

6. POTENTIAL FOR HUMAN EXPOSURE

6.1 OVERVIEW

1,1,2,2-Tetrachloroethane has been identified in at least 329 of the 1,699 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (HazDat 2008). However, the number of sites evaluated for 1,1,2,2-tetrachloroethane is not known. The frequency of these sites can be seen in Figure 6-1.

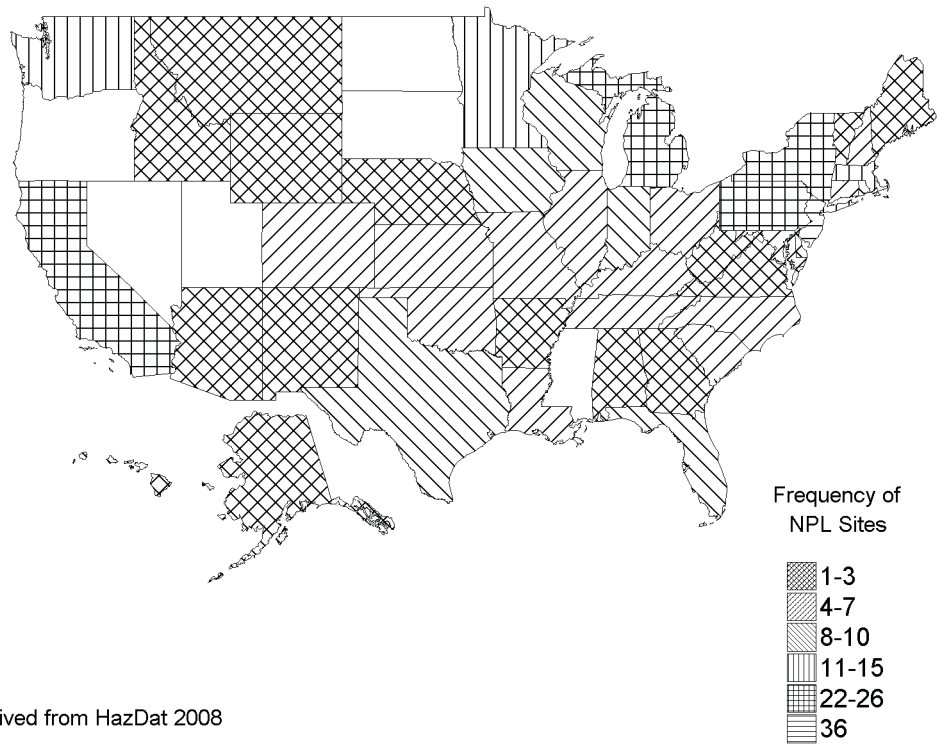
1,1,2,2-Tetrachloroethane is a synthetic chemical and is not known to occur naturally in the environment (IARC 1979). This chemical has been used as an intermediate in the production of chlorinated ethenes, as an industrial solvent and extractant, and as an ingredient in a few pesticide preparations. Its production as an end-product declined markedly after the late 1960s, and by the early 1990s, its manufacture as an end-product had ceased both in the United States and in Canada (CEPA 1993). Therefore, current releases of 1,1,2,2-tetrachloroethane are limited to fugitive emissions or discharges during its production and use as a chemical intermediate or during its formation as a byproduct.

1,1,2,2-tetrachloroethane is released primarily to the atmosphere and to surface water; very small amounts are now being land-applied. If released onto soil, some of the chemical would be expected to volatilize, with the remainder leaching into the subsurface soil profile and, possibly, into groundwater.

1,1,2,2-Tetrachloroethane is not expected to adsorb to soils and sediments based on measured K_{oc} values ranging from 46 to 240 (Borisover and Graber 1997; Chiou et al. 1979; Chu and Chan 2000; Swann et al. 1983; Valsaraj et al. 1999). If 1,1,2,2-tetrachloroethane is released to surface water, most of it would volatilize based on estimated volatilization half-lives of 6.9 hours to 6.1 days (Leighton and Calo 1981; Thomas 1990), with the remainder dissolving in water where it would undergo degradation through hydrolysis. In groundwater, the major degradation processes involve anaerobic biodegradation and chemical hydrolysis. Chemical hydrolysis is very sensitive to pH and is much faster under basic or neutral conditions. 1,1,2,2-Trichloroethylene is the primary metabolite of chemical hydrolysis. Measured half-lives for the chemical hydrolysis of 1,1,2,2-tetrachloroethane at neutral pHs range from 29 to 102 days. Anaerobic biodegradation proceeds by hydrogenolysis, dichloroelimination, or dehydrochlorination; products of biodegradation include 1,2-dichloroethylene, 1,1,2-trichloroethane, 1,2-dichloroethane, and the highly toxic vinyl chloride. Bioconcentration of this substance in aquatic organisms is

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



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expected to be low based on measured BCF values of 2 and 8 (ASTER 1995; Barrows et al. 1980; Franke et al. 1994).

In the atmosphere, 1,1,2,2-tetrachloroethane is removed primarily via reaction with photochemically generated hydroxyl radicals. The half-life of this reaction is 54 days, calculated using a measured rate constant (Tosato et al. 1991). Atmospheric removal may also occur through washout by precipitation; however, most 1,1,2,2-tetrachloroethane removed by this mechanism will likely reenter the atmosphere by volatilization. Slow diffusion into the stratosphere will also occur, where 1,1,2,2-tetrachloroethane may participate in reactions that generate ozone-destroying chlorine radicals. However, this chemical is not expected to contribute significantly to the destruction of the ozone layer since <1% of the tropospheric 1,1,2,2-tetrachloroethane is expected to reach the stratosphere (EPA 1979; WHO 1998).

Reported average concentrations of 1,1,2,2-tetrachloroethane measured in ambient air from both urban and rural locations across the United States are generally <10 ppt (Brodzinsky and Singh 1982; Class and Ballschmiter 1986; EPA 1988c; Pratt et al. 2000). However, average urban air concentrations as high as 57 ppb have been reported (Harkov et al. 1981, 1983; Liroy et al. 1985; Singh et al. 1981, 1982).

