6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

1,2,3-Trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene have been identified in 31, 187, and 4 of the 1,699 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2007). However, the number of sites evaluated for trichlorobenzenes is not known. The frequency of these sites can be seen in Figures 6-1, 6-2, and 6-3.

Trichlorobenzenes can be released to the environment from their production and use as solvents, dye carriers and chemical intermediates (Rossberg et al. 2006). They are also formed unintentionally during the combustion of organic materials when chlorine is present and from the degradation of higher chlorinated benzenes, such as tetrachlorobenzene, pentachlorobenzene, and hexachlorobenzene, or the degradation of the pesticide, lindane (γ-hexachlorocyclohexane). Since trichlorobenzenes are minor impurities in mono- and dichlorobenzene; their production and use may also result in the release of trichlorobenzenes to the environment. At one time, mixed isomers of trichlorobenzene were used for the control of termites around the foundations of buildings, which also led to their direct release into the environment. Trichlorobenzenes are volatile substances; consequently, they partition to the atmosphere and are frequently detected in ambient air samples. In addition to being detected in air, trichlorobenzenes have been identified in water, soil, sediment, plants, fish, animals, and food samples. It is often difficult to determine whether levels monitored in environmental samples arise from the direct release of trichlorobenzenes or their unintentional formation from other processes.

1,2,4-Trichlorobenzene is one of 188 chemicals that is designated as a hazardous air pollutant (HAP) under the Clean Air Act. Monitoring data from 2008 indicate that average atmospheric levels in the United States are typically <1 ppbv; however, maximum levels >3 ppbv have been observed (EPA 2010a). In the atmosphere, trichlorobenzenes exist primarily in the vapor phase. Vapor-phase trichlorobenzenes are removed from air by reacting with photochemically produced hydroxyl radicals. The half-life for this reaction is approximately 16–38 days, suggesting that they are susceptible to long-range atmospheric transport.

Trichlorobenzenes volatilize from water surfaces; however, they also tend to adsorb to suspended solids in the water column and partition to sediment, which attenuates the rate at which volatilization occurs.

Figure 6-1. Frequency of NPL Sites with 1,2,3-Trichlorobenzene Contamination

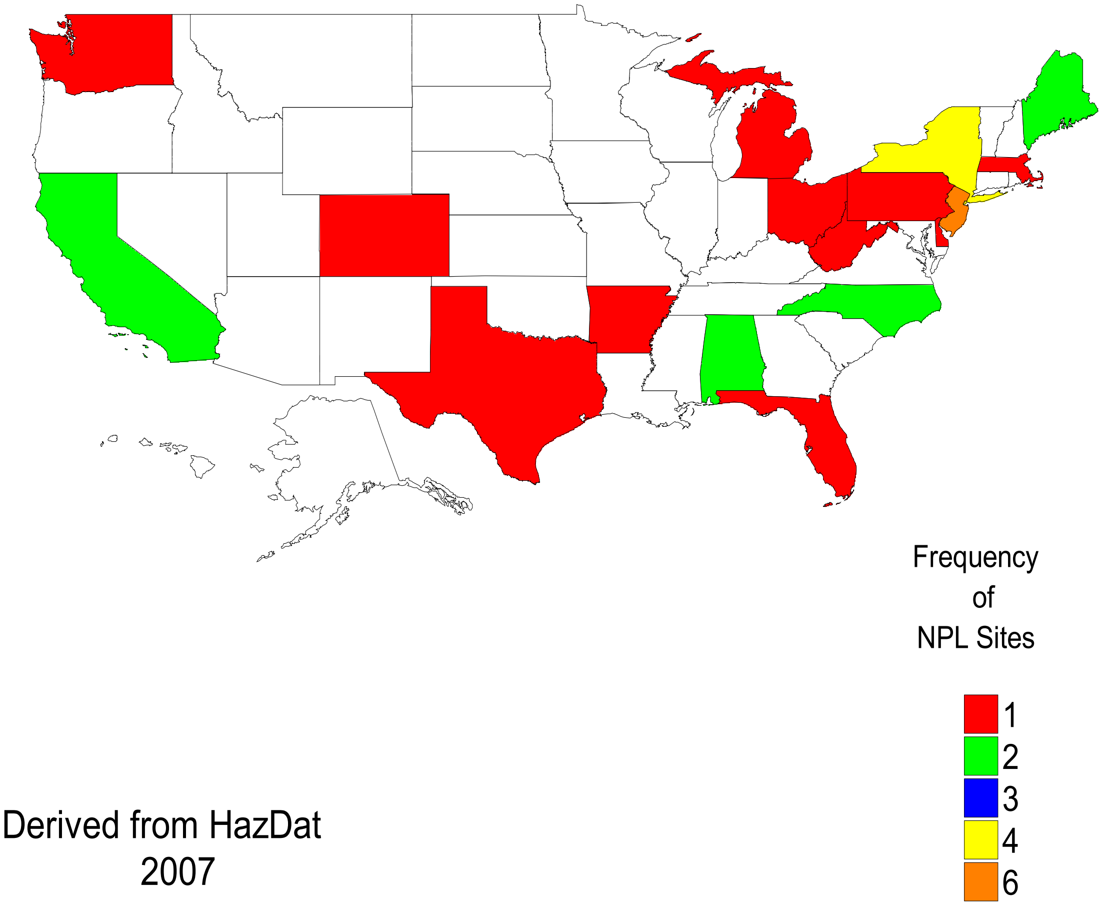
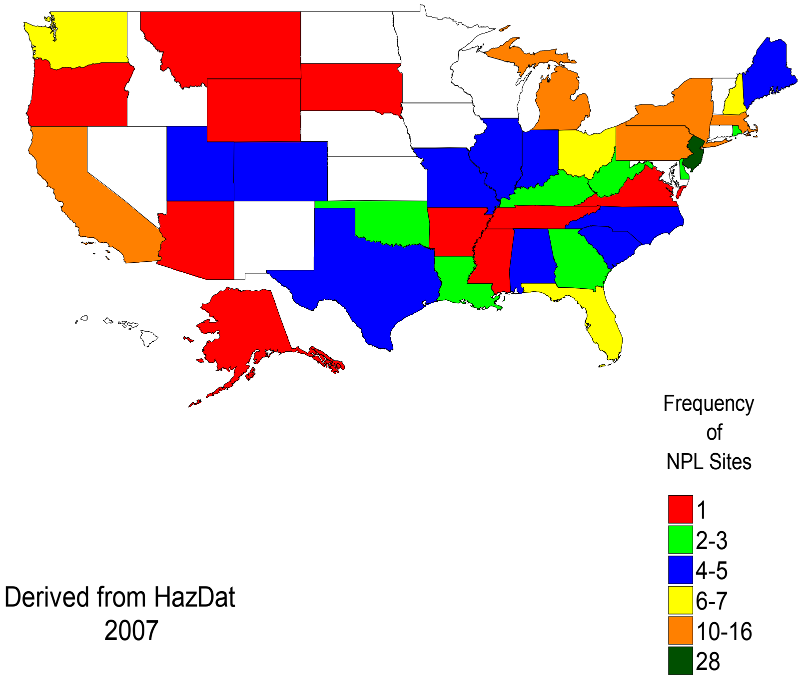
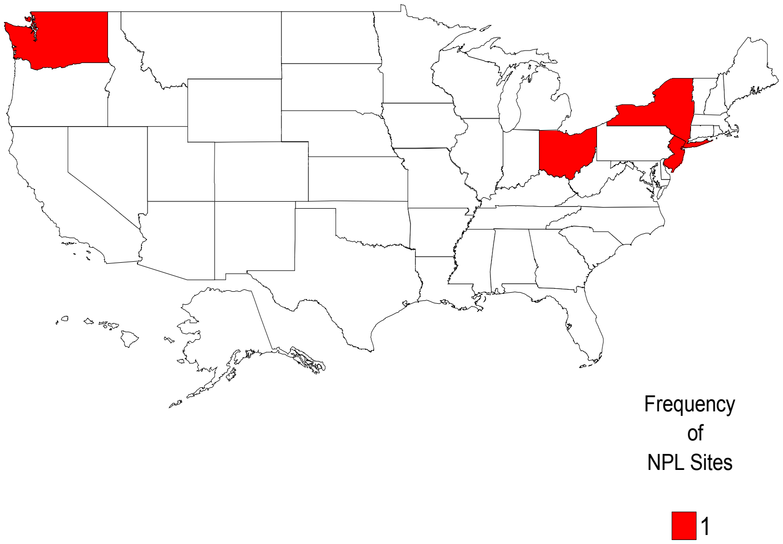


