Entz et al. 1982), but usually at concentrations (0.1–6 µg/L) below those found in municipal water supplies. Cooking foods in water containing bromodichloromethane is unlikely to lead to contamination, since bromodichloromethane would rapidly volatilize (Kool et al. 1981).

Bromodichloromethane is biosynthesized by marine macroalgae, and has been measured in these organisms at 7–22 ng/g dry weight (Gschwend and MacFarlane 1985). Whether bromodichloromethane enters and accumulates in the food chain from this source appears to be unlikely, but has not been studied.

Bromodichloromethane has been detected in the milk of rats at a concentration of 0.38 µg/g after exposure to 112 mg/kg-day, but was not detected in placentas, amniotic fluid, or fetal tissue collected on GD 21, nor plasma collected from postpartum day 29 weanling pups, after similar exposures (EPA 2005b). Bromodichloromethane was detected in one fetus and in the placentas of rabbits exposed to 76 mg/kg/day, but it was not detected in placentas of rabbits exposed to approximately 32 mg/kg/day, nor in amniotic fluid or the remaining fetuses from rabbits exposed to doses of approximately 76 mg/kg/day (EPA 2005b).

5.6 GENERAL POPULATION EXPOSURE

The general population can be exposed to bromodichloromethane via ingestion and dermal contact of water containing this chemical and also by inhalation of bromodichloromethane that has volatilized into air. Exposure may occur when people are involved in water-related actives such as showering, bathing, swimming pool activities, and washing dishes in water containing bromodichloromethane. Occupational exposure may occur via inhalation and dermal contact for individuals who work at swimming pools (e.g., lifeguards).

No studies were located examining the exposures of children to bromodichloromethane. Exposure will likely occur through inhalation, dermal contact, and, ingestion of water containing bromodichloro-methane. Exposures would be expected to vary depending on the amount of water consumed, the length of time a child spends doing water-related activities, and the quality of the water the child is exposed to.

The average exposures to bromodichloromethane for the general human population from surface water and groundwater systems have been estimated at 20 and 8.1 µg/person/day, respectively (EPA 2005b). The estimated exposure of the general human population to bromodichloromethane from ingesting drinking water containing bromodichloromethane, assuming a median bromodichloromethane

concentration of 1.4–2.1 µg/L (ppb) and a water intake for an adult of 2 L/day, would be 2.8–4.2 µg/day (EPA 2005b). Exposure can also occur by inhalation of bromodichloromethane volatilized from chlorinated water (e.g., while showering, cooking, or swimming), and by dermal contact with such water. In 67% of breath samples, collected from 11 subjects in Texas and North Carolina, bromodichloromethane concentrations ranged from 0.12 to 4.36 µg/m^3 (EPA 2005b). Based on a chemical structure analogy to chloroform, an estimated dermal exposure to bromodichloromethane in a child swimming 2 hours/day in a saline pool would typically be 0.003 mg/day, with a maximum of 0.04 mg/day (Beech et al. 1980). Higher exposure levels might occur through ingestion of water contaminated with bromodichloromethane near a waste site, but available data suggest that this is not a common occurrence.

The updated Fourth National Report on Human Exposure to Environmental Chemicals (CDC 2019) includes results from the assessment of bromodichloromethane levels in the National Health and Nutrition Examination Survey (NHANES) for blood samples from the U.S. general population surveyed during the years 2001–2016. As shown in Table 5-15, geometric mean bromodichloromethane levels were 2.21, 1.50, 1.41, 1.52, 1.61, and 1.34 pg/mL for the survey years 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012 respectively; in 2013–2014 and 2015–2016, geometric mean levels could not be calculated because the proportion of results below the limit of detection was too high to provide a valid result. The analytical method used for the analysis was gas chromatography with high-resolution mass spectrometry (Bonin et al. 2005). The limits of detection (LODs) for survey years 2001–2002, 2003–2004, 2005–2006 2007–2008, 2009–2010, 2011–2012, 2013–2014, and 2015–2016 are 0.233, 0.62, 0.62, 0.62, 0.62, 0.62, 6.00, and 6.00 pg/mL, respectively.

After activities such as bathing, showering, or swimming in chlorinated water, median blood levels of bromodichloromethane increased over baseline levels, and then returned to baseline during the next 1–2 hours following the end of the activity (Ashley et al. 2005; Lourencetti et al. 2010; Silva et al. 2013).