1,1,2,2-Tetrachloroethane was detected in approximately 43% of 12,476 water samples (surface water and groundwater) listed in the STORET database (EPA 2006f). However, only 3% of the samples contained 1,1,2,2-tetrachloroethane above the quantitation limit (unspecified). The range, mean, and median of quantifiable 1,1,2,2-tetrachloroethane concentrations were 0.1–25, 0.6, and 0.5 ppb, respectively.

1,1,2,2-Tetrachloroethane was detected in <0.001% of 166,559 public water system samples collected in the United States between 1993 and 1997 (EPA 2001b). Limited monitoring data are available for 1,1,2,2-tetrachloroethane in soil or sediment. The existing data indicate that this substance is not widely detected in these media (EPA 2006f; Krill and Sonzogni 1986; Shilling 1985; Westrick et al. 1984).

1,1,2,2-Tetrachloroethane has not been detected in table-ready foods (FDA 2005b).

Based on the low levels of 1,1,2,2-tetrachloroethane measured in the environment and the decreased use of this substance in nonindustrial settings, exposure of the general population to 1,1,2,2-tetrachloroethane is expected to be very low. However, individuals located near hazardous waste sites or facilities where 1,1,2,2-tetrachloroethane is used as a chemical intermediate may be exposed to this substance by inhalation of contaminated air, by ingestion of contaminated drinking water, or by dermal contact with contaminated soil. Occupational exposures are expected to occur primarily via inhalation and dermal contact.

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6.2 RELEASES TO THE ENVIRONMENT

The Toxics Release Inventory (TRI) data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ 10 or more full-time employees; if their facility is included in Standard Industrial Classification (SIC) Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20–39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under RCRA Subtitle C, 42 U.S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis); and if their facility produces, imports, or processes $\geq 25,000$ pounds of any TRI chemical or otherwise uses $>10,000$ pounds of a TRI chemical in a calendar year (EPA 2005).

6.2.1 Air

Estimated releases of 3,170 pounds (1.4 metric tons) of 1,1,2,2-tetrachloroethane to the atmosphere from 20 domestic manufacturing and processing facilities in 2005, accounted for about 90% of the estimated total environmental releases from facilities required to report to the TRI (TRI05 2007). These releases are summarized in Table 6-1.

1,1,2,2-Tetrachloroethane is expected to be released into the air during the process of manufacturing trichloroethylene and other chlorinated hydrocarbons (WHO 1998). It may also be emitted from hazardous waste landfills (Harkov et al. 1987). In the past, 1,1,2,2-tetrachloroethane may have been released to the air during its use as a metal degreasing agent; as a paint, varnish, and rust remover; and as an extractant, solvent, and chemical intermediate (Lewis 2001). However, these are no longer expected to be important sources of release since the use of 1,1,2,2-tetrachloroethane as an end-product appears to have ceased in the United States.

1,1,2,2-Tetrachloroethane was one of the 10 most prevalent chlorinated chemicals found in solvent wastes that were incinerated each year prior to 1980 (Travis et al. 1986). A study was performed to ascertain the annual emissions of these chlorinated chemicals from a hypothetical 4,400 kw rotary kiln incinerator,

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Table 6-1. Releases to the Environment from Facilities that Produce, Process, or Use 1,1,2,2-Tetrachloroethane^a

State ^c	RF ^d	Air ^e	Water ^f	UI ^g	Land ^h	Other ⁱ	Reported amounts released in pounds per year ^b		
							Total release		
							On-site ^j	Off-site ^k	On- and off-site
AR	1	54	No data	0	0	0	54	0	54
CO	1	0	No data	0	0	0	0	0	0
KY	1	122	0	0	0	0	122	0	122
LA	8	1,986	5	0	35	0	1,991	35	2,026
NY	1	0	No data	0	No data	0	No data	0	0
OH	1	5	0	0	255	0	5	255	260
SC	1	0	No data	0	0	0	0	0	0
TX	6	1,003	1	0	18	0	1,022	0	1,022
Total	20	3,170	6	0	308	0	3,194	290	3,484

^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, waste water 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

Source: TRI05 2007 (Data are from 2005)

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with each chemical being represented according to its fraction in the stack of the incinerator. Annual stack emissions of 1,1,2,2-tetrachloroethane from such an incinerator were estimated to be 7.1 kg, assuming a standard destruction and removal efficiency of 99.99% and a waste throughput of 2.76×10^7 kg/year. Current information on incinerator-related generation of 1,1,2,2-tetrachloroethane could not be identified. Tam and Neumann (2004) reported that 607 pounds of 1,1,2,2-tetrachloroethane were emitted into the air in Portland, Oregon during 1996.

1,1,2,2-Tetrachloroethane has been identified in air samples collected at 20 of the 1,699 NPL hazardous waste sites where it was detected in some environmental media (HazDat 2008).

6.2.2 Water

Estimated releases of 6 pounds (0.002 metric tons) of 1,1,2,2-tetrachloroethane to surface water from 20 domestic manufacturing and processing facilities in 2005, accounted for <1% of the estimated total environmental releases from facilities required to report to the TRI (TRI05 2007). These releases are summarized in Table 6-1.

1,1,2,2-Tetrachloroethane may be released into water through effluent from manufacturing facilities that use this substance as a chemical intermediate. Though no longer representing current conditions, a comprehensive waste water survey conducted by the Effluent Guidelines Division of the EPA (Shackelford et al. 1983) documented that 1,1,2,2-tetrachloroethane has been detected in a variety of waste water discharges. Approximately 4,000 samples of waste water from a broad range of industrial facilities and publicly owned treatment works (POTWs) were analyzed in this survey.

1,1,2,2-Tetrachloroethane has been identified in groundwater and surface water samples collected at 218 and 43 of the 1,699 NPL hazardous waste sites, respectively, where it was detected in some environmental media (HazDat 2008).

6.2.3 Soil

Estimated releases of 308 pounds (0.1 metric tons) of 1,1,2,2-tetrachloroethane to soils from 20 domestic manufacturing and processing facilities in 2005, accounted for about 9% of the estimated total

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environmental releases from facilities required to report to the TRI (TRI05 2007). These releases are summarized in Table 6-1.

1,1,2,2-Tetrachloroethane may be released to soil when it is disposed of in landfills. Another possible mode of release to soil is from accidental spills of products or wastes containing 1,1,2,2-tetrachloroethane during overland transportation.

