7. ANALYTICAL METHODS

The purpose of this chapter is to describe the analytical methods that are available for detecting, measuring, and/or monitoring 1,1,2,2-tetrachloroethane, its metabolites, and other biomarkers of exposure and effect to 1,1,2,2-tetrachloroethane. The intent is not to provide an exhaustive list of analytical methods. Rather, the intention is to identify well-established methods that are used as the standard methods of analysis. Many of the analytical methods used for environmental samples are the methods approved by federal agencies and organizations such as EPA and the National Institute for Occupational Safety and Health (NIOSH). Other methods presented in this chapter are those that are approved by groups such as the Association of Official Analytical Chemists (AOAC) and the American Public Health Association (APHA). Additionally, analytical methods are included that modify previously used methods to obtain lower detection limits and/or to improve accuracy and precision.

7.1 BIOLOGICAL MATERIALS

A few studies were found in the literature that report the determination of this compound in biological matrices. The discussion about the method that may be most sensitive for the determination of tetrachloroethane levels in environmental samples and the advantages and disadvantages of the commonly used methods (see Section 7.2) are also applicable to biological samples. Because of its higher boiling point and the possibility of its loss through chemical reactions (Yasuda and Loughran 1977), the recovery of this compound from complex biological samples by most analytical methods is expected to be lower than the recoveries from air and water samples. The analytical methods for the determination of 1,1,2,2-tetrachloroethane in biological matrices are given in Table 7-1. Information about methods for metabolites of 1,1,2,2-tetrachloroethane in animal samples is given in Section 7.3.1; these methods should be applicable to human samples.

Chen et al. (1993) have reported a method for 1,1,2,2-tetrachloroethane in blood and several types of tissue from rats. Samples were homogenized with saline and isooctane, and an aliquot of the isooctane was transferred to a sampling vial for headspace/gas chromatography (GC) analysis. Fairly low detection limits (400 ng/g) and good recoveries (90–100%) were reported. Another method for volatile compounds in blood, urine, and tissues that should be applicable to the analysis of 1,1,2,2-tetrachloroethane was reported by Streete et al. (1992). In this case, headspace analysis was used to determine 1,1,2,2-tetrachloroethane in blood, urine, and tissue (after treatment with a proteolytic enzyme). The authors stress

Table 7-1. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Biological Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Exhaled air	Collection of exhaled air through valved, Teflon spirometer in Tedlar bag; organics adsorbed onto Tenax as air is pulled through adsorbent; thermal desorption of Tenax	Cryofocus-sing HRGC/MS	No data	No data	Hartwell et al. 1987
Whole blood	Analyte adsorbed onto Tenax during purge and trap; thermal desorption onto GC column	GC/MS	500 ppt (500 ng/L)	22–27 at 1 ppb	Cramer et al. 1988
Blood	Purge and trap of 10 mL blood that was collected into specially prepared vacutainers; quantitation based on isotopically-labeled internal standards	GC/HRMS	0.005 ppb (5 ng/L)	116 at 0.063 ppb to 76 at 0.41 ppb	Ashley et al. 1992
Liver, brain, kidney, fat, heart, lung, muscle, blood	Placement of tissue into chilled 20 mL glass vials containing 2 mL ice-cold saline and 8 mL isooctane; homogenization (3–20 s depending on tissue), vortexing and centrifugation; transferring 20 µL of isooctane to 8 mL headspace vial, equilibration for 10 minutes/100 °C and injection of aliquot of headspace into GC	GC/ECD	400 ng/g (400 ppb) assuming 1 g of tissue	90–100 (average % RSD=1.7%) depending on tissue	Chen et al. 1993
Blood, urine, tissues, consumer products	Blood/urine: Equilibration of sample with internal standard in 7 mL vial at 65 °C for 15 minutes. Injection of 0.1–0.3 mL of headspace into GC using gas tight syringe	GC then split to both FID and ECD	No data	No data	Streete et al. 1992
Blood, urine, tissues, consumer products	Tissue: Placement of 20–50 mg wet mass (removed while it is frozen) into 7 mL vial with internal standard and 1 mg Subtilisin A; equilibration and analysis as for blood	GC then split to both FID and ECD	No data	No data	Streete et al. 1992
Blood, urine, tissues, consumer products	Product: Analysis of headspace after placing small volume of product into vial	GC then split to both FID and ECD	No data	No data	Streete et al. 1992

