Massachusetts Chemical Fact Sheet

Formaldehyde

This fact sheet is part of a series of chemical fact sheets developed by TURI to help Massachusetts companies, community organizations and residents understand the chemical's use and health and environmental effects, as well as the availability of safer alternatives.

A simple and versatile substance, many products are made from or contain formaldehyde, including resins and adhesives, permanent press fabric treatments, tissue preservatives, lawn fertilizers, cosmetics and disinfectants. Formaldehyde has been linked to cancer in humans and may cause adverse reproductive outcomes.

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. It is often targeted as a cause of health complaints associated with "sick building syndrome," such as respiratory irritation and headaches.

In 2010, Massachusetts companies used more than 2.5 million pounds of formaldehyde.

FORMALDEHYDE FACTS	
Chemical Formula	**CH_2O**
CAS Number	**50-00-0**
Solubility	Very soluble in water and polar solvents; up to 55% soluble in freshwater at 20 °C
Flammability	Extremely flammable
Description	Colorless gas at room temperature and pressure with a strong, irritating odor. Often in solution as formalin.

Hazards

Because it is highly reactive, water soluble and rapidly metabolized, people may experience toxic, irritating and sensitizing effects at the site of contact. Inhaled formaldehyde is readily absorbed by the upper respiratory tract and is rapidly metabolized by almost every cell in the body.

Acute (Short-Term) Health Effects

- Acute exposure to formaldehyde causes throat, nose, eye and skin irritation. People with asthma may be more sensitive to the effects of inhaled formaldehyde.
- Skin contact results in severe irritation and burns and some formaldehyde may pass through the skin.
- When inhaled, formaldehyde causes narrowing of the bronchi resulting in coughing, wheezing, chest pains, and bronchitis. At high levels, formaldehyde can cause fluid build-up in the lungs and can result in death.

Chronic (Long-Term) Health Effects

- In 2006, IARC changed the formaldehyde classification from Group 2A (probable human carcinogen) to Group 1 (carcinogenic to humans). This classification was based on "sufficient evidence of nasopharyngeal cancer in humans, strong but not sufficient evidence of leukemia in humans, and limited evidence of sinonasal cancer in humans." In 2009, IARC reaffirmed the Group 1 classification and also concluded that there was sufficient evidence of leukemia in humans.
- Studies conducted by the National Cancer Institute (NCI) found an increased risk of lung and nasopharyngeal cancers and leukemia among funeral industry workers, such as embalmers in mortuaries, from occupational exposure to formaldehyde.
- The Association of Occupational and Environmental Clinics (AOEC) lists formaldehyde as an occupational asthmagen. The Collaborative on Health and the Environment (CHE) states that there is good evidence for an association between formaldehyde and the onset of allergic asthma. Studies indicate that repeated prolonged exposures may result in sensitization of the individual, who are then more likely to experience contact dermatitis and asthma attacks.
- Formaldehyde exposure has been associated with reproductive effects such as spontaneous abortions, congenital malformations, low birth weights, infertility and endometriosis.

(For section references, see endnote #1)

Exposure Routes

The primary route of exposure is through inhalation. Occupational and consumer exposure can, however, also include dermal exposure, especially to formaldehyde in solution.

Worker Health

The primary sources of occupational exposure to formaldehyde are:

- Industrial production (resins, molding compounds, fertilizer, paper, wood products, furniture, laminates, plastics, pesticides, chemical manufacture, rubber, leather tanning, iron foundries, photographic film, textiles, scientific supply and cosmetics)

- Agriculture (sugar production, grain and seed preservation)
- Oil extraction (well-drilling fluids)
- Funerary work (embalming fluid)
- Hospitals, laboratories and schools (preserved tissue and specimens)
- Construction (manufactured wood products)
- Transportation and energy (product of combustion)
- Beauty salons (sanitizers, hair products and cosmetics)