1,1,2,2-Tetrachloroethane has been identified in soil and sediment samples collected at 112 and 22 of the 1,699 NPL hazardous waste sites, respectively, where it was detected in some environmental media (HazDat 2008).

6.3 ENVIRONMENTAL FATE

6.3.1 Transport and Partitioning

Most of the 1,1,2,2-tetrachloroethane that is released to the environment enters the atmosphere, where it is expected to be degraded by reaction with photochemically produced hydroxyl radicals. The half-life for this reaction is approximately 54 days based on a measured rate constant of $2.50 \times 10^{-13} \text{ cm}^3/\text{molecule-second}$ (Tosato et al. 1991). 1,1,2,2-Tetrachloroethane that is not degraded in the troposphere may be transported to the stratosphere by processes such as diffusion, where it will then photodegrade rapidly. However, based on an estimated half-life and a tropospheric-to-stratospheric turnover time of 30 years (EPA 1979), it has been predicted that <1% of tropospheric 1,1,2,2-tetrachloroethane would eventually reach the stratosphere. Removal of 1,1,2,2-tetrachloroethane from the atmosphere may also occur through washout by precipitation; however, most 1,1,2,2-tetrachloroethane removed by this mechanism will likely reenter the atmosphere by volatilization.

1,1,2,2-Tetrachloroethane that is released into surface water will be lost by volatilization in a period of days to weeks. Based on a measured Henry's law constant of $3.67 \times 10^{-4} \text{ atm-m}^3/\text{mol}$ (Leighton and Calo 1981), the volatilization half-life of 1,1,2,2-tetrachloroethane (assuming first-order decay kinetics) is estimated to be 6.9 hours from a model river 1 m deep flowing 1 m/second with a wind of 3 m/second and 6.1 days from a model lake 1 m deep flowing 0.05 m/second with a wind of 0.5 m/second (Thomas 1990). In waste water treatment plants that receive volatile compounds such as 1,1,2,2-tetrachloroethane from industrial discharges or other sources, air stripping is an important mechanism for transferring the chemical from the water into the air. Air stripping technologies involve cascading waste waters over

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trickling towers, the use of spray devices to convert the fluids into droplets or aerosols, and other techniques to increase the ordinary volatilization processes across liquid surfaces. In stripping, as opposed to ordinary volatilization, the liquid and gas phases are dispersed. As a result, the interfacial surface area is much greater and liquid/gas mass transfer is greatly enhanced. Stripping, not biodegradation, was found to be responsible for removing 96% of the 1,1,2,2-tetrachloroethane in tests performed with activated sludge reactors (Kincannon et al. 1983). The half-disappearance time for 1,1,2,2-tetrachloroethane removal by stripping was 0.3 hours. In view of its moderate vapor pressure and low adsorptivity to soil, 1,1,2,2-tetrachloroethane would be expected to readily volatilize from soil surfaces. However, 1,1,2,2-tetrachloroethane may also leach into groundwater as indicated by its presence in aquifer discharge (Lorah and Voytek 2004).

The K_{oc} of 1,1,2,2-tetrachloroethane is 46 in a silt loam soil (Chiou et al. 1979). Valsaraj et al. (1999) reported K_{oc} values of 240, 216, and 173 for 1,1,2,2-tetrachloroethane in sandy soil (0.11% organic carbon), clay soil (0.25% organic carbon), and silty clay soil (1.13% organic carbon), respectively. K_{oc} values of 118 and 83 have also been reported (Borisover and Graber 1997; Chu and Chan 2000). These K_{oc} values suggests that 1,1,2,2-tetrachloroethane will not adsorb appreciably to soil, suspended solids, and sediment (Swann et al. 1983).

The bioconcentration factor (BCF) of 1,1,2,2-tetrachloroethane measured in bluegill sunfish was 8 in a 14-day experiment (Barrows et al. 1980). A bioconcentration factor of 2 for 1,1,2,2-tetrachloroethane in fathead minnows has also been reported (ASTER 1995). According to a classification scheme, these BCF values suggest that the potential for bioconcentration of 1,1,2,2-tetrachloroethane in aquatic organisms is low (Franke et al. 1994).

6.3.2 Transformation and Degradation

6.3.2.1 Air

The primary reaction of 1,1,2,2-tetrachloroethane in the atmosphere is expected to be with photochemically produced hydroxyl radicals. Based on a measured rate constant of 2.50×10^{-13} $\text{cm}^3/\text{molecule-seconds}$ at 25 °C and a hydroxyl radical concentration of 5.00×10^5 $\text{molecules}/\text{cm}^3$, the half-life for this reaction is 64 days (Tosato et al. 1991). 1,1,2,2-Tetrachloroethane that reaches the stratosphere is expected to be photolyzed by the shorter wavelength ultraviolet light present at these altitudes to produce chlorine radicals (EPA 1979; Spence and Hanst 1978). These chlorine radicals can destroy ozone

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molecules found in the stratosphere. However, since <1% of tropospheric 1,1,2,2-tetrachloroethane is expected to reach the stratosphere, release of this chemical into the atmosphere is not expected to contribute significantly to the depletion of the ozone layer (EPA 1979; WHO 1998).

6.3.2.2 Water

1,1,2,2-Tetrachloroethane undergoes base-catalyzed hydrolysis in water at environmental pH to form trichloroethylene (Cervini-Silva 2003; Cooper et al. 1987; Haag and Mill 1988). Investigators have measured the hydrolysis rate over a range of pHs. A second-order hydrolysis half-life of 102 days at 25 °C and pH 7.0 has been reported (Cooper et al. 1987). In solutions of a much lower ionic strength more typical of groundwater, empirical half-disappearance times of 573 days at pH 6.05 and 36 days at pH 7.01 were obtained for 1,1,2,2-tetrachloroethane (Haag and Mill 1988). Similarly, researchers at Dow Chemical Company found that at ppm concentrations, 1,1,2,2-tetrachloroethane undergoes abiotic transformation to trichloroethylene in a sterile, anaerobic solution at pH 7.0 (Klečka and Gonsior 1983). After 28 days, 25% of the chemical had degraded. Hydrolysis of 1,1,2,2-tetrachloroethane was not affected by contact with the low-carbon aquifer materials associated with groundwater. 1,1,2,2-Tetrachloroethane in pore-water extracted from sediments showed a 29.1-day half-life at pH values between 7.0 and 7.5 (Haag and Mill 1988). In an anoxic sediment-water system (pH unreported) the half-life of 1,1,2,2-tetrachloroethane was 6.6 days (Jafvert and Wolfe 1987). Chemical hydrolysis and biodegradation were competing processes. 1,1,2,2-Tetrachloroethane (8.4 mg/L) was degraded by 100% after 4 days in anaerobic cell free extract with a reducing agent included and by approximately 35% after 13 days in this extract without a reducing agent (Chen et al. 1996).