Figure 6-2. Frequency of NPL Sites with 1,2,4-Trichlorobenzene Contamination



Derived from HazDat
2007

Figure 6-3. Frequency of NPL Sites with 1,3,5-Trichlorobenzene Contamination



Derived from HazDat
2007

The rate of hydrolysis and biodegradation is generally considered slow under environmental conditions. These substances have the potential to bioconcentrate in fish and other aquatic species. Trichlorobenzenes have been detected in surface water, groundwater, and drinking water sources near hazardous waste sites or industrialized areas that produce chlorinated substances. Levels are typically in the parts per trillion (ng/L) range in surface water and drinking water, but vary based on location and emission sources. Trichlorobenzenes have low mobility in soil and typically do not leach into groundwater unless there is a large spill to a soil surface. 1,2,3-Trichlorobenzene and 1,2,4-trichlorobenzene were not detected in an analyses of groundwater samples collected at about 2,400 domestic wells and about 1,100 public wells in a monitoring program conducted by the United States Geological Survey (USGS) to assess groundwater quality in major aquifers in the United States (USGS 2006). However, 1,2,4-trichlorobenzene was detected in groundwater in the ppm range at superfund sites where chlorinated substances were used and disposed of (Carmichael et al. 1999; EPA 1976).

Volatilization is expected to be an important environmental fate process for trichlorobenzenes released to soil; however, adsorption may reduce the rate at which trichlorobenzenes evaporate from soil surfaces. Trichlorobenzenes biodegrade slowly in soils under aerobic conditions, but undergo reductive dechlorination under methanogenic conditions, yielding lower chlorinated species (monochlorobenzene and dichlorobenzenes).

Exposure of the general population to trichlorobenzenes is possible through inhalation of ambient air and ingestion of contaminated food and water. The average daily intake (AVDI) of 1,2,4-trichlorobenzene was estimated to range from 3.34×10^{-5} to 0.0715 mg/kg/day, with ingestion of root crops, fish, and drinking water identified as the primary exposure routes (European Communities 2003). Occupational exposure to trichlorobenzenes is possible through inhalation and dermal contact at workplaces where these substances are manufactured and used.

6.2 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 2005b). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ 10 or more 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 2005b).

6.2.1 Air

Estimated releases of 7,110 pounds (~3.2 metric tons) of 1,2,4-trichlorobenzene to the atmosphere from 14 domestic manufacturing and processing facilities in 2012, accounted for about 82% of the estimated total environmental releases from facilities required to report to the TRI (TRI12 2013). These releases are summarized in Table 6-1. There is no information on releases of 1,2,3-trichlorobenzene and 1,3,5-trichlorobenzene to the atmosphere from manufacturing and processing facilities because these releases are not required to be reported (EPA 1998c).

Section 112 of the Clean Air Act (CAA) lists 1,2,4-trichlorobenzene as one of 188 hazardous air pollutants (HAPs) known to cause or suspected of causing cancer or other serious human health effects or ecosystem damage (EPA 2000b). EPA's National Emission Inventory (NEI) database contains detailed information about sources that emit criteria air pollutants and their precursors, and HAPs for the 50 United States, Washington DC, Puerto Rico, and the U.S. Virgin Islands (prior to 1999, criteria pollutant emission estimates were maintained in the National Emission Trends [NET] database and HAP emission estimates were maintained in the National Toxics Inventory [NTI] database). The NEI database derives emission data from several sources including state and local environmental agencies, the TRI database, computer models for on-road and off-road emissions, and databases related to EPA's Maximum Achievable Control Technology (MACT) programs to reduce emissions of hazardous air pollutants. Table 6-2 provides emissions data for 1,2,4-trichlorobenzene obtained from the NEI in 2005. The total emissions of 1,2,4-trichlorobenzene in 2005 are significantly lower than total emissions from previous years. According to the National-Scale Air Toxic Assessment that used data from the NEI, total emissions of 1,2,4-trichlorobenzene were approximately 264 tons in 2002. Using composite data from the NTI database from 1990 to 1993, it was estimated that the annual emissions of 1,2,4-trichlorobenzene in the United States was nearly 6,000 tons per year during that time frame (EPA 2000b).

Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use 1,2,4-Trichlorobenzene[a]

		Reported amounts released in pounds per year[b]							
							Total release		
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
AL	2	10	0	0	0	0	10	0	10
GA	1	44	0	0	0	0	44	0	44
KY	1	0	0	0	0	0	0	0	0
LA	2	16	0	0	17	0	16	17	33
MI	1	77	0	0	0	0	77	0	77
OH	2	6,573	0	0	21	250	6,573	271	6,844
PA	2	23	0	0	250	0	23	250	273
TX	3	367	0	1,070	1	0	1,438	0	1,438
Total	14	7,110	0	1,070	289	250	8,181	538	8,719

[a] The 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.

[b] Data in TRI are maximum amounts released by each facility.

[c] Post office state abbreviations are used.

[d] Number of reporting facilities.

[e] The sum of fugitive and point source releases are included in releases to air by a given facility.

[f] Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).

[g] Class I wells, Class II-V wells, and underground injection.

[h] Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other on-site landfills, land treatment, surface impoundments, other land disposal, other landfills.

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

[j] The sum of all releases of the chemical to air, land, water, and underground injection wells.

[k] Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI12 2013 (Data are from 2012)

Table 6-2. Emissions of 1,2,4-Trichlorobenzene in 2011

Emission category	Annual emissions (pounds)
Fuel combustion, all processes	4,644.16
Industrial process, transferal categories	208,646.24
Solvent, all categories	199.04
Waste disposal	3,789.73
Total	**217,279.20**

Source: EPA 2014

Trichlorobenzenes are also indirectly released to air from combustion processes, such as those that might occur at hazardous waste incinerators. The European Union Risk Assessment for 1,2,4-Trichlorobenzene (European Communities 2003) summarized several combustion experiments, which resulted in the formation of trichlorobenzenes. Plastic waste, including polyethylene and polyvinyl chloride (PVC), was burned in a laboratory scale rotary kiln simulator. Combustion at temperatures exceeding 1,066°C and excess air resulted in the formation of dichlorobenzenes, trichlorobenzenes, pentachlorobenzene, and hexachlorobenzene when polyethylene and PVC were burned together. No chlorinated aromatics were formed, when polyethylene was burned alone. No higher chlorinated (>2) benzenes were formed, when PVC was burned alone (European Communities 2003).

1,2,4-Trichlorobenzene was detected in air samples at nine current or former NPL hazardous waste sites where it was detected in some environmental media (HazDat 2007). The other two isomers, 1,2,3-trichlorobenzene and 1,3,5-trichlorobenzene, were not detected in air samples at any of the current or former NPL hazardous waste sites.

