ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA
ENTRY FOR TETRACHLOROETHYLENE (PERC)

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Like a library or many large databases (such as EPA's national STORET water quality database), this document contains information of variable quality from very diverse sources. In compiling this document, mistakes were found in peer reviewed journal articles, as well as in databases with relatively elaborate quality control mechanisms [366,649,940]. A few of these were caught and marked with a "[sic]" notation, but undoubtedly others slipped through. The [sic] notation was inserted by the editors to indicate information or spelling that seemed wrong or misleading, but which was nevertheless cited verbatim rather than arbitrarily changing what the author said.

Most likely additional transcription errors and typos have been added in some of our efforts. Furthermore, with such complex subject matter, it is not always easy to determine what is correct and what is incorrect, especially with the "experts" often disagreeing. It is not uncommon in scientific research for two different researchers to come up with different results which lead them to different conclusions. In compiling the Encyclopedia, the editors did not try to resolve such conflicts, but rather simply reported it all.

It should be kept in mind that data comparability is a major problem in environmental toxicology since laboratory and field methods are constantly changing and since there are so many different "standard methods" published by EPA, other federal agencies, state agencies, and various private groups. What some laboratory and field investigators actually do for standard operating practice is often a unique combination of various standard protocols and impromptu "improvements." In fact, the interagency task force on water methods concluded that [1014]:

> It is the exception rather than the rule that water-quality monitoring data from different programs or time periods can be compared on a scientifically sound basis, and that...
>
> No nationally accepted standard definitions exist for water quality parameters. The different organizations may collect data using identical or standard methods, but identify them by different names, or use the same names for data collected by different methods [1014].

Differences in field and laboratory methods are also major issues related to (the lack of) data comparability from media other than water: soil, sediments, tissues, and air.

In spite of numerous problems and complexities, knowledge is often power in decisions related to chemical contamination. It is therefore often helpful to be aware of a broad universe of conflicting results or conflicting expert opinions rather than having a portion of this information arbitrarily censored by someone else. Frequently one wants to know of the existence of information, even if one later decides not to use it for a particular application. Many would like to see a high percentage of the information available and decide for themselves what to throw out, partly because they don't want to seem uniformed or be caught by surprise by potentially important information. They are in a better position if they can say: "I knew about that data, assessed it based on the following quality assurance criteria, and decided not to use it for this application." This is especially true for users near the end of long decision processes, such as hazardous site cleanups, lengthy ecological risk assessments, or complex natural resource damage assessments.

For some categories, the editors found no information and inserted the phrase "no information found." This does not necessarily mean that no information exists; it simply means that during our efforts, the editors found none. For many topics, there is probably information "out there" that is not in the Encyclopedia. The more time that passes without encyclopedia updates (none are planned at the moment), the more true this statement will become. Still, the Encyclopedia is unique in that it contains broad ecotoxicology information from more sources than many other reference documents. No updates of this document are currently planned. However, it is hoped that most of the information in the encyclopedia will be useful for some time to come even without updates, just as one can still find information in the 1972 EPA Blue Book [12] that does not seem well summarized anywhere else.

Although the editors of this document have done their best in the limited time available to insure accuracy of quotes or summaries as being "what the original author said," the proposed interagency funding of a bigger project with more elaborate peer review and quality control steps never materialized.

> The bottom line: The editors hope users find this document useful, but don't expect or depend on perfection herein. Neither the U.S. Government nor the National Park Service make any claims that this document is free of mistakes.

The following is one chemical topic entry (one file among 118). Before utilizing this entry, the reader is strongly encouraged to read the README file (in this subdirectory) for an introduction, an explanation of how to use this document in general, an explanation of how to search for power key section headings, an explanation of the organization of each entry, an information quality discussion, a discussion of copyright issues, and a listing of other entries (other topics) covered.

See the separate file entitled REFERENC for the identity of numbered references in brackets.

HOW TO CITE THIS DOCUMENT: As mentioned above, for critical applications it is better to obtain and cite the original publication after first verifying various data quality assurance concerns. For more routine applications, this document may be cited as:

> **Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese**, and **W. Basham.** 1997. Environmental Contaminants Encyclopedia. National Park Service, Water Resources Division, Fort Collins, Colorado. Distributed within the Federal Government as an Electronic Document (Projected public availability

on the internet or NTIS: 1998).

Tetrachloroethylene (Tetrachloroethylene, 1,1,2,2-; PERC; Perchloroethylene, Tetrachloroethene; CAS number 127-18-4)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

Tetrachloroethylene is a carcinogenic priority pollutant and is used in dry cleaning and as an industrial solvent [446,331]. It is classified as a volatile organic compound (VOC) [868,903]. This compound is considered a purgeable halocarbon [1010].

This compound is a synthetic chemical that is widely used for dry cleaning fabrics and for metal-degreasing operations. It is also used as a starting material (building block) for making other chemicals and is used in some consumer products. It evaporates easily into the air and has a sharp, sweet odor. Most people can smell tetrachloroethylene when it is present in the air at a level of 1 ppm or more. In an experiment, some people could smell tetrachloroethylene in water at a level of 0.3 ppm [934].

Tetrachloroethylene enters the environment mostly by evaporating into the air during use. It can also get into water supplies and the soil during disposal of sewage sludge and factory waste. Tetrachloroethylene may also get into the air, soil, or water by leaking or evaporating from storage and waste sites [934].

Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations (40 CFR 401.15, 7/1/88) [609].

Br.Haz: General Hazard/Toxicity Summary:

Potential Hazards to Fish, Wildlife, Invertebrates, Plants, and other Non-Human Biota:

There has been more publicity and attention given to tetrachloroethylene as a potential hazard to humans than to fish wildlife; thus there is more literature related to humans and the information found on other species is comparatively sparse compared to the more detailed human health literature.

Effects of this volatile solvent to non-human biota would often result from high concentrations immediately after a spill (before the compound has volatilized into the atmosphere) or be the indirect result of contamination of groundwater. For example, if highly polluted groundwater water comes into surface waters from springs or seeps, local effects may occur in the mixing zone where the groundwater enters surface water.

Tetrachloroethylene has been/ shown to release lysosomal enzymes from granular fractions prepared from nematodes. Since gut of nematodes seems to be specialized for lysosomal intracellular digestion of nutrients, interference with this process may well explain action of tetrachloroethylene; it has been assumed that affected worms are paralyzed sufficiently to release their attachment to intestinal wall (Goodman, L.S., and A. Gilman., eds., The Pharmacological Basis of Therapeutics. 5th ed. New York: Macmillan Publishing Co., Inc., 1975. 1031).

One potentially important aspect of the presence of perchloroethylene (tetrachloroethylene) is that it can break down into other hazardous compounds. Tetrachloroethylene (PCE) can be transformed by reductive dehalogenation to trichloroethylene (TCE), dichloroethylene and vinyl chloride (VC) under anaerobic conditions [366]. Thus, when PCE levels have been reduced to acceptable levels, it is still necessary to check to see that levels of the suspected hazardous breakdown products are also acceptably low. For more information, see the Fate.Detail section below.

Trichloroacetic acid, One photodegradation breakdown product, is a known heribicide; see Environment Canada summary for air pollution effects on plants [935].

Potential Hazards to Humans:

Ingestion of a small amount of tetrachloroethylene is unlikely to cause permanent injury (Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 5, 79, 761) [609].

Acute hepatic necrosis and oliguric uremia have followed human exposure (Gosselin, R.E., R.P. Smith, H.C. Hodge. Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams and Wilkins, 1984.,p. II-165) [609].

Tetrachloroethylene has been used safely as a general anesthetic agent, so at high concentrations it is known to produce loss of consciousness [934].

The health effects of breathing in air or drinking water with low levels of tetrachloroethylene are not known [934].

This compound's defatting action on skin can lead to dermatitis (The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1315) [609].

Excessive exposure has resulted in effects on the central nervous system, mucous membranes, eyes, & skin, & to a lesser extent the lungs, liver, kidneys. The effects most frequently noted have been on the nervous system. Unconsciousness, dizziness, headache, vertigo or light. Cases of CNS depression have occurred in many instances after occupational exposures (American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH:American Conference of Governmental Industrial Hygienists, 1986. 464) [609].

Several comprehensive reports on the hazards of tetrachloroethylene are available. EPA has a free and informative (several page) health advisory on this compound, available through the Office of Drinking Water, EPA, Washington, D.C. or through NTIS. A comprehensive toxicological profile for tetrachloroethylene, especially as it relates to human health, is available from ATSDR [934]. Due to lack of time, important highlights from this ATSDR document have not yet been completely incorporated into this entry.

However, since there is so much information available related to human health, much of the information summarized below is taken from other government summary sources such as the Hazardous Substances Data Bank [609], EPA IRIS database [893], and the ATSDR Human Toxicology Profile [934].

Environment Canada has prepared the comprehensive Priority Substances List Assessment Report for tetrachloroethylene [935]. The Canadian report stressed the need for more information on groundwater, carcinogenicity, effects of contaminated soil and sediment [935].

Br.Car: Brief Summary of Carcinogenicity/Cancer Information:

EPA 1996 IRIS information [893]:

> The classification of this substance is currently under review. A final decision on whether this substance should be classified B2 or C has not yet been made. If this substance is classified as C, the lifetime HA calculated here is recommended. If the classification is B2, no lifetime HA is recommended.

Tetrachloroethylene has been classified as a probable human carcinogen by EPA [331]. It has been treated as a carcinogen for EPA PRG and RBC modeling purposes [893,903].

IARC Summary and Evaluation [609]:

> Inadequate evidence of carcinogenicity in humans. Sufficient evidence of carcinogenicity in animals. OVERALL EVALUATION: Group 2B: The agent is possibly carcinogenic to humans [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer,1972-PRESENT, (Multivolume work).,p. S7 72 (1987)].
>
> Classification of carcinogenicity: 1) Evidence in humans: inadequate; 2) evidence in animals: sufficient; Overall summary evaluation of carcinogenic risk to humans is group 2B: The agent is possibly carcinogenic to humans [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer,1972-PRESENT. (Multivolume work).,p. S7 335, 1987)].

This compound often makes the news related to potential cancer risk and ground water. For example: Electronic News Media Report [Greenwire: February 21, 1997, presented for information purposes, neither the accuracy nor the value of this report has been verified]:

> MASSACHUSETTS: HIGH CANCER RATE LINKED TO LAB Residents of one section of Natick, MA, experienced more than twice the expected rate of an "often-fatal" cancer from 1982 to 1990, according to state records released this week. Nine people within 1.5 miles of the US Army Soldier Systems Command contracted pancreatic cancer during that time period. Marco Kaltofen, a local chemist and co-chair of an advisory committee monitoring the cleanup of the federal Superfund site at the Army lab, has raised concerns that carcinogens from the lab could have reached groundwater and contributed to the high incidence of cancer. Kaltofen: "There

may be other sources, but you'd be a fool to ignore the Army labs." Locals think the two chemicals -- trichloroethylene and tetrachloroethane -- may have penetrated a well field in the Springvale area. The town is currently completing a $4 million treatment system for the Springvale wells. But state Dept. of Public Health officials said the cause of the pancreatic cancer could not be pinpointed. The Springvale wells serve all of Natick, not just the area near the lab, and other sources of contamination are possible, they said. Also, the levels of contamination in the wells near the lab did not regularly exceed state drinking-water standards, they said (Scott Allen, BOSTON GLOBE, 2/20).

Br.Dev: Brief Summary of Developmental, Reproductive, Endocrine, and Genotoxicity Information:

Except for indirect and somewhat controversial results from one study, there is no evidence that tetrachloroethylene is a human teratogen [934].

Results from inhalation studies in animals suggest that tetrachloroethylene is fetotoxic but not teratogenic at concentrations that are also maternally toxic [934].

Pregnant mice and rats were exposed to a concentration of 300 ppm. Both species were exposed for periods of 7 hours daily, on days 6 through 15 of gestation. No fetal toxicity or teratogenicity was detected (Shepard, T.H. Catalog of Teratogenic Agents. 5th ed. Baltimore, MD: The Johns Hopkins University Press, 1986. 547) [609].

In humans, some occupational exposure reproductive problems have been noted among dry cleaning workers [934].

There is only one reproductive study in animals, and it had serious limitations in design and conduct. Therefore, it provides no conclusive evidence for reproductive effects [934].

The lack of strong genotoxic effects seen in assays of human lymphocytes following occupational exposure to tetrachloroethylene is consistent with data on the metabolism of this compound [934]. It is not clear whether the low levels of tetrachloroethylene found at most hazardous waste sites would cause observable genotoxic effects in humans [934].

Tetrachloroethylene was not mutagenic in 2 strains of Salmonella typhimurium in the presence of a postmitochondrial mouse liver supernatant, following exposure to vapors (Bartsch H et al; Arch Toxicol 41 (4): 249-78, 1979) [609].

Results of the mutagenicity test using L5178Y mouse lymphoma cells were positive for tetrachlorethylene (NTP; Fiscal Year 1987 Annual Plan p.82, 1987, NTP-87-001) [609].

The ability of tetrachloroethylene to induce DNA repair in the hepatocyte primary culture (HPC) system was evaluated using hepatocytes from male B6C3F1 mice and Osborne-Mendel rats. In both the mouse and rat HPC/DNA repair assays, tetrachloroethylene was cytotoxic from 0.01% to 0.1% and was not genotoxic from 0.001% to 0.00001% (Naylor Dana Institute; DNA Repair Tests of 11 Chlorinated Hydrocarbon Analogs, Final Report., 1983, EPA Document No. 40-8324292, Fiche No. OTS0509403) [609].

Lymphocytes from 10 factory workers exposed to tetrachloroethylene for 3 mo to 18 yr showed no significant dose-related changes in chromosome aberrations, sister chromatid exchange rate, proportion of M2+M3 metaphases or mitotic index, compared with controls (Ikeda m et al; toxicology letters 5: 251, 1980) [609].

Br.Fate: Brief Summary of Key Bioconcentration, Fate, Transport, Persistence, Pathway, and Chemical/Physical Information:

Much of the tetrachloroethylene that gets into water and soil will evaporate to the air. However, because tetrachloroethylene can travel through many soils quite easily, it can get into underground drinking water supplies. Tetrachloroethylene that gets into underground water may stay there for many months without being broken down. If conditions are right, bacteria will break down some of it and some of the chemicals formed may also be harmful (see following paragraph). Under some conditions, tetrachloroethylene may stick to the soil and stay there. It does not seem to build up in animals that live in water, such as fish, clams, and oysters. It is not known if it builds up in plants grown on land [934].

This compound moves readily from soil to water and air, and some benchmarks take into account harmonization between media. Thus one benchmark (such as soil) needs to take into account not causing the exceedance of a benchmark in another media (such as air, water, or sediment) [655].

