Massachusetts Chemical Fact Sheet

Chlorine

Often the subject of environmental and public health concerns by association with chlorinated chemicals like polychlorinated biphenyls (PCBs) and chlorinated fluorocarbons (CFCs), chlorine itself is a potentially serious hazard to workers and the environment. In Massachusetts, overall chlorine use is declining. However, in some industry sectors like high tech etching, gold refining, chlorinated rubber products, and water purification, its use is on the rise. In most applications safer substitutes for chlorine are available, but sometimes at a higher cost

FACTS

Common Name:	Chlorine
Chemical formula:	Cl_2, gas
CAS Number:	7782-50-5
Vapor Pressure:	4,800 mm Hg, 20°C
Water Solubility:	Slightly Soluble

Chlorine gas is heavier than air.

Hazards

Acute (Short-Term) Health Effects

Chlorine poses the greatest potential for harm to human health through acute exposure.

- Chlorine is an extremely corrosive gas. It will burn skin, eyes, nose, throat, lungs, and even teeth at doses as low as 15 parts per million (ppm).
- At doses of 25 ppm, chlorine may burn the lungs, cause fluid buildup (pulmonary edema), and result in death.
- A chlorine gas leak at an industrial or wastewater treatment facility poses a serious hazard to worker and public health.

Chronic (Long-Term) Health Effects

- The lungs are the primary organs effected by chronic chlorine exposure. Repeated exposure to chlorine may result in bronchitis or pneumonia.
- No information is available on the carcinogenic or teratogenic (reproductive) effects of chlorine on humans. Animal studies have failed to identify any carcinogenic or teratogenic effects from chlorine exposure.

Ecological Health Effects

- Chlorine is extremely toxic to aquatic organisms; less than 0.1 micrograms of chlorine per liter of water has killed 50% of the exposed aquatic organisms.

(For section references, see endnote #1.)

Exposure Routes

Worker Health

Facilities using chlorine must minimize worker exposure and take precautions to avoid fires and leaks.

- Use chlorine in closed systems. If a closed production system is infeasible, facilities need to enclose operations and use local exhaust ventilation. Where the potential for exposure to chlorine exceeds 0.5 ppm use a Mine Safety and Health Administration/National Institute for Occupational Safety and Health-approved supplied-air respirator with a full facepiece.

- Take precautions to avoid chlorine contact with skin and eyes.
- Outside the daily routine, leaks and fires pose the greatest threat to workers. As a gas, chlorine is stored under pressure and has the potential to leak. While not a flammable or reactive chemical, chlorine containers may explode and release poisonous gases during fires.

Public Health

- Leaks and fires pose the greatest direct threats to public health. In fact, to eliminate the chlorine hazard some cities now use alternative disinfectants for wastewater treatment.
- Toxic byproducts result from chlorine use in water purification systems and products. Trihalomethanes (THMs) form during water purification when chlorine reacts with natural and synthetic organic chemicals in the water. Research by the Centers for Disease Control and the New Jersey Department of Health identified potential associations between high THM levels in drinking water and low birth weights and birth defects.
- The burning of chlorine-containing products (such as PVC) in incinerators releases dioxins and furans into the ambient environment.

(For section references, see endnote #1.)

Use Nationally and in Massachusetts

Widely used in industry, American businesses and wastewater treatment facilities consumed 13.360 million pounds of chlorine in 1995.[2] The major end-uses for chlorine in the U.S. are organic and inorganic chemical production, and direct applications.

- The major organic chemical end-use for chlorine is polyvinyl chloride (PVC). PVC and its intermediaries, ethylene dichloride and vinyl chloride monomer, accounted for 35% of national chlorine consumption in 1995. Production of chlorinated organics, including PVC and other hazardous chemicals like perchloroethylene, and trichloroethylene, accounted for 76% of national chlorine consumption in 1995.
- Inorganic chemical production -- which includes titanium dioxide, hydrogen chloride, and sodium and calcium hypochlorites -- accounted for 13% of national chlorine consumption in 1995.
- Direct applications -- such as bleached paper products, water treatment, and metals production -- consumed 11% of national chlorine consumption in 1995.

In Massachusetts, industrial facilities use chlorine to regenerate etchants used in the electronics industry, refine gold, manufacture chlorinated organic chemicals, and purify water.

- Massachusetts' facilities used 627,000 pounds of chlorine in 1996 (see Table 1). The regeneration of etching solutions was the primary end-use for chorine; "etchant regeneration" accounted for over