6.2.2 Water

There were no estimated releases of 1,2,4-trichlorobenzene to surface water from facilities required to report to the TRI (TRI12 2013). There is no information on releases of 1,2,3-trichlorobenzene and 1,3,5-trichlorobenzene to the water from manufacturing and processing facilities because these releases are not required to be reported (EPA 1998c).

1,2,3-Trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene were detected in waste water effluents from treatment plants located along the Niagara River and Grand River in Western, New York at mean concentrations of 2, 11, and 0.3 ng/L, respectively (Oliver and Nicol 1982). 1,2,4-Trichlorobenzene was detected in the industrial effluents of 10 out of 114 industrial sites monitored in the Rhône-Alpes region in France in 1993 (European Communities 2003). Measured levels in these effluents ranged from 9 μg/L (paint manufacturing plant) to 6,150 μg/L (textile dying facility).

1,2,3-Trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene were detected in groundwater samples at 20, 114, and 2 current or former NPL hazardous waste sites, respectively, where they were detected in some environmental media (HazDat 2007). 1,2,4-Trichlorobenzene was detected in surface water samples at 18 NPL hazardous waste sites where it was detected in some environmental media

(HazDat 2007). The other two isomers, 1,2,3-trichlorobenzene and 1,3,5-trichlorobenzene, were not detected in surface water samples at any of the NPL hazardous waste sites.

6.2.3 Soil

Estimated releases of 289 pounds of 1,2,4-trichlorobenzene to soils from 14 domestic manufacturing and processing facilities in 2012, accounted for ~3% of the estimated total environmental releases from facilities required to report to the TRI (TRI12 2013). An additional 1,070 pounds (~0.5 metric tons), constituting about 12% of the total environmental emissions, were released via underground injection (TRI12 2013). These releases are summarized in Table 6-1. There is no information on releases of 1,2,3-trichlorobenzene and 1,3,5-trichlorobenzene to the soil from manufacturing and processing facilities because these releases are not required to be reported (EPA 1998c).

The reductive dechlorination of highly chlorinated benzenes, such as tetrachlorobenzene, pentachlorobenzene, and hexachlorobenzene, results in the formation of trichlorobenzenes in soils and sediment. In addition, the degradation of the pesticide, lindane, has also been demonstrated to result in the formation of 1,2,4-trichlorobenzene (Bharati et al. 1998; Nagpal and Paknikar 2006). Hexachlorobenzene was dechlorinated to tri- and dichlorobenzenes in anaerobic sewage sludge within a three-week incubation period (Fathepure et al. 1988). Greater than 90% of the added hexachlorobenzene was recovered as 1,3,5-trichlorobenzene, and there was no evidence for further dechlorination of 1,3,5-trichlorobenzene The former use of trichlorobenzenes as a soil treatment to control termite damage around the foundation of buildings also released these compounds directly to the environment; however, the quantitative amount released from this former use is unknown.

1,2,3-Trichlorobenzene, 1,2,4-trichlorobenzene and 1,3,5-trichlorobenzene were detected in soil samples at 17, 125, and 1 current or former NPL hazardous waste sites, respectively where they were detected in some environmental media (HazDat 2007). 1,2,3-Trichlorobenzene was detected in sediment samples at 1 NPL site and 1,2,4-trichlorobenzene was detected in sediment samples at 34 NPL sites. 1,3,5-Trichlorobenzene was not detected in sediment samples at any of the current or former NPL hazardous waste sites.

6.3 ENVIRONMENTAL FATE

6.3.1 Transport and Partitioning

All three isomers of trichlorobenzene possess vapor pressures and Henry's Law constants (see Table 4-2) that suggest a tendency for these compounds to partition into the atmosphere where they will exist predominantly in the vapor phase. In the atmosphere, trichlorobenzenes have fairly long half-lives and therefore, may be subject to long-range atmospheric transport.

Trichlorobenzenes are expected to possess low mobility in soil given their soil adsorption coefficients. The soil adsorption coefficient (K_{oc}) measured in the upper horizon (0–28 cm depth) of a sandy forest soil obtained from North Carolina (91% sand, 8.4% silt, 0.6% clay) was 2,850 (Njoroge et al. 1998). The K_{oc} value of 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene have been also reported as 1,622 (log K_{oc} 3.21), 10,715 (log K_{oc} 4.03), and 4,898 (log K_{oc} 3.69), respectively (Beck et al. 1995).

Laboratory and field studies demonstrated that volatilization is an important environmental fate process for trichlorobenzenes released to surface water (Wakeham et al. 1983a, 1983b). Volatilization half-lives ranged from approximately 11 days (summer-time conditions) to 22 days (spring-time conditions) for 1,2,4-trichlorobenzene in mesocosm experiments used to simulate ecosystem conditions of Narragansett Bay, Rhode Island (Wakeham et al. 1983a). Trichlorobenzenes are hydrophobic substances that are expected to adsorb to suspended solids and sediment in natural waters. Using water and sediment from the Niagara River, the sediment-water adsorption coefficient of 1,2,4-trichlorobenzene was measured to range from 63,096 to 199,526 (log K_{oc} 4.8–5.3) (Oliver 1987). Other studies have also indicated that trichlorobenzenes adsorb strongly to sediment in the water column. Jonker and Smedes (2000) measured the log K_{oc} values of 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene as 5.79, 6.12, and 5.96, respectively, using water and sediment (0–30 cm depth) from Lake Ketelmeer, the Netherlands. The log K_{oc} values were reported as 5.56 (1,2,3-trichlorobenzene), 5.50 (1,2,4-trichlorobenzene), and 5.36 (1,3,5-trichlorobenzene) using sediment from a deeper (40–120 cm) layer. The rate of adsorption to sediment as well as the extent to which adsorption takes place within the water column may attenuate the rate of volatilization of trichlorobenzenes under environmental conditions.

Trichlorobenzenes have been shown to bioconcentrate in fish. The measured bioconcentration factors (BCF) of 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene measured at different concentrations in carp over a 6-week incubation period are provided in Table 6-3 (NITE 2002). The

Table 6-3. Measured Bioconcentration Factors (BCF) of Trichlorobenzenes in Carp

Isomer	BCF range in carp
1,2,3-Trichlorobenzene	350–980 (concentration 100 μg/L); 130–1,200 (concentration 10 μg/L)
1,2,4-Trichlorobenzene	420–1,140 (concentration 100 μg/L); 120–1,320 (concentration 10 μg/L)
1,3,5-Trichlorobenzene	620–1,620 (concentration 100 μg/L); 150–1,700 (concentration 10 μg/L)

Source: NITE 2002

mean BCF values of 1,2,4-trichlorobenzene measured in rainbow trout maintained in a flow-through aquarium at initial concentrations of 3.2 and 52 ng/L, were 1,300 and 3,200, respectively, over an exposure period exceeding 100 days (Oliver and Niimi 1983). The mean BCF values of 1,3,5-trichlorobenzene using initial concentrations of 2.3 and 45 ng/L were measured as 1,800 and 4,100, respectively (Oliver and Niimi 1983). American flagfish (*Jordanella floridae*) exposed to 3.8 μg/L (3,800 ng/L) of 1,2,4-trichlorobenzene for 28 days followed by a depuration period of 5–7 days, had a whole-body BCF of 2,026 and the metabolic half-life was estimated to be 1.21 days (European Communities 2003). Spot fish (*Leiostomus xanthurus*) were placed in aquariums containing 10 μg/L (10,000 ng/L) 1,2,4-trichlorobenzene and fed either shrimp exposed to 1,2,4-trichlorobenzene or noncontaminated shrimp over a 28-day exposure period (Heitmuller and Clark 1989). Uptake was determined to occur primarily through the gills rather than accumulation from food. BCF values of 69–135 measured for these fish suggest only modest bioconcentration of 1,2,4-trichlorobenzene and the rapid rate of depuration (half-life of 0.2 days) appeared to be responsible for the lack of accumulation in these fish.

