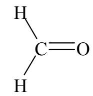
FORMALDEHYDE (GAS)
CAS No. 50-00-0
First Listed in the *Second Annual Report on Carcinogens*



CARCINOGENICITY

Formaldehyde (gas) is *reasonably anticipated to be a human carcinogen* based on limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals (IARC 1982, 1987, 1995).

Excess incidences of nasopharyngeal cancers were observed in two of six cohort studies, three of four case-control studies, and in meta-analyses. In addition, two of three case-control studies showed a positive association between occupational exposure to formaldehyde and squamous-cell carcinomas of the nasal cavities and paranasal sinuses. Three other case-control studies examined cancer (unspecified cell type) of the nasal cavity and paranasal sinuses; two studies presented negative results, but one showed weak positive results. The overall observed incidences of cancers of the nasal cavities and paranasal sinuses in occupational cohorts were lower than expected. The occurrence of these cancers showed an exposure-response gradient in more than one study; however, the numbers of exposed cases were often small, and there was a lack of consistency between cohort and case-control studies. Cohort studies of embalmers and other professionals that use formaldehyde showed some excess risk for brain cancer. The available epidemiological data did not show an excess risk for oropharyngeal, laryngeal, lung, lymphatic, or hematopoietic cancers. The slight excesses of cancer among professionals noted in several studies generally did not display the patterns of increasing risk with various measures of exposure (i.e., latency, duration, level, or cumulative) typically seen for occupational carcinogens. No other cancer showed consistent excess incidences across the various studies (IARC 1987, 1995).

When administered by inhalation, formaldehyde induced squamous cell carcinomas of the nasal cavity in rats of both sexes. Inhalation studies in hamsters or mice did not show evidence of carcinogenicity or were inadequate for evaluation. Rats administered formaldehyde in drinking water had increased incidences of forestomach papillomas in one study and leukemia and gastrointestinal tract tumors in another (IARC 1995).

PROPERTIES

Formaldehyde is a flammable, colorless gas with a pungent, suffocating odor. It is highly soluble in water (up to 55%), acetone, benzene, chloroform, diethyl ether, and ethanol. The gas is stable in the absence of water, but it is incompatible with oxidizers, alkalis, acids, phenols, and urea. Explosive reactions occur with peroxide, nitrogen oxide, and performic acid. Anhydrous gaseous formaldehyde is not available commercially. Most formaldehyde is sold as aqueous solutions, known as formalin, containing 30% to 50% formaldehyde with 0.5% to 15% methanol as a polymerization inhibitor. Polymerization may also be inhibited by the addition of up to 100 mg/kg of stabilizers such as cellulose ethers (IARC 1982, 1995, ATSDR 1999).

Formaldehyde is also available in the United States as its cyclic trimer, trioxane, and as paraformaldehyde. Trioxane is a crystalline solid with a chloroform-like odor. It is soluble in water, alcohols, ketones, ether, acetone, chlorinated and aromatic hydrocarbons, and other organic solvents and slightly soluble in pentane, petroleum ether, and lower paraffins. In nonaqueous systems, trioxane readily converts to monomeric formaldehyde. Paraformaldehyde is available as a powdered or flaked product containing the equivalent of 91% to 93% formaldehyde, a maximum of 9% water, and a maximum of 0.03% acidity as formic acid. It is soluble in fixed alkali hydroxide solutions, slowly soluble in cold water, more readily soluble in hot water with evolution of formaldehyde vapors, and insoluble in alcohol and ether. Formaldehyde gas can be regenerated from paraformaldehyde by heating (IARC 1982, 1995, ATSDR 1999).

USE

The primary uses for formaldehyde are for the production of urea-formaldehyde resins (23%), phenolic resins (19%), acetylenic chemicals (12%), polyacetal resins (11%), methylene diisocyanate (6%), pentaerythritol (5%), urea-formaldehyde concentrates (4%), hexamethylenetetramine (4%), melamine resins (4%), and miscellaneous products (chelating agents, trimethylolpropane, pyridine chemicals, nitroparaffin derivatives, textile treatings, and trimethylolethane) (12%). Urea-formaldehyde resins and phenol-formaldehyde resins are used primarily as adhesives in the manufacture of particle board, fiberboard, and plywood, and for molding, paper treating and coating, textile treating, surface coating, and foams for insulation. The percentage of total formaldehyde production used in urea-formaldehyde resins and phenol-formaldehyde resins have ranged between 20% and 26% each since the early 1960s (IARC 1982, 1995, ATSDR 1999).

