Great Lakes Binational Toxics Strategy

Draft Report for

Mercury Reduction Options

Prepared for:

U.S. EPA
Great Lakes National Program Office
Contract #68-W-99-033

September 1, 2000

Prepared by:

Ross & Associates
Environmental Consulting, Ltd.

TABLE OF CONTENTS

TABLES, FIGURES, AND ATTACHMENTS

INTRODUCTION

Every year, an estimated 60,000 children are born at risk of developmental deficits, including decreased school performance, as the result of exposure to methylmercury in the womb, usually stemming from their mother's consumption of contaminated fish.[1] Methylmercury is the organic form of mercury that bioaccumulates in the environment. Exposure to elemental mercury vapor in indoor air as the result of household or workplace spills also poses a health threat. Elemental or inorganic mercury released into the environment as the result of human activities can be converted into methylmercury, and bioaccumulate up the food chain. Releases of mercury into the air eventually lead to contamination of water, because mercury deposits from the atmosphere onto land and water.

Mercury is a common element found naturally in a free state or mixed with ores or rocks. It is a volatile heavy metal that can exist in gas, liquid, or solid form, and is the only heavy metal that exists as a liquid at room temperature. Mercury has high electrical conductivity, alloys with other metals, and expands and contracts evenly with temperature. Due to these unique qualities, mercury has been used in thousands of industrial, agricultural, medical, and household applications.

As an element, mercury cannot be broken down, diluted, or entirely eliminated from the environment. Once deposited, it can be re-emitted back into the atmosphere to be re-deposited elsewhere. As mercury cycles between the atmosphere, land, and water, it undergoes a series of complex chemical and physical transformations.

Because of the recognized toxicity of mercury, industrial demand for the substance has declined by about 75 percent between 1988 and 1996, due largely to the elimination of mercury in paints and pesticides, and the reduction of mercury in batteries. Nevertheless, mercury contamination continues to be one of the most frequent basis for fish advisories issued by States or Tribes, represented in 60 percent of all water bodies with advisories. Thirty-nine states have issued fish consumption advisories in one or more water bodies, and ten States have issued statewide mercury advisories (US EPA).

Mercury Elimination Efforts

Due to its toxicity, persistence, and tendency to bioaccumulate in the environment, mercury has been classified by the International Joint Commission (US and Canada) as a persistent toxic substance subject to the requirements of the 1978 Great Lakes Water Quality Agreement (WQA). Under this agreement, both countries pledged to seek the virtual elimination of the discharge of persistent toxic substances to the Great Lakes. Fifteen years later, in 1993, EPA's Great Lakes National Program Office (GLNPO) launched its "Virtual Elimination Pilot Project" to meet this challenge, focusing its initial efforts on mercury and PCBs.

In 1994, Canada and the Province of Ontario signed the "Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem" (COA). COA provides the framework for systematic and strategic coordination of shared Federal and Provincial responsibilities for environmental management in the

[1] Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology, National Research Council. Toxicological Effects of Methylmercury. National Academy Press, 2000. (Publication forthcoming, but prepublication manuscripts can be purchased. See http://www.nap.edu/catalog/).

Great Lakes Basin. The purpose of COA is to renew and strengthen planning, cooperation, and coordination between Canada and Ontario in implementing actions to restore and protect the Great Lakes ecosystem, to prevent the release of pollutants into the ecosystem, and to conserve species, populations, and habitats in the Great Lakes Basin. COA seeks to achieve a 90% reduction in the use, generation or release of mercury (as well as other persistent, bioaccumulative and toxic substances).

In 1995 Prime Minister Chrétien of Canada and President Clinton announced that the two countries would work together on the Great Lakes Binational Toxics Strategy (BNS), targeting a common set of toxic substances.[2] The Strategy sets a goal of virtual elimination of mercury from the Great Lakes Basin, with a U.S. challenge of 50 percent reductions nationwide in the use and release of mercury by 2006, and a Canadian challenge of 90 percent reduction in release of mercury in the Great Lakes basin by 2000.

To assist in achieving these goals, the Strategy involves a four-step process for each pollutant addressed. Step One involves gathering information about sources and uses; Step Two is the analysis of current regulations, initiatives and programs which manage or control the pollutant; Step Three involves the identification of cost-effective options to achieve further reductions, and Step Four is the implementation of actions towards the goal of virtual elimination. This report documents Step Three, by identifying cost-effective options to achieve reductions in mercury use and releases.

Report Overview

This options paper explores potential emission reduction opportunities that may be considered to help achieve the BNS mercury reduction goal. The paper begins with a brief overview of mercury, its sources, uses, and health and environmental effects to provide some background for new readers. The remainder of the report will articulate the different options for reducing mercury emissions from the major mercury sources across the country, organized by "source category." Under each source category, reduction options will include, when available, a description of the option, mercury emission reduction potential, reduction cost-effectiveness, and implementation issues associated with the option. Each source category will also include a list of resources, references, and Internet links where additional information can be obtained.

This report draws heavily on previously published documents pertaining to mercury reduction options, including the following.

- U.S. EPA. Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units -- Final Report to Congress, Volume 1. February 1998. http://www.epa.gov/ttn/oarpg/t3rc.html

- U.S. EPA. Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs. December 1997. http://www.epa.gov/oar/mercury.html

- Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury

[2]The Virtual Elimination Pilot Project has since been subsumed under the Binational Toxics Strategy project.

Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.[3]

- Michigan Mercury Pollution Prevention Task Force. Mercury Pollution Prevention in Michigan: Summary of Current Efforts and Recommendations for Future Activities. April 1996. http://www.deq.state.mi.us/aqd/publish/m2p2.html

- Wisconsin Department of Natural Resources. Draft Wisconsin Mercury Sourcebook, 1997. http://www.epa.gov/glnpo/bnsdocs/hgsbook/index.html

These reports provide substantial background information on different options for mercury elimination across different sectors, and have been extremely valuable in the development of this report.

Overview of Mercury

Sources and Uses of Mercury

Although mercury emissions can originate from natural sources, including volcanic and geothermal activity, this report focuses on anthropogenic sources of mercury. Human activities that contribute to mercury contamination can be divided into two categories: intentional use and incidental release.

Intentional Use. Intentional use occurs when mercury is an input in production processes or consumer products. In the electrical industry, mercury can be used in fluorescent lamps, wiring devices and switches (e.g., thermostats) and mercuric oxide batteries. Navigational devices, thermometers and other devices that measure heat and pressure may also use mercury. In addition, mercury may be used as a component of dental amalgams for repairing cavities. Until the early 1990s, the mercury compound phenylmercuric acetate was used to control mildew in latex paints

Industrial processes that use mercury include production of chlorine and caustic soda by mercury cell chlor-alkali plants and nuclear reactors, and wood processing (as an anti-fungal agent). Mercury may also be used as a solvent for reactive and precious metals, and as a preservative in pharmaceutical products.

The mercury uses described above can lead to emissions in the production process, during use, and in the recovery from and/or disposal of the discarded products and waste. Incineration of wastes that contain mercury, in particular, can lead to substantial mercury emissions. Mercury is less likely to reach the environment if it is landfilled than if it is incinerated, as incineration causes mercury to volatilize while landfilling can immobilize significant amounts of mercury.

When considering intentional uses of mercury, because the quantity used directly influences a significant amount of the mercury ultimately released into the environment, several leverage points are

[3] Minnesota's SRFRS Committee report is available at www.pca.state.mn.us/air/mercury-mn.html. Contact Carol Andrews (phone 651/297-8333 or e-mail her at *carol.andrews@pca.state.mn.us*) or Bob McCarron (phone 651/296-7324 or e-mail him at *robert.mccarron@pca.state.mn.us*). Or, mail your request to Carol Andrews or Bob McCarron, Major Facilities Section, Policy & Planning Division, Minnesota Pollution Control Agency, 520 Lafayette Rd., Saint Paul, MN 55155-4194

potentially available to reduce mercury releases. The price and supply of mercury, the feasibility of recycling, the availability of alternative inputs or processes, and the structure of existing regulations all contribute to a company's decision to use mercury in their production processes or products.

Incidental Release. Incidental releases of mercury most often occur as a result of energy production, where the fuel source contains mercury. In fact, the largest remaining identified source of mercury emissions are coal-fired utility boilers. Commercial, industrial, and residential boilers also contribute to mercury emission. Incidental releases can also occur in manufacturing process where trace amounts of mercury is contained in the raw material, such as portland cement and pulp and paper manufacturing, as well as copper, lead, and zinc smelting.

