Minimizing the Toxic Effects of Formaldehyde

DANGER: FORMALDEHYDE: IRRITANT AND POTENTIAL CANCER HAZARD: AUTHORIZED PERSONNEL ONLY.

This warning sign is mandated by the Occupational Safety and Health Administration (OSHA, Washington, DC) in any laboratory or industrial area where formaldehyde mixtures or solutions are used in concentrations greater than 0.1% or where materials capable of releasing formaldehyde into the air at concentrations reaching or exceeding 0.1 ppm are used (see “OSHA Safety Mandates for Formaldehyde Exposure”). Formaldehyde may be a lot more than an irritant but much less of a cancer hazard than believed when reports and studies of its toxicity are carefully analyzed.

What Is Formaldehyde?

Natural formaldehyde is a simple and nontoxic but highly reactive organic compound that is environmentally ubiquitous. Low concentrations are normal in fruits and vegetables, and formaldehyde is a metabolite in mammals. The pure product, commercial formaldehyde, is a colorless aldehyde gas with the formula HCHO and a molecular weight of 30.03. It is toxic and has a pungent, suffocating odor. Most formaldehyde is available as 30% to 50% solutions with buffers to inhibit intrinsic polymerization. Formalin, a commercial preparation, is a colorless 37% aqueous solution of formaldehyde that is soluble in alcohol and acetone and has a vapor density of 1.04, a boiling point of 101°C (214°F), a specific gravity of 1.08, and a pH of 2.8 to 4.0. Formaldehyde may be refined or converted to a polymerized white powder or flake known as paraformaldehyde, which slowly releases gaseous formaldehyde. Other names for formaldehyde include formic aldehyde, methyl aldehyde, methylene glycol, and methyleneoxide. Laboratory personnel are exposed to the liquid and gas forms of formaldehyde. Pathology residents, pathology assistants, and histology technicians, in particular, are exposed to the 10% formaldehyde solution through direct contact and inhalation; the 37% to 50% stock solutions are not usually handled by residents. A concern for the safety of our laboratory staff while handling formaldehyde led us to review the literature on formaldehyde toxicity and devise a simple survey of a representative sample of pathology residents on adverse reactions to formaldehyde exposure.

Survey of New York Pathology Residents

We sent 232 questionnaires to house staff in pathology training programs in the New York City metropolitan area. The major question asked the effects of formaldehyde exposure on the resident’s health. A literature review of articles about formaldehyde toxicity, including governmental regulations, also was undertaken to complement the study.
Of the 69 residents responding to all or most questions, 30 (43%) reported exposures from 1 to 5 hours per day, and 29 (42%) from 6 to 10 hours per day. Sixty-two (89%) claimed adverse reactions that were not much different from the adverse reactions reported in the world literature by diverse groups of people in occupational and nonoccupational settings (Table), including anatomic pathologists, histology technicians, and mortuary personnel.

Comment
Formaldehyde, a chemical compound, exists in natural and commercial forms. The medical concern is with the commercial formaldehyde to which many people are exposed in industry, hospitals, and clinical laboratories.

**OSHA Safety Mandates for Formaldehyde Exposure**

- **Monitor exposure**, with follow-up at least every 6 months whenever levels of airborne formaldehyde are at or above the action levels (a concentration of 0.5 ppm calculated as an 8-hour time-weighted average [TWA]) or at least once a year if the levels are at or above the short-term exposure limit (STEL).
- **Provide written notification** of monitoring results to affected employees, including a description of the corrective actions.
- **Post warning signs** where airborne formaldehyde concentrations exceed the TWA or the STEL.
- **Implement engineering and work practice controls** to reduce and maintain exposures at or below the TWA or STEL. Provide appropriate respirators if exposure cannot be reduced and for use during cleanup of spills.
- **Use protective equipment**, including clothing that is impervious to formaldehyde, goggles, and face shields.
- **Provide quick-drench showers and eye wash facilities** within the immediate work area.
- **Establish a program for prevention, detection, and treatment for spills and leaks and a medical surveillance program** for employees in whom signs or symptoms of overexposure to formaldehyde develop.
- **Affix warning labels** on all containers with hazardous concentrations of formaldehyde.
- **Provide safety information and training** for all new and current employees assigned to hazardous areas, at least annually. Include discussion of OSHA regulations and the Material Safety Data Sheet on formaldehyde.
- **Maintain documentation** on all formaldehyde safety programs and corrective actions. Exposure records and determinations must be kept for at least 30 years, and medical records must be kept for the duration of employment of the affected person plus 30 years.

