How does trichloroethylene affect drinking water?

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What are chlorinated solvents?

Subsurface soils and groundwater contaminated with nonaqueous-phase organic liquids cause major environmental concerns. These pollutants, such as chlorinated solvents and their natural transformation products, represent the most prevalent organic groundwater contaminants in the country. And since they are quickly adsorbed, they are difficult to remove from subsurface environments.

These organic liquids act as a continuous source of dissolved organic pollutants to groundwater. Even at low levels, they can contaminate large quantities of groundwater. Nonchlorinated solvents and lightly chlorinated solvents are generally biodegradable in aerobic (in presence of oxygen) conditions. Highly chlorinated solvents are more recalcitrant (resistant to biodegradation) to aerobic degradation, but more susceptible under anaerobic (in absence of oxygen) conditions.

One chlorinated solvent, trichloroethylene (TCE), has been getting a lot of attention, and it is estimated to be present in 34 percent of the nation's drinking water supplies. TCE possesses unique physical and chemical properties that pose serious health risks and make groundwater treatment expensive. Microbial degradation byproducts of TCE make its treatment even more difficult. The current discussion focuses on TCE, its effects on health, and its treatment.

How is TCE different from other contaminants?

TCE is a nonflammable liquid with a sweet odor that most people can smell, even at concentrations as low as 1 ppm [parts per million]. TCE is colorless at room temperature, less viscous than water (will sink in water), and a suspected carcinogen. Based on animal testing, TCE may cause cancer, birth defects, and genetic damage. TCE can decompose at high temperatures forming toxic gases, such as hydrogen chloride, chlorine, and phosgene. Due to its high volatility, it evaporates quickly from surface waters—but not from the soil. TCE can percolate quickly through soil along with rainwater to the groundwater. Once it reaches the groundwater, it adsorbs onto the soil and may attach itself to water particles, and then it travels until it reaches an impermeable surface. When groundwater is drawn from this TCE-contaminated region, it poses serious health risks.

Does TCE have other names?

TCE is also known as acetylene trichloride; 1-Chloro-2,2-dichloroethylene; 1,1-dichloro-2-chloroethylene; ethinyl trichloride; ethylene trichloride; trichloroethene; and 1,1,2-trichlorethylene. Its Chemical Abstracts Service (CAS) Registry Number is 79-01-6 (a number assigned by the CAS in the U.S. used as a unique identifying number worldwide).

What is TCE used for?

TCE is produced in the petrochemical industry and has many uses, such as in dry cleaning operations, paint and printing ink removal, fumigation of rodents, manufacturing fluorocarbons, and as an anesthetic. Trichloroethylene is used for degreasing metal parts (the automotive and metal industries are the primary users). TCE also is used for scouring cotton and other fabrics in the textile industry. It is used in the pharmaceutical industry as a solvent for waxes, fats, resins, and oils and in the aerospace industry for flushing liquid oxygen. Many consumer products, such as correction fluid, paint remover, adhesives, and spot removers, contain TCE. Its historical use in foods, beverages

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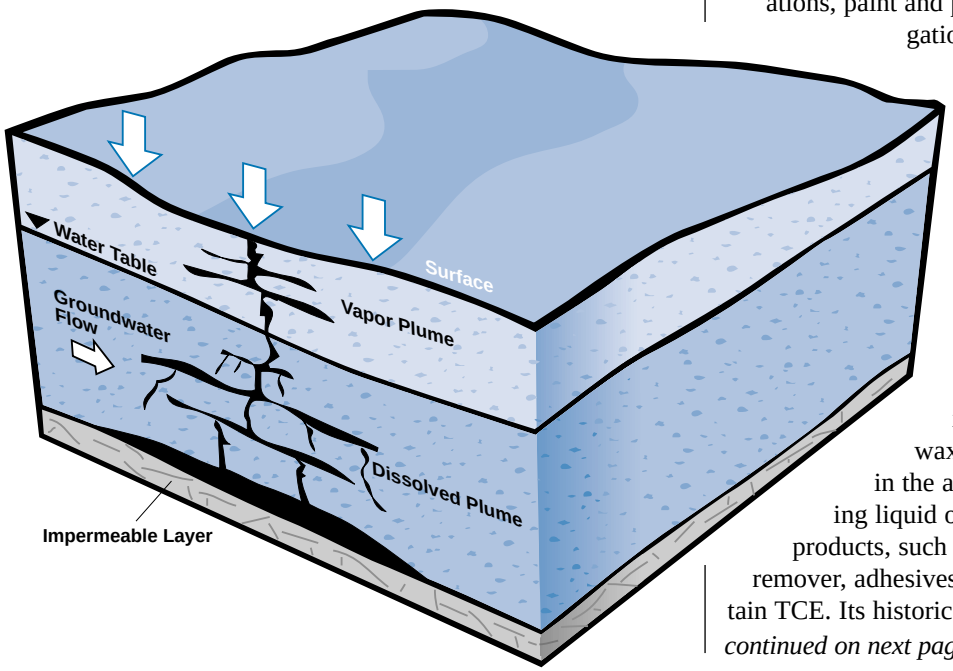

