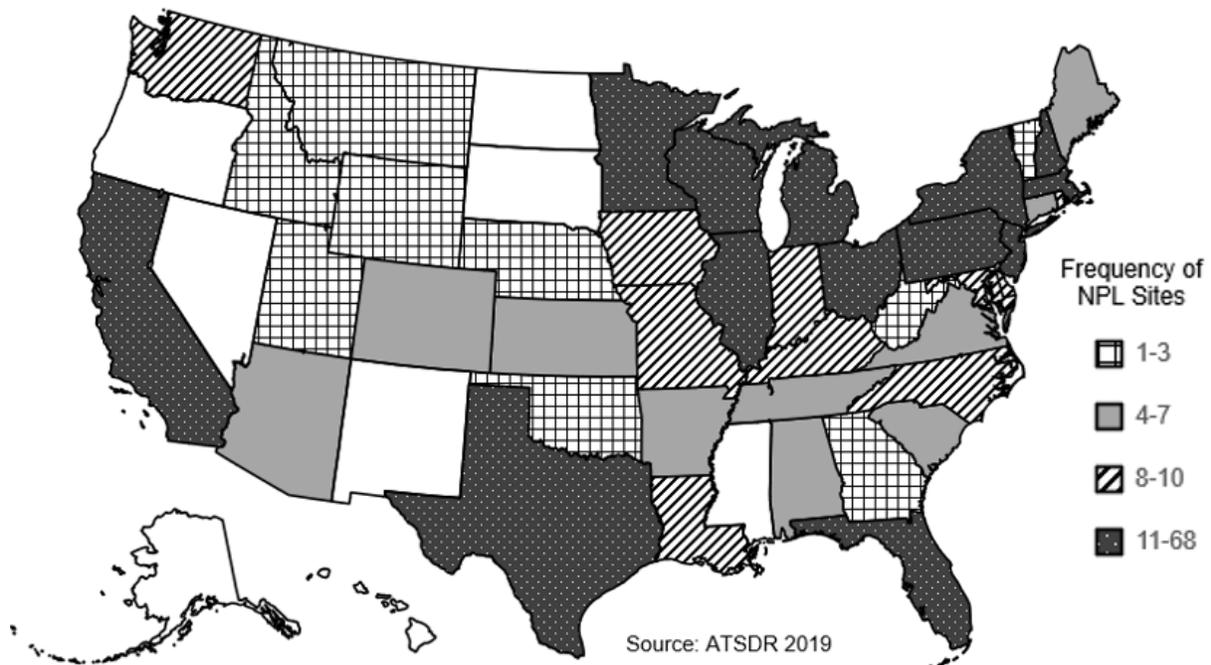


CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Chlorobenzene has been identified in at least 491 of the 1,867 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2019). However, the number of sites in which chlorobenzene has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, 490 are located within the United States, and 1 is located in Puerto Rico (not shown).

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



- The most likely sources of potential exposure of the general population to chlorobenzene are from breathing air, drinking water, or eating food that contains chlorobenzene.
- Chlorobenzene has been detected in only very small quantities in air, water, and limited food sources.
- Chlorobenzene degrades rapidly in air, water, and soil; it is not expected to bioconcentrate.

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5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL**5.2.1 Production**

Production of chlorobenzene in the United States declined by nearly 60%, from the peak production volume of 274,000,000 kg in 1960 to 112,000,000 kg in 1987. This decline is attributed primarily to the replacement of chlorobenzene by cumene in phenol production and the cessation of DDT production in the United States. In addition, pesticide production using chlorobenzene as an intermediate has declined and no major new uses have been found for chlorobenzene in recent years. Therefore, the decline in chlorobenzene production is expected to continue (EPA 1980a; Hughes et al. 1983; USITC 1988).

In the 1980s, chlorobenzene was produced by three United States chemical companies: Monsanto Chemical Company, Sauget, Illinois; PPG Industries, Inc., Natrium, West Virginia; and Standard Chlorine Chemical Co., Inc., Delaware City, Delaware. Production capacity for chlorobenzene at these plants remained constant after 1985, although it appeared that actual production declined slightly after 1985 (Hughes et al. 1983; SRI 1985, 1986, 1987, 1988; USITC 1988).

