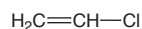


Vinyl Chloride

CAS No. 75-01-4

Known to be a human carcinogen

First Listed in the *First Annual Report on Carcinogens* (1980)



Carcinogenicity

Vinyl chloride is *known to be a human carcinogen* based on sufficient evidence of carcinogenicity in humans. The strongest evidence that vinyl chloride causes cancer in humans is based on numerous epidemiological studies and case reports that show its association with angiosarcoma of the liver, a very rare tumor. Several studies also have reported that exposure to vinyl chloride causes cancer at other tissue sites including the liver (tumors other than angiosarcoma), brain, lung, lymphatic system, and hematopoietic system (organs and tissues involved in production of blood) (IARC 1987).

Since vinyl chloride was listed in the *First Annual Report on Carcinogens*, epidemiological studies have continued to provide strong evidence for an association with liver cancer (predominantly angiosarcoma of the liver) and somewhat weaker evidence for an association with brain cancer. As of 1999, 197 cases of vinyl chloride-associated angiosarcoma of the liver have been reported including 50 in the United States. Additionally, recent studies suggest that lung cancer, lymphoma, and leukemia may not be associated with vinyl chloride exposure (Kielhorn *et al.* 2000).

There is sufficient evidence for the carcinogenicity of vinyl chloride in experimental animals. Exposure of mice, rats, and hamsters to vinyl chloride by inhalation or oral administration caused malignant and benign tumors at multiple tissue sites, including angiosarcoma of the liver (IARC 1979, 1987). In mice of both sexes, vinyl chloride caused angiosarcoma of the liver, lung tumors, mammary-gland tumors, and angiosarcoma (blood-vessel tumors) and adenocarcinoma (tumors of the linings of organs) at other sites. In rats, vinyl chloride caused angiosarcoma of the liver, Zymbal-gland tumors, and kidney tumors (nephroblastoma) in both sexes, mammary-gland and liver tumors in females, and angiosarcoma and liver tumors (hepatoma) in newborns. In hamsters, vinyl chloride caused skin tumors in males and mammary gland, skin, and stomach tumors and angiosarcoma (of the liver, spleen, and skin) in females. Combined oral exposure to ethanol and inhalation exposure to vinyl chloride caused more liver tumors (including angiosarcoma) than did exposure to vinyl chloride alone.

Additional Information Relevant To Carcinogenicity

Vinyl chloride is metabolized by cytochrome P-450 enzymes to form chloroethylene oxide, which can undergo spontaneous rearrangement to form chloroacetaldehyde; both of these metabolites can bind to DNA. One major DNA adduct (7-[2'-oxoethyl]guanine) and four minor adducts (etheno adducts) have been identified. The etheno adducts (but not the major adduct) cause mutations, mainly base-pair substitutions and, to a lesser degree, frameshift mutations. Mutations have been detected in the *p53* tumor-suppressor gene and the *ras* proto-oncogene in liver tumors from humans (angiosarcoma of the liver) and rats (angiosarcoma of the liver or hepatocellular carcinoma) exposed to vinyl chloride. Most of the mutations occurred at A:T base pairs, which is consistent with the mutagenic properties of the etheno adducts (especially the 1,*N*⁶-ethenoadenine adduct) (Kielhorn *et al.* 2000).

Vinyl chloride caused genetic damage in many test systems, including bacteria, yeast, insects, cultured human and other mammalian cells, and rodents exposed *in vivo*, and in exposed humans.

The genetic damage included mutations, DNA damage, micronucleus formation (a sign of chromosome damage or loss), chromosomal aberrations (changes in chromosome structure or number), and sister chromatid exchange. Vinyl chloride caused mutations in bacteria with or without metabolic activation (addition of rodent liver microsomes to simulate mammalian metabolism); however, its metabolites chloroethylene oxide and chloroacetaldehyde were more potent mutagens than vinyl chloride. These results suggest that vinyl chloride may require metabolic activation in order to cause genetic damage in other test systems (Giri 1995).