Table 7-1. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Biological Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Blood, urine	Blood: 400 µL placed in a 4-mL vial fitted with a septum and placed on the heater for 30 minutes at 50 °C. The septum was pierced with the SPME syringe needle and the fiber was exposed to the headspace for 10 minutes. The fiber was then thermally desorbed for 1 minute.	SPME then GC/MS	0.5 µg/L	No data	Guidotti et al. 2001
Blood, urine	Urine: 2 mL placed in a 4-mL vial with a septum and placed on the heater for 30 minutes at 50 °C. The septum was pierced with the SPME syringe needle and the fiber was exposed to the headspace for 10 minutes. The fiber was then thermally desorbed for 1 minute.	SPME then GC/MS	4 ng/L	No data	Guidotti et al. 2001

ECD = electron capture detector; FID = flame ionization detector; GC = gas chromatography; HRGC = high resolution gas chromatography; HRMS = high resolution mass spectrometry; MS = mass spectrometry; RSD = relative standard deviation; SPME = solid phase microextraction

the importance of collecting liquid samples in a container with no headspace and keeping tissue samples frozen until a 20–50 mg piece is placed into the headspace-sampling vial. The most sensitive method found is based on purge and trap isotope dilution GC in conjunction with high resolution mass spectrometry (GC/HRMS). This method from the Centers for Disease Control and Prevention laboratory in Atlanta (Ashley et al. 1992) reported a limit of detection (LOD) for 1,1,2,2-tetrachloroethane in blood of 0.005 ppb with recoveries ranging from 116% at 0.063 ppb to 76% at 0.41 ppb. Great effort was devoted to the clean-up of collection and analysis equipment to make such LODs possible. Additional information about the mass spectrometric (MS) aspects of the method was reported by Bonin et al. (1992). Guidotti et al. (2001) describes a solid-phase microextraction (SPME) method that can be used to determine 1,1,2,2-tetrachloroethane in blood and urine. In this method, a fiber made of a fused silica support coated with the appropriate phase is exposed to sample headspace. After the appropriate amount of time has passed, the fiber is removed and thermally desorbed. Separation and detection of analytes is accomplished by GC-MS.

7.2 ENVIRONMENTAL SAMPLES

Methods for the analysis of 1,1,2,2-tetrachloroethane in environmental samples are presented in Table 7-2. There are two common methods used for the concentration of 1,1,2,2-tetrachloroethane from air. One is the direct collection of organics in a cryogenically cooled trap in line with a GC; the other method is concentration of the organic via adsorption on a sorbent column followed by thermal or solvent desorption. An advantage of the direct sampling approach is that it can be very simple. The disadvantages of the cryogenic cooling approach are that the method is cumbersome and that condensation of moisture from air may block the passage of further air flow through the trap. The sorbent-based concentration methods permit very large concentration factors and, as a result, good LODs. The disadvantages of sorbent tubes are that the sorption and desorption efficiencies may not be 100% (breakthrough during collection and poor recovery during analyte desorption) and that the background impurities in the sorbent tubes might elevate the method detection limit (Cox 1983). An additional problem with sorbent tubes is that analyte can be lost if the tube is improperly stored after sample collection. For example, Atlas and Schauffler (1991) reported losses for 1,1,2,2-tetrachloroethane of 50% when the charcoal sorbent tube was stored at room temperature for 2 days before desorption and analysis. The recoveries from the same type of tubes were very good when the tubes were stored frozen for up to 30 days after sample collection. Chemical transformation of 1,1,2,2-tetrachloroethane to trichloroethylene has been reported (NIOSH 1994) on certain types of charcoal sorbents. It is also important to note that water introduced to the GC after both cryogenic and sorbent-based collection