One potentially important aspect of the presence of perchloroethylene (tetrachloroethylene) is that it can break down into other hazardous compounds. Tetrachloroethylene (PCE) can be transformed by reductive dehalogenation to trichloroethylene (TCE), dichloroethylene and vinyl chloride (VC) under anaerobic conditions [366]. For more information, see the Fate.Detail section below. One photodegradation breakdown product, trichloroacetic acid, is a known heribicide [935].

Human exposure to tetrachloroethylene will occur through inhalation of contaminated ambient air and ingestion of contaminated drinking water (especially from polluted groundwater sources). Occupationally, exposure will occur from inhalation of contaminated air (especially in urban/industrial areas, in and around metal degreasing and dry cleaning industries). Food does not appear to be a major source, but the data are poor [609].

Environmental Fate/Exposure Summary [609]:

Tetrachloroethylene (PCE) is likely to enter the environment by fugitive air emissions from dry cleaning and metal degreasing industries and by spills or accidental releases to air, soil, or water. If PCE is released to soil, it will be subject to evaporation into the atmosphere and to leaching to the groundwater. Biodegradation may be an important process in anaerobic soils based on laboratory tests with methanogenic columns. Slow biodegradation may occur in groundwater where acclimated populations of microorganisms exist. If PCE is released to water, it will be subject to rapid volatilization with estimated half-lives ranging from <1 day to several weeks. It will not be expected to significantly biodegrade, bioconcentrate in aquatic organisms or significantly adsorb to sediment. PCE will not be expected to significantly hydrolyze in soil or water under normal environmental conditions. If PCE is released to the atmosphere, it will exist mainly in the gas-phase and it will be subject to photooxidation with estimates of degradation time scales ranging from an approximate half-life of 2 months to complete degradation in an hour. Some of the PCE in the atmosphere may be subject to washout in rain based on the solubility of PCE in water; PCE has been detected in rain. Major human exposure is from inhalation of contaminated urban air, especially near point sources such as dry cleaners, drinking contaminated water from contaminated aquifers and drinking water distributed in pipelines with vinyl liners, and inhalation of contaminated occupational atmospheres in metal degreasing and dry cleaning industries.

Synonyms/Substance Identification:

Perchloroethylene [617]
PCE [617]
    (Note: other chemicals also use this acronym)
Tetrachloroethene [617]
Perk [617]
Perc [617]
Tetrachloroethylene, 1,1,2,2- [617]
1,1,2,2-TETRACHLOROETHYLENE [609]
CZTEROCHLOROETYLEN (POLISH) [609]
ETHENE, TETRACHLORO- [609]
ETHYLENE TETRACHLORIDE [609]
PERCHLOORETHYLEEN, PER (DUTCH) [609]
PERCHLORAETHYLEN, PER (GERMAN) [609]
PERCHLORETHYLENE [609]
PERCHLORETHYLENE, PER (FRENCH) [609]
PERCLOROETILENE (ITALIAN) [609]
TETRACHLOORETHEEN (DUTCH) [609]
TETRACHLORAETHEN (GERMAN) [609]
TETRACHLORETHYLENE [609]
TETRACLOROETENE (ITALIAN) [609]
AI3-01860 [609]
Ankilostin [609]
Didakene [609]
ENT 1,860 [609]
Ethylene, tetrachloro- [609]
Fedal-un [609]
NCI-C04580 [609]
Nema [609]
Perclene [609]
Persec [609]
Tetlen [609]
Tetracap [609]
Tetraleno [609]
Tetropil [609]
Antisal 1 [609]
Antisol 1 [609]
Dow-Per [609]
Fedal-Un [609]
Per [609]
Perawin [609]
Perchlor [609]
Percosolv [609]
Perklone [609]
Tetraguer [609]
Tetralex [609]
Tetravec [609]
Tetroguer [609]

Molecular Formula:
C_2-Cl_4 [609]

Associated Chemicals or Topics (Includes Transformation Products):

See also individual entries:

Trichloroethylene
Dichloroethylene, 1,1-
Vinyl Chloride

Site Assessment-Related Information Provided by Shineldecker (Potential Site-Specific Contaminants that May be Associated with a Property Based on Current or Historical Use of the Property) [490]:

Raw Materials, Intermediate Products, Final Products, and Waste Products Generated During Manufacture and Use:

- Tetrachloroethane

A new form of substance abuse in adolescents is the inhalation of fumes from typewriter correction fluids (Liquid Paper, Wite-Out, Snopake, etc), which are composed of various chlorinated solvents, /including tetrachloroethylene/, to induce euphoria. Medical complications of such abuse and medical management of acute toxic episodes are discussed herein, along with suggestions for controlling this substance abuse (Greer JE; South Med J 77 (3): 297-8, 1984) [609].

Metabolism/Metabolites [609]:

Metabolites: trichloroacetic acid; trichloroethanol; inorg chloride; trans-1,2-dichloroethylene in expired air. /From table/ [Sunshine, I. (ed.). CRC Handbook of Analytical Toxicology. Cleveland: The Chemical Rubber Co., 1969. 381].

In tetrachloroethylene exposure, urinary metabolite levels of trichloroethanol, total trichloro compounds, and trichloroacetic acid increased until the atmospheric concn of the solvent reached 50 to 100 ppm; little incr in these metabolites occurred at higher solvent concn [Ikeda m et al; brit j ind med 29 (3): 328-33 (1972)].

The relationship among dose, metabolism and hepatotoxicity in mice which resulted from subchronic exposure to the chlorinated solvents trihloroethylene and perchloroethylene were examined. Male Swiss-Cox mice received either trichloroethylene (0 to 3200 mg/kg/day) or perchlorothylene (0 to 2000 mg/kg/day) in corn oil by gavage for 6 weeks. Urinary metabolites from individual mice were quantified to estimate the extent to which each compound was metabolized. Four parameters of hepatotoxicity were assessed: liver weight, triglycerides, glucose-6-phophatase activity, and serum glutamic-pyruvic transaminase (SGPT) activity. Trichloroethylene significantly affected liver weight and glucose-6-phosphatase activity; perchloroethylene affected all four parameters. The metabolism of trichloroethylene was linearly related to dose through 1600 mg/kg, but then became saturated. The metabolism of perchloroethylene was saturable. The dose-effect curves of the affected hepatotoxicity parameters of both compounds were nonlinear and resembled the dose-metabolism graph of the corresponding solvent. Plots of the hepatotoxicity data of each compound against total urinary metabolites were linear in all cases, suggesting that the hepatotoxicity of both perchloroethylene and trichloroethylene in mice is directly related to the extent of their metabolism. This pattern is consistent with formation of the toxic intermediate in the primary metabolic pathway of each compound (Buben JA, O'Flaherty EJ; Toxicol Appl Pharmacol 78 (1): 105-22 (1985)].

Water Data Interpretation, Concentrations and Toxicity (All Water Data Subsections Start with "W."):

W.Low (Water Concentrations Considered Low):

Surface water samples from unpolluted areas are usually less than 1 ppb [934].

W.High (Water Concentrations Considered High):

In one polluted area, surface water was 182,000 ppb [934]..

W.Typical (Water Concentrations Considered Typical):

Information from HSDB [609]:

Samples for analysis of volatile organic compounds were collected from 315 wells in the Potomac-Raritan-Magothy aquifer system in southwestern New Jersey and a small adjacent area in Pennsylvania (USA) during 1980-1982. Volatile organic compounds were detected in all 3 aquifer units of the Potomac-Raritan-Magothy aquifer system. Most of the contamination appeared to be confined to the outcrop area. Low levels of contamination were found downdip of the outcrop area in the upper and middle aquifer. Trichloroethylene, tetrachloroethylene and benzene were the most frequently detected compounds. Differences in the distributions of light chlorinated hydrocarbons, /(including tetrachloroethylene)/, trichloroethylene, and aromatic hydrocarbons, ie, benzene, were noted and were probably due to differences in the uses of the compounds and the distribution patterns of potential contamination sources. The distribution patterns of volatile organic compounds differed greatly among the 3 aquifer units. The upper aquifer, which cropped out mostly in less-developed areas, had the lowest percentage of wells with volatile organic compounds detected (10% of wells sampled). The concentrations in most wells in the upper aquifer which had detectable levels were <10 ug/l. In the middle aquifer, which cropped out beneath much of the urban and industrial area adjacent to the Delaware River, detectable levels of volatile organic compounds were found in 22% of wells sampled, and several wells contained concentrations >100 ug/l. The lower aquifer, which was confined beneath much of the outcrop area of the aquifer system, had the highest percentage of wells (28%) with detectable levels. This was probably due to vertical leakage of contamination from the middle aquifer and the high percentage of wells tapping the lower aquifer in the most heavily developed areas of the outcrop (Fusillo TV et al; Ground Water 23 (3): 354-60 (1985)].

The National Health Department (Italy) had promoted and supported a preliminary survey on the presence of some chlorinated organic compounds in the drinking water. The drinking water of some cities of northern Italy was analyzed for the presence of trichloroethylene, tetrachloroethylene, methylchloroform, carbon tetrachloride, trihalomethanes, polychlorinated biphenyls, and the most common chlorinated pesticides. From March, 1981 to June, 1982, 8 controls were done for 11 sampling points. All water underwent different treatments with carbon. In the raw water, trichloroethylene (47/48) and tetrachloroethylene (34/48) showed the highest frequency of positivity. One well had the highest concentrations of these compounds (trichloroethylene 81-158 ug/l; tetrachloroethylene 15-32 ug/l). In the finished waters, carbon trichloride the most abundant trihalomethane formed during chlorination, was detected in 80% of the 39 samples, against 31% in the 48 raw water samples. No polychlorinated biphenyls and chlorinated pesticides were found at the chosen detection limit (0.05 ug/l) (Ziglio G et al; Ig Mod 82 (3): 419-35 (1984)].

DRINKING WATER: 180 USA cities with finished surface water - 0.3 ppb median, 21 ppb max; 36 US cities with finished groundwater - 3.0 ppb median; roughly 25% of the samples were positive(1). Contaminated wells had much higher concentrations (a maximum of 1.5 ppm)(2,3). 30 Canadian potable water treatment facilities (treated water) 1 ppb avg, 2 ppb max(4); 230 Groundwater public drinking water sources in the Netherlands: 64 are >10 ppb, 12 are >100 ppb, 4 are >1 ppm and 2 are >100 ppm(5). Federal survey of finished waters in USA: Tetrachloroethylene occurred in 26.1% of groundwater supplies, max concentrate in groundwater and surface water supplies 1500 and 21 ppb, respectively(6). [(1) Coniglio WA et al; Occurrence of Volatile Organics in

Drinking Water. p. 7 Unpublished EPA report (1980) (2) Burmaster DE; Environ 24: 6-13, 33-6 (1982) (3) Giger W, Molnar-Kubica E; Bull Environ Contam Toxicol 19: 475-80 (1978) (4) Otson R et al; J Assoc Off Anal Chem 65: 1370-4 (1982) (5) Trouwborst T; Sci Total Environ 21: 41-6 (1981) (6) Dyksen JE, Hess AF III; J Amer Water Works Assoc 74: 394-403 (1982)].

DRINKING WATER: Maximum concentration in tapwater from bank filtered Rhine water in the Netherlands 50 parts per trillion(1). Old Love Canal, Niagara Falls, NY (9 homes) 350-2900 parts per trillion, 470 parts per trillion median(2). USA surveys: State data, 1569 samples, 14% pos, trace to 3000 ppb, National Organics Monitoring Survey (NOMS, initiated in 1975), 113 samples, 42.4% pos, 0.2-3.1 ppb, National Screening Program (NSP, 1977-1981), 142 samples, 16.9% pos, trace to 3.2 ppb, Community Water Supply Survey (CWSS, 1978), 452 samples, 4.9% pos, 0.5-30 ppb, Ground Water Supply Survey (GWS, 1982, finished drinking water), 466 samples selected at random from 1000 in survey, 7.3% pos, 0.5 ppb median, 23 ppb max(3). [(1) Piet GJ, Morra CF; pp. 31-42 in Artificial Groundwater recharge; Huismon L, Olsthorn TN eds; Pitman Pub (1983) (2) Barkley J et al; Biomed Mass Spectrum 7: 139-47 (1980) (3) Cotruvo JA et al; pp. 511-30 in: Organic Carcinogens in Drinking Water (1986)].

GROUNDWATER: 27 USA cities, 0.6 ppb median (range 0.1-2 ppb)(1) San Fernando Valley, CA (1981-1983) - 17 of 106 wells exceeded 4 ppb, max 130 ppb(2). 10 British groundwaters: Equal or <2 ppb in 8 waters and higher levels at 2 sites where the aquifer was grossly polluted(3). Groundwater underlying 2 rapid infiltration sites 0.07 and 0.63 ppb(4). Japan, national groundwater survey, 1982, 1,083 shallow wells (most for domestic uses other than drinking water in private homes), 27% pos, 0.2-23,000 ppb, 277 deep wells (public, industrial, and commercial supplies), 30% pos, 0.2-150 ppb(5). [(1) Coniglio WA et al; Occurrence of Volatile Organics in Drinking Water. p. 7 Unpublished EPA report (1980) (2) Chemical Engineering 90: 35 (1983) (3) Fielding M et al; Environ Technol Lett 2: 545-50 (1981) (4) Hutchins SR et al; Environ Toxicol Chem 2: 195-216 (1983) (5) Magara Y, Furuichi T; pp. 231-43 in: New Concepts and Development in Toxicol. Chambers PL et al eds. Elsevier Sci Publ (1986)].

SURFACE WATER: 154 USA cities - 2.0 ppb median, 13.6% positive(1). Ohio R (1980-81, 11 stations, 4972 samples) - 49% positive, 340 basins in USA (204 sites)-77 sites above 1 ppb, 1 site above 11 ppb(2). Lake Ontario (95 stations) 9 parts per trillion mean standard deviation 65 parts per trillion(3). Rhine R, km 865 (1976-1982) 0.12-0.62 ppb with lower concentrations after 1978(4). Surface of Lake Zurich - 25-140 parts per trillion, greater concentrations below the surface(5,6). STORET Database, 9,323 data points, 38.0% pos, 0.100 ppb median(7). [(1) Coniglio WA et al; Occurrence of Volatile Organics in Drinking Water. p. 7 Unpublished EPA report (1980) (2) Ewing BB et al; Monitoring to Detect Previously Unrecognized Pollutants in Surface Water. EPA-560/6-77-015 & EPA-560/6-77-015A (1977) (3) Kaiser KLE et al; J Great Lakes Res 9: 212-23 (1983) (4) Malle KG; Z Wasser Abwasser Forsch 17: 75-81 (1984) (5) Grob K, Grob G; J Chrom 90: 303-13 (1974) (6) Schwarzenbach RP et al; Environ Sci Technol 13: 1367-73 (1979) (7) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)].