Ashley et al. (2005) and Gordon et al. (2006) investigated human exposure to bromodichloromethane via dermal, ingestion, and inhalation pathways. Activities included drinking a hot and cold beverage, showering/bathing in hot water, drinking 0.5 L of tap water, washing and drying a load of laundry, washing hands, running a dishwasher, and opening and removing dishes from a dishwasher, washing clothes with chlorine bleach, washing dishes by hand, and staying in a room adjoining an operating shower. These activities led to approximately a 3–4-fold increase in bromodichloromethane levels in the blood of the seven subjects following showering, bathing, or hand washing. Dermal exposure was cited

Table 5-15. Blood Bromodichloromethane Levels in the NHANES U.S. Population

	Survey years	Geometric mean (95% CI) (pg/mL)	Selected percentiles (95% confidence interval) (pg/mL)				Sample size
			50th	75th	90th	95th	
Total	2001–2002	2.21 (1.65–2.97)	2.30 (1.56–3.21)	4.63 (3.24–6.20)	8.45 (5.86–12.0)	12.0 (7.68–19.2)	785
	2003–2004	1.50 (1.20–1.86)	1.40 (1.10–1.90)	3.40 (2.60–4.20)	6.20 (5.30–7.00)	9.50 (7.00–12.0)	1,322
	2005–2006	1.41 (1.09–1.83)	1.30 (0.880–1.80)	3.00 (2.10–4.40)	6.30 (4.30–9.70)	10.0 (6.80–14.0)	3,139
	2007–2008	1.52 (1.24–1.86)	1.42 (1.05–1.90)	3.13 (2.50–4.20)	6.42 (4.70–8.30)	9.59 (7.05–14.6)	2,982
	2009–2010	1.61 (1.23–2.10)	1.44 (0.911–2.33)	3.84 (2.64–5.33)	7.89 (6.36–9.58)	12.0 (9.65–14.5)	3,275
	2011–2012	1.34 (1.07–1.67)	1.18 (0.817–1.66)	2.94 (2.07–3.92)	5.89 (4.32–8.29)	8.95 (6.35-13.5)	2,700
	2013–2014	*	<LOD	<LOD	7.00 (<LOD–8.00)	10.0 (8.00–11.0)	3,160
	2015–2016	*	<LOD	<LOD	9.00 (6.00–13.0)	13.0 (9.00–21.0)	3,077
Age group							
12–19 years	2005–2006	1.23 (0.954–1.58)	1.00 (0.620–1.60)	2.80 (1.70–4.10)	5.50 (4.10–7.20)	8.20 (6.20–12.0)	932
	2007–2008	1.49 (1.19–1.86)	1.26 (0.910–1.88)	3.10 (2.42–4.05)	6.20 (4.13–8.52)	9.02 (6.20–15.0)	482
	2009–2010	1.42 (0.912–2.34)	3.84 (2.65–5.82)	8.41 (5.45–12.7)	8.41 (5.45–12.7)	13.0 (8.78–18.0)	558
	2011–2012	*	0.956 (<LOD–1.21)	2.03 (1.51–3.00)	4.19 (3.06–6.62)	9.06 (6.49–13.7)	507
	2013–2014	*	<LOD	<LOD	<LOD	9.00 (6.00–10.0)	594
	2015–2016	*	<LOD	<LOD	6.00 (<LOD–10.0)	9.00 (<LOD–15.0)	543
20–59 years	2001–2002	2.21 (1.65–2.97)	2.30 (1.56–3.21)	4.63 (3.24–6.20)	8.45 (5.86–12.0)	12.0 (7.68–19.2)	785
	2003–2004	1.50 (1.20–1.86)	1.40 (1.10–1.90)	3.40 (2.60–4.20)	6.20 (5.30–7.00)	9.50 (7.00–12.0)	1,322
	2005–2006	1.45 (1.11–1.89)	1.30 (0.900–1.90)	3.10 (2.10–4.60)	6.40 (4.30–10.0)	11.0 (6.90–14.0)	1,537
	2007–2008	1.60 (1.28–2.01)	1.56 (1.13–2.04)	3.33 (2.61–4.43)	6.90 (4.94–9.29)	11.0 (7.39–15.6)	1,607
	2009–2010	1.67 (1.24–2.26)	1.53 (0.893–2.56)	4.07 (2.66–5.85)	8.47 (6.66–10.2)	13.0 (10.1–16.2)	1,797
	2011–2012[a]	1.38 (1.09–1.075)	1.22 (0.862–1.82)	2.91 (2.08–3.88)	6.00 (4.35–8.62)	9.06 (6.49–13.7)	2,196
	2013–2014[a]	*	<LOD	<LOD	7.00 (<LOD–9.00)	10.0 (8.00–12.0)	2,566
	2015–2016[a]	*	<LOD	<LOD	9.00 (6.00–14.0)	15.0 (10.0–19.0)	2,534
≥60 years	2005–2006	1.43 (0.996–2.05)	1.40 (0.850–2.00)	3.20 (1.60–5.90)	6.50 (3.20–15.0)	9.70 (5.00–18.0)	670
	2007–2008	1.28 (1.07–1.53)	1.20 (0.870–1.59)	2.60 (1.90–3.41)	4.88 (3.67–6.50)	7.39 (5.70–8.80)	893
	2009–2010	1.41 (1.13–1.78)	1.33 (0.851–1.86)	3.25 (2.39–4.25)	6.07 (5.07–7.59)	8.42 (6.95–11.6)	920