Because these processes do not rely on mercury, their mercury emissions are not influenced by the costs associated with using mercury. They are affected by regulatory costs associated with releasing mercury, and by the relative costs associated with using raw materials that contain mercury. Therefore, the opportunities for reducing mercury releases from these sources will differ from those for sources that rely on mercury for some aspect of their business.

Pathways of Contamination

Because airborne mercury can travel great distances, and can persist in the environment for 30 years or more, it can contaminate widespread areas. Once it enters an aquatic environment, mercury can be converted to organic methylmercury – the form most likely to bioaccumulate in the food chain. Mercury enters the food chain through uptake by phytoplankton, and is so efficiently bioaccumulated that fish at the top of the food chain can have levels of mercury in their muscle tissue one million times higher than the mercury concentration in the water. Also, because of mercury's bioaccumulation properties, it takes only a small amount to contaminate a lake: it has been said that only 1/70th of a teaspoon, under the right conditions, could contaminate a 35-acre lake and make fish unsafe for consumption (Environmental Working Group). Fish with the highest mercury levels are those at the top of the food chain, such as pike, largemouth bass, walleye, swordfish, and tuna. Adverse effects of mercury on fish include reduced reproductive success, impaired growth and development, behavioral abnormalities, and death.

Fish consumption dominates the pathway for human and wildlife exposure to methylmercury. Critical elements in estimating methylmercury exposure and risk from fish consumption include the species of fish consumed, the concentrations of methylmercury in the fish, the quantity of fish consumed, and how frequently fish is consumed. Fish and wildlife around highly acidic lakes also tend to have higher mercury levels than organisms near waterbodies with lower sulfate concentrations. Methylmercury can threaten fish-eating birds such as loons, mallard ducks, pheasants, eagles, and herons, and fish-eating mammals such as minks, otters, and racoons. Adverse effects on wildlife are similar to those of fish.

Fetuses, infants, and young children who eat high amounts of fish or seafood, and Native Americans and other subsistence fishers, are most at risk of exposure. Pregnant and nursing women are especially cautioned against eating potentially contaminated fish, as methylmercury can affect the developing central nervous system tissue in fetuses and be passed on to an infant through breast milk. In humans, damage typically manifests as delayed walking, speaking, or as subtle learning, memory, and behavioral effects. Convulsions and death can occur at extremely high exposures.

Overview of Different Option Categories

Options for mercury reductions fall into several categories, ranging from alternatives that completely eliminate the possibility of mercury contamination, to those that reduce contamination and/or the likelihood of contamination. These categories include:

- **Substitution:** The use of alternative products or process inputs that are mercury free and either less toxic than mercury, or non-toxic can completely reduce mercury emissions associated with that use.

- **Recycle/Disposal:** This involves ensuring proper end-of-life handling of products containing mercury, to help guarantee minimal air and water contamination.

- **Energy Efficiency:** The more efficient use of energy, such that less energy is necessary, and energy production by-products (e.g., mercury emissions) are reduced.

- **Control**: Where mercury is a pollution by-product of manufacturing, energy generation, or waste disposal, in-process or end-of-pipe control technologies can be very effective in reducing emissions of mercury and other hazardous substances.

- **Clean-up**: When mercury spills do occur, proper spill response planning and clean-up (followed by proper disposal) can help reduce the severity of the contamination.

- **Education**: By informing the general public about the hazards of mercury, the risks of day-to-day household contamination can be reduced. Education can also lead to a greater willingness to engage in alternative lifestyle approaches (e.g., increasing energy efficiency, buying alternative consumer products, etc.)

Together, these options can help reduce mercury emissions and associated environmental and human health effects. In the future, new product development efforts will continue to formulate cost-effective and functional alternatives, new and more effective control technologies will be developed, and public education efforts will reach greater populations. As these efforts grow, the virtual elimination of mercury will become an increasingly approachable reality. **Appendix A** contains a summary of Mercury reduction options, cost effectiveness and reduction potential, based on information developed by the Minnesota Pollution Control Agency (MPCA).

MERCURY FROM ENERGY PRODUCTION

Background

Energy-generation that results in mercury emissions takes place via the burning of wood, oil, natural gas, or coal in stationary and mobile residential and industrial energy production processes.

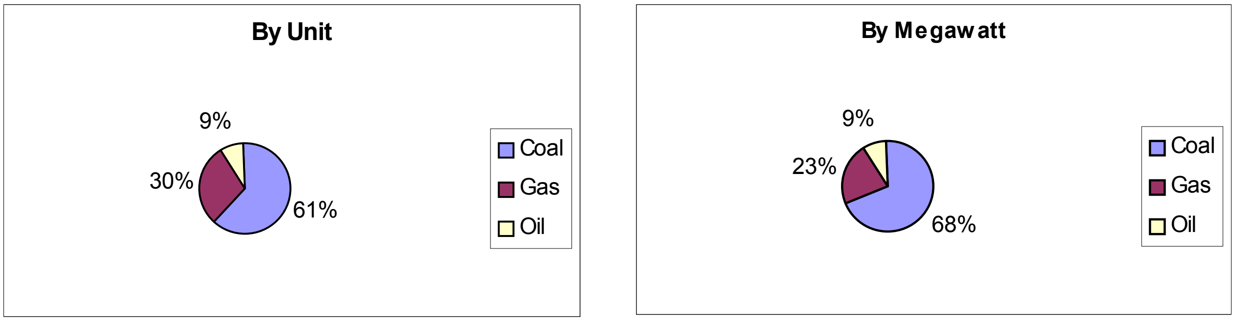
- Electric utilities use boilers to generate electricity. Private residences and industry also use boilers.
  - Utility boilers are used by public and private utilities to generate electricity, using coal, oil, natural gas, or a combination of these fuels. Mercury emissions from boilers in this sector are estimated to be 51.6 tons per year, primarily from coal combustion. **Figure 1** shows the 1994 distribution of fossil fuel use by the electric utility industry by unit and by total megawatts. Approximately 61 percent of utility boiler energy consumption is from coal combustion, representing about 68 percent of total coal combustion nationwide (Report to Congress, Vol. 2).
  - Commercial/industrial boilers in business and industrial plants also may use coal, oil, or natural gas. Mercury emissions from boilers in these sectors are estimated to be 3.2 tons per year.
  - Residential boilers are comparatively small, and can use coal, oil, or natural gas as fuel.[4] Like other boilers, coal- and oil-fired residential boilers emit mercury as a trace contaminant as a result of the combustion process. Residential boilers emit an estimated 1.4 tons of mercury per year.
- Wood and wood wastes can be used as fuel in the industrial and residential sectors. Industries burn wood waste in industrial boilers to provide process heat. Wood is also used in residential and commercial fireplaces and wood stoves to produce heat. While studies have shown that wood and wood waste contains mercury and therefore may release mercury upon burning, insufficient data are available to estimate these amounts (Report to Congress, Vol. 2).
- Mobile sources are defined as diesel- and gasoline-powered, on-road, light-duty vehicles,[5] with gasoline-powered vehicles making up the most significant emissions. A very limited number of studies have been conducted of mobile source mercury emissions, and all have contained inconsistent or questionable results. Due to uncertainties surrounding mobile source emissions data for mercury, indecision on ways to address this source of emissions remains (Report to Congress, Vol. 2).

---

[4] Mercury emissions from natural gas combustion are considered insignificant.

[5] As defined in the Mercury Report to Congress, Volume 2, 3-8.

Figure 1: Distribution of Fossil Fuel Use



Source: Report to Congress, Volume 1

Coal as a Fuel Source for Energy

Coal power provides vast quantities of inexpensive, reliable power. Known coal reserves are expected to last for up to three centuries at current usage rates.[6] In both 1990 and 1995 emissions inventories conducted by EPA, coal-fired utility boilers ranked as the largest source of U.S. mercury emissions. Coal-fired utility boilers make up 99% of the mercury emissions from electric U.S. utilities. Commercial, industrial, and residential boilers also contribute to mercury emissions, primarily as a result of coal combustion. **See Table 1**. For this reason, coal-fired boilers, and coal-fired utility boilers specifically, will represent the primary focus of this section.

