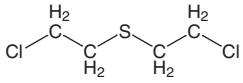
Mustard Gas (bis[2-Chloroethyl] sulfide) CAS No. 505-60-2

Known to be a human carcinogen
First Listed in the *First Annual Report on Carcinogens* (1980)



Carcinogenicity

Mustard gas is *known to be a human carcinogen* based on sufficient evidence of carcinogenicity in humans. In several epidemiology studies, exposure to mustard gas (through military use or occupationally) was associated with an increased risk of lung or other respiratory-tract cancer. Among mustard-gas production workers, the risk of respiratory cancer was higher in individuals who had been exposed to mustard gas for longer periods (IARC 1975, 1987). Since mustard gas was reviewed for listing in the *First Annual Report on Carcinogens* and subsequently reviewed by IARC (1987), it has been reported to be associated with cancer at several other tissue sites. A cohort study in England found significant excesses of laryngeal, pharyngeal, upper respiratory tract, and lung cancer in workers employed in the manufacture of mustard gas during World War II (Easton *et al.* 1988).

The findings in humans are supported by studies in laboratory animals where mustard gas caused cancer in mice of both sexes. When administered by inhalation or intravenous injection, mustard gas caused lung tumors, and when administered by subcutaneous injection, it caused tumors at the injection site (fibrosarcoma or sarcoma) (IARC 1975, 1987).

Additional Information Relevant to Carcinogenicity

Mustard gas caused genetic damage in all systems in which it was tested, including bacteria, fungi, insects, cultured rodent cells, and mice exposed *in vivo*. It caused DNA damage in bacteria and mutations in fungi. In insects, it caused dominant lethal mutations, sex-linked recessive lethal mutations, aneuploidy (extra or missing chromosomes), and heritable translocations (exchanges of parts of chromosomes). In cultured rodent cells, it caused mutations, chromosomal aberrations (changes in chromosome structure or number), and DNA damage. Mustard gas was shown to covalently bind to DNA, RNA, and protein in mice exposed by intraperitoneal injection (IARC 1987).

Properties

Mustard gas is an alkylating agent with a molecular weight of 159.1. Despite its name, it is not a gas, but a clear to pale yellow, oily liquid with a slightly sweet to garlic-like odor. It melts at 13°C to 14°C and boils at 215°C to 217°C. Mustard gas is sparingly soluble in water and soluble in fat, fat solvents, and other common organic solvents. The log octanol-water partition coefficient has been reported as 1.37, 2.03, and 2.41. Mustard gas has a specific gravity of 1.27 at 25°C and a vapor pressure of 0.11 mm Hg at 25°C; the vapor is heavier than air, with a density of 5.4. Mustard gas volatilizes in steam and is combustible when exposed to heat or flame, with a flash point of 221°F (105°C). It is readily hydrolyzed in aqueous solution (ATSDR 2001, HSDB 2003).

Use

Mustard gas is a vesicant (blister-inducing agent) first used in chemical warfare in World War I. It also was used in chemical warfare in Ethiopia in 1936 and in the Iran–Iraq war from 1984 to 1988. Small amounts are used in research as a model compound in biological studies of alkylating agents. Mustard gas was tested as an anticancer agent, but its clinical use was not successful because of its high toxicity (IARC 1975, ATSDR 2001).

Production

By the end of World War I, daily U.S. production of mustard gas had reached about 18,000 kg (40,000 lb). The United States continued to produce and stockpile mustard-gas chemical weapons until 1968, accumulating more than 34 million pounds (15,400 metric tons) (ATSDR 2001). The United States no longer produces, imports, or exports mustard gas and signed the International Chemical Weapons Convention treaty in 1997, which mandates destruction of all chemical weapons by 2007 (USCWC 2003). Four U.S. suppliers of mustard gas in research quantities were identified in 2003 (ChemSources 2003).

Exposure

The primary routes of potential human exposure to mustard gas are inhalation and dermal contact; however, the general population typically is not exposed to mustard gas. Aging stockpiles of mustard gas are stored at seven U.S. army bases and are scheduled for destruction. Although the greatest risk of exposure to date has been for military personnel, there is some small risk of exposure for people living near military installations where mustard gas is stockpiled and destroyed or in the event of accidental releases or a chemical warfare attack. People also may be exposed to residues of mustard gas disposed of in bulk quantities years or even decades ago if these disposal sites are disturbed (ATSDR 2001, HSDB 2003).

Bullman and Kang (1994) reviewed the effects of mustard gas and other hazards on U.S. military personnel. During World War I, as many as 28,000 of the American Expeditionary Forces were exposed to mustard gas, but seldom to lethal concentrations, because the gas was dispersed on the battlefield. Although mustard gas was not used in World War II, the United States produced and stockpiled it for possible use and conducted research to prepare for the threat of chemical warfare attack. Top-secret experiments to test protective equipment, clothing, and antivesicant ointments, involving patch or drop tests, chamber tests, and field tests, were conducted with military volunteers. In the patch or drop tests, which assessed the strength of protective ointments, 15,000 to 60,000 soldiers and sailors were exposed to mustard gas. In chamber tests, protective masks and clothing were evaluated by exposure of volunteers to the chemical in a gas chamber for an hour or more every day or every other day until penetration was observed, evidenced by moderate to intense chemical burns on the skin. The same outcome was sought in field tests of the quality of masks, protective clothing, and ointments, which required soldiers to cross tropical or subtropical lands where the gas was dropped. In chamber and field tests, at least 4,000 servicemen were exposed to mustard gas.

Regulations

EPA

Emergency Planning and Community Right-To-Know Act
- Threshold Planning Quantity (TPQ) = 500 lb
- Reportable Quantity (RQ) = 500 lb
- Toxics Release Inventory: Listed substance subject to reporting requirements

Resource Conservation and Recovery Act
- Listed as a Hazardous Constituent of Waste

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