March 31, 1987

TETRACHLOROETHYLENE (PCE)

Health Advisory
Office of Drinking Water
U.S. Environmental Protection Agency

I. INTRODUCTION

The Health Advisory (HA) Program, sponsored by the Office of Drinking Water (ODW), provides information on the health effects, analytical methodology and treatment technology that would be useful in dealing with the contamination of drinking water. Health Advisories describe nonregulatory concentrations of drinking water contaminants at which adverse health effects would not be anticipated to occur over specific exposure durations. Health Advisories contain a margin of safety to protect sensitive members of the population.

Health Advisories serve as informal technical guidance to assist Federal, State and local officials responsible for protecting public health when emergency spills or contamination situations occur. They are not to be construed as legally enforceable Federal standards. The HAs are subject to change as new information becomes available.

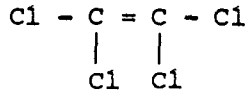
Health Advisories are developed for One-day, Ten-day, Longer-term (approximately 7 years, or 10% of an individual's lifetime) and Lifetime exposures based on data describing noncarcinogenic end points of toxicity. Health Advisories do not quantitatively incorporate any potential carcinogenic risk from such exposure. For those substances that are known or probable human carcinogens, according to the Agency classification scheme (Group A or B), Lifetime HAs are not recommended. The chemical concentration values for Group A or B carcinogens are correlated with carcinogenic risk estimates by employing a cancer potency (unit risk) value together with assumptions for lifetime exposure and the consumption of drinking water. The cancer unit risk is usually derived from the linear multistage model with 95% upper confidence limits. This provides a low-dose estimate of cancer risk to humans that is considered unlikely to pose a carcinogenic risk in excess of the stated values. Excess cancer risk estimates may also be calculated using the One-hit, Weibull, Logit or Probit models. There is no current understanding of the biological mechanisms involved in cancer to suggest that any one of these models is able to predict risk more accurately than another. Because each model is based on differing assumptions, the estimates that are derived can differ by several orders of magnitude.

This Health Advisory (HA) is based on information presented in the Office of Health and Environmental Assessment Criteria Document (CD) for Tetrachloroethylene (U.S. EPA, 1985a). Individuals desiring further information on the toxicological data base or rationale for risk characterization should consult the CD. The CD is available for a fee from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA, 22161. The toll-free number is (800) 336-4700; in the Washington, D.C. area: (703) 487-4650.

II. GENERAL INFORMATION AND PROPERTIES

CAS No. 127-18-4

Structural Formula



Synonyms

PCE, Perchloroethylene, 1,1,2,2-Tetrachloroethylene, Perc

Uses

Solvent for many organic substances
In drycleaning processes
Metal degreaser
Intermediate in the synthesis of certain fluorocarbons
In the textile industry (Fuller, 1976)

Properties (Verschueren, 1977; Torkelsen and Rowe, 1981; Windholz, 1983)

Chemical Formula	C_2Cl_4
Molecular Weight	165.85
Physical State	liquid
Boiling Point	121.2°C
Melting Point	--
Density	--
Vapor Pressure	19 mm Hg
Specific Gravity	1.623
Water Solubility	150 mg/L (25°C)
Log Octanol/Water Partition Coefficient	2.86
Taste Threshold	--
Odor Threshold (water)	300 ug/L
1 ppm in air	6.78 mg/m^3
Conversion Factor	--