SEAWATER: 0.1 to 0.8 parts per trillion(1,2). May be several orders of magnitude higher (10 ppb) near source, but concentration diminishes rapidly away from source(3). Gulf of Mexico (open and coastal) 0-40 parts per trillion where there is anthropogenic influence and <1 parts per trillion in unpolluted areas(4). Surface seawater Eastern Pacific Ocean 1981 (0-10 m depth), 30 samples, 90% pos, range of pos, 0.1-2.8 parts per trillion, avg of all data, 0.7 parts per trillion(5). [(1) Murray AJ, Riley JP; Nature 242: 37-8 (1973) (2) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (3) Helz GR, Hsu RY; Limnol Oceanogr 23: 858-69 (1978) (4) Sauer TC Jr; Org Geochem 3: 91-101 (1981) (5) Singh HB et al; J Geophys Res 88: 3675-83 (1983)].

RAIN/SNOW: West Los Angeles (3/26/82) - 21 parts per trillion(2). Industrial city in England - 150 parts per trillion(1). La Jolla, California - 5.7 parts per trillion(3). Central and Southern California - 1.4 and 2.3 parts per trillion resp(3). [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (2) Kawamura K, Kaplan IR; Environ Sci Technol 17: 497-501 (1983) (3) Su C, Goldberg ED; Mar Poll Transfer 1976: 353-74 (1976)].

Effluents Concentrations [609]:

Industrial 1-20 ppb; Municipal treatment plants 1-10 ppb(1); Baltimore Municipal Treatment Plant 8-129 ppb (higher levels in winter)(2). Industries in which mean or maximum levels in raw wastewater exceeded 1 ppm are (number of samples, percent pos, mean, max, ppm): raw wastewater: auto and other laundries (28 samples, 71.4% pos, <8.4 ppm mean, 93 ppm max), aluminum forming (4, 100%, <2.6, <4.0), metal finishing (96, 42.7%, 4.5, 110), organic chemical/plastics manufacturing (number of samples not reported, 19 pos, 5.1 mean, max concn not reported), and paint and ink formulation (36, 55.6%, 0.95, 4.9); treated wastewater: auto and other laundries (5 samples, 80% pos, 0.58 ppm mean, 1.0 ppm max), aluminum forming (16, 87.5%, <0.24, 3.0), metal finishing (not reported), organic chemical/plastics manufacturing (number of samples not reported, 14 pos, 0.047 mean, max concn not reported), and paint and ink formulation (24, 33.3%, 0.19, 0.70)(3). Industrial effluent, STORET Database, 1,390 data points, 10.1% pos, 5.0 ppb median(4). [(1) STORET Data Base (2) Helz GR, Hsu RY; Limnol Oceanogr 23: 858-69 (1978) (3) US EPA; Treatability Manual. p.I.12.26-1 to I.12.26-5 USEPA-600/2-82-001A (1981) (4) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)].

W.Concern Levels, Water Quality Criteria, LC50 Values, Water Quality Standards, Screening Levels, Dose/Response Data, and Other Water Benchmarks:

W.General (General Water Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Water Concentrations Versus Mixed or General Aquatic Biota):

Water Quality Criteria in ug/L [446]:

Freshwater Acute Criteria: Insufficient data to develop criteria. Lowest Observed Effect Level: 5,280

Freshwater Chronic Criteria: Insufficient data to develop criteria. Lowest Observed Effect Level: 840

Marine Acute Criteria: Insufficient data to develop criteria. Lowest Observed Effect Level: 10,200

Marine Chronic Criteria: Insufficient data to develop criteria. Lowest Observed Effect Level: 450

The Netherlands' Harmonized (between media) Maximum Permissible Concentration (MPC) for this compound in water is 330 ug/L [655].

Note: Harmonization takes into account whether or not the MPC in one media (such as soil) would lead to exceeding the MPC in another media (such as air, water, or sediment) [655].

The Netherlands' Harmonized (between media) Negligible Concentration (NC) for this compound in water is 1% of the MPC, or 3.3 ug/L [655].

Canadian 1991 interim remediation criteria for water for protection of aquatic life: 260 ug/L [656].

W.Plants (Water Concentrations vs. Plants):

A study was designed to determine the effects of tetrachloroethylene on the phyto- and zooplankton community at initial concentrations of 1.2 and 0.44 mg/l in separated compartments of an experimental pond. Measurements in the surrounding water were made simultaneously to detect possible effects of compartmentalization. Residues as low as 0.1 mg/l could be analyzed 5 days (low dose) and 38 days (high dose) post-application. In all applied biotopes, a lethal effect on the Daphnia population was detected. The phytoplankton community showed an increase of relative abundance and a decrease in species diversity. Studies of the frequency distribution of 6 selected phytoplankton species. (Spirogyra species, Microcystis flos-aquae, Stichococcus bacillaris, Nitzschia acicularis, Chilomonas parameium, Actinophrys species) demonstrated the total elimination of at least 4 species from the treated compartments. In spite of different dosing, only weak differences were found in toxic effects between the low and high dosed compartments. No significant chemically induced effect was observed on the physicochemical properties of the treated water (Lay JP et al; Arch Environ Contam Toxicol 13, 2: 135-42, 1984) [609].

W.Invertebrates (Water Concentrations vs. Invertebrates):

Adverse effects to Daphnia magna occured at concentrations as low as 0.44 mg/l [935]. More details [609]:

> A study was designed to determine the effects of tetrachloroethylene on the phyto- and zooplankton community at initial concentrations of 1.2 and 0.44 mg/l in separated compartments of an experimental pond. Measurements in the surrounding water were made simultaneously to detect possible effects of compartmentalization. Residues as low as 0.1 mg/l could be analyzed 5 days (low dose) and 38 days (high dose) post-application. In all applied biotopes, a lethal effect on the Daphnia population was detected. The phytoplankton community showed an increase of relative abundance and a decrease in species diversity. Studies of the frequency distribution of 6 selected phytoplankton

species. (Spirogyra species, Microcystis flos-aquae, Stichococcus bacillaris, Nitzschia acicularis, Chilomonas parameium, Actinophrys species) demonstrated the total elimination of at least 4 species from the treated compartments. In spite of different dosing, only weak differences were found in toxic effects between the low and high dosed compartments. No significant chemically induced effect was observed on the physicochemical properties of the treated water. [Lay JP et al; Arch Environ Contam Toxicol 13 (2): 135-42 (1984)].

LC50s for Tanytarsus dissimilis (midge) were 54.5 mg/L for a 24-hr exposure, and 30.8 mg/L for a 48-hr exposure [998].

Information from HSDB [609]:

LC50 Daphnia magna (water flea) 18 mg/l/48 hr, static bioassay, at 22 deg C [Le Blanc GA; Bull Environ Contam Toxicol 24: 684-91 (1980) as cited in WHO; Environ Health Criteria: Tetrachloroethylene p.15 (1984)].

LC50 Tanytarsus dissimilis (midge) 30, 840 ug/l/48 hr, static bioassay [USEPA; Task 11, Contract No 68-01-3887 (1980) as cited in USEPA; Ambient Water Quality Criteria Doc: Tetrachloroethylene p.B-1 (1980) EPA 440/5-80-073].

W.Fish (Water Concentrations vs. Fish):

Long term adverse effects to brook trout growth occured at concentrations as low as 1.52 mg/l [935].

LC50s for Cyprinodon variegatus (Sheepshead minnow) were between 29 and 52 mg/L for 4-day exposures. Death was not observed at concentrations below 29 mg/L for a 96-hr exposure [998].

LC50s for Jordanella floridae (flagfish) were 11.5 mg/L for a 24-hr exposure, 10.9 mg/L for a 48-hr exposure, 8.9 for a 72-hr exposure, and 4.0 and 8.4 mg/L for two 96-hr exposures. The lowest-observed-effect-concentrations (LOEC) for death were 3.1 and 3.7 mg/L for a 10-day and a 28-day exposure, respectively [998].

LC50s for Oncorhynchus mykiss (rainbow trout, donaldson trout) were 4.99 and 6.31 mg/L for a 24-hr exposure, 4.99 and 5.95 mg/L for a 48-hr exposure, 4.99 and 5.81 mg/L for a 72-hr exposure, 5.84 mg/L for a 96-hr exposure, and 1.40 mg/L for a 32-day exposure [998].

LC50s for Pimephales promelas (fathead minnow) for a 24-hr exposure period were 17.9 and 23.5 mg/L, and 18.9 and 14.9 mg/L for a 72-hr exposure [998].

Information from HSDB [609]:

> LC50 Poecilia reticulata (guppy) 18 ppm/7 days /Conditions of bioassay not specified/ [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1080].
>
> LC50 Pimephales promelas (fathead minnow) 18.4 mg/l/96 hr (flow-through bioassay) [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1080].
>
> LC50 Pimephales promelas (fathead minnow) 21.4 mg/l/96 hr (static bioassay) [Verschueren, K. Handbook of Environmental Data of Organic Chemicals. 2nd ed. New York, NY: Van Nostrand Reinhold Co., 1983. 1080].
>
> LC50 Lepomis macrochirus (bluegill sunfish) 46 mg/l/24 hr at 21-23 deg c (95% confidence limit 11-15 mg/l) /conditions of bioassay not specified/ [BUCCAFUSCO RJ ET AL; BULL ENVIRONM CONTAM TOXICOL 26: 446 (1981)].
>
> LC50 Lepomis macrochirus (bluegill sunfish) 13 mg/l/96 hr at 21-23 deg c (95% confidence limit 11-15 mg/l) /conditions of bioassay not specified/ [BUCCAFUSCO RJ ET AL; BULL ENVIRONM CONTAM TOXICOL 26: 446 (1981)].
>
> LC50 Salmo gairdneri (rainbow trout) 5 mg/l/96 hr, static bioassay at 12 deg C [Shubat PJ et al; Bull Environ Contam Toxicol 28: 7-10 (1982) as cited in WHO; Environ Health Criteria: Tetrachloroethylene p.24 (1984)].
>
> LC50 Lepomis macrochirus (bluegill sunfish) 12,900 ug/l/96 hr, static bioassay [USEPA; Contract No 68-01-4646 (1978) as cited in USEPA; Ambient Water Quality Criteria Doc: Tetrachloroethylene p.B-2 (1980) EPA 440/5-80-073].

LC50 Limanda limanda (dab) 5 mg/l/96 hr, flow-through bioassay [Pearson CR, McConnell G; Proc R Soc Land B 189: 305-32 (1975) as cited in WHO; Environ Health Criteria: Tetrachloroethylene p.24 (1984)].

W.Wildlife (Water Concentrations vs. Wildlife or Domestic Animals):

Oak Ridge National Lab, 1994: Risk Assessment Screening Benchmarks for Wildlife derived from No-Observed-Adverse-Effect (NOAEL) levels (see Tis.Wildlife, B) section below for these). To be considered unlikely to represent an ecological risk, water concentrations should be below the following benchmarks for each species present at the site [650]:

For CAS 127-18-4 (1,1,2,2-Tetrachloroethylene, the benchmarks are [650]:

SPECIES	WATER CONCENTRATION (ppm)
Mouse (test species)	0.00000
Short-tailed Shrew	7.99900
Little Brown Bat	13.82600
White-footed Mouse	5.17000
Meadow Vole	9.04800
Cottontail Rabbit	4.28700
Mink	4.44600
Red Fox	3.17300
Whitetail Deer	1.77500

W.Human (Drinking Water and Other Human Concern Levels):

EPA 1995 Region 9 Preliminary remediation goals (PRG) for tap water, 1995 [868]: 1.1 ug/L [868].

Drinking Water MCL, EPA 1996: 5.0 ug/L [952].

Water Quality Criteria in ug/L:

Human Health (10-6 Risk Level for Carcinogens):

Published Criteria for Water and Organisms: 0.8 ug/L [446,689].

Published Criteria for Organisms Only: 8.85 ug/L [446,689].

IRIS Recalculated Criteria for Water and

Organisms: 0.8 ug/L [689].

IRIS Recalculated (1993) Criteria for Organisms Only: 8.9 ug/L [689].

Criteria Federal Register Notice Number: 45 FR 79340 [893].

Note: Before citing a concentration as EPA's water quality criteria, it is prudent to make sure you have the latest one. Work on the replacement for the Gold Book [302] was underway in March of 1996, and IRIS is updated monthly [893].

EPA 1996 IRIS database information [893]:

Note: In mid 1996, IRIS was silent on most of the criteria listed above, perhaps because the carcinogenicity classification was in the process of being re-assessed [893]. The following information was in IRIS [893]:

Crit. Dose: 14 mg/kg-day [Study 1 NOAEL(adj)] UF: 1000 MF: 1 [893].

RfD: 1E-2 mg/kg-day Confidence: Medium [893, 689].

DRINKING WATER HEALTH ADVISORIES:

Substance Name: Tetrachloroethylene CASRN: 127-18-4

The Office of Water provides Drinking Water Health Advisories (HAs) as technical guidance for the protection of public health. HAs are not enforceable Federal standards. HAs are concentrations of a substance in drinking water estimated to have negligible deleterious effects in humans, when ingested, for a specified period of time. Exposure to the substance from other media is considered only in the derivation of the lifetime HA. Given the absence of chemical-specific data, the assumed fraction of total intake from drinking water is 20%. The lifetime HA is calculated from the Drinking Water Equivalent Level (DWEL) which, in turn, is based on the Oral Chronic Reference Dose. Lifetime HAs are not derived for compounds which are potentially carcinogenic for humans because of the difference in assumptions concerning toxic threshold for carcinogenic and noncarcinogenic effects. A more detailed description of the assumptions and methods used in the derivation of HAs is provided in the Health Advisory Background Document [893].

ONE-DAY HEALTH ADVISORY FOR A CHILD:

Note: The available studies were not considered sufficient for calculation of a One-day HA. It is recommended that the value for the Ten-day HA, 2 mg/L, be use for the One-day HA [893].

TEN-DAY HEALTH ADVISORY FOR A CHILD:

HA: 2E+0 mg/liter NOAEL: 20 mg/kg-day UF: 100 allows for interspecies and intrahuman variability with the use of a NOAEL from an animal study [893].

Assumptions: 1 L/day water consumption for a 10-kg child [893].

Principal Study: Buben and O'Flaherty, 1985 [893].

Discussion: Male Swiss-Cox mice were administered tetrachloroethylene by gavage at doses of 0, 20, 100, 200, 500, 1000, 1500, and 2000 mg/kg, 5 days/week for 6 weeks. Liver toxicity was evaluated by several parameters including liver weight-to-body weight ratio, hepatic triglyceride concentrations, DNA content, histopathological evaluation and serum enzyme levels. Increased liver triglycerides were first observed in mice treated with 100 mg/kg. Liver weight/body weight ratios were significantly higher than controls for the 100 mg/kg group, and slightly higher than controls in the 20 mg/kg group. A NOAEL of 20 mg/kg/day was identified based on the absence of hepatotoxic effects. After 5 days of exposure, a NOAEL of 20 mg/kg/day was identified [893].