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. Formaldehyde is regarded as a common indoor air contaminant. Contained in many construction products and home furnishings (including plywood, particleboard, medium density fiberboard, oriented strand board, insulation, carpets, other flooring, and related adhesives), unreacted formaldehyde off-gases into the air. Off-gassing is highest for new products and decreases over time. Tobacco smoke is another source of formaldehyde exposure in indoor environments.
- Manufacturing facilities and combustion sources are major sources of formaldehyde in outdoor air. Additional sources include automobiles, power plants, incinerators, and refineries which create formaldehyde as a byproduct of incomplete combustion.
- Formaldehyde is formed when sunlight breaks down ozone and nitrogen oxides, and is therefore found in smog in the lower atmosphere.
- Consumer products such as antiseptics, medicines, cosmetics, hair care products, permanent-press clothing, fabric softeners, shoe-care agents, carpet cleaners, glues and adhesives, lacquers, paper and plastics can contain formaldehyde.

Environmental Fate

Formaldehyde is a natural component of the environment and the human body. It biodegrades readily in air, water and soil under both aerobic and anaerobic conditions. In the air, formaldehyde breaks down in sunlight to form carbon monoxide and formic acids, a component of acid rain. It is not commonly found in drinking water and only in limited quantities in foods such as cheeses and grains where it occurs naturally and is also added to kill pathogens. Formaldehyde is not bioaccumulative.

(For Hazard and Exposure Route references, see endnote #1)

Use Nationally and in Massachusetts

Formaldehyde is a basic building block chemical and it finds its way, either directly or in derivative chemicals, into almost all sectors of the economy and thousands of products.

Formaldehyde is available in multiple forms. These include formaldehyde gas, formalin solution (formaldehyde dissolved with methanol in water), trioxane, and paraformaldehyde (a polymerized form of formaldehyde). While available and used in a variety of concentrations, formaldehyde is most commonly used in 37% formalin solutions.

U.S. manufacturers' annual consumption is about 10 billion pounds of formaldehyde. Because of formaldehyde's chemical properties which inhibit long range export, U.S. formaldehyde production closely tracks U.S. consumption. The U.S. formaldehyde market decreased by over 15%, between 2006 and 2010, largely due to the decline in the housing market and the construction industry.

The primary uses of formaldehyde are the manufacture of formaldehyde-based resins and as an intermediary in the manufacture of chemicals, plastics, and controlled-release fertilizers. Wood adhesives used to make plywood, particleboard and other manufactured wood products are the dominant end use of formaldehyde, accounting for 63% of the total worldwide consumption in 2009. Formaldehyde resins can be grouped into two main categories: phenolic resins and amino resins (e.g., urea-formaldehyde and melanine-formaldehyde). Phenol-formaldehyde resins are used in plywood, varnishes, laminates and foam insulation. Amino resins are used in plywood, particle board, and medium density fiberboard (for use in cabinets and furniture).

Formaldehyde is an intermediary chemical in the manufacture of several commercially important chemicals, including 1,4-butanediol (used to make polyurethane and spandex® fibers), methylene diisocyanate (MDI is a common substitute for formaldehyde in wood adhesives) and amino polycarboxylic acids (e.g., EDTA), which are used in cosmetics, pesticides and textile coatings. Other end uses of formaldehyde include embalming agents, gasoline stabilizers, drying agents, preservatives in cosmetics, and biocides in metal machining fluids.

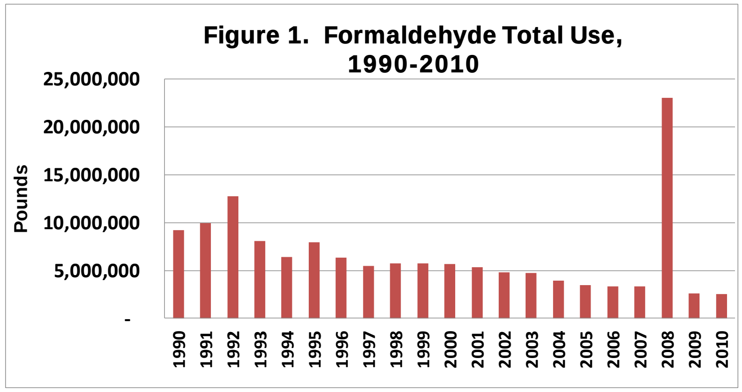
Massachusetts experienced an overall 73% reduction in the use of formaldehyde from 1990 to 2010