Table 5-15. Blood Bromodichloromethane Levels in the NHANES U.S. Population

	Survey years	Geometric mean (95% CI) (pg/mL)	Selected percentiles (95% confidence interval) (pg/mL)				Sample size
			50th	75th	90th	95th	
Sex							
Males	2001–2002	2.19 (1.60–3.00)	2.31 (1.63–3.21)	4.64 (3.21–6.08)	7.96 (5.74–15.3)	13.0 (6.93–20.5)	382
	2003–2004	1.48 (1.18–1.85)	1.40 (0.940–2.00)	3.40 (2.60–4.30)	6.60 (5.40–7.20)	11.0 (7.20–14.0)	650
	2005–2006	1.39 (1.07–1.80)	1.20 (0.830–1.70)	3.00 (2.00–4.30)	6.50 (4.30–10.0)	11.0 (6.80–16.0)	1,489
	2007–2008	1.52 (1.24–1.87)	1.50 (1.03–1.95)	3.23 (2.59–4.20)	6.72 (4.80–9.02)	11.0 (7.31–15.9)	1,487
	2009–2010	1.48 (1.18–1.85)	1.41 (0.861–2.23)	3.79 (2.46–5.62)	8.32 (6.36–10.6)	13.0 (10.1–17.2)	1,616
	2011–2012	1.33 (1.06–1.67)	1.17 (0.756–1.69)	2.91 (2.08–3.88)	5.92 (4.48–8.29)	9.17 (6.65–13.3)	1,363
	2013–2014	*	<LOD	<LOD	7.00 (<LOD–9.00)	10.0 (8.00–12.0)	1,523
	2015–2016	*	<LOD	<LOD	9.00 (6.00–14.0)	14.0 (9.00–21.0)	1,523
Females	2001–2002	2.24 (1.66–3.01)	2.28 (1.49–3.24)	4.63 (3.09–7.01)	8.62 (5.26–12.9)	11.1 (7.68–25.0)	403
	2003–2004	1.51 (1.21–1.90)	1.50 (1.10–1.90)	3.30 (2.50–4.20)	6.10 (4.69–7.30)	7.80 (6.40–12.0)	672
	2005–2006	1.44 (1.10–1.88)	1.30 (0.900–1.90)	3.10 (2.10–4.60)	6.20 (4.20–9.40)	9.40 (6.30–13.0)	1,650
	2007–2008	1.51 (1.22–1.87)	1.40 (1.01–1.92)	3.03(2.42–4.10)	6.20 (4.60–7.82)	8.31 (6.80–12.9)	1,495
	2009–2010	1.62 (1.24–2.16)	1.53 (0.946–2.46)	3.92 (2.79–5.19)	7.67 (6.22–9.28)	11.2 (8.99–13.9)	1,659
	2011–2012	1.35 (1.06–1.67)	1.22 (0.828–1.70)	2.94 (1.96–4.06)	5.87 (4.05–8.63)	8.63 (5.87–13.3)	1,337
	2013–2014	*	<LOD	<LOD	6.00 (<LOD–8.00)	9.00 (7.00–11.0)	1,637
	2015–2016	*	<LOD	<LOD	8.00 (<LOD–13.0)	13.0 (7.00–21.0)	1,554
Race/ethnicity							
Mexican Americans	2001–2002	3.28 (2.29–4.68)	3.32 (2.19–4.70)	6.81 (3.71–10.4)	10.8 (8.24–14.7)	14.7 (11.1–20.5)	227
	2003–2004	1.65 (1.15–2.38)	1.60 (0.820–2.80)	3.50 (2.60–4.90)	7.30 (4.50–10.0)	10.0 (7.30–11.0)	244
	2005–2006	1.95 (1.19–3.18)	1.90 (1.00–3.70)	4.40 (2.10–9.10)	9.10 (4.80–17.0)	14.0 (7.50–22.0)	771
	2007–2008	1.61 (1.27–2.03)	1.57 (1.08-2.20)	3.44 (2.42–4.50)	5.93 (4.70-8.15)	8.90 (6.80-13.2)	574
	2009–2010	2.19 (1.37–3.49)	2.18 (1.10–4.16)	5.50 (3.20–8.98)	11.3 (6.59–19.5)	16.2 (11.2–22.5)	667
	2011–2012	1.53 (1.16–2.04)	1.19 (0.761–2.16)	3.44 (2.41–5.20)	9.06 (5.21–15.4)	15.9 (6.55–40.0)	298
	2013–2014	*	<LOD	<LOD	<LOD	10.0 (<LOD–14.0)	500
	2015–2016	*	<LOD	<LOD	9.00 (7.00–12.0)	13.0(9.00–17.0)	552
Non-Hispanic blacks	2001–2002	2.32 (1.82–2.94)	2.50 (1.56–3.55)	4.57 (3.60–5.56)	8.69 (5.63–9.49)	10.0 (5.89–13.5)	130
	2003–2004	1.56 (1.15–2.13)	1.70 (1.10–2.20)	2.90 (2.15–3.80)	5.10 (3.80–6.60)	6.60 (4.90–13.0)	290
	2005–2006	1.74 (1.27–2.37)	1.70 (1.00–2.70)	3.80 (2.70–4.80)	6.40 (4.50–8.90)	8.70 (6.60–11.0)	817
	2007–2008	1.72 (1.42–2.08)	1.70 (1.30–2.21)	3.29 (2.80–4.01)	5.78 (4.70–7.30)	7.49 (6.03–9.70)	593
	2009–2010	1.97 (1.50–2.58)	1.99 (1.41–2.53)	3.76 (2.55–5.82)	7.70 (5.35–10.2)	10.5 (8.52–13.4)	579
	2011–2012	1.84 (1.09–3.12)	1.72 (0.734–3.80)	4.48 (2.11–8.95)	9.60 (5.03–15.2)	13.0 (8.47–22.3)	712
	2013–2014	*	<LOD	<LOD	7.00 (<LOD–10.0)	9.00 (8.00–11.0)	603
	2015–2016	*	<LOD	<LOD	7.00 (<LOD–13.0)	11.0 (6.00–18.0)	639