Chlorobenzene is produced commercially by the chlorination of benzene in the presence of a catalyst (e.g., ferric chloride, aluminum chloride, or stannic chloride). This process yields a mixture of chlorobenzene, dichlorobenzenes, and higher analogs, which are distilled and crystallized to obtain pure products (EPA 1985; Hughes et al. 1983).

The Hazardous Substance Data Bank (HSDB) listed the following figures for U.S. production capacity (in lbs/year): 368 million in 1990; 371 million in 1993; 370 million in 1996; 358 million in 1999; and 205 million in 2004; and 52.7 million in 2014 (NLM 2020). Table 5-1 summarizes information on U.S. companies that manufactured or used chlorobenzene in 2018 (TRI18 2020).

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

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
AL	1	10,000	99,999	6, 7
AR	4	100	999,999	7, 12
CA	1	100,000	999,999	7, 11
CO	1	10,000	99,999	6, 10

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

State ^a	Number of facilities	Minimum amount on site in pounds ^b	Maximum amount on site in pounds ^b	Activities and uses ^c
GA	1	1,000,000	9,999,999	1, 2, 3, 6, 11
IA	2	100,000	999,999	7, 10
IL	1	1,000	9,999	12
IN	3	100	99,999	9, 12, 14
KS	3	100	999	12
KY	3	10,000	999,999	1, 3, 6, 7, 9
LA	10	0	9,999,999	1, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13
MI	3	0	999,999	1, 5, 6, 10, 11, 13, 14
MO	3	1,000	99,999	10, 12
NE	1	100,000	999,999	9, 12
NY	2	100	99,999	10, 12
OH	6	1,000	9,999,999	9, 10, 12, 14
PA	1	1,000	9,999	12
SC	1	0	0	0
TN	2	10,000	99,999	1, 5, 6, 10, 13
TX	16	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14
UT	1	100,000	999,999	12
WI	3	0	999,999	6, 7, 12

^aPost office state abbreviations used.

^bAmounts on site reported by facilities in each state.

^cActivities/Uses:

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

Source: TRI18 2020 (Data are from 2018)

5.2.2 Import/Export

Import and export data for chlorobenzene are not readily available. Estimates indicated that both imports and exports were negligible in the late 1970s and early 1980s (Hughes et al. 1983).

From 2002 to 2003, U.S. exports of chlorobenzene declined from 3.5 million to 1.5 million pounds annually. Imports remained negligible during that time period (NLM 2020; Kirschner 2004).

Current data regarding import and export of chlorobenzene were not located.

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5.2.3 Use

Historically, the primary uses of chlorobenzene were as a solvent for pesticide formulations, diisocyanate manufacture, degreasing automobile parts, and for the production of nitrochlorobenzene and diphenyl oxide. Solvent uses accounted for about 37% of chlorobenzene consumption in the United States in 1981, nitrochlorobenzene production for 33%, and diphenyl oxide and phenylphenol production for 16% of consumption. Chlorobenzene has also been used in silicone resin production and as an intermediate in the synthesis of other halogenated organics, including DDT (Hughes et al. 1983). Recent data regarding chlorobenzene uses were not located.

5.2.4 Disposal

Because chlorobenzene is listed as a hazardous substance, disposal of waste chlorobenzene is controlled by a number of federal regulations. Spent solvent wastes, which may include chlorobenzene, are prohibited from land disposal, except under specific conditions. Land disposal restrictions (treatment standards) are proposed for other wastes containing chlorobenzene. Wastes containing chlorobenzene may be disposed of by liquid injection, rotary kiln, or fluidized bed incineration (EPA 1988, 1989). Since chlorobenzene is a volatile compound and is used extensively as a solvent, large quantities are released to the air. Some estimates indicate that 30–50% of the annual production of chlorobenzene is released to the atmosphere, while <0.1% is found in wastewater and <1% is disposed of on land (EPA 1985).

5.3 RELEASES TO THE ENVIRONMENT

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

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

5.3.1 Air

Estimated releases of 546,112 pounds (~248 metric tons) of chlorobenzene to the atmosphere from 69 domestic manufacturing and processing facilities in 2018, accounted for about 77.94% of the estimated total environmental releases from facilities required to report to the TRI (TRI18 2020). These releases are summarized in Table 5-2.