- Seven facilities reported using formaldehyde in 2010, a decrease from 16 facilities in 1990. In 2008 reported use of formaldehyde increased significantly due to reporting by one facility that in both prior and subsequent years claimed trade secret (as shown in Figure 1).
- In 2010, Massachusetts' facilities reported using more than 2.5 million pounds of formaldehyde under the Toxics Use Reduction Act (TURA) (see Table 1).
- Three companies accounted for over 84% of Massachusetts' publicly reportable formaldehyde use in 2010: The Dodge Company (manufacturer of embalming agents), Chemiplastica (manufacturer of urea- and melamine formaldehyde resins for molding dinnerware,

medical products, and household fixtures) and Rohm & Haas Electronic Materials (manufacturer of specialty chemicals for use in printed wiring board fabrication and surface finishing).

- One Massachusetts manufacturer, INEOS Melamines LLC in Springfield, typically claims trade secret when reporting formaldehyde use; trade secret information is not included in the publicly-available TURA database or in total quantities in this factsheet. However, the 2008 data were not claimed trade secret, and indicated that INEOS Melamines used 10 times more formaldehyde than the other users combined for that reporting year.

Table 1 summarizes the uses of formaldehyde in Massachusetts in 1990 and 2010.



Between 1990 and 2010, use of formaldehyde in Massachusetts dropped by almost 8.5 million pounds.

Table 1. Summary of Formaldehyde Use in Massachusetts

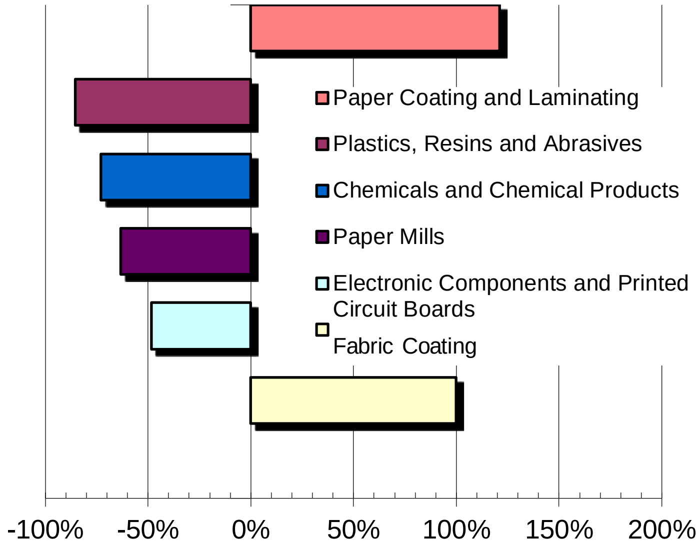
Industry Sector	*Facility Name*	*Location*	*Use (pounds)*	
			1990	***2010***
Chemicals and Chemical Products	Borden & Remington	Fall River	1,792,554**	74,570
	Monson Companies Inc.	Leominster	26,385	0
	The Dodge Company	Cambridge	1,300,000	785,734
	WR Grace & Company	Acton	45,799	0
Fabric Coating	Lewcott Corporation	Millbury	0	209,648
Paper Coating and Laminating	Suddekor LLC	East Longmeadow	0	51,647
	National Coating Corporation	Rockland	10,258	0
	Printed Circuit Corporation	Woburn	13,096	0
Paper Mills	Crane & Co Inc. Pioneer Mill	Dalton	53,366	0
	Hollingsworth & Vose Company	West Groton	16,000	0
	Onyx Specialty Papers Inc. - Willow Mill	South Lee	0	65,193
	PWA Rollan Decor Inc.	Fitchburg	108,000	0
Electronic Components and Printed Circuit Boards	Altron	Wilmington	24,450	0
	Rohm & Haas Electronic Materials	Marlborough	586,000	321,042
	Bull HN Information Systems	Boston	12,000	0
Plastics, Resins and Abrasives	Hercules Inc.	Chicopee	606,180	0
	Chemiplastica (formerly Perstorp Compounds)	Florence	6,241,211	1,009,180
	Specialty Polymers	Leominster	84,150	0
	FAPL Inc.	Worcester	47,286	0
	Tyrolit North America Inc.	Westborough	10,742	0
		Total Formaldehyde Use	***10,977,477***	***2,517,014***