*From OSHA.*

Opportunities for occupational and nonoccupational exposure to commercial formaldehyde abound. An estimated 2.2 million workers in the United States are exposed regularly to formaldehyde. Eighty percent of commercial formaldehyde is used in the production of resins and plastics and by allied industries, such as the plastic board industry. Plastic board is plastic material molded as a flat slab for a variety of uses, eg, in folding cartons instead of paperboard. The remaining 20% of commercial formaldehyde is used to make a wide variety of products, such as laboratory reagents, embalming fluid, animal feed, concrete and plaster, deodorants, dyes, flame retardants, ink, and leather.

Nonoccupational exposure to formaldehyde occurs often. Cigarette smoke and the fumes from automobile exhaust systems and incinerators contain formaldehyde. Municipal and industrial effluents contain formaldehyde, and it may be released into the environment from building materials (eg, particle board and some foam insulation), cosmetics, textiles, furniture, draperies, cooking gas, and preservatives.

The limit for airborne exposure to formaldehyde set by OSHA is 0.75 ppm in an 8-hour time-weighted average and 2 ppm for a 15-minute short-term exposure. No established permissible levels of exposure exist for direct contact with skin, eyes, or mouth because any contact is deleterious, although not necessarily serious or irreversible. OSHA estimates that approximately 37,000 people in 12,000 laboratories, including biomedical, chemical, research, and animal laboratories, are exposed to ambient air containing formaldehyde vapors at levels greater than 0.5 ppm.

The specific hazards of formaldehyde exposure depend on the form of the substance, its concentration, the route of exposure, and the period of exposure (short- or long-term).

The odor threshold of formaldehyde is low, at 1 ppm. However, the perception of the odor of formaldehyde and the irritant effects on the eyes and throat decrease with time because adaptation occurs, thereby increasing the risk of overexposure. The threshold for subjective effects varies considerably from 0.1 to 2.5 ppm; most people feel symptoms in the throat first.

Short-term exposure to formaldehyde induces nasal, ocular, and bronchial symptoms. Mild conjunctival irritation and tearing occur at 3 to 5 ppm, while heavy tearing occurs at 10 to 20 ppm. Direct eye contact may result in
minimal irritation, corneal erosion, clouded vision, or blindness.\textsuperscript{1,2}

Formaldehyde vapors are strong respiratory tract irritants. Irritation of the nose and throat is felt at 0.5 to 2.0 ppm, but higher concentrations may result in progressively more serious respiratory effects; 10 to 20 ppm may provoke cough with or without mucus and difficulty in breathing, and 25 to 30 ppm can produce pulmonary edema and pneumonitis. Exposure to higher concentrations, such as 100 ppm, can cause death.\textsuperscript{1} Fortunately, such extreme formaldehyde concentrations rarely, if ever, are encountered in the hospital and laboratory. If formaldehyde is spilled, however, specific actions should be taken (see “What To Do if Formaldehyde Is Spilled”).

Contact dermatitis is commonly reported as a short-term effect of exposure to liquid formaldehyde, although the actual incidence is low considering the wide extent of exposure. Most reactions are irritative. However, formalin is among the 10 top sensitizers and is incorporated in the standard series for the patch test recommended by the American Academy of Dermatology, Evanston, Ill.