Table 5-2. Releases to the Environment from Facilities that Produce, Process, or Use Chlorobenzene^a

Reported amounts released in pounds per year ^b										
State ^c	RF ^d	Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Total release			
							On-site ^j	Off-site ^k	On- and off-site	
AL	1	10	0	0	0	0	10	0	10	
AR	4	780	0	0	14	76	780	90	870	
CA	1	324	0	0	0	0	324	0	324	
CO	1	32	0	0	0	0	32	0	32	
GA	1	61,167	0	0	4,564	0	61,167	4,564	65,731	
IL	1	1	0	0	13	0	1	13	14	
IN	3	164	0	0	580	0	164	580	744	
IA	2	800	0	0	0	0	800	0	800	
KS	3	1	0	0	0	0	1	0	1	
KY	3	533	9	0	0	0	542	0	542	
LA	10	206,072	250	130,000	241	207	336,322	448	336,770	
MI	3	930	25	0	9	0	955	9	964	
MO	3	281	0	0	0	643	281	643	924	
NE	1	10	0	0	12	0	10	12	22	
NY	2	65	1	0	0	0	65	1	67	
OH	6	236,342	360	0	5,683	0	236,452	5,932	242,384	
PA	1	64	0	0	0	0	64	0	64	
SC	1	0	0	0	0	0	0	0	0	
TN	2	422	74	0	20	0	516	0	516	
TX	16	30,170	42	9	11,638	85	41,544	400	41,944	
UT	1	3	0	0	0	0	3	0	3	

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Table 5-2. Releases to the Environment from Facilities that Produce, Process, or Use Chlorobenzene^a

Reported amounts released in pounds per year ^b									
State ^c	RF ^d	Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Total release		
							On-site ^j	Off-site ^k	On- and off-site
WI	3	7,942	0	0	0	0	7,942	0	7,942
Total	69	546,112	762	130,009	22,773	1,011	687,974	12,694	700,668

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

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

^cPost office state abbreviations are used.

^dNumber of reporting facilities.

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

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

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

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

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

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

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

RF = reporting facilities; UI = underground injection

Source: TRI18 2020 (Data are from 2018)

5.3.2 Water

Estimated releases of 762 pounds (~0.35 metric tons) of chlorobenzene to surface water from 69 domestic manufacturing and processing facilities in 2018, accounted for about 0.11% of the estimated total environmental releases from facilities required to report to the TRI (TRI18 2020). These releases are summarized in Table 5-2.

The principal source of chlorobenzene in water is release from chemical manufacturing facilities. Dow Chemical Company estimated that 0.1% of its annual production entered waters (EPA 1980b). EPA (1979) found chlorobenzene in 6/63 industrial effluent in concentrations up to 100 µg/L. Based on 1,338 samples collected from about 1980 to 1983, the medium concentration of chlorobenzene in waste effluent was <3 ppb and was detected in 54 samples. The total amount released to the environment was not reported (Staples et al. 1985). Chlorobenzene has been detected in both surface and groundwater samples at hazardous waste sites.

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5.3.3 Soil

Estimated releases of 22,773 pounds (~10.3 metric tons) of chlorobenzene to soil from 69 domestic manufacturing and processing facilities in 2018, accounted for about 0.03% of the estimated total environmental releases from facilities required to report to the TRI (TRI18 2020). Estimated releases of 130,009 pounds (~55 metric tons) of chlorobenzene via underground injection from 69 domestic manufacturing and processing facilities in 2018, accounted for about 18.56% of the estimated total environmental releases from facilities required to report to the TRI (TRI18 2020). These releases are summarized in Table 5-2.

5.4 ENVIRONMENTAL FATE**5.4.1 Transport and Partitioning**

The air, undoubtedly, plays a large role in the environmental transport and degradation of chlorobenzene, although studies addressing this aspect were not found. Chlorobenzene is volatile and has only moderate solubility in water (500 mg/L). Chlorobenzene was observed to evaporate (>99%) from an unaerated aqueous solution in 72 hours (Garrison and Hill 1972). Chlorobenzene is considered sufficiently volatile and toxic to pose inhalation risk via vapor intrusion from soil and groundwater (EPA 2018a).

5.4.2 Transformation and Degradation

Under hypoxic conditions in groundwater, shifts in the bacterial community may occur as a result of syntrophic interactions rather than competitive interactions, facilitating the degradation of chlorobenzene (Kiesel et al. 2007). Syntrophy occurs when one organism lives off the product of another organism, rather than the organism itself.