Properties

Vinyl chloride is a chlorinated aliphatic hydrocarbon with a molecular weight of 62.5, occurring as a colorless gas with a faintly sweet odor. It melts at -153.7°C and boils at -13.3°C . Vinyl chloride is slightly soluble in water, soluble in ethanol, and very soluble in ether, carbon tetrachloride, and benzene (HSDB 2003), with a log octanol-water partition coefficient of 1.36 (ATSDR 1997). Its vapor pressure is 2,980 mm Hg at 25°C , and the vapor is heavier than air, with a density of 2.15. Vinyl chloride is extremely flammable and is easily ignited by heat, sparks, or flames. It forms explosive mixtures with air, and it tends to self-polymerize explosively if peroxidation occurs. It reacts vigorously with oxidizers, and it corrodes iron and steel in the presence of moisture. Fires with vinyl chloride may release irritating and toxic gases, including carbon dioxide, carbon monoxide, hydrogen chloride, and traces of phosgene. Technical-grade vinyl chloride is commercially supplied as 99.9% pure liquid under pressure (HSDB 2003).

Use

Vinyl chloride is used almost exclusively by the plastics industry to produce polyvinyl chloride (PVC) and copolymers. PVC is a plastic resin used in many consumer and industrial products, including automotive parts and accessories, furniture, medical supplies, containers, wrapping film, battery cell separators, electrical insulation, water distribution systems, flooring, windows, videodiscs, irrigation systems, and credit cards. More than 95% of all vinyl chloride monomer produced is used to make PVC and its copolymers; the rest is used in organic synthesis and miscellaneous applications (Kielhorn *et al.* 2000, HSDB 2003). Vinyl chloride-vinyl acetate copolymers are used extensively to produce films and resins (IARC 1974, NCI 1978, IARC 1979, ATSDR 1997). Vinyl chloride previously was used as a refrigerant, as an extraction solvent, and in aerosol propellants, but these uses were banned in 1974 because of vinyl chloride's carcinogenic effects (HSDB 2003).

Production

Vinyl chloride was first produced commercially in the 1920s and is now one of the highest-volume chemicals produced in the United States. Annual U.S. production increased from approximately 6 to 9 billion pounds (2.7 to 4.1 billion kilograms) in the late 1970s through the 1980s to approximately 15 billion pounds (6.8 billion kilograms) in the mid 1990s (Kirschner 1996, HSDB 2003). Among chemicals produced in the United States, vinyl chloride ranked 18th in production volume in 1995 and 17th in 1994 (Kirschner 1996). The production capacity for vinyl chloride was reported to be 17.6 billion pounds (8.0 billion kilograms) (CMR 2000). In 2003, 10 U.S. suppliers (ChemSources 2003) and 13 U.S. producers of vinyl chloride were identified (SRI 2003).

U.S. imports of vinyl chloride reached a peak of 302 million pounds (137 million kilograms) in 1989. Imports have fluctuated since then and were 168 million pounds (76.2 million kilograms) in 2002 (ATSDR 1997, ITA 2003). From the late 1970s to the mid 1990s, annual exports fluctuated between about 685 million pounds (311 billion kilograms) and 2.2 billion pounds (1 billion kilograms)

(ATSDR 1997, HSDB 2003). U.S. exports were approximately 1.03 billion kilograms (2.3 billion pounds) in 2000 and 782 million kilograms (1.7 billion pounds) in 2002 (ITA 2003).

Exposure

The general population potentially is exposed to vinyl chloride through inhalation of contaminated air, ingestion of contaminated drinking water and foods, or dermal contact with consumer products. However, the exposure levels for the majority of the population are very low (ATSDR 1997, Kielhorn *et al.* 2000, HSDB 2003). Occupational exposure occurs through inhalation or dermal contact during production or use of vinyl chloride.

Vinyl chloride is released into the environment in emissions and effluents from the plastics industry. Segments of the general population living near emission sources potentially are exposed to relatively high levels of vinyl chloride in air. Concentrations in the air near emission sources ranged from trace levels to over 2,600 µg/m³, and the average daily intake of vinyl chloride by residents living near emission sources ranged from trace amounts to 2,100 µg. Ambient air in rural and urban areas of the United States typically does not contain detectable levels of vinyl chloride.