Table 5-15. Blood Bromodichloromethane Levels in the NHANES U.S. Population

	Survey years	Geometric mean (95% CI) (pg/mL)	Selected percentiles (95% confidence interval) (pg/mL)				Sample size
			50th	75th	90th	95th	
Non-Hispanic whites	2001–2002	2.02 (1.42–2.87)	2.16 (1.36–3.09)	4.34 (2.92–6.01)	7.33 (4.72–15.3)	11.1 (6.01–26.1)	365
	2003–2004	1.42 (1.11–1.81)	1.30 (0.850–1.90)	3.30 (2.30–4.40)	6.20 (5.20–7.20)	9.80 (6.70–13.0)	684
	2005–2006	1.29 (0.989–1.67)	1.10 (0.710–1.70)	2.70 (1.80–4.10)	5.80 (4.00–8.60)	9.40 (6.20–14.0)	1,318
	2007–2008	1.45 (1.11–1.87)	1.32 (0.917–1.90)	3.03 (2.23–4.30)	6.50 (4.20–9.29)	9.59 (6.30–15.3)	1,347
	2009–2010	1.46 (1.06–2.02)	1.25 (06.73–2.30)	3.59 (2.22–5.37)	7.28 (5.51–9.28)	10.9 (8.50–14.3)	1,470
	2011–2012	1.18 (0.909–1.53)	1.03 (<LOD–1.51)	2.55 (1.65–3.42)	4.83 (3.26–6.95)	7.54 (4.79–12.6)	933
	2013–2014	*	<LOD	<LOD	7.00 (<LOD–10.0)	9.00 (8.00–11.0)	1,288
	2015–2016	*	<LOD	<LOD	9.00 (<LOD–15.0)	14.0 (8.00–21.0)	999
All Hispanics	2011–2012	1.70 (1.39–2.08)	1.52 (1.11–2.16)	3.66 (2.86–4.69)	8.08 (5.98–9.67)	12.9 (7.51–22.1)	587
	2013–2014	*	<LOD	<LOD	7.00 (<LOD–10.0)	11.0 (8.00–14.0)	798
	2015–2016	*	<LOD	<LOD	9.00 (7.00–12.0)	13.0 (9.00–17.0)	964
Asians	2011–2012	1.49 (1.20–1.84)	1.43 (0.998–1.96)	3.04 (2.39–4.11)	5.23 (4.63–6.51)	7.44 (5.99–9.64)	388
	2013–2014	*	<LOD	<LOD	9.00 (<LOD–12.0)	12.0 (9.00–15.0)	361
	2015–2016	*	<LOD	<LOD	9.00 (6.00–13.0)	14.0 (12.00–15.0)	349