Air. Physical constants for chlorobenzene, especially its vapor pressure and water solubility, indicate that the air is an important, and perhaps the dominant, medium for the transport and transformation of chlorobenzene. As an aromatic molecule with strong ultraviolet-absorption, chlorobenzene has a half-life of 20–40 hours under simulated atmospheric conditions (Dilling et al. 1976). This appears to be confirmed by the large difference between chlorobenzene measurements in urban air (3,000 ng/m³ [0.66 ppb]) and in rural air (not detected) in 1982 (EPA 1983).

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Water. Biodegradation in a wastewater inoculum was studied by Tabak et al. (1981). Among 57 environmental pollutants tested, chlorobenzene at 5 mg/L (5 ppm) was among the more rapidly biodegraded substances, with 89% degradation in a week and 100% after adaptation. Biodegradation is therefore a major degradation process in oxygenated waters, while evaporation will play an additional role in surface waters.

Few data are available from the field, but evaporation, hydrolysis, and microbial degradation, in that order, are likely to be the major fates of chlorobenzene discharged to water.

Bioconcentration of chlorobenzene does not appear to be a significant process in aquatic environments. However, bioconcentration factors for chlorobenzene do increase somewhat in phytoplankton as temperature increases between 4.5 and 27.6°C (Koelmans and Sanchez 1994).

Oxygen appears to be required for the initial activation of chlorobenzene and the fission of the aromatic ring, although it can be partially replaced by nitrate (Nestler et al. 2007).

Metabolic dechlorination of chlorobenzenes seems to proceed fastest under methanogenic conditions (Adrian and Görisch 2002; Ramanand et al. 1993). While the negative changes in Gibbs free energy associated with all 20 possible dechlorination reactions of chlorobenzenes are large enough to be coupled to adenine triphosphate (ATP) generation, not all of those reactions have been observed in laboratory systems, and the extent to which any of them occurs in nature remains unknown (Adrian and Görisch 2002).

The potential for anaerobic degradation has also been studied in contaminated groundwater plumes, where oxygen levels are generally lower than they are outside the plume. In a study of three North Central Florida landfills, Hallbourg et al. (1992) found that due to the high water table, anaerobic degradation predominated. In a contaminated aquifer in Bitterfeld, Germany, the decreases of chlorobenzene concentrations at the horizontal fringes of the plume and at shallower depths were accompanied by changes in isotopic composition (i.e., enrichment in ^{13}C) that suggested the *in situ* anaerobic degradation of chlorobenzene was occurring, albeit slowly (Kaschl et al. 2005). Since the known aerobic pathway initiated by dioxygenases in chlorobenzene-degrading strains (*Ralstonia* sp. DSM 8910, *Acidovorax facilis* UFZ B517, *Rhodococcus erythropolis* UFZ B528, and *Pseudomonas verinii* UFZ B547) did not result in isotopic fractionation, it was concluded that a novel anaerobic pathway resulting in isotopic fractionation was the predominant process of chlorobenzene degradation in this

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aquifer. Chlorobenzene contamination of this aquifer was the likely result of its proximity to a site where lindane had been formerly produced; chlorobenzene was measured at up to 30 ppm. The anaerobic microbial degradation of [$^{13}\text{C}_6$]-chlorobenzene was confirmed by Nijenhuis et al. (2007). In a constructed wetland designed to treat contaminated groundwater, Braeckevelt et al. (2007a) observed an isotope shift that was higher than expected for aerobic chlorobenzene degradation and concluded that an anaerobic degradation pathway must be making a significant contribution to the overall degradation. Natural attenuation of ^{13}C -labeled chlorobenzene in this constructed wetland was indicated by: (1) detection of ^{13}C -labeled (i.e., reductively dechlorinated) benzene; (2) incorporation of chlorobenzene-derived radiolabel (^{13}C) into bacterial fatty acids; and (3) a systematic correlation between decreasing chlorobenzene concentration and significant enrichment in ^{13}C with increasing distance from the source of contamination (Braeckevelt et al. 2007b).

Sediment and Soil. Biodegradation of chlorobenzene is rapid, leaving no detectable residues after 1 or 2 weeks. Adaptation is also rapid (Tabak et al. 1981).