Table 1: U.S. Mercury Emissions Estimates

Source	Emissions	
	Tons/yr	**% of total**
Utility boilers	51.6	35%
Commercial boilers	1.1	0.7%
Industrial boilers	2.1	1.4%
Residential Heating	1.4	0.9%
Total	56.2	38%

[6]From the American Coal Foundation website at www.acf-coal.org

Regulatory Status of Coal-Fired Utility Boilers

Although currently unregulated for mercury emissions, coal-fired utilities were the subject of intensive study mandated by the 1990 Clean Air Act amendments (§112(n)(1)(A)). This study was completed on February 24, 1998 in a Final Report to Congress. Here, EPA stated that mercury is the hazardous air pollutant (HAP) of greatest potential concern from coal-fired utilities and that additional research and monitoring are necessary.

Accordingly, in November 1998, EPA issued a Information Collection Request (ICR) to obtain mercury-in-coal data from each coal-fired utility in the U.S. and additional speciated mercury emissions data from a subset of these coal-fired utilities. This was to be used as a possible basis for developing regulations pertaining to HAP emissions from coal-fired utility boilers. Data collection was completed by the end of 1999, and data analysis is to occur throughout 2000. Using this data, EPA will decide whether to regulate mercury emissions from electric utilities by December 2000.

In addition to providing detailed information about mercury emissions from coal-fired utilities, the ICR may also yield important information on the multiple pollution control benefits of technological controls set in place to reduce the emissions of other targeted substances, such as sulfur dioxide (SO_2). Analyses using ICR-Part One data indicate that several air pollution controls currently used by coal-fired utilities provide corollary mercury reduction benefits (Environmental Working Group). These corollary benefits will be explored in more detail throughout this section.

Options for Mercury Reductions from the Energy Production Industry

As mentioned, pollution control strategies to reduce mercury emissions can be highly inter-related. Strategies to reduce emissions of any one pollutant from power generation can have effects on emissions of the other pollutants. The cost and other impacts of control strategies for these pollutants are also highly interdependent.

Technologies discussed below fall into three categories:

- **Pre-combustion:** Utilized in the process before fuel is burned to produce energy. These methods employ chemical, biological, or other alternative techniques to remove, or reduce the possibility of, high percentages of ash. Coal cleaning, coal switching, fuel switching, and co-firing fall under this category.

- **Post-combustion:** These technologies clean flue gases emitted from coal burning. They are generally located in the duct work leading to the smokestack. Wet scrubbing, carbon injection, and carbon filter beds are examples.

- **Energy Efficiency:** This option involves the implementation of strategies that increase the efficiency of energy production and/or decrease the demand for energy. Demand Side Management is one such strategy.

Below are descriptions of the different options for reducing mercury emissions from energy sources, primarily coal-fired utilities. Information on reduction potential and costs was taken primarily from the following sources:

- Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

- U.S. EPA. Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs. December 1997.

- Center for Clean Air Policy Discussion Paper: Mercury Emissions from Coal-fired Power Plants. November 1998.

Pre-Combustion

Option 1: Coal Cleaning

Conventional coal cleaning methods are based on the principle that coal is lighter than the pyritic sulfur, rock, clay, or other ash-producing impurities that are mixed or embedded in it. To clean coal, mechanical devices using pulsating water or air currents physically stratify and remove the ash component which contains trace minerals including mercury, before the coal is crushed and introduced into the boiler for combustion (Report to Congress, Vol. 8). Currently, about 75-85% of eastern coals are cleaned, while only 10-15% of western coals are cleaned (Center for Clean Air Policy).

Reduction Potential

- Average mercury removal efficiency: 21 percent
  - 77-85% percent removal for Eastern and Midwestern bituminous coal
  - 10-15% of Powder River Basin (Western) coal (Center for Clean Air Policy).

Cost

- The costs range from requiring no additional cost for mercury to a cost of $33,000 per pound of mercury removed for removal levels ranging from 12% to 58% on a heat basis (Center for Clean Air Policy).
- Estimates for Powder River Basin Coal range from $47,000 to $58,000 per pound of mercury removed.[7]

Other Benefits

- Many coal cleaning processes, especially those used on eastern coals, are also designed to liberate pyritic sulfur (which requires additional grinding) to reduce acid rain-related emissions of $S0_2$. Coal cleaning also reduces various other HAPs.[8]

[7] For an 11% reduction

[8] Other HAP reductions were not incorporated into cost estimates.

- Cleaned coal could improve boiler efficiency and reduce transportation costs (Minnesota Pollution Control Agency).
- Coal cleaning can result in lower shipping, storage, and handling costs per unit of heating value, and can improve boiler output per unit weight input of coal.

Potential Drawbacks

- Reduction success is unproven on sub-bituminous coal.
- Coal cleaning increase in tailings and other wastes at coal cleaning facilities.
- Conventional coal cleaning may increase the probability of mercury contamination of water bodies.
- The potential impact on post combustion from, and control of, the remaining mercury has not been thoroughly investigated. Chemical cleaning techniques being considered may provide a coal that yields a different form of mercury under combustion and post-combustion conditions (Report to Congress, Vol. 8).
- There is some uncertainty about the long term stability of the residues from coal cleaning. Mercury removed from coal as a result of physical cleaning processes is expected to remain trapped in naturally occurring minerals in the waste material. However, the permanence of intense conventional coal cleaning, and especially chemical cleaning, should be confirmed through testing. It is theoretically possible that chemical cleaning methods would alter the physical, chemical, and/or mineralogical forms of the coal resulting in increased potential of re-emission or leaching. (Minnesota Pollution Control Agency).

Additional Considerations: Advanced Coal Cleaning

Advanced Coal Cleaning methods such as selective agglomeration and column froth flotation have the potential to increase the amount of mercury removed by conventional cleaning alone. Column froth flotation has been tested to reduce mercury concentrations remaining in the washed coals by 1 to greater than 51 percent, with an average of 26 percent. Selective agglomeration reduced mercury concentrations remaining in the washed coals by greater than 8 percent to 38 percent, with an average of 16 percent (Report to Congress, Vol. 8).

Mercury removal could also potentially be enhanced by optimizing cleaning processes for mercury, by cleaning western coals that are lower in sulfur and ash but higher in mercury on a per trillion Btu basis, and/or by upgrading those facilities that are less effective in removing sulfur and trace elements (Center for Clean Air Policy).

Option 2: Coal Switching.

Coal switching refers to switching from coal that is high in mercury per Btu to one that is low in mercury per Btu (Center for Clean Air Policy). In some cases, switching from one coal source to another may reduce mercury emissions. This could occur either due to the new coal source containing less mercury or to changes in coal characteristics that improves the mercury collection efficiency of existing control equipment (Minnesota Pollution Control Agency).

Potential Reductions/Cost

- Reduction potential and cost effectiveness are not known because facility-specific testing is needed to determine the results of coal switching. In addition, lower mercury coals won't necessarily lead to lower emissions in all cases: speciation influences the mercury control efficiency and fate of mercury emissions (Minnesota Pollution Control Agency).[9]

Additional Considerations

- Coal switching may be complicated where there are high variations within individual seams or smaller variations between cleaned coals from different seams (Center for Clean Air Policy). Furthermore, this option is feasible only if facilities can burn coal from different sources -- i.e., coal characteristics are compatible with the facility design (Minnesota Pollution Control Agency).

Option 3: Fuel Switching.
(for coal- and oil-fired boilers)

This option involves switching to a less polluting fuel source (e.g., from coal or oil to natural gas) to achieve desired mercury emission reductions. The use of cleaner fuels would largely eliminate emissions of mercury, particulates, other metals, sulfur dioxide, and also significantly reduce emissions of nitrogen oxides and carbon dioxide.

Fuel switching typically entails one of two options: (1) replace an existing coal plant with a new combined cycle natural gas plant; and (2) replace the coal at an existing plant with gas. The new gas option involves higher capital costs than the gas switch option, but fuel and operating costs are lower. Compared with the coal and gas switch options, the new gas option is more fuel economical with lower operating costs (Center for Clean Air Policy).

Reduction Potential

- 100% reduction potential (Center for Clean Air Policy).

Cost

- The Center for Clean Air Policy estimates that replacing an existing coal plant with a combined cycle natural gas plant would cost on the order of $50,000 to $78,000 per pound of mercury emissions reduced (if replacing coal with a high mercury content). Replacing the same coal with gas at an existing plant is estimated to cost about $105,000 per pound reduced (Center for Clean Air Policy).

