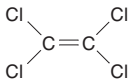
Tetrachloroethylene

CAS No. 127-18-4

Reasonably anticipated to be a human carcinogen

First listed in the *Fifth Annual Report on Carcinogens* (1989)

Also known as perchloroethylene or perc



Carcinogenicity

Tetrachloroethylene is *reasonably anticipated to be a human carcinogen* based on sufficient evidence of carcinogenicity from studies in experimental animals.

Cancer Studies in Experimental Animals

Tetrachloroethylene caused tumors in two rodent species, at several different tissue sites, and by two different routes of exposure. Inhalation exposure to tetrachloroethylene caused benign and malignant liver tumors (hepatocellular adenoma and carcinoma) in mice of both sexes and mononuclear-cell leukemia in rats of both sexes. In male rats, it also increased the combined incidence of benign and malignant tubular-cell kidney tumors, which are rare in rats (NTP 1986). Liver tumors were also observed in mice of both sexes administered tetrachloroethylene by stomach tube (NTP 1977, IARC 1979, 1987).

Cancer Studies in Humans

The data available from epidemiological studies were inadequate to evaluate the relationship between human cancer and exposure specifically to tetrachloroethylene at the time it was listed in the *Fifth Annual Report on Carcinogens*. A number of cohort and case-control studies of occupational exposure to tetrachloroethylene had been conducted. Although tetrachloroethylene may have been the predominant solvent to which workers were exposed, co-exposure to other chemicals (in particular trichloroethylene) among workers in the drycleaning industry was common (IARC 1982, 1987).

Since tetrachloroethylene was listed *Fifth Annual Report on Carcinogens,* additional epidemiological studies have been identified. Several ecological studies assessed cancer outcomes among residents exposed to groundwater contaminated with tetrachloroethylene, among other chemicals. The International Agency for Research on Cancer (IARC 1995) concluded that there was limited evidence for the carcinogenicity of tetrachloroethylene in humans, based mainly on evidence of consistent associations between tetrachloroethylene exposure and esophageal cancer, cervical cancer, and non-Hodgkin lymphoma; however, confounding by exposure to other chemicals could not be ruled out, and the total numbers in the combined cohort studies were small.

Properties

Tetrachloroethylene is a halogenated alkene that exists at room temperature as a colorless liquid with a mildly sweet, ethereal odor (NTP 1986, HSDB 2009). It is only slightly soluble in water but is miscible with alcohol, ether, chloroform, benzene, and solvent hexane and soluble in most fixed and volatile oils. Tetrachloroethylene can be oxidized in air and sunlight and reacts with chemically active metals (e.g., barium or lithium) (IARC 1995). Physical and chemical properties of tetrachloroethylene are listed in the following table.

Property	Information
Molecular weight	165.8
Specific gravity	1.6227 at 20°C/4°C
Melting point	–22.3°C
Boiling point	121.3°C
Log K_{ow}	3.4
Water solubility	206 mg/L at 25°C
Vapor pressure	18.5 mm Hg at 25°C
Vapor density relative to air	5.7

Source: HSDB 2009.

Use

Tetrachloroethylene is used primarily as a cleaning solvent and as a chemical precursor for fluorocarbons. Several commercial grades are available that differ in the amount and type of added stabilizers (e.g., amines, phenols, and epoxides). In the 1970s, domestic use patterns were as follows: 58% for drycleaning and textile processing, 18% for metal cleaning, 12% for chemical intermediates, and 12% for all other uses (IARC 1995). During the 1990s, tetrachlorethylene use in the drycleaning industry declined in order to meet stringent government regulations for workplace exposure. By 2002, uses were 15% for drycleaning, 10% for metal cleaning, 65% for chemical intermediates, and 10% for other uses (CMR 2002). Tetrachloroethylene also has been used as an insulating fluid and cooling gas in electrical transformers; in paint removers, printing inks, adhesive formulations, paper coatings, and leather treatments; in aerosol formulations, such as water repellents, automotive cleaners, silicone lubricants, and spot removers; as an extractant for pharmaceuticals; to remove soot from industrial boilers; and as an antihelminthic agent (IARC 1995).