Occurrence

- Tetrachloroethylene (PCE) is a synthetic chemical with no natural sources.
- Production of PCE was 550 million pounds in 1982 (U.S. ITC, 1983).
- The majority of PCE is not consumed during its various uses, but is released directly to the atmosphere. Tetrachloroethylene that does not evaporate during use becomes heavily contaminated with grease and oil and is disposed of in the forms of solid and liquid wastes. During disposal, PCE is dischrarged directly to land and surface water. Because metal and fabric cleaning industries are widely dispersed, PCE releases occur nationwide.
- PCE released to air degrades in a matter of days or weeks. PCE released to water degrades slowly; volatilization appears to be the major transport process for removal of PCE from aquatic systems (U.S. EPA, 1979). It is very mobile in soil and readily migrates to ground water. In ground water, where volatilization does not occur, PCE remains for months or years. Under certain conditions, PCE in ground water has been reported to degrade to trichloroethylene and then to dichloroethylene and vinyl chloride (Parsons et al., 1984; Vogel and McCarty, 1985).
- Tetrachloroethylene is ubiquitous in the air with levels in the ppt to ppb range. It is also a common contaminant in ground and surface waters with higher levels found in ground water. Surveys of drinking water supplies have found that 3% of all public systems derived from well water contain PCE levels of 0.5 ug/L or higher. A small number of systems (0.7%) have levels higher than 5 ug/L. Public systems derived from surface water have also been found to contain tetrachlorethylene but at lower levels.
- The major sources of exposure to tetrachloroethylene are from contaminated water and to a lesser extent air. Tetrachloroethylene has been reported to occur in some foods in the ppm range, but food is considered only a minor source of exposure (U.S. EPA, 1983).

III. PHARMACOKINETICS

Absorption

- Single oral doses of (^{36}Cl)-PCE were absorbed completely when administered to rats at a concentration of 189 mg/kg (Daniel, 1963) as were doses of (^{14}C)-PCE administered to mice at a dose of 500 mg/kg (Schumann et al., 1980).
- Human volunteers at rest absorbed about 25 percent of PCE administered by inhalation exposure at 72 or 144 ppm over a four-hour period. The compound initially was absorbed rapidly, with decreasing uptake as exposure continued. Absorption was determined by measuring PCE and its metabolites (trichloroethanol, trichloroacetic acid) in exhaled air, blood and urine (Monster, 1979; Monster et al., 1979; Monster and Houtkooper, 1979).

Distribution

- Once in the bloodstream, PCE tends to distribute to body fat. In human tissue at autopsy, ratios of fat to liver concentrations are greater than 6:1 (McConnell et al., 1975). The fat to blood ratio is about 90 and the half-life for saturation of the fat to 50% of its equilibrium concentration is about 25 hours (Monster, 1979).

- In rats exposed via inhalation, PCE levels rise more or less continuously with duration of exposure in brain, lungs, and fat, but tend to level off in blood and liver after a 3-hour exposure. Brain cerebrum concentrations of PCE exceed blood levels by about four-fold, and brain cerebellum by about three-fold, independent of the duration of exposure (Savolainen et al., 1977).

Metabolism

- Only small amounts of PCE (less than 4% of the estimated absorbed dose) are metabolized and excreted as trichloroacetic acid in humans (Ogata et al., 1971; Fernandez et al., 1976).

- Oxidative metabolism is proposed to proceed via an epoxide intermediate which can lead to the major metabolite, trichloroacetic acid. (U.S. EPA, 1985a). In humans, PCE is metabolized to trichloroethanol, trichloroacetic acid and unidentified chlorinated products (Ikeda and Ohtsuji, 1972; Ikeda, 1977).

- Workers exposed occupationally reached a plateau rate of urinary metabolite excretion (measured as total trichloro-compounds) when the workplace air concentrations of PCE approached 100 ppm. Metabolite excretion did not increase when air concentrations rose to 400 ppm (Ikeda et al., 1972).

Excretion

- PCE itself is eliminated primarily via the lungs. The respiratory half-life for PCE elimination has been estimated at 65 to 70 hours (Stewart et al., 1970; Ikeda and Imamura, 1973).

- Trichloroacetic acid, as a metabolite of PCE, is eliminated with a half-life of 144 hours via the urine (Ikeda and Imamura, 1973).

IV. HEALTH EFFECTS

Humans

- Liver, kidney, and CNS effects have been observed in humans occupationally exposed to tetrachloroethylene (U.S. EPA, 1985a).