Ingestion of formaldehyde solutions by humans is rare. Ingestion of a diluted solution (0.03\%-0.04\%) may result in gastric and pharyngeal discomfort, whereas ingestion of a concentrated solution (10\%-40\%) provokes severe oral, pharyngeal, and gastric irritation, hemorrhage, ulceration, and, possibly, death.\textsuperscript{1,2}

The long-term effects of exposure to formaldehyde are controversial and mainly include potential carcinogenesis, toxic respiratory effects, and autoimmunity. The American Medical Association (Chicago) concluded, after a comprehensive review of the adverse effects of exposure to formaldehyde, that formaldehyde “acts on humans, principally as an irritant to the eyes and upper respiratory system, and can produce allergic contact dermatitis when aqueous formaldehyde comes into contact with the skin. Formaldehyde is known to cause nasal tumors in some rodents, but it is not proved conclusively to be responsible for these tumors and other tumors in humans.”\textsuperscript{3} Indeed, after many case control, cohort, and proportional mortality studies, the cancer risk to humans posed by inhaled formaldehyde vapors seems remote, particularly at the current levels of exposure.\textsuperscript{1,2}

Just as controversial is the evidence that long-term or repeated exposure to formaldehyde results in toxic respiratory effects or hypersensitivity that may manifest as abnormal pulmonary function,
Ethel L. Tiu, MD, PGY-5 resident in pathology, processes surgical specimens. Note the personal protective equipment as well as other safety features that prevent exposure to formaldehyde, including two exhaust fans. On a counter next to the work station is a formaldehyde dispenser with warning labels and nearby, Material Safety Data Sheets.

chronic bronchitis, asthma, or formation of autoantibodies and formaldehyde-specific serum IgE antibodies.\(^1,3-6\)

**Conclusion**

Formaldehyde is harmful to the skin, eyes, and other tissues on direct contact, and inhalation of vapors irritates the respiratory tract and can induce severe damage to the lungs and even death at very high concentrations. The long-term effects of human exposure to formaldehyde, particularly as related to formaldehyde as a primary cause of chronic bronchitis, asthma, or cancer of the upper or lower respiratory tracts or other sites, have not been satisfactorily evaluated. The proven carcinogenicity in experimental animals, however, underscores the necessity of vigilance during use and efforts to minimize human exposure to reduce any potential carcinogenic risk.\(^\text{©}\

**References**


**What To Do if Formaldehyde Is Spilled**

To minimize injury after a formaldehyde spill, specific steps must be taken.\(^1\) These include the following:

1. **Evacuate all personnel from the area.** Move persons who have been exposed to the formaldehyde to an area with fresh air.
2. **Ventilate the area as much as possible.** Turn on the exhaust fan, open the windows, and open the hood system sash wider. Close the door to prevent the spread of fumes to other areas.
3. **Rescue, treat, or tend to the affected personnel.** Administer oxygen to persons exposed to high concentrations of formaldehyde. Remove contaminated clothing and wash or shower the affected skin, preferably using soap or a mild detergent and abundant water for at least 15 minutes. Chemical burns must be covered with a sterile dry dressing and bandage. Eyes should be washed immediately with abundant water for at least 15 minutes, occasionally lifting the eyelids so water penetrates between eyelids and eyeball. If formaldehyde has been ingested and the victim is conscious, administer milk, activated charcoal, or plain water to inactivate, dilute, or absorb formaldehyde (Note: Any organic material will inactivate formaldehyde). Assess the need for medical surveillance of persons affected and refer them to the employee health service or the emergency department.
4. **Assess the extent of the spill.** Small spills (\(<3.8 \text{ L}\)) can be managed by laboratory personnel. Large spills (\(\geq3.8 \text{ L}\)) usually are handled by the institutional safety department, which may decide to ask an environmental agency for assistance.
5. **For cleanup of small spills, follow these steps:**
   - **Don protective clothing,** which should be available outside areas of risk, including an apron impervious to formaldehyde, nitrile gloves, and nonvented goggles or a full-face respirator with formaldehyde-absorbing cartridges (only fit-tested, medically approved, trained employees are permitted to wear the mask).
   - **Sprinkle** appropriate material from a spill kit (eg, Spill-X-Check Sample, ST-201. Chicago, Ill: ASCP; 1994.\(^\text{©}\
   - **Sweep** the contaminated material from the floor and place it in a sealable plastic waste bag for hazardous material.
   - **Wash** the area thoroughly. Wash the protective equipment and store it.
   - **Write** a report of the incident, including how and where it happened, who reported it, who was injured, the extent of injuries and treatment, the size of the spill, the cleanup procedure, and the action taken to prevent recurrence.\(^1\)


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*From OSHA.\(^1\)
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