*** Borden & Remington began reporting formaldehyde in 1991*

- A significant change occurred between 1992 and 1993, when Chemiplastica (then Perstorp Compounds) decreased its formaldehyde use by 3.5 million pounds. Overall, Chemiplastica reduced its use of formaldehyde by approximately 5.2 million pounds from 1990 to 2010.
- Between 1990 and 1991 The Dodge Company, which manufactures embalming chemicals, reported a one-time 750,000 pound reduction in formaldehyde processing. This decrease was accompanied by an increase in methanol use of over 112,000 lb. Dodge then steadily increased its use of formaldehyde by over 60% from 1991 to 2010.
- Borden & Remington, which has used formaldehyde to manufacture dispersants and also repackages formaldehyde for resale, first reported formaldehyde in 1991. In 2004, their use decreased substantially, and they reported only repackaging formaldehyde for resale.

Figure 2 illustrates the percent changes in use by industry sector. As shown in Figure 2, increases in use of formaldehyde between 1990 and 2010 are related to the coating and laminating applications.

Figure 2. Percent Change in Formaldehyde Use by Industry Sector from 1990 to 2010



Lewcott Corporation had not used reportable amounts of formaldehyde in 1990. It began reporting in 1993 and showed an 83% increase in use from 1993 to 2010. Lewcott only represents about 8% of the total formaldehyde used in Massachusetts in 2010. Suddekor is a relatively new manufacturer in Massachusetts, and has only been reporting on its use of formaldehyde since 2007. Between 2007 and 2010 Suddekor has increased its use of formaldehyde by 70% (though the total amount of formaldehyde used by this company only represents about 2% of the total amount used in Massachusetts).

Both inputs (including formaldehyde that is manufactured or processed, as well as formaldehyde that is "otherwise used" – ancillary uses that do not become incorporated into the final product) and outputs (including formaldehyde that is generated as byproduct and the amount that is shipped in or as product) have been significantly reduced in the Commonwealth from 1990 to 2010.

From 1990 to 2010 the amount of formaldehyde manufactured or processed was reduced by 73%; the amount of formaldehyde that was otherwise used decreased by more than 96%. The amount shipped in product over the same time period was reduced by over 86% and the amount of byproduct generated decreased by over 67%. Of note:

- Chemiplastica reduced its generation of formaldehyde byproduct by 68,500 pounds, between 1990 and 2010.
- Bordon & Remington reported 1.2 million pounds of formaldehyde shipped in product and 13,800 pounds generated as byproduct in 1991. By 2010 they had reduced both these quantities significantly – shipping only 74,569 pounds in product, and generating only 1 pound as byproduct (because dispersants no longer manufactured).
- A significant contributor to the amount of byproduct generated in 1990 was PWA Rollan Décor, Inc. who reported 71,500 pounds. Later purchased by Munksjo Paper, Inc., their byproduct had dropped to 11,137 lbs in 1998, their final year of reporting formaldehyde.

(For National and Massachusetts Use references, see endnote #2)

Alternative Manufacturing Processes

Coating and Laminating Applications

Formaldehyde is used as a wet strength resin in paper coating for architectural finish applications, and a fiber relaxer in fabric coating applications.

