THE MASSACHUSETTS TOXICS USE REDUCTION INSTITUTE

Massachusetts Chemical Fact Sheet

Formaldehyde

Formaldehyde is a probable human carcinogen and potential reproductive hazard. Off-gassed from construction products and released by manufacturing facilities and combustion sources, formaldehyde is almost ubiquitous at low levels in both indoor and outdoor air. In 1998, Massachusetts manufacturers used more than 5.6 million pounds of formaldehyde.

FACTS

Chemical Formula:	CH_2O
CAS Number:	50-00-0
Vapor Pressure:	10 mm Hg at -88°C
Water Solubility:	Soluble
Flammability:	Extremely flammable
Description:	Gas at room temp., pungent odor

Hazards

Acute (Short-Term) Health Effects

- Primary acute effects from formaldehyde exposure are eye, nose, and throat irritation and respiratory problems.

- When inhaled, formaldehyde causes coughing, wheezing, chest pains, and bronchitis. At high levels, formaldehyde can cause fluid build-up in the lungs and death.

Chronic (Long-Term) Health Effects

- Formaldehyde is a probable human carcinogen. The U.S. EPA classifies it as a Group B1 carcinogen and the International Agency for Research on Cancer (IARC) classifies it as a Group 2A carcinogen. Studies identified increased incidences of lung and nasopharyngeal cancer.

- Formaldehyde exposure is a potential reproductive hazard, associated with increased incidence of menstrual disorders and pregnancy problems.

(For section references, see endnote #1.)

Exposure Routes

Worker Health

Facilities using formaldehyde must minimize worker exposure:

- Use formaldehyde in closed systems. If a closed production system is infeasible, enclose operations and use local exhaust ventilation.

- Take precautions to avoid formaldehyde contact. If formaldehyde contacts skin, wash immediately and get medical attention.

- A combustible liquid and explosion hazard, any formaldehyde solution should not be heated above its flash point.

Public Health

A widely used chemical, especially in building products, and a byproduct of combustion, formaldehyde is ubiquitous in urban areas and buildings at low levels.

- The highest levels of formaldehyde detected in air have been in indoor air. Contained in many construction products, including plywood and particleboard, unreacted formaldehyde off-gases into the air. Smoking is another source of formaldehyde exposure.

- Manufacturing facilities and combustion sources are major sources of formaldehyde in outdoor air. Automobiles, power plants, incinerators, and refineries create formaldehyde as a byproduct of incomplete combustion.

- Formaldehyde is also formed when sunlight breaks down ozone and nitrogen oxides.

(For section references, see endnote #1.)

Use Nationally and in Massachusetts

In 1996, U.S. manufacturers consumed 9 billion pounds of formaldehyde. The primary national uses of formaldehyde are the manufacture of formaldehyde-based resins and as an intermediary in the manufacture of chemicals, plastics, and controlled release fertilizers. Formaldehyde is an intermediary chemical in the manufacture of acetylene-based chemicals, polyacetal resins, methylenebis-4-phenyl isocyanate, pentaerythritol, and hexamethylenetetramine. Other end uses of formaldehyde include its use as an embalming agent, a stabilizer in gasoline, a drying agent and preservative in cosmetics, and a biocide in drilling fluids.

- Formaldehyde-based resins consumed 4.2 billion pounds of formaldehyde in 1996. Formaldehyde resins are used in adhesive and bonding applications (especially in the manufacture of plywood, particleboard, and oriented strandboard), molding compounds (especially for the automotive and electronics industries), and in protective coating applications.

- The construction industry consumes 60-70% of all formaldehyde-based products. Construction products are a major consumer of formaldehyde resins and polyols (chemicals used in surface coating applications). The formaldehyde resins can be grouped into two main categories: phenolic resins (e.g., phenol-formaldehyde) and amino resins (e.g., urea-formaldehyde and melanine-formaldehyde). Phenol-formaldehyde resins have been used in plywood, varnishes, laminates and foam insulation. Amino resins have been used in plywood, particle board, and medium density fiberboard (for use in cabinets and furniture).