- Hookworm treatment with oral PCE was prevalent in the 1920s and 1930s in India and the Pacific Islands. Thousands of individuals received oral doses of approximately 0.15 mL/kg (Kendrick, 1929) or a total dose of about 4 mL for adults (Fernando et al., 1939). No-effect levels for oral exposure cannot be derived from these clinical reports,

although they suggest that PCE is relatively nontoxic by the oral route at these doses.

- Stewart et al. (1974) exposed 19 volunteers to PCE (20 to 150 ppm) for a 5-week period and noted deleterious effects (decreased odor perception, diminished response on the modified Romberg test) at 100 ppm but not at 20 ppm.

Animals

Short-term Exposure

- In mice, the 24-hour LD_{50}s/LC_{50}s are: 8.8 to 10.8 g/kg by the oral route (Wenzel and Gibson, 1951), 5,200 ppm with 4 hours inhalation exposure (Friberg et al., 1953) and 4.7 g/kg intraperitoneal (Klaassen and Plaa, 1966).

- In rats, the 24-hour LD_{50}s/LC_{50}s are 13 g/kg oral (Smyth et al., 1969) and 4,000 ppm with four hours inhalation exposure (Carpenter et al., 1949).

- Single oral gavage doses of 2,158 mg/kg PCE to rabbits resulted in a 50% increase in serum lipoprotein levels and mild transient elevations of serum enzymes (alkaline phosphatase, SGOT, SGPT) which were indicative of liver damage (Fujii, 1975).

- A dose-response related increase in fatty infiltration of the livers of mice was observed after four hours of exposure to 200 to 3,000 ppm (1400 to 20,000 mg/m^3) via inhalation (Kylin et al., 1963). Decreased hepatic ATP and increased total lipid and triglyceride levels were observed in mice exposed to 800 ppm PCE in air for three hours (Ogata et al., 1968).

- Schumann, et al. (1980) administered tetrachloroethylene in corn oil to rats and mice via gavage for 11 consecutive days at does of 100, 250, 500 and 1000 mg/kg. For mice, histopathological changes (centrilobular swelling) were observed at all dose levels and increased body weight/liver weight ratios were observed at doses of 250 mg/kg/day and higher. Rats were more resistant with toxicity (increased liver weight and serum enzyme levels) apparent only at the highest dose. A LOAEL of 100 mg/kg/day was identified based on histopathological changes in mice.

Longer-term Exposure

- Rats were exposed to 70, 230 or 470 ppm PCE (470, 1600, or 3200 mg/m^3) by inhalation 8 hours/day, 5 days/week for 150 days. No significant changes were observed at 70 ppm; renal and liver congestion and swelling were observed at 230 and 470 ppm (Carpenter, 1937).

- Rats, rabbits and monkeys were exposed via inhalation to PCE at 400 ppm (2700 mg/m^3) 7 hours/day, 5 days/week for up to 179 days (Rowe, et al., 1952). Histopathological examination of the liver, kidney and spleen revealed no significant changes at this exposure level.

- Guinea pigs showed a dose dependent increase in liver weight and fatty infiltration of the liver when exposed to 100, 200 or 400 ppm (680, 1400, or 2700 mg/m^3) for up to 169 exposures over 236 days (Rowe et al., 1952).

- Kylin et al. (1965) observed fatty infiltration in livers of mice exposed to 200 ppm (1400 mg/m^3), 4 hours/day, 5 days/week for 8 months.

- In a study by Buben and O'Flaherty (1985), male Swiss-Cox mice were exposed to tetrachloroethylene in corn oil via 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 /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 th 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.

- Toxic nephropathy was observed in mice exposed to 386 and 1072 mg/kg in corn oil via gavage, 5 days/week, for 78 weeks (NCI, 1977).

Reproductive Effects

- Rabbits showed liver enzyme changes and renal function alterations following 200 to 300 ppm exposures (1400 to 20,000 mg/m^3), 4 hours/day, 5 days/week for 9 weeks (Brancaccio et al., 1971; Mazza, 1972).

