THE MASSACHUSETTS TOXICS USE REDUCTION INSTITUTE

Massachusetts Chemical Fact Sheet

Cadmium and Cadmium Compounds

A naturally occurring metal, cadmium[1] is a well-established human and environmental hazard; it is carcinogenic and a potential reproductive hazard. Once widely used in industry for corrosion resistance, color and electrical properties, cadmium use is now on the decline in the U.S. and Massachusetts. Manufacturers of batteries, pigments, coating and plating products, plastics, and metal alloys are turning to safer and cleaner alternatives to reduce costs and comply with regulations.

FACTS

CAS Numbers:	
7440-43-9	Cadmium
1306-23-6	Cadmium Sulfide
1306-19-0	Cadmium Oxide
Symbol:	Cd
Water Solubility:	varies from practically insoluble to quite soluble

Hazards

Acute (Short-Term) Health Effects

- Acute inhalation of cadmium may harm the lungs, causing bronchial and pulmonary irritation. Even one acute exposure at a high concentration can result in long-term impairment of lung function.

- Acute inhalation of cadmium can also cause nausea, vomiting, and diarrhea.

- At concentrations of 9 milligrams (mg) per cubic meter (m^3), cadmium is immediately dangerous to life and health.

Chronic (Long-Term) Health Effects

- Cadmium is a probable carcinogen. The U.S. EPA (Environmental Protection Agency) classifies cadmium as a Group B1 carcinogen: a probable human carcinogen of medium carcinogenic hazard. Human and animal studies have identified an increase in lung cancer from the chronic inhalation of cadmium. The International Agency for Research on Cancer (IARC) classifies cadmium as a Group 2A carcinogen; it is probably carcinogenic to humans.

- Cadmium is a potential reproductive and developmental toxicant. In animal studies chronic exposure to cadmium caused low fetal weight and skeletal malformations, and impaired neurological development. In humans, studies indicate that cadmium exposure decreases the birth weight of infants, but the data are inconclusive.

- Of all the human organs, cadmium is most likely to harm the kidney; inhalation and oral exposure may permanently damage the kidney.

Exposure Routes

Worker Health

Facilities using cadmium and its compounds must minimize worker exposure.

- Ideally, cadmium should be used in closed systems, where it is automatically transferred from storage to process containers. If a closed production system is infeasible, facilities need to enclose operations and use local exhaust ventilation.

- Facilities must implement precautions to avoid contact with skin and eyes.

- To avoid exposing family members to cadmium,

This is one in a series of Massachusetts Chemical Fact Sheets prepared for each of the chemicals in significant use on the Toxics Use Reduction Science Advisory Board's 'more hazardous chemicals' list. For more information on the Chemical Categorization Project, consult the Institute's Technical Report #47.

companies must require workers to leave clothing at work for professionals to clean.

- For exposures greater than 0.002 mg/m^3 use a Mine Safety and Health Administration/National Institute for Occupational Safety and Health-approved supplied-air respirator with a full facepiece.

- While cadmium is not flammable, contact with fire will produce poisonous gases.

Public Health

Drinking water, food products, cigarettes, and the air are all potential sources of cadmium exposure.

- Oil and coal combustion sources, municipal solid waste incinerators, copper and lead smelters, and iron and steel manufacturers are all sources of airborne cadmium. Cadmium is a byproduct from these sources and is difficult to remove using standard pollution control equipment.

- Smokers have roughly twice the levels of cadmium in their bodies as non-smokers.

Use Nationally and in Massachusetts

Nationally[2] batteries, pigments for painting applications, coated and plated metal products, plastics, and specialty metal alloys are the primary end-uses for cadmium.

Data for 1994 U.S. consumption of cadmium are as follows (percentages are % of total use):

- Batteries, primarily rechargeable nickel-cadmium batteries, were the largest end-use and accounted for 63.7%.
- Pigments, the second largest end-use, accounted for 14.7%.

- Coating and plating applications, once the largest end-use (until 1988), accounted for 9.8%.

- Plastics and synthetic products also accounted for 9.8%.

- Alloys and other products accounted for 2%.

Between 1990 and 1994 (the last year for which data are available), total U.S. cadmium consumption declined by 62%. Prompted by serious negative environmental and human health effects and increasingly stringent regulations, cadmium users are seeking safer alternatives.