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(decaffeination of coffee), pet foods, medicine, pharmaceuticals, and cosmetics has been banned because of its toxicity.

Is TCE regulated?

Due to its serious health effects, the U.S. Environmental Protection Agency (EPA) has set the Maximum Contaminant Level Goal (MCLG) for trichloroethylene at zero because EPA believes that at this level of protection, TCE will not cause any potential health problems. However, the Maximum Contaminant Level (MCL) has been set at five parts per billion (ppb) because EPA believes, given present technology and resources, this is the lowest level at which water systems can reasonably be required to remove it from drinking water.

How is one exposed to TCE?

One can be exposed to TCE by inhaling air contaminated with TCE vapors from water, and products made with it, such as spot removers and correction fluid. Other modes include drinking TCE-contaminated water, showering, or swimming in contaminated water. Coming into contact with soil contaminated with TCE also is a mode of exposure.

TCE is rapidly absorbed into the bloodstream following inhalation and ingestion, and it is rapidly distributed to organs, including the liver, kidneys, and cardiovascular and nervous systems. Also, small amounts can be absorbed through the skin. TCE is excreted from the body at a moderate rate, mostly in the urine.

What are TCE's health effects?

Exposure to TCE can cause a variety of health problems ranging from minor irritation to death. The most serious effects are related to the central nervous system. Breathing large amounts of TCE may cause impaired heart function, coma, and ultimately death. If exposed for longer periods, TCE may cause nerve, lung, kidney, and liver damage. Breathing small amounts for shorter periods may cause headaches, dizziness, slowed reaction time, depression, insomnia, anorexia, and facial numbness.

Though TCE is noticeable by smell at lower concentrations in air (82 ppm), people can become accustomed to the odor and may not smell TCE until it reaches higher concentrations. At very high concentrations (2,000 ppm), the odor may cause irritation of the nose and throat, drowsiness, dizziness, and nausea within five minutes.

Drinking large quantities of water contaminated with TCE may cause nausea, convulsions, liver and kidney damage, impaired heart function, coma, or even death. Though inconclusive, some studies with mice and rats suggest that exposure to high TCE levels may cause liver and lung cancer.

Long-term exposure to high concentrations may cause facial numbness or discomfort as well as jaw weakness. TCE is a severe skin irritant, and prolonged contact with it may cause reddening of the skin, irritation, and blister formation. Though TCE can be absorbed through the skin, researchers do not expect this mode of transmission to cause significant, harmful effects. Contact with eyes may cause severe eye irritation, including temporary clouding of the cornea, disturbances in eyesight, reduced eyesight, and blurred, double, and tunnel vision. Ingestion may cause a burning sensation in the mouth and throat, followed by abdominal pain, severe lung irritation, and damage to the lung tissues.

Does TCE cause cancer?

The International Agency for Research on Cancer (IARC) concluded that there is limited evidence for the carcinogenicity (capability to cause cancer) of TCE in humans. However, IARC also concluded that there is sufficient evidence from animal studies that TCE may be carcinogenic.

How do I treat TCE-contaminated water?

Treatment of groundwater contaminated by chlorinated solvents is more difficult than cleaning groundwater contaminated with less dense liquids, such as gasoline and diesel fuel, which float on the surface of water. As these dense liquids (chlorinated solvents) travel and sink faster through water, larger quantities of water become contaminated in a shorter time period.

As TCE quickly evaporates, using irrigation sprinklers is one treatment option. These sprinklers diffuse water droplets through the air, removing the TCE. One research study indicates that the contaminated water can be pumped out, treated, and reinjected back into the subsurface below the actual contamination. This reinjected water helps prevent further contamination.