Table 1. Massachusetts Chlorine Data: Inputs and Outputs for1990 and 1996				
Input Data -- MA TURA	**Inputs (pounds) 1990**	**1996**	**Change in Inputs (pounds)**	**% Change**
Manufactured or Processed	975,610	230,086	-745,524	-76%
Otherwise Used	337,151	396,991	59,840	18%
Total TURA Inputs	**1,312,761**	**627,077**	**-685,684**	**-52%**
Output Data -- MA TURA	**Outputs (pounds) 1990**	**1996**	**Change in Outputs (pounds)**	**% Change**
Byproduct	59,561	12,996	-46,565	-78%
Shipped In/As Product	12,204	7,722	-4,482	-37%
Total TURA Outputs	**71,765**	**20,718**	**-51,047**	**-71%**
Releases and Transfers (R&T) Data -- EPA	**R&T (pounds) 1990**	**1996**	**Change in R&T (pounds)**	**% Change**
Environmental Releases	40,220	1,724	-38,496	-96%
Off-site Transfers	20,088	260	-19,828	-99%
Total EPA R&T	**60,308**	**1,984**	**-58,324**	**-97%**
Sources: MA TURA -- Massachusetts Toxics Use Reduction Act data, 1998; and EPA -- US Environmental Protection Agency, Toxics Release Inventory data,1998.				

one-third of all Massachusetts chlorine use in 1996 (see Table 2). Etching solutions contain the inorganic chlorinated compounds ferric chloride and cupric chloride, and are used in the manufacture of electronic components. The second largest end-use for chlorine was gold refining, which accounted for 24% of Massachusetts chlorine use.

- Chlorine use dropped dramatically, by over 50%, between 1990 and 1996 in Massachusetts. The primary cause of the decline: Zeneca, Inc., ceased using 866,000 pounds of chlorine due to cutbacks in production. Zeneca's dramatic reduction masked other increases in chlorine use.

- Between 1990 and 1996, chlorine use increased in four use categories: etchant regeneration, gold refining, water purification, and chlorinated rubber production. These four use categories increased chlorine consumption by 116,000 pounds, for a 30% increase.

Table 1 includes two sources of "output" data: Massachusetts Toxics Use Reduction Act (MA TURA) and U.S. Environmental Protection Agency (EPA), Toxics Release Inventory (TRI) data. The MA 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").

Table 2. Massachusetts Chlorine Use by Use Categories for 1990 and 1996

Use Categories[1]	Facility Name	Use (pounds) 1990	1996	% Change
Chlorinated Organics Production	Chemdesign Corp.	0	123,237	n/a[2]
	Samuel Cabot Inc [3]	10,510	0	-100%
	Zeneca, Inc	866,600	0	-100%
	Total	877,110	123,237	-86%
Chlorinated Rubber Production	Acushnet Rubber Co.	10,800	14,849	37%
	Titleist and Foot Joy	0	9,800	n/a
	Total	10,800	24,649	128%
Etchant Regeneration	Photofabrication Eng.	16,000	24,000	50%
	Tech Etch	10,800	0	-100%
	Techomet Etched Products	1,800	0	-100%
	Texas Instruments	168,000	192,000	14%
	Total	196,600	216,000	10%
Gold Refining	Attleboro Refining Company	59,500	92,000	55%
	Metalor USA Refining	30,240	58,120	92%
	Total	89,740	150,120	67%
Paperboard Bleaching	Sonoco Products	20,000	0	-100%
	Total	20,000	0	-100%
Water Purification	CocaCola	31,933	0	-100%
	Crocker Papers, Inc	0	10,650	n/a
	Erving Paper Mills	0	34,148	n/a
	Massachusetts Refusetech	0	55,000	n/a
	Merckens Chocolate	19,578	0	-100%
	Montaup Electric Co.	0	13,273	n/a
	Solutia	39,000		-100%
	Total	90,511	113,071	25%
Unknown [4]	M&V Electroplating	28,000	0	-100%
	Total	28,000	0	-100%
	Total Chlorine Use	**1,312,761**	**627,077**	**-53%**

[1] Use categories were assigned based on the Institute's examination of data provided to the Massachusetts Toxics Use Reduction Program and may not represent actual use; [2] n/a = not applicable; [3] In 1991 the company noted that their chemical use should be reported as sodium hypochlorite, and stopped reporting chlorine; [4] Company reported otherwise used data but no production unit data; Source: Massachusetts Toxics Use Reduction Act data, 1998.

- MA TURA outputs declined by 70% between 1990 and 1996. The dramatic decline in MA TURA outputs resulted primarily from two facilities -- Merckens Chocolate and Solutia -- which ceased reporting chlorine use by 1996. Outputs are lower than inputs for chlorine because production and treatment processes transform chlorine into other chemicals.

- EPA TRI releases and transfers dropped by 97% between 1990 and 1996. Merckens Chocolate and Solutia accounted for the majority of the decline.

Alternatives

Alternatives are available for most uses of chlorine. Before switching, facilities should evaluate alternatives based on their environmental and human health hazards, economic costs, and performance in production or products.