A field study measured the bioaccumulation factor (BAF) of 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene in four aquatic species (mummichog, blue crabs, gulf menhaden and Atlantic croaker) living in an effluent/cooling water canal receiving discharge from a chemical manufacturing plant in the Bayou d'Inde, Louisiana (Burkhard et al. 1997). The lipid-normalized log BAFs for the three species of fish ranged from approximately 4.64 to 4.80 for 1,2,3-trichlorobenzene and 4.68 to 4.86 for 1,2,4-trichlorobenzene (Burkhard et al. 1997). The log BAF for blue crabs were 4.63 and 4.62 for 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene, respectively. These values were found to be consistent with measurements made for trichlorobenzenes in Atlantic croaker, spotted sea trout, blue crabs, and blue catfish obtained from another sampling location of in the Bayou d'Inde (Pereira et al. 1988).

In general, whole-body BCF and BAF values that are >5,000 suggest a high potential for a chemical substance to bioaccumulate under typical environmental conditions, while values <1,000 suggest a much lower potential. Given the range of BCF and BAF values for the trichlorobenzenes, the weight of evidence suggests that these substances may bioconcentrate and bioaccumulate to some extent in the environment, but do not possess the same high degree of bioaccumulation potential as higher chlorinated substances such as hexachlorobenzene.

6.3.2 Transformation and Degradation

6.3.2.1 Air

Trichlorobenzenes released to the atmosphere will degrade by reacting with photochemically generated hydroxyl radicals. Degradation by reaction with other common atmospheric oxidants such as nitrate radicals or ozone, and degradation by direct sunlight photolysis are not expected to be important environmental fate pathways. Second-order hydroxyl radical rate constants were estimated using a quantitative structure estimation method (Meylan and Howard 1993). Using these estimated rate constants and assuming a 12-hour hydroxyl radical concentration of 1.5×10^6 hydroxyl radicals per cubic cm of air, estimated half-lives for 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene are 38, 38, and 16 days, respectively.

6.3.2.2 Water

Trichlorobenzenes are expected to biodegrade slowly in water. The rate of aerobic biodegradation of chlorinated aromatic substances decreases as the degree of chlorination on the benzene ring increases. Standardized screening methods used to characterize the capability of rapid mineralization of a substance have determined that trichlorobenzenes and higher chlorinated benzenes are not readily biodegradable under aerobic conditions. A mixture of trichlorobenzene isomers present at 100 mg/L achieved 0% of its theoretical biochemical oxygen demand (BOD) using an activated sludge inoculum at 30 mg/L and the modified MITI test (OECD 301C) over a 28-day incubation period (NITE 2002).

The degradation pattern of 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene was studied using methanogenic water-sediment slurries obtained from nine eutrophic ponds and slow moving streams (Peijnenburg et al. 1992). The degradation pattern was bi-phasic in each water-sediment slurry with an initial half-life range of 62–212 days for 1,2,4-trichlorobenzene and 63–323 days for 1,2,3-trichlorobenzene after a characteristic lag period of approximately 4–8 weeks.

1,2,3-, 1,2,4-, and 1,3,5-Trichlorobenzene were shown to undergo photoreductive dechlorination in water with the presence of a photosensitizing agent, suggesting that photolysis in sunlit surface waters containing natural photosensitizers may be an important environmental fate process (Choudhry et al. 1986). Hydrolysis is not expected to be an important environmental fate process for the trichlorobenzene isomers. The hydrolysis half-life of 1,2,4-trichlorobenzene at pH 7 and 25°C was reported as 3.4 years (USGS 1998).

6.3.2.3 Sediment and Soil

Degradation of highly chlorinated benzenes is generally slow under aerobic conditions but occurs under methanogenic conditions by reductive dechlorination, yielding lower chlorinated benzenes. 1,2,4-Trichlorobenzene was completely degraded within 4 days using a methanogenic microbial culture isolated from sediment obtained from polluted regions of the Rhine River, Lake Ketelmeer, and an anaerobic waste water treatment plant located in the Netherlands (Middeldorp et al. 1997). 1,4-Dichlorobenzene and monochlorobenzene were observed as the main biodegradation byproducts. The degradation of trichlorobenzenes was studied using sediment obtained from the Rhine River and a municipal water treatment facility in the Netherlands (Bosma et al. 1996). 1,2,4-Trichlorobenzene was partially degraded under aerobic conditions, but only after a long lag time. 1,3,5-Trichlorobenzene and 1,2,3-trichlorobenzene were not degraded under aerobic conditions. Under methanogenic conditions, degradation to mono- and dichlorobenzenes were observed for all three isomers after a 2-month lag period. All three isomers of trichlorobenzene were biodegraded by an acclimated anaerobic sediment slurry using sediment and water from the Tsurumi River, Japan (Masunaga et al. 1996). The first-order biodegradation rate constants for 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene were 0.0299/days, 0.017/days, and 0.0198/days, respectively; corresponding to half-lives were about 23 days (1,2,3-trichlorobenzene), 41 days (1,2,4-trichlorobenzene), and 35 days (1,3,5-trichlorobenzene).

The biodegradation rate of 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene were studied in a Nixon sandy loam under aerobic conditions (Marinucci and Bartha 1979). It was determined that the trichlorobenzenes became increasingly toxic to soil microorganisms at concentrations exceeding 50 μg/g soil and that mineralization proceeded at very slow rates (approximately 0.35 nanomoles/day/20 g soil for 1,2,3-trichlorobenzene and 1.0 nanomoles per day per 20 grams of soil for 1,2,4-trichlorobenzene). Primary degradation products of 1,2,3-trichlorobenzene were identified as 3,4,5-trichlorophenol and 2,4- and 2,6-dichlorophenol. The primary degradation products of 1,2,4-trichlorobenzene were 2,4-, 2,5-, and 3,4-dichlorophenol. 1,2,4-Trichlorobenzene was not significantly biodegraded in soil slurries using a silty loam soil containing 8% organic matter or a loamy sand soil containing 2.6% organic matter over the course of a 30-day incubation period (Brunsbach and Reineke 1994). Trichlorobenzene isomers were extensively degraded under aerobic conditions by enriched microbial cultures that were isolated from contaminated soil samples obtained from a location heavily polluted with electrical transformer fluids (Adebusoye et al. 2007). Both 1,2,3- and 1,3,5-trichlorobenzene were degraded 91% over the course of a 202-hour incubation period using two strains of bacteria isolated from the contaminated soil.

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to trichlorobenzenes depends in part on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of trichlorobenzenes 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 trichlorobenzenes 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. The analytical methods available for monitoring trichlorobenzenes in a variety of environmental media are detailed in Chapter 7 (Analytical Methods).

6.4.1 Air

The Air Quality System (AQS) database is EPA's repository of criteria air pollutant and hazardous air pollutants monitoring data. Detailed air monitoring data for 1,2,4-trichlorobenzene in various cities in the United States for 2008 are shown in Table 6-4. Data for other years are available as zipped Microsoft Access database files that may be accessed directly from the EPA website. In general, the average concentration of 1,2,4-trichlorobenzene in outdoor air is <1 ppbC (ppbC is equivalent to ppbv multiplied by the number of carbons of the compound) for the majority of the U.S. locations sampled. Maximum concentrations >3 ppbC (0.5 ppbv) were identified at three U.S. cities (Davie, Florida; Hollywood, Florida; Tulsa, Oklahoma). The mean and median daily concentrations of 1,2,4-trichlorobenzene in outdoor air samples in the United States had previously been reported as 0.172 and 0.100 ppbv, respectively (Shah and Singh 1988). Grosjean (1991) reported a maximum concentration of 1,2,4-trichlorobenzene of 0.34 ppbv in measurements of air quality of cities in California. Indoor air concentrations of 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene were reported as <1 $\mu g/m^3$ (<0.13 ppbv) at unspecified locations (Brown et al. 1994). Unspecified isomers of trichlorobenzene were reportedly identified in indoor air at two buildings in the United States at a mean concentration of 0.065 ppbv (Otson and Fellin 1992). In a survey of 300 Dutch homes, 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene were measured in indoor air at maximum levels of 28, 33, and 5 $\mu g/m^3$ (3.6, 4.3, and 0.65 ppbv), respectively (Otson and Fellin 1992).