Option 4: Co-firing.
(For coal- and oil-fired boilers)

(a.) ***Natural Gas Co-Firing.*** This option involves burning natural gas to replace a percentage of coal or oil burned at existing power plants. In assessing this option for coal, the Minnesota Pollution Control Agency assumed enough gas is used to replace coal such that mercury emissions are reduced by twenty percent. Twenty percent, as the percentage of natural gas to be burned, was chosen in order to assess a reduction potential. The actual percentage of gas co-firing needed to achieve a twenty percent mercury emission reduction would depend on the type of coals being

[9]This estimate is for the State of Minnesota only.

replaced, changes in boiler efficiency associated with co-firing, etc. (Minnesota Pollution Control Agency).

Reduction Potential: 280 pounds per year (at 20%) (Minnesota Pollution Control Agency).[10]

Cost: $410,000- $922,000 per pound, based solely upon incremental fuel costs (Minnesota Pollution Control Agency).[11]

Other Benefits

- Since burning gas over coal would lower particulate matter and sulfur dioxide emissions (along with mercury), lowering emissions may ease compliance with other environmental regulations and permitting requirements (Minnesota Pollution Control Agency).

Additional Considerations

- High volume gas supply lines may need to be constructed
- Winter curtailment of gas would affect reliability as an energy source
- Natural gas supplies are not infinite (less than coal).

(b.) ***Wood/Biomass Co-firing.*** This option involves co-firing organic materials (wood, wood waste, etc.) to replace a portion of the oil or coal used at an existing power plant. In assessing this option for coal, the Minnesota Pollution Control Agency assumed replacement would be at a rate of 5-10% (Minnesota Pollution Control Agency).

Reduction Potential: 70-140 lbs/year based on a 5-10% co-fire rate.[12]

Cost: Unknown, and highly dependent on distance between biomass source and the power plant; fuel type; fuel handling characteristics; conversion rate; fuel prices; capital costs; and O&M costs. Cost is largely a function of boiler feed system design (Minnesota Pollution Control Agency).

Potential Drawbacks

- Changes may affect boiler operation and downstream emission control devices, depending on the biomass material used (Minnesota Pollution Control Agency).

Other Benefits

- Potential resulting greenhouse gas "sinks" created by the planting of more trees.

(c.) ***Wind Co-firing.*** This option involves co-firing new wind power and back-up generation to replace a portion of the coal or oil used at an existing power plant. In assessing this option for

[10] This estimate is for the State of Minnesota only.

[11] This estimate is for the State of Minnesota only.

[12] This estimate is for the State of Minnesota only.

coal, the Minnesota Pollution Control Agency assumed replacement would be at a rate of 10%, which would involve a voluntary set-aside of 10% of existing coal-fired capacity. Because wind turbines will generate electricity only when the wind is actually blowing, and utilities must have the capability to produce energy upon demand, backup generation has been added to the cost of this option (Minnesota Pollution Control Agency).

Reduction Potential: 140 pounds per year; if the back-up fuel contained mercury, the overall decrease would be less (Minnesota Pollution Control Agency).[13]

Cost: $537,000-$937,000 per pound[14]

Potential Drawbacks
- Limited areas have good wind resources.
- Wildlife issues, such as migratory flyways, may need to be considered.

Other Benefits
- Other environmental benefits associated with the switch to wind power.

Post-Combustion

Option 5: Flue Gas Desulfurization (FGD) or Wet Scrubbers.
(for coal- and oil-fired boilers)

Scrubbers are used to remove SO_2 from power plants by containing the flue gas with an absorbing solution. Scrubbers use sorbents to create the chemical reactions needed to remove sulfur dioxide. While both wet and dry scrubbers are utilized, wet scrubbers are more efficient (up to 95%) in removing sulfur dioxide than dry scrubbers. Wet Flue Gas Desulfurization Scrubbers (FGD) are currently installed on about 25% of the coal-fired utility generating capacity in the US (Center for Clean Air Policy). Although their primary function is to remove SO_2 emissions, wet FGD systems can also be effective in removing mercury emissions from boiler flue gas (Report to Congress, Vol. 8).

In the US, most commercial wet FGD systems are used downstream of electrostatic precipitators.[15] ESPs remove most of the particulate-bound mercury from the boiler flue gas before it reaches the wet scrubber, so most of the mercury that enters a wet scrubber is in the vapor phase, as elemental or oxidized mercury. Because oxidized mercury is much more soluble in the aqueous solution present in a wet scrubber than elemental mercury, oxidized mercury is more likely to be removed from the flue gas. Wet scrubbers are also known to have a lower mercury removal efficiency if the scrubbers treat sub-bituminous coal gas, and a higher mercury removal efficiency if it treats bituminous coal gas (Report to Congress, Vol. 8).

[13]This estimate is for the State of Minnesota only.

[14]This estimate is for the State of Minnesota only.

[15]Electrostatic precipitators are the most frequently used PM control device used on utility boilers. They operate by imparting an electrical charge to incoming particles, then attracting the particles to oppositely charged plates for collection. (Report to Congress, Vol. 1).

Some evidence suggests elemental mercury can be generated in a wet scrubber system via the reduction of a portion of the oxidized mercury absorbed in the scrubbing solution. Tests by Radian and B&W have noted higher concentrations of elemental mercury in the outlet of a wet scrubber system compared to the inlet concentrations of elemental mercury (Report to Congress, Vol. 8).

Reduction potential

- Studies indicate that wet scrubbers may reduce up to 90% or more of the soluble forms of mercury from the flue gas. This estimate, however, is based on a limited set of laboratory, bench-scale, and field data[16] (Center for Clean Air Policy). Variability in the amount of mercury in flue gas in the soluble form should also be considered as part of the reduction potential.

Cost

- EPRI calculations indicate that wet scrubbers installed primarily for mercury cost between $76,000 and $174,000 per pound of mercury removed. This variation is the result of different assumptions about the elemental/oxidized ratio and the amount of sulfur in the coal (Center for Clean Air Policy).

Additional Considerations*: *Increase Wet Scrubber Efficiency

As mentioned, some utility boilers utilize wet scrubbers to remove particulate matter, SO_2, or both. It has been shown, based on limited experiments, that wet scrubbers are effective at removing the oxidized form of mercury at the same efficiency as the SO_2 removed for wet scrubbers designed for SO_2 removal. Thus, it has been assumed that if lime or limestone is added to the scrubber to increase the percentage of SO_2 removed the same percentage increase in the amount of oxidized mercury removed would occur (18%) (Minnesota Pollution Control Agency).

Scrubbers for enhanced mercury control have not been applied to boilers in the US, although technologies are being considered. Argonne National Laboratory is investigating several additives that combine strong oxidizing properties with relatively high vapor pressures to enhance the capture of mercury in a wet scrubber. Due to a much higher solubility compared to elemental mercury, oxidized mercury is more readily removed in a wet scrubber. Experimentation is continuing on the effect of solutions of chlorine, bromine, and iodine on the conversion and removal of elemental mercury in a laboratory-scale reactor (Report to Congress, Vol. 8).

Radian International LLC has also investigated the conversion of vapor-phase elemental mercury to more soluble oxidized mercury at the bench- and pilot-scales. Radian screened a number of catalysts and coal-based fly ashes for their ability to oxidize elemental mercury, including the effect of flue gas temperature, flue gas vapor phase compounds, and residence time on the oxidation potential of the materials (Report to Congress, Vol. 8).

Reduction Potential/Cost

- 30 pounds per year (Minnesota Pollution Control Agency).[17]

[16]The removal efficiencies can vary widely depending on the mercury species in the incoming flue gas, the design and operation of the wet scrubber system, and the reactions of mercury species in the scrubbing solution.

[17]This estimate is for the State of Minnesota only.