Lorah and Olsen (1999a, 1999b) reported that 1,1,2,2-tetrachloroethane (300 µg/L) in groundwater from a contaminated aquifer was anaerobically degraded to levels below detection within a 1.0 m vertical distance in the upward discharge through wetland sediment under increasingly reducing conditions. 1,1,2,2-Tetrachloroethane (approximately 200 µg/L) was completely degraded 16 days after it was added to a wetland sediment and groundwater microcosm under methanogenic conditions. In contrast, only 60% of 1,1,2,2-tetrachloroethane added to a sterile microcosm was degraded after 34 days, which indicates that both biotic and abiotic processes contributed to the degradation of this substance in these microcosms. The metabolites trichloroethylene, 1,2-dichloroethylene, 1,1,2-trichloroethane, 1,2-dichloroethane, and vinyl chloride were also degraded to below detectable levels within the 1.0 m vertical distance during the field study and within 34 days after addition of 1,1,2,2-tetrachloroethane during the microcosm tests (Lorah and Olsen 1999a, 1999b; Lorah and Voytek 2004). Further environmental fate and transport

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information for these degradation products can be found in their separate ATSDR profiles, which are available through the internet (<http://www.atsdr.cdc.gov/toxpro2.html>). The anaerobic biodegradation of 1,1,2,2-tetrachloroethane can proceed through hydrogenolysis, dichloroelimination, or dehydrochlorination (Chen et al. 1996; Ferguson and Pietari 2000; Lorah and Olsen 1999b). Probable anaerobic degradation pathways for 1,1,2,2-tetrachloroethane are shown in Figure 6-2.

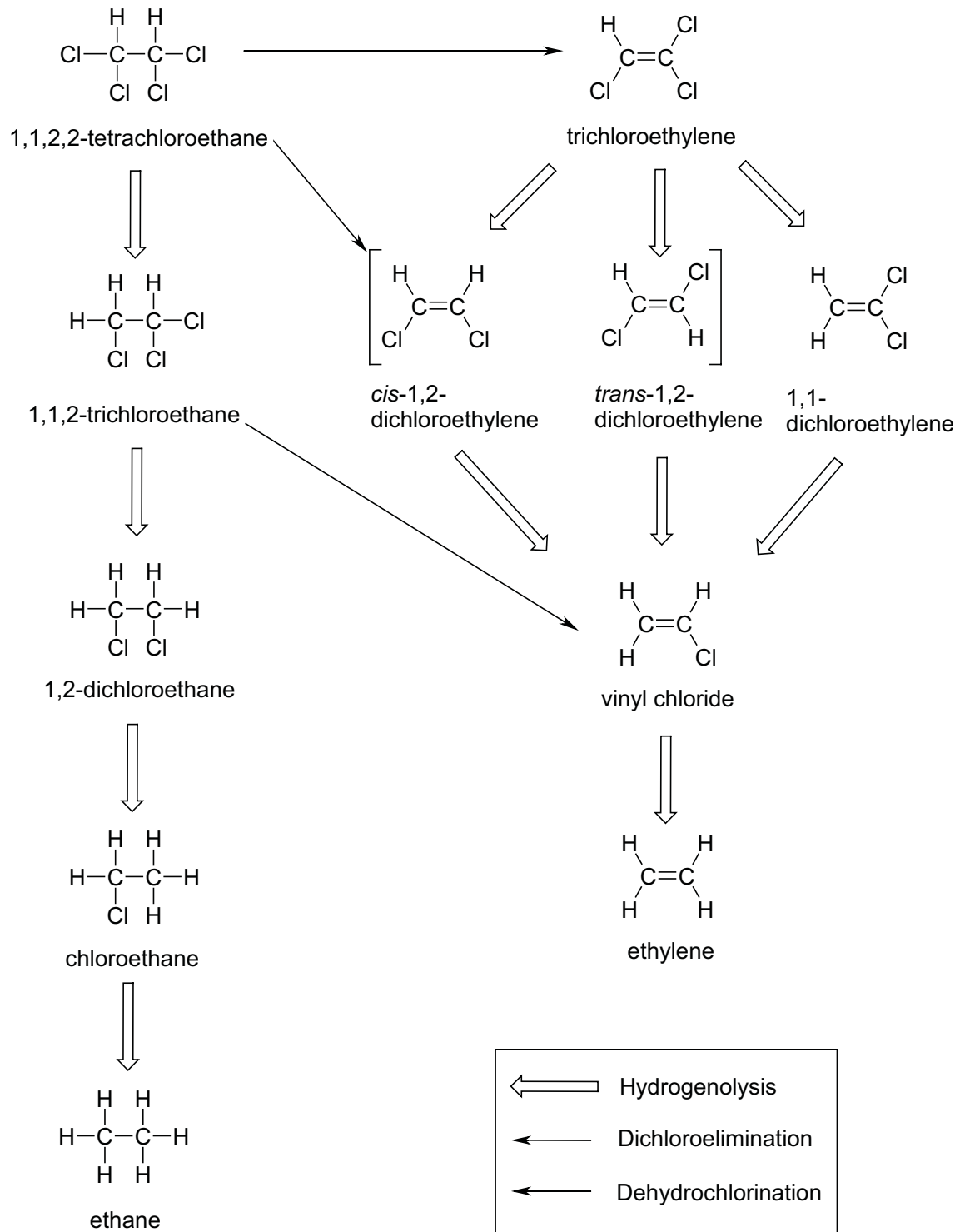
Results of aerobic biodegradability tests are conflicting. One study, in which 5 and 10 ppm of the chemical were incubated with sewage seed for 7 days, followed by 3 successive 7-day subcultures, found no significant degradation under aerobic conditions (Tabak et al. 1981). Other investigators reported that 1,1,2,2-tetrachloroethane (4.4 ppm) was degraded by 41% after 24 days in an unacclimated biodegradability test while no degradation of this substance (0.85 ppm) occurred after 5 days in a test using an acclimated seed (Mudder and Musterman 1982). A 19% loss of 1,1,2,2-tetrachloroethane (initial concentration 17.3 ppm) was obtained in a 5-day river die-away test using an acclimated system. None of the other chlorinated ethanes and ethenes in the study were found to be biodegradable. Many researchers, however, would attribute most losses involved with sewage treatment to air-stripping processes and not biodegradation (Kincannon et al. 1983).