Table 6-4. 1,2,4-Trichlorobenzene Air Levels at Monitoring Stations Throughout the United States in 2008[a]

Number of observations	Mean concentration (ppbC)[a]	City	State
23	0.09	Phoenix	Arizona
39	0.103	Phoenix	Arizona
46	0.09	Grand Junction	Colorado
16	0.12	Washington	District of Columbia
32	1.232	Davie	Florida
11	0.09	Davie	Florida
16	1.125	Pompano Beach	Florida
25	1.294	Hollywood	Florida
23	0.817	Not specified	Florida
12	0.09	Not specified	Florida
42	0.205	Tampa	Florida
45	0.206	Plant City	Florida
19	0.497	Tallahassee	Florida
38	0.22	Winter Park	Florida
46	0.203	Saint Petersburg	Florida
45	0.213	Pinellas Park	Florida
14	0.06	Milledgeville	Georgia
11	0.07	Macon	Georgia
13	0.06	Savannah	Georgia
14	0.06	Douglas	Georgia
14	0.06	Not specified	Georgia
29	0.06	Decatur	Georgia
14	0.06	Decatur	Georgia
15	0.06	Rome	Georgia
15	0.06	Not specified	Georgia
15	0.06	Not specified	Georgia
10	0.06	Brunswick	Georgia
19	0.06	Gainesville	Georgia
12	0.06	Warner Robins	Georgia
13	0.06	Valdosta	Georgia
13	0.06	Columbus	Georgia
15	0.06	Not specified	Georgia
12	0.06	Augusta	Georgia
5	0.45	Not specified	Idaho
7	0.45	Boise City (corporate name for)	Idaho
6	0.45	Nampa	Idaho
5	0.45	Not specified	Idaho
42	0.092	Schiller Park	Illinois

Table 6-4. 1,2,4-Trichlorobenzene Air Levels at Monitoring Stations Throughout the United States in 2008[a]

Number of observations	Mean concentration (ppbC)[a]	City	State
49	0.09	Northbrook	Illinois
5	0.09	Northbrook	Illinois
4	0.05	Clarksville	Indiana
51	0.05	Gary	Indiana
13	0.05	East Chicago	Indiana
14	0.05	Whiting	Indiana
16	0.05	Hammond	Indiana
15	0.05	Indianapolis (remainder)	Indiana
16	0.05	Indianapolis	Indiana
15	0.05	Indianapolis (remainder)	Indiana
16	0.05	Ogden Dunes (Wickliffe)	Indiana
14	0.05	Lafayette	Indiana
14	0.05	Evansville	Indiana
25	0.38	Cedar Rapids	Iowa
17	0.329	Des Moines	Iowa
25	0.4	Davenport	Iowa
28	0.12	Essex	Maryland
30	0.12	Beltsville	Maryland
30	0.12	Baltimore	Maryland
31	0.12	Baltimore	Maryland
30	0.506	Sault Ste. Marie	Michigan
5	0.09	Dearborn	Michigan
44	0.01	Rosemount	Minnesota
45	0.01	Inver Grove Heights	Minnesota
48	0.01	Rosemount	Minnesota
48	0.01	Rosemount	Minnesota
50	0.01	Apple Valley	Minnesota
46	0.01	Richfield	Minnesota
49	0.01	Minneapolis	Minnesota
46	0.01	Minneapolis	Minnesota
46	0.01	Minneapolis	Minnesota
50	0.01	Minneapolis	Minnesota
46	0.01	Minneapolis	Minnesota
45	0.01	St. Louis Park	Minnesota
49	0.01	St. Paul	Minnesota
31	0.01	St. Paul	Minnesota
41	0.01	Duluth	Minnesota
46	0.01	St. Paul Park	Minnesota
29	0.01	St. Paul Park	Minnesota

Table 6-4. 1,2,4-Trichlorobenzene Air Levels at Monitoring Stations Throughout the United States in 2008[a]

Number of observations	Mean concentration (ppbC)[a]	City	State
47	0.01	Newport	Minnesota
29	0.01	Bayport	Minnesota
50	0.01	Bayport	Minnesota
10	0.09	Gulfport	Mississippi
12	0.09	Tupelo	Mississippi
46	0.09	St. Louis	Missouri
34	0.09	Camden	New Jersey
43	0.09	North Brunswick Township	New Jersey
44	0.09	Chester	New Jersey
41	0.09	Elizabeth	New Jersey
45	0.05	New York	New York
46	0.11	New York	New York
41	0.08	Lackawanna	New York
39	0.05	Tonawanda	New York
43	0.05	Tonawanda	New York
37	0.05	Tonawanda	New York
46	0.05	Tonawanda	New York
28	0.05	Tonawanda	New York
29	0.05	Not specified	New York
40	0.05	Not specified	New York
45	0.1	New York	New York
45	0.06	Rochester	New York
31	0.07	New York	New York
39	0.07	Niagara Falls	New York
42	0.16	New York	New York
30	0.06	Troy	New York
39	0.09	Troy	New York
39	0.06	Troy	New York
44	0.12	New York	New York
44	0.08	New York	New York
24	0.32	Asheville	North Carolina
26	0.3	Not specified	North Carolina
12	0.37	Charlotte	North Carolina
26	0.33	Candor	North Carolina
24	0.39	Not specified	North Carolina
24	0.36	Not specified	North Carolina
22	0.33	Raleigh	North Carolina
16	0.47	Middletown	Ohio
15	0.38	Cleveland	Ohio

Table 6-4. 1,2,4-Trichlorobenzene Air Levels at Monitoring Stations Throughout the United States in 2008[a]

Number of observations	Mean concentration (ppbC)[a]	City	State
14	0.39	Cleveland	Ohio
15	0.38	Cleveland	Ohio
13	0.39	Cleveland	Ohio
22	0.44	Columbus	Ohio
23	0.46	Steubenville	Ohio
22	0.46	Marietta	Ohio
14	0.09	Not specified	Oklahoma
41	0.09	Tulsa	Oklahoma
5	0.09	Tulsa	Oklahoma
43	0.167	Tulsa	Oklahoma
4	0.09	Tulsa	Oklahoma
44	0.093	Tulsa	Oklahoma
6	0.09	Tulsa	Oklahoma
30	0.06	Not specified	Pennsylvania
24	0.06	Not specified	Pennsylvania
18	0.06	Not specified	Pennsylvania
18	0.06	Chester	Pennsylvania
17	0.06	Marcus Hook	Pennsylvania
22	0.06	Erie	Pennsylvania
31	0.12	Lancaster	Pennsylvania
26	0.06	Lancaster	Pennsylvania
26	0.06	West Norriton	Pennsylvania
32	0.06	Collegeville	Pennsylvania
29	0.07	Philadelphia	Pennsylvania
30	0.09	Philadelphia	Pennsylvania
30	0.1	Philadelphia	Pennsylvania
28	0.07	Philadelphia	Pennsylvania
30	0.05	Philadelphia	Pennsylvania
17	0.06	Not specified	Pennsylvania
31	0.05	Not specified	South Carolina
31	0.05	Not specified	South Carolina
45	0.09	Not specified	South Dakota
46	0.09	Sioux Falls	South Dakota
45	0.09	Loudon	Tennessee
4	0.09	Loudon	Tennessee
45	0.09	Loudon	Tennessee
5	0.09	Loudon	Tennessee
17	0.09	Memphis	Tennessee
47	0.09	Bountiful	Utah

Table 6-4. 1,2,4-Trichlorobenzene Air Levels at Monitoring Stations Throughout the United States in 2008[a]

Number of observations	Mean concentration (ppbC)[a]	City	State
34	0.214	Underhill (town of)	Vermont
18	0.214	Burlington	Vermont
18	0.214	Burlington	Vermont
18	0.214	Rutland	Vermont
18	0.214	Brattleboro (town of)	Vermont
15	0.12	Franconia	Virginia
16	0.12	Not specified	Virginia
16	0.12	Virginia Beach	Virginia
46	0.09	Seattle	Washington
4	0.09	Seattle	Washington

[a] ppbC is equivalent to ppbv multiplied by the number of carbons of the compound.