Evaporation and microbial degradation, in that order, are likely to be the major fates of chlorobenzene in soils. However, very few data are available from the field. Most relevant information comes from laboratory studies on amended soils and strains of soil bacteria isolated from contaminated water, soil, or sediments.

Under aerobic conditions, all 15 volatile and semivolatile organic compounds (including chlorobenzene) in a soil-applied mixture disappeared rapidly during a 7-day observation period due to abiotic factors (Anderson et al. 1991). Feidieker et al. (1995) documented the aerobic degradation of chlorobenzene with mixed bacterial cultures. Complete metabolism of chlorinated benzenes is not a feature that is generally found in aerobic bacteria. However, at chlorobenzene-contaminated sites, indigenous bacteria populations appear able to evolve the capacity for natural attenuation of chlorobenzene (Van der Meer et al. 1998). *Pseudomonas putida* MST that was previously isolated in the presence of α -methylstyrene was shown to regioselectively hydroxylate chlorobenzene to 3-chlorocatechol, and 2- and 4-chlorophenol to 3- and 4-chlorocatechol, respectively (Bestetti et al. 1992). Inoculation of a soil slurry with *Pseudomonas aeruginosa* (105 microbes/g soil) led to rapid and complete degradation of 0.8 mM chlorobenzene within 30 hours (Brunsbach and Reineke 1994). Indigenous soil microbes also degraded chlorobenzene, but the higher chlorobenzenes persisted.

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Chlorobenzene contamination of soil stimulates the growth of indigenous, chlorobenzene metabolizing bacteria. The latter may even out-compete inoculated strains of *Pseudomonas* (Nishino et al. 1994).

In an *in vitro* study, Nowak et al. (1996) demonstrated the total reductive dechlorination of chlorobenzenes by a methanogenic culture enriched from Saale River sediment. Dechlorination of chlorobenzene to benzene was also observed in these cultures. However, the amount of benzene formed was extremely low and the reaction occurred only in the presence of higher chlorinated benzenes (Nowak et al. 1996). Presumably, this was a co-metabolic process (i.e., one in which the metabolism of chlorobenzene occurred without benefit to the organism), but was co-incident with the metabolism of the substrate on which the microbe actually depended for energy production. Such reactions are useful in bioremediation because they can proceed at concentrations far below those required to support the organism (Hazen 2009).

As previously documented in the field for pesticides and other contaminants, the residue of chlorobenzene in soil that is not volatilized or metabolized tends to bind more tightly to soil with time, a phenomenon known as “aging” (Sharer et al. 2003). As a result, degradation occurs at lower rates and to a lesser extent, even though chlorobenzene-degrading bacteria still have access to sorbed chlorobenzene in aged wetland soils (Lee et al. 2009).

The reductive dechlorination of chlorobenzenes in an anaerobic estuarine sediment followed first-order reaction kinetics, with rate constants ranging from 0.0016 to 0.0389 day⁻¹ or half-lives between 17 and 433 days (Kochany and Boltob 1992; Masunaga et al. 1996). From the detected intermediates, it was apparent that the removal of chlorine atoms occurred at all possible positions on the aromatic ring, but removal followed a thermodynamically favored order (i.e., a chlorine atom flanked on both sides by another > one of two adjacent chlorine atoms > a chlorine with no adjacent chlorine atoms) (e.g., the dechlorination of chlorobenzene) (Masunaga et al. 1996).

Other Media. No studies on the transformation or degradation of chlorobenzene in food or other media were located.

5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to chlorobenzene depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens.

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Concentrations of chlorobenzene 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 chlorobenzene 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 5-3 shows the lowest limit of detections that are achieved by analytical analysis in environmental media. An overview summary of the range of concentrations detected in environmental media is presented in Table 5-4.