[a]Values for participants 20+ years of age.

*= geometric mean not calculated because the proportion of results below the limit of detection (0.62 in 2011–2012 and 6.00 pg/mL in 2013–2014 and 2015 and 2016) was too high to provide a valid result; LOD = limit of detection; NHANES = National Health and Nutrition Examination Survey

Source: CDC 2019; https://www.cdc.gov/exposurereport/pdf/FourthReport_UpdatedTables_Volume1_Jan2019-508.pdf

as the primary route of exposure during bathing, while inhalation played a stronger role during showering (Gordon et al. 2006).

Tables 5-16, 5-17, and 5-18 contain available human blood, breath, and urine concentrations of bromodichloromethane resulting from exposure to this substance via water-related activities.

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

The environmental medium most likely to be contaminated with bromodichloromethane is chlorinated water, so any person with above-average contact with such water could have above-average exposures. This includes individuals who drink very large quantities of water. It may also include persons with swimming pools or saunas, where exposure could occur by inhalation (especially if the pool or sauna is indoors) or by dermal contact. Since bromodichloromethane levels depend on the organic content of the source water before chlorination, persons whose water source is high in organics are likely to have finished water with higher-than-average bromodichloromethane levels.

People working in chemical plants or laboratories where bromodichloromethane is made or used would also have potentially high exposures to the chemical, most likely by inhalation exposure. Persons living near waste sites may have potentially high exposure to bromodichloromethane, but this can only be evaluated on a case-by-case basis.

People working at and using chlorinated swimming pools (especially indoor pools), such as lifeguards, pool and/or water venue operators, and regular or professional/athletic swimmers, may be exposed to bromodichloromethane more often than the general population (Fantuzzi et al. 2001; Lindstrom et al. 1997).

Table 5-16. Exposure and Blood Concentrations

Population and exposure scenario	Study date	Average media concentration	Average blood concentration before activity	Average blood concentration during activity	Average blood concentration after activity	Reference
100 subjects, ages 18–45; 10-minute controlled shower[a]	2004	70.9–74.3 µg/m^3 (shower air); 19.9 µg/L (shower water)	0.00225 µg/L (2.25 ng/L)	0.0648 µg/L (64.8 ng/L) (10 minutes after shower)	0.0326 µg/L (32.6 ng/L) (30 minutes after shower)	Silva et al. 2013
7 subjects, ages 21–30; hot water shower	Not reported	8.0–46.4 µg/L (tap water)	Not reported	25.5–95.2 ng/L (5 minutes after shower)	Not reported	Ashley et al. 2005
7 subjects, ages 21–30; hot water bath	Not reported	6.3–33.0 µg/L (tap water)	Not reported	26.0–64.7 ng/L (5 minutes after bath)	Not reported	Ashley et al. 2005
150 women; showering/bathing, bathing children, postshower/ bathroom time, washing dishes by hand, and swimming in summer	Not reported	1.3–12.2 µg/L (water)	1.1–4.7 ng/L[b]			Rivera-Núñez et al. 2012
150 women; showering/bathing, bathing children, postshower/ bathroom time, washing dishes by hand, and swimming in winter	Not reported	6.0–7.3 µg/L (water)	2.1–5.6 ng/L[b]			Rivera-Núñez et al. 2012
150 women; ingestion of water; showering/bathing, bathing children, postshower/bathroom time, washing dishes by hand, and swimming	Not reported	6.3–8.5 µg/L (yearly average water)		2.0–3.3 ng/L		Rivera-Núñez et al. 2012
150 women; non-ingestion of water; showering/bathing, bathing children, postshower/bathroom time, washing dishes by hand, and swimming	Not reported	6.3–8.5 µg/L (yearly average water)		2.3–2.6 ng/L		Rivera-Núñez et al. 2012
31 adult subjects; drinking tap water	Not reported	5.52 µg/L	2.6 pg/mL	3.8 pg/mL (10 minutes after drink)	2.8 pg/mL (60 minutes after drink)	Backer et al. 2000