- Pregnant rats exposed to 300 ppm PCE (20,000 mg/m^3) for 7 hours/day, on days 6 through 15 of gestation had 4 to 5% reduction in body weight and twice the number of resoprtions per implantation compared with controls (Schwetz et al. (1975).

Developmental Effects

- Schwetz et al. (1975) assayed for reproductive and developmental effects in rats and mice exposed to 300 ppm PCE (20,000 mg/m^3) by inhalation for 7 hours/day on gestational days 6 through 15. Pregnant mice exhibited a significant increase in the mean relative liver weights and their fetuses weighed significantly less than controls. In the mouse pups, significant subcutaneous edema, delayed skull ossification and the presence of split sternebrae were observed.

- Offspring of rats exposed to PCE (900 ppm [6100 mg/m^3], days 7-13 of gestation; 900 ppm, days 14-20 of gestation; 100 ppm [680 mg/m^3], days 14-20 of gestation) were evaluated with respect to brain histopathology and biochemistry and several behavioral parameters. No significant differences were found between controls and the 100 ppm dose group. Differences in neurotransmitter levels and some alterations on behavioral tests were noted in the 900 ppm dose groups.

Mutagenicity

- Several mutagenicity studies have been performed on PCE which employ the Ames Salmonella/microsome test or modifications of this test. Most tests reveal little or no evidence of mutagenic activity by PCE except at concentrations which result in greater than 90% bacterial toxicity (U.S. EPA, 1985a).

Carcinogenicity

- PCE containing stabilizers was concluded by NCI (1977) to be a liver carcinogen in $B6C3F_1$ mice administered 386 to 1,072 mg/kg by gavage for 78 weeks. No conclusion concerning the effects on Osborne-Mendel rats administered 471 to 949 mg/kg by gavage could be made because of high mortality rates (median survival for treated animals was less than 68 weeks compared to greater than 88 weeks for controls).

- In the NTP (1985) inhalation bioassay, rats and mice of both sexes were exposed to 0, 200 and 400 ppm (rats) and 0, 100 and 200 ppm (mice) tetrachloroethylene. Male rats exhibited a significantly increased incidence of mononuclear cell leukemia, and an increased incidence of renal tubular adenomas/carcinomas (combined). PCE induced hepatocellular carcinomas in male and female mice at both doses. Classification of PCE as carcinogenic in the rat is controversial. The Science Advisory Board's Halogenated Organics Subcommittee (U.S. EPA, 1987) has questioned the relevance of mononuclear leukemia to man, a species not susceptible to this type of leukemia, and the validity of combining renal adenomas/carcinomas to achieve statistical significance to the results.

V. QUANTIFICATION OF TOXICOLOGICAL EFFECTS

Health Advisories (HAs) are generally determined for One-day, Ten-day, Longer-term (approximately 7 years) and Lifetime exposures if adequate data are available that identify a sensitive noncarcinogenic end point of toxicity. The HAs for noncarcinogenic toxicants are derived using the following formula:

$$HA = \frac{(NOAEL \text{ or } LOAEL) \times (BW)}{(UF) \times (\_\_\_ \text{ L/day})} = \_\_\_ \text{ mg/L } (\_\_\_ \text{ ug/L})$$

where:

NOAEL or LOAEL = No- or Lowest-Observed-Adverse-Effect-Level in mg/kg bw/day.

BW = assumed body weight of a child (10 kg) or an adult (70 kg).

UF = uncertainty factor (10, 100 or 1,000), in accordance with NAS/ODW guidelines.

___ L/day = assumed daily water consumption of a child

One-day Health Advisory

The available studies were not considered sufficient for derivation of a One-day HA. It is recommended that the value for the Ten-Day HA, 2 mg/l, be used at this time as a conservative estimate for the One-Day HA.