- For units with existing scrubbers, cost estimates range from \$62,000-\$258,000 per pound, with a reduction potential of 30 pounds/year.[18]

Additional options include:

- Improving the Liquid-to-Gas Ratio. The liquid-to-gas ratio of a wet FGD system impacts the removal efficiency of oxidized mercury (high efficiencies (95% removal) have ratios of 120 gal/1000 acf to 150 gal/1000 acf. In two separate pilot studies, increasing the liquid-to-gas ratio from 40 gal/1000 acf to 125 gal/1000 acf increased the removal efficiency of oxidized mercury from 90 percent to 99 percent. (Report to Congress, Vol. 1)

- Wet Flue Gas Desulfurization Tower Design. Research has shown that tray tower or open spray tower designs can be effective in removing oxidized mercury from boiler flue gas. The tray tower design removed from 85 to 95 percent of the total mercury (where the composition of the flue gas was mostly oxidized mercury). The open spray tower design removed from 70 to 85 percent of the total mercury. (Report to Congress, Vol. 1)

Other Benefits

- Results in additional SO_2 reductions

Option 6: Carbon Injection.
(for coal-fired boilers only)

Carbon injection involves the direct injection of activated carbon into the flue gas stream of a utility boiler, prior to existing air particulate control devices. The activated carbon contains multiple internal pores and has a very high specific surface area. With this internal pore structure, the activated carbon can absorb a broad range of trace contaminants, including mercury (Report to Congress, Vol. 8). The used carbon and attached waste products are then captured by existing particulate matter controls, such as electrostatic precipitators or baghouses. The activated carbon process creates large quantities of particulate materials that need to be captured and managed (Center for Clean Air Policy). The collected ash and carbon is then typically land filled or disposed of in ash ponds, although some ash utilization methods may still be viable (Minnesota Pollution Control Agency).

Reduction Potential

- Activated carbon injection has been tested on several pilot-scale facilities and slipstreams from utility boilers while firing different coals. The US test programs have shown mercury removals of 50 to over 95 percent, depending on the carbon feed rate (Report to Congress, Vol. 8).

Cost

- EPA estimates it would cost between \$67,700 and \$70,000 per pound to achieve a 90% control level across the industry (1997). This estimate should be considered preliminary since activated carbon has not been tested at full scale at coal-fired power plants.

---

[18]Scrubbers installed for particulate removal are not designed to handle lime or limestone additions, so additional (retrofitting) costs would be incurred. There may also be additional potential costs for increasing pumping capacity, adding spray levels, adding de-misters, etc. (Minnesota Pollution Control Agency).

- Minnesota Pollution Control estimates:[19]
  - 55 lbs per year with 30 percent control ($37,000-$200,000 per lb)
  - 200 lbs per year with 60 percent control ($11,000 - $110,000 per lb)
  - 520 lbs per year with 90 percent control ($9,000 - $275,000 per lb)

Potential Drawbacks

- There is the potential release of mercury or other emissions during the coal-charring segment of the carbon activation process. However, this amount is very small compared with the amount captured by the injected carbon.
- May have impacts on operation of particulate control equipment (carbon can impact the particulate collection efficiency and baghouse pressure).
- The secondary pollutant benefits of carbon injection are limited.
- This is not a permanent solution. Rather, it shifts mercury releases from air emissions to a waste material. It is expected, however, to slow significantly the rate of release.
- Activated carbon can't be used with wet scrubbers unless it is used upstream with its own particulate collection device. (Report to Congress, Vol. 8).

Other Benefits

- In addition to removing mercury, injection of activated carbon will increase the removal of chlorinated dioxins and furans and potentially other semivolatile organics.

Additional Considerations

- Factors likely to influence the effectiveness and cost-effectiveness of activated carbon include: flue gas temperature (flue gas temperature to preferably be below 150 degrees C. For the mercury to absorb onto the carbon); the amount of carbon injected; particulate control equipment design; the amount, concentration, and species of mercury in the flue gas; the contact between the carbon and mercury (efficient distribution is needed for the carbon to absorb the mercury); the type of carbon used -- activated carbon that is chemically impregnated with sulfur, iodide, chloride or calcium hydroxide may be more effective by 25-45% than nonimpregnated activated carbon, particularly when most of the mercury is in elemental form (Center for Clean Air Policy).

Option 7: Carbon Filter Beds.
(for coal-fired boilers only)

The carbon filter bed is an end-of-pipe technology that enables carbon to absorb pollutants. Rather than injecting carbon into the flue gas, the flue gas is evenly distributed throughout a bed of carbon. Spent carbon can be disposed of by combustion if the unit is equipped with a wet scrubbing system. The combustion process destroys the organic compounds captured in the carbon, and the wet scrubber collects the heavy metals and acid gases. Sources equipped with dry or semi-dry flue gas cleaning systems can also dispose of carbon in a landfill, possibly as a hazardous waste (Report to Congress, Vol. 8).

Reduction Potential

---

[19] This estimate is for the State of Minnesota only.

- Carbon filter bed technology is assumed by EPA to remove 80-90% of the mercury in flue gas at two large (generic) individual facilities at a cost of $33,00 to $38,000 per pound of mercury removed (Center for Clean Air Policy).

Other Benefits

- In addition to mercury, carbon filter beds provide removal of residual organic compounds, other heavy metals, and acid gases (Report to Congress, Vol. 8).

Potential Drawbacks

- Another concern with this technology is the formation of "hot spots" in the bed that can result in bed fires. Filter beds need to be monitored for excess heat (to prevent fires) and the release of very small amounts of mercury when the carbon is reactivated.
- There is the potential release of mercury or other emissions during the coal-charring segment of the carbon activation process. However, this level of mercury release is insignificant when compared with the amount of mercury removed from the flue gas when using carbon filter beds (Report to Congress, Vol. 8, Center for Clean Air Policy).

Energy Efficiency

For years, energy efficiency has been promoted as a way to help preserve dwindling fuel supplies. More recently, there is a growing understanding that through enhanced energy efficiencies, utilities (and industries in general) can also enhance profits by reducing energy and material use through energy efficiency. In addition to saving in raw material usage (e.g., coal), savings can also potentially occur through increased production efficiencies and productivity, and reductions in disposal costs, environmental compliance costs, etc.

A July 2000 report issued by the American Council for an Energy Efficient Economy (ACEEE) and the Regulatory Assistance Project (RAP) concluded that electric utilities could and should take steps energy efficiency steps to save up to 100,000 megawatss (MW) of electrical demand by 2010. This could be enough a savings to stall the need to build new power plants to meet increased electricity demand throughout the next decade. Energy efficiency recommendations include: tuning up residential air conditioning systems (saving 40,000 MW); more efficient air conditioning systems in the commercial sector (saving upt to 30,000 MW); and more efficient commercial lighting (saving up to 10,000 MW) (Environmental News Service).

From a societal perspective, energy efficiency may also be the least-cost option in many cases, when the payback in cost savings to utility customers is considered. For instance, use of more energy-efficient lighting is a cost-free (even financially rewarding) means of reducing mercury emissions. Therefore, utilities, governments and NGOs should support energy-efficiency programs through market transformation strategies (energy efficient mortgages, EnergyStar, code changes, training and education), perhaps financed through statewide system benefit charges.

Additional opportunities for energy efficiency -- demand-side management, co-generation, and other policy options -- are discussed below.

Option 8: Demand-Side Management.

(for coal-, oil-, and natural gas-fired boilers)