Table 5-16. Exposure and Blood Concentrations

Population and exposure scenario	Study date	Average media concentration	Average blood concentration before activity	Average blood concentration during activity	Average blood concentration after activity	Reference
31 adult subjects; bathing	Not reported	6.22 µg/L	2.3 pg/mL	17.0 pg/mL (10 minutes after bath)	9.9 pg/mL (30 minutes after bath)	Backer et al. 2000
31 adult subjects; showering	Not reported	6.27 µg/L	3.3 pg/mL	19.4 pg/mL (10 minutes after shower)	10.3 pg/mL (30 minutes after shower)	Backer et al. 2000
50 females; showering	1999	12.2–13.5 ppb (µg/L) (median house water concentrations)	6.2–6.8 ppb (µg/L)	Not reported	38–43 ppb (µg/L)	Lynberg et al. 2001

[a]40°C shower temperature and a water flow rate between 5.6 and 6.7 L/minute; average concentration of bromodichloromethane in shower water.
[b]Average concentration throughout specified season.

Table 5-17. Exposure and Breath (Alveolar Air) Concentrations

Population and exposure scenario	Average media concentration	Average breath concentration before activity	Average breath concentration during activity	Average breath concentration after activity	Reference
9 subjects ages 22–37; 10-minute controlled shower	1.9 µg/L (shower water) 1.1 µg/m^3 (shower air)	0.1 µg/m^3		1.3 µg/m^3	Lourencetti et al. 2010
11 subjects; 40-minute swim indoor pool	1.9 µg/L (pool water) 1.1 µg/m^3 (pool air)	0.1 µg/m^3		1.8 µg/m^3	Lourencetti et al. 2010
Swimmers exposed under training conditions for 2 hours using indoor pool	2.68 µg/m^3 (pool air)	Not reported; <2.68 µg/m^3	3–3.2 µg/m^3 (1 hour into activity); 4.5–5.5 µg/m^3 (2 hours into activity)	2 µg/m^3 (outside for 10 minutes); <1 µg/m^3 (outside for 55 minutes)	Lindstrom et al. 1997
32 subjects working at public indoor pools	2–5.3 µg/L (pool water); 8.7, 3.5, and 2.9 µg/m^3 (poolside, reception area, and engine room)		0.3–9.5 µg/m^3 (average concentrations during work day)		Fantuzzi et al. 2001

Table 5-18. Exposure and Urine Concentrations

Population and exposure scenario	Average media concentration	Average urine concentration before activity	Average urine concentration at end of exposure	Average urine concentration postexposure	Reference
14 male and female indoor swimming pool workers ages 23–50; 2–4-hour work shifts	2.2 µg/L (2,200 ng/L) (pool water)	18–23 ng/L (mean 20 ng/L)	23.9 ng/L (2 hour shift) 26.9 ng/L (4 hour shift)		Caro and Gallego 2007
1 indoor swimming pool worker; 2-hour work shift	2.2 µg/L (2,200 ng/L) (pool water)	20 ng/L	40 ng/L	20 ng/L (120 minutes after exposure)	Caro and Gallego 2007
10 swimmers using indoor pool ages 23–50; 2 times/week 1 hour swimming	2.2 µg/L (2,200 ng/L) (pool water)	21.0 ng/L	70.4 ng/L (at the end of 1 hour)		Caro and Gallego 2007
1 swimmer using indoor pool; 2 times/week 1 hour swimming	2.2 µg/L (2,200 ng/L) (pool water)	20 ng/L	80 ng/L (at the end of 1 hour)	20 ng/L (180 minutes after exposure)	Caro and Gallego 2007