6.3.2.3 Sediment and Soil

Based on limited information identified in the literature, both hydrolysis and anaerobic biodegradation appear to be significant transformation processes in soils and sediments.

In a study of the transformation of various chlorinated ethenes and ethanes under conditions simulating soil conditions of landfills, 1,1,2,2-tetrachloroethane was transformed into such products as 1,1,2-trichloroethane, trichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, 1,1-dichloroethene, and vinyl chloride. Samples were incubated for six weeks under anaerobic conditions after inoculation with a microorganism culture obtained from the anaerobic digester of a municipal waste water treatment facility (Hallen et al. 1986). These transformations were attributed in large measure to the anaerobic microorganisms. In another study, the transformation of 1,1,2,2-tetrachloroethane in sterilized, sediment-extracted pore water was investigated (Haag and Mill 1988). After a 6-day period, approximately 34% of the original 1,1,2,2-tetrachloroethane had been transformed at pH 6.05 and a temperature of 25 °C; at the same temperature and a pH of 7.01, 74% of the 1,1,2,2-tetrachloroethane was converted. In this experiment, the transformation was attributed primarily to hydrolysis. There was little observed sorption of 1,1,2,2-tetrachloroethane to the sediment, a low-carbon sandy material.

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Figure 6-2. Anaerobic Degradation Pathways for 1,1,2,2-Tetrachloroethane

Source: adapted from Lorah and Olsen 1999b

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6.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to 1,1,2,2-tetrachloroethane depends in part on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of 1,1,2,2-tetrachloroethane in unpolluted atmospheres and in pristine surface waters are often so low as to be near the limits of current analytical methods. In reviewing data on 1,1,2,2-tetrachloroethane levels monitored or estimated in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable. The analytical methods available for monitoring 1,1,2,2-tetrachloroethane in a variety of environmental media are detailed in Chapter 7.

6.4.1 Air

Background levels of 1,1,2,2-tetrachloroethane measured in the troposphere have ranged from ≤ 0.1 to 0.4 ppt (Class and Ballschmiter 1986). Two air samples from rural areas of the United States did not contain detectable levels of the chemical (Brodzinsky and Singh 1982). In data collected in the late 1970s to early 1980s at 853 urban/suburban sites in the United States, the median sample concentration of 1,1,2,2-tetrachloroethane was 5.4 ppt, with values ranging from less than detection limits to a maximum of 4,800 ppt (Brodzinsky and Singh 1982). More information has subsequently been added to this database, bringing the sample size for 1,1,2,2-tetrachloroethane to 1,011 monitoring records (EPA 1988c). With the addition of the new data, the overall median was computationally at or below the database lower detection limit value of zero; 75% of the samples showed concentrations ≤ 8 ppt. 1,1,2,2-Tetrachloroethane was found infrequently in the air of New Jersey cities; it was found in 9 of 38 samples in Newark, 1 of 37 samples in Elizabeth, and 4 of 35 samples in Camden in the summer of 1981 (Harkov et al. 1983), and in 4 out of 105 samples from the same 3 cities in the winter of 1982 (Harkov et al. 1987).

1,1,2,2-Tetrachloroethane concentrations were <1 ppbV in urban air samples from 13 sites located in Louisiana, Texas, Vermont, and New Jersey collected from September, 1996 to August, 1997 (Mohamed et al. 2002). 1,1,2,2-Tetrachloroethane was detected above $0.07 \mu\text{g}/\text{m}^3$ (9.8 ppt) in 609 out of 2,507 air samples collected from 25 sites across the state of Minnesota over a period of 8 years (1991–1998) (Pratt et al. 2000). The mean, median, and maximum concentrations were 0.06, 0.03, and $6.87 \mu\text{g}/\text{m}^3$ (8.4, 4.2, and 962 ppt), respectively. Mean concentrations of 1,1,2,2-tetrachloroethane in major U.S. cities listed in

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other reports ranged from trace levels below detection limits to 57 ppb (Harkov et al. 1981, 1983; Lioy et al. 1985; Singh et al. 1981, 1982; Spicer et al. 1996).

The only data on indoor levels of 1,1,2,2-tetrachloroethane were contained in a study of eight homes in Knoxville, Tennessee, obtained during the winter (Gupta et al. 1984). Ten of 16 samples (detection limits were not reported) contained 1,1,2,2-tetrachloroethane, with a mean concentration of $13.0 \mu\text{g}/\text{m}^3$ (1.8 ppb). Although the source of the chemical was not investigated, the contamination might be attributed to consumer products used in the home or to outgassing of the chemical from construction material or household furnishings.

An EPA study of the indoor-air pollution potential associated with 1,159 common household products (Sack et al. 1992) included 1,1,2,2-tetrachloroethane as one of 31 volatile organic compounds selected for analysis. 1,1,2,2-Tetrachloroethane was found in 216 of these products. It was especially common, in trace amounts, in adhesives, oils, greases, and lubricants. Concentrations in the products were uniformly near detection limits (detection limits not reported). Although trace amounts were present in a wide variety of products, Sack et al. (1992) concluded that 1,1,2,2-tetrachloroethane has a low potential to pose unacceptable human exposure risks in indoor air.