In 1998, Massachusetts' facilities reported using more than 5.6 million pounds of formaldehyde under the Toxics Use Reduction Act (TURA) (see Table 1). Chemical producers are the principal users of formaldehyde in Massachusetts.

- Four chemical producers accounted for 98% of Massachusetts' publicly reportable formaldehyde use in 1998: Borden & Remington (chemical distributor and manufacturer of aqueous dispersants), The Dodge Company (manufactures embalming agents), Perstorp Compounds (manufactures urea- and melamine-formaldehyde resins for molding dinnerware, medical products, and household fixtures) and Shipley Company (manufactures specialty chemicals for use in printed wiring board fabrication and surface finishing). See Table 2.

- One Massachusetts manufacturer, Solutia, Inc. in Springfield, claims trade secret when reporting formaldehyde use. Therefore, no information about that chemical is included in the publicly available TURA database or in total quantities in this factsheet. Information regarding Solutia's releases and off-site transfers is publicly available under the U.S. Environmental Protection Agency (EPA) Toxics Release Inventory (TRI), and is noted in Table 1.

- Other Massachusetts' users of formaldehyde include the electronics, leather tanning, and paper and fabric coating industries. Electronics manufacturers use formaldehyde in the production of printed wiring boards. A leather tanner uses formaldehyde resins in the manufacture of shoe welting. Manufacturers of coated fabrics and paper products use formaldehyde-based chemicals in coating, laminating, and treating applications. Formaldehyde is also incidentally manufactured and released by electricity generation facilities.

Between 1990 and 1998, Massachusetts' formaldehyde use dropped by 39%, or 3.6 million pounds (see Table 1).

- The most significant change occurred between 1992 and 1993, when Perstorp Compounds decreased its formaldehyde use by 3.5 million pounds. Perstorp's overall change from 1990 to 1998 was a decrease of 2.9 million pounds. The Dodge Company also reported a large one-time decrease resulting in an overall 0.6 million pound decrease from 1990 to 1998.

Table 1. Formaldehyde: Use and Output Data for Massachusetts 1990 and 1998 (pounds)

Use Data -- MA TURA	1990	1998	Change	% Change
Manufactured or Processed	9,148,693	5,575,926	-3,572,767	-39%
Otherwise Used	36,230	25,288	-10,942	-30%
Total TURA Inputs	9,184,923	5,601,214	-3,583,709	-39%
Output Data -- MA TURA	**1990**	**1998**	**Change**	**% Change**
Generated as Byproduct	280,221	62,639	-217,582	-78%
Shipped In or As Product	8,162,243	5,486,096	-2,676,147	-33%
Total TURA Outputs	8,442,464	5,548,735	-2,893,729	-34%
Releases and Transfers -- US EPA, TRI	**1990**	**1998**	**Change**	**% Change**
Environmental Releases	180,152	48,829	-131,323	-73%
Off-site Transfers	23,951	11,084	-12,867	-54%
Total TRI R&T	204,103	59,913	-144,190	-71%

Note: Releases and Transfers do not include quantities publicly reported to the U.S. Environmental Protection Agency (EPA) under the Toxics Release Inventory (TRI) by Solutia Inc., Springfield, MA. Solutia claims trade secret under the Massachusetts Toxics Use Reduction Act (TURA), therefore its data are not part of the TURA publicly available database. Under TRI, Solutia reported 570,750 lb of off-site transfers and 390 lb of environmental releases for formaldehyde in 1997; Table Sources: MA TURA -- data, 2000; and US EPA, TRI data, 1999.