Table 7-2. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Environmental Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Air	Sample pre-concentration in liquid oxygen-cooled trap	GC/ECD	<1 ppt (<6.98 ng/m^3)	85	Singh et al. 1981
Breathing zone air	Sample collection by adsorption onto Tenax followed by thermal desorption	Cryofocussing HRGC-MS	No data	80–120	Hartwell et al. 1987; Krost et al. 1982;
Air	Sample adsorption onto Tenax followed by thermal desorption	HRGC-ECD	0.1 ppt (0.698 ng/m^3) for 1 L	No data	Class and Ballschmiter 1987
Air	Preconcentration of analyte onto Tenax-GC followed by thermal desorption onto GC column (EPA Method TO1)	GC/MS	No data	No data	EPA 1984b
Air	Collection of an aliquot of the air into a SUMMA passivated canister followed by pumping an aliquot of the air through a cryogenic trap to focus volatile organics; thermal desorption onto GC column (EPA Method TO14)	GC/MS (full scan or selected ion monitoring); GC/FID/ECD/ PID	No data; depends on air aliquot size and mode of detection	No data; generally very good for non-polar volatile organics	EPA 1984c
Air	Preconcentration of analyte onto adsorbent trap containing 5 mg charcoal followed by immediate elution of traps with 30–50 µL of redistilled benzene in 3–5 aliquots	GC/ECD	Low parts per trillion in 20 L sample	85	Atlas and Schauffler 1991
Air	Passive collection onto carbon-based badge (3M OVM 3500); extraction with carbon disulphide containing internal standard	GC/MS (SIM)	<1 µg/m^3 (0.14 ppb)	89.3	Otson et al. 1994

Table 7-2. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Environmental Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Air	Equilibration of air with polymer-coated fiber for analyte concentration followed by thermal desorption of fiber (SPME)	GC/MS	0.06 ppbv (1.5% RSD)	70–98 depending on how fiber is stored after collection	Chai and Pawliszyn 1995
Air	Direct injection of 1 mL air into GC and cryogenic focusing (-150 °C) of volatiles followed by rapid heating to +150 °C in 20 minutes.	High speed GC/FID	2 ppb (14 µg/m^3) (depends on retention time)	No data	Mouradian et al. 1991
Occupational air	Preconcentration of analyte from air onto solid sorbent tube (petroleum charcoal); desorption with CS_2 and injection of 5 µL into GC. Working range is 1.5–15 ppm (10–100 mg/m^3) for a 10 L air sample. (NIOSH Method 1019)	GC/FID	0.01 mg/sample (0.3 mg/m^3 for 30 L sample volume)	106	NIOSH 1994
Air from waste and landfill sites	Adsorption of analyte onto Tenax followed by thermal desorption	Cryofocussing HRGC-MS or HRGC-ECD	0.01–0.1 ppb (0.07–0.7 µg/m^3)	No data	Gianti et al. 1984; LaRegina et al. 1986
Treated and raw source water	Purge and trap followed by thermal desorption	GC/MS	<1.0 µg/L	90	Otson 1987
Treated and raw source water	Purging of sample and on-column trapping	GC/FID and GC/HECD	1 µg/L (FID); 0.5 µg/L (HECD)	24 (HECD)	Otson and Williams 1982
Finished drinking/raw source water	Purge and trap onto Tenax/silica/charcoal followed by thermal desorption	Subambient programmable HRGC-MS (EPA Method 524.1)	0.28–0.41 µg/L	111 at 1 µg/L	EPA 1986c
Finished drinking/raw source water	Purge and trap onto Tenax/silica/charcoal followed by thermal desorption	Cryofocussing (wide or narrow bore) HRGC-MS (EPA Method 524.2)	0.04 µg/L (wide bore), 0.20 µg/L (narrow bore)	91 at 0.4–10 µg/L (wide bore), 100 at 0.5 µg/L (narrow bore)	EPA 1986d