Production

Tetrachloroethylene was first prepared in 1821, and commercial production in the United States began in 1925. Production was 1.1 million pounds in 1941 and peaked at 763 million pounds in 1980 (IARC 1995, ATSDR 1997). Combined production plus imports were estimated to exceed 250 million pounds in 2015 (EPA 2016) (as shown in the table below), similar to the production volumes from the mid 1990s through 2002 (CMR 2002). U.S. imports of tetrachloroethylene ranged from 36 million to 140 million pounds from 1977 to 2008, but had decreased to less than 5 million pounds in 2017. From 1978 to 2017, U.S. exports ranged from 22 million to 64 million pounds (HSDB 2009, USITC 2018). In 2009, tetrachloroethylene was available from 115 suppliers, including 43 U.S. suppliers (ChemSources 2009).

Category	Year	Quantity (million lb)
Production + imports[a]	2015	250 to 500
U.S. imports[b]	2017	4.8
U.S. exports[b]	2017	59.5

Sources: [a]EPA 2016. [b]USITC 2018.

Exposure

Workers involved in drycleaning, metal degreasing, and fluorocarbon production are likely to be exposed to tetrachloroethylene. The National Occupational Exposure Survey (conducted from 1981 to 1983) estimated that 688,000 workers in 49,025 U.S. facilities potentially were exposed to tetrachloroethylene (NIOSH 1990). A 1994 survey prepared by industry estimated that 450,000 workers potentially were exposed (IARC 1995). Occupational exposure has trended lower over the past several decades. Typical tetrachloroethylene concentrations in workplace air at drycleaning facilities were 350 to 700 mg/m^3 (about 50 to 100 ppm) in the 1970s and 70 to 350 mg/m^3 (about 10 to 50 ppm) in the 1980s (IARC 1995). The highest exposures occur during loading and unloading of the drycleaning machines. More recent

studies by the National Institute for Occupational Safety and Health indicated that exposure levels in the drycleaning industry were below the recommended occupational exposure guideline of 25 ppm (ATSDR 1997). In 2003, the mean concentration of tetrachloroethylene at U.S. drycleaning facilities was 3.8 ppm (Toraason *et al.* 2003).

Evidence that people living in the United States are exposed to tetrachloroethylene (reported as tetrachloroethene) is provided by the 2013–2014 National Health and Nutrition Examination Survey (CDC 2018a). The 95th-percentile concentration of tetrachloroethylene in whole blood for the U.S. general population was 0.083 ng/mL (based on a sample of 2,970 individuals of all ages and race and ethnicity groups). In general, the 95th-percentile tetrachloroethylene blood level did not vary with tobacco smoking status or race; however, it was over 10 times higher (1.2 ng/mL) among male smokers over the age of 50 than in the general population (CDC 2018a,b). People are exposed to tetrachloroethylene from breathing contaminated air (primarily indoors, from its uses in drycleaning) and ingestion of contaminated water or food. Dermal exposure also may occur, but is not important for the majority of the population (ATSDR 1997).

Studies conducted in New York City measured ambient indoor-air concentrations of tetrachloroethylene in apartments and in a day-care facility located in buildings containing drycleaning facilities (Schreiber *et al.* 2002). Concentrations of tetrachloroethylene were much higher in the buildings with drycleaning facilities than in buildings without such facilities. Tetrachloroethylene levels were measured in exhaled breath by personal monitoring devices and in samples of blood from individuals living in apartments over drycleaning facilities. Concentrations of tetrachloroethylene were elevated in samples from exposed individuals. The general population may also be exposed to tetrachloroethylene through use of coin-operated laundromats that contain drycleaning machines or through exposure to freshly drycleaned clothing. Studies show elevated concentrations of tetrachloroethylene in laundromats (even months after removal of the drycleaning machines). Tetrachloroethylene concentrations in homes with freshly drycleaned clothing stored in the closets may be 2 to 30 times higher than average background levels. In addition, workers in the drycleaning industry may carry tetrachloroethylene home on their person or clothes and therefore serve as a source of exposure of their families. In one study, indoor air concentrations of tetrachloroethylene in apartments where drycleaning workers lived were over 10 times the levels in other apartments in the same buildings, where the occupants were not employed by drycleaning facilities (ATSDR 1997).

Tetrachloroethylene is widely distributed in the environment, because it is released from many industrial processes and consumer products. According to the U.S. Environmental Protection Agency's Toxics Release Inventory, total environmental releases of tetrachloroethylene declined by almost 94% from 37.7 million pounds in 1988 to 2.2 million pounds in 2008. In 2008, most of the releases, from 225 facilities, were to air (TRI 2010). Numerous studies have detected tetrachloroethylene in the air in the United States in rural, urban, and industrial areas. Typical concentrations in rural and remote areas were in the low parts-per-trillion range, while concentrations in urban and industrial areas were in the high parts-per-trillion to low parts-per-billion range.