Airborne TCE can be removed using activated carbon filtration and resins. Air stripping is used to treat contaminated groundwater. Soil vapor extraction can be used to remove TCE present in the soil. Granular activated carbon (GAC) in combination with packed tower aeration has long been recognized as an effective method of removing TCE from water. As the cost of GAC is increasing, use of synthetic

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Water Fact

BLUE THUMB

Setting standards for water quality is a complex process. It involves scientific research, analysis, evaluating health benefits and costs, and identifying appropriate treatment technologies.

Blue Thumb
American Water Works Association

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carbonaceous adsorbents has been on the rise. Carbona-ceous adsorbents have better adsorption capacity and can be easily regenerated onsite.

Researchers have identified and isolated several species of bacteria that can remove halogens (eg., chlorine) from TCE. Generally, a site's environmental chemistry determines the rate of TCE biodegradation. TCE's initial metabolism in groundwater involves a biochemical process described as sequential reductive dechlorination. (Reduction is any chemical reaction that adds electrons to an element. For reduction to occur, some other material must be oxidized.)

When sequential reductive dechlorination occurs, two electrons are transferred to the chlorinated compound being reduced. One of these electrons combines with a chlorine atom that is bonded with a carbon atom to become a negatively charged chloride ion. The second electron combines with a proton (hydrogen ion) to become a hydrogen atom that replaces the chlorine atom in the byproduct. One chlorine atom at a time is replaced with hydrogen, and each transfer occurs in sequence. As an example, tetrachloroethylene is reduced to TCE, then any of the three dichloroethylenes, then to monochloroethylene (commonly called vinyl chloride), then to the chlorine-free carbon skeleton ethylene, then finally to ethane.

References:

Spenrath, A.R. 1995. "Trichloroethylene coming to a tap near you," *Water Conditioning & Purification.*

Hand, D.W., J.A.Harlevich Jr, D.L Perram, and J.C. Crittenden, 1994. "Synthetic adsorbent versus GAC for TCE removal," *Journal AWWA.*

Carter, M.C., W.J. Weber Jr., and K.P Olmstead, 1992. "Effects of background dissolved organic matter on TCE adsorption by GAC," *Journal AWWA.*

Basic Information on Trichloroethylene and Health Effects of TCE. *www.ccohs.ca/oshanswers/chemicals/chem_profiles/trichloroethylene/trichloroethylene.htm.*

Trichloroethylene. *www.atsdr.cdc.gov/tfacts19.html.*

National Primary Drinking Water Regulations, "Technical Fact Sheet on TCE," *www.epa.gov/ogwdw/dwh/t-voc/trichlor.html.*

Gullickson, R. "Reference data sheet on common chlorinated solvents," *www.mcs.net/~hutter/tee/chlorina.html.*

Wilson, J. 1996. "Chlorinated Solvents Biodegradation," *www.clu-in.org/products/newsltrs/gwc/gwcchlrs.htm.*

Alternative Technologies Conference Set for March

The Nebraska Department of Environmental Quality's Nebraska Environmental Partnerships program is teaming with the Nebraska Water Environment Association, regional chapters of the Solid Waste Association of North America, the National Drinking Water Clearinghouse, and many other sponsors to present two conferences: the 1st Alternative Water and Wastewater Technologies for Small Communities Conference and the 45th Annual Great Plains Waste Management Conference. These conferences will be held on March 28 and 29, 2001, at the Holiday Inn Convention Center in Omaha, Nebraska.

Providing safe drinking water and effective wastewater systems are key to protecting a community's environmental health and are strongly linked to its social and economic development. Furthermore, because small systems' managers and operators encounter special challenges when working with complex financial, technical, and regulatory information, the conference will highlight lower cost, alternative technologies that have been installed and used in communities with populations with fewer than 5,000. The conference includes a full day of alternative technology presentations. In many cases, community representatives will be available to explain the projects from the community's perspective.

In addition, University of Nebraska students will display research posters.

The conference will target community leaders, community utility workers, engineers, contractors, technical assistance providers, state regulators, funding organizations, and national/regional researchers.

If you are interested in attending this conference or would like more information, please contact M.J. Rose at the Nebraska Environmental Partnerships program at (402) 471-3193, or Kirk Pfeffer at the Nebraska Environment Association at (402) 444-4923, or visit Nebraska Department of Environmental Quality's Web site at www.deq.state.ne.us.