Table 1 includes two sources of "output" data: Massachusetts TURA and U.S. EPA TRI. The TURA database includes all non-product material created by a process line prior to release, on-site treatment, or transfer ("byproduct") and the amount of toxic chemical incorporated into a product ("shipped in or as product"). The U.S. EPA, TRI database includes information on the waste materials generated by a facility after on-site treatment including: releases to air, land, and water ("environmental releases") and transfers off-site for treatment or disposal ("off-site transfers"). Mirroring the decline in use, MA TURA formaldehyde outputs declined by 34% between 1990 and 1998.

- Perstorp Compounds and The Dodge Company together shipped 3.5 million less pounds of formaldehyde in product in 1996 than in 1990.

- Formaldehyde "shipped in or as product" only declined by 2.7 million pounds because other users that reported in 1990 increased shipments and new reporters (facilities that did not report in 1990) reported shipping 0.6 million pounds of formaldehyde in 1998.

TRI environmental releases declined by 73%.

- One leading cause of the decline was Perstorp Compounds. Perstorp Compounds cut releases by 92%, or 64,000 pounds, between 1990 and 1998. In 1990 PWA Rollan Décor, Inc. reported 67,400 pounds, and no longer reported after 1992.

- Apparent increases resulted from reporting by electricity generation facilities, which were not required to report in 1990, and reported 25,000 pounds of releases in 1998.

(For section references, see endnote #2.)

Alternative Manufacturing Processes

Manufacture of Phenolic Resins

Alternative methods for manufacturing phenolic resins include enzymatic water-based polymerization processes (based on horseradish peroxidase and soy peroxidase) and pyrolysis of biomass.

- In 1998, the Institute's University Research in Sustainable Technologies Program funded research into the control of hydrogen peroxide (an enzymatic inhibitor) in the horseradish peroxidase process.

- The soy peroxidase enzyme can be used to manufacture a variety of phenolic resins. These systems can result in decreased processing time and increased yield.

Table 2. Formaldehyde: Consumption by Use Categories in Massachusetts (1990 and 1998)

Use Category [1]	Facility Name	Use (pounds) 1990	Use (pounds) 1998	Percent Change
Chemical Products [4]	Chemical Distributor/Specialty Chem. Mfr.			
	Borden & Remington	0 [2]	607,554	n/a [3]
	Chemical Distributor			
	Monson Companies Inc	26,385	0	-100%
	Electronics			
	Shipley Co Inc	586,000	826,000	41%
	Specialty Polymers	84,150	0	-100%
	Embalming			
	The Dodge Company	1,300,000	693,000	-47%
	Thermoset Molding Compounds			
	Perstorp Compounds Inc	6,241,211	3,339,066	-46%
	Polyamide Resins			
	Hercules Inc	606,180	0	-100%
	End-uses Unknown			
	WR Grace & Co	45,799	0	-100%
	subtotal	8,889,725	5,465,620	-39%
Coating and Laminating Applications	Fabric Coating			
	Lewcott Corporation	0	13,908	n/a
	Paper Coating and Laminating			
	Crane & Co Inc Pioneer Mill	53,366	0	-100%
	Hollingsworth & Vose Company	16,000	19,000	19%
	Munksjo Paper Decor Inc	0	20,816	n/a
	National Coating Corp	10,258	0	-100%
	PWA Rollan Décor Inc	108,000	0	-100%
	subtotal	187,624	53,724	-71%
Electronic Components	Altron	24,450	0	-100%
	Bull HN Information	12,000	0	-100%
	Printed Circuit Corp	13,096	25,288	93%
	Sanmina Corp	0	32,453	n/a
	subtotal	49,546	57,741	17%
Leather Tanning	FAPL Inc	47,286	0	-100%
	subtotal	47,286	0	-100%
Electricity Generation	Canal Electric Co.	0	12,882	n/a
	Sithe New England Holdings LLC	0	11,247	n/a
	subtotal	0	24,129	n/a
Abrasives	Tyrolit North America Inc	10,742	0	-100%
	subtotal	10,742	0	-100%
Total		9,184,923	5,601,214	-39%

[1] Use Categories were assigned based on the Institute's examination of TURA data and in some cases may not represent the actual use; [2] "0" indicates that the facility is either not using the chemical or has dropped below the reportable threshold; [3] n/a = not applicable; [4] Does not include quantities claimed trade secret by Solutia Inc. Source: Massachusetts Toxics Use Reduction Act data, 2000.