Ten-day Health Advisory

Hepatotoxicity in mice exposed to tetrachloroethylene was selected as the basis for calculating the Ten-day HA value. Schumann et al. (1980) administered PCE in corn oil to rats and mice via gavage for 11 consecutive days at doses of 0, 100, 250, 500 and 1000 mg/kg. For mice, histopathological changes (centrilobular hepatocellular swelling) were observed in all treated animals, and increased liver weight/body weight ratios were observed in animals exposed to doses of 250 mg/kg and higher. The lowest dose, 100 mg/kg/day, represents the LOAEL for the study. This value is consistent with the estimated LOAEL (based on altered hepatic lipid and triglyceride content) of 160 mg/kg/day for mice exposed to 200 ppm for 4 hours (Kylin et al, 1963; see appendix), and could be used as the basis for the Ten-Day Health Advisory with the application of an uncertainty factor of 1000. This uncertainty factor is in accordance with NAS/ODW guidelines for derivation of the HA based on a LOAEL from an animal study. Data from longer-term studies indicates that an uncertainty factor of 1000 may be overly conservative in this case.

Buben and O'Flaherty (1985) treated mice with doses ranging from 20 to 2000 mg/kg, 5 days/week for 6 weeks and observed a slight increase in liver weight in mice treated with 20 mg/kg; at 100 mg/kg, increases were significantly different from controls. From this study, a dose of 20 mg/kg was identified as a NOAEL and 100 mg/kg was identified as a LOAEL. Basing the Ten-day HA on the NOAEL of 20 mg/kg with an uncertainty factor of 100 is consistent with the protection of humans from the CNS effects observed by Stewart et al. (1980) at 100 ppm for 7 hours (approximately 20 mg/kg, see appendix).

The value was calculated as follows:

$$\text{Ten-day HA} = \frac{(20\ \text{mg/kg/day})\ (10\ \text{kg})}{(100)\ (1\ \text{L/day})} = 2.0\ \text{mg/L} = 2{,}000\ \text{ug/L}$$

where:

20 mg/kg/day = NOAEL based on the absence of effects on liver weight of mice exposed to tetrachloroethylene via gavage.

10 kg = assumed body weight of child.

100 = uncertainty factor, chosen in accordance with NAS/ODW guidelines for use of a NOAEL from an animal study.

1 L/day = assumed daily water consumption for a child.

Longer-term Health Advisory

The study by Buben and O'Flaherty was also selected as the basis for the longer-term HA. Lifetime carcinogenicity bioassays did not provide an indication of toxicity at the low dose range (NCI, 1977; NTP, 1985). The NOAEL of 20 mg/kg/day and the LOAEL of 100 mg/kg/day identified in the study by Buben and O'Flaherty are consistent with estimates of LOAELs from inhalation studies. A LOAEL of 63 mg/kg/day (based on increased liver weight and fatty infiltration of the liver) was estimated from chronic exposure of guinea pigs to 100 ppm for 7 hours/day (Rowe et al., 1952; see appendix), and a LOAEL of 160 mg/kg/day (based on fatty infiltration of the liver) from mice exposed to 200 ppm for 4 hours (Kylin et al, 1965). The Longer-term HA value for a 10-kg child was calculated as follows:

$$\text{Longer-term HA} = \frac{(20 \text{ mg/kg/day})(5/7)(10 \text{ kg})}{(100)\ (1 \text{ L/day})} = 1.4 \text{ mg/L} = 1{,}400 \text{ ug/L}$$

where:

20 mg/kg/day = NOAEL based on the absence of effects on liver weight for mice exposed to tetrachloroethylene via gavage.

5/7 = factor to convert 5 day/week exposure to daily exposure.

10 kg = assumed weight of child.

100 = uncertainty factor chosen in accordance with NAS/ODW guidelines for used of a NOAEL from an animal study.

1 L/day = assumed water consumption for a 10 kg child.

The Longer-term HA value for a 70-kg adult was calculated as follows:

$$\text{Longer-term} = \frac{(20 \text{ mg/kg/day})(5/7)(70 \text{ kg})}{(100)\ (2 \text{ L/day})} = 5.0 \text{ mg/L} = 5{,}000 \text{ ug/L}$$

where:

20 mg/kg/day = NOAEL based on the absence of effects on liver weight for mice exposed to tetrachloroethylene via gavage.