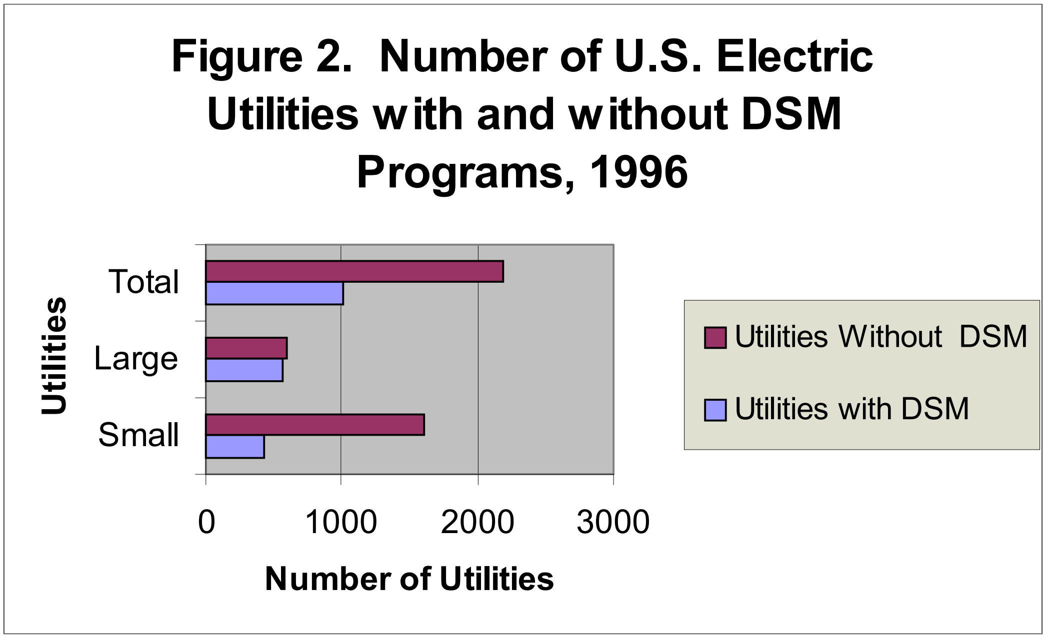
Demand-Side Management (DSM) consists of planning, implementing, and monitoring activities that encourage consumers to alter their electricity consumption behaviors. DSM can entail the application of energy efficiency measures enabling consumers to perform the same function with less energy, and load management programs designed to achieve load reductions during peak loads. In 1996, energy efficiency programs accounted for 96.8 percent of the energy savings through DSM programs. Such savings can be achieved by substituting technologically more advanced equipment to produce equal levels of energy services (e.g., lighting, heating, motor drive) with less electricity. Examples include energy saving appliances and lighting, high-efficiency heating, ventilating and air conditioning (HVAC) systems, or control modification, efficient buildings design, advanced electric motors and drive systems, and heat recovery systems. Financing or financial incentives are also frequently incorporated into energy efficiency programs (Energy Information Administration).

Between 1992 and 1996, electric utilities steadily increased DSM programs. In 1996, more utilities reported having energy efficiency programs in place in the residential sector than in the commercial or industrial sectors. For residences, end-use programs were utilized primarily for heating systems, cooling systems, and water heating. Lighting and cooling system programs were utilized for the commercial sector, and advanced motor programs for the industrial sector. (Energy Information Administration) Since then, with the advent of utility industry de-regulation, DSM programs have begun to decrease.

Reduction Potential

- Where DSM measures can be implemented to offset the demand for fossil-fired electricity (especially coal-fired power plants), mercury emissions will be avoided.
- The reduction potential and cost-effectiveness of increased DSM efforts will vary from utility to utility dependent upon levels of DSM already in place. In general, the most cost-effective DSM efforts are implemented first and therefore, costs are likely to rise as levels increase (Minnesota Pollution Control Agency). See **Figure 2**, showing utilities with and without DSM programs.
- Minnesota estimated DSM cost-effectiveness using DSM measures implemented by Northern States Power (NSP), based on levels of DSM NSP proposed to implement in its Resource Plan (incremental efforts that go beyond programs currently in place). This equated to 7- 17 pounds of reduction per year, and 108 to 171 pounds over 10 to 15 years.

Figure 2[20]



Cost

- NSP's proposed Resource Plan was estimated to cost $493,000 to $810,000 per pound of mercury reduced (Minnesota Pollution Control Agency). This calculation represents the costs to NSP, but not the offsetting cost savings to electricity users. From a broad societal perspective, energy saving measures can save money, while reducing emissions.

Potential Drawbacks

- As electric utilities prepare for restructuring and increased competition in the electric power industry, demand-side management (DSM) programs are undergoing careful review. Competition may create pressure for utilities to cut costs; this can result in a reduction in DSM expenditures and customer rebate programs (i.e., reducing demand may not allow utilities to maintain competitive prices) (Energy Information Administration).
- In 1996, 10 large and 40 small electric utilities either discontinued DSM programs or tracking of the program effects, and spending on DSM programs declined from 1995 reported expenditures by $519.1 million dollars or 21 percent (Energy Information Administration).
- Some argue that only small reductions in coal use actually take place as a result of DSM, with subsequently insignificant reductions in mercury emissions (M2P2 Task Force).

Other Benefits

- Environmental benefits such as reduction in SO_2, NOx, and CO_2 emissions are likely, and should be taken into consideration as part of any DSM economic analysis.

[20] Source: Energy Information Administration.

Additional Considerations

- Demand-side services may be competitively marketed as a means of helping consumers manage their energy bills. Utility consortiums have been formed in the Pacific Northwest and New England to support energy efficiency market transformation. Specifically, these are programs that are attempting to create more lasting change in markets for energy efficient products. Efforts like these may best achieve long-term, economical energy savings via demand side management.

Option 9: Co-Generation.
(for coal-, oil-, and natural gas-fired boilers)

Co-generation is the simultaneous production of heat and electric power, where the efficiency of electric production and overall energy use is improved by recapturing waste heat that would otherwise be exhausted. Co-generation extracts much more usable energy from the same fuel. This can be accomplished in a number of ways, but most commonly involves using waste heat from the production of steam for an industrial process to turn an electric turbine, or in utilities where the waste heat from the steam or hot water line is used to generate electricity (M2P2 Task Force).

Co-generation can offer benefits to energy users in the form of reduced energy costs, and to the general community in the form of more efficient use of energy resources; lower overall emissions (including mercury) from combustion of fuels, and smaller, distributed additions to a region's electric generating capacity (Center for Energy & the Environment).

Examples of different co-generation technologies, as articulated by the Minnesota Center for Energy and Environment include:

- **Steam Turbine Co-generation Systems**: Lower pressure steam is taken from the turbine exhaust or extracted at an intermediate pressure to provide thermal energy for process loads or space conditioning. Steam turbine co-generation systems are designed on a site-specific basis for each application. Steam turbines used in co-generation typically have electrical efficiencies of only 9 to 12 $percent_{HHV}$. Their overall efficiency is in the 76 to $78\%_{HHV}$ range. Installed costs are on the order of $2000 to $4000/kW or more, and maintenance costs are typically around $0.003 to $0.0035/kWh. (Center for Energy & the Environment).

- **Combustion Turbine System**. Thermal energy is recovered from the turbine exhaust gasses. Most combustion turbine systems are site-engineered, but the smaller ones may be packaged systems. The electrical efficiency of gas-fired combustion turbines is generally in the range of 20 to 36%HHV, while the overall efficiency (electric plus thermal) is 60 to 80%HHV. The installed cost is typically between $800 and $1200/kW, and maintenance costs typically range from $0.002 to $0.01/kWh. (Center for Energy & the Environment).

- **Reciprocating Engine System**. Thermal energy is recovered primarily from the jacket cooling water and from the engine exhaust. Many engine-driven co-generation systems are sold as factory-assembled packages with connections for electrical output and heat recovery. Reciprocating engine co-generation systems typically have electrical efficiencies of 25 to 25%HHV, and overall efficiencies of 67 to 85%HHV. The installed cost is typically $800 to $1000/kW, and the maintenance cost is about $0.015/kWh. (Center for Energy & the Environment).

The most common co-generation fuel is natural gas (for nearly all of the gas turbine, combined cycle, and internal combustion engine co-generation capacity) followed by coal and wood (for most simple cycle steam turbines) (Center for Energy & the Environment).

Reduction Potential

C Reductions are difficult to estimate given the site-specific nature of efficiency improvements resulting from a co-generation application. Fuel-to-energy conversion efficiencies of up to 80-90 percent could be achieved with co-generation, depending on the needs of the steam host, type of fuel, and equipment employed. By doubling the energy efficiency, air emissions could be reduced by ½ (Minnesota Pollution Control Agency).

Cost

C Cost-effectiveness has not been determined for existing coal-fired facilities. However, co-generation should have little or no cost in new facilities/units, depending on the proximity to a host site. However, co-generation could potentially be profitable in ideal situations.

Potential Drawbacks

C Potential regulatory hurdles (such as New Source Review under federal and State Clean Air statutes may be applied to modifications to existing boilers) may create a disincentive under this option.

Other Benefits

C Co-generation reduces greenhouse gas emissions and other pollutants.

Option 10: Alternative Policy Approach

Emissions Cap Programs set a ceiling of allowable emissions, with some flexibility regarding how these limits can be met. The emissions limits, in addition to penalties for exceeding the limit, are set by the applicable regulatory agency. The costs associated with remaining under these caps are dictated by individual markets and the innovations used. In certain jurisdictions and under specified conditions, trading with other sources of the same pollutant can be one very cost effective way to meet an emissions cap (Report to Congress, Volume 8).