The ranges of mean and maximum air concentrations of 1,1,2,2-tetrachloroethane in air at five NPL hazardous waste sites in New Jersey were 0.01–0.59 and 0.17–11.38 ppb, respectively, while the corresponding values for an urban landfill receiving municipal waste and nonhazardous industrial waste were 0.01 and 0.19 ppb (LaRegina et al. 1986). Samples of air surrounding the Kin-Buc waste disposal site near Edison, New Jersey contained up to 2.1 ppb of 1,1,2,2-tetrachloroethane. Air concentrations of 0.226 ppb of 1,1,2,2-tetrachloroethane were found in Iberville Parish, Louisiana along the Mississippi River, where many organic chemical production and storage facilities are located (Pellizzari 1982).

1,1,2,2-Tetrachloroethane was detected in air samples collected over the western Pacific Ocean between 43 and 4 °N; however, concentrations were not specified (Quack and Suess 1999).

6.4.2 Water

Representative samples of surface water from New Jersey were analyzed during 1977–1979 (Page 1981). These samples were collected from urban, suburban, and rural areas showing every type of land use common in the state. Sixty-seven of the 608 surface water samples (11%) contained 1,1,2,2-tetrachloro-

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ethane in concentrations as high as 3.0 ppb. Concentrations of 1,1,2,2-tetrachloroethane in U.S. surface waters reported in several studies range up to 9 ppb (EPA 1977, 1980; Konasewich et al. 1978; Ohio River Valley Sanitation Commission 1980; Page 1981). According to 1999–2006 nationwide U.S. monitoring data from the STORET database, 1,1,2,2-tetrachloroethane was detected in 5,343 out of 12,476 water samples (includes surface water and groundwater); however, only 391 of these detections were above the quantitation limit (unspecified). The mean, median, and range of quantifiable concentrations were 0.6, 0.5, and 0.1–25 µg/L (ppb), respectively (EPA 2006f).

Representative samples of groundwater from New Jersey were also analyzed during 1977–1979 in a project summarized in Page (1981). Sixty-four of the 1,072 groundwater samples (6%) contained 1,1,2,2-tetrachloroethane, with concentrations as high as 2.7 ppb. An example of groundwater pollution by an industrial source is the case of an abandoned organic chemical manufacturing facility in Salem, Ohio that operated from 1961 to 1973 (Khourey et al. 1984). Maximum concentrations of 1,1,2,2-tetrachloroethane were 0.501–43.0 ppm in five on-site monitoring wells and 0.556 ppm in an off-site private well. 1,1,2,2-Tetrachloroethane was detected in 5 out of 15 groundwater wells located at a landfill in Niagara Falls, New York that was contaminated with chlorinated solvents (Lee et al. 1995).

1,1,2,2-Tetrachloroethane concentrations in these wells were 1.3, 250, 14, 1.6, and 1.1 ppm. The concentration of 1,1,2,2-tetrachloroethane during 4 bimonthly analyses of a surficial aquifer at Beach Point which is located in the Edgewood Area of the U.S. Army Garrison, Aberdeen Proving Ground, Maryland ranged from 9,000 to 17,000 µg/L (ppb) (Burton et al. 2002). The water from the aquifer discharges into the Bush River, a tributary of the Chesapeake Bay. The concentration of 1,1,2,2-tetrachloroethane were below the detection limit of 0.09 µg/L (ppb) in 30 randomly distributed monitoring wells located in Wichita, Kansas during the High Plains Regional Ground-Water Study conducted in 2000 as part of the U.S. Geological Survey's National Water Quality Assessment Program (USGS 2002). The concentration of 1,1,2,2-tetrachloroethane was below 0.13 µg/L (ppb) in 34 wells (including 5 public use wells) in Cook Inlet Basin, Alaska sampled during 1999 (USGS 2001).

In the only study of rainwater located in the literature, 1,1,2,2-tetrachloroethane was not found in nine rain events in Portland, Oregon, during the spring and fall of 1982 (Pankow et al. 1984).

There is limited information on the occurrence of 1,1,2,2-tetrachloroethane in ambient surface water or groundwater used as drinking water supplies for community water supply systems. A study of 30 Canadian public water treatment facilities did not show levels of 1,1,2,2-tetrachloroethane above a 1 ppb detection limit (Otson et al. 1982). In a United States Groundwater Supply survey, none of the

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945 water supplies derived from tested groundwater sources contained 1,1,2,2-tetrachloroethane at the sensitivity limit of 0.5 ppb (Westrick et al. 1984). It was detected in 1 of 13 drinking water wells in Tacoma, Washington (Shilling 1985). It was not found in any of the 1,174 community wells and 617 private wells in a Wisconsin survey conducted in the early 1980s (Krill and Sonzogni 1986). According to Round 2 data (1993–1997) reported under the EPA Unregulated Contaminant Monitoring Program (UCM), 1,1,2,2-tetrachloroethane was detected in 81 out of 166,599 samples collected from public water systems across the United States with a mean concentration of 5.0 ppb and a range of 0.05–200.00 ppb (EPA 2001b).

6.4.3 Sediment and Soil

Limited information was located on general background levels of 1,1,2,2-tetrachloroethane in soils and sediments, with most studies focusing on problems associated with the remediation of waste sites. In an analysis of test wells around RCRA disposal sites, 1,1,2,2-tetrachloroethane was documented at levels above detection limits at 25 of 479 sites from a national sample (Plumb 1991). At one waste disposal site in Pennsylvania (Sabel and Clark 1984), the concentration of 1,1,2,2-tetrachloroethane in a soil sample was 2.4 ppm. Reported concentrations of 1,1,2,2-tetrachloroethane in sediment collected from the Calcasieu River estuary in Louisiana ranged from 0 to 13.0 mg/kg (Redmond et al. 1996). According to 1999–2006 nationwide U.S. monitoring data from the STORET database, 1,1,2,2-tetrachloroethane was detected in 6 out of 635 soil samples. The mean, median, and range of 1,1,2,2-tetrachloroethane concentrations in the six samples were 0.06, 0.02, and 0.0012–0.21 mg/kg, respectively (EPA 2006f). According to STORET data, 1,1,2,2-tetrachloroethane was detected in 142 out of 335 sediment samples; however, only 3 of these detections were above the quantitation limit (unspecified). Concentrations in the three samples were 160, 130, and 180 µg/kg.

