

6. POTENTIAL FOR HUMAN EXPOSURE

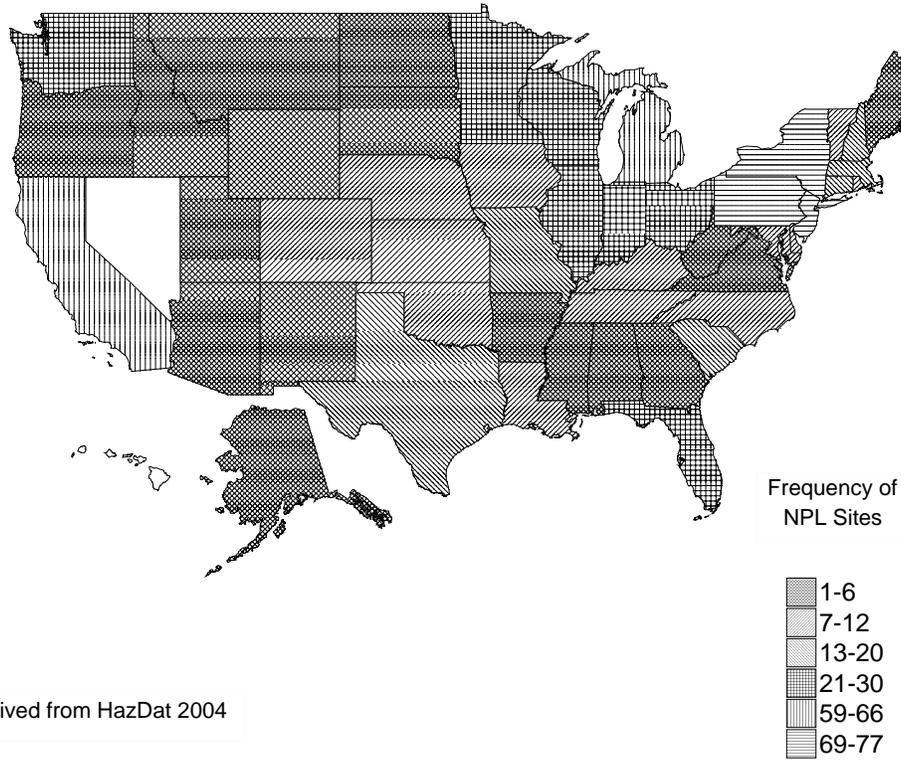
6.1 OVERVIEW

1,1,1-Trichloroethane has been identified in at least 809 of the 1,647 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2004). However, the number of sites evaluated for 1,1,1-trichloroethane is not known. The frequency of these sites can be seen in Figure 6-1. Of these sites, 804 are located within the United States, 3 are located in the Commonwealth of Puerto Rico (not shown), 1 is located in the Virgin Islands (not shown), and 1 is located in Guam (not shown).

1,1,1-Trichloroethane is a synthetic compound that is released to the environment by human industrial activity. It was released to the environment by process and fugitive emissions during its manufacture, formulation, and use in both consumer and industrial products. Because 1,1,1-trichloroethane is volatile and was used as a solvent in many products, it was most frequently found in the atmosphere due to volatilization during production and use. 1,1,1-Trichloroethane is an ozone depleting substance and has been listed as a class I substance under Section 602 of the Clean Air Act. Class I substances have an ozone depletion potential (ODP) of ≥ 0.2 and include chlorofluorocarbons (CFCs), halons, carbon tetrachloride, 1,1,1-trichloroethane, and methyl bromide. Although recent estimates have yielded an ODP of 0.12 for 1,1,1-trichloroethane, it is still listed as a class I substance. Under Section 604 of the Clean Air Act as amended in 1990, all production and use of 1,1,1-trichloroethane was scheduled to cease as of January 1, 2002. However, 1,1,1-trichloroethane may still be used for essential applications such as medical devices and aviation safety (for the testing of metal fatigue and corrosion of existing airplane engines and other parts susceptible to corrosion) until January 1, 2005. 1,1,1-Trichloroethane (and other class I substances) may also be produced domestically for export to developing countries as specified in Section 604(e) of the Clean Air Act. This exception to the phase-out is scheduled to end by January 1, 2012 for 1,1,1-trichloroethane (EPA 2004m). 1,1,1-trichloroethane was still being manufactured in the United States in 2002 in a production volume range of $>100 - <500$ million pounds. More current production data are not yet available and therefore, it is unclear what stage the phase-out is in at this time.

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Figure 6-1. Frequency of NPL Sites with 1,1,1-Trichloroethane Contamination



Derived from HazDat 2004

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1,1,1-Trichloroethane is no longer used in common household products. The current likelihood of exposure of the general population to 1,1,1-trichloroethane is remote. Possible routes of exposure to 1,1,1-trichloroethane were inhalation, dermal contact, or through the ingestion of either contaminated water or food. Exposure by inhalation was expected to predominate. The general population was exposed to 1,1,1-trichloroethane because of its prevalence in common household products. Indoor air concentrations were determined to be greater than nearby outdoor concentrations, probably as a result of its presence in a myriad of consumer products in the past. Occupational exposure to 1,1,1-trichloroethane could occur by inhalation or dermal contact during its manufacture and formulation, during its use as a cleaner of manufactured components, and during the application of the numerous paints, resins, adhesives, and cleaners containing it as a solvent. At hazardous waste sites, inhalation is expected to be the predominant route of exposure; however, ingestion of contaminated water may occur also.

The dominant environmental fate process for 1,1,1-trichloroethane is volatilization to the atmosphere. Once in the atmosphere, reaction with photochemically-produced hydroxyl radicals is expected to be the most important transformation process for 1,1,1-trichloroethane; the estimated atmospheric lifetime for this process is about 6 years. This long atmospheric lifetime allows about 15% of 1,1,1-trichloroethane to migrate to the stratosphere, where it may be degraded by lower wavelength ultraviolet light, not available in the troposphere, to produce atomic chlorine. The chlorine atoms produced in the stratosphere by this process may react with ozone causing the erosion of the ozone layer. However, direct photochemical degradation of 1,1,1-trichloroethane in the troposphere should not occur. The moderate water solubility of 1,1,1-trichloroethane suggests that rain washout can occur; however, 1,1,1-trichloroethane removed from the atmosphere by this process would be expected to re-volatilize. The lengthy half-life for 1,1,1-trichloroethane in the troposphere allows it to be carried great distances from its original point of release, and it has been found in remote places far from any known source of release.

If released to soil, 1,1,1-trichloroethane should display high mobility and the potential for leaching into groundwater. Volatilization from soil surfaces to the atmosphere is expected to be an important fate process. Although data regarding biodegradation of 1,1,1-trichloroethane in soil are lacking, it is not expected to be an important fate process. 1,1,1-Trichloroethane is not expected to undergo aerobic biodegradation, but there is some experimental evidence that biodegradation may occur under anaerobic conditions.

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Once released to surface water, 1,1,1-trichloroethane is expected to undergo volatilization to the atmosphere. Neither adsorption to sediment nor bioconcentration in aquatic organisms is recognized as an important removal process. Aerobic biodegradation of 1,1,1-trichloroethane can occur in the presence of methane-oxidizing bacteria. If released to groundwater, biodegradation of 1,1,1-trichloroethane under anaerobic conditions is known to occur; however, it appears to be a slow process under most environmental conditions.

1,1,1-Trichloroethane may very slowly undergo abiotic degradation in soil or water by elimination of hydrochloric acid (HCl) to form 1,1-dichloroethene, which also can be considered a pollutant, or it can undergo hydrolysis to form the naturally occurring acetic acid. Direct photochemical degradation is not expected to be an important fate process.

6.2 RELEASES TO THE ENVIRONMENT

The manufacture and use of 1,1,1-trichloroethane was scheduled to be phased out by 2002. Since the declines in emissions closely follow the declines in production and use, the emissions of 1,1,1-trichloroethane to the atmosphere should show a corresponding decline (EPA 2004m).

6.2.1 Air

A correlation of data from the EPA Air Toxics Emission Inventory with industrial source codes (SIC codes), shows that volatile emissions of 1,1,1-trichloroethane are associated with 122 different industrial classifications that run the gamut from manufacturing and formulation to secondary uses (Pacific Environmental Services, Inc. 1987). Release of 1,1,1-trichloroethane, in most cases, is an expected result of its use (Spence and Hanst 1978). Small amounts of 1,1,1-trichloroethane is also released to the atmosphere from coal-fired power plants (Garcia et al. 1992), from incineration of hospital wastes (Green et al. 1992; Walker and Cooper 1992), incineration of military nerve agents (Mart and Henke 1992), incineration of industrial wastes containing certain plastics and waste solvents (Nishikawa et al. 1992, 1993), and incineration of municipal waste water sludge (Vancil et al. 1991). 1,1,1-Trichloroethane contained in consumer products was released into the atmosphere during the application, drying, or curing of these products. 1,1,1-Trichloroethane can enter the atmosphere via the air-stripping treatment of waste water. Volatilization, which accounts for $\approx 100\%$ of removal in waste water, occurs during this process (Kincannon et al. 1983a). Volatilization from waste lagoons is also likely (Shen 1982).

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Precise quantitative data on 1,1,1-trichloroethane air emissions are lacking. A large proportion of total production probably found its way into the atmosphere. Estimates for 1984 suggest that 100.4 kilotons (220 million pounds) were released during use by the European Economic Community (EEC) and other western European countries, a figure representing some 70% of total consumption in Europe (Herbert et al. 1986). Global estimates indicate that 1,497 million pounds (679 million kg) of 1,1,1-trichloroethane were released to the atmosphere in 1988 (Midgley 1989). 1,1,1-Trichloroethane releases in air from facilities in each state in the United States that manufactured or processed 1,1,1-trichloroethane during 2002 are reported in the Toxics Release Inventory (TRI) and listed in Table 6-1 (TRI02 2004). According to TRI02 (2004), an estimated total of 234,013 pounds of 1,1,1-trichloroethane, amounting to 85.5% of the total environmental release, was discharged to the air from manufacturing and processing facilities in the United States in 2001. The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list. However, a comparison of TRI data for 1992 and 2002 (115 million pounds and 234,013 pounds, respectively) shows that the nationwide emission of 1,1,1-trichloroethane in the atmosphere has decreased by 97.9% during this period. A 36% reduction in atmospheric emissions was observed in Irvine, California, from 1989 to 1990 (Brown and Hart 1992). Most processes that use 1,1,1-trichloroethane result in some fugitive emissions. For example, the release of 1,1,1-trichloroethane from an industrial solvent recycling facility was 16.7% of the throughput (Balfour et al. 1985).