Source: EPA 2010a

6.4.2 Water

1,2,4-Trichlorobenzene was detected at mean concentrations of 0.6 and 0.2 ng/L in Lake Ontario and Lake Huron, respectively, in surface water samples collected between April and November of 1980 (Oliver and Nicol 1982). 1,2,3-Trichlorobenzene and 1,3,5-trichlorobenzene were also detected in Lake Ontario at mean concentrations of 0.1 ng/L; however, neither isomer was detected in surface water obtained from Lake Huron. All three isomers of trichlorobenzene were detected in certain locations of the Niagara River. 1,2,3-Trichlorobenzene was identified in three of four sampling locations at concentrations ranging from 2 to 38 ng/L; 1,2,4-trichlorobenzene was identified at four out of four sampling locations at levels ranging from 0.1 to 107 ng/L; and 1,3,5-trichlorobenzene was detected in three out of four sampling locations at levels ranging from 1 to 8 ng/L (Oliver and Nicol 1982). 1,2,3-Trichlorobenzene and 1,2,4-trichlorobenzene were detected at concentrations of 12 and 40 ng/L, respectively, in surface water obtained from the Bayou d'Inde, Louisiana near an industrial plant that produced trichloroethylene and perchloroethylene (Pereira et al. 1988). In surface water obtained from the Niagara River at Niagara on the Lake, 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene were detected at levels of 1.8, 6.4, and 0.7 ng/L, respectively (Fox et al. 1983). During the same sampling period, 1,2,4-trichlorobenzene was detected in Fort Erie water samples at a concentration of 0.1 ng/L. Neither 1,2,3- nor 1,3,5-trichlorobenzene were detected at this location.

Both 1,2,3- and 1,2,4-trichlorobenzene were monitored for, but not detected in, aquifer samples in a comprehensive survey conducted by the USGS of volatile organic compounds in private and public groundwater wells used for drinking water (USGS 2006). Neither isomer was detected in samples obtained from nearly 2,000 public and private wells across the United States. However, 1,2,3-trichlorobenzene was detected in 2 of 19 groundwater wells two years after a polychlorinated biphenyls/ trichlorobenzene spill of transformer fluid near Kingston, Tennessee at concentrations of 0.18 and 0.097 mg/L (EPA 1976). 1,2,4-Trichlorobenzene was detected at levels ranging from 4.43 to 5.02 mg/L in groundwater at the Ciba-Geigy Toms River, New Jersey Superfund site, a location that manufactured dyes, pigments, resins, and epoxy additives from 1952 to 1990 (Carmichael et al. 1999).

1,2,3- and 1,2,4-Trichlorobenzene were detected at mean concentrations of 0.1 and 2 ng/L from municipal drinking water samples obtained from three cities in the Lake Ontario region (Oliver and Nicol 1982). Samples were obtained prior to and immediately after chlorine treatment, and no increase in the levels of trichlorobenzene and other chlorobenzenes were observed following chlorination. 1,3,5-Trichlorobenzene was monitored for, but not detected in drinking water at these locations. 1,2,3-Trichlorobenzene was detected at a level of approximately 100 ng/L in chlorinated drinking water samples from 2 out of 10 Canadian water treatment plants (Otson et al. 1986).

6.4.3 Sediment and Soil

Chlorobenzenes, including trichlorobenzenes are widespread in Western, New York, particularly in the Niagara Falls region. 1,2,3-Trichlorobenzene was detected in soil samples at mean concentrations of 0.19, 0.54, 0.42, 0.17, and 0.16 ng/g at five locations in Erie County, New York, including the Love Canal area (Ding et al. 1992). 1,2,4-Trichlorobenzene was detected at mean concentrations of 0.96, 2.53, 1.80, 1.00, and 0.48 ng/g in soils at the same five locations. 1,2,4-Trichlorobenzene levels in soil samples in the Toms River Superfund site in New Jersey ranged from below detection limits to 440 ng/g (Carmichael et al. 1999).

Trichlorobenzenes were detected in surficial sediment samples obtained from four of the Great Lakes during sampling conducted between April and November of 1980 (Oliver and Nicol 1982). The results are summarized in Table 6-5. The substantial concentrations of trichlorobenzenes (and other chlorinated substances) observed in the sediment samples obtained from Lake Ontario in comparison to the levels in the other lakes were attributed to the large amount of waste disposal sites and chemical manufacturing plants along the Niagara River leading into Lake Ontario. Suspended solids obtained from the Niagara River contained 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene at levels of 5.4–38, 33–210, and 1.5–23 ng/g, respectively (Fox et al. 1983). 1,2,3-, 1,2,4-, and 1,3,5-Trichlorobenzene were detected at concentrations of 9.6, 306.0, and 83.0 μg/kg (ng/g), respectively, in bottom sediment obtained from the Bayou d’Inde, Louisiana near an industrial plant that produced trichloroethylene and perchloroethylene (Pereira et al. 1988).

1,2,4-Trichlorobenzene was detected in stream bed sediment samples obtained at 1 out of 517 sites in 20 major river basins in the continental United States sampled from August 1992 to September 1995 (Lopes and Furlong 2001). The maximum concentration was reported as 68 μg/kg (ng/g).

6.4.4 Other Environmental Media

Trichlorobenzenes have been detected in a variety of environmental media including plants, fish, animals, and foods. 1,2,4-Trichlorobenzene was identified, not quantified, in various plant material grown in an Illinois coal refuse reclamation site (Webber et al. 1994) and was also present in plants at an average

Table 6-5. The Range and Mean Concentration of Trichlorobenzene Isomers in Sediment Samples Obtained From the Great Lakes

Isomer	Lake Superior (ng/g)	Lake Heron (ng/g)	Lake Erie (ng/g)	Lake Ontario (ng/g)
1,2,3-Trichlorobenzene	ND–1.0 (range); 0.2 (mean)	0.1–1 (range); 0.3 (mean)	0.1–1 (range); 0.4 (mean)	1–16 (range); 7 (mean)
1,2,4-Trichlorobenzene	0.1–4 (range); 1 (mean)	1–26 (range); 6 (mean)	1–9 (range); 3 (mean)	20–220 (range); 94 (mean)
1,3,5-Trichlorobenzene	ND–0.4; 0.2 (mean)	ND–4 (range); 0.7 (mean)	0.1–5 (range); 1 (mean)	7–250 (range); 60 (mean)

ND = Not detected

Source: Oliver and Nicol 1982

concentration of 0.002 mg/kg in localities contaminated by agrochemical and communal waste (Veningerova et al. 1997).