Table 5-3. Lowest Limit of Detection Based on Standards^a

Media	Detection limit	Reference
Air	0.47 ppt	Krost et al. 1982
Drinking water	0.01 µg/L (ppb)	NEMI 2019
Surface water and groundwater	0.003 µg/L (ppb)	NEMI 2019
Soil	0.003 µg/L (ppb)	NEMI 2019
Sediment	0.002 ng/mL (ppb)	Wolska et al. 2003
Whole blood	0.011 ng/mL (ppb)	CDC 2018

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

Table 5-4. Summary of Environmental Levels of Chlorobenzene

Media	Low	High	For more information
Outdoor air (ppbv)	<0.05	0.50	Section 5.5.1
Surface water (ppb)	<0.01	10	Section 5.5.2
Ground water (ppb)	<1	<5	Section 5.5.2
Drinking water (ppb)	No data		Section 5.5.2
Food (ppb)	<2	13	Section 5.5.4
Soil (ppb)		<5 (median value)	Section 5.5.3

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

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

Medium	Median ^a	Geometric mean ^a	Geometric standard deviation ^a	Number of quantitative measurements	NPL sites
Water (ppb)	38	73.5	23.4	215	127
Soil (ppb)	1,550	1,780	84.9	92	64
Air (ppbv)	1.92	2.66	35.2	28	19

^aConcentrations found in ATSDR site documents from 1981 to 2019 for 1,867 NPL sites (ATSDR 2019). 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

Air samples at 56 localities in the United States in 1982 showed mean chlorobenzene concentrations of 0.24 ppb (EPA 1983). The highest concentration measured concentrations were in urban and suburban areas; the median concentration in these areas were 0.33 ppb. Chlorobenzene was not detectable in rural and remote areas. The median concentration at the sites of production was 0.03 ppb. EPA (1981) measured average concentrations of chlorobenzene of 0.309, 0.240, and 0.290 ppb in Houston, Texas, St. Louis, Missouri, and Denver, Colorado, respectively, with a calculated residence time of 13 days. Data collected from three urban sites in New Jersey from 1981 to 1982 contained mean chlorobenzene concentrations of ranging from 0.07 to 0.22 ppb (Harkov et al. 1987). A study of New Jersey waste sites found similar air levels of chlorobenzene (mean values of 0.05–0.80 ppb) (Harkov et al. 1985). However, air levels found by another study performed for the EPA (1978) were an order of magnitude lower, with only the air over a waste site approaching the mean urban concentrations reported above.

Ambient air outside homes of "Old Love Canal" (Niagara Falls, New York) contained chlorobenzene ranging from not detectable at four sites to traces at four sites and 120 ng/m³ (0.026 ppb) at one site (Barkley et al. 1980). Corresponding indoor air concentrations of chlorobenzene were not detected at six sites and ranged from 60–600 ng/m³ (0.0013–0.13 ppb) at the remaining three sites (Barkley et al. 1980). In an air sampling study in West Virginia (Cohen et al. 1989), chlorobenzene was not detected in outdoor air samples; however, corresponding indoor air concentrations of chlorobenzene were reported at mean, median, and maximum values of 16.5, 5.62, and 72.22 µg/m³, respectively (3.62, 1.23, and 15.8 ppb), in 63% of homes evaluated.

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5.5.2 Water

Historically, chlorobenzene was found in U.S. rivers at levels up to and exceeding 10 µg/L (10 ppb) (EPA 1976; Sheldon and Hites 1978). Private wells near a hazardous waste site contained as much as 41 µg/L (41 ppb) (Clark et al. 1982) and tap water at Love Canal contained concentrations ranging from 10 to 60 ng/L (0.01–0.06 ppb) (Barkley et al. 1980). Of 2,401 groundwater samples from domestic wells and 1,096 samples from public wells in a survey in the United States, >90% of the chlorobenzene concentrations were <1 ppb and none were as high as 5 ppb (USGS 2006).

Chlorobenzene was not detected in thousands of surface water and groundwater samples collected across the United States from 2016 to 2020 (WQP 2020). The highest concentration of chlorobenzene in landfill leachate samples collected during this time period was 6.09 ppb (WQP 2020). Chlorobenzene was not found in the limited number of storm water samples reported (WQP 2020).

A risk assessment on chlorobenzene for the marine environment (the North Sea area) was conducted in which “risk” was indicated by the ratio of predicted environmental concentration (PEC) to the predicted no-effect concentration (PNEC) (set to 32 µg/L [ppb]) for the marine aquatic environment (Van Wijk et al. 2004). Since monitoring data indicated that chlorobenzene in surface waters was below the detection limits of 0.1, 0.2, and 0.5 µg/L (ppb), the worst-case PEC was assumed to be 0.5 µg/L (ppb), yielding a PEC/PNEC of at least 60, without even taking into account dilution of chlorobenzene-containing surface waters in the sea. The authors concluded that chlorobenzene is not a toxic, persistent, or bioaccumulating substance, and that current use of the compound posed no unacceptable risk to the aquatic environment (Van Wijk et al. 2004).