6.2.2 Water

1,1,1-Trichloroethane can be released to surface water from the waste water of industries in any of the numerous industrial classifications that used or produced this compound. The STORET database for values registered in the years 1980–1988 shows that 1,1,1-trichloroethane tested positive in 12% of effluent samples with maximum, median, and mean concentrations of 6,500, 8.0, and 171 mg/L, respectively (STORET 1988). 1,1,1-Trichloroethane releases in water, including release to publicly owned treatment works (POTW), from facilities in each state in the United States that manufactured or processed 1,1,1-trichloroethane during 2002 are reported in Table 6-1 (TRI02 2004). According to TRI02 (2004), 0.049% of the total 1,1,1-trichloroethane environmental release was discharged to environmental waters from manufacturing and processing facilities in the United States in 2002. The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list. Higher concentrations of 1,1,1-trichloroethane have been found in surface waters near known

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Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use 1,1,1-Trichloroethane^a

State ^c	RF ^d	Reported amounts released in pounds per year ^b							Total release	
		Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	On-site ^j	Off-site ^k	On- and off-site	
AR	3	592	No data	0	0	0	592	0	592	
CA	6	12,057	No data	0	0	0	12,057	0	12,057	
IL	2	10	No data	0	198	154	10	352	362	
IN	4	284	No data	0	0	0	284	0	284	
KS	1	500	No data	0	5	0	500	5	505	
KY	2	16,605	6	0	250	0	16,611	250	16,861	
LA	4	151,670	46	0	18	0	151,717	17	151,734	
MI	2	505	No data	0	38,405	0	38,881	29	38,910	
MO	1	3	0	0	0	0	3	0	3	
MS	1	500	No data	0	0	0	500	0	500	
NE	1	255	No data	0	0	0	255	0	255	
NJ	2	111	28	0	27	0	162	4	166	
NM	1	6,000	No data	0	250	0	6,000	250	6,250	
NY	1	0	No data	0	0	5	0	5	5	
OH	4	3,106	5	12	258	0	3,111	270	3,381	
PA	1	80	No data	0	0	0	80	0	80	
SC	1	470	No data	0	0	0	470	0	470	
TX	5	3,317	14	0	0	0	3,331	0	3,331	
UT	2	37,937	No data	0	0	0	37,937	0	37,937	
WI	2	10	No data	0	0	0	10	0	10	
Total	46	234,013	99	12	39,411	159	272,512	1,182	273,694	

Source: TRI02 2004 (Data are from 2002)

^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 on-site 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

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industrial sources, such as effluent outfalls or disposal sites, compared to the levels found upstream from these sources (see Table 6-2) (Dreisch et al. 1980; Hall 1984; Kaiser and Comba 1986; Kaiser et al. 1983; Wakeham et al. 1983a).

1,1,1-Trichloroethane has been found in samples from four U.S. cities measured in the National Urban Runoff Program (Cole et al. 1984). 1,1,1-Trichloroethane has been found in the effluent from water treatment plants and municipal waste water (Comba and Kaiser 1985; Corsi et al. 1987; DeWees et al. 1992; Feiler et al. 1979; Lue-Hing et al. 1981; McCarty and Reinhard 1980; Namkung and Rittman 1987; Otson 1987; Pincince 1988; Rogers et al. 1987; Vancil et al. 1991; Young 1978; Young et al. 1983).

1,1,1-Trichloroethane can enter groundwater from various sources. Contamination as a result of industrial activity has occurred (Dever 1986; Hall 1984). Leachate from landfills has percolated into groundwater (Barker 1987; Plumb 1987). The measured soil sorption coefficient (K_{oc}) value of 2.02 (Chiou et al. 1980; Gossett 1987) suggests that 1,1,1-trichloroethane released to soil can leach into groundwater. Measurements of 1,1,1-trichloroethane in drinking water from probability-based population studies (Wallace et al. 1984a, 1987a, 1988), indicate the potential for exposure from drinking water.

6.2.3 Soil

1,1,1-Trichloroethane release on land, including underground injection, from facilities in each state in the United States that manufactured or processed 1,1,1-trichloroethane during 2002 are reported in Table 6-1 (TRI02 2004). According to TRI02 (2004), an estimated total of 39,411 pounds of 1,1,1-trichloroethane, amounting to 14.48% of the total environmental release, was discharged to the land from manufacturing and processing facilities in the United States in 2002. The TRI data should be used with caution because only certain types of facilities are required to report. This is not an exhaustive list.

Data on soil contamination by 1,1,1-trichloroethane are lacking in the literature, which is what one would expect based on the TRI02 (2004) data given in Table 6-1. Contamination of soil is possible by direct application of insecticides and rodenticides that contain 1,1,1-trichloroethane as a solvent. Land application of sewage sludge at typical application rates may slightly elevate the level of 1,1,1-trichloroethane in agricultural soil, but the level is not expected to be of environmental concern in the majority of cases (Wilson et al. 1994). The most likely routes for soil contamination are through accidental spills, the contamination of soil by landfill leachates, leaching of contaminated surface waters from

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Table 6-2. Detection of 1,1,1-Trichloroethane in Water and Sediments

Media type/location	Sampling dates	Number of Samples	Concentration (ppb)		Reference
			Range	Mean	
Surface water					
Ohio River (Huntington, WV)	1978–1979	22	ND–0.57 ^a	NS	Dreisch et al. 1980
Schuylkill Creek (Philadelphia, PA)		33	ND–0.28	NS	
Niagara River	1981	17	ND–0.017 ^b	0.007	Kaiser et al. 1983
Lake Ontario		82	ND–0.180	NS	
Lake St. Clair, Canada	1984	64	0–0.112 ^b	0.052	Kaiser and Comba 1986
Brazos River, TX	1981–1982	10	ND–0.61 ^a	0.1	McDonald et al. 1988
Quinnipiac River (Southington, CT)	1980	5	ND–9.7 ^a	2.6	Hall 1984
Valley of the Drums, KT (on-site standing water)	1979	NS	ND–9.4 ^a		Stonebraker and Smith 1980
Lang Property, NJ	1985	NS	9 ^a		EPA 1987c
Pacific Ocean	1975	NS	0.00062–0.0105 ^c		Su and Goldberg 1976
Summit National, OH (NPL site)	1987				EPA 1988n
on-site	3	5–66	13		
off-site	6	ND–29	4.8		
Sediments:					
Lake Pontchartrain, LA	1980	NS	ND–0.01 ^d		Ferrario et al. 1985
Pacific Ocean (Los Angeles)	1981	2		<0.5	Young et al. 1983
Detroit River, MI	1982	2	1–2 ^e	NS	Fallon and Horvath 1985
Summit National, OH (NPL site) on-site pond sediment	1987	7	50–2,500 ^f	670 ^f	EPA 1988n
Groundwater:					
CERCLA ^g hazardous waste sites	1981–1984	178	NS		Plumb 1987
Landfill Sites, Ontario, Canada	NS	NS	ND–2.8 ^a	NS	Barker 1987
Southington, CT	1980	28	ND–11,000 ^a	NS	Hall 1984
New Jersey	1980–1982	315	NS	NS	Fusillo et al. 1985

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Media type/location	Sampling dates	Number of Samples	Concentration (ppb)		Reference
			Range	Mean	
Montgomery County, MD	1983	4	<10–1,600 ^a	NS	Dever 1986
Hastings, NE	1984	15	ND–12.1 ^a	NS	Fischer et al. 1987
Hastings, NE	1984	15	ND–12.1 ^a	NS	Fischer et al. 1987
U.S. cities					
Population <10,000 (random samples)	1981–1982	280	ND–18 ^a		Westrick et al. 1984
Population <10,000 (nonrandom) ^h		321	ND–8.2		
Population >10,000 (random samples)		186	ND–3.1		
Population >10,000 (nonrandom) ^h		158	ND–21		
Minnesota ⁱ	1983	20	ND–470 ^a	NS	Sabel and Clark 1984
Lang property, NJ	1985	NS	8,200 ^a		EPA 1987c
Marshall landfill, CO ^j	1983	NS	ND–350 ^a		EPA 1986b
Forest Waste Disposal Site, Genesee County, MI ^j	1983	NS	130 ^a		EPA 1986c
Palmer, MA PSC Resources, Inc. (NPL site)	1987	NS			
on-site			NS	40,000 ^k	Massachusetts Department of Public Health 1989
off-site			NS	3,700 ^k	
Idaho National Eng. Lab, IO	1987	112	ND–140 ^a		Mann and Knobel 1988
9 Urban land-use studies	1991	208	ND–230 ^a	NS	Kolpin et al. 1997
Drinking water:					
Old Love Canal, NY	1978	9	0.010–0.120 ^b		Barkley et al. 1980
Bayonne/Elizabeth, NJ	1980				Wallace et al. 1984a

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Media type/location	Sampling dates	Number of Samples	Concentration (ppb)		Reference
			Range	Mean	
home		75	0.03–3.50 ^l	0.02	
work		45	0.02–1.60	0.07	
Research Triangle Park, NC					
home		30	0.02–1.90		
work		18	0.02–0.89		
New Jersey	1981		NS–5.3	0.6	Wallace et al. 1987a
	1982		NS–2.6	0.2	
	1983		NS–1.6	0.2	
North Carolina	1982		NS–0.05	0.03	
North Dakota	1982		NS–0.07	0.04	
Los Angeles, CA	February 1984	117	NS	0.15 ^a	Wallace et al. 1988
Los Angeles, CA	June 1984	52	NS	0.08 ^a	
Contra Costa, CA	May 1984	71	NS	0.09 ^a	
Drinking water wells (groundwater):					
Maine	NS	NS	NS–5,440	NS	Burmaster 1982
New York			NS–5,100		
Connecticut			NS–1,600		
New Jersey			NS–965		
Nassau County, NY			NS–310	9	
Suffolk County, NY	1976–1986				Zaki 1986
public wells		575	NS–900 ^a	16.5	
private wells		19,000	NS–12,200	23.8	
Wisconsin	1980–1984				Krill and Sonzogni 1986
community wells		1,174	NS		
private wells		617	NS		
Rock River Terrace, IL ^j	1985	NS	NS–3.2		EPA 1986d
South Brunswick, NJ	1977	NS	150–1,500		Althoff et al. 1981
Sewage Sludge					
United States (Site NS)	1978	2	23–99 ^a		Feiler et al. 1980
Forest Waste Disposal Site, MI ⁱ	1983	NS	25 ^a		EPA 1986c
Vestal, NY ^j	1985–1986	2	25–47 ^a	36 ^a	ATSDR 1988
Urban runoff:					

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Media type/location	Sampling dates	Number of Samples	Concentration (ppb)		Reference
			Range	Mean	
Washington, DC; Denver, CO Rapid City, SD Lake Quinsigamond, MA	NS–1982	NS	1.6–10 ^a	NS	Cole et al. 1984
Rain:					
Los Angeles, CA	1982	1		0.069 ^b	Kawamura and Kaplan 1983
Beaverton, OR	1982	21	0.128–0.924 ^m	0.434	Rasmussen et al. 1983
Snow:					
Mt. Hood, OR	1981–1982	25	0.063–0.128 ^m	0.091	Rasmussen et al. 1983
California	1975	2	0.0006–0.0062 ^c		Su and Goldberg 1976
Alaska		1	0.027		

^aData reported in µg/L; converted to ppb using the conversion factor 1 ppb=1 µg/L

^bData reported in ng/L; converted to ppb using the conversion factor 1 ppb=1,000 ng/L

^cData reported in pg/mL; converted to ppb using the conversion factor 1 ppb=1,000 pg/mL

^dData reported in ng/g; converted to ppb using the conversion factor 1 ppb=1 ng/g

^eData reported in mg/kg; converted to ppb using the conversion factor 1 ppb=0.001 mg/kg

^fData reported in µg/kg; converted to ppb using the conversion factor 1 ppb=1 µg/kg

^gComprehensive Emergency Response, Compensation, and Liability Act

^hNonrandom sites were chosen by states/municipalities in an attempt to identify problem areas.

ⁱSite near municipal solid waste site

^jNPL site

^kData reported in ppm; converted to ppb using the conversion factor 1 ppb=0.001 ppm

^lData reported in ng/mL; converted to ppb using the conversion factor 1 ppb=1 ng/mL

^mData reported in ppt; converted to ppb using the conversion factor 1 ppb=1,000 ppt

ND = not detected; NPL = National Priorities List; NS = not specified

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treatment/storage lagoons, wet deposition, and possibly by the percolation of contaminated rainwater through soil.

6.3 ENVIRONMENTAL FATE

6.3.1 Transport and Partitioning

1,1,1-Trichloroethane is a volatile organic compound with moderate water solubility (1,500 mg/L at 25 °C) (Horvath 1982). The experimental Henry's law constants measured for this compound range from 6.3×10^{-3} to 17.2×10^{-3} atm m³/mol at 25 °C (Chiou et al. 1980; Gossett 1987; Tse et al. 1992); this suggests that volatilization from water should be the dominant fate process. Volatilization of 1,1,1-trichloroethane from water has readily occurred in the laboratory, in the field, and during waste water treatment (Dilling 1977; Dilling et al. 1975; Kincannon et al. 1983b; Piwoni et al. 1986; Wakeham et al. 1983b). Volatilization of 1,1,1-trichloroethane also has occurred from soil and from the groundwater of unconfined aquifers to the soil (Kreamer 1984; Piwoni et al. 1986).