Utilities and other sectors may find such an incentive-based program to reduce mercury emissions attractive. The option has the potential to reduce compliance costs, bank credits for future regulatory requirements, and demonstrate environmental leadership. A mercury emissions trading program may also be attractive from an environmental standpoint, in light of the fact that mercury emissions do not always have local environmental impact, and are subject to long-range transport. Trading can balance overall emissions from different geographic regions. Finally, the potential to engage in cost-effective trading may create incentives for companies to produce better mercury emission reduction and measuring technologies (Report to Congress, Volume 8).

The Future

Nationally, the electric industry is in transition, the electricity industry is moving away from a vertically integrated monopoly towards a competitive industry (Report to Congress, Vol. 2). This restructuring process may lead to a more efficient supply of power and reduced energy costs. However, a more competitive market structure will result in increased generation, which may lead to increased pollution from electricity generators with lower operating costs and that rely more heavily on higher-emitting coal-fired power plants (Center for Clean Air Policy).

Furthermore, with the advent of competition, some energy efficiency programs may be considered anti-competitive, as they could potentially increase electricity rates. Large industrial and commercial customers in a state whose utilities are subject to higher environmental compliance costs may simply chose to purchase less expensive electricity from neighboring states, or even move their businesses to those states (M2P2 Task Force).

Future trends in mercury emissions from changes in the utilities industry are largely dependent on both the nation's future energy needs and the fuel chosen to meet those needs. However, it has been estimated that up to 2,000 MW of capacity (equivalent to two major power stations) will need to be built every week throughout the world -- 25% or more based on coal (World Coal Institute).

These increases in coal use for power generation might be partly offset (even in the absence of controls specifically targeting mercury) by reductions that occur as a by-product of installing other technologies designed primarily to reduce emissions of other air pollutants, including sulfur dioxide and nitrogen oxide.

EPA has modeled the mercury reduction implications of strategies to reduce other pollutants. While reductions in mercury emissions from coal fired power plants appear to be more expensive (compared to expenses incurred by sectors that are currently regulated for mercury), this modeling suggests that the multiple pollutant/multiple benefits approach should be considered (Center for Clean Air Policy).

EPA modeling has shown:

- Implementation of the National Ambient Air Quality Standards (NAAQS) for fine particulates alone could reduce mercury emissions by 21 tons from current levels.[21] (Center for Clean Air Policy).

- Implementation of the new NAAQS combined with stabilization of carbon dioxide emissions at 1990 levels could reduce mercury emissions by 44% from current levels.[22]

Projections such as these suggest that mercury reductions could be enhanced by considering multiple benefits approaches, particularly in meeting carbon dioxide emission reduction requirements. The Center for Clean Air Policy has also researched the multiple benefits approach. This research has found that the cost-effectiveness of switching to natural gas improves once other environmental benefits (reductions in greenhouse gases, fine particulate matter, ozone, and acid rain) associated with reducing CO_2, SO_2, and NO_x are taken into account. **See Tables 3 and 4.**

[21]This projection assumes wet scrubbers are installed on an additional 60 GW of coal-fired capacity, and that electricity from natural gas would increase by 16% above baseline levels.

[22]Projections assume fuel switching to gas.

Table 3.[23]: Costs of Switching from Coal to Natural Gas

Type of Coal Being Replaced	Cost per Pound of Mercury Reduced	
	New Gas Plant	Replace Coal with Gas at Existing Plant
High Mercury Medium Mercury Low Mercury	$0 $0 $17,000	$71,000 $134,000 $299,00

Table 4.[24]: Costs of Switching from Coal to Wind Power

Type of Coal Being Replaced	Cost per Pound of Mercury Reduced For Replacing Coal Generation with Wind Power	
	"Best guess" capital cost estimate ($750/KW)	High Capital Cost Case ($1000/KW)
High Mercury Medium Mercury Low Mercury	$23,000 $46,000 $93,000	$75,000 $147,000 $295,00

Research will continue on ways to improve mercury capture by conventional emission control devices and the development of novel techniques. To most effectively develop low-cost mercury strategies for power generation, research on the chemistry and interactions of flue gas constituents, fly ash, and mercury species must continue as well. Nonetheless, as new and refined technology options arise and new standards are promulgated and implemented (e.g., fine particulate compliance), cost-effectiveness estimates for mercury removal -- under a multiple benefits approach -- are likely to improve.

[23]Includes CO_2, NO_x, and SO_2 benefits; required reductions in CO_2 emissions in association with the Kyoto Protocol are assumed; factors in conservative values for the SO_2, CO_2, and NO_x credits that would be earned by switching to gas. Source: Center for Clean Air Policy.

[24]Source: Center for Clean Air Policy.

Resources used in creating this section

Center for Clean Air Policy Discussion Paper: Mercury Emissions from Coal-Fired Power Plants. Science, Technology and Policy Options. Center for Clean Air Policy Discussion Paper. November 1998.

Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels. U.S. Electric Utility Demand-Side Management: 1996. December 1997.

Environmental Working Group. Mercury Falling: An Analysis of Mercury Pollution from Coal-Burning Power Plants. November 1999.

Michigan Mercury Pollution Prevention Task Force. Mercury Pollution Prevention in Michigan: Summary of Current Efforts and Recommendations for Future Activities. April 1996.

Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

U.S. EPA. Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units -- Final Report to Congress, Volume 1. February 1998.

U.S. EPA. Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs. December 1997.

Web sites

www.utilityguide.com

MERCURY IN THE MANUFACTURING INDUSTRY

There are many ways mercury is used or released in industrial manufacturing processes:

- in the manufacturing and use of devices;
- in the use of products that incorporate mercury-containing devices;
- in the manufacturing and use of chemicals; and
- in the raw materials used in manufacturing processes, such as taconite processing, Portland cement manufacturing and energy production.

Many of these manufacturing processes are also very energy intensive, and may contribute mercury to the environment indirectly through the combustion of fuels.

The most effective way of reducing mercury pollution is through pollution prevention: not using mercury or mercury-containing items in the first place. The Minnesota Pollution Control Agency estimates that 90% of all current uses of mercury-containing products are avoidable and that using mercury-free substitutes could lead to a reduction in mercury in Minnesota alone of 7000 pounds per year! The cost of purchasing mercury-free devices (e.g., mercury switches, thermostats, gauges) in place of mercury-containing ones has not been quantified, but is expected to be relatively low.

This chapter is comprised of four sections: 1) manufacturing and use of mercury-containing devices; 2) industries that put mercury-containing devices in their products; 3) manufacturing and use of mercury-containing chemicals; and 4)industries that release mercury as a by-product of a manufacturing process.

A. MANUFACTURING AND USE OF MERCURY-CONTAINING DEVICES

Mercury has unique properties that make it very valuable in many manufacturing processes. It is a very good electrical conductor, making it useful in some electrical processes and materials; it uniformly expands and contracts, allowing temperature to be precisely measured; and, it is a good antifungal and antibacterial agent, making it useful in paints, pesticides and medicinal products (e.g., thimerosal in vaccines, contact solution and nasal spray).

There are industries that manufacture mercury-containing devices, using mercury in their processes and there are industries that purchase and use those devices in other industrial processes. Some of the options in this section pertain to manufacturers who use mercury, others pertain to those who use mercury-containing devices and some options pertain to both.

Mercury-containing devices that are manufactured and used in an industrial setting include temperature measurement equipment (i.e., thermostats and thermometers), pressure measurement equipment (i.e., barometers and manometers) and electrical switching equipment (switches, relays, timers and gauges). Mercury-containing products that are used in an industrial setting are often found in boiler rooms, associated with furnaces, heating and cooling equipment, and capital equipment. Manufacturing plants may also stock elemental mercury for servicing equipment as well as fluorescent lighting and batteries.

Electrical, appliance and automobile manufacturing are the predominant industries that manufacture mercury-containing products. These industries and many others also use the mercury-containing items that these manufacturers produce. The removal of mercury from these types of manufacturing could eliminate the use of mercury-containing items in many other industries, thereby decreasing overall mercury pollution from industry. Many manufacturers are already using and developing new processes that are not reliant on mercury.

This section is divided into two sub-sections: 1) industries that manufacture and use mercury-containing devices and 2) industries that put mercury-containing devices in products (with a focus on automobiles). Each sub-section contains background information and options for reducing mercury pollution relating to the manufacturing and use of mercury-containing devices.