- Substitute paper coating resins can be made from polyamide, polyamine, epichlorohydrin and acrylic, as well as polyurethane dispersions. Some of these alternatives pose health concerns. Additional research is needed.
- Formaldehyde resins have been used to improve the wrinkle resistance of garments. However, due to the formaldehyde off-gassing and emission issues, replacements are being investigated. Alternatives that are showing some efficacy include phosphinocarboxylic acid, maleic acid and sodium hypophosphite. Other possible alternatives include glyoxal resins, butane tetracarboxylic acid, and polymeric carboxylic acid/citric acid.

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.

- TURI has 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.
- 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, electroless copper using sodium hypophosphite as the reducing agent, and conductive polymer technologies have been evaluated.

- Other potential alternatives include electroless nickel, conducting polymers like polypyrrole and non-formaldehyde-based electroless copper.
- Two formaldehyde-free electroless copper systems exist: the first of which uses hypophosphite as an alternative reducing agent to formaldehyde; the second is a catalytic process that uses a boron compound as an alternative reducing agent to formaldehyde

Other Processes

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 electron beam-cured systems.

Product Alternatives

Sanitary Storage in Barbering/Cosmetology

The Massachusetts Board of Cosmetology currently requires that "dry sanitizer" be used in drawers where hair brushes are kept. This dry sanitizer is para-formaldehyde, a solid form of formaldehyde. The TURA program has been working with the Board to amend its regulations to eliminate this requirement.

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 in the U.S. and Canada by the use of solutions containing formaldehyde. Formaldehyde is also used to preserve biological specimens in middle and high school and university teaching and research 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, although these may pose other worker health and safety concerns.
- One study funded by the U.S. EPA in the Burlington, Mass. public school system found that formaldehyde in science laboratories may have routinely exceeded permissible exposure limits and that the laboratories lacked sufficient ventilation. Less toxic alternatives are readily available from scientific supply vendors. Alternatives to formaldehyde preservation of specimens that best replicate the technical specifications of formaldehyde-preserved specimens for educational purposes include various formaldehyde-free solutions (e.g., propylene glycol, diazolidinyl urea and glutaraldehyde) and video/virtual dissection. Again, some of these alternatives have health and safety concerns, in particular glutaraldehyde, which is an asthmagen.

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.

Building materials of interest include hardwood plywood (used for exterior building panels, and high-end interior applications such as bathroom and kitchen cabinetry) and structural panels.

- In 2009 TURI funded research into alternative resin systems as replacements for the formaldehyde-based phenolic resins commonly used in building products. This research investigated the use of epoxidized vegetable (soy, linseed and castor) oils as alternative feedstocks. Additional research and development would be necessary to create a viable alternative for specific building products.
- Alternative building materials include those made from non-wood sources (e.g., recycled paper, wood fiber-Portland cement blend, rammed earth, metal, stone and brick) or solid wood. Agricultural fiber alternatives can come from crops grown specifically for fiber (e.g., kenaf and bagasse) and residues of crops grown for other purposes (e.g., corn stalks/cobs and cotton stalks).
- Pressed wood adhesive 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) generally emit lower levels of formaldehyde.
- Hardwood plywood and softwood plywood or oriented strand board can be manufactured using alternative adhesives, such as the soy-based resin developed for wood panel applications by Columbia Forest Products. Note that one of the resin feedstocks is epichlorohydrin, which is a probable human carcinogen that can result in negative impacts on respiratory and hematological systems.
- Composites of wood fiber and polypropylene thermoplastics are used extensively as substitutes for wood lumber, and are being developed for use in wood panel applications.
- Soybean protein modified with sodium dodecyl sulfate can also be used as an alternative resin for wood fiber medium density fiberboard preparation.

(For Alternative Process and Product references, see endnote #3)

Regulatory Context

Table 2 summarizes pertinent regulations that affect the use of formaldehyde both in the United States and internationally.