Catfish obtained from the Bayou d'Inde, Louisiana near an industrial plant that produced trichloroethylene and perchloroethylene had levels of 1,3,5-trichlorobenzene, 1,2,4-trichlorobenzene, and 1,2,3-trichlorobenzene of 480, 3,900, and 770 ng/g, respectively (Pereira et al. 1988). The levels decreased to 250 ng/g (1,3,5-trichlorobenzene), 1,900 ng/g (1,2,4-trichlorobenzene), and 370 ng/g (1,2,3-trichlorobenzene) in catfish obtained 1 mile downstream from the plant. Atlantic croakers, blue crabs, and spotted sea trout obtained 1 mile downstream from the plant had levels of 1,3,5-trichlorobenzene, 1,2,4-trichlorobenzene, and 1,2,3-trichlorobenzene of 50–420, 140–3,200, and 20–710 ng/g, respectively (Pereira et al. 1988). 1,2,3-Trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene were detected in trout from Lake Superior, Lake Huron, Lake Erie, Lake Ontario, and the Niagara River (Oliver and Nicol 1982). Levels of 1,2,3-trichlorobenzene ranged from 0.1 to 1 ng/g, levels of 1,2,4-trichlorobenzene ranged from 0.5 to 5 ng/g, and levels of 1,3,5-trichlorobenzene ranged from 0.1 to 4 ng/g. In each case, the highest levels were obtained from trout in Lake Ontario or the Niagara River. 1,3,5-Trichlorobenzene and 1,2,4-trichlorobenzene were also detected in trout caught near the Niagara River mouth in Lake Ontario at levels of 1.0 and 3.7 ng/g, respectively (Fox et al. 1983).

Hoekstra et al. (2003) measured the levels of persistent chlorinated substances in muscle and liver tissue of Arctic foxes obtained from Holman, Canada, Arviat, Canada, and Barrow, Alaska. Total chlorobenzene levels (1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, 1,3,5-trichlorobenzene, pentachlorobenzene, and hexachlorobenzene) ranged from 4.4 to 17.6 ng/g in muscle tissue and 4.2 to 12 ng/g in liver tissue.

Trichlorobenzene isomers were detected in nine different vegetables collected from supermarkets in Great Britain (Wang and Jones 1994). The results of this study are summarized in Table 6-6. Peattie et al. (1984) identified isomers of trichlorobenzene in seed oils produced from corn, soybean, rape, sunflower, peanut, sesame, walnut, hazelnut, and poppy. 1,2,3-, 1,2,4-, and 1,3,5-Trichlorobenzene were detected in various foods purchased at grocery stores in Ontario, Canada (Davies 1988). Leafy vegetables, fruits, milk, and eggs/meat contained trichlorobenzene levels of 0.11–0.40, 0.12–0.14, 0.14–1.2, and 0.70–0.74 μg/kg, respectively. These results suggest that ingestion of some foods may be a significant source of trichlorobenzene exposure to the general population.

Table 6-6. Trichlorobenzene Concentrations in Whole Vegetables

Vegetable	1,2,3-Trichlorobenzene (µg/kg)	1,2,4-Trichlorobenzene (µg/kg)	1,3,5-Trichlorobenzene (µg/kg)
Carrots	ND	ND	ND
Potato	0.0484	0.0038	0.010
Cabbage	ND	0.0068	0.0225
Cauliflower	ND	0.0309	ND
Lettuce	ND	0.0027	0.0030
Onion	0.0490	ND	0.0363
Beans	ND	ND	ND
Peas	ND	0.0342	0.117
Tomatoes	0.0440	ND	ND

ND = not detected

Source: Wang and Jones 1994

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The general population is exposed to trichlorobenzene from inhalation of ambient air and ingestion of food and drinking water (see Sections 6.4.1–6.4.4 for background environmental levels). In a European Union Risk Assessment Report, four different exposure scenarios were developed to estimate the average daily intake of 1,2,4-trichlorobenzene. The total daily intake was 0.0715 mg/kg/day for the exposure scenario, which yielded the highest estimated total daily intake for humans (European Communities 2003). The estimates suggest that the most important human intake routes are ingestion of root crops, fish, and drinking water. Davies (1988) used the concentration of trichlorobenzene residues in food items purchased in Ontario, Canada and estimated an annual dietary intake of approximately 147 μg/year (0.402 μg/day) for all three combined isomers. MacLeod and Mackay (1999) estimated the daily intake of 1,2,4-trichlorobenzene for residents in Southern Ontario, Canada as 0.3 μg/day, with the greatest contribution arising from inhalation of ambient air (75.4% of the total exposure) followed by ingestion of meat (14.3%), milk (6.4%), and eggs (2.5%).

Trichlorobenzenes have been detected in human body burden studies. Trichlorobenzenes are lipophilic substances, so they tend to concentrate in fatty tissues. In autopsies of Canadian citizens, 1,2,3- and 1,3,5-trichlorobenzene were detected in biopsy fatty tissue at median levels of 1.9 and 1.1 ng/g, respectively, and at maximum levels of 9.1 and 3.7 ng/g, respectively (Mes 1992). Levels were below the detection limits (1.17 ng/g for 1,2,3-trichlorobenzene and 4.02 ng/g for 1,3,5-trichlorobenzene) in blood samples. 1,2,4-Trichlorobenzene was detected in human follicular fluid at a mean concentration of 214 pg/mL for patients undergoing in vitro fertilization in Canada (Younglai et al. 2002). 1,2,4-Trichlorobenzene was detected in follicular fluid in over 50% of the patients tested. It was also identified, but not quantified in human female serum obtained at the time of oocyte retrieval for *in vitro* fertilization (Younglai et al. 2002). Serum samples obtained from former residents of Love Canal, New York were examined for the presence of organochlorines, including trichlorobenzene (Kielb et al. 2010). The serum samples had been collected in 1978–1979 and stored by the New York State Department of Health and analyzed between 1999 and 2004. 1,2,4-Trichlorobenzene was detected in 97% of all of the samples studied (detection limit 0.02 ng/g lipid). Median serum levels for 1,2,4-trichlorobenzene of 126.9 ng/g (n=9) were reported for residents living closest to the site when it was still open and 42.2 ng/g (n=67) for residents living on the peripheries of the site. The median levels of 1,2,4-trichlorobenzene in serum samples was 204.2 ng/g (n=171) and 35.9 ng/g (n=213) for residents residing nearer and at the peripheries of the site, respectively, after it was closed and the most toxic portion reburied with dirt and clay (Kielb et al. 2010).

Occupational exposure to trichlorobenzenes arises from inhalation and dermal contact with these compounds at workplaces where they are produced and used. According to the National Occupational Exposure Study (NOES) conducted by NIOSH from 1981 to 1983, an estimated 691 workers (all employed in the textile mill trade) were potentially exposed to 1,2,3-trichlorobenzene in the workplace (NIOSH 1990a, 1990b). In addition, 4,033 workers, including 1,463 female employees, were potentially exposed to 1,2,4-trichlorobenzene (NIOSH 1990a, 1990b). The NOES database does not contain information on the frequency, concentration, or duration of occupational exposure to any of the chemicals listed. The survey provides only estimates of the numbers of workers for whom potential exposure in the workplace is an issue. Data from the EPA Inventory Update Reporting database indicate that >1,000 workers can be reasonably expected to have some form of exposure to 1,2,4-trichlorobenzene and between 100 and 999 workers are expected to be exposed to 1,2,3-trichlorobenzene in the United States (EPA 2010b, 2010e). However, this database does not indicate the level of exposure or the primary exposure route for these workers. Levels of 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene in the breathing zone at different locations of a chemical warehouse located in Michigan ranged from 0.03 to 0.06 ppmv and 0.57 to 1.4 ppmv, respectively (Dow Chemical 1981). The highest levels were observed in locations where trichlorobenzenes and trichloroethane were being packaged into drums. The NIOSH ceiling limit (concentration not to be exceeded at any time during the work day) is 5 ppmv (37 mg/m^3) for 1,2,4-trichlorobenzene (NIOSH 2005).

