

Formaldehyde Toxicology

Formaldehyde (H₂CO) is the simplest aldehyde; it consists of one carbonyl (C=O). Formaldehyde is produced in nature during the oxidation of methane and other organic compounds, like those found in forest fires. In the atmosphere, sunlight and oxygen act on methane, producing formaldehyde. In industry, formaldehyde is produced by the oxidation of methanol in the presence of a catalyst. Common catalysts are silver or iron oxide mixed with molybdenum or vanadium.

Formaldehyde has many uses in industry. Annual worldwide production of formaldehyde is 21 million tons. About half of this is used to make formaldehyde resins. These resins are extremely strong and are used as permanent adhesives in plywood and carpeting, and are even found in toilet paper, facial tissue, and napkins. The resins can be foamed to make insulation or in castings. Formaldehyde is also used in the textiles industry to make fabrics crease-resistant, and as a preservative in vaccines. Another common use is in embalming human remains. Formaldehyde, of all the aldehydes, works best at preserving human tissue.

Occupational routes of exposure to formaldehyde can occur through inhalation, ingestion, or skin contact. As such, formaldehyde exerts its toxic effects at many sites throughout the body. Acute low-level exposures (0.1-5ppm) can cause upper airway irritation, lacrimation, and burning of the eyes. Higher concentrations can cause inflammation of the lower respiratory tract, leading to narrowing of the bronchi, pneumonitis, and pulmonary edema. In sensitized individuals, asthma has occurred.

Effects on the central nervous system from acute exposures include headaches, sleeplessness, irritability, and malaise. Ingestion of formaldehyde can damage the esophagus and stomach, causing vomiting, diarrhea, abdominal pain, and inflammation of the stomach. If the formaldehyde is stabilized with methanol, systemic toxicity can occur, including permanent loss of vision. Skin contact with formaldehyde solutions or vapors can cause skin irritation and burns. In sensitized workers, even low levels of formaldehyde can cause contact dermatitis.

Chronic exposure of formaldehyde, primarily through inhalation, has been indicated in various forms of cancer. A large study of industrial workers exposed to formaldehyde found an increase in the cases of nasopharyngeal cancer. There is also strong but not conclusive evidence of a relationship between leukemia and occupational exposure to formaldehyde.

Epidemiological studies have not been able to show a link between sinonasal cancer and formaldehyde exposure, mostly due to confounding from wood dust. This resulted in a high relative risk for those in the study, particularly for adenocarcinomas. Because of these findings, the International Agency for Research on Cancer (IARC) has classified formaldehyde as a Group I carcinogen, meaning there is sufficient evidence in humans and experimental animals as to the carcinogenicity of formaldehyde¹.

Because of the many toxic effects from acute and chronic exposure and its industry-wide use, the Occupational Safety and Health Administration (OSHA) has created a standard for protection against formaldehyde². The standard details methods of compliance if exposure is above the permissible exposure limit (PEL) of 0.75ppm as an 8-hour time-weighted average. The short-term exposure limit (STEL) is 2ppm, and the action limit is 0.5ppm.

An employer covered by the formaldehyde standard must conduct monitoring to determine their employee's exposure³. Periodic monitoring must be conducted at least every 6 months if monitoring results are above the action level⁴, or 12 months if above the STEL⁵. After any workplace monitoring is done, affected employees must be notified of the results within 15 working days of receiving the results⁶. Engineering controls and work practices must be implemented to bring areas under the PEL or STEL⁷. When these controls are not sufficient in reducing exposure, respirators must be provided⁸. This, of course, requires compliance with the Respiratory Protection Standard (29CFR1910.134). For employees at or above the action limit, above the STEL, or who are showing signs and symptoms of overexposure to formaldehyde, the standard requires medical surveillance⁹. The standard also details hazard communication¹⁰, employee training¹¹, and recordkeeping¹².

There are several methods of controlling employee exposure to formaldehyde. Perhaps the best would be product substitution, as long as any risks associated with the substituted product are accounted for. Substitution

¹ International Agency for Research on Cancer Monographs, Volume 88, (IARC, 2006)

² Code of Federal Regulations, 29CFR1910.1048

³ 29CFR1910.1048(d)(1)(i)

⁴ 29CFR1910.1048(d)(3)(ii)

⁵ 29CFR1910.1048(d)(3)(iii)

⁶ 29CFR1910.1048(d)(6)

⁷ 29CFR1910.1048(f)(1)

⁸ 29CFR1910.1048(g)(1)(iii)

⁹ 29CFR1910.1048(l)(i)

¹⁰ 29CFR1910.1048(m)

¹¹ 29CFR1910.1048(n)

¹² 29CFR1910.1048(o)

is rarely feasible, especially in the case of formaldehyde where it is required in so many manufacturing processes.

A more likely option would be an engineering control, such as ventilation. Two options for ventilation are dilution or local exhaust. Dilution ventilation relies on mixing of the air to dilute contaminants to safe levels. This type of ventilation requires a lot of energy in order to condition the air. Because of the toxicity of formaldehyde, local exhaust ventilation, like fume hoods or vented embalming tables, should be used. Examples of each, from the 25th edition of the ACGIH Industrial Ventilation Manual, can be found in Figures 1 and 2. These should be placed as close to the source of exposure as possible.

Administrative controls include shift changes. As a last resort, personal protective equipment (PPE) can be explored. An example of PPE is using a respirator to minimize exposure. Use of a respirator requires enrollment in a respiratory protection program and compliance with OSHA's respirator standard¹³. Of course any workplace using formaldehyde should be properly set up and include proper safety items, like emergency eyewashes and showers, and spill kits, as well as good housekeeping practices.

Being informed of the potential health effects of formaldehyde exposure, as well as implementation of proper workplace controls, can limit employee exposure to this often used industrial chemical.

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¹³ 29CFR1910.134