5/7 = factor to convert 5 day/week exposure to daily exposure.

100 = uncertainty factor, chosen in accordance with NAS/ODW guidelines for use of a NOAEL from an animal study.

70 kg = assumed weight of adult.

2 L/day = assumed water consumption for 70 kg adult.

Lifetime Health Advisory

The Lifetime HA represents that portion of an individual's total exposure that is attributed to drinking water and is considered protective of noncarcinogenic adverse health effects over a lifetime exposure. The Lifetime HA is derived in a three step process. Step 1 determines the Reference Dose (RfD), formerly called the Acceptable Daily Intake (ADI). The RfD is an estimate of a daily exposure to the human population that is likely to be without appreciable risk of deleterious effects over a lifetime, and is derived from the NOAEL (or LOAEL), identified from a chronic (or subchronic) study, divided by an uncertainty factor(s). From the RfD, a Drinking Water Equivalent Level (DWEL) can be determined (Step 2). A DWEL is a medium-specific (i.e., drinking water) lifetime exposure level, assuming 100% exposure from that medium, at which adverse, noncarcinogenic health effects would not be expected to occur. The DWEL is derived from the multiplication of the RfD by the assumed body weight of an adult and divided by the assumed daily water consumption of an adult. The Lifetime HA is determined in Step 3 by factoring in other sources of exposure, the relative source contribution (RSC). The RSC from drinking water is based on actual exposure data or, if data are not available, a value of 20% is assumed for synthetic organic chemicals and a value of 10% is assumed for inorganic chemicals. If the contaminant is classified as a Group A or B carcinogen, according to the Agency's classification scheme of carcinogenic potential (U.S. EPA, 1986), then caution should be exercised in assessing the risks associated with lifetime exposure to this chemical.

No suitable chronic oral or lifetime oral studies were located in the literature to serve as the basis for the Lifetime HA value. NOAELs were not identified in the NCI (1977) study in which LOAELs were identified at high doses (386 mg/kg/day, mice, 471 mg/kg/day, rats). The NTP (1983) study in which lower doses were tested has not been validated.

Approximate NOAELs and LOAELs calculated from chronic and lifetime inhalation studies give less conservative estimates of toxic doses than the six-week oral study of Buben and O'Flaherty (1985). LOAEL estimates of 63 mg/kg/day for guinea pigs exposed to 100 ppm, 7 hrs/day (Rowe et al., 1952), 400 mg/kg/day for rats exposed to 475 ppm for 7 hr/day (Carpenter, 1937) and 160 mg/kg/day for mice exposed to 100 ppm for 6 hr/day (NTP, 1985) are consistent with the NOAEL of 20 mg/kg/day and LOAEL of 100 mg/kg/day identified in the study by Buben and O'Flaherty. In this study, mice were treated with doses of 20 to 2000 mg/kg/day, 5 days/week for 6 weeks. A slight increase in liver weight was observed at 20 mg/kg; at 100 mg/kg, liver weight and hepatic triglyceride levels were significantly increased over controls. Using the NOAEL of 20 mg/kg/day and an uncertainty factor of 1000 consistent with the use of data from less than lifetime studies, the Reference dose and DWEL were calculated as follows:

Step 1: Determination of the Reference Dose (RfD)

$$\text{Reference Dose} = \frac{(20 \text{ mg/kg/day})\ (5/7)}{1000} = 0.0143 \text{ mg/kg/day}$$

where:

20 mg/kg/day = NOAEL based on the absence of effects in liver weight for mice exposed to tetrachloroethylene via gavage.

5/7 = factor to convert 5 day/week exposure to daily exposure.

1000 = uncertainty factor, chosen in accordance with NAS/ODW guidelines for use with a NOAEL from an animal study of less-than-lifetime duration.

Step 2: Determination of the Drinking Water Equivalent Level (DWEL)

$$DWEL = \frac{(0.0143 \text{ mg/kg/day})\ (70 \text{ kg})}{(2 \text{ L/day})} = 0.5 \text{ mg/L} = 500 \text{ ug/L}$$

where:

0.0143 mg/kg/day = RfD.