Tetrachloroethylene may also be formed in small quantities during chlorination of water. EPA estimated that in 1985, 11.4 million people were exposed to tetrachloroethylene at concentrations of at least 0.5 µg/L and 874,000 were exposed to concentrations of at least 5 µg/L from municipal water supplies in the United States (IARC 1995). Contamination of drinking water with tetrachloroethylene was reported in the Cape Cod, Massachusetts, area in the late 1970s (Webler and Brown 1993). The chemical leached from the vinyl lining of asbestos-cement water distribution pipes. The highest level reported was 18 mg/L from a pipe in Falmouth, Massachusetts, but levels of 1,600 to 7,750 µg/L were reported for pipes running along dead-end streets (Wakeham *et al.* 1980, Aschengrau *et al.* 2003). Tetrachloroethylene has also been detected in rainwater, sea water, rivers, groundwater, commercial deionized charcoal-filtered water, dairy products, meats, oils and fats, beverages, fruits and vegetables, fresh bread, fish, shellfish, marine mammals, glues, printing inks, lubricants, stain and paint removers, and other consumer products (IARC 1995, ATSDR 1997). It has even been detected in snow in Antarctica (Zoccolillo *et al.* 2007). It was detected in 67 items in the U.S. Food and Drug Administration's Total Diet Study (FDA 2006).

Regulations

Coast Guard (Dept. of Homeland Security)

Minimum requirements have been established for safe transport of tetrachloroethylene on ships and barges.

Consumer Product Safety Commission (CPSC)

Visual novelty devices containing tetrachloroethylene have labeling requirements.

Department of Transportation (DOT)

Tetrachloroethylene is considered a hazardous material and a marine pollutant, and special requirements have been set for marking, labeling, and transporting this material, including transporting it in tank cars.

Environmental Protection Agency (EPA)

Clean Air Act

National Emission Standards for Hazardous Air Pollutants: Listed as a hazardous air pollutant.
New Source Performance Standards: Manufacture of tetrachloroethylene is subject to certain provisions for the control of volatile organic compound emissions.
Urban Air Toxics Strategy: Identified as one of 33 hazardous air pollutants that present the greatest threat to public health in urban areas.

Clean Water Act

Effluent guidelines: Listed as a toxic pollutant.
Water quality criteria: Based on fish or shellfish and water consumption = 10 µg/L; based on fish or shellfish consumption only = 29 µg/L.

Comprehensive Environmental Response, Compensation, and Liability Act

Reportable quantity (RQ) = 100 lb.

Emergency Planning and Community Right-To-Know Act

Toxics Release Inventory: Listed substance subject to reporting requirements.

Resource Conservation and Recovery Act

Characteristic Hazardous Waste: Toxicity characteristic leaching procedure (TCLP) threshold = 0.7 mg/L.
Listed Hazardous Waste: Waste codes for which the listing is based wholly or partly on the presence of tetrachloroethylene = U210, F001, F002, F024, F025, K016, K019, K020, K073, K116, K150, K151.
Listed as a hazardous constituent of waste.

Safe Drinking Water Act

Maximum contaminant level (MCL) = 0.005 mg/L.

Food and Drug Administration (FDA, an HHS agency)

Maximum permissible level in bottled water = 0.005 mg/L.

Occupational Safety and Health Administration (OSHA, Dept. of Labor)

While this section accurately identifies OSHA's legally enforceable PELs for this substance in 2018, specific PELs may not reflect the more current studies and may not adequately protect workers.
Permissible exposure limit (PEL) = 100 ppm.
Ceiling concentration = 200 ppm (5 min in any 3 h).
Acceptable peak exposure = 300 ppm.

Guidelines

American Conference of Governmental Industrial Hygienists (ACGIH)

Threshold limit value – time-weighted average (TLV-TWA) = 25 ppm.
Threshold limit value – short-term exposure limit (TLV-STEL) = 100 ppm.
Biological Exposure Index (BEI) (prior to shift) = 3 ppm in end-exhaled air; = 0.5 mg/L in blood.

National Institute for Occupational Safety and Health (NIOSH, CDC, HHS)

Recommends that workplace exposure levels of substance be minimized.
Immediately dangerous to life and health (IDLH) limit= 150 ppm.
Listed as a potential occupational carcinogen.

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