Based on the experimental values for the log octanol/water partition coefficient (K_{ow}), 2.49 (Hansch and Leo 1985), and log K_{oc} , in the range of 2.02–2.26 (Chiou et al. 1979; Friesel et al. 1984; Park and Lee 1993), 1,1,1-trichloroethane would be expected to show high mobility in soil and readily leach into groundwater (Lyman et al. 1990; Swann et al. 1983). In surface waters, 1,1,1-trichloroethane would not be expected to show appreciable adsorption to sediment or suspended organic material. An experimental bioconcentration factor (BCF) of 9 (bluegill sunfish) has been determined for 1,1,1-trichloroethane (Barrows et al. 1980), suggesting that in fish and other aquatic organisms, uptake from water should not be an important fate process.

1,1,1-Trichloroethane has a vapor pressure of 123 mm Hg at 20 °C (see Table 4-2), which means that it exists in the vapor phase in the atmosphere (Eisenreich et al. 1983). Since this compound has moderate water solubility (see Table 4-2), vapor phase 1,1,1-trichloroethane will be removed from the air via washout by rain and transported to the terrestrial surface. It has been identified in rainwater (Jung et al. 1992; Kawamura and Kaplan 1983; Pluemacher and Renner 1993; Rasmussen et al. 1983). 1,1,1-Trichloroethane removed by rain water would be expected to re-volatilize rapidly to the atmosphere. Because of its long half-life of ≈ 4 years in the atmosphere (see Section 6.3.2.1), tropospheric 1,1,1-trichloroethane will be transported to the stratosphere, where it will participate in the destruction of the ozone layer. It will also undergo long-distance transport from its sources of emissions to other remote

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and rural sites. This is confirmed by the detection of this synthetic chemical in forest areas of Northern and Southern Europe and in remote sites (Ciccioli et al. 1993).

6.3.2 Transformation and Degradation

6.3.2.1 Air

The dominant atmospheric fate process for 1,1,1-trichloroethane is predicted to be degradation by interaction with photochemically-produced hydroxyl radicals. Earlier experimental rate constants for this gas-phase reaction ranged from 2.8×10^{-14} to 1.06×10^{-14} $\text{cm}^3/\text{mol}\cdot\text{sec}$ (20–30 °C) (Butler et al. 1978; Chang and Kaufman 1977; Cox et al. 1976; Crutzen et al. 1978; Howard and Evenson 1976; Jeong et al. 1984). More recent work indicates that this rate constant ranges from 0.95×10^{-14} $\text{cm}^3/\text{mol}\cdot\text{sec}$ to 1.2×10^{-14} $\text{cm}^3/\text{mol}\cdot\text{sec}$ (Finlayson-Pitts et al. 1992; Jiang et al. 1992; Lancar et al. 1993; Talukdar et al. 1992). 1,1,1-Trichloroethane is degraded via H-atom abstraction to $\text{CCl}_3\text{CH}_2\cdot$ and reacts with O_2 to yield the peroxy radical ($\text{CCl}_3\text{CH}_2\text{O}_2$) (DeMore 1992; Spence and Hanst 1978). Using an estimated atmospheric hydroxyl ($\text{OH}\cdot$) radical concentration of 5.0×10^5 mol/cm^3 (Atkinson 1985), the more recent rate constants translate to a calculated lifetime or residence time of ≈ 6 years. The estimated atmospheric lifetime of 1,1,1-trichloroethane which incorporates all removal processes, was also estimated to be ≈ 6 years (Prinn et al. 1987; Prinn et al. 1992). This indicates that the predominant tropospheric sink of 1,1,1-trichloroethane is through its reaction with OH radicals.

Photolytic degradation experiments have been performed in the presence of NO and NO_2 ; 1,1,1-trichloroethane underwent <5% degradation in 24 hours in the presence of NO (Dilling et al. 1976). In a smog chamber experiment in the presence of NO_x , 1,1,1-trichloroethane showed a disappearance rate of 0.1% per hour (Dimitriadis and Joshi 1977). Other studies have also concluded that 1,1,1-trichloroethane has low potential to form ozone as a result of photochemical reaction in the presence of NO_x (Andersson-Skoeld et al. 1992; Derwent and Jenkin 1991).

Under laboratory conditions thought to mimic atmospheric smog conditions, direct photochemical irradiation of 1,1,1-trichloroethane in the presence of elemental chlorine was performed. 1,1,1-Trichloroethane was the least reactive and thus the most stable of all chloroethanes under these conditions (Spence and Hanst 1978).

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Direct photochemical degradation of 1,1,1-trichloroethane in the troposphere is not expected to be an important fate process, because there is no chromophore for absorption of ultraviolet light (>290 nm) found in sunlight at tropospheric altitudes (Hubrich and Stuhl 1980; VanLaethem-Meuree et al. 1979). A laboratory experiment performed in sealed Pyrex ampules showed loss of 1,1,1-trichloroethane in 2 weeks under the influence of sunlight; however, catalysis by the Pyrex surface was probably responsible for the enhanced reactivity (Buchardt and Manscher 1978).

The relatively long tropospheric residence time for 1,1,1-trichloroethane suggests that migration to the stratosphere should be important. An estimated 11–15% of 1,1,1-trichloroethane released to the atmosphere is expected to survive and migrate to the stratosphere (Prinn et al. 1987; Singh et al. 1992). In the stratosphere, chlorine atoms produced from 1,1,1-trichloroethane by ultraviolet light may interact with ozone contributing to the destruction of the stratospheric ozone layer. Compared to CFC-11 (trichlorofluoromethane), the steady state ozone depletion potential of 1,1,1-trichloroethane has been estimated to be 0.1–0.16 (Gibbs et al. 1992; Solomon and Albritton 1992).

6.3.2.2 Water

Slow biodegradation of 1,1,1-trichloroethane can occur under both anaerobic and aerobic conditions. Anaerobic degradation of 1,1,1-trichloroethane is thought to occur predominantly through reductive dechlorination by methane-producing bacteria (Vargas and Ahlert 1987; Vogel and McCarty 1987) and by sulfate-reducing organisms (Cobb and Bouwer 1991; Klecka 1990). Determined experimental half-lives for anaerobic degradation using mixed culture bacteria ranged from 1 day to 16 weeks in the laboratory (Bouwer and McCarty 1983a, 1984; Hallen et al. 1986; Parsons et al. 1985; Vogel and McCarty 1987; Wood et al. 1985), based on a study from an injection well, after 3 months of injection, the predicted half-life of 1,1,1-trichloroethane in an aquifer was 200–300 days (Bouwer and McCarty 1984). Results obtained in a grab sample study of an aquifer suggest that anaerobic biodegradation of 1,1,1-trichloroethane will not occur (Wilson et al. 1983); however, the spiked concentration of 1,1,1-trichloroethane in the study, 1 mg/L, was in a range determined to be toxic to microorganisms (Barth and Bunch 1979; Benson and Hunter 1977; Vargas and Ahlert 1987). Another grab sample study, performed using more realistic concentrations, indicates that 1,1,1-trichloroethane slowly degrades under anaerobic conditions to 1,1-dichloroethane in groundwater (Parsons and Lage 1985; Parsons et al. 1985). However, when mixed anaerobic cultures were provided with acetate as primary substrate, the biodegradation of secondary substrate 1,1,1-trichloroethane occurred even without acclimation at concentrations exceeding

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1 mg/L (Hughes and Parkin 1992). A laboratory study showed that anaerobic biodegradation of 1,1,1-trichloroethane did not occur under denitrification conditions even after 8 weeks of incubation (Bouwer and McCarty 1983b).

Aerobic biodegradation in surface water and groundwater is not likely to be an important fate process since experimental studies did not indicate significant aerobic degradation of 1,1,1-trichloroethane (Klecka et al. 1990; Mudder and Musterman 1982; Nielson et al. 1990; Wilson and Pogue 1987). One study showed that 1,1,1-trichloroethane underwent aerobic degradation in the presence of Fe^{+2} /porphyrin solution (82% in 21 days), thought to be a catalyzed reductive chlorination (Klecka and Gonsior 1984). It is difficult to interpret these results in terms of the potential for environmental significance. One study reported that 1,1,1-trichloroethane underwent moderate biodegradation with significant concomitant volatilization (Tabak et al. 1981); however, experimental details are not sufficient to rule out loss due solely to volatilization. Halogenated aliphatic hydrocarbons, including 1,1,1-trichloroethane, act as cometabolic substrates for certain aerobic chemotrophs. In such cases, the organisms grow on another substrate and the enzymes induced under the particular growth conditions fortuitously biodegrade the halogenated aliphatics (Leisinger 1992). Such aerobic biodegradation of 1,1,1-trichloroethane up to a concentration of 1.2 mg/L was observed with methane-oxidizing (methanotrophic) bacteria isolated from an aquifer (Arvin 1991).

Anaerobic biodegradation proceeds via reductive dechlorination (Leisinger 1992; McCarty 1993). The major product from the anaerobic degradation of 1,1,1-trichloroethane has been identified as 1,1-dichloroethane, which slowly degrades to chloroethane in a secondary reaction (Hallen et al. 1986; Vogel and McCarty 1987). Therefore, total biodegradation of 1,1,1-trichloroethane is feasible by combining anaerobic dehalogenation with subsequent aerobic treatment (Leisinger 1992). Aerobic biodegradation of 1,1,1-trichloroethane, on the other hand, proceeds via substitutive and oxidative mechanisms with the production of trichloroethyl alcohol, which is further oxidized to chloride, carbon dioxide, and water (McCarty 1993).

Products from the abiotic degradation of 1,1,1-trichloroethane have also been identified. Acetic acid can arise from the hydrolysis of 1,1,1-trichloroethane (calculated half-life of 1.2 years at 25 °C and pH 7). Elimination of HCl can produce 1,1-dichloroethene (Hallen et al. 1986; Parsons et al. 1985; Vogel and McCarty 1987). The calculated half-life for this reaction is 4.8 years at 25 °C and pH 7 (Ellenrieder and Reinhard 1988). The half-lives of abiotic degradation of 1,1,1-trichloroethane by reaction with

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nucleophiles, such as HS^- and S_2O_2^- , which might be present in water, should be insignificant compared to the other processes described (Haag and Mill 1988). A 2.8 mmol aqueous solution of 1,1,1-trichloroethane reacted with ozone (concentration 1 mg/L) with a half-life of >32 days at 22 °C and a pH of 7 (Yao and Haag 1991). Therefore, reaction with ozone will not be an important process for the transformation of 1,1,1-trichloroethane present in natural bodies of water.

6.3.2.3 Sediment and Soil

Data are lacking on the degradation of 1,1,1-trichloroethane in soil. In a grab sample experiment, anaerobic degradation of 1,1,1-trichloroethane occurred slowly in soil (16% in 6 days) (Henson et al. 1988). If the microorganisms in the soil were first activated by using methane as a nutrient source, 46% of 1,1,1-trichloroethane degraded during the same period under aerobic conditions (Henson et al. 1988). Incubation of 1,1,1-trichloroethane in soil under aerobic conditions resulted in no measurable biodegradation (Klecka 1990).

6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

The manufacture and use of 1,1,1-trichloroethane was scheduled to be phased out by 2002 under the Clean Air Act (EPA 2004m). Since it is no longer in use domestically, the levels estimated in the environment, other than near point sources, should drop to insignificant amounts.