Table 7-2. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Environmental Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Finished drinking water, raw source water, or drinking water in any treatment stage	Purging of organics from water using inert gas and trapping onto a sorbent; thermal desorption onto GC (EPA Method 502.2)	GC/PID (10.0 eV nominal)/ ELCD	0.01 µg/L with ELCD (no response from PID)	99 (6.8% RSD)	EPA 1988b
Drinking water, raw source water, or drinking water in any treatment stage	Purging of organics from water using inert gas and trapping onto a sorbent; thermal desorption of compounds onto GC (EPA Method 502.1)	GC/ electrolytic conductivity or GC/micro-coulometric detector	0.01 µg/L	95 (n=18) at 0.40 µg/L	EPA 1988a
Water	Purge and trap (Standard Methods 6210D; equivalent to EPA Method 524)	GC/MS	0.02–0.2 µg/L	100 (12% RSD for n=7) at 0.5 µg/L (narrow bore capillary column)	APHA 1989a
Water	Purge and trap (Standard Methods 6230D; equivalent to EPA Method 502.2)	GC/PID/ ELCD or micro-coulometric detector	0.1–0.05 µg/L	99 at 10 µg/L; SD=6.8 µg/L	APHA 1989b
Water	Addition of isotopically labeled analogs of compounds of interest to the water sample followed by purge and trap (EPA-EAD Method 1624)	GC/MS	10 µg/L	Not available	EPA 2001
Water	Purge and trap (ASTM Method D5790)	GC/MS	0.19 µg/L	101	NEMI 2001
Water	Purge and trap (Standard Methods 6200B)	GC/MS	0.06 µg/L	104	NEMI 1997a
Water	Purge and trap (Standard Methods 6200C)	GC/ELCD	0.03 µg/L	88	NEMI 1997b
Water	Purge and trap followed by thermal desorption (USGS-NWQL Method O-3115)	GC/MS	3 µg/L	Not available	USGS 1983

Table 7-2. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Environmental Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Water	Purge and trap (USGS-NWQL Method O-4127-96)	GC/MS	0.077 µg/L	95–116.7	USGS 1998
Municipal and industrial waste water	Purging of organics from water using inert gas and trapping onto a sorbent. Thermal desorption of compounds onto GC. (EPA Method 601)	GC/ electrolytic conductivity or GC/micro-coulometric detector	30 ng/L (depending on interferences)	0.95 c+0.19 where c=true value for concentration in µg/L	EPA 1984a
Groundwater and solid wastes	Purge and trap (EPA Method 8240)	GC/MS	Groundwater: 5 µg/L; soil/ sediment: 5 µg/kg. Both values for fairly clean matrix; LODs much worse for complex wastes	0.93 c+1.76 where c is concentration in µg/L	EPA 1986a
Waste water	Purge and trap onto Tenax/silica followed by thermal desorption	GC/MS (EPA Method 624)	6.9 µg/L	102 at 10–1,000 µg/L	EPA 1982a
Groundwater and surface water	Cryogenic trapping of analyte released into reduced pressure headspace (modification of vacuum distillation)	GC/ECD	1 ng/L	48	Comba and Kaiser 1983
Groundwater	Purge and trap onto Tenax/silica followed by thermal desorption	GC/MS (EPA-CLP Method)	5 µg/L	No data	EPA 1987
Fish	Vacuum distillation and cryogenic trapping	HRGC/MS	No data	No data	Hiatt 1983

Table 7-2. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Environmental Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Various fatty and non-fatty foods and beverages	Extraction of clear beverages with isooctane. Homogenization of composited food with >70% fat or oil and direct dilution or melting followed by dilution with isooctane. Preparation of other foods with solid or pulpy consistency via extraction with 20% acetone -5% NaCl in 25% phosphoric acid and isooctane. Isooctane analyzed directly by GC. Extracts from samples containing 21–70% fat had fat removed using Florisil.	GC/ECD or GC/ELCD	No data	Florisil treated: 38–122 (mean=80%, CV=23%); non-Florisil treated: 8–89 (mean=57%, CV=38%)	Daft 1989
Soil and sediment	Purging of sample suspension in water, adsorption of volatiled compounds onto Tenax/silica followed by thermal desorption	GC/MS	5 µg/kg	No data	EPA 1987
Sediment	Purge and trap with collection of released compounds onto Porapak followed by desorption with methanol	HRGC/ECD	1 µg/kg	60–82	Amin and Narang 1985
Sediment	Extraction of sediment with methanol followed by transfer of an aliquot of methanol extract to water for purge and trap analysis	GC/ECD/FID	0.05 µg/g (ppm)	84–86 (7% RSD)	Amaral et al. 1994
Sewage sludge	Extraction with pentane, addition of internal standard, filtration	GC/ECD	0.08 µg/L (wet)	111 (10.6% RSD)	Wilson et al. 1994