LONGER-TERM HEALTH ADVISORY FOR A CHILD:

HA: 1.4E+0 mg/liter NOAEL: 14 mg/kg-day UF: 100 allows for interspecies and intrahuman variability with the use of a NOAEL from an animal study [893].

Assumptions: 1 L/day water consumption for a 10-kg child

Principal Study: Buben and O'Flaherty, 1985

Discussion: See ten-day HA [893].

LONGER-TERM HEALTH ADVISORY FOR AN ADULT:

HA: 5.0E+0 mg/liter NOAEL: 14 mg/kg-day UF: 100 allows for interspecies and intrahuman variability with the use of a NOAEL from an animal study; dose adjusted for dosing schedule of 5 days/week [893].

Assumptions: 2 L/day water consumption for a 70-kg adult [893].

Principal Study: Buben and O'Flaherty, 1985 [893].

Discussion: See ten-day HA [893].

DRINKING WATER EQUIVALENT LEVEL / LIFETIME HEALTH ADVISORY:

DWEL: 5E-1 mg/liter Basis: Oral RfD verified on: 05/20/85 Lifetime HA: 1E-2 mg/liter 20% Exposure by Drinking Water Assumptions: 2 L/day water consumption for a 70-kg adult [893].

Principal Study: Buben and O'Flaherty, 1985 [893].

Discussion: See oral RfD. A safety factor of 10 was used in the derivation of this HA, in addition to the UF of 1000 for the RfD, to account for the possible carcinogenicity of this substance. The classification of this substance is currently under review. A final decision on whether this substance should be classified B2 or C has not yet been made. If this substance is classified as C, the lifetime HA calculated here is recommended. If the classification is B2, no lifetime HA is recommended [893].

State Standard for Human Consumption: State Water Quality Standards: Many States have water qualtity drinking water standards from 0.002 ug/L to 0.7 ug/L in 1995 [934].

Suggested No-Adverse-Response Level (SNARL): In light of the lack of definitive information regarding the quantity of TCE that must be ingested to depress psychophysiological function, it seems appropriate that calculations for a SNARL be based upon quantities of the chemical that are required to produce tissue injury. The 0.3 ml/kg (0.49 g/kg) dose appears to be a reasonable "minimum toxic dose" from which to calculate a 24-hr SNARL for contamination of drinking water, assuming that the sole source of TCE during this period will be from 2 l/day of drinking water consumed by a 70 kg human. A safety factor of 100 is applied: 490 mg/kg times 70 kg/100 times 2 l = 172 mg/l. The above considerations ignore the possibility that TCE may be carcinogenic. ... a 7-day standard for drinking water contamination, which was obtained by dividing the 24-hr standard by 7 (172 mg/l/7 days= 24.5 mg/l), should protect against adverse effects by the chemical (National Research Council. Drinking Water and Health. Volume 3. Washington, DC: National Academy Press, 1980. 140) [609].

W.Misc. (Other Non-concentration Water Information):

No information found.

Sediment Data Interpretation, Concentrations and Toxicity (All Sediment Data Subsections Start with "Sed."):

Sed.Low (Sediment Concentrations Considered Low):

No information found.

Sed.High (Sediment Concentrations Considered High):

Analyses of sewage sludges from 50 publicly owned treatment works by the U.S. Environmental Protection Agency (1985): The mean concentration of tetrachloroethylene was 3.47 ppm (dry weight) [347].

Sed.Typical (Sediment Concentrations Considered Typical):

Most sediments from nonpolluted areas are less than 5 ppb [934].

SEDIMENT: Liverpool Bay/172 stations - 4.8 parts per trillion avg(1). STORET Database, 359 data points, 7% pos, <0.050 ppb median(2). [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (2) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)] [609].

Sed.Concern Levels, Sediment Quality Criteria, LC50 Values, Sediment Quality Standards, Screening Levels, Dose/Response Data and Other Sediment Benchmarks:

Sed.General (General Sediment Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Sediment Concentrations Versus Mixed or General Aquatic Biota):

The Netherlands' Harmonized (between media) Maximum Permissible Concentration (MPC) for this compound in sediments is 4 mg/kg [655].

Note: Harmonization takes into account whether or not the MPC in one media (such as soil) would lead to exceeding the MPC in another media (such as air, water, or sediment) [655].

The Netherlands' Harmonized (between media) Negligible Concentration (NC) for this compound in sediments is 1% of the MPC, or 0.04 mg/kg [655].

Sed.Plants (Sediment Concentrations vs. Plants):

No information found.

Sed.Invertebrates (Sediment Concentrations vs. Invertebrates):

No information found.

Sed.Fish (Sediment Concentrations vs. Fish):

No information found.

Sed.Wildlife (Sediment Concentrations vs. Wildlife or Domestic Animals):

No information found.

Sed.Human (Sediment Concentrations vs. Human):

No information found.

Sed.Misc. (Other Non-concentration Sediment Information):

No information found.

Soil Data Interpretation, Concentrations and Toxicity (All Soil Data Subsections Start with "Soil."):

Soil.Low (Soil Concentrations Considered Low):

No information found.

Soil.High (Soil Concentrations Considered High):

Analyses of sewage sludges from 50 publicly owned treatment works by the U.S. Environmental Protection Agency (1985): The mean concentration of tetrachloroethylene was 3.47 ppm (dry weight) [347].

Soil.Typical (Soil Concentrations Considered Typical):

No information found.

Soil.Concern Levels, Soil Quality Criteria, LC50 Values, Soil Quality Standards, Screening Levels, Dose/Response Data and Other Soil Benchmarks:

Soil.General (General Soil Quality Standards, Criteria, and Benchmarks Related to Protection of Soil-dwelling Biota in General; Includes Soil Concentrations Versus Mixed or General Soil-dwelling Biota):

The Netherlands' Harmonized (between media) Maximum Permissible Concentration (MPC) for this compound in soil is 0.16 mg/kg [655].

Note: Harmonization takes into account whether or not the MPC in one media (such as soil) would lead to exceeding the MPC in another media (such as air, water, or sediment) [655].

The Netherlands' Harmonized (between media) Negligible Concentration (NC) for this compound in soil is 1% of the MPC, or 0.0016 mg/kg [655].

Soil.Plants (Soil Concentrations vs. Plants):

No information found.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

No information found.

Soil.Wildlife (Soil Concentrations vs. Wildlife or Domestic Animals):

No information found.

Soil.Human (Soil Concentrations vs. Human):

EPA 1996 National Generic Soil Screening Level (SSL) designed to be conservative and protective at the majority of sites in the U.S. but not necessarily protective of all known human exposure pathways, land uses, or ecological threats [952]:

SSL = 12 mg/kg for ingestion pathway [952].

SSL = 11 mg/kg for inhalation pathway [952].

SSL = 0.003 to 0.06 mg/kg for protection from migration to groundwater at 1 to 20 Dilution-Attenuation Factor (DAF) [952].

EPA 1995 Region 9 Preliminary remediation goals (PRGs), 1995 [868]:

Residential Soil: 7 mg/kg wet wt.
Industrial Soil: 25 mg/kg wet wt.

NOTE:
1) PRGs focus on the human exposure pathways of ingestion, inhalation of particulates and volatiles, and dermal absorption. Values do not consider impact to groundwater or ecological receptors.
2) Values are based on a non-carcinogenic hazard quotient of one.
3) PRGs for residential and industrial landuses are slightly lower concentrations than EPA Region III RBCs, which consider fewer aspects [903].

EPA 1995 Region 3 Risk based concentration (RBC) to protect from transfers to groundwater:

0.04 mg/Kg dry weight [903].

Soil.Misc. (Other Non-concentration Soil Information):

No information found.

Tissue and Food Concentrations (All Tissue Data Interpretation Subsections Start with "Tis."):

Tis.Plants:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Plants:

No information found.

B) Body Burden Residues in Plants: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

Concentration 13-23 ppb in marine algae (Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-22, 1975) [609].

Tis.Invertebrates:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Invertebrates:

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Invertebrates:

No information found.

C) Body Burden Residues in Invertebrates: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

No information found.

Tis.Fish:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Fish (Includes FDA Action Levels for Fish and Similar Benchmark Levels From Other Countries):

Risk Based Concentration (RBC) for fish tissue consumed by humans, EPA 1995 Region III: 0.061 mg/kg based on cancer risk [903].

B) Concentrations or Doses of Concern in Food Items Eaten by Fish:

No information found.

C) Body Burden Residues in Fish: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

Fish/Seafood Concentrations [609]:

0.3-43 ppb in marine fish, 0.5-176 ppb in marine invertebrates in England(1), 250 ppb in American eel (Delaware River), 1050 ppb in American eel (Newark Bay), 77 ppb in carp (Delaware River), 108 ppb in striped bass (Raritan River), 88 ppb in spot fish (Houston Ship Channel)(2). Rhine River from Strassburg to Lake Constance - a small number of fish 25-100 ppb, a few exceded 100 ppb(3). [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (2) Dickson AG, Riley JP; Mar Pollut Bull 7: 167-9 (1976) (3) Binnemann PH et al; A Lebensm - Unters Forsch 176: 253-61 (1983)].

Tis.Wildlife: Terrestrial and Aquatic Wildlife, Domestic Animals and all Birds Whether Aquatic or not:

A) As Food: Concentrations or Doses of Concern to Living

Things Which Eat Wildlife, Domestic Animals, or Birds:

No information found.

B) Concentrations or Doses of Concern in Food Items Eaten by Wildlife, Birds, or Domestic Animals (Includes LD50 Values Which do not Fit Well into Other Categories, Includes Oral Doses Administered in Laboratory Experiments):

Oak Ridge National Lab, 1994: Risk Assessment Screening Benchmarks for Wildlife derived from No-Observed-Adverse-Effect (NOAEL) levels (mg contaminant per kg body weight per day). To be considered unlikely to represent an ecological risk, wet-weight field concentrations should be below the following (right column) benchmarks for each species present at the site [650]:

For CAS 127-18-4 (1,1,2,2-Tetrachloroethylene, the benchmarks are [650]:

SPECIES	NOAEL (mg/kg/day)	FOOD CONCENTRATION (ppm)
Mouse (test species)	1.40000	0.00000
Short-tailed Shrew	1.76000	2.93300
Little Brown Bat	2.21200	6.63600
White-footed Mouse	1.55100	10.03500
Meadow Vole	1.23400	10.85700
Cottontail Rabbit	0.41400	2.09800
Mink	0.44000	3.21300
Red Fox	0.26800	2.67900
Whitetail Deer	0.11600	3.77500

Comment: Actually, the number of significant figures for a benchmark value should never be more than one; even if these values have been taken directly from another report, they should be rounded; otherwise the impression is given of a level of accuracy that is simply unwarranted. The uncertainties are too large to justify such a fine distinction (Owen Hoffman, SENES Oak Ridge, Personal Communication, 1997).

Only a nearly lethal /oral/ dose (4 g/kg body wt) caused swelling of the convoluted /kidney/ tubules and hydropic degeneration in male mice ... Ip doses of 1.6-2.3 G/kg body wt caused slight calcification of the tubules of the kidney in dogs (IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health

Organization, International Agency for Research on Cancer,1972-PRESENT. (Multivolume work).,p. V20 502, 1979) [609].

C) Body Burden Residues in Wildlife, Birds, or Domestic Animals: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

Animal Concentrations [609]:

A concentration of 0.6-19 ppb in grey seal blubber (NE Coast of England); 1.4-39 ppb in marine and freshwater birds, coast of England (Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32, 1975).

Tis.Human:

A) Typical Concentrations in Human Food Survey Items:

See also Tis.Fish, C) above.

Average daily water INTAKE (assume 0.3-3 ppb(6)) 0.6-6 ug; average daily FOOD INTAKE - insufficient data(SRC) (Coniglio WA et al; Occurrence of Volatile Organics in Drinking Water. p. 7 Unpublished EPA report, 1980) [609].

Food Survey Results [609]:

Chinese style sauce, 2 ppb; Quince jelly, 2.2 ppb; Crab apple jelly, 2.5 ppb; Grape jelly, 1.6 ppb; Chocolate sauce, 3.6 ppb. Not detected in seven market basket composites of meats (detection limit = 4.6 ppb), oils and fats (detection limit = 13 ppb), beverages (detection limit = 0.5 ppb) or dairy products (detection limit = 2.3 ppb)(1). Various categories of food in England - 0.01-13 ppb, highest values in fats and oils(2). USA, wheat, 10 samples, 20% pos, 1.8-2.1 ppb, corn, 2 samples, 100% pos, 0.45-0.54 ppb; not detected in one sample each of oats and corn grits, 2 samples of corn meal(3). [(1) Entz RC, Hollifield HC; J Agric Food Chem 30: 84-8 (1982) (2) McConnell G et al; Endeavour 34: 13-18 (1975) (3) Heikes DL, Hopper ML; J Assoc Off Anal Chem 69: 990-8 (1986)].

Tetrachloroethylene concentrations in foods ranged from non-detectable amounts (<0.01 ug/kg) in orange juice to 13 ug/kg in English butter. [McConnell G et al; Endeavour 34: 13 as cited in USEPA; Ambient Water Quality Criteria Doc: Tetrachloroethylene p.C-1 (1980) EPA 440/5-80-073].

B) Concentrations or Doses of Concern in Food Items Eaten by Humans (Includes Allowable Tolerances in Human Food, FDA, State and Standards of Other Countries):

Risk Based Concentration (RBC) for fish tissue consumed by humans, EPA 1995 Region III: 0.061 mg/kg based on cancer risk [903].

Crit. Dose: 14 mg/kg-day [Study 1 NOAEL(adj)] UF: 1000 MF: 1 [893].

RfD: 1E-2 mg/kg-day Confidence: Medium [893,952].

Residual organ damage is not commonly observed in humans who have been exposed to large quantities of the compound. Tetrachloroethylene was formerly used widely as an intestinal anthelminthic. Oral doses of 2.8 to 4.0 ml given for this purpose were quite effective & safe. Inebriation was the only troublesome side effect that was noted in 46,000 treated patients. Inhalation of tetrachloroethylene sufficient to produce inebriation & unconsciousness has failed to elicit hepatic, renal, or hematological abnormalities in some individuals. However, in other cases, mild to severe hepatotoxicity has been diagnosed. In most such instances, liver injury was not manifest until several days after exposure. Recovery was uneventful, but sometimes prolonged, particularly in the more severe cases. Tetrachloroethylene was quite slowly eliminated, in that approx 1 ppm tetrachloroethylene was measured in the breath of victims as long as 11 to 12 days after exposure. Little evidence of kidney injury or damage of any other organ was noted in any of the aforementioned cases (National Research Council. Drinking Water and Health. Volume 3. Washington, DC: National Academy Press, 1980. 136) [609].