70 kg = assumed body weight of an adult.

2 L/day = assumed daily water consumption of an adult.

Step 3: Determination of the Lifetime Health Advisory

A lifetime HA is not recommended for PCE because of its classification as group B2: probable human carcinogen (US EPA, 1986). The estimated excess cancer risk associated with lifetime exposure to drinking water containing tetrachloroethylene at 500 ug/L is approximately 1×10^{-3}. This estimate represents the upper 95% confidence limit from extrapolations prepared by EPA's Carcinogen Assessment Group using the linearized, multistage model. The actual risk is unlikely to exceed this value, but there is considerable uncertainty as to the accuracy of risks calculated by this methodology.

Controversy surrounds the classification of PCE. The Science Advisory Board, Halogenated Organics Subcommittee has recommended a classification of Group C: possible human carcinogen (U.S. EPA, 1987). This committee concluded that the animal evidence of carcinogenicity was limited and questioned grouping rat renal adenomas/carcinomas for statistical analysis and extrapolating mouse mononuclear cell leukemia to man, a species which is not susceptible to this type of leukemia. In contrast to group B2 carcinogens for which no lifetime HA values are recommended, lifetime HA values are calculated for group C carcinogens as follows:

$$\text{Lifetime HA} = \frac{500 \text{ ug/L} \times 20\%}{10} = 10 \text{ ug/L}$$

where:

500 ug/L = DWEL.

20% = assumed relative source contribution from water.

10 = additional uncertainty factor per ODW policy to account for possible carcinogenicity.

Evaluation of Carcinogenic Potential

° The National Academy of Sciences (NAS, 1977, 1980) and EPA's Carcinogen Assessment Group (Anderson, 1983) have calculated drinking water concentrations that would be estimated to increase the risk by one excess cancer per million (10^{-6}) and per one hundred thousand (10^{-5}). Assuming consumption of 2 liters of water/day by a 70 kg adult over a 70 year lifetime, NAS calculated drinking water concentrations of 3.5 ug/L and 35 ug/L for 10^{-6} and 10^{-5} risks, respectively. CAG calculated concentrations of 66, 6.6 and 0.7 ug/L for 10^{-4}, 10^{-5} and 10^{-6} risks, respectively. Each group employed the linearized, non-threshold multistage model, extrapolating from data obtained in the 1977 NCI bioassay in mice.

° The linear multistage model is only one method of estimating carcinogenic risk. It is possible to estimate carcinogenic risk with the probit, logit or Weibull models, but for PCE the data are inadequate for calculating reasonable risk estimates using these techniques. While recognized as statistically alternative approaches, the range of risks described by using any of these modelling approaches has little biological significance unless data can be used to support the selection of one model over another. In the interest of consistency of approach and in providing an upper bound on the potential cancer risk, the Agency has recommended use of the linearized multistage approach.

° IARC (1979) stated that there is limited evidence to conclude that it is a carcinogen in mice, and placed it in Group 3.

° The US EPA Carcinogen Assessment Group (CAG) classified tetrachloroethylene in Group B2: Probable human carcinogen (U.S. EPA, 1986). This classification has been questioned by the Science Advisory Board, Halogenated Organics Subcommittee, which has recommended a classification of Group C: Possible human carcinogen (U.S. EPA, 1987).

VI. OTHER CRITERIA, GUIDANCE AND STANDARDS

° The World Health Organization has recommended a tentative guideline value of 10 ug/L for PCE in drinking water, based on carcinogenic properties (WHO, 1984).

° The National Academy of Sciences (NAS, 1980) calculated 24-hour and 7-day SNARLS. The 24-hour SNARL was 172 mg/L, based on a 490 mg/kg LOAEL following i.p. administration, a 100-fold uncertainty factor, and a 70 kg adult drinking 2 L/day of drinking water. A 7-day SNARL of 24.5 mg/liter was calculated by dividing the 24-hour SNARL by seven.