Table 7-2. Analytical Methods for Determining 1,1,2,2-Tetrachloroethane in Environmental Materials

Sample matrix	Preparation method	Analytical method	Sample detection limit	Percent recovery	Reference
Liquid and solid waste	Dispersion of solid and viscous samples in a glycol followed by purge and trap using Tenax/silica/ charcoal and thermal desorption	GC/HECD (EPA Method 5030 and 8010)	0.3 µg/L (groundwater); 0.3 µg/kg (soil); 15 µg/L (liquid waste); 37.5 µg/kg (sludge or solid waste)	0.95 c+0.19 where c is actual concentration	EPA 1982b, 1986b
Solid and liquid waste	Dispersion of solid and viscous samples in a glycol followed by purge and trap using Tenax/silica/ charcoal and thermal desorption	GC/HECD and PID in series	0.9 µg/L (water 1–5 mg/kg (soil)	93 at 6 µg/L (water)	Lopez-Avila et al. 1987
Groundwater and solid waste	Purge and trap direct injection, vacuum distillation, or head space (EPA-OSW 8021B)	GC/HECD and/or PID	0.01 µg/L (HECD); not available (PID)	99 (HECD); not available (PID)	EPA 1996b
Air, water, solid waste	Purge and trap (aqueous, solid, and waste oil), direct injection (waste oil), automatic static headspace (solid), closed system vacuum distillation (aqueous, solid, oil, and tissue), or desorption from trapping media (air) (EPA-OSW 8260B)	GC/MS	0.04 µg/L (wide-bore capillary column); 0.20 µg/L (narrow-bore capillary column)	91 (wide-bore capillary column); 100 (narrow-bore capillary column)	EPA 1996a

[a]For liquid samples: ppm = mg/L; ppb = µg/L; ppt = ng/L; for air samples: ppbv = nmoles analyte:liter air

ECD = electron capture detector; ELCD = electrolytic conductivity detector; FID = flame ionization detector; GC = gas chromatography; HECD = hall electrolytic conductivity detector; HRGC = high resolution gas chromatography; MC = microcoulometry; MS = mass spectrometry; PID = photoionization detector; RSD = relative standard deviation (coefficient of variation); SD = standard deviation; SIM = selected ion monitoring; SPME = solid phase microextraction

methods can result in shifts in GC retention times and in the alteration of instrumental response in MS detection that results from pressure changes in the ion source during elution of the water.

The most common method for the determination of 1,1,2,2-tetrachloroethane levels in water, sediment, soil, and other high solid samples is to purge the compound with an inert gas from the sample directly or after suspension of the sample in water, and to trap the purged vapors onto a sorbent trap (purge and trap). Subsequent thermal desorption is used for the determination of the analyte concentration. Different purging methods have been compared by Melton et al. (1981). Purge and trap methods for source and drinking water have also been described by Otson (1987) and Otson and Williams (1982). A purge and trap method has even been adapted and applied to highly radioactive waste samples (Tomkins et al. 1989). Dynamic thermal stripping is a variation of the purge and trap method. It has been shown to extend the range of analyte molecular weights that can be accessed using this type of methodology (Lesage 1991). The determination of 1,1,2,2-tetrachloroethane can be accomplished by both the purge and trap and dynamic thermal stripping methods. Matz and Kesners (1993) have described a "spray and trap" method in which the sample is continuously sprayed into a container that is swept with gas to transport the volatilized organics to a sorbent trap. Unlike the bubble stripping of purge and trap, the spray extraction offers a continuous analyte flux of constant concentration for optimum trapping conditions. A publication by Daft (1989) demonstrates the poor accuracy that can result when liquid/liquid extraction approaches are applied to samples containing volatile organic compounds.