- In etching processes, manufacturers use chlorine gas to regenerate spent etchant (ferric chloride and cupric chloride). The regeneration process entirely consumes the chlorine and drastically reduces waste etchant. Hydrogen peroxide and ozone can be substituted for chlorine, but they are not as effective in regenerating the solution, create more waste and have other hazards associated with their use.
- Rubber product manufacturers in Massachusetts are actively pursuing alternatives to chlorine, but no alternatives have been found that provide adequate surface characteristics.
- Sodium hypochlorite, chlorine dioxide, ozone, and ultraviolet (UV) radiation can replace chlorine as a water purifier. For example, the Salisbury Massachusetts Wastewater Treatment Plant won the 1998 "Governor's Award for Outstanding Achievement in Toxics Use Reduction" for their UV-based wastewater treatment system; it uses no chlorine. By removing chlorine from the treatment plant Salisbury officials achieved their goal of making the neighborhood and worksite safer.
- Chlorine dioxide, hydrogen peroxide, oxygen and/or ozone can replace chlorine in pulp and paper bleaching operations. Pulp and paper facilities should choose bleaching systems that optimize water reuse and use less than 5 cubic meters of water to manufacture a metric ton of bleached kraft pulp.

Regulatory Context

Chlorine, as both an individual chemical and as the building block for many other chemical products, has come under increasing scrutiny by regulators and environmental organizations worldwide.

- The Occupational Safety and Health Administration (OSHA) workplace permissible exposure limit, not to be exceeded at any time, is 1 ppm.

The U.S. EPA regulates chlorine under the authority of at least five environmental statutes. Under the:

- Clean Air Act chlorine is a "hazardous air pollutant."
- Clean Water Act, chlorine use in bleaching pulp and paper products must be phased-out because chlorine combines with organic matter in trees to form dioxins, furans, and chlorinated phenolics.
- Comprehensive Environmental Responsibility, Compensation and Liability Act (popularly known as "Superfund") chlorine is an "extremely hazardous substance."
- Emergency Planning and Community Right-to-Know Act, Toxics Release Inventory (TRI) program, all large quantity users of chlorine must submit data on chlorine releases and transfers.
- Safe Drinking Water Act a "maximum contaminant level" (MCL) is set for trihalomethanes, a byproduct of chlorine use in purifying water, at 0.10 milligram per liter. The MCL is the maximum permissible level of a

contaminant in drinking water from a public water system.

Chlorine is also under scrutiny at the international level.

- Chlorine is on Sweden's "Observation List" of phase-out chemicals because it may "give rise to large risks to human health and/or the environment."
- In 1992, the International Joint Commission (IJC) recommended that Canada and the U.S. take a precautionary approach to chlorine and phase-out its use: 'We know that when chlorine is used as a feedstock in a manufacturing process, one cannot necessarily predict or control which chlorinated organics will result, and in what quantity. Accordingly, the Commission concludes that the use of chlorine and its compounds should be avoided in the manufacturing process. We recognize that socio-economic and other consequences of banning the use of chlorine 'and subsequent use of alternative chemicals or processes' must be considered in determining the timetable."

Industry analysts foresee a cloudy future for continued chlorine growth because of:

- increasing awareness of safety risks and environmental hazards caused by chlorine and its derivatives,
- actions by environmentalists against the production and use of chlorine,
- end-users reducing or eliminating the use of chlorine and chlorine-containing chemicals, and
- the phasing-out of chlorofluorocarbons (CFCs) and chlorine in pulp bleaching.

(For section references, see endnote #3.)

Endnotes

1 The data in this section were collected from the following sources: Richard J. Lewis, Sr. (ed.), 1993, Hazardous Chemicals Desk Reference (third edition) (New York: Van Nostrand Reinhold); New Jersey Department of Health, 1991, "Chlorine" (Trenton, New Jersey -- see the webpage: http://www.rkt.net); Swedish National Chemicals Inspectorate (KemI), 1995, Chlorine and Chlorine Compounds: Use, Occurrence and Risks -- The Need for Action (Report No. 1/95; Solna, Sweden: KemI); Swedish National Chemicals Inspectorate (KemI), 1995, Chlorine and Chlorinated Compounds: Survey of Fluxes to and in the Environment, Pools in the Environment and Health and Environmental Risks (Report No. 5/95; Solna, Sweden: KemI); and U.S. EPA, Office of Air Quality Planning and Standards, 1998, "Chlorine" (Washington, D.C.: U.S. EPA -- see webpage: http://www.epa.gov/ttn/uatw/hlthef/chlorine.html).

2 The source for the national chemical use data is Stanford Research Institute (SRI) International, 1996, Chemical Economics Handbook, "Chlorine/Sodium Hydroxide" (Palo Alto, California: SRI).

3 The data in this section are from the following sources: Environmental Defense Fund (EDF), 1999, "Chemical Profile for Chlorine" (New York: EDF -- see webpage: http://www.scorecard.org/chemical-profiles); New Jersey Department of Health, 1991 (see endnote #1 for full citation); International Joint Commission (IJC), 1992, Sixth Biennial Report on Great Lakes Water Quality (Washington, D.C.: IJC); SRI International, 1996 (see endnote #2); Swedish National Chemicals Inspectorate (KemI), 1991, Risk Reduction of Chemicals: A Government Commission Report (Report No. 1/91) (Solna, Sweden: KemI); and U.S. EPA, Office of Water, 1998, "Final Pulp and Paper Cluster Rule," published in the Federal Register, 63 FR 18504-18751, April 15, 1998 and 63 FR 42238-42240, August 7, 1998 (or see the webpage: http://www.epa.gov/OST/pulppaper/cluster.html).

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