6.4.4 Other Environmental Media

The data on 1,1,2,2-tetrachloroethane in fish or other biotic tissue samples are very limited. Examination of EPA's Fish Consumption Advisory Database (EPA 1995) showed an advisory in effect for all species of fish on the lower Ashtabula River. Such fish consumption advisories are issued by states if there is some concern over the management of risks from the public eating fish caught in rivers and other water bodies. While the pollution issues in the Ashtabula River have led to cautionary warnings in the consumption of locally caught fishes, available information on bioconcentration factors summarized in

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Section 6.3.1 above does not suggest a tendency for 1,1,2,2-tetrachloroethane to bioconcentrate, biomagnify, or bioaccumulate in the tissues of fish or shellfish.

1,1,2,2-Tetrachloroethane was analyzed for but not detected in approximately 90 foods during the U.S. Food and Drug Administration's Total Diet Study (TDS) (FDA 2005b). During a study of organic compounds in tobacco smoke, the concentrations of 1,1,2,2-tetrachloroethane in ultra low tar, full flavor low tar, and full flavor cigarette brands were 6.00, 3.78, and 3.19 µg/cigarette, respectively (Bi et al. 2005).

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Exposure of the general population to 1,1,2,2-tetrachloroethane is expected to be very low based on the low concentrations reported for this substance in environmental media and the fact that it is no longer used as an end product. Individuals located near hazardous waste sites and facilities where this substance is used as a chemical intermediate may be exposed to 1,1,2,2-tetrachloroethane via inhalation of contaminated air, ingestion of contaminated drinking water, or dermal contact with contaminated soil. Exposures are also possible in areas around incinerators or cement kilns. Modeling estimates were made of 1,1,2,2-tetrachloroethane exposure due to inhalation and ingestion of contamination produced by incinerating chlorinated solvent waste at incinerator facilities at sites in southern California, the central Midwest, and the northern Midwest (Travis et al. 1986). For the California site, the average individual inhalation and ingestion intake was 774 and 285 µg/year, respectively. While food intake accounted for 27% of the total individual dose at the California site, this contribution was 60 and 65% for the two Midwestern sites.

A National Occupational Exposure Survey (NOES) conducted by NIOSH from 1981 to 1983 estimated that 4,145 workers are potentially exposed to 1,1,2,2-tetrachloroethane in the United States (NIOSH 2006). Of these estimated exposures, 3,666 were in occupations involving work in chemical research and development laboratories with the other exposures involving jobs in industrial chemical plants. The estimate is provisional since all the data for trade name products which may contain 1,1,2,2-tetrachloroethane have not been analyzed. The NOES study was based on field surveys of 4,490 facilities and was designed as a nationwide survey based on a statistical sample of virtually all workplace environments in the United States where 8 or more persons are employed (based on all Standard Industrial Classification (SIC) code workplace types except mining and agriculture) (Sieber et al. 1991). The NOES database does

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not contain information on the frequency, concentration, or duration of exposure; the survey provides only estimates of workers potentially exposed to chemicals in the workplace.

According to OSHA (1991), the current 8-hour TWA permissible exposure level for 1,1,2,2-tetrachloroethane is 1 ppm. According to NIOSH (1992), the recommended exposure level for a 10-hour TWA is 1 ppm (7 mg/m³) 1,1,2,2-tetrachloroethane.

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).

Data regarding the exposure of children to 1,1,2,2-tetrachloroethane (including body burden data, detection in breast milk, dietary exposure data, pathways of exposure, differences in intake compared to adults, and secondary exposure data) are not available in the literature. However, based on human breast milk/blood partition coefficients of 2.26-3.55 calculated for other chlorinated alkanes (Fisher et al. 1997), it is assumed that 1,1,2,2-tetrachloroethane would readily partition to breast milk. Children who live near areas where 1,1,2,2-tetrachloroethane is released may be exposed by breathing contaminated air, by touching or eating contaminated soil, or by contact with or drinking contaminated water.

6.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Exposures are possible for individuals living near waste disposal facilities where 1,1,2,2-tetrachloroethane site contamination has occurred. Higher exposures may occur for workers at facilities where

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1,1,2,2-tetrachloroethane is still used as a chemical intermediate. Other populations with higher exposures would include people living close to NPL or other waste sites where leachates or runoff from contaminated soils could affect groundwater used for drinking water. In at least one instance, pollution from a large NPL site in Ohio has resulted in a fish consumption advisory for local recreational and subsistence fishers. Higher concentrations of 1,1,2,2-tetrachloroethane have been found in groundwater at a few locations in the United States. Individuals who use or drink the groundwater from these locations may have higher exposures to 1,1,2,2-tetrachloroethane.

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 1,1,2,2-tetrachloroethane 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 1,1,2,2-tetrachloroethane.

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 1,1,2,2-tetrachloroethane are well characterized and allow prediction of the environmental fate of the compound (see Table 4-2). No additional studies are required at this time.

Production, Import/Export, Use, Release, and Disposal. According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and off-site transfer information to the EPA. The TRI, which contains this

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information for 2004, became available in May of 2006. This database is updated yearly and should provide a list of industrial production facilities and emissions.

Production methods and uses for 1,1,2,2-tetrachloroethane are documented (Archer 1979; IARC 1979), but there is no recent detailed breakdown of the percentage of production consumed by each use category. Figures on current exports are also lacking. Approximately 440 million pounds (199 million kg) of 1,1,2,2-tetrachloroethane were produced in the United States in 1967 (Konietzko 1984). Production declined markedly thereafter, falling to an estimated 34 million pounds (15 million kg) by 1974. While 1,1,2,2-tetrachloroethane is apparently no longer produced as a final product, it may occur as a chemical intermediate or waste product in the manufacture of other chemicals (CEPA 1993). Better quantitative measures of current production, including production for export, is a data need for estimating the potential for environmental releases from various industries, as well as potential concentrations in the environment. Knowledge of which consumer products contain 1,1,2,2-tetrachloroethane is also a data need for estimating general population exposure. Unfortunately, this type of detailed information is difficult to obtain since companies consider it to be confidential information. While monitoring information on discharges was gathered during the 1970s and early 1980s when the EPA was developing criteria and effluent guidelines for a number of priority pollutant toxics (Shackelford et al. 1983), the TRI now constitutes the only major broad-based survey of releases to the environment. According to the most recent TRI information (TRI04 2006), releases to the air and water still continue from processing facilities in the United States. At present, the TRI data only cover major industrial sectors, so some releases may go unreported. Possible expansions of the types of facilities required to submit information under the TRI reporting requirements could help make this source of information more comprehensive.