Table 2. Summary of Regulations

US Federal Regulation	
Emergency Planning and Community Right-to-know Act	• Subject to reporting under TRI Sec. 313 • 500 lb reporting threshold under TPQ Sec. 302 and 100 lb reporting threshold under Sec. 304
Clean Air Act	• A listed Hazardous Air Pollutant, and is subject to the Maximum Achievable Control Technology (MACT) standards for devices under the Clean Air Act.
Occupational Safety and Health Act	• Time weighted average permissible exposure limit = 0.75 ppm • Short term exposure limit = 2 ppm • Immediately Dangerous to Life or Health limit = 100 ppm • Employers must take action to protect employees if exposures reach 0.5 ppm.
Safe Drinking Water Act	Federal drinking water guidelines are for no more than 1,000 µg/l formaldehyde.
Consumer Product Safety Commission	All household products with 1% or more formaldehyde to bear a warning label.
FIFRA	Registered pesticide
Massachusetts Regulations	
Toxics Use Reduction Act	Designated as a high hazard substance, and subject to reporting when more than 1,000 lb/year used
Public and Environmental Health	Ambient Air Guidelines: 24-hour threshold effects exposure limit is 2 ppb; allowable ambient limit: 0.06 ppb
Other U.S. State Regulations	
California	Listed as a carcinogen under Proposition 65 of the Safe Drinking Water and Toxics Act of 1986
International Regulations	
European Union	Formaldehyde is a candidate for authorization under the REACH directive
Non-Regulatory Initiatives	
Leadership in Energy and Environmental Design	No urea-formaldehyde resins may be used in building products under this leadership standard

(For Regulatory Context references, see endnote #4)

Endnotes

1. Agency for Toxic Substances and Disease Registry, 1999, "*ToxFAQs:Formaldehyde, CAS #50-00-0*", US Dept of Public Health, Public Health Service; Environmental Defense Fund (EDF), 1999, "*Chemical Profile: Formaldehyde*" (New York: EDF; see webpage: http://www.scorecard.org/ chemical-profiles/summary.tcl?edf_substanc_id=+50-00-0); International Agency for Research on Cancer, Agents Reviewed by the IARC Monographs: Volume 1-100A. Available at http://monographs.iarc.fr/ENG/Classification/ Listagentsalphorder.pdf; National Academy of Sciences, "Review of the Environmental Protection Agency's Draft IRIS Assessment of Formaldehyde," April 2011; A Review of Human Carcinogens – Part F: Chemical Agents and Related Occupations. *The Lancet Oncology*, Volume 10 (12): 1143-1144; National Cancer Institute. 2009. Factsheet: Formaldehyde and Cancer Risk. Available at http://www.cancer.gov/images/documents/687f2693-82b5-4ec7-9c6f-e4e917d6ee53/Fs3_8.pdf; Collaborative on Health and the Environment (CHE); Environmental Health Center (a division of the National Safety Council), 2002, "IAQ Factsheet: Formaldehyde" (Washington, D.C.: EHC; see webpage: http://www.nsc.org/EHC/indoor/formald.htm); Hazardous Substances Data Bank "*Formaldehyde*" – see webpage: http://www.toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~lIYS59:1;U.S. EPA, Office of Air Quality Planning and Standards, 2000, "*Formaldehyde*" (Washington, D.C.: U.S. EPA—see webpage: http://www.epa.gov/ ttn/uatw/hlthef/formalde.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. "Formaldehyde Uses and Market Data", accessed at www.icis.com/v2/ chemicals/9076013/formaldehyde/uses.html; Stanford Research Institute (SRI) International, 2009, *Chemical Economics Handbook*, "Formaldehyde" (Palo Alto, California: SRI); Massachusetts Department of Environmental Protection (MA DEP), 2010, "Mass. TUR Act Chemical Reporting Data" (Boston: MA DEP). Toxics Use Reduction Institute "Five Chemicals Alternatives Assessment Study" 2006 – see webpage: http://www.turi.org/ industry/research/five_chemicals_study
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