6.4.1 Air

1,1,1-Trichloroethane has been identified in urban, rural, and indoor air throughout the United States at concentrations shown in Table 6-3. Due to the nature of 1,1,1-trichloroethane's use, volatilization to the atmosphere is a predictable outcome, and thus, its widespread detection is not unexpected. It is the only chlorinated ethane regularly seen as a background pollutant in the troposphere (Spence and Hanst 1978). For the year 1980, an estimated global atmospheric quantity of 1,1,1-trichloroethane, based on absolute concentrations obtained over a 3-year period, was 2.58×10^9 kg (5,690 million pounds) (Prinn et al. 1983). An estimated average concentration of 0.14 ppb in 1980, based on a characterization of its sources, abundance, and atmospheric sinks, was also reported (Ramanathan et al. 1985). The data indicate that the average atmospheric concentration of 1,1,1-trichloroethane was 0.13 ppb for the middle of 1988 (Khalil

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Urban air:					
El Monte, CA	1982–1983	NS	0.8–6.6 ^a	2.1	Shikiya et al. 1984
Los Angeles, CA	1983		0.8–2.4	NS	
Dominguez Hills, CA			0.6–2	NS	
Riverside, CA			0–0.8	NS	
Research Triangle Park, NC	1980	61	0.0024–43.7 ^b	0.83	Wallace et al. 1984a
Houston, TX	1980		0.134–1.499 ^c	0.353	Singh et al. 1992
St. Louis, MO			0.132–0.896	0.235	
Denver, CO			0.171–2.699	0.713	
Riverside, CA			0.205–1.349	0.747	
Staten Island, NY	1981		0.221–1.427	0.468	
Pittsburgh, PA			0.158–1.595	0.486	
Chicago, IL			0.241–0.909	0.476	
Iberville Parish, LA	1977	11	ND–1.61 ^b	0.31	Pellizzari 1982
Kib–Buc Disposal Site, NJ	1977	4	ND–22.0		
Rutherford, NJ	1978	150	ND–6.3	0.17	Bozzelli and Kebbekus 1979
Rutherford, NJ (North)		29	ND–3.6	0.55	
Rutherford, NJ (Clifton)		26	ND–trace		
Newark, NJ		110	ND–7.8	0.39	
Bridgewater, NJ		22	ND–0.83	0.05	
Los Angeles Basin	1972	59	0.01–2.30	0.37	Simmonds et al. 1974
Los Angeles, CA	1984	23	NS–3.70	0.74	Pellizzari et al. 1986
Los Angeles, CA	1979		0.224–5.144 ^c	1.028	Singh et al. 1981
Phoenix, AZ			0.197–2.813	0.823	
Oakland, CA			0.142–0.967	0.290	
New Jersey					
fall (day)	1981	86	ND–86 ^b	0.60 ^d	Wallace et al. 1985,
fall (night)		86 ^e	ND–7.3	0.68	1987a; Hartwell et al.
summer	1982	60		0.93	1984b
winter	1983	8		0.26	
Bozeman, MN	1976 ^e	1	0.15		Taketomo and Grimsrud 1977
Seagirt, NJ	1974	NS	0.044–0.20	0.10	Lillian et al. 1975
New York, NY			0.10–1.6	0.61	
Sandy Hook, NJ			0.030–0.330	0.15	
Delaware City, DE			0.03–0.30	0.10	

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Baltimore, MD			0.044–0.21	0.12	
Wilmington, OH			0.030–0.35	0.097	
Bayonne, NJ	1973		0.075–14.4	1.59	
Greensboro, NC	1982	32		11.1 ^b	Wallace et al. 1987a
Devils Lake, ND		24		0.009 ^b	
La Jolla, CA	1974–1976	23	0.13–1.1	0.00037	Su and Goldberg 1976
California coast (marine air)	1974	5	0.14–0.30	0.00019	
Washington, DC	1974	1	0.5		
Los Angeles (Chinatown), CA	1974	1	3.4		
Santa Monica, CA	1974	1	1.3		
Orange County, CA	1974	3	0.37–0.68		
Chicago, IL	1974	2	0.37–0.68		
Greensboro, NC	1980	20	NS–9.81 ^b	0.33	Hartwell et al. 1984a
Baton Rouge, LA	198	127	NS–13.5	0.11	Pellizzari et al. 1984a, 1986
Houston, TX	1981	11	NS–1.41	0.47	
Bayonne/Elizabeth, NJ	1980	165	0.133–131 ^b		Wallace et al. 1984a
Bayonne/Elizabeth, NJ	1981	80–90	NS–87 ^b	1.68	Wallace et al. 1985
Chicago, IL	1986–1990	103	NS	0.61 ^b	
St. Louis, IL		83		0.72 ^b	Sweet and Vermette 1992
Hawthorne, CA	1987–1990	NS	0.8–7.0 0.8–18.0	NS	Hisham and Grosjean 1991
Long Beach, CA			2.2–14.7 2.2–9.9		
Anaheim, CA			0.5–8.5 13.2–22.2		
Los Angeles, CA			2.7–6.3 8.3–14.0		
Burbank, CA			1.2–6.1 7.1–28.4		
Azusa, CA			3.2–17.1		
Claremont, CA			3.3–15.0		
Los Angeles, CA			1.7–6.5		
Ventura, CA			0.5–2.7		
West Los Angeles, CA			1.6–2.2		
Los Angeles, CA (UCLA)			0.5–0.9		
Malibu, CA			0.5–1.6		

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Northeast Los Angeles, CA			0.8–7.2		
Burbank, CA			0.5–5.7 0.13–1.17		
Los Angeles, CA	February 1984	24	NS	6.3 ^b	Wallace et al. 1988
Los Angeles, CA	May 1984	23		1.1 ^b	
Contra Costa, CA	June 1984	10		0.52 ^b	
Hawthorne, CA	1987–1990	NS	NS		Hisham and Grosjean 1991
fall				12.9	
summer				3.4	
Long Beach, CA					
fall				6.3	
summer				8.5	
Anaheim, CA					
fall				16.9	
summer				3.0	
Los Angeles, CA					
fall				9.9	
summer				4.5	
Burbank, CA					
fall				18.5	
summer				3.1	
Washington, DC	1989	5	0.28–0.42 ^b	0.35 ^b	EPA 1990b
Los Angeles, CA (winter)	1987	51	NS	1.09 ^{b,f}	Hartwell et al. 1992
Columbus, OH	June–July 1989	NS		0.72	Spicer et al. 1996
Baton Rouge LA	Sept 1996–Aug1997	NS	NS	0.124	Mohamed et al. 2002
Brownsville TX	Sept 1996–Aug1997	NS	NS	0.107	
Brattleboro VT	Sept 1996–Aug1997	NS	NS	0.097	
Burlington VT	Sept 1996–Aug1997	NS	NS	0.094	
Camden NJ	Sept 1996–Aug1997	NS	NS	0.13	
El Paso TX	Sept 1996–Aug1997	NS	NS	0.097	
Garyville LA	Sept 1996–Aug1997	NS	NS	0.116	

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Hahnville LA	Sept 1996– Aug1997	NS	NS	0.122	
Port Neches TX	Sept 1996– Aug1997	NS	NS	0.12	
Rutland VT	Sept 1996– Aug1997	NS	NS	0.098	
Underhill VT	Sept 1996– Aug1997	NS	NS	0.084	
Winooski VT	Sept 1996– Aug1997	NS	NS	0.101	
Rural air:					
Pullmam, WA	1974–1975	NS	NS	0.100 ^c	Grimsrud and Rasmussen1975
Eastern WA	1976	389	0.090 ^c –0.18	0.135	Cronn et al. 1983
Stanford Hills, CA	1975	75		0.0776 ^c	Singh et al. 1977
Point Reyes, CA		300	NS	0.0903	
Pacific NW, USA	1975			0.087 ^c	Rasmussen et al. 1981
	1976			0.098	
	1977			0.107	
	1978			0.117	
	1979			0.135	
	1980			0.156	
Antarctica	1975			0.045	
	1976			0.057	
	1977			0.070	
	1978			0.085	
	1979			0.095	
	1980			0.102	
Pt. Barrow, AL	1980–1982	NS	0.150–0.172 ^c	0.152 (0.168) ^g	Khalil and Rasmussen 1983
Midland, MI	1975	7	0.0916–0.188 ^h	0.104	Russell and Shadoff 1977
Old Love Canal, NY	1978	9	ND–0.989 ^h		Barkley et al. 1980
White Face Mountains, NY	1974	NS	0.032–0.13	0.067	Lillian et al. 1975
Mt Hood, OR	1981–1982	7	0.104–0.179	0.156	Rasmussen et al. 1983
Beaverton, OR	1982	7	0.154–0.363	0.202	
Mt. Cuyamaca, CA	1975	1		0.41	Su and Goldberg 1976
Montgomery Pass, NE				10.34	
Lytton Lake, CA				10.07	
Champaign, IL	1986–1990	23	NS	0.2 ^b	Sweet and Vermette 1992

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Chattanooga, TN	1986–1987	30	0.18–9.6 ^b	3.98 ^b	Parkhurst et al. 1988
San Nicolas Island, CA	1987	NS	0.55–0.57	NS	Hisham and Grosjean 1991
Kanawha Valley, WV	NS ^e			353.6 ^b	Cohen et al. 1989
Minnesota at 25 sites	1991–1998	3,648		0.28	Pratt et al. 2000
Indoor Air:					
Old Love Canal, NY					
	1978	9	ND–0.220 ^h	14	Barkley et al. 1980
Bozeman, MN	NS ^e	8	0.12–0.73		Taketomo and Grimsrud 1977
Greensboro, NC	1980	20	NS–28.7 ^b	1.15	Hartwell et al. 1984a; Pellizzari et al. 1986
Baton Rouge, LA	1981	27	NS–45.0	0.28	
Houston, TX	1981	11	NS–5.73.7		
Elizabeth/Bayonne, NJ	1981	25	NS–163 ^b	2.96	Pellizzari et al. 1986
	1982	71	NS–22.2	1.83	
	1983	9	NS–31.53.7		
Los Angeles, CA					
winter	1984	25	NS–37.0	4.44	
summer	1984	23	NS–17.4	1.46	
Antioch–W. Pittsburgh, CA					
Public access buildings	1984	16	NS–2.590.78		Wallace et al. 1987c
Recently constructed building after occupancy	1983–1985	70.55–7.5 ^b 30.73–69.6	0.36–18.3		
Elderly home	NS	NS	0.12–22.6	NS	Pellizzari et al. 1984b
Los Angeles, CA	1987	51			Hartwell et al. 1992
kitchen			NS	1.78 ^b	
living area			NS	2.33 ^b	
Chattanooga, TN	1986				Parkhurst et al. 1988
residential		34	0.37–37 ^b	5.1 ^b	
public buildings		37	0.92–50 ^b	13 ^b	
Dallas, TX					Gallagher and Kurt 1990
incubator air in an intensive care nursery	1988		460,000– 160,000 ⁱ	95,000 ⁱ	
Washington DC, U.S. EPA headquarters:					EPA 1990b
Waterside Mall		51	0.42–4.8 ^b	1.6 ^b	
Crystal City		5	0.56–0.70 ^b	0.61 ^b	

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Fairchild		5	1.2–1.3 ^b	1.2 ^b	
Neenah, WI, telephone switching office	1987				Shields and Weschler 1992
second floor break room		NS	NS	0.17 ^b	
second floor break room		1	NS	0.11 ^b	
		NS	NS	0.056 ^b	
		1	NS	0.26 ^b	
Southern California museums	1986				Hisham and Grosjean 1991
El Pueblo			1.2–5.1	NS	
LACMA			2.9–3.9	NS	
Page			>30	NS	
Getty			3.7–4.8	NS	
Southwest			2.2–7.3	NS	
Personal air:					
Chapel Hill, NC	1978		172.65–19.6 ^b	15.0	Zweidinger et al. 1983
Beaumont, TX		11	1.51–196	33	Wallace et al. 1982
New Jersey	1981				Wallace et al. 1987a
fall (day)		346–48	ND–6,040 ^b	3.5 ^d	
New Jersey					Wallace et al. 1985
fall (night)		339–41	ND–1520	3.5	
fall (summer)	1982	148		1.7 ^d	
winter	1983	48		4.0	
Bayonne/Elizabeth, NJ	1980	165 (9)	0.13–130 ^b	1.7	Wallace et al. 1984a
Research Triangle Park, NC		61 (3)	0.024–43.2	0.82	
Bayonne/Elizabeth, NJ	1981	339–348	NS–61,100	22.2	Wallace et al. 1984b, 1985
Devils Lake, ND	1982	24	^b	4.63 ^b	Wallace et al. 1987a
Greensboro, NC	1982	32	^b	5.92 ^b	
Los Angeles, CA	February 1984	110	NS	17.8 ^b	Wallace et al. 1988
Los Angeles, CA	May 1984	50	NS	8.1 ^b	
Contra Costa, CA	June 1984	67	NS	2.9 ^b	
Los Angeles, CA	1987	51	NS	2.6 ^{b,f}	Hartwell et al. 1992
Near waste/landfill site:					
Hamilton, OH	1983	NS	0.36–23.8 ^b	NS	Levine et al. 1985
Elizabeth, NJ	1980	NS	ND–330	NS	
New Jersey (NPLHS)	1983				