C) Body Burden Residues in Humans: Typical, Elevated, or of Concern Related to the Well-being of Humans:

Information from HSDB [609]:

Has been detected in 7 of 8 samples in mother's milk from 4 urban areas in the US(1). One hour after a visit to a dry cleaning plant, one sample of mother's milk contained 10 ppm tetrachloroethylene. This decreased to 3 ppm after 24 hr(2). Old Love Canal, NY - 9 individuals: Human breath 600-4500 ng/cu m; Blood 0.35-260 ng/ml; Urine 120-690 ng/ml(3). Human body fat (8 subjects) 0.4-29.2 ppb; Various human organs less than 6 ng/g(4). Alveolar air geometric mean in 136 residents living near 12 dry-cleaning stores were: Living equal to or <5 floors above the stores 5 mg/cu m, adjacent houses 1 mg/cu m, one house away 0.2 mg/cu m, across street <.1 mg/cu m, whereas the mean concentration in 18 workers was 73 mg/cu m(5). [(1) Pellizzari ED et al; Bull Environ Contam Toxicol 28: 322-8 (1982) (2) Jensen AA; Res Rev 89: 1-128 (1983) (3) Barkley J et al; Biomed Mass Spectrom 7: 139-47 (1980) (4) McConnell G et al; Endeavour 34: 13-8 (1975) (5) Verberk MM, Scheffers TML; Environ Res 21: 432-7 (1980)].

Whole blood, USA survey of 250 (121 males, 129 females), 0.7-23 ppb, 2.4 ppb avg(1). Breath samples (ug/cu m, weighted statistics), Elizabeth and Bayonne, NJ, 1981, 295-339 samples, 93% pos, 280 max, 13.0 avg, 6.8 median(2). Alveolar air in children and teachers in school situated near factory were 24 ug/cu m avg for children and 11 and 47 ug/cu m for the teachers(3). The mean concentration of tetrachloroethylene in the classroom was 13 ug/cu m(3). Alveolar air of residents of a nursing home situated near a former chemical waste dump averaged 7.8 ug/cu m first floor and 1.8 ug/cu m on the second floor, where ambient concentrations averaged 8.2 and 1.6 ug/cu m, respectively(3). USA FY82 National Human Adipose Tissue Survey specimens, 46 composites, 61% pos (>3 ppb, wet tissue concn), 94 ppb max(4). [(1) Antoine SR et al; Bull Environ Contam Toxicol 36: 364-71 (1986) (2) Wallace L et al; J Occup Med 28: 603-7 (1986) (3) Monster AC, Smolders JFJ; Int Arch Environ Health 53: 331-6 (1984) (4) Stanley JS; Broad Scan Analysis of the FY82 National Human Adipose Tissue Survey Specimens Vol. I Executive Summary p. 5 USEPA-560/5-86-035 (1986)].

Tis.Misc. (Other Tissue Information):

No information found.

Bio.Detail: Detailed Information on Bioconcentration, Biomagnification, or Bioavailability:

BCF: 30.6 [689]. Low to moderate potential for bioconcentration [935].

Bioconcentration [609]:

BCF: fathead minnow (Pimephales promelas), 38.9(1); bluegill sunfish (lepomis macrochirus) 49(2). Based on a reported log Kow of 3.40(4), a BCF of 226 was estimated(3,SRC). Based on the reported and estimated

BCF's, tetrachloroethylene will not be expected to significantly bioconcentrate in aquatic organisms(SRC). [(1) Neely WB et al; Environ Sci Technol 8: 1113-15 (1974) (2) Barrows ME et al; Dyn., Exposure Hazard Assess. Toxic Chem. Ann Arbor MI: Ann Arbor Sci. p. 379-92 (1980) (3) Lyman WJ et al; Handbook of Chem Property Estimation Methods NY: McGraw-Hill p. 5-5 (1982) (4) Hansch C, Leo AJ; Medchem Project Issue No. 26 Claremont, CA: Pomona College (1985)].

Other Information from HSDB [609]:

The elimination of tetrachloroethylene in expired air ranged from 50 to 150 ppm (339 to 1,017 mg/cu m) for up to 8 hr. Biological half-life for fat stores was 71.5 hr. [Gruberan E, Fernandez J; Brit J Ind Med 31: 159 (1974)].

The biological half-life of tetrachloroethylene metabolites (as measured as total trichloro-compounds) is 144 hours. [Ikeda M and Imamura T; Int Arch Arbeitsmed 31: 209 (1973) as cited in USEPA; Ambient Water Quality Criteria Doc: Tetrachloroethylene p.C-4 (1980) EPA 440/5-80-073].

Elimination is slow (biological half-life of 65 hours for exhaled perchloroethylene) because of continuing release of perchloroethylene from fat stores. [Ellenhorn, M.J. and D.G. Barceloux. Medical Toxicology - Diagnosis and Treatment of Human Poisoning. New York, NY: Elsevier Science Publishing Co., Inc. 1988. 986].

Interactions:

No information found.

Uses/Sources:

Major Uses [609]:

Used in the textile industry for dry-cleaning & for processing & finishing; used in both cold cleaning & vapor degreasing of metals; it is used as a chem intermediate in the synthesis of fluorocarbon 113, 114, 115, & 116; it is used as a heat-exchange fluid [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer,1972-PRESENT. (Multivolume work).,p. V20 494 (197)].

Scouring, sizing & desizing agent in textile manufacture [SRI].

Component of aerosol laundry-treatment products [SRI].

Solvent, eg, for silicones [SRI].

Insulating fluid & cooling gas in electric transformers [SRI].

In typewriter correction fluids (eg, Liquid Paper, Wite-Out, Snopake, etc) [Greer JE; South Med J 77 (3): 297-8 (1984)].

MEDICATION VET: use in small animals as a ruminant anthelmintic (vermifuge) has been largely replaced by drugs that are less toxic & easier to admin [Booth, N.H., L.E. McDonald (eds.). Veterinary Pharmacology and Therapeutics. 5th ed. Ames, Iowa: Iowa State University Press, 1982. 839].

Formerly used, but no longer approved, in mixtures with grain protectants and certain liquid grain fumigants [Farm Chemicals Handbook 87. Willoughby, Ohio: Meister Publishing Co., 1987.,p. C-248].

Natural Occurring Sources [609]:

Tetrachloroethylene is not known to occur in nature. (SRC)

Artificial Sources [609]:

Water pollution by tetrachloroethylene leaching from vinyl liners in asbestos-cement water pipelines for water distribution. [Yuskus LR; J Am Water Works Assoc 76 (2): 76-81 (1984)].

Vaporization losses from dry cleaning and industrial metal cleaning(1). Wastewater, particularly from metal finishing, laundries, aluminum forming, organic chemical/plastics manufacturing and municipal treatment plants. It is also estimated that emissions account for approximately 90% of the tetrachloroethylene produced in the United States(2). [(1) Chemical Marketing Reporter. Chemical Profile March 14, 1983 (1983) (2) Singh HB et al; Atmospheric Distributions, Sources and Sinks of Selected Halocarbons, Hydrocarbons, SF6 and N2O; p.34 EPA-600/3-79-107 (1979)].

During chlorination water treatment, it can be formed in small quantities. [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 769].

Forms/Preparations/Formulations:

Information from HSDB [609]:

Available in the United States in veterinary preparations (eg, Nema Worm Capsules (Parke-Davis)). These capsules contain pure tetrachloroethylene. Avail sizes are 0.2, 0.5, 1.0, 2.5 & 5 ml. [American Medical Association, Department of Drugs. Drug

Evaluations. 6th ed. Chicago, Ill: American Medical Association, 1986. 1612].

Tetrachloroethylene is avail in the USA in the following grades: purified, technical, USP, spectrophotometric, & dry-cleaning. The technical & dry-cleaning grades both meet specifications for technical grade & differ only in the amount of stabilizer added to prevent decomposition. Stabilizers incl amines or mixtures of epoxides & esters. Typical analysis of the commercial grade is nonvolatile residue, 0.0003%; free chlorine, none; moisture, no cloud at -5 deg C ... USP grade contains not less than 99.0% & no more than 99.5% tetrachloroethylene, the remainder consisting of ethanol [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer,1972-PRESENT. (Multivolume work).,p. V20 492 (1979)].

Food Grade [Kuney, J.H. and J.N. Nullican (eds.) Chemcyclopedia. Washington, DC: American Chemical Society, 1988. 116].

Tetrachloroethylene (BP) may contain thymol 0.01% wt/wt as a preservative. [Reynolds, J.E.F., Prasad, A.B. (eds.) Martindale-The Extra Pharmacopoeia. 28th ed. London: The Pharmaceutical Press, 1982. 106].

Tetrachloroethylene Capsules (USP, BP, 1973) [Reynolds, J.E.F., Prasad, A.B. (eds.) Martindale-The Extra Pharmacopoeia. 28th ed. London: The Pharmaceutical Press, 1982. 107].

Tetrachloroethylene Draught (BNF, 1966): tetrachloroethylene 2.5 ml, acacia 2 g, peppermint emulsion 0.3 ml, chloroform water to 50 ml. [Reynolds, J.E.F., Prasad, A.B. (eds.) Martindale-The Extra Pharmacopoeia. 28th ed. London: The Pharmaceutical Press, 1982. 107].

Perklone (ICI Mond, UK): a brand of tetrachloroethylene for dry-cleaning purposes. [Reynolds, J.E.F., Prasad, A.B. (eds.) Martindale-The Extra Pharmacopoeia. 28th ed. London: The Pharmaceutical Press, 1982. 107].

Chem.Detail: Detailed Information on Chemical/Physical Properties:

Solubilities [609]:

Miscible with alcohol, ether, chloroform, benzene [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1315].

Miscible with solvent hexane; dissolves in most of the fixed and volatile oils [Osol, A. (ed.). Remington's Pharmaceutical

Sciences. 16th ed. Easton, Pennsylvania: Mack Publishing Co., 1980. 1184].

0.015 G/100 ML WATER AT 25 DEG C [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer,1972-PRESENT. (Multivolume work).,p. V20 492 (1979)].

Vapor Pressure [609]:

18.47 mm Hg at 25 deg C [Riddick JA et al; Organic Solvents: Physical Properties and Methods of Purification. Techniques of Chemistry. 4th ed. Wiley-Interscience pp. 1325 (1986)].

Molecular Weight [609]:

165.83 [Weast, R.C. (ed.) Handbook of Chemistry and Physics, 68th ed. Boca Raton, Florida: CRC Press Inc., 1987-1988.,p. C-272].

Density/Specific Gravity [609]:

1.6227 AT 20 DEG C/4 DEG C [Weast, R.C. (ed.) Handbook of Chemistry and Physics, 68th ed. Boca Raton, Florida: CRC Press Inc., 1987-1988.,p. C-272].

Octanol/Water Partition Coefficient [609]:

log Kow= 3.40 [Hansch C, Leo AJ; Medchem Project Issue No. 26 Claremont, CA: Pomona College (1985)].

Boiling Point [609]:

121 DEG C AT 760 MM HG [Weast, R.C. (ed.) Handbook of Chemistry and Physics, 68th ed. Boca Raton, Florida: CRC Press Inc., 1987-1988.,p. C-272].

Melting Point [609]:

-19 DEG C [Weast, R.C. (ed.) Handbook of Chemistry and Physics, 68th ed. Boca Raton, Florida: CRC Press Inc., 1987-1988.,p. C-272].

Color/Form [609]:

Colorless liquid [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1315].

Odor [609]:

Ethereal-like odor [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1315].

Mildly sweet, chloroform-like odor [U.S. Coast Guard, Department of Transportation. CHRIS - Hazardous Chemical Data. Volume II. Washington, D.C.: U.S. Government Printing Office, 1984-5.].

Chlorinated solvent odor [Ruth JH; Am Ind Hyg Assoc J 47: A-142-51 (1986)].

Fate.Detail: Detailed Information on Fate, Transport, Persistence, and/or Pathways:

One potentially important aspect of the presence of perchloroethylene (tetrachloroethylene) is that it can breakdown into vinyl chloride. According to EPA's health advisories (available through the Office of Drinking Water, EPA, Washington, D.C. or through NTIS) on vinyl chloride and dichloroethylene, vinyl chloride is a degradation product of trichloroethylene and tetrachloroethylene in groundwater, with dichloroethylene being an intermediate breakdown product. The common progression is tetrachloroethylene to trichloroethylene to dichloroethylene to vinyl chloride (Mario Fernandez, Jr., USGS, personal communication,1994).

Although some vinyl chloride can result from the breakdown of the above-listed solvents, not 100% of the breakdown route is to vinyl chloride (some other breakdown pathways exist and different resultant breakdown products are sometimes produced, Karl Ford, BLM, personal communication, 1994).

Information from HSDB [609]:

TERRESTRIAL FATE: If tetrachloroethylene (PCE) is released to soil, it will evaporate fairly rapidly into the atmosphere due to its high vapor pressure and low adsorption to soil. It can leach rapidly through sandy soil and therefore may reach groundwater(1-3). Biodegradation may be an important process in anaerobic soils based on laboratory tests with methanogenic columns. Slow biodegradation may occur in groundwater where acclimated populations of microorganisms exist. There is some evidence of slow degradation in subsurface soils from a groundwater recharge project. PCE should not hydrolyze under normal environmental conditions. (SRC) [(1) Wilson JT et al; J Environ Qual 10: 501-6 (1981) (2) Tomson MB et al; Water Res 15: 1109-16 (1981) (3) Schwarzenbach RP et al; Environ Sci Technol 17: 472-9 (1983)].

AQUATIC FATE: If tetrachloroethylene (PCE) is released in water, the primary loss will be by evaporation. The half-life for evaporation from water will depend on wind and mixing conditions and is estimated to range from 3 hours to 14 days in rivers, lakes and ponds. Chemical and biological degradation are expected to be very slow. PCE will not be expected to significantly bioconcentrate in aquatic organisms or to adsorb to sediment. A mesocosm experiment was conducted to simulate Narraganset Bay during different seasons. Volatilization was the major removal process during all seasons and seasonal differences can be explained by hydrodynamics and the measured half-lives were 25 days in spring, 11 days in winter and 14 days in summer(4). In one experiment in which half-lives were calculated from concentration reduction between sampling points on the Rhine River and a lake in the Rhine basin, half-lives were 10 days and 32 days, respectively(1). In a seawater aquarium, an 8 day half-life was demonstrated to be predominately the result of evaporation(2). In a natural pond, PCE disappeared in 5 and 36 days at low (25 ppm) and high (250 ppm) dose levels, respectively(3). [(1) Zoeteman BCJ et al; Chemosphere 9: 231-49 (1980) (2) Jensen S, Rosenberg R; Water Res 9: 659-61 (1975) (3) Lay JP et al; Arch Environ Contam Toxicol 13: 135-42 (1984) (4) Wakeham SG et al; Environ Sci Technol 17: 611-7 (1983)].