Between 1990 and 1996, Massachusetts' manufacturers

Table 1. Massachusetts Cadmium and Cadmium Compounds: Input and Output Data for 1990 and 1996

Input Data -- MA TURA	Inputs (pounds) 1990	1996	Change in Inputs (pounds)	% Change
Manufactured or Processed	836,521	20,493	-816,028	-98%
Otherwise Used	22,360	26,551	4,191	19%
Total TURA Inputs	858,881	47,044	-811,837	-95%

Output Data -- MA TURA	Outputs (pounds) 1990	1996	Change in Outputs (pounds)	% Change
Byproduct	807,220	29,001	-778,219	-96%
Shipped In/As Product	33,775	6,167	-27,608	-82%
Total TURA Outputs	840,995	35,168	-805,827	-96%

Releases and Transfers (R&T) -- EPA	R & T (pounds) 1990	1996	Change in R&T	% Change
Environmental Releases	1,240	513	-727	-59%
Off-site Transfers	20,993	21,015	22	0%
Total EPA & R&T	22,233	21,528	-705	-3%

Sources: MA TURA -- Massachusetts Toxics Use Reduction Act data, 1998; and US EPA, TRI -- US Environmental Protection Agency, Toxics Release Inventory data, 1998.

followed the national trend, as formulators of plastics, metal platers, and alloy manufacturers all reported decreased use of cadmium.

- Cadmium use declined by 95% in Massachusetts between 1990 and 1996 — from 860,000 pounds to 47,000 pounds (see Table 1).

The removal of cadmium as a stabilizer in plastic and synthetic products, especially in polyvinyl chloride (PVC), is the primary reason for the dramatic decline in cadmium use.

- The reported use of cadmium by plastics formulators declined by 100% in Massachusetts between 1990 and 1996, dropping from 733,000 pounds to 0 pounds[3] (see Table 2).

Other users of cadmium in Massachusetts followed the national trend and reported a decrease in use between 1990 and 1996.

- Cadmium use in coating and plating applications declined by 57%.
- Cadmium use in alloy manufacturing declined by 65%.

Cadmium outputs also declined in Massachusetts (see Table 1). Table 1 includes two sources of "output" data: Massachusetts Toxics Use Reduction Act (MA TURA) and U.S. 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").

- MA TURA outputs declined by 96% between 1990 and 1996.
- EPA, TRI data for Massachusetts companies show a 3% decline in releases and transfers between 1990 and 1996.

Table 2. Massachusetts Cadmium and Cadmium Compounds Use by Use Categores for 1990 and 1996

Use Categories [1]	Facility Name	Use (pounds) 1990	1996	% Change
Alloy Manufacturing and Refining Silver/Gold	Attleboro Refining Company, Inc.	0	10,138	n/a
	Chemet Corp	18,180	20,493	13%
	Engelhard Corp	69,800	0	-100%
	Total	87,980	30,631	-65%
Metal Plating	New Method Plating	22,360	16,413	-27%
	Texas Instruments [2]	16,000	0	-100%
	Total	38,360	16,413	-57%
Plastics Formulation: Additives and Pigments	Alphagary	433,952	0	-100%
	American Insulated Wire Corp	180,000	0	-100%
	Regalite Plastics Corporation	37,368	0	-100%
	Reed Plastics Corp	46,300	0	-100%
	Vernon Plastics Company	34,921	0	-100%
	Total	732,541	0	-100%
Total Cadmium and Cadmium Compound		858,881	47,044	-95%

[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] Texas Instruments uses cadmium both in plating and to manufacture cadmium-based alloys; Source: Massachusetts Toxics Use Reduction Act data, 1998.

Alternatives

Cadmium is used in low melting point and brazing alloys with bismuth, lead and tin. Cadmium-containing alloys are used as bearings, solders and copper hardeners in fire detection devices, high-speed machinery, automotive components and nuclear reactor control rods. In addition, silver-containing cadmium oxide is used as an electrical contact in switches, relays and circuit breakers.[4] As solders tin-silver, indium-tin and indium-silver are alternatives in some applications. However tin-silver is less ductile than cadmium solders and indium is expensive.

For metal plating applications, one alternative is to redesign the production process to eliminate the need for the coating. Another alternative is to use a metal deposition technology that does not require a plating bath (e.g., vapor-deposited aluminum). If these alternatives are not viable due to required surface characteristics or cost, zinc-based alloys (e.g., zinc-nickel or zinc-cobalt) in acid or alkaline baths offer alternatives in a variety of applications. Zinc processes are very common in the surface finishing industry but the zinc-based alloys have only recently been considered as replacements for more toxic cadmium.