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Site A		24	ND–4.49	0.38	Laregina et al. 1986
Site B		15	ND–1.84	0.51	Harkov et al. 1985
Site C		14	ND–18.97	3.04	
Site D		14	ND–2.89	0.57	
Site E		15	ND–1.22	0.84	
Landfill LF		15	ND–7.15	1.29	
New Jersey	1976	4	ND–22.2	9.0	Pellizzari 1982
California	1984–1986	NS	ND–3,600 ⁱ	NS	Wood and Porter 1987
Stanislaus County, CA	1987				Hodgson et al. 1992
on site		NS	<10–13,000	NS	
outside (nearby residential home)		NS	NS	0.3	
inside (nearby residential home [basement])		NS	NS	0.7	
20 Class II landfills:					
Long Island, NY	1982				Walsh et al. 1988
on site			140 ⁱ		
nearby residential homes			1		
nearby school			1		
Troposphere					
Western Pacific Region 114–165 °E longitude latitudes > 25 °N					Blake et al. 1997
7–12.6 km	Sept–Oct 1991	175	0.108–0.166 ^c	0.125 ^c	
	Feb–Mar 1994	274	0.078–174 ^c	0.119 ^c	
2–7 km	Sept–Oct 1991	309	0.107–0.188 ^c	0.126 ^c	
	Feb–Mar 1994	347	0.111–0.377 ^c	0.127 ^c	
0–2 km	Sept–Oct 1991	149	0.695–0.114 ^c	0.137 ^c	
	Feb–Mar 1994	134	0.128–0.550 ^c	0.133 ^c	
Western Pacific Region 114–165 °E longitude latitudes < 25 °N					
7–12.6 km	Sept–Oct 1991	233	0.104–0.145 ^c	0.124 ^c	

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Table 6-3. Detection of 1,1,1-Trichloroethane in Air

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
2–7 km	Feb–Mar 1994	454	0.100–0.134 ^c	0.122 ^c	
	Sept–Oct 1991	243	0.104–0.162 ^c	0.122 ^c	
0–2 km	Feb–Mar 1994	341	0.111–0.133 ^c	0.123 ^c	
	Sept–Oct 1991	172	0.102–0.194 ^c	0.124 ^c	
	Feb–Mar 1994	178	0.117–0.189 ^c	0.127 ^c	

^aMonthly mean

^bData reported in $\mu\text{g}/\text{m}^3$; converted to ppb using the conversion factor 1 ppb=5.4 $\mu\text{g}/\text{m}^3$

^cData reported in ppt; converted to ppb using the conversion factor 1 ppb=1,000 ppt

^dWeighted geometric mean

^eDate of study not given

^fData reported as median

^gSummer (winter)

^hData reported in ng/m^3 ; converted to ppb using the conversion factor 5,400 $\text{ng}/\text{m}^3=1$ ppb

ⁱData reported in ppm; converted to ppb using the conversion factor 0.001 ppm=1 ppb

ND = not detected; NS = not specified

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and Rasmussen 1989). Based on absolute concentrations obtained over a 12-year period, a global atmospheric concentration of 157 ppt (0.157 ppb) was estimated for 1,1,1-trichloroethane in the middle of 1990 (Prinn et al. 1992). Atmospheric measurements at several surface stations made between 1978 and 1990 indicated that the global average concentration of 1,1,1-trichloroethane increased at a rate of $4.4 \pm 0.2\%$ over this time period (Prinn et al. 1992).

The measured concentration of 1,1,1-trichloroethane in urban air usually ranges from 0.1 to 1 ppb; however, levels $\leq 1,000$ ppb have been observed in large urban areas or near hazardous waste sites. Representative monitoring data on the concentration of 1,1,1-trichloroethane in air can be found in Table 6-3. Rural levels of 1,1,1-trichloroethane are typically <0.2 ppb. The long atmospheric lifetime of 1,1,1-trichloroethane allows the compound to be carried a considerable distance from its initial point of release; detectable levels have been measured in numerous remote areas throughout the world and are shown in Table 6-3 (Class and Ballschmiter 1986; DeBortoli et al. 1986; Guicherit and Schulting 1985; Hov et al. 1984; Ohta et al. 1976; Rasmussen et al. 1982). The mean background concentration of 1,1,1-trichloroethane over subarctic North America in the summer of 1990 was 0.155 ppb (Wofsy et al. 1994). During a period of arctic haze, the concentration of 1,1,1-trichloroethane in the polluted Arctic air was 2–15% higher than in clean air over the Arctic (Khalil and Rasmussen 1993). The mean concentration of 1,1,1-trichloroethane in the troposphere over northwestern Pacific region (114–165 °E longitude) was found to range from 0.12 to 0.13 ppb (Blake et al. 1997, Table 6-3 Mohamed et al. 2002). The concentrations of 1,1,1-trichloroethane near industrial facilities emitting 1,1,1-trichloroethane were found to be only marginally higher than those measured at sites away from facilities emitting 1,1,1-trichloroethane.

The concentration of 1,1,1-trichloroethane in indoor air is variable, and seems to depend on individual practices, season, outdoor concentration, age of building, and building air-exchange characteristics (Cohen et al. 1989; Hartwell et al. 1987a, 1987b, 1992; Hisham and Grosjean 1991; Lioy et al. 1991; Wallace 1986; Wallace et al. 1986a, 1986b, 1988, 1989, 1991). For example, college students monitored simultaneously on the same campus were found to have levels of personal exposure varying by as much as two orders of magnitude (Wallace et al. 1982; Zweidinger et al. 1983). Further, two studies suggest that buildings with air conditioning may have higher levels of 1,1,1-trichloroethane in indoor air (Cohen et al. 1989; Hisham and Grosjean 1991). 1,1,1-Trichloroethane has been found at levels ≤ 70 ppb in newly constructed buildings (Wallace et al. 1987b). The concentration of 1,1,1-trichloroethane in new and recently renovated buildings was as high as 290 ppb (Rothweiler et al. 1992). New carpet and other

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new building materials that contain 1,1,1-trichloroethane may be responsible for higher levels in new and renovated buildings. During normal periods (no renovation or construction), the levels of total volatile organics are inversely proportional to the air exchange rate of the building (Shields and Weschler 1992). Higher levels of 1,1,1-trichloroethane are expected to be found in indoor air during winter than any other season (Wallace et al. 1991). The effect of outdoor air on indoor air was demonstrated by the detection of higher levels of 1,1,1-trichloroethane during outdoor stagnation conditions when the levels were higher compared to levels under non-stagnation conditions (Lioy et al. 1991). Representative data taken from five geographic areas located throughout the United States report indoor concentrations of 0.3–4.4 ppb and outdoor concentrations of 0.11–0.92 ppb (Pellizzari et al. 1986). Several studies have determined the presence of 1,1,1-trichloroethane in products expected to be in most households (Section 6.5) (EPA 1987; Maklan et al. 1987; Sack et al. 1992; Spicer et al. 1987). An EPA Region V (Minnesota, Wisconsin, Michigan, Illinois, Indiana, and Ohio) National Human Exposure Assessment Survey (NHEXAS) detected a mean concentration of 1,1,1-trichloroethane to be 1.15 ppb in indoor air samples collected from residential areas from July 1995 to May 1997 (Bonanno et al. 2001). The maximum concentration of trichloroethane detected in the same study was 34 ppb.

6.4.2 Water

1,1,1-Trichloroethane has been identified in surface water, groundwater, drinking water, effluent, rain, snow, and urban runoff. The amount of the chemical detected in surface and groundwater depends upon the location of the sampling point. Concentrations in surface water removed from point-source emissions such as industrial waste water, hazardous waste sites, and spill locations are usually <1 ppb. In random samples of groundwater taken in the United States, concentrations have ranged from 0 to 18 ppb. Groundwater samples obtained near sources of release to soil or the ground have been as high as 11,000 ppb. Drinking water from surface or groundwater sources contained 1,1,1-trichloroethane concentrations of 0.01–3.5 ppb.

Data on the occurrence of 1,1,1-trichloroethane in water are presented in Table 6-2. Data on the concentration of 1,1,1-trichloroethane in effluent can be found in Table 6-4.

1,1,1-Trichloroethane was found in groundwater at hazardous waste sites in 18.9% of 178 sites from the Comprehensive Emergency Response, Compensation and Liability Act (CERCLA) database, making it the seventh most frequently detected compound in this study (Plumb 1987). It was found in water

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Table 6-4. Detection of 1,1,1-Trichloroethane in Effluent

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Industrial waste water:					
Textile plants	1975	64	2–300 ^a	NS	Rawlings and Deangelis 1979
Municipal waste water:					
Los Angeles, CA	1978	NS			
primary				340 ^a	Young 1978
secondary				<10	Young et al. 1983
Los Angeles, CA					
primary				130	
secondary				180	
Orange County, CA					
primary				4,000	
secondary				<10	
San Diego, CA					
primary				68	
Water factory 21					McCarty and Reinhard 1980
influent	1976	50	<0.3–38 ^a	4.794	
Orange County, CA	1978				
effluent		51	0.1–1.2	0.07	
influent		28	0.3–15	2.9	
effluent		17	<0.1–41	0.14	
Chicago, IL, Calumet plant	1980	2			Lue-Hing et al. 1981
influent				14 ^a	
effluent				<10	
John Egan plant		1		11	
influent				<10	
effluent					
Denver, CO					
reuse influent	1985–1986	14	1.70–6.9 ^a	3.74	Rogers et al. 1987
Landfill leachates:					
Collegeville, PA ^b	1983 ^c	NS	1–60	NS	Varma 1985
Minnesota ^d	1983	6	ND–7.6 ^a		Sabel and Clark 1984
Nuclear power plant emissions:					

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Table 6-4. Detection of 1,1,1-Trichloroethane in Effluent

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Denver, CO	1989				Sturges and Taylor 1990
downwind		6	0.06–0.623 ^e	0.27 ^e	
upwind		8	0.088–0.251 ^e	0.137 ^e	

^aData reported in µg/L; converted to ppb using the conversion factor 1 ppb=1 µg/L

^bNational Priority Hazardous Waste Site

^cDate of study not given

^dMunicipal Solid Waste site

^eData reported in ppt; converted to ppb using the conversion factor 1 ppb=1,000 ppt

ND = not detected; NS = not specified

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samples from 42 of 357 Contract Laboratory Program (CLP) sites; the concentration range of the mean values was 1.75–1,100 ppb (Viar 1987).

6.4.3 Sediment and Soil

Monitoring data on the occurrence of 1,1,1-trichloroethane in soil are not as extensive as for water or air, which precludes an estimate of typical levels found in soil. The reported levels of 1,1,1-trichloroethane in soils are shown in Table 6-5. In two grab soil samples taken in 1980 from two former sludge lagoons of a solvent recovery operation at Southington, Connecticut, the measured concentrations of 1,1,1-trichloroethane were 23,000 and 120,000 ppb (Hall 1984). The limited data on the concentration of 1,1,1-trichloroethane in soil may be due to its rapid volatilization from soil, its ability to leach through soil, or both. The concentrations of 1,1,1-trichloroethane in sediments are shown in Table 6-2. The mean concentration of 1,1,1-trichloroethane in sediments from a river passing through an industrial area in Japan was 0.4 ppb, although it was not detected in the river water or in the sediment of a river passing through a non-industrial area (Grotoh et al. 1992).