6.6 EXPOSURES OF CHILDREN

This section focuses on exposures from conception to maturity at 18 years in humans. Differences from adults in susceptibility to hazardous substances are discussed in Section 3.7, Children’s Susceptibility.

Children are not small adults. A child’s exposure may differ from an adult’s exposure in many ways. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface in proportion to their body volume. A child’s diet often differs from that of adults. The developing human’s source of nutrition changes with age: from placental nourishment to breast milk or formula to the diet of older children who eat more of certain types of foods than adults. A child’s behavior and lifestyle also influence exposure. Children crawl on the floor, put things in their mouths, sometimes eat inappropriate things (such as dirt or paint chips), and spend more time outdoors. Children also are closer to the ground, and they do not use the judgment of adults to avoid hazards (NRC 1993).

Children are exposed to trichlorobenzenes by the same means that adults are: inhalation of ambient air, and ingestion of contaminated food and drinking water. Trichlorobenzenes have also been identified in breast milk; therefore, infants may also be potentially exposed through breast feeding. The mean, median, and maximum concentrations of 1,2,3-trichlorobenzene from 412 breast milk samples obtained from different provinces in Canada in 1986 were 0.98, 0.49, and 18.33 ng/g, respectively, for whole milk samples and 38.7, 15.3, and 466.3 ng/g, respectively, in milk fat (Mes et al. 1993). Only maximum levels of 1,2,4-trichlorobenzene and 1,3,5-trichlorobenzene were reported. The maximum levels of 1,2,4-trichlorobenzene in whole milk and milk fat were 17.40 and 4490.9 ng/g, respectively. The maximum levels of 1,3,5-trichlorobenzene in whole milk and milk fat were 5.18 and 128.2 ng/g, respectively. The mean concentrations of 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene in whole milk obtained from 497 breast milk samples in Canada collected in 1992 were reported as 0.07, 0.11, and 0.04 ng/g, respectively (Newsome et al. 1995). The mean concentrations in milk fat were 2.79 ng/g for 1,2,3-trichlorobenzene, 3.81 ng/g for 1,2,4-trichlorobenzene, and 1.40 ng/g for 1,3,5-trichlorobenzene.

No studies were located that expressed the level of trichlorobenzenes or its metabolites in amniotic fluid, meconium, cord blood, or neonatal blood. Children are unlikely to be exposed to trichlorobenzenes from their parents clothing or playing on the ground (soil, carpeting, etc.) due to the volatility of these substances.

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

High levels of trichlorobenzenes have been identified in soil and water samples in heavily industrialized areas or at superfund sites such as the Love Canal site in Niagara Falls, New York. Populations residing near these locations may be exposed to higher levels of trichlorobenzenes than the general population. In addition, certain food items have been shown to contain high levels of trichlorobenzenes, in particular fish and root crops. Individuals who consume large amounts of these products may have higher exposures to trichlorobenzenes as compared to the general population.

6.8 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of trichlorobenzenes is available. Where adequate information is not available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of trichlorobenzenes.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would reduce the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

6.8.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties necessary for characterizing the environmental fate of all three isomers of trichlorobenzene have been measured or can be adequately estimated. No data needs have been identified.

Production, Import/Export, Use, Release, and Disposal. According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and off-site transfer information to the EPA. The TRI, which contains this information for 2012, became available in February of 2013. This database is updated yearly and should provide a list of industrial production facilities and emissions.

Data are available through the U.S. EPA Inventory Update Reporting system regarding the levels of trichlorobenzenes that are either manufactured or imported in quantities of ≥25,000 pounds at a single site during a calendar year. Data are available for 1,2,4-trichlorobenzene and 1,2,3-trichlorobenzene. No data are available for 1,3,5-trichlorobenzene. Trichlorobenzenes appear to have no significant uses in household products in which the general population may be exposed, but have been identified in food. Sufficient use and disposal data exists for the trichlorobenzenes (HSDB 2010; Rossberg et al. 2006); however, a data need exists to determine the quantity of trichlorobenzenes that may have been exported. A data need also exists to estimate the amount of trichlorobenzenes released to the environment from both direct emissions and indirect releases via the degradation of higher chlorinated benzenes and lindane.

Environmental Fate. Trichlorobenzenes are volatile substances that tend to partition to air and sediment when released to the environment and are generally slow to degrade in the environment

(European Communities 2003; Peijnenburg et al. 1992;USGS 1998). Sufficient data exists to characterize the transport and environmental fate of trichlorobenzenes and consequently no data needs are identified.

Bioavailability from Environmental Media. Studies characterizing the ADME (Absorption, Distribution, Metabolism, and Elimination) of 1,2,3-, 1,2,4-, and 1,3,5-trichlorobenzene following oral exposure in humans are not available. In addition no ADME, data are available for inhalation and dermal exposure in humans and animals. A data need to determine the bioavailability of trichlorobenzenes from environmental media exists.

Food Chain Bioaccumulation. Trichlorobenzenes have the potential to bioconcentrate and bioaccumulate in the environment and have been quantified in fish (Burkhard et al. 1997; Pereira et al. 1988), animals (Hoekstra et al. 2003) and food crops (Wang and Jones 1994). No data needs are identified.

Exposure Levels in Environmental Media. Monitoring data are available for trichlorobenzenes in air (EPA 2010a; Grosjean 1991; Shah and Singh 1988), water (Carmichael et al. 1999; Fox et al. 1983; Oliver and Nicol 1982; Pereira et al. 1988), soil and sediment (Carmichael et al. 1999; Fox et al. 1983; Pereira et al. 1988), plants (Veningerova et al. 1997; Webber et al. 1994) and food (Davies 1988; Wang and Jones 1994). Human intakes have been estimated from environmental media (European Communities 2003; MacLeod and Mackay 1999). Reliable monitoring data for the levels of trichlorobenzenes in contaminated media at hazardous waste sites are needed so that the information obtained on levels of trichlorobenzenes in the environment can be used in combination with the known body burden of trichlorobenzenes to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

Exposure Levels in Humans. Limited studies have shown that trichlorobenzenes have been detected in human blood (Mes 1992), adipose tissue (Mes 1992), follicular fluid (Younglai et al. 2002), and breast milk (Mes et al. 1993) in Canada. Additional studies on exposure levels to the U.S. population are needed.

This information is necessary for assessing the need to conduct health studies on these populations.

Exposures of Children. Children are exposed to trichlorobenzenes by the same routes that affect adults. Trichlorobenzenes have been detected in breast milk samples collected from Canadian females

(Mes et al. 1993; Newsome et al. 1995). A data need exists to determine current trichlorobenzene residues and their sources in breast milk of members of the U.S. general population and whether children differ in weight-adjusted intakes of trichlorobenzenes as compared to adult populations.

Child health data needs relating to susceptibility are discussed in Section 3.12.2, Identification of Data Needs: Children's Susceptibility.

Exposure Registries. No exposure registries for trichlorobenzene were located. This substance is not currently one of the compounds for which a sub-registry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for sub-registries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to this substance.

Few populations are expected to have high exposures to trichlorobenzenes. Persons residing near hazardous waste sites where chlorinated substances are disposed of may be subject to higher levels of trichlorobenzene than the general population. In addition, certain food items have been shown to contain high levels of trichlorobenzenes, in particular fish and root crops. Individuals who consume large amounts of these products may have higher exposures to trichlorobenzenes as compared to the general population.

6.8.2 Ongoing Studies

No ongoing studies pertaining to trichlorobenzenes were identified in Toxline (2013).