VII. ANALYTICAL METHODS

° Analysis of tetrachloroethylene is by a purge-and-trap gas chromatographic procedure used for the determination of volatile organohalides in drinking water (U.S. EPA, 1985b). This method calls for the

bubbling of an inert gas through the sample and trapping tetrachloroethylene on an adsorbant material. The adsorbant material is heated to drive off the tetrachloroethylene onto a gas chromatographic column. This method is applicable to the measurement of tetrachloroethylene over a concentration range of 0.03 to 1500 ug/L. Confirmatory analysis for tetrachloroethylene is by mass spectrometry (U.S. EPA, 1985c). The detection limit for confirmation by mass spectrometry is 0.3 ug/L.

VIII. TREATMENT TECHNOLOGIES

- Treatment technologies which will remove tetrachloroethylene from water include granular activated carbon adsorption (GAC), aeration and boiling.

- Dobbs and Cohen (1980) developed adsorption curves for several organic chemicals including PCE. It was reported that Filtrasorb® 300 carbon exhibited adsorptive capacities of 51 mg, 14 mg, 3.9 mg and 1.1 mg PCE/gm carbon at equilibrium concentration of 1,000, 100, 10 and 1 mg/L respectively. USEPA-DWRD installed pilot-scale adsorptiion columns in New Jersey and Rhode Island. In Rhode Island, a Filtrasorb® 400 GAC column maintained a concentration of PCE below 0.1 mg/L for 11 weeks of operation and below for 20 weeks of operation in the effluent, given an influent concentration that ranged from 600 to 2,500 mg/L (Love and Eilers, 1982). In New Jersey, PCE concentration ranging from 60 to 205 mg/L were reduced to less than 0.1 mg/L by GAC over a 58-week study period (Love and Eilers, 1982).

- PCE is amenable to aeration on the basis of its Henry's Law Constant of 1,100 atm (Kavanaugh and Trussell, 1980). In a pilot-scale packed tower aeration study, removal efficiencies of 72 to 99.8% for PCE were achieved using air-to-water ratios of 5-80, respectively (ESE, 1985).

- In diffused-air aeration pilot-scale studies using either spiked Cincinnati tap water (17-1,025 mg/L PCE) or actual PCE contaminated New Jersey groundwater (94 mg/L PCE), diffused aeration removed 90% of PCE at an air-to-water ratio of 4 for the latter and 98+% for the Cincinnati water at air-to-water ratios of 8, 16 and 20 (Love and Eilers, 1982).

- Air stripping is an effective, simple and relatively inexpensive process for removing PCE and other volatile organics from water. However, use of this process then transfers the contaminant directly to the air stream. When considering use of air stripping as a treatment process, it is suggested that careful consideration be given to the overall environmental occurrence, fate, route of exposure and various other hazards associated with the chemical.

IX. REFERENCES

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Appendix

Estimation of absorbed dose based on inhalation exposure

Species	Approx. weight (kg)	Approximate minute vol. (liter/min)	[PCE] (ppm)	Time of Exposure (hr/day)	Approximate dose (mg/kg/day)[a]	Reference
Human	70.0	10.0	100	7	20	Stewart et al, 1977
Guinea pig	0.50	0.222	100	7	63	Rowe et al, 1952
Rat	0.25	0.132	200	6	130	Savolainen et al, 1977
			400	6	260	Savolainen et al, 1977
			230	8	200	Carpenter, 1937
			470	8	400	Carpenter, 1937
Mouse	0.025	0.024	100	6	120	NTP, 1985
			200	6	230	NTP, 1985
			200	4	160	Kylin, 1963, 1965

[a]Dose = [PCE(mg/L)][min. vol.(L/hr)][Time(hr/day)][50% absorption]/[bw(kg)]

where:

[PCE(mg/L] = [PCE(ppm)] x (6.78 mg/m^3 - ppm) x (1 $L/1000\ m^3$)

[min. vol.(L/hr)] = [min. vol.(L/min)] x (60 min/hr)