6.4.4 Other Environmental Media

Limited data on the occurrence of 1,1,1-trichloroethane in other media were located. 1,1,1-Trichloroethane has been found in raw, processed, and prepared food products. These data are presented in Table 6-6. 1,1,1-Trichloroethane has been found in fish and shrimp taken from the Pacific Ocean at average concentrations of 2.7 and <0.3 ppm, respectively (Young et al. 1983). It has also been detected in clams and oysters from Lake Pontchartrain, Louisiana, with mean concentrations ranging from 39 to 310 ppm (Ferrario et al. 1985) and from a polluted river in Japan at concentrations ranging from 0.6 to 1.8 ppb wet weight (wt/wt) (Grotoh et al. 1992). 1,1,1-Trichloroethane was detected in 2 of 265 table-ready foods of FDA Total Diet Study at an average concentration of 12.7 ppb (Heikes et al. 1995).

1,1,1-Trichloroethane has been detected in four shoe and leather glues in Denmark in the concentration range 0.1–2.7% (wt/wt) (Rastogi 1992). Six samples of glues manufactured in the United States and in Europe and used for assembling various consumer goods and toys contained 1,1,1-trichloroethane in the concentration range 0.002–97.5% (wt/wt) (Rastogi 1993). In various brands of imported typing correction fluids in Singapore, the equilibrium vapor phase concentration of 1,1,1-trichloroethane ranged from <1 to 95% (v/v) (Ong et al. 1993).

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Table 6-5. Detection of 1,1,1-Trichloroethane in Soils

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Urban:					
Southington, CT	1980	2	23,000–120,000 ^a		Hall 1984
National Priorities List:					
Lang property, NJ	1985				EPA 1987c
surface		NS	ND–980 ^b	322	
subsurface		NS	ND–140	71	
Galloway Ponds site, TN	1984	NS	13,000 ^c		EPA 1987b
1,1,1-Trichloroethane producer/user:					
Plant A	1976–1977	4	0.06–0.68		Battelle Labs 1977
Plant B		2	0.45–0.94		
Plant C		2	0.13–0.28		
Plant D		2	0.14–1.0		
User A		2	0.40–0.65		
Summit National, OH (NPL site)	1987				EPA 1988a
on-site surface		31	3 ^d –51,000 ^b	2,216 ^b	
on-site subsurface (2–4 feet)		5	10–43,000 ^b	8,391 ^b	
on-site subsurface (4–6 feet)		2	5–2,800 ^{d,b}	561 ^b	
on-site subsurface (6–8 feet)		15	4 ^d –230,000 ^b	10,252 ^b	
Residence near a landfill:					
Stanislaus County, CA	September 1987	NS	1.4–11	4.9	Hodgson et al. 1992
	October 1987		2.8–9.4	6.1	

^aData reported in µg/L; converted to ppb using the conversion factor 1 ppb=1 µg/L

^bData reported in µg/kg; converted to ppb using the conversion factor 1 ppb=1 µg/kg

^cData reported in ppm; converted to ppb using the conversion factor 1 ppb=0.001 ppm

^dData were estimated.

ND = not detected; NS = not specified

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Table 6-6. Detection of 1,1,1-Trichloroethane in Foods

Type	Food	Sampling dates	Concentration (ppb)		Reference
			Range	Mean	
Unprepared, uncooked, off-the-shelf	Split peas	NS		3	Daft 1987
	Allspice			16,000	
	Pickling spice			549	
	Celery seed			909	
	Tea			10	
	Dumplings (dry)			7	
	Instant hot cereal			421	
	Ready-to-eat cereals			4	
	Cake mix (golden)			8	
	Cake mix (yellow)			87	
	Pancake mix			16	
	Breaded fish			2	
	Onion rings (precooked)			76	
	Intermediate	Yellow corn meal	1984		
Fudge brownie mix			2.9–3.0	0.74	
Yellow cake mix					
Fresh	Nectarine	1985–1986		NS ^a	Takeoka et al. 1988
Cooked, aroma	Beef	NS		NS ^a	Galt and MacLeod 1984
	Bakers cheese	NS		1.3 ^b	Uhler and Diachenko 1987
Prepared	Cottage cheese	NS	2.7–10.6	6.4	Miller and Uhler 1988
	Ricotta cheese		ND–30.6	3.0	
	Mozzarella (skim milk)		9.5–37.3	1.2	
	Vanilla ice cream		NS–7,500		
	Chocolate ice cream				
	Butter pecan ice cream				
	Butter				
Cooked, aroma	Baked potatoes	NS		ND	Coleman et al. 1981
	Ice	1975 (NS)		0.0039 ^c	
Cereals	Commercial machine				Su and Goldberg 1976
	Shredded wheat	NS		4 ^b	
	Raisin bran			6	
	Granola, plain			22	
	Oat ring			6	
	Rolled oats, cooked			35	
	Farina, cooked			8	
	Corn grits, cooked			3	

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Table 6-6. Detection of 1,1,1-Trichloroethane in Foods

Type	Food	Sampling dates	Concentration (ppb)		Reference			
			Range	Mean				
Vegetables	Peas, cooked	NS		1 ^b	Daft 1988			
	Peas, canned			2				
	Corn, boiled			2				
	Onion rings, cooked			9				
	French fries, cooked			2				
	Mashed potatoes			6				
	Sweet potatoes, candied			3				
	Cream of potato soup			2				
	Catsup			2				
Baked goods	Cornbread	NS		3 ^b	Daft 1988			
	Biscuits, baking powder			2				
	Blueberry muffins			11				
	Saltine crackers			7				
	Corn chips			9				
	Pancakes			3				
	Potato chips			8				
	Macaroni and cheese			2				
	Chocolate cake/icing			40				
	Yellow cake			40				
	Coffeecake, frozen			14				
	Donuts, cake, plain			17				
	Sweet roll, Danish			29				
	Cookies, chocolate chip			8				
	Cookies, sandwich			28				
	Apple pie, frozen			14				
	Nuts/nut products		Peanut butter, creamy	NS			10 ^b	Daft 1988
			Peanuts, dry roasted				24	
			Pecans				228	
Dairy products	Whole milk	NS		1 ^b	Daft 1988			
	Chocolate milk			5				
	Milkshake, chocolate			152				
	Yogurt, strawberry			2				
	Cheese, processed			8				
	Cheese, cheddar			16				
	White sauce			10				
	Margarine, stick			13				
	Butter, stick			18				
	Cream, half & half			4				
	Ice cream, chocolate			4				
Instant pudding, chocolate		1						

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Table 6-6. Detection of 1,1,1-Trichloroethane in Foods

Type	Food	Sampling dates	Concentration (ppb)		Reference
			Range	Mean	
Dairy products (continued)	Ice cream sandwich			15	
	Ice milk, vanilla			520	
	Butter	Nov 20–27 1992	1.0–4	1.82	Miyahara et al. 1995
	Margarine		ND–74	5.29	
	Milk		ND		
	Ice cream		ND–3.2	0.88	
	Yogurt, plain		ND–1.2	0.06	
	Ice milk		ND–0.9	0.2	
Sugars, jams, candy	Candy, milk chocolate	NS		15 ^b	Daft 1988
Meats, meat dishes	Beef, ground, fried	NS		8 ^b	Daft 1988
	Beef, chuck roast			6	
	Beef, sirloin, cooked			10	
	Pork, ham, cured			5	
	Pork chop, cooked			76	
	Pork, sausage, cooked			7	
	Pork, bacon, cooked			2	
	Pork roast, loin, cooked			3	
	Lamb chop, cooked			7	
	Veal cutlet, cooked			8	
	Chicken, pieced, fried			14	
	Frankfurters, cooked			33	
	Bologna			8 ^b	
	Salami			8	
	Tuna, canned in oil			3	
	Shrimp, breaded, fried			3	
	Fish sticks, cooked			12	
	Pizza, cheese, cooked			8	
	One-fourth pound hamburger			27	
	Meatloaf, beef			15	
	Chicken noodle casserole			4	
	Lasagna			2	
	Potpie, chicken			6	
Frozen dinner, chicken			10		
Brown gravy			2		
Infant/toddler blends	Oatmeal, applesauce, banana	NS		6 ^b	Daft 1988

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Table 6-6. Detection of 1,1,1-Trichloroethane in Foods

Type	Food	Sampling dates	Concentration (ppb)		Reference
			Range	Mean	
Fruits	Apple, red, raw	NS		3 ^b	Daft 1988
	Grapes, purple/green			2	
	Raisins, dried			16	
	Prunes, dried			21	
	Avocado, raw			32	
	Grapefruit juice			4	
	Lemonade			11	
Clear beverages	Grape juice	NS		3 ^b	Daft 1988
	Whiskey, 80 proof			2	

^aDetected in sample; no quantitative results given

^bData reported in ng/g; converted to ppb using the conversion factor 1 ppb=1 ng/g

^cData reported in pg/mL; converted to ppb using the conversion factor 1 ppb=1,000 pg/mL

ND = not detected; NS = not specified

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6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Although the manufacture and use of 1,1,1-trichloroethane was scheduled to be phased out by 2002 under amendments made to Section 604 of the Clean Air Act (EPA 2004m); it is still being manufactured in the United States by two producers with production volumes of at least 100 million pounds as of 2002 (EPA 2002; SRI 2003). Its relatively long atmospheric half-life and continued production suggest that the general population may be expected to have continued exposure to this compound into the foreseeable future.

The ubiquitous occurrence, in the past, of low levels of 1,1,1-trichloroethane in ambient air and other environmental samples, together with the fact that many consumer products previously used to contain this chemical, suggests that much of the general population of the United States was exposed to low levels of 1,1,1-trichloroethane. This exposure could have occurred occupationally, environmentally, or as a result of the use of commercial products that contain 1,1,1-trichloroethane. 1,1,1-Trichloroethane has been detected in the blood, milk, breath, and urine of humans. An EPA Region V (Minnesota, Wisconsin, Michigan, Illinois, Indiana, and Ohio) National Human Exposure Assessment Survey (NHEXAS) detected a mean concentration of 1,1,1-trichloroethane to be 0.05 ppb in blood samples collected from July 1995 to May 1997 (Bonanno et al. 2001). The maximum concentration of trichloroethane detected in the same study was 2.7 ppb. Data on human body burdens associated with this compound can be found in Table 6-7. Table 5-2 provides a sampling of consumer products containing 1,1,1-trichloroethane. The levels of this chemical in human breath have been correlated with its levels in personal air by probability-based population studies (Wallace et al. 1985, 1986c, 1987a, 1988).

If the average urban concentration of 1,1,1-trichloroethane is taken to be 1 ppb and the average rural concentration is taken to be 0.1 ppb, then daily non-occupational intakes of 108 and 10.8 $\mu\text{g}/\text{day}$, respectively, can be obtained based on an average human air intake of 20 m^3/day . In areas where 1,000 ppb have been measured, the daily intake using this methodology would be 108 mg. However, Wallace et al. (1984a) have determined that the mean daily air exposure for 12 subjects from urban New Jersey and Research Triangle Park, North Carolina, was 370 mg. Further, the mean daily intake from all sources (air, food, and water) was between 50 and 1,000 mg/day for 1,1,1-trichloroethane (Wallace et al. 1984a).