Formaldehyde is used in relatively small quantities for preservation and disinfection. These include disinfecting hospital wards, dwellings, ships, storage houses, utensils, and clothing; preserving and embalming biological specimens; sterilizing soil; as a germicide, insecticide, and fungicide; and as an antibacterial agent in soaps, shampoos, hair preparations, deodorants, lotions, make-up, mouthwashes, and nail products (IARC 1995, ATSDR 1999).

Compounds produced from formaldehyde have many applications. Polyacetal plastics are used in automobiles and in audio and video electronics equipment; pentaerythritol is used in surface coatings and explosives; hexamethylenetetramine is used as a cross-linking agent for phenol-formaldehyde resins and in explosives; and nitrilotriacetic acid and ethylenediaminetetraacetic acid are chelating agents and are used in some detergents. Other compounds are used to manufacture polyurethane and polyester plastics, synthetic resin coatings and lubricating oils, plasticizers, dyes, tanning agents, extraction agents, crop protection agents, animal feeds, perfumes, vitamins, flavorings, and drugs (IARC 1982, 1995).

PRODUCTION

Formaldehyde has been produced commercially since the early 1900s and has ranked in the top 25 among the 50 highest volume chemicals produced in the United States in recent years. Seventeen current U.S. manufacturers and 40 suppliers were identified (ATSDR 1999, Chem Sources 2001). Formaldehyde production data in the U.S. were reported for the 37% aqueous solution rather than the gas (IARC 1982, 1995, HSDB 2001). Annual U.S. production was approximately 848,000 metric tons (1.87 billion lb) in 1960 and increased to 5.14 million metric tons (11.3 billion lb) by 1998. The annual growth rate averaged 11.7% between 1958 and 1968 and 2.7% between 1988 and 1997 (ATSDR 1999).

The United States imported 2.5 million lb, 16.2 million lb, and 8.5 million lb of formaldehyde (including solutions) in 1978, 1983, and 1985, respectively (HSDB 2001). Imports increased to 87 million lb in 1994 and 140 million lb in 1997 (ATSDR 1999). In 2000, the U.S. imported about 62 million lb of formaldehyde and 18.3 million lb of paraformaldehyde (ITA 2001).

U.S. exports of formaldehyde exceeded imports in 1978 and 1983 with 22.9 million lb and 172 million lb, respectively. This trend apparently shifted by 1985 when only 880,000 lb were exported (HSDB 2001). Exports were 25 million lb in 1994 and 17.4 million lb in 2000 (ATSDR 1999, ITA 2001). In addition, the U.S. exported 50.8 million lb of paraformaldehyde in 2000 (ITA 2001).

EXPOSURE

Formaldehyde is released to the environment from both anthropogenic and natural sources. The primary routes of potential human exposure to formaldehyde are inhalation and dermal contact. Formaldehyde does occur naturally in fruits and some foods, and it is formed endogenously in mammals, including humans, as a consequence of oxidative metabolism of many xenobiotics.

Combustion processes account for most of the formaldehyde released to the environment. These include automobile exhausts, power plants, incinerators, refineries, wood stoves, kerosene heaters, and cigarettes. Indirect sources include photochemical oxidation of hydrocarbons (especially methane) and other formaldehyde precursors released from combustion sources (IARC 1982, 1995, ATSDR 1999). According to EPA's Toxic Chemicals Release Inventory (TRI), annual environmental releases of formaldehyde totaled 17.2 million to 24.9 million lb between 1988 and 1999 with the majority (50% to 66%) released to the atmosphere. Releases for 1999 were approximately 24.2 million lb from 849 facilities; however, the top two facilities accounted for 42% of the total (TRI99 2001). Formaldehyde has a short half-life in the environment because it is removed from the air by photochemical processes and precipitation and biodegradation.

Most of the formaldehyde produced in the United States is synthesized from methanol in closed automated process systems; therefore, the risk of exposure during production is minimized. Potential occupational exposure may occur during the production of end products in which formaldehyde and its solutions are used, in the garment industry, during various preservation processes, and in laboratories. Health care professionals such as pharmacists, physicians, veterinarians, dentists, and nurses may be exposed to vapors during the preparation, administration, or clean up of medicinal products. Patients who receive the medicines are directly exposed. Pathologists and histology technicians, and teachers and students who handle preserved specimens represent potential high-exposure groups (ATSDR 1999, HSDB 2001).