The ability to replace a cadmium coating with a zinc-based alloy depends on the specific characteristics required. Zinc cannot match the lubricity that can be achieved with cadmium and has poor solderability. A tin-zinc alloy can be used to increase the solderability of the coating but is expensive.

Although presently very costly, metallic-ceramic coatings, using zinc, aluminum, or alloys of these metals, possess the corrosion resistance characteristic of cadmium, without the same environmental issues. Metallic-ceramic coatings have successfully replaced cadmium in more expensive military applications, including landing gear axles of modern aircraft, gas-turbine-engine compressor sections, and allied parts.[5]

As the TURA data clearly demonstrate alternatives to cadmium in plastic formulations do exist. Flexible polyvinyl chloride is the largest market for cadmium-based stabilizers. Cadmium compounds inhibit degradation of the polymer during processing and retard discoloration from ultraviolet light.[6] Alternative stabilizers in plastics include calcium-zinc and barium-zinc salts, and organotin. Organotin compounds are not necessarily safer substitutes as they are on Sweden's sunset list due to high toxicity, especially to marine animals.

Table 3. OSHA Permissible Exposure Limits for Cadmium

Use Category	Description	PEL (ug Cd/m3)
Nickel-Cadmium Battery Manufacture	Plate making and plate preparation	50
Zinc-Cadmium Refining	Cadmium refining, casting, melting, oxide production, sinter plant	15
Pigment Manufacture	Calcine, crushing, and blending	50
	All other processes	50
Stabilizer Production	Cadmium oxide charging, crushing, drying, blending	50
Lead Smelting	Sinter plant, blast furnace, baghouse, yard area	50
Plating	Mechanical plating	15
All Other		5

Sources: SRI International, Chemical Economics Handbook, 1997

In plastics formulations, cadmium-based pigments provide brilliant colors and do not degrade from exposure to light. The replacements, both inorganic and organic, provide some but not all of cadmium's characteristics. Possible alternatives include iron oxide, nickel titanium, monoazo, monoazo naphthol, quinacridone, and perylene. From a request by a Massachusetts Plastics Focus Group, the Toxics Use Reduction Institute is currently supporting a research project to identify the alternatives to heavy-metal-based pigments used in plastics.

Regulatory Context

A well-known hazard to human and environmental health, both the U.S. Occupational Safety and Health Administration (OSHA) and EPA regulate cadmium.

- The OSHA permissible exposure limit (PEL) for an eight-hour workshift for cadmium ranges from 5 micrograms per cubic meter (ug Cd/m^3) to 50 ug Cd/m^3 (see Table 3). The variations in PELs reflect the different challenges and costs of reducing cadmium exposures across manufacturing processes.

The EPA regulates cadmium under the authority of six environmental statutes. Under the:

- Clean Air Act cadmium is a "hazardous air pollutant."
- Clean Water Act cadmium is a "priority pollutant."
- Comprehensive Environmental Responsibility, Compensation and Liability Act (popularly known as "Superfund") cadmium is a "hazardous substance."
- Emergency Planning and Community Right-to-Know Act, TRI program, all large quantity users of cadmium must submit data on cadmium releases and transfers.
- Resource Conservation and Recovery Act cadmium is a "hazardous constituent."
- Safe Drinking Water Act a "maximum contaminant level" (MCL) is set for cadmium at 0.005 milligram per liter. The MCL is the maximum permissible level of a contaminant in drinking water from a public water system.

Internationally both the European Union and Sweden have taken significant actions to reduce the hazards of cadmium exposure.

- The European Union limits the amount of cadmium metal in a finished plastic product or component to 0.01% by mass of the polymer.
- In Sweden, cadmium is a "sunset" chemical — a chemical whose use should be phased-out due to extreme potential for environmental and human health damage. In particular, Sweden is concerned with its use in batteries and presence in phosphate fertilizers.

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Endnotes

1 Unless otherwise noted, "cadmium" encompasses both cadmium and its compounds. The primary cadmium compounds used in manufacturing are cadmium oxide and cadmium sulfide (SRI, 1997, p. 233.3350J).

2 All national data in this section are from SRI, 1997.

3 Some facilities may be using cadmium below the reportable threshold.

4 SRI, 1997, p. 233.3350N.

5 Davis, et al, 1994, p. 119.

6 SRI, 1997.