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Table 6-7. Detection of 1,1,1-Trichloroethane in Human Samples

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Adipose tissue:					
United States	1984	46	ND–830 ^a	48	Stanley 1986a, 1986b
Blood/serum:					
New Orleans		250	ND–26	NS	Antoine et al. 1986
Old Love Canal	1978	9	0.24–1.8 ^b		Barkley et al. 1980
Denver	1976	3	1,300–2,700 ^c	1,800	Gunter et al. 1977
U.S. NHANES III Non-smokers	NS	126	ND–0.0106 ^d	0.0035	Ashley et al. 1995
U.S. NHANES III Smokers	NS	42	ND–0.0132 ^d	0.0052	
U.S. NHANES III Non-occupationally exposed	NS	574	NS	0.34	Ashley et al. 1994
Milk:					
Bridgeville, PA; Bayonne, NJ; Jersey City, NJ; Baton Rouge, LA		12	NS		Pellizzari et al. 1982
Breath:					
Chicago, IL		387		0.0018 ^d	Krotosznski et al. 1979
Texas		10	ND–140 (µg/hour)	40	Conkle et al. 1975
Old Love Canal, NY	1978	9	Trace–0.513 ^e		Barkley et al. 1980
Chapel Hill, NC	1978	17	1.1–8.72 ^f	81.81	Zweidinger et al. 1983
Beaumont, TX		17	0.081–29.6	15.97	
New Jersey					
fall	1981	322		1.2 ^f	Wallace et al. 1987a
summer	1982	110		0.95	
winter	1983	49		0.37	
Devils Lake, ND	1980	23		1.7	Wallace et al. 1984a
		48(9)	0.022–16.0 ^f	0.88	
Bayonne/Elizabeth, NJ	1981	295–339	ND–95	0.88 ^g	Wallace et al. 1985
		17(3)	0.053–1.4	0.11	
Los Angeles, CA					
winter	1984	112–115		1.17 ^{g,f}	Wallace et al. 1987d
spring		51		0.70	
Antioch-Pittsburgh, PA		66–69		0.017	Wallace et al.
Elizabeth-Bayonne, NJ	1981	295–339	NS–96.2	2.78	1984b, 1985, 1986b, 1987a

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Table 6-7. Detection of 1,1,1-Trichloroethane in Human Samples

Media type/location	Sampling dates	Number of samples	Concentration (ppb)		Reference
			Range	Mean	
Elizabeth-Bayonne, NJ	1981	48	0.022–15.7		Wallace et al. 1984a
Research Triangle Park, NC	1981	17	0.054–1.142		
Urine:					
Old Love Canal, NY	1978	9	0.03–0.180	100	Barkley et al. 1980

^aData in ng/g; 1 ppb=1 ng/g

^bData in ng/mL; 1 ppb=1 ng/mL

^cData in mg/dL; 1 ppb=0.00001 mg/dL

^dData in ng/L; 1 ppb=1000 ng/L

^eData in ng/m³; 1 ppb=5400 ng/m³

^fData in µg/m³; 1 ppb=5.4 µg/m³

^gWeighted geometric mean

ND = not detected; NHANES = National Health and Nutrition Examination Survey; NS = not specified

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1,1,1-Trichloroethane has been detected in newly constructed buildings (Wallace et al. 1987b). 1,1,1-Trichloroethane was found in 216 of 1,159 common household products preselected to contain solvents at concentrations >0.1% by weight (Sack et al. 1992). In a similar study, 1,1,1-trichloroethane was found in all 67 categories of household products (1,026 brands tested) likely to be in the average U.S. home (EPA 1987; Maklan et al. 1987). The categories of these common household products are given in Table 5-2. The occurrence of 1,1,1-trichloroethane in 62% of the effluent samples taken from a community septic tank also suggests the presence of this compound in household products (De Walle et al. 1985).

Human exposure could occur directly via ingestion of contaminated water, but also indirectly through the inhalation of 1,1,1-trichloroethane that has volatilized from contaminated tap water. Based on a theoretical concentration of 1 mg/L (ppm) of 1,1,1-trichloroethane in tap water, the average estimated air concentrations for the entire house, bathroom, and shower stall were 2.3×10^{-4} , 5.1×10^{-3} , and 2.6×10^{-2} mg/L, respectively (McKone 1987). For a tap water concentration of 20 mg/L, the estimated daily exposure to 1,1,1-trichloroethane was 20.0 mg from ingestion and 22.8 mg from inhalation while showering (Foster and Chrostowski 1986). The Total Exposure Assessment Methodology (TEAM) studies demonstrated that levels of personal air exposure determined using samples obtained on the same day could vary by orders of magnitude for subjects living in the same municipality, most likely as a result of variances in consumer practices and occupation (Hartwell et al. 1987a, 1987b, 1992; Wallace 1986, 1987; Wallace et al. 1986a, 1986b, 1988, 1989; Zweidinger et al. 1983). The maximum exposure levels of 1,1,1-trichloroethane during personal activities were: 185 ppb when visiting the dry cleaners, 18.5 ppb when working in a chemistry lab, 12 ppb when working as a lab technician, 48 ppb when using household cleaners, 20 ppb when using pesticides, and 20 ppb when using paint (Wallace et al. 1989). Exposure of the general population from the use of commercial products may be more significant than exposure resulting from industrial release.

According to the National Occupational Exposure Survey (NOES) conducted by NIOSH between 1981 and 1983, it has been statistically estimated that $\approx 2,528,300$ workers in the United States were potentially exposed to 1,1,1-trichloroethane (NIOSH 1990). The largest number of workers are exposed in the following types of industries/services: sewing machine operators in apparel industry; registered nurses, maids, janitors and cleaners in hospitals; electricians, technicians, assemblers, installers, machinists and repairers in electrical and electronic industry; and janitors and cleaners in building maintenance service. From the existing monitoring data, it appears that most occupational exposure occurs by inhalation.

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Specific industrial applications of 1,1,1-trichloroethane that might result in elevated levels of exposure are processes involving the degreasing and cleaning of fabricated metal parts (Gunter et al. 1977; Kominsky 1976; Levy and Meyer 1977; Markel 1977), manufacture of electronic components (Giles and Philbin 1976), mixing and application of commercial resins (Giles 1976), and spray painting and spray gluing (Whitehead et al. 1984). Table 6-8 lists occupations in which 1,1,1-trichloroethane has been detected in the air. Other occupations where workers can be exposed to 1,1,1-trichloroethane include automotive assembly plants (Nelson et al. 1993), kraft pulp mills (Rosenberg et al. 1991), and fuel cell assembly plants (NIOSH 1993). In a survey (1990–1991) of a fuel cell assembly plant, the levels of 1,1,1-trichloroethane in some of the personal breathing zone and general area samples were found to exceed the NIOSH short-term exposure limit of 350 ppm (NIOSH 1993). More current worker information was not available; however, since the production and use of 1,1,1-trichloroethane is being phased out, exposures would be expected to decrease. Exposure to 1,1,1-trichloroethane should be limited to those workers who are still involved in the manufacture and production of this compound or the limited uses as allowed for essential applications in the medical industry and aviation industry or the export of 1,1,1-trichloroethane as specified under Section 604 of the Clean Air Act.

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).

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Table 6-8. Occupational Air Levels of 1,1,1-Trichloroethane

Location/occupation	Sampling dates	Concentration (ppb)		Reference
		Range	Mean	
Bozeman, MT	1976			
Auto repair garage			2.2	Taketomo and Grimsrud 1977
Bookstore			6.7	
Restaurant			0.2	
Department store		0.8–1.7		
Newspaper press room			2.2	
Grocery store		1.9–21		
Dry cleaner		1.8–14.4		
Chemistry building (academic)		0.1–1.2		
Tampa, FL				
Telephone central office	1979	27–65		Oblas et al. 1979, 1980
Hobbs, NM				
Telephone business office			50	
Waltham, MA				
Laboratory air			4.5	
Organic solvent recycling plant	1984	ND–20,000 ^a	3,110	Kupferschmid and Perkins 1986
Booth spray painting/gluing	1981	NS–22,000 ^a	1,200	Whitehead et al. 1984
Screw machine manufacturing company, AR	1976	12,000–99,800 ^b		Markel 1977
Rifle scope producer, Denver, CO	1976	7,700–478,000 ^b		Gunter et al. 1977
Heating and cooling coil manufacturing, IL	1976	1,460–16,600 ^b		Levy and Meyer 1977
Electric apparatus manufacturing, PA	1975	2,500–79,500 ^a		Giles 1976
Electrical resistor manufacturing, PA	1976	6,000–83,000 ^a		Giles and Philbin 1976
Valve part manufacturer, IN	1976	4,000–37,000 ^a		Kominsky 1976
Aircraft manufacturer, GA	1983–1984	ND–23,000 ^a		Salisbury et al. 1986
Sport racket manufacturer, CO	1985	NS		Pryor 1987
Nail manufacturer, CO	1987	7,510–406,000 ^b		NIOSH 1987
Fiber manufacturer, IL	1986	59–115 ^b		Daniels et al. 1988
Mens' shirt company, IN	1974			Nord 1974
Film optical shops, NY	1979	500–1,320,000 ^b		Peter and Edelbrock 1980
Joint/shaft manufacturer, IN	1979	800–1,300 ^a		McQuilkin et al. 1979
Battery manufacturer, CO	1979	9,160–36,400 ^b		NIOSH 1980a

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Table 6-8. Occupational Air Levels of 1,1,1-Trichloroethane

Location/occupation	Sampling dates	Concentration (ppb)		Reference
		Range	Mean	
Typesetter/photographer, GA	1979	3,900–4,600 ^a		NIOSH 1980b
Graphic services, OH	1979	<1,000 ^a		NIOSH 1980c
Welding shop	1979	3,200–4,799 ^a		Vegella 1979
Suitcase manufacturer, CO	1978	500–756,000 ^a		Apol and Singal 1979
Ski/tennis racquet manufacturing, CO	1979	22,500–85,800 ^b		Gunter 1979
Sewer workers, OH	1981	1,000–40,000 ^a		McGlothlin and Cone 1983
Solar cell producer, CA	1979	ND–74,000 ^b		Briggs and Garrison 1982
Medical therapeutic system manufacturing, CO	1979	400–3,600 ^a		NIOSH 1980d
Navigation information products, CO	1981	549–2,750 ^b		Gunter 1983
Tractor manufacturer, ND	1979	ND–62,600 ^a		NIOSH 1980e
U.S. Department of the Treasury, DC	1982	NS		Lee 1984
School district print shop, OR	1983	100 ^a		Apol and Helgerson 1983
Electrical maintenance company, OH	1981	123,000–385,000 ^b		Kominsky and Lipscomb 1985
Electrical commutators manufacturers, IL	1983	ND–4 ^a		Almaguer 1985
Crystal fabricator, CO	1984	366–2700 ^b		Gunter and Thoburn 1986
Silk screening of textiles, KS	1975	ND–75,000 ^b		Hervin 1975
Aluminum vane manufacturers, OH	1976	74,000–396,000 ^a		Giles 1977
Catapult cylinder manufacturers, OH	1975	2,400–18,400 ^a		Giles 1977
Chemical recovery plant, OH	1980	1,900–4,500 ^b		Albrecht 1980
Pump manufacturer, NY	1978–1979	ND–2,930		Fannick 1980
Uranium company, WY	1980	ND–155,000 ^b		Gunter 1980
Theater, NY	1985	458–10,700 ^b		Fannick 1986

^aData reported in ppt; converted to ppb using the conversion factor 1 ppb=1,000 ppt

^bData reported in mg/m³; converted to ppb using the conversion factor 1 ppb=0.0054 mg/m³

ND = not detected; NS = not specified

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Exposures of the embryo or fetus to volatile organic compounds such as 1,1,1-trichloroethane may occur if the expectant mother is exposed. A newborn infant may be exposed by breathing contaminated air and through ingestion of mother's milk that can contain small amounts of 1,1,1-trichloroethane. Children may be exposed through accidental ingestion of products containing 1,1,1-trichloroethane. Older children and adolescents may be exposed to 1,1,1-trichloroethane in their jobs or hobbies, or through deliberate solvent abuse by "sniffing." Epidemiological studies and case reports discussing reproductive and/or developmental toxicity of 1,1,1-trichloroethane in humans have been reviewed in Chapter 3.