Standardized methods used for detection of 1,1,2,2-tetrachloroethane in water samples by purge and trap followed by GC/MS include EPA Methods 524.2, 624, and 1624, Standard Methods 6200B and 6200C, ASTM Method D5790, and USGS-NWQL Methods O-4127-96 and O-3115 (EPA 1982a, 1986b, 2001a; NEMI 1997a, 1997b, 2001; USGS 1983, 1998). Detection limits and percent recoveries for determination of this substance in water are 0.02–10 ppb and 88–116.7%, respectively, using these methods. EPA-OSW Methods 8021B and 8260B can be applied to solid waste samples. Method 8021B uses GC followed by a photoionization detector (PID) and a Hall electron capture detector (HECD) connected in series (EPA 1996a, 1996b).

The two routine quantification methods that provide the lowest detection limits are halogen-specific detection (e.g., Hall electrolytic conductivity detector) and MS. Since the compound has four chlorine atoms, electron capture detection (ECD) is also very sensitive for this compound. The advantages of halogen-specific detectors are they are not only very sensitive, but are also selective for halogen-containing compounds. The mass spectrometer, on the other hand, provides additional confirmation of

the presence of a compound through the compound's characteristic fragmentation pattern, and this selectivity can be very desirable when the simultaneous quantification of many compounds is required. The inability of halogen-specific detectors to detect and quantify nonhalogen compounds can be overcome by using other detectors (e.g., photoionization detector) in series (Driscoll et al. 1987; Lopez-Avila et al. 1987). Atomic emission detectors can provide signals from many elements within the molecule (C, H, and Cl for 1,1,2,2-tetrachloroethane) simultaneously (Ryan et al. 1990; Yieru et al. 1990a, 1990b). A detection limit of 10 pg 1,1,2,2-tetrachloroethane was reported using a helium discharge detector in conjunction with GC (Ryan et al. 1990).

High-resolution gas chromatography (HRGC) with capillary columns is a better method for volatile compounds than packed columns because capillary columns provide better resolution of closely eluting compounds and increase the sensitivity of detection. Sample purge and on-column cryotrapping can eliminate the need for the conventional purge and trap unit and can reduce the time of analysis (Pankow and Rosen 1988). Although this approach is most easily accomplished using packed columns, capillary columns can provide better separation and method sensitivity. The plugging of the trap (or column) by moisture condensation during cryotrapping in an open tubular column can be avoided through the use of a very wide bore capillary column; the chromatographic resolution of such a column is inferior to narrow bore capillary columns (Mosesman et al. 1987; Pankow and Rosen 1988) and limits the method sensitivity.

7.3 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.

7.3.1 Identification of Data Needs

Methods for Determining Biomarkers of Exposure and Effect. A few methods were found for the determination of 1,1,2,2-tetrachloroethane levels of biological matrices. The most sensitive method found was that of Ashley et al. (1992) in which the LOD for 1,1,2,2-tetrachloroethane in human blood was reported to be 0.005 ppb with a recovery of 116% at 0.063 ppb. Chen et al. (1993) reported methods for the determination of this compound in blood and tissues from rats that were used to study the toxicokinetics of 1,1,2,2-tetrachloroethane after intra-arterial administration. The LOD reported was 400 ng/g, depending on the tissue, with 90–100% recovery and an average precision of 1.7% relative standard deviation (RSD). The methods for rat tissues should be applicable to human tissues, but have not been evaluated. The study of the levels of the parent compound in human blood, urine, or other biological matrices can be useful in deriving a correlation between levels of this compound in the environment and those in human tissue or body fluid. Such controlled correlation studies are unavailable for this compound.

No metabolite or biomarker of 1,1,2,2-tetrachloroethane from human exposure specific to this compound has yet been identified (see Section 3.8). The changes in metabolite concentrations with time in human blood, urine, or other appropriate biological medium may be useful in estimating its rate of metabolism in humans. In some instances, a metabolite or a biomarker might be useful in correlating the exposure doses to the human body burden but, as previously noted, the metabolites are not specific to 1,1,2,2-tetrachloroethane. Such studies on the levels of metabolites/biomarkers in human samples are not available for this compound, although metabolic products of this compound from animal and *in vitro* studies have been identified (see Chapter 3) and analytical methods for their quantification are available. The metabolites, chloral hydrate, trichloroethanol, trichlorethanol glucuronide, and trichloroacetic acid, have all been determined using variations of headspace analysis (Breimer et al. 1974; Christensen et al. 1988; Koppen et al. 1988). These compounds are metabolites of TCE that can be formed from 1,1,2,2-tetrachloroethane. Reported sensitivities were approximately 20 ng/mL (20 ppb). Assuming a greater abundance in urine of metabolites relative to parent compound, these methods might be adequate but this has not been demonstrated. Additional methods need to be validated or developed to detect metabolites of 1,1,2,2-tetrachloroethane after exposures at the MRLs.