ATMOSPHERIC FATE: If tetrachloroethylene (PCE) is released to the atmosphere, it will be expected to exist in the vapor phase(5) based on a reported vapor pressure of 18.47 mm Hg at 25 deg C(4). Vapor phase PCE will be expected to degrade by reaction with photochemically produced hydroxyl radicals or chlorine atoms produced by photooxidation of PCE. Estimated photooxidation time scales range from an approximate half-life of 2 months(1,2) to complete degradation in an hour(3). Some of the PCE in the atmosphere may be subject to washout in rain based on the solubility of PCE in water (150 ppm(4)); PCE has been detected in rain. [(1) Singh HB et al; Atmos Environ 15: 601-12 (1981) (2) Howard CJ; J Chem Phys 65: 4771-7 (1976) (3) Dimitriades B et al; J Air Pollut Control Assoc 33: 575-87 (1983) (4) Riddick JA et al.; Organic Solvents: Physical Properties and Methods of Purification. Techniques of Chemistry. 4th ed. Wiley-Interscience pp. 1325 (1986) (5) Eisenreich SJ et al; Environ Sci Technol 15: 30-8 (1981)].

Biodegradation [609]:

Tetrachloroethylene (PCE) can be transformed by reductive dehalogenation to trichloroethylene (TCE), dichloroethylene and vinyl chloride (VC) under anaerobic conditions. In addition, (14)C-PCE was at least partially mineralized to carbon dioxide. Mineralization of 24% of the PCE occurred in a continuous flow mixed film methanogenic column with a liquid detection time of 4 days. TCE was the major intermediate formed, but traces of dichloroethylene isomers and VC were also found. In other column studies under a different set of methanogenic conditions, nearly quantitative conversion of PCE to VC was found. TCE and VC are major intermediates in PCE biotransformation under anaerobic conditions and the potential exists for the complete mineralization of PCE to CO2 in soil and aquifer systems and in biological treatment processes. [Vogel TM, McCarty PL; Appl Environ Microbiol 49 (5): 1080-3 (1985)].

No degradation occurred in 21 days in 3 biodegradability tests with acclimated or unacclimated inocula or in a river die-away test(4). Microbial degradation did not contribute to the removal of tetrachloroethylene (PCE) in a mesocosm experiment which simulated Narraganset Bay, RI(5). Under aerobic conditions there is no degradation in 25 weeks in a batch experiment with a sewage inoculum(1) or when low concentrations of PCE (16 ug/l) were circulated through an acclimated aerobic biofilm column over a period of 1 year(2). While only 3.75% of the PCE treated by conventional, extended and 2-stage activated-sludge pilot plants appeared in the effluent, most of the PCE was discharged to the air from the extended aeration(3). [(1) Bouwer EJ et al; Environ Sci Technol 15: 596-9 (1981) (2) Bouwer EJ, McCarty PL; Environ Sci Technol 16: 836-43 (1982) (3) Watanabe H; Gesuido Kyokaiski 20: 29-37 (1983) (4) Mudder TI; Amer Chem Soc Div Env Chem Conf p. 52-3 (1982) (5) Wakeham SG; Environ Sci Technol 17: 611-7 (1983)].

There is evidence that slow biodegradation of tetrachloroethylene (PCE) occurs under anaerobic conditions when the microorganisms have been acclimated, yielding trichloroethylene (TCE) as a product(1,2). An experiment in a continuous-flow laboratory methanogenic column using well acclimated mixed culture and a 2-day detention time had an average PCE removal rate of 76%(3). In a continuous-flow mixed-film methanogenic column with a liquid detention time of 4 days, mineralization of 24% of the PCE present occurred; TCE was the major intermediate formed(72%), but traces of dichloroethylene isomers and VC were also found(4). In other column studies under a different set of methanogenic conditions, nearly quantitative conversion of PCE to VC was found in 10 days(4). Removal of 86% PCE occurred in a methanogenic biofilm column (8 weeks of activation followed by 9-12 weeks of acclimation(5)). [(1) Bouwer EJ, McCarty PL; Appl Environ Micribiol 45: 1286-94 (1983) (2) Wilson JT et al; Devel Indust Microbiol 24: 225-33 (1983) (3) Bouwer EJ, McCarty PL; Ground Water 22: 433-40 (1984) (4) Vogel TM, McCarty PL; Appl Environ Microbiol 49: 1080-3 (1985) (5) Bouwer EJ, Wright JP; Am Chem Soc Div Environ Chem. 191st Natl Meet 26: 42-5 (1986)].

A large reduction of tetrachloroethylene which had been recirculated through a soil column for 14 days was attributed to adsorption and volatilization(2). In a microcosm containing muck from an aquifer recharge basin, 72.8% loss was observed in 21 days against 12-17% in controls, and the metabolites trichloroethylene, cis- and trans-1,2-dichloroethylene, dichloromethane, and chloroethene were identified(3). However, when subsurface samples were aseptically removed from above and below the water table and incubated in the laboratory, no degradation occurred in 16 weeks(4). In one field groundwater recharge project, degradation was observed in the 50 day recharge period(1). [(1) Bouwer EJ et al; Environ Sci Technol

15: 596-99 (1981) (2) Bouwer EJ et al; Water Res 15: 151-59 (1981) (3) Parsons F et al; J Amer Wat Works Assoc 76: 56-9 (1984) (4) Wilson JT et al; Ground Water 21: 134-42 (1983)].

Abiotic Degradation [609]:

Tetrachloroethylene can be transfromed by reductive dehalogenation to trichloroethylene under anaerobic conditions. [Vogel TM, McCarty PL; Appl Environ Microbiol 49 (5): 1080-3 (1985)].

Tetrachloroethylene (PCE) reacts with hydroxyl radicals which are produced by sunlight in the troposphere with an estimated half-life of about 2 months or a loss of 1.5% per sunlit day(1,2). Photooxidation in pure air with simulated tropospheric light is much faster than that predicted from the reaction with hydroxyl radicals with complete degradation occurring in 7 days in 1 report(3) and from 0.5% to 100% loss per hour in another(4). The rate of loss is very sensitive to radiation in the 280-330 nm region and increases with increasing PCE concentration, the presence of nitrogen oxides has little effect on the rate of loss(4), and the main reaction product is phosgene (70-85%) with smaller amounts of carbon tetrachloride (8%), dichloroacetyl chloride, and trichloroacetyl chloride(3). The proposed mechanism involved the molecular reaction with chlorine radicals produced by photooxidation of PCE(4). [(1) Singh HB et al; Atmos Environ 15: 601-12 (1981) (2) Howard CJ; J Chem Phys 65: 4771-7 (1976) (3) Singh HB et al; Environ Lett 10: 253-6 (1975) (4) Dimitriades B et al; J Air Pollut Control Assoc 33: 575-87 (1983)].

Photodegradation in the stratosphere is rapid(1). Some photodegradation occurs when tetrachloroethylene (PCE) in air-saturated water is exposed to sunlight. In one year, 75% degradation occurred whereas 59-65% degradation was noted for dark controls(2). When PCE adsorbed to silica gel is irradiated through a pyrex filter, 50-90% is lost in 6 days(3). It is not clear whether PCE adsorbed on particulate matter will photograde as readily(SRC). Hydrolysis is not a significant degradative process (half-life 9 months at 25 deg C in purified, de-ionized water)(2). [(1) Mueller JPH Korte F; Chemosphere 3: 195-8 (1977) (2) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (3) Gaeb S et al; Nature 270: 331-3 (1977)].

Soil Adsorption/Mobility [609]:

Tetrachloroethylene was slightly adsorbed on sand and clay minerals. The Henry's adsorption coefficients were approx in proportion to the organic content of the soil samples. [Urano K, Murata C; Chemosphere 14 (3-4): 292-9 (1985)].

Koc: 209(1); 210(2). In a laboratory system simulating a rapid-infiltration site, tetrachloroethylene (PCE) appeared in the effluent but at significantly reduced concentration levels(3,7) although in a bank-infiltration system in Switzerland and The Netherlands, PCE was rapidly transported to groundwater(4,5). It is estimated that in a bay such as Narraganset Bay, RI, only about 0.01% of PCE is adsorbed to particulate matter(6). [(1) Schwarzenbach RP, Westall J; Environ Sci Technol 15: 1360-67 (1981) (2) Chiou CT et al; Science 206: 831-2 (1979) (3) Hutchins SR, Ward CH; J Hydrol (Amsterdam) 67: 223-33 (1984) (4) Gegir W et al; Ges, Wasser, Abwasser 63: 517-31 (1983) (5) Piet GJ et al; Studies Env Sci 17: 557-64 (1981) (6) Wakeham SG et al; Environ Sci Technol 17: 611-7 (1983) (7) Hutchins SR et al; Environ Toxicol Chem 2: 195-216 (1983)].

A Koc of 238 was calculated(2,SRC) based on a reported Kom of 137.7 in a peaty soil(1). Based on a reported log Kow of 3.40(3), a Koc of 1,685 was estimated(2,SRC). Based on the reported and estimated Koc's, tetrachloroethylene will be expected to exhibit low to medium mobility in soil(4) and therefore may leach slowly to the groundwater(SRC). [(1) Friesel P et al; Fresenius Z Anal Chem 319: 160-4 (1984) (2) Lyman WJ et al; Handbook of Chem Property Estimation Methods NY: McGraw-Hill p. 4-2 to 4-9 (1982) (3) Hansch C, Leo AJ; Medchem Project Issue No.26 Claremont, CA: Pomona College (1985) (4) Swann RL et al; Res Rev 85: 17-28 (1983)].

Volatilization from Water/Soil [609]:

Tetrachloroethylene will evaporate rapidly from water based on estimates of half-life for the evaporation from water which range from fractions of an hour to several hours in laboratory experiments(1-4). Two values of the ratio of the volatilization rate constant relative to the rearation rate of oxygen are 0.52(4) and 0.61(5). Using representative oxygen reaeration rates for various bodies of water, the half-lives for evaporation are as follows: pond 5-12 days; river 3 hr-7 days; lake 3.6-14 days(4,SRC). Measured volatilization half-lives in a mesocosm simulating Narraganset Bay, RI were 11 days in winter, 25 days in spring, and 14 days in summer(6). [(1) Dilling WL; Environ Sci Technol 11: 405-9 (1977) (2) Chiou CT et al; Environ Inter 3: 231-6 (1980) (3) Smith JH et al; Environ Sci Technol 14: 1332-7 (1980) (4) Lyman WL et al; Handbook of Chemical Property Estimation Methods NY: McGraw-Hill p. 15-35 (1981) (5) Roberts PV, Dandliker PG; Environ Sci Technol 17: 484-9 (1983) (6) Wakeham SG; Environ Sci Technol 17: 611-7 (1983)].

Due to its high vapor pressure (18.47 mm Hg at 25 deg C(1)) and low adsorption to soil, volatilization of tetrachloroethylene from dry soil should be rapid(SRC). [(1) Riddick JA et al; Organic Solvents: Physical Properties and Methods of Purification. 4th. Wiley-Interscience pp. 1325 (1986)].

Absorption, Distribution and Excretion [609]:

1. Readily absorbed through the lung and to a much smaller degree through skin or mucous membranes or following ingestion. [Arena, J.M. and Drew, R.H. (eds.) Poisoning-Toxicology, Symptoms, Treatments. 5th ed. Springfield, IL: Charles C. Thomas Publisher, 1986. 257].

2. Metabolism Is relatively slow with only few percent of dose being excreted as metabolites, major one being trichloroacetic acid [Doull, J., C.D. Klaassen, and M. D. Amdur (eds.). Casarett and Doull's Toxicology. 2nd ed. New York: Macmillan Publishing Co., 1980. 476].

3. (36)CL-Tetrachloroethylene fed to rats is excreted largely unchanged in expired air (98% of dose in 2 days), and is metabolized, to only slight extent, into trichloroacetic acid (2%) which is excreted in urine. [Parke, D. V. The Biochemistry of Foreign Compounds. Oxford: Pergamon Press, 1968. 213].

4. Concn curves of perchloroethylene in blood and exhaled air after exposure showed that it was eliminated from the body at three different rates with corresponding half-life. [Monster AC, Houtkooper JM; Int Arch Occup Env Health 42: 319 (1979)].

5. Personal monitoring of exposure to tetrachloroethylene and analyses of urine for total trichloro-compounds were carried out in two groups of workers ... one group (20 males and 19 females) in dry-cleaning workshops and the other (16 males and 6 females) engaged in the removal of glue from silk cloth. Comparison of the urinary trichloro-compounds levels with tetrachloroethylene in the environment revealed that, while the metabolite levels increased essentially linear to tetrachloroethylene concn up to 100 ppm, leveling off was apparent in the metabolite excretion when the exposure to tetrachloroethylene was more intense (eg more than 100 ppm), indicating that the capacity of humans to metabolize tetrachloroethylene is rather limited. A tentative calculation ... indicated that, at the end of an 8 hr shift with exposure to tetrachloroethylene at 50 ppm (TWA), 38% of the tetrachloroethylene absorbed through the lung would be exhaled unchanged and less than 2% would be metabolized to be excreted into the urine, while the rest would remain in the body to be eliminated later. [Ohtsuki T et al; Int Arch Occup Environ Health 51: 381-90 (1983)].

6. Tetrachloroethylene was still detectable in the breath of rats 16 hr after a single exposure to levels of 339-3390 mg/cu m for 1-40 hr. [WHO; Environ Health Criteria: Tetrachloroethylene p.21 (1984)].

7. Male Sprague-Dawley rats exposed to (14)C-tetrachloroethylene by either gavage (1.0 mg/kg) or inhalation

(10 ppm, 10.4 mg/kg) excreted 70% of the dose unchanged in expired air. Approximately 3% was excreted as carbon dioxide, and approximately 23% was excreted in the urine and feces as nonvolatile metabolites. [NTP; Toxicology and Carcinogenesis Studies of Tetrachloroethylene p.19 Report #311 (1986) NIH Pub# 86-2567].

8. Once in the bloodstream, tetrachloroethylene tends to distribute to body fat. In human tissue at autopsy, ratios of fat to liver concentrations are greater than 6:1 [McConnell G et al; Endeavor 34: 13-8 (1975) as cited in USEPA; Health Advisories for 25 Organics: Tetrachloroethylene p.307 (1987) PB 87-235578].

9. An autopsy after a fatal tetrachloroethylene exposure revealed an 8 times greater concn in brain compared with blood [Ellenhorn, M.J. and D.G. Barceloux. Medical Toxicology - Diagnosis and Treatment of Human Poisoning. New York, NY: Elsevier Science Publishing Co., Inc. 1988. 986].

10. Tetrachloroethylene (PCE) is eliminated primarily via the lung. The respiratory half-life for PCE elimination has been estimated at 65 to 70 hours. [Stewart RD et al; Arch Environ Health 20: 224-9 (1970) as cited in USEPA; Health Advisories for 25 Organics: Tetrachloroethylene p.307 (1987) PB 87-235578].