The majority of the general population is not expected to be exposed to vinyl chloride in drinking water. Only 0.74% of 945 water supplies sampled throughout the United States contained detectable levels of vinyl chloride. In another study, vinyl chloride was detected in only 12 of 11,202 public water supplies using surface waters as their primary source. The U.S. Environmental Protection Agency (EPA) estimated that approximately 0.9% of the U.S. population is exposed to vinyl chloride in drinking water at concentrations of 1.0 µg/L or higher and that 0.3% of the population is exposed to concentrations higher than 5 µg/L.

In the past, vinyl chloride was detected in various foods and beverages that were packaged in materials made of PVC; however, U.S. Food and Drug Administration regulations have essentially eliminated this route of exposure. The estimated average daily intake of vinyl chloride from the diet is below the limit of detection (ATSDR 1997). Vinyl chloride also has been detected in domestic and foreign cigarettes and little cigars at levels ranging from 5.6 to 27 ng per cigarette and in a marijuana cigarette at 5.4 ng (IARC 1979).

Occupational exposures to vinyl chloride generally occur after production, when the finished monomer is piped to storage or transportation, or during maintenance. The potential for exposure is high during the process of polymerization to form PVC resins or other materials, because vinyl chloride monomer may escape into the air (NCI 1978). The National Occupational Exposure Survey (1981–1983) estimated that 81,314 workers potentially were exposed to vinyl chloride (ATSDR 1997).

According to the U.S. EPA's Toxics Release Inventory for 2001 (TRI01 2003), an estimated 732,200 lb (332,100 kg) of vinyl chloride (88% of the total environmental releases from 49 manufacturing and processing facilities) was discharged to the air, 102 lb (46 kg) was discharged to surface water, 96,000 lb (43,500 kg) was injected underground, and approximately 1,000 lb (454 kg) was treated off site. Annual environmental releases declined slowly from approximately 1.4 million pounds (635,000 kg) in 1988 to less than 1 million pounds (454,000 kg) since 1998.

Regulations

CPSC

Self-pressurized products intended for household use that contain vinyl chloride are banned

DOT

Vinyl chloride is considered a hazardous material and special requirements have been set for marking, labeling, and transporting this material

EPA

Clean Air Act

NESHAP: Listed as a Hazardous Air Pollutant (HAP)

NSPS: Manufacture of substance is subject to certain provisions for the control of Volatile Organic Compound (VOC) emissions

Prevention of Accidental Release: Threshold Quantity (TQ) = 10,000 lbs

Urban Air Toxics Strategy: Identified as one of 33 HAPs 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/shellfish and water consumption = 2.0 µg/L; based on fish/shellfish consumption only = 530 µg/L

Comprehensive Environmental Response, Compensation, and Liability Act

Reportable Quantity (RQ) = 1 lb

Emergency Planning and Community Right-To-Know Act

Toxics Release Inventory: Listed substance subject to reporting requirements

Resource Conservation and Recovery Act

Characteristic Toxic Hazardous Waste: TCLP Threshold = 0.2 mg/L

Listed Hazardous Waste: Waste codes in which listing is based wholly or partly on substance - U043, K019, K020, K028, K029

Listed as a Hazardous Constituent of Waste

Safe Drinking Water Act

Maximum Contaminant Level (MCL) = 0.002 mg/L

FDA

Maximum permissible level in bottled water = 0.002 mg/L

Aerosol drug products containing vinyl chloride have been withdrawn from the market and may not be compounded because vinyl chloride was found to be unsafe or not effective. Vinyl chloride is banned from use in cosmetic aerosol products

OSHA

Permissible Exposure Limit (PEL) = 1 ppm

Ceiling Concentration = 5 ppm (15-minutes)

"Comprehensive Standards" for occupational exposure to this substance have been developed

Guidelines

ACGIH

Threshold Limit Value - Time-Weighted Average Limit (TLV-TWA) = 1 ppm

NIOSH

Listed as a potential occupational carcinogen

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