The National Occupational Exposure Survey (1981-1983) indicated that 1,329,332 workers were potentially exposed to formaldehyde (ATSDR 1999). The National Occupational Hazard Survey, conducted by NIOSH from 1972 to 1974, estimated that 1.6 million workers were exposed to formaldehyde in more than 60 industrial categories. Of these workers, approximately 57,000 were exposed for 4 hours or more per day. Nearly one-third (507,200) were engaged in medical and other health services, and another third (457,200) were in the following categories: chemicals and allied products, printing and publishing, paper and allied products, machinery (other than electrical), retail general merchandise, automotive dealers and service stations, eating and drinking establishments, and personal services (i.e., funeral services and crematoriums, photographic studios, and dry cleaning plants) (NIOSH 1976, 1981).

The general population may be exposed to formaldehyde through its use in construction materials, wood products, textiles, home furnishings, paper, cosmetics, cigarette smoke, and pharmaceuticals. Formaldehyde released to indoor air from construction materials, furnishings, and cigarettes are major sources of exposure. Cigarettes may contribute as much as 10% to 25% of the indoor exposure. Automobile exhaust is a major source of formaldehyde in ambient air. In addition, formaldehyde can be absorbed through the skin from cosmetics or contact with other consumer products containing formaldehyde. Subpopulations with particularly high potential for formaldehyde exposure include the 2.2 million residents of mobile homes containing particle board and plywood, the 1.7 million persons living in conventional homes insulated with urea-formaldehyde foam, and individuals who come in contact with large amounts of unwashed permanent press fabrics treated with formaldehyde-releasing resins (CHIP 1979, Chem. Eng. News 1984, ATSDR 1999)

REGULATIONS

Under the authority of the Federal Hazardous Substances Act (FHSA), the Consumer Product Safety Commission (CPSC) requires warning labels on household products containing 1% or more of formaldehyde, warning that formaldehyde is a strong sensitizer. Under the authority of the Consumer Product Safety Act (CPSA), CPSC banned the use of urea-formaldehyde foam insulation in residences and schools. A U.S. Court of Appeals issued an opinion that would vacate the ban. After CPSC petitioned the court for a rehearing that resulted in no change in the decision, the Solicitor General was asked to appeal the decision to the Supreme Court. The Solicitor General did not appeal and the ban was vacated. The CPSC studied the bioavailability and dermal penetration of formaldehyde from textiles. No penetration of the intact skin by formaldehyde was observed. Therefore, no further action, based on carcinogenic risk, was taken on the presence of formaldehyde in textiles. The CPSC worked with the National Bureau of Standards and the Oak Ridge National Laboratory to develop models for indoor air levels of formaldehyde based on emission rates from pressed wood products and is now working with industry to pursue voluntary standards for these products.

EPA regulates formaldehyde under the Clean Air Act (CAA), Clean Water Act (CWA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Food, Drug, and Cosmetic Act (FD&CA), Resource Conservation and Recovery Act (RCRA), Superfund Amendments and Reauthorization Act (SARA), and Toxic Substances Control Act (TSCA). EPA has designated formaldehyde as a hazardous air pollutant, water pollutant, waste constituent, and inert ingredient of pesticide products. EPA has set the reportable quantity (RQ) at 100 lb for formaldehyde under CERCLA. General threshold amounts and a threshold planning quantity have been established under SARA. Under TSCA, EPA requires that manufacturers submit safety and health studies related to exposure to urea-formaldehyde resins.

FDA regulates formaldehyde as an indirect food additive under FD&CA.

ACGIH recommends a ceiling value of 0.3 ppm (0.37 mg/m^3). NIOSH has established a recommended exposure limit (REL) of 0.016 ppm with a 0.1-ppm ceiling exposure concentration over a 15-minute period in the workplace. OSHA has set a permissible exposure limit (PEL) of 0.75 ppm as an 8-hr time-weighted average (TWA). OSHA has also established a short-term exposure limit (STEL) of 2 ppm over a 15-minute period. OSHA regulates formaldehyde under the Hazard Communication Standard and as a chemical hazard in laboratories. Regulations are summarized in Volume II, Table 89.

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