While regulatory coverage for halogenated organic wastes has become increasingly more well defined (EPA 1989), record keeping under RCRA procedures works best when a chemical is a major constituent in a waste. Since 1,1,2,2-tetrachloroethane is now usually a minor component in other waste materials, there is often little documentation of the amounts of 1,1,2,2-tetrachloroethane entering waste disposal sites.

Environmental Fate. Half-lives and degradation rates for the atmospheric photooxidation, aqueous hydrolysis, and biodegradation of 1,1,2,2-tetrachloroethane are available. 1,1,2,2-Tetrachloroethane is quite volatile, but the highest potential for persistent pollution is when the chemical has been introduced into sediments and groundwater (Atkinson 1987; HSDB 1996; Mackay and Shiu 1981). While the chemical can be biodegraded under anaerobic conditions (Bouwer and McCarty 1983), there are major

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differences under aerobic conditions (Tabak et al. 1981). Further investigation would be helpful to resolve the discrepancies in the aerobic degradation data for 1,1,2,2-tetrachloroethane and would rank as a major data need.

Bioavailability from Environmental Media. Based on available animal studies (Mitoma et al. 1985; Morgan et al. 1970; Yllner 1971) and inferences from studies of similar low molecular weight chlorinated alkanes in humans, inhalation, ingestion, and dermal exposure are the major routes of exposure (Pellizzari et al. 1982). 1,1,2,2-Tetrachloroethane in air and/or water can be expected to be absorbed readily into the systemic circulation, and 1,1,2,2-tetrachloroethane in soil may be absorbed to some extent through the skin. Analyses of 1,1,2,2-tetrachloroethane and its stable metabolites in body fluids and tissues of people exposed to the chemical is a data need to improve the knowledge base on the bioavailability of 1,1,2,2-tetrachloroethane.

Food Chain Bioaccumulation. Given its tendency to either volatilize to the atmosphere (Atkinson 1987; Mackay and Shiu 1981) or become transformed into such other chemicals as TCE (Cooper et al. 1987; Haag and Mill 1988), 1,1,2,2-tetrachloroethane shows little potential for bioaccumulation. Based on measured bioconcentration factors (ASTER 1995; Barrows et al. 1980), 1,1,2,2-tetrachloroethane is not expected to bioconcentrate and is not considered to show significant potential to bioaccumulate in food chains. No major data needs are apparent for this information category.

Exposure Levels in Environmental Media. Reliable monitoring data for the levels of 1,1,2,2-tetrachloroethane in contaminated media at hazardous waste sites are needed so that the information obtained on levels of 1,1,2,2-tetrachloroethane in the environment can be used in combination with the known body burden of 1,1,2,2-tetrachloroethane to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

In studies based on monitoring data from the late 1970s and early 1980s, 1,1,2,2-tetrachloroethane concentrations in receiving waters (primarily rivers) of at least 10 ppb were documented in approximately 10% of the samples collected in a national study of runoff from urban areas, with a maximum reported concentration of 1,400 ppb (Cole et al. 1984). In soils and sediments, information from NPL sites shows detections at 112 and 22 of 1,699 sites, respectively. Since the treatment, storage, and distribution processes used in large community drinking water systems will generally release volatile chemicals to the air, 1,1,2,2-tetrachloroethane concentrations in public drinking water are generally very low. The chemical has been detected in untreated groundwater formations used for private wells in some parts of

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New Jersey (Page 1981). The highest levels have been found in groundwater in the vicinity of waste disposal sites (Khourey et al. 1984). Background levels of 1,1,2,2-tetrachloroethane in the air are typically <0.4 ppt (Brodzinsky and Singh 1982; Class and Ballschmiter 1986). Limited data collected in the vicinity of waste disposal sites has shown ambient air levels considerably higher (from >1 ppb to as high as 2.1 ppb) (Gupta et al. 1984; LaRegina et al. 1986).

Although commercial use of this substance appears to have ceased, it is still produced and used in large amounts as a chemical intermediate; therefore, the potential exists for this substance to be released in large amounts into the environment. More recent data concerning the levels of this chemical in the atmosphere as well as in soils, sediment, groundwater, and surface water are needed for determining current background concentrations and exposure levels. Reliable monitoring data for the levels of 1,1,2,2-tetrachloroethane in contaminated media at hazardous waste sites are needed, so that the information obtained on levels of 1,1,2,2-tetrachloroethane in the environment can be used in combination with the known body burdens of 1,1,2,2-tetrachloroethane to assess bioavailability and potential risks of adverse health effects in populations living in the vicinity of hazardous waste sites. Monitoring of 1,1,2,2-tetrachloroethane levels in the air of homes and buildings located near areas where this substance is released would be helpful. Although 1,1,2,2-tetrachloroethane does not appear to be present in food, additional information would be helpful in verifying this. Monitoring data on the concentrations of this substance in plants and animals in the environment are needed.

Exposure Levels in Humans. Information on exposure levels in humans is extremely limited, with most conclusions on health effects being based on inferences from animal studies (Yllner 1971). General population and occupations exposure levels have been based on models (Travis et al. 1986) or provisional estimation techniques (NIOSH 2006). Improved information on human exposure levels is therefore a data need. Information on known populations with unusually high exposures to 1,1,2,2-tetrachloroethane would be helpful.

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

Exposures of Children. Data regarding the exposure of children to 1,1,2,2-tetrachloroethane (including body burden data, detection in breast milk, dietary exposure data, pathways of exposure, differences in intake compared to adults, and secondary exposure data) are not available and would be helpful in satisfying this data need. In addition, means of decreasing exposure of children to this substance should be identified.

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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 1,1,2,2-tetrachloroethane were located. This substance is not currently one of the compounds for which a sub-registry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for sub-registries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to this substance.

6.8.2 Ongoing Studies

No information was found to indicate that there are studies in progress that relate to the environmental fate of 1,1,2,2-tetrachloroethane (FEDRIP 2006). Similarly, no ongoing monitoring or exposure studies were identified.