- The National Renewable Energy Laboratory of the U.S. Department of Energy has researched the use of pyrolysis (rapid heating in the absence of oxygen) of agricultural and forestry wastes to produce phenolic resins. This process is predicted to cost half as much as the current process.

Printed Wiring Boards

In the manufacture of printed wiring boards, it is necessary to make through-holes conductive. The most common process to accomplish this is the formaldehyde-containing electroless copper process. Formaldehyde acts as a reducing agent in the process.

- The U.S. EPA, through its Design for the Environment Printed Wiring Board Project, has evaluated the technical, environmental and financial performance of alternatives to the formaldehyde-containing electroless copper process. Carbon, graphite, organic-palladium, tin-palladium, non-formaldehyde electroless copper (sodium hypophosphite reducing agent) and conductive polymer technologies have been evaluated. These technologies have proven viable and have been implemented for their lower operating costs in addition to their environmental benefits. However, lack of capital, knowledge about, and confidence in these alternatives have hampered their adoption.

Other processes

- Formaldehyde resins have been used to improve the wrinkle resistance of garments but due to the formaldehyde off-gassing and emission issues, replacements such as glyoxal resins, butanetetracarboxylic acid, sodium hypophosphite, and polymeric carboxylic acid/citric acid are being investigated.

- In many surface coating applications, alternatives to the formaldehyde-containing resins have been developed in an effort to comply with the Clean Air Act Amendments. These include water-based, ultraviolet-cured and E-beam-cured systems.

Alternatives for Consumer Products

Building Materials

Traditionally formaldehyde has been a component of the resins used in many building materials. As far back as the 1970s, the off-gassing of formaldehyde from these products, particularly foam insulation and medium density fiberboard, caused concern. During the last 30 years manufacturers have developed many “formaldehyde-free” and “low-formaldehyde” products.

- Alternative building materials currently include those made from non-wood sources (e.g., straw-based particleboard, rammed earth, metal, stone, brick) or solid wood.

- Pressed wood alternatives include those labeled “formaldehyde-free” or “low-emitting” or those made from phenol-formaldehyde (such as oriented strand board, softwood plywood or exterior grade plywood) rather than urea-formaldehyde as the phenol-formaldehyde products generally emit lower levels of formaldehyde.

Embalming and Tissue Preservation

Embalming is a mortuary custom of temporarily preserving bodies after death, generally by the use of chemical substances and most often by the use of formaldehyde (a fungicide and bactericide) in the U.S. and Canada. Formaldehyde is also used to preserve biological specimen in middle and high school and university laboratories.

- Respecting personal choice and religious custom, embalming may not be necessary depending on the funeral arrangements.

- Concern for mortuary workers’ exposures to formaldehyde has prompted research into alternative embalming chemicals. Ethyl alcohol/polyethylene glycol, glutaraldehyde and phenoxyethanol are alternatives to formaldehyde but may possess other worker health and safety concerns.

- One study funded by the U.S. EPA in the Burlington, Mass. public school system found that formaldehyde odors may have routinely exceeded permissible exposure limits and that the laboratories lacked sufficient ventilation. Less toxic alternatives are readily available from scientific supply vendors.

(For section references, see endnote #3.)

Regulatory Context

The U.S. Occupational Safety and Health Administration (OSHA), U.S. EPA, and Consumer Product Safety Commission regulate formaldehyde.

- The OSHA permissible exposure limit (PEL) for an eight-hour workshift for formaldehyde is 0.75 ppm and the short-term exposure limit (STEL) — not to be exceeded during any 15-minute work period—is 2 ppm.