11. Tetrachloroethylene reached near steady-state levels in blood of human volunteers with two hours of continuous exposure. [Stewart RD et al; Arch Environ Health 2: 516 (1961) as cited in USEPA; Ambient Water Quality Criteria Doc: Tetrachloroethylene p.C-3 (1980) EPA 440/5-80-073].

12. Absorption of tetrachloroethylene (PCE) through the skin by immersing the thumbs of volunteers in PCE for 40 minutes and measuring the PCE in the exhaled air. High concentrations of PCE in exhaled breath (160 to 260 ug/cu m) were measurable five hours after exposure. [Stewart RD and Dodd HC; Am Ind Hug Assoc Jour 25: 439 (1964) as cited in [USEPA; Ambient Water Quality Criteria Doc: Tetrachloroethylene p.C-4 (1980) EPA 440/5-80-073].

13. Tetrachloroethylene excretion in breast milk has been associated with obstructive jaundice in newborn infants. [Ellenhorn, M.J. and D.G. Barceloux. Medical Toxicology - Diagnosis and Treatment of Human Poisoning. New York, NY: Elsevier Science Publishing Co., Inc. 1988. 986].

14. Nine unrelated groups (659 males) working in plastic boat, chemical, plastic button, paint, and shoe factories were studied. Urine samples were collected at the beginning of the workshift and at the end of the first half of the shift. A close relationship (correlation coefficient always above 0.85) between the average environmental solvent concentration (mg/cu

m) measured in the breathing zone and the urinary concentration of unchanged solvent (ug/L) was observed. The authors recommended a biological equivalent exposure limit of 101 ug/L. biological exposure data for urine collected over 4 hr during random sampling for at least 1 yr could be used to evaluate long-term exposure and probability of non-compliance for individual or groups of workers. [Ghittori S et al; Am Ind Hyg Assoc J 48 (9): 786-90 (1987)].

Laboratory and/or Field Analyses:

In the past, many methods have been used to analyze for this compound [861,1010,1011,1013]. EPA methods for NPDES permits are specified in 40 CFR Part 136 [1010]. EPA methods for drinking water are specified in 40 CFR Part 141 [1011].

EPA (RCRA Group) publishes requirements for solid waste methods in 40 CFR Part 261, Appendix III, with details in the following periodically updated publication [1013]:

> Environmental Protection Agency. 1997. Test methods for evaluating solid waste, physical/chemical methods, SW-846, EPA Office of Solid Waste and Emergency Response, EPA, Washington, D.C. Update 3 finalized in 1997. Available from NTIS or GPO. Previous 1995 update 2 was available on CD-ROM [1013].

RCRA (SW-846) methods tend to include provisions for using the specified method or something better. RCRA SW-846 methods typically require instrument calibration before analyses, but some labs don't do it, and many labs actually use some kind of hybrid between RCRA, CERCLA, or various other "standard protocols" (Roy Irwin, Park Service, Personal Communication, 1997, based on conversations with various EPA and private lab staff members). The guidance in SW-846 must be used in some states, but is considered "guidance of acceptable but not required methods" in most federal applications.

In the past, EPA has also published separate (not SW-846) guidance documents with suggestions on field sampling and data quality assurance related to sampling of sediments [1016] and soils [1017,1018,1019].

EPA (CERCLA) publishes various Contract Laboratory Program (CLP) methods documents periodically, available from EPA and NTIS. CERCLA CLP methods tend to require things done exactly per contract specifications. A few examples of CLP publications (this list is not complete) [861]:

> User's Guide CLP CERCLA User's Guide to the Contract Laboratory Program. USEPA - Office of Emergency and Remedial Response. Dec 1988
>
> 9240_0-0XFS Multi-Media/Conc Superfund OSWER CERCLA Multi-Media, Multi-Concentration Organic/Inorganic Analytical Service for Superfund, Quick Reference Fact Sheets, 9240.0-08FS (organic) and 9240-0-09FS (inorganic), August 1991. The

organic/inorganic analytical service provides a technical and contractual framework for laboratories to apply EPA/Contract Laboratory Program (CLP) analytical methods for the isolation, detection and quantitative measurement of 33 volatile, 64 semi-volatile, 28 pesticide/Aroclor, and 24 inorganic target analytes in water and soil/ sediment environmental samples.

AOC/Contract Laboratory Program (CLP), Routine Analytical Services, Summary on EPA Home Page under Superfund Subdirectory, EPA Office of Remedial and Emergency Response, 1997, Internet.

When analyzing for this compound, the investigator should also specify the addition of any relevant compounds suspected of being present but not typically found on the standard EPA scans. Since tetrachloroethylene can breakdown into trichloroethylene, dichloroethylene, ethylene, trichloroacetic acid, trichloroethanol, chloride, vinyl chloride (strong carcinogen) and trichloroacetic acid (known herbicide), see Fate.Detail and Associated chemicals sections for details, those compounds should often be analyzed where tetrachloroethylene is present.

Recommended Detection Limits:

For optimum risk or hazard assessment work, lab methods with low detection limits should be used. Ideally, the detection limit should be at least 10 times higher than the comparison benchmark or criteria [676]. This may require the use of Selective Ion Mode (SIM) modifications of standard methods such as EPA 8260. Method 8260 is replacing method 8240 [1013]. Sometimes it is necessary to have a robotic auto sampler replacing manual sample injection, GC/HSD (halide sensitive detectors) or using new electron multipliers.

GC/HSD methods can achieve 0.03 ppb in both liquid and solid media [934]. For NPDES permit applications using EPA method 601 for purgeable halocarbons, EPA also specifies a water detection limit of 0.03 ug/L for this compound (40 CFR, Part 136, Appendix A, Table 1) [1010]. Many States have had water qualtity drinking water standards from 0.002 ug/L to 0.7 ug/L in 1995 [934], so often very low detection limits are necessary.

However, if no one is drinking the water and no other comparison benchmarks in question require detection limits this low, higher limits may be considered. One should keep in mind, however, that the lower the detection limits, the less chance of the results being false negatives. Many water benchmarks are below 1 ppb (see W.Human section above), so detection limits no higher than those required by benchmark comparisons should be used.

USGS can achieve detection limits of 0.05 ug/L for this compound using USGS 1996 Custom Method 9090 (see description, below, Brooke Connor, USGS Water Quality Lab, Denver, Personal Communication, 1996).

States have also gravitated towards lower detection limits: In concert with need to compare values with low benchmark concentrations, the regulatory requirements of states such as Wisconsin, detection limits should be as low as possible and in all cases no higher than 25 ppb in soil [913]. in water. Wisconsin requires a detection limit of 0.5 ug/L for all VOCs [923].

EPA CLP methods for CERCLA were designed for use in contaminated areas and often have detection limits that are not low enough for use in relatively clean areas or where low detection levels are needed in comparison with low concentration criteria or benchmarks. Under EPA's Contract Laboratory Program, all contract laboratories are required to maintain certain levels of performance to meet specific quantitation levels [931]. For volatiles, the EPA Superfund/CERCLA Contract Required Quantitation Level (CRQL) for water is 1 ug/L. For volatiles, the EPA Superfund/CERCLA Contract Required Quantitation Level (CRQL) for soil is 10 ug/kg (AOC/Contract Laboratory Program --CLP, Routine Analytical Services, Summary on EPA Home Page under Superfund Subdirectory, EPA Office of Remedial and Emergency Response, 1997, Internet).

Holding time:

According to EPA, for this purgeable halocarbon, the maximum holding time for NPDES water samples is 14 days; samples should be kept iced or refrigerated, with no headspace or bubbles in the container (40 CFR, Part 136,3, 1994) [1010]. Holding time in soil, sediments, and sludge is also 14 days [1013].

Containers:

Both EPA and APHA (Standards Methods Book) recommend glass containers for the collection of organic compounds [141,1010]. EPA specifies the use of teflon lined caps and teflon lined cap septums in glass vial containers for volatiles (VOCs and purgeable halocarbons such as the common organic solvents) [1010]. No headspace is allowed [1010,1013]. Actually, vials are not the best choice for avoiding false negatives through volatilization losses in soil samples, since the use of brass liners for collection resulted in 19 fold higher VOCs than when 40 mL vials were used [798] (see Wisconsin protocol discussion below).

Guidance from other federal agencies (USGS, FWS, NOAA) also recommends glass containers for organics, and discourages the use of plastic containers for a variety of reasons (Roy Irwin, National Park Service, Personal Communication, 1997, based on a glance through recent internal guidance of several agencies). Some federal agency quality control procedures call for voiding or red-flagging the results of organic analyses if the lab receives the sample in plastic containers (Roy Irwin, National Park Service, Personal Communication, 1997). The APHA pointed out some the potential hazards of the use of certain plastic containers for storing organic samples [141]:

A) Potential contamination of the sample via leaching of compounds from the plastic, and/or

B) The plastic container walls can sometimes be attacked by certain organics and fail, and/or

C) The possibility that some of organic compound will dissolve into the walls of the plastic container, reducing the concentration of the compound in the container [141].

Typical "standard method" protocols recommend proper cleaning of glass containers before use. Some collectors simply use pre-cleaned jars from I-Chem or Eagle Pitcher (no government endorsement implied) or equivalent suppliers. EPA [1010], USGS, and most other federal agencies recommend cleaning procedures for the glass containers, usually involving detergent rinsing, baking, and sometimes HCL rinses (Roy Irwin, National Park Service, Personal Communication, 1997).

Field Collection Protocols:

Standard field collection method protocols are published by the Fish and Wildlife Service, the USGS, DOE, NOAA, and EPA. These recommendations change over time, with the newest recommendations sometimes being quite different than the old, thereby producing different results. The Fish and Wildlife Service methods are similar in many ways to NOAA field protocols [676]. Many recommended EPA field methods for organics are not very detailed, although the 3rd update of SW-846 for RCRA solid waste methods is becoming more detailed [1013].

The various EPA methods for organics are different from each other, with the selection of the appropriate method depending upon the specific application (RCRA vs. CERCLA vs. NPDES permits, vs. Drinking Water, etc.) [861,1010,1013]. The EPA-recommended field methods are scattered through various EPA and ASTM publications.

> For PAHs (lab method 610) and other semi-volatiles, EPA recommends: that "conventional sampling practices" be followed as specified by ASTM D-330-76 [1010,1012]. ASTM also publishes standard method guidance for numerous very specific applications, like sampling from pipes (D 3370-95a) and sampling for VOCs in soils (ASTM method D 4547] [1018].
>
> EPA recommends certain detailed collecting protocols, including the use of grab samples rather than composites, and the proper cleaning for both volatile and semi-volatile organics [1010,1013]. Mixing composite samples of volatile samples (and even samples of the lighter semi-volatiles such as naphthalene) is not advisable since some of the compounds can thereby be lost through volatization to the air during the mixing process (Roy Irwin, National Park Service, Personal Communication, 1997). In a soil sampling guidance publication, EPA recommended caution in the use of composite soil samples whether organic or inorganic, citing statistical complications and stating that the compositing of samples cannot, in general, be justified unless for a stated specific purpose and unless a justification is provided [1017].

For drinking water, in the past, EPA has recommended the following less rigorous methods for analyses of certain volatiles: Purge and trap capillary gas chromatography (EPA 502.2); gas chromatographic/mass spectrometry (EPA 524.2); purge and trap gas chromatography (EPA 503.1); gas chromatography/mass spectrometry (EPA 524.1); PQL= 0.005 mg/L [893].

One method recommended for the analysis of tetrachloroethylene in drinking water is by a purge-and-trap gas chromatographic procedure used for the determination of volatile organohalides in drinking water [893].

Regardless of what lab methods are used, the investigator must take special precautions to prevent the escape of volatiles during sample shipment, storage, extraction, and cleanup [798,1013]. This is especially true for soil and sediment sampling. Nationwide guidance for minimizing loss of volatiles in samples of soil, sediments, and groundwater is found in the third update of EPA SW-846 guidance [1013].

The results of analyses of volatiles can be dramatically effected by small details such as how the samples are collected, stored, held, and analyzed in the lab, since volatile compounds can readily volatilize from samples in both field and lab procedures. The realization that better methods were needed began when the lab results of EPA methods 8020 and 8240 were negative even when contamination by volatiles was obvious in the field, in other words, when investigators began seeing clearly false negative results [798]. In one study, the use of brass liners for collection of soil samples resulted in 19 fold higher VOCs than when 40 mL vials were used [798].

National guidance for minimizing loss of volatiles in field sampling is found in EPA RCRA method 5035 as described in update 3 of SW-846 [1013,1018].

Some states have detailed methods. After researching various papers which documented volatile losses of 9 to 99% during sampling and then finding 100% losses in samples held over 14 days in their own facilities, the Wisconsin DNR requires the following for soil sampling of volatiles [913]:

1) Concentrated (1:1 by weight of preservative vs soil) methanol preservation be used for all samples [913], and

2) samples stored in brass tubes must be preserved in methanol within 2 hours and samples stored in EnCoreTM samplers must be preserved in 48 hours [913].

3) Detection limits should be no higher than 25 ug/Kg (ppb) dry weight for VOCs or petroleum volatiles in soil samples [913].

> Note: The use of methanol for soil sample preservation can make lower detection limits difficult, but the tradeoff can be worth it since otherwise high percentages of volatiles can be lost in very short periods of time, for example in 2 hours for benzene. In other words, low detection limits do not help much if you are losing all the volatiles from the soil sample before analysis. A possible alternative to using methanol for soil samples of volatiles would be to use the EnCoreTM sampler and to analyze as soon as possible (no later than 48 hours) after collection using the methods that give lower detection limits (Donalea Dinsmore, State of Wisconsin DNR, personal communication, 1997).

The USGS NAWQA program also recognized the problem of potential losses of volatile compounds, and recommends the use of strong (1:1) HCL as preservative material.

Variation in concentrations of organic contaminants may sometimes be due to the typically great differences in how individual investigators treat samples in the field and in the lab rather than true differences in environmental concentrations. Contaminants data from different labs, different states, and different agencies, collected by different people, are often not very comparable (see disclaimer section at the top of this entry for more information).