5.5.3 Sediment and Soil

Staples et al. (1985) reported that the median concentration of chlorobenzene in the United States was estimated to be <5 ppb dry sediments. In more than 3,000 sediment data points compiled from Storage and Retrieval (STORET) Data Warehouse and the National Water Information System (NWIS), chlorobenzene was not detected in over 82%, was reported at less than the detection limit in about 18%, and was found above the detection limit in about 0.4% (WQP 2020).

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5.5.4 Other Media

A national survey of the United States indicated that chlorobenzene was below detection limits in milk supplies (Schaum et al. 2003). VOCs were analyzed in 70 food types over a 5-year period, of the 41 types reported, chlorobenzene was identified in nine (cheddar cheese, chocolate cake with frosting, carbonated cola beverage, chocolate chip cookies, sour cream, French fries, cheese and pepperoni pizza, sugar cookies, cake doughnuts with icing) at concentrations ranging from 2 to 13 ppb (Fleming-Jones and Smith 2003).

5.6 GENERAL POPULATION EXPOSURE

Chlorobenzene was found in 96% of human adipose tissue samples from all regions of the United States at levels ranging from 1 to 9 ng/g (EPA 1986). At Love Canal, Niagara Falls, chlorobenzene was detected in the breath of one of nine people evaluated for exposure and in the urine of six of nine persons at concentrations ranging from 20 to 120 ng/L (Barkley et al. 1980).

Personal sampling at chemical companies (NIOSH 1981) indicated that chlorobenzene levels, measured at up to 4 ppm in workplace air did not exceed the American Conference of Governmental Industrial Hygienists (ACGIH) and Occupational Safety and Health Administration (OSHA) permissible limit of 75 ppm.

According to the results of the National Health and Nutrition Examination Survey (NHANES), chlorobenzene was undetectable in blood samples of every age group, gender, race, and ethnicity studied in the survey years between 2003 and 2016 (CDC 2019). The detection limit was 0.011 ng/mL.

Vapor intrusion may also be a potential source of chlorobenzene exposure, as vapor intrusion has been observed for several VOCs with similar properties. EPA's compilation of six studies of background indoor air concentrations found a 0–8% detection rate for chlorobenzene in 1,050 U.S. resident samples between 1997 and 2004 (EPA 2011). The background medians ranged from <0.01 to <0.92 $\mu\text{g}/\text{m}^3$ and the maximum values ranged from 0.04 to 9.7 $\mu\text{g}/\text{m}^3$. ATSDR extracted environmental data from 135 ATSDR reports evaluating the vapor intrusion pathway at 121 sites published between 1994 and 2009 (Burk and Zarus 2013). The levels of chlorobenzene did not exceed comparisons values (concentrations used by ATSDR to identify contaminants requiring further evaluation).

5. POTENTIAL FOR HUMAN EXPOSURE

Chlorobenzene in water is expected to volatilize; thus, there is potential for inhalation exposure during showering and bathing. ATSDR's three-compartment Shower and Household-Use Exposure (SHOWER) model predicts air concentrations in the shower stall, bathroom, and main house throughout the day by estimating the contribution from showering or bathing and the contribution from other water sources in the house, such as the dishwasher, clothes washer, and faucets. This information, along with human activity patterns, is used to calculate a daily time-weighted average exposure concentration via inhalation exposure and from dermal uptake from skin contact. ATSDR's SHOWER model is available by sending a request to showermodel@cdc.gov.

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Occupational settings provide the greatest potential for high exposures to chlorobenzene. Data from the National Occupational Exposure Survey (NOES), conducted by the National Institute for Occupational Safety and Health (NIOSH) from 1980 to 1983, indicated that 18,050 workers, including 3,881 women, in 912 plants spanning 35 occupations were potentially exposed to chlorobenzene in the workplace (NIOSH 2018a). Since chlorobenzene is a volatile compound and is used extensively as a solvent, large quantities may be released to the workplace air. Other populations that might be exposed include persons living near industrial facilities where chlorobenzene emissions are not properly controlled.