The U.S. EPA regulates formaldehyde under the authority of six environmental statutes. Under the:

- Clean Air Act: formaldehyde is both a “hazardous air pollutant” and a “regulated toxic, explosive, or flammable substance.”
- Comprehensive Environmental Responsibility, Compensation and Liability Act (popularly known as “Superfund”): formaldehyde is an “extremely hazardous substance.”
- Emergency Planning and Community Right-to-Know Act, TRI program: all large quantity users of formaldehyde must submit data on environmental releases and off-site transfers.
- Federal Insecticide, Fungicide, and Rodenticide Act: formaldehyde is a “registered pesticide.”
- Resource Conservation and Recovery Act: formaldehyde is a “hazardous constituent.”

The Consumer Product Safety Commission, under authority of the federal Hazardous Substances Act, requires all household products with 1% or more formaldehyde to have a warning label.

(For section references, see endnote #4.)

Endnotes

1 Environmental Defense Fund (EDF), 1999, “Chemical Profile: Formaldehyde” (New York: EDF; see webpage: http:/www.scorecard.org/chemical-profiles); Environmental Health Center (EHC is a division of the National Safety Council), 1997, “Environment Writer: Formaldehyde (HCHO) Chemical Backgrounder” (Washington, D.C.: EHC; see webpage: http://www.nsc.org/ehc/ew/chems/formalde.htm); Richard J. Lewis, Sr. (ed.), 1993, *Hazardous Chemicals Desk Reference* (third edition) (New York: Van Nostrand Reinhold); U.S. EPA, Office of Air Quality Planning and Standards, 1998, “Formaldehyde” (Washington, D.C.: U.S. EPA—see webpage: http://www.epa.gov/ttn/uatw/hlthef/formalde.html); World Health Organization (WHO), 1990, “International Chemical Safety Card: Formaldehyde” (ICSC: 0275) (Geneva: WHO; see webpage: http://www.cdc.gov/niosh/ipcsneng/neng0275.html); U.S. EPA, Office of Research and Development, 1988, *Health and Environmental Effects Profile for Formaldehyde* (EPA/600/x-85/362) (Cincinnati, Ohio: EPA).

2 Stanford Research Institute (SRI) International, 1997, *Chemical Economics Handbook*, “Formaldehyde” (Palo Alto, California: SRI); Massachusetts Department of Environmental Protection (MA DEP), 2000, “Mass. TUR Act Chemical Reporting Data” (Boston: MA DEP).

3 National Safety Council Environmental Health Center, “Formaldehyde,” (Washington, D. C.: National Safety Council – see webpage: http://www.nsc.org/EHC/indoor/formald.htm); U.S. EPA, 1998, “Alternative Technologies for Making Holes Conductive: Cleaner Technologies for Printed Wiring Board Manufacturers,” EPA/744-R-98-002, (Washington, D.C.: U.S. EPA – see webpage: http://www.epa.gov/opptintr/dfe/pwb/pubs.htm); Massachusetts Toxics Use Reduction Institute (MA TURI), “Formaldehyde Use Reduction in Mortuaries,” 1994, (Lowell, MA: TURI); U.S. EPA, “A Case Study of Environmental, Health and Safety Issues Involving the Burlington, Massachusetts Public School System: Formaldehyde,” (Washington, D.C.: U.S. EPA – see webpage: http://www.epa.gov/rgytgrnj/kids/dress10.htm); Institute for Local Self-Reliance, 1992, “The Carbohydrate Economy,” (Washington, D.C.: Institute for Local Self-Reliance – see webpage http://www.carbohydrateeconomy); Wei, Weishu and Charles Yang, 2000 “Polymeric Carboxylic Acid and Citric Acid as a Nonformaldehyde DP Finish,” *Textile Chemist and Colorist*, (Research Triangle Park, NC: American Association of Textile Chemists and Colorists) Vol. 32, No. 2, February 2000.

4 EDF, 1999; and SRI International, 1997 (see endnotes #1 & #2)