Young children often play close to the ground and frequently play in dirt, which increases their dermal exposure to toxicants in dust and soil. They also tend to ingest soil, either intentionally through pica or unintentionally through hand-to-mouth activity. Children, thus, may be orally and dermally exposed to 1,1,1-trichloroethane present as a contaminant in soil and dust. 1,1,1-Trichloroethane has a log organic carbon-water partition coefficient of 2.03, indicating low adsorption to soil (Chiou et al. 1979; Friesel et al. 1984). Most of the 1,1,1-trichloroethane present in the upper layers of the soil is volatilized to air within 24 hours (vapor pressure =124 mm Hg at 25 °C, Boublik et al. 1984). The rapid volatilization of 1,1,1-trichloroethane results in inhalation being the most likely route of exposure.

Children breathe in more air per kilogram of body weight than an adult. Therefore, a child in the same micro-environment as an adult is likely to be exposed to more 1,1,1-trichloroethane from ambient air. Young children are closer to the ground or floor because of their height. The 1,1,1-trichloroethane vapors being heavier than air (vapor density =4.63 g/mL; HSDB 2004) tend to concentrate near the ground. The children, therefore, are at a greater risk of exposure than adults during accidental spills of 1,1,1-trichloroethane.

Children may also be exposed to fumes of 1,1,1-trichloroethane by working with or playing near sources. Children's exposure also occurs through accidental ingestion and inhalation of the chemicals into the lungs. Children are also exposed to higher concentrations of 1,1,1-trichloroethane (0.1–1 ppb, Table 6-3) in urban areas compared to children living in rural areas (concentrations typically <0.2 ppb, Table 6-3).

Animal studies demonstrated that, once absorbed, 1,1,1-trichloroethane is distributed by the blood to tissues and organs throughout the body, including developing fetuses, with preferential distribution to fatty tissues (Holmberg et al. 1977; Katagiri et al. 1997; Schumann et al. 1982a; Takahara 1986b).

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There are no existing studies that have monitored the level of exposure from 1,1,1-trichloroethane to children. Most uses of 1,1,1-trichloroethane are associated with occupational purposes, so it is unlikely that children will receive significant doses. Under extreme conditions where products containing high concentrations of 1,1,1-trichloroethane are used in the presence of children in an enclosed area with little or no ventilation, children could receive significant exposure. There are studies that examine the exposure to children from parents' work clothes, skin, hair, tools, or other objects removed from the workplace (NIOSH 1995); however, this type of "take home" or secondary exposure is unlikely due to the high volatility of 1,1,1-trichloroethane. Additional exposure from consumer products can occur, but is unlikely to be significant, although little data are available at this time.

It is not known whether children differ in their weight-adjusted intake of 1,1,1-trichloroethane. However, children drink more fluids per kg of body weight than adults (NRC 1993) and 1,1,1-trichloroethane has been detected in drinking water (Section 6.4.2, Table 6-2).

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

The general population is potentially exposed to low levels of 1,1,1-trichloroethane through the ingestion of contaminated water or food and by breathing air contaminated with this compound. Since most applications and uses of 1,1,1-trichloroethane have been or are currently being discontinued, human exposure is expected to decrease accordingly. The manufacture and use of 1,1,1-trichloroethane was scheduled to be phased out by 2002 under the Clean Air Act (EPA 2004m). Since it is no longer in use, the exposure of the general population should drop to insignificant levels. Low levels of contamination in drinking water sources have been documented (Althoff et al. 1981; Barkley et al. 1980; Burmaster 1982; EPA 1986a; Krill and Sonzogni 1986; Wallace et al. 1984a; Zaki 1986). According to Table 6-2, levels of 0.01–12,220 ppb 1,1,1-trichloroethane have been found in drinking water sources. 1,1,1-Trichloroethane was used as a component of adhesives for food packaging, and this practice may have contributed to human exposure by ingestion (Miller and Uhler 1988). Airtight, highly-insulated houses are likely to have high indoor concentrations from use of household products containing 1,1,1-trichloroethane. Very high levels of exposure are expected to occur for those who intentionally inhale 1,1,1-trichloroethane for its euphoric/narcotic properties.

Workers who are still involved in processes using this compound may encounter high exposure levels. Occupations in which 1,1,1-trichloroethane has been found in the air are given in Table 6-8; however, it is

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noted that many of these occupational exposures are no longer expected to occur today since the production and use of 1,1,1-trichloroethane is being phased out. Analysis of these data shows that ambient air concentrations in industries using 1,1,1-trichloroethane are up to 4 orders of magnitude higher than what is typically found in urban air.

1,1,1-Trichloroethane was used in some adhesive remover pads of incubators in intensive care nurseries, and there is evidence that infants in incubators could be exposed to high concentrations of 1,1,1-trichloroethane (Gallagher and Kurt 1990). This use of 1,1,1-trichloroethane has been discontinued.

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 1,1,1-trichloroethane 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 1,1,1-trichloroethane.

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 of 1,1,1-trichloroethane are well documented, and little additional information in this area is required. Only one BCF for 1,1,1-trichloroethane was located in the available literature. This value is, however, consistent with what would be expected based on the other physical and chemical properties of 1,1,1-trichloroethane.

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Production, Import/Export, Use, Release, and Disposal. Historical data on the production, use, release, and disposal of 1,1,1-trichloroethane in the United States are well represented in the literature. The past production volumes of 1,1,1-trichloroethane manufactured in the United States is known. According to the 1990 amendments to the Clean Air Act and the Montreal Protocol, future U.S. production was to be cut incrementally until a total phase-out by January 1, 2002 (EPA 2004m). However, current data suggests that large quantities of 1,1,1-trichloroethane are still being produced domestically, and information regarding the current production volumes as well as export volumes are important to assess the potential for exposure. The past use of 1,1,1-trichloroethane is well-documented. It was used extensively in industrial applications, and it was found in numerous consumer products for the home. Mandates on production, however, are expected to decrease the use of 1,1,1-trichloroethane and subsequent potential exposure to 1,1,1-trichloroethane.

There are a few food monitoring studies in the literature that provide several examples of food contamination with 1,1,1-trichloroethane. The ubiquitous nature of 1,1,1-trichloroethane suggests that additional information in this area would allow a complete determination of the levels of human exposure to this chlorinated solvent. The release of 1,1,1-trichloroethane to the environment is well established since there are numerous studies that indicate the presence of this compound in environmental media. The quantity of 1,1,1-trichloroethane released to the environment during its production, formulation, and use is known. 1,1,1-Trichloroethane is listed on the Toxics Release Inventory (TRI). Methods for the disposal of 1,1,1-trichloroethane exist. Data on the removal of 1,1,1-trichloroethane from waste streams during biological treatment processes are lacking. Information on the amount of 1,1,1-trichloroethane disposed of annually is scarce. Rules and regulations governing the disposal of 1,1,1-trichloroethane exist.

According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit chemical release and off-site transfer information to the EPA. TRI, which contains this information for 2001, became available in 2002. This database will be updated yearly and should provide a list of industrial production facilities and emissions.

Environmental Fate. Data on the environmental fate of 1,1,1-trichloroethane are well represented in the literature. The partitioning of 1,1,1-trichloroethane from soil or water to the atmosphere is well established, and there is sufficient evidence to indicate that the compound can leach into groundwater. The relatively slow rate of degradation and the major routes of 1,1,1-trichloroethane degradation in all

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environmental compartments have been established. The relatively long persistence of 1,1,1-trichloroethane in the atmosphere indicates that a significant portion of this compound migrates to the stratosphere. Data on the biodegradation of 1,1,1-trichloroethane in soil are particularly lacking.

Bioavailability from Environmental Media. Numerous toxicokinetic and toxicity studies in humans and animals have demonstrated the bioavailability of 1,1,1-trichloroethane from air and drinking water. Although some data on the bioavailability of 1,1,1-trichloroethane from air to mammalian skin (Mattie et al. 1994), and from air to other mammalian tissues (blood, muscle, liver) (Connell et al. 1993) are available, no studies on the bioavailability of 1,1,1-trichloroethane from food or soil were located. Some of the important routes of exposure to 1,1,1-trichloroethane for residents near waste sites will be inhalation of airborne dusts, ingestion of soil (children) and dermal contact with contaminated soil (mostly children). Therefore, it would be helpful to develop reliable data for the bioavailability of 1,1,1-trichloroethane from dust as a result of inhalation of contaminated airborne dust, from soil as a result of ingestion of soil, and from soil as a result of dermal contact with soil.

Food Chain Bioaccumulation. 1,1,1-Trichloroethane is not believed to bioconcentrate in fish and aquatic organisms; thus, it is not expected to biomagnify in the food chain. There are limited data regarding food chain biomagnification of 1,1,1-trichloroethane.

Exposure Levels in Environmental Media. Volumes of data exist on levels of 1,1,1-trichloroethane in environmental media, with the exception of levels in soil samples. Continued monitoring of environmental media is warranted. Blind monitoring at this stage, however, might be replaced with methods that allow both the continued determination of the environmental burden of 1,1,1-trichloroethane and correlation with human burden, like that performed in the TEAM studies. These and other studies have estimated human intake of 1,1,1-trichloroethane from environmental media. For members of the general population near hazardous waste sites, total exposure to 1,1,1-trichloroethane will include exposure from environmental media and exposure from consumer products.

Reliable monitoring data for the levels of 1,1,1-trichloroethane in contaminated media at hazardous waste sites are needed so that the information obtained on levels of 1,1,1-trichloroethane in the environment can be used in combination with the body tissue/fluid levels of 1,1,1-trichloroethane to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

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Exposure Levels in Humans. 1,1,1-Trichloroethane has been detected in human tissues and expired air. Studies have recently determined that the potential for exposure of the general population may be significantly higher inside the home. Additional information that correlates the lifestyle of the individual with the total body burden of 1,1,1-trichloroethane would aid in reducing future exposure to the general population. This information is necessary for assessing the need to conduct health studies on these populations.

Exposures of Children. A study on usefulness of intervention methods in cases of inhalant abuse by pregnant women would be helpful. More research is needed to rule out concomitant risk factors and to identify specific chemicals and patterns of use associated with adverse effects.

Children are at a greater risk of inhalation exposure to 1,1,1-trichloroethane as they breathe in more air per kilogram of body weight than an adult. They also spend more time closer to ground because of their height. 1,1,1-Trichloroethane vapors, being heavier than air, tend to concentrate closer to the ground, thereby increasing the risk for children. No data are available on the exposure of the children to 1,1,1-trichloroethane present in the air.

Means of protecting young children from ingestion of home products containing 1,1,1-trichloroethane need study and action. Child-proof containers and clearer warnings to parents should be considered to avoid unwanted exposure.

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 1,1,1-trichloroethane were located. This substance is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for subregistries 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.

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6.8.2 Ongoing Studies

The Federal Research in Progress (FEDRIP 2004) database provides additional information obtainable from a few ongoing studies that may fill in some of the data needs identified in Section 6.8.1.

Researchers at Physical Optics Corporation (POC) proposes to develop a group-specific active optical chemical sensor for halohydrocarbons (including trichloroethylene, dichloroethylene, perchloroethylene, and 1,1,1-trichloroethane) that can be interfaced with a cone penetrometer for subsurface applications. No liquid chemical substances will be used in the final sensor design, enabling simple fiber optic-based downhole deployment.

Researchers at University of Washington, College of Forest Resources propose to test the ability of several plant strains to take up and transform various chlorinated hydrocarbons, including carbontetrachloride, chloroform, bischloromethane, 1,1,1-trichloroethane, perchloroethylenes, trichloroethylene, dichloromethanes, and vinyl chloride using laboratory mass balance reactors. They will identify the mechanisms involved in the chlorinated hydrocarbon oxidation in poplar and use molecular methods to enhance that activity.