Methods for Determining Parent Compounds and Degradation Products in Environmental Media. The occurrence of this compound in environmental media can be used to indicate possible

exposure of humans to this compound through the inhalation of air and ingestion of drinking water and foods containing 1,1,2,2-tetrachloroethane. The MRL for intermediate-duration inhalation exposure is 0.4 ppm (see Section 2.3). Methods for the measurement of 1,1,2,2-tetrachloroethane in air at the ppt level and at least 85% accuracy are available (Atlas and Schauffler 1991; Class and Ballschmiter 1987; Singh et al. 1981). No new methods are needed for this compound in air. Methods for the measurement of 1,1,2,2-tetrachloroethane in drinking water are sensitive to sub-ppb (sub-μg/L) and ppt (ng/L) levels with 91–100% accuracy (APHA 1989a, 1989b; EPA 1986c, 1988b). No new methods are needed for drinking water. Very little information was found for 1,1,2,2-tetrachloroethane in food; additional detection methods are needed for foods.

Although the products of biotic and abiotic processes of this compound in the environment are adequately known, no systematic study is available that measures the concentrations of its reaction products in the environment. In instances where the product(s) of an environmental reaction is more toxic than the parent compound, it is important to know the level of the reaction products in the environment. It is known that 1,1,2,2-tetrachloroethane degrades under anaerobic conditions (e.g., in anaerobic landfills, leading to contamination of groundwater) and via hydrolysis to trichloroethylene (see Section 6.3.2, and Cooper et al. [1987] and Haag and Mill [1988]). Hallen et al. (1986) also reported isolating 1,1,2-trichloroethane, cis-1,2-dichloroethylene, trans-1,2-dichloroethylene, 1,1-dichloroethylene, and vinyl chloride after 6 weeks of incubation of 1,1,2,2-tetrachloroethane in a simulated landfill. The analytical methods for the determination of the levels of these environmental reaction products of 1,1,2,2-tetrachloroethane are available. Drinking water would be expected to be the main route of oral exposure. All of these compounds can be measured in drinking water using EPA Method 502.2 (EPA 1988b). Method detection limits (μg/L) are stated to be 0.01 for trichloroethylene, not determined for 1,1,2-trichloroethane, 0.01 for cis-1,2-dichloroethylene, 0.05 for trans-1,2-dichloroethylene, 0.07 for 1,1-dichloroethylene, and 0.02 for vinyl chloride. Precisions were reported to be between 2 and 4% RSD. All of the stated degradation products except cis- and trans-1,2-dichloroethylene can be measured in soils and solid wastes using EPA method 8240 (EPA 1986a) with practical quantitation limits (PQLs) of approximately 5 μg/L in groundwater, 5 μg/kg in soils/sediments, and 0.5 mg/kg in wastes. All of the degradation products except cis-1,2-dichloroethylene can be measured in municipal and industrial wastes with PQLs ranging from 0.02 μg/L for 1,1,2-trichloroethane to 0.18 μg/L for vinyl chloride. Assuming that the concentrations of these degradation products are much less than the concentration of 1,1,2,2-tetrachloroethane and knowing that the methods for the parent compound are sufficiently sensitive to measure background levels, no additional methods are needed at the present time.

7.3.2 Ongoing Studies

The Environmental Health Laboratory Sciences Division of the National Center for Environmental Health, Centers for Disease Control and Prevention, is developing methods for the analysis of 1,1,2,2-tetrachloroethane and other volatile organic compounds in blood. These methods use purge and trap methodology, HRGC, and magnetic sector MS, which gives detection limits in the low ppt range.

No other ongoing studies related to analytical methods were identified.