As of 1997, the problem of lack of data comparability (not only for water methods but also for soil, sediment, and tissue methods) between different "standard methods" recommended by different agencies seemed to be getting worse, if anything, rather than better. The trend in quality assurance seemed to be for various agencies, including the EPA and others, to insist on quality assurance plans for each project. In addition to quality control steps (blanks, duplicates, spikes, etc.), these quality assurance plans call for a step of insuring data comparability

[1015,1017]. However, the data comparability step is often not given sufficient consideration. The tendency of agency guidance (such as EPA SW-846 methods and some other new EPA methods for bio-concentratable substances) to allow more and more flexibility to select options at various points along the way, makes it harder in insure data comparability or method validity. Even volunteer monitoring programs are now strongly encouraged to develop and use quality assurance project plans [1015]. The basics of these quality assurance plans for chemical analyses should include the following quality control steps:

> At minimum, before using contaminants data from diverse sources, one should determine that field collection methods, detection limits, and lab quality control techniques were acceptable and comparable. The goal is that the analysis in the concentration range of the comparison benchmark concentration should be very precise and accurate. Typical lab quality control techniques should have included the following considerations (John Moore, Fish and Wildlife Service, Personal Communication, 1997):
>
> Procedural Blanks should be analyzed to assure that no contaminants are added during the processing of the samples. The standards for adequacy depend on the method and the media being measured.
>
> > Different federal agencies publish different acceptable limits. For one program, NOAA stated that at least 8% of samples should be blanks, reference or control materials [676].
> >
> > The basic idea is that neither samples nor blanks should be contaminated. Because the only way to measure the performance of the modified procedures is through the collection and analysis of uncontaminated blank samples in accordance with this guidance and the referenced methods, it is highly recommended that any modifications be thoroughly evaluated and demonstrated to be effective before field samples are collected [1003].
>
> Duplicate samples are analyzed to provide a measure of precision of the methods. The standards for adequacy depend on the method and the media being measured.
>
> > Different federal agencies publish different acceptable limits. There appears to be an inverse relationship between precision and sensitivity [676].
> >
> > Some EPA methods state that a field duplicate must be collected at each sampling site, or one field duplicate per every ten samples, whichever is more frequent [1003]. Some protocols call for the preparation of one Ongoing precision and recovery (OPR) standard for every ten or fewer field samples. Great care should be taken in

> > preparing ongoing precision and recovery standards [1003].
>
> Spiked samples are analyzed to provide a measure of the accuracy of the analysis methods. The standards for adequacy depend on the method and the media being measured.
>
> > Different federal agencies publish different acceptable limits.

It should be kept in mind that quality control field and lab blanks and duplicates will not help in the data quality assurance goal as well as intended if one is using a method prone to false negatives. Methods may be prone to false negatives due to the use of detection limits that are too high, the loss of contaminants through inappropriate handling, or the use of inappropriate methods. The use of inappropriate field collection methods, and the resultant escape of VOCs, is particularly common for solvents.

USGS 1996 Method for VOC analyses (Brooke Connor, USGS Water Quality Lab, Denver, Personal Communication, 1996, also previously distributed on the internet):

> Subject: Custom Method 9090: Basic Description of the Method and more Date: Tue, 14 May 1996 From: "John S Zogorski, Supervisory Hydrologist, Rapid City, SD" Custom Method 9090: Basic Description of the Method, Identification and Quantification Strategy, and Data Transfer...
>
> General Description of the Method: Custom method 9090 uses capillary column gas chromatography / mass spectrometry (GC/MS) to identify and quantitate 87 analytes, and to tentatively identify unknowns. The method is intended to identify and measure low concentrations of VOCs that may occur in the environmental settings sampled in the NAWQA program, and which may be associated with either point and non-point sources, especially in urban areas. Fifty-five of the analytes included on 9090 are referred to as NAWQA VOC target analytes and were selected because of their known human health concern (A or B carcinogens), aquatic toxicity, frequency of occurrence, and/or emerging chemicals with a potential for wide-scale use and significance. Custom method 9090 builds on the same VOC analytical technology, GC/MS, that has been used at the NWQL and elsewhere for many years, and which is considered the conventional approach for high-quality analysis of VOCs in water...Persons unfamiliar with the GC/MS method for VOCs may wish to refer to 2 recent reports: Rose, D.L., and M.P. Schroeder, 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory -- Determination of volatile organic compounds in water by purge and trap capillary gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 94-708, 26 p. Raese, J.W., D.L Rose, and M.W. Sandstrom, 1995, U.S. Geological Survey Laboratory Method for Methyl tert-Butyl Ether and Other Fuel Oxygenates: U.S. Geological Survey Fact Sheet 219-95, 4 p.

Description of EPA standard methods 8240 and 8260 from EPA EMMI Database on Lab methods [861]:

EPA Method 8240 for Volatile Organics [861] (Being replaced by 8260):

OSW 8240A S Volatile Organics - Soil, GCMS 73 SW-846 GCMS ug/kg EQL Method 8240A "Volatile Organics by Gas Chromatography/Mass Spectrometry (GC/MS): Packed Column Technique" The volatile compounds are introduced into the gas chromatograph by the purge and trap method or by direct injection (in limited applications) [861]. The components are separated via the gas chromatograph and detected using a mass spectrometer, which is used to provide both qualitative and quantitative information [861]. The chromatographic conditions, as well as typical mass spectrometer operating parameters, are given [861]. If the above sample introduction techniques are not applicable, a portion of the sample is dispersed in methanol to dissolve the volatile organic constituents [861]. A portion of the methanolic solution is combined with organic-free reagent water in a specially designed purging chamber [861]. It is then analyzed by purge and trap GC/MS following the normal water method [861]. The purge and trap process - An inert gas is bubbled through the solution at ambient temperature, and the volatile components are efficiently transferred from the aqueous phase to the vapor phase [861]. The vapor is swept through a sorbent column where the volatile components are trapped [861]. After purging is complete, the sorbent column is heated and backflushed with inert gas to desorb the components, which are detected with a mass spectrometer [861].

Note: Method 8260 is replacing 8240 in the third update of SW-846 [1013].

OSW 8240A W Volatile Organics - Water, GCMS 73 SW-846 GCMS ug/L EQL Method 8240A "Volatile Organics by Gas Chromatography/Mass Spectrometry (GC/MS): Packed Column Technique" The volatile compounds are introduced into the gas chromatograph by the purge and trap method or by direct injection (in limited applications) [861]. The components are separated via the gas chromatograph and detected using a mass spectrometer, which is used to provide both qualitative and quantitative information [861]. The chromatographic conditions, as well as typical mass spectrometer operating parameters, are given [861]. If the above sample introduction techniques are not applicable, a portion of the sample is dispersed in methanol to dissolve the volatile organic constituents [861]. A portion of the methanolic solution is combined with organic-free reagent water in a specially designed purging chamber [861]. It is then analyzed by purge and trap GC/MS following the normal water method [861]. The purge and trap process - An inert gas is bubbled through the solution at ambient temperature, and the volatile components are efficiently transferred from the aqueous phase to the vapor phase [861]. The vapor is swept through a sorbent column where the volatile components are trapped [861]. After purging is complete, the sorbent column is heated and backflushed with inert gas to desorb the components, which are detected with a mass spectrometer [861].

EPA Method 8260 (for GC/MS Volatile Organics):

Note: Method 8260 is replacing 8240 in the third update of SW-846 [1013].
EPA description [861]:

OSW 8260 Volatile Organics - CGCMS 58 SW-846 CGCMS ug/L MDL Method 8260 "Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS): Capillary Column Technique" The volatile compounds are introduced into the gas chromatograph by the purge and trap method or by direct injection (in limited applications) [861]. Purged sample components are trapped in a tube containing suitable sorbent materials [861]. When purging is complete, the sorbent tube is heated and backflushed with helium to desorb trapped sample components [861]. The analytes are desorbed directly to a large bore capillary or cryofocussed on a capillary precolumn before being flash evaporated to a narrow bore capillary for analysis [861]. The column is temperature programmed to separate the analytes which are then detected with a mass spectrometer interfaced to the gas chromatograph [861]. Wide capillary columns require a jet separator, whereas narrow bore capillary columns can be directly interfaced to the ion source [861]. If the above sample introduction techniques are not applicable, a portion of the sample is dispersed in solvent to dissolve the volatile organic constituents [861]. A portion of the solution is combined with organic- free reagent water in the purge chamber [861]. It is then analyzed by purge and trap GC/MS following the normal water method [861]. Qualitative identifications are confirmed by analyzing standards under the same conditions used for samples and comparing resultant mass spectra and GC retention times [861]. Each identified component is quantified by relating the MS response for an appropriate selected ion produced by that compound to the MS response for another ion produced by an internal standard [861].

Description of other misc. (mostly less rigorous) lab methods which have been used in the past in media such as drinking water for volatiles [893] (lab method description from EPA [861]):

EMSLC 502.2 ELCD VOA's - P&T/CGCELCD/CGCPID 44 DRINKING_WATER CGCELD ug/L MDL "Volatile Organic Compounds in Water by Purge and Trap Capillary Column Gas Chromatography with Photoionization and Electrolytic Conductivity Detectors in Series" This method is used for the identification and measurement of purgeable volatile organic compounds in finished drinking water, raw source water, or drinking water in any treatment stage [861]. The method is applicable to a wide range of organic compounds, including the four trihalomethane disinfection by-products, that have sufficiently high volatility and low water solubility to be efficiently removed from water samples with purge and trap procedures [861]. An inert gas is bubbled through a 5 mL water sample [861]. The volatile compounds with low water solubility are purged from the sample and trapped in a tube containing suitable sorbent materials [861]. When purging is complete, the tube is heated and backflushed with helium to desorb trapped sample components onto a capillary gas chromatography (GC) column [861]. The column is temperature programmed to separate the analytes which are then detected with photoionization detector (PID) and halogen specific detectors in series [861]. Analytes are identified by comparing retention times with authentic standards and by comparing relative responses from the two detectors [861]. A GC/MS may be used for further confirmation [861].

EMSLC 502.2 PID VOA's - P&T/CGCELCD/CGCPID 33 DRINKING_WATER CGCPID ug/L MDL "Volatile Organic Compounds in Water by Purge and Trap Capillary Column Gas Chromatography with Photoionization and Electrolytic Conductivity Detectors in Series" This method is used for the identification and measurement of purgeable volatile organic compounds in finished drinking water, raw source water, or drinking water in any treatment stage [861]. The method is applicable to a wide range of organic compounds, including the four trihalomethane disinfection by-products, that have sufficiently high volatility and low water solubility to be efficiently removed from water samples with purge and trap procedures [861]. An inert gas is bubbled through a 5 mL water sample [861]. The volatile compounds with low water solubility are purged from the sample and trapped in a tube containing suitable sorbent materials [861]. When purging is complete, the tube is heated and backflushed with helium to desorb trapped sample components onto a capillary gas chromatography (GC) column [861]. The column is temperature programmed to separate the analytes which are then detected with photoionization detector (PID) and halogen specific detectors in series [861]. Analytes are identified by comparing retention times with authentic standards and by comparing relative responses from the two detectors [861]. A GC/MS may be used for further confirmation [861].

EMSLC 503.1 Volatile Aromatics in Water 28 DRINKING_WATER GCPID ug/L MDL "Volatile Aromatic and Unsaturated Organic Compounds in Water by Purge and Trap Gas Chromatography" This method is applicable for the determination of various volatile aromatic and unsaturated compounds in finished drinking water, raw source water, or drinking water in any treatment stage [861]. Highly volatile organic compounds with low water solubility are extracted (purged) from a 5-ml sample by bubbling an inert gas through the aqueous sample [861]. Purged sample components are trapped in a tube containing a suitable sorbent material [861]. When purging is complete, the sorbent tube is heated and backflushed with an inert gas to desorb trapped sample components onto a gas chromatography (GC) column [861]. The gas chromatograph is temperature programmed to separate the method analytes which are then detected with a photoionization detector [861]. A second chromatographic column is described that can be used to help confirm GC identifications or resolve coeluting compounds [861]. Confirmation may be performed by gas chromatography/mass spectrometry (GC/MS) [861].

APHA 6230 D Volatile Halocarbons - CGCELCD STD_METHODS GCELCD "6230 Volatile Halocarbons" GCPID 6230 D [861]. Purge and Trap Capillary-Column Gas Chromatographic Method: This method is similar to Method 6230 C., except it uses a wide-bore capillary column, and requires a high-temperature photoionization detector in series with either an electrolytic conductivity or microcoulometric detector [861]. This method is equivalent to EPA method 502.2; see EMSLC\502.2 [861]. Detection limit data are not presented in this method, but the method is identical to 502.2; therefore, see EMSLC\502.2 for detection limit data [861]. Method 6230 B., 17th edition, corresponds to Method 514, 16th edition [861]. The other methods listed do not have a cross-reference in the 16th edition [861].

EMSLC 524.1 Purgeable Organics - GCMS 48 DRINKING_WATER GCMS ug/L MDL "Measurement of Purgeable Organic Compounds in Water by Packed Column Gas Chromatography/Mass Spectrometry" This is a general purpose method for the identification and simultaneous measurement of purgeable volatile organic compounds in finished drinking water, raw source water, or drinking water in any treatment stage [861]. Volatile organic compounds and surrogates with low water solubility are extracted (purged) from the sample matrix by bubbling an inert gas through the aqueous sample [861]. Purged sample components are trapped in a tube containing suitable sorbent materials [861]. When purging is complete, the trap is backflushed with helium to desorb the trapped sample components into a packed gas chromatography (GC) column interfaced to a mass spectrometer (MS) [861]. The column is temperature programmed to separate the method analytes which are then detected with the MS [861]. Compounds eluting from the GC column are identified by comparing their measured mass spectra and retention times to reference spectra and retention times in a data base [861]. Reference spectra and retention times for analytes are obtained by the measurement of calibration standards under the same conditions used for samples [861]. The concentration of each identified component is measured by relating the MS response of the quantitation ion produced by that compound to the MS response of the quantitation ion produced by a compound that is used as an internal standard [861]. Surrogate analytes, whose concentrations are known in every sample, are measured with the same internal standard calibration procedure [861].

EMSLC 524.2 Purgeable Organics - CGCMS 60 DRINKING_WATER CGCMS ug/L MDL "Measurement of Purgeable Organic Compounds in Water by Capillary Column Gas Chromatography/Mass Spectrometry" This is a general purpose method for the identification and simultaneous measurement of purgeable volatile organic compounds in finished drinking water, raw source water, or drinking water in any treatment stage [861]. Volatile organic compounds and surrogates with low water solubility are extracted (purged) from the sample matrix by bubbling an inert gas through the aqueous sample [861]. Purged sample components are trapped in a tube containing suitable sorbent materials [861]. When purging is complete, the sorbent tube is heated and backflushed with helium to desorb the trapped sample components into a capillary gas chromatography (GC) column interfaced to a mass spectrometer (MS) [861]. The column is temperature programmed to separate the method analytes which are then detected with the MS [861]. Compounds eluting from the GC column are identified by comparing their measured mass spectra and retention times to reference spectra and retention times in a data base [861]. Reference spectra and retention times for analytes are obtained by the measurement of calibration standards under the same conditions used for samples [861]. The concentration of each identified component is measured by relating the MS response of the quantitation ion produced by that compound to the MS response of the quantitation ion produced by a compound that is used as an internal standard [861]. Surrogate analytes, whose concentrations are known in every sample, are measured with the same internal standard calibration procedure [861].