Background on Mercury-Containing Devices

Light Bulbs and Lamps

Mercury is used in five types of widely-used lamps: fluorescent, mercury vapor, metal halide, high-pressure sodium vapor and neon. See Attachment 1 for more information about these lamps.

The most commonly used lamp is the fluorescent light; therefore, this discussion will focus on fluorescent lighting. Mercury from these lamps is emitted when they are broken, disposed of in landfills or incinerated. EPA estimated that 1.5 tons of mercury are released annually from fluorescent lamps breakage, although the lamp industry believes that releases are much lower.

Although fluorescent bulbs contain mercury and require special handling and disposal, they are 3-4 times more energy efficient than incandescent bulbs and often last much longer. The use of fluorescent lighting therefore minimizes our use of energy, including energy from coal-fired power plants which are a major source of mercury pollution. Fluorescent lighting is thus an attractive option, if handled and disposed of properly.

Switches in Relays and Thermostats

Temperature measurement and control is essential to many industrial operations. Mercury is used in temperature and pressure sensitive switches and in switches that are activated by a change from the vertical to horizontal position (mercury tilt switch). If a mechanical switch is not in operation, mercury switches are most likely in use.

Switches used in furnaces and bimetallic thermostats are examples of temperature sensitive mercury switches used in electric heating control. Bimetallic thermostats are used when inaccurate temperature control [±10EF (±6EC) or more] is acceptable and when work load temperature changes fairly slowly over time.

Relays are also devices used for temperature control in electrical heaters and coolers. Relays convert output from the temperature control device into heating or cooling production by opening or closing electrical contacts in a circuit. Mercury-wetted contact relays are used for reliable switching of wide ranges of signal and power levels because the load does not affect either contact life or performance (due to the fact that no solid metal to metal contact occurs).

Mercury tilt and float switches are examples of positional and/or motion switches. Tilt switches are used for example, to stop a spin cycle in a washing machine and turn on a light when a lid to a freezer or a trunk is opened. Tilt switches are used in space heaters and irons for safety precautions: when the heater or iron falls over, it turns off. They operate by opening or closing an electric circuit through position and/or motion of the switch. Mercury float switches turn equipment on or off when water is at a certain level; these switches are often used in sump and bilge pumps.

Pressure-sensitive mercury switches are often used in industrial applications, such as within a reactor vessel. In Michigan, seventy-nine tons of mercury were used in the manufacture of all mercury-containing switches in 1994 (M2P2 Task Force).

Thermometers

Mercury thermometers are used in industrial settings. The mercury thermometer consists of a capillary tube which is filled with mercury that expands and contracts in a consistent fashion with temperature changes.

Manometers and Barometers

Manometers and barometers are pressure-measurement devices. Barometers specifically measure atmospheric pressure while manometers measure hydrostatic pressure.

Mercury manometers are often used to measure pressure in systems that rely on vacuums such as power plants, refrigerant systems, plastics manufacturing and milking systems. In power plants mercury manometers are used to check condenser efficiency by monitoring the vacuum at several points on the condenser. In refrigerator or air conditioner systems, mercury manometers are also used to measure the vacuum (a complete vacuum must be pulled before filling the system with freon). In plastics manufacturing, a vacuum must be maintained to insure that the plastics resins stay liquefied. If a vacuum is not maintained, the plastic product will begin to solidify. Manometers are also used in the dairy milking systems to measure pressure in the vacuum lines that remove and transport milk from the cows' udders to a bulk tank. It is important to monitor the vacuum pressure because large pressure fluctuations may indicate operational inefficiencies and can cause health problems in the cows.

Options

In the options described below, some pertain to manufacturers, others to the product users and some to both manufacturers and product users. The following options are grouped accordingly:

Options for Manufacturers of Mercury-containing Devices:

- ***Discontinue manufacturing of mercury-containing devices and make available non-mercury products***
- ***Participate in the development of a national mercury labeling requirement***
- ***Support recycling efforts of mercury-containing products***

Options for Product Users*:*

T *Buy mercury-free alternatives*

T *Conduct an inventory of mercury and mercury-containing devices*

Options for Both Manufacturers and Product Users:

T *Establish a spill response plan*

T *Properly dispose of and recycle mercury-containing items*

Option 1: Discontinue manufacturing of mercury-containing devices and make available non-mercury products

All industries that introduce mercury into their products should look for ways to manufacture them without mercury. By participating in mercury pollution prevention, these industries can provide many benefits to the environment as well as to their businesses, such as:

- reduction of occupational exposures and releases of mercury to the environment;
- avoidance of the costs associated with the use of mercury, such as disposal or recycling, collection and storage prior to disposal, paper work for tracking hazardous waste disposal, training and equipment for spill response, training for employees who handle mercury-containing products, and liability for environmental problems or worker exposure; and
- avoidance of increased regulation in the future.

The lighting industry has made great strides in reducing the amount of mercury in lamps by making significant investments in the manufacturing process and new lamp designs to continue to decrease mercury content in lamps. These investments have reportedly reduced the average mercury content of a four foot fluorescent lamp from 48.2 mg in 1985 to 11.6 mg in 2000. Philips Electronics currently manufactures a fluorescent lamp (with the product name of ALTO) that contains less than 10 milligrams of mercury, and is not considered a hazardous waste by the federal government.

Option 2: Participate in the development of a national mercury labeling requirement

For products or components which contain a significant percentage of mercury, device manufacturers should work with environmental agencies to devise and implement a national mercury labeling requirement. This effort would identify whether a product contains mercury, and allow consumers and businesses to make informed decisions about pollution prevention and environmental safety. (Minnesota Pollution Control Agency)

An example of the need for mercury labeling is the Northwest Indiana Steel Mills' attempt to identify the equipment in their facilities that contained mercury. They found that it was a difficult and time-consuming process because each item had to be identified with the model number and plant purchase order in order to contact the vendor and determine if the equipment contained mercury. If the mercury-containing equipment were labeled, the identification and replacement process would have been much quicker. (NW Indiana Steel Mills)

Option 3: Support recycling efforts of mercury-containing products

Manufacturers that sell mercury-containing products should support recycling of those products. There are at least two successful programs (described below) for recycling thermostat switches containing mercury. These types of programs could be expanded to include additional geographic locations or to include other mercury-containing products.

The Thermostat Recycling Corporation (TRC) launched a program in 1997 to recycle mercury-switch thermostats in nine states, including Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The TRC is a private corporation established by thermostat manufacturers Honeywell, General Electric, and White-Rodgers. Under the program, heating and cooling contractors can drop off old mercury-switch thermostats at participating wholesalers. The wholesalers will collect the thermostats in protective bins provided by TRC and send them to TRC's recycling center where the switches will be removed and forwarded to a mercury recycler. TRC reports that it has processed 120 pounds of mercury in the program's first nine months, much of which comes from Great Lakes states. The TRC also announced plans to expand the program to 13 east-coast states and DC as soon as it obtains the necessary regulatory approvals. For more information on this program, contact Ric Erdheim, Acting Executive Director, TRC, 703/841-3249.

The state of Wisconsin also has a thermostat recycling program. Wisconsin DNR is partnering with electric utilities through the Thermostat Recycling Corporation (TRC), community clean sweeps, household hazardous waste collection facilities, and other means to promote recycling and replacement of mercury-switch thermostats. Two of the state's six major utilities have included promotional materials with customer bills and/or on their web sites. TRC reports that, since November 1997, 932 thermostats have been collected; 69 recycling bins have been issued; and 9.7 pounds of mercury have been reclaimed. For more information, contact: Kristin Churchill, Wisconsin DNR, 608267-7603.

Option 4: Buy mercury-free alternatives

Fluorescent light bulbs
There are no mercury-free alternatives to fluorescent lamps, but there are reduced mercury fluorescent bulb versions which should be used and recycled when burnt out.

Thermostats/Tilt Switches
The estimated cost for replacing mercury switches in use at electric utilities at the end of their useful life is approximately $10 per pound. To replace mercury switches before the end of their useful life is about $1000 per pound. Some argue that the avoided cost of a spill cleanup could lead to the replacement of mercury items being a cost saving. The cost for recycling and replacing mercury switches in personal businesses and households has not been estimated. (Minnesota Pollution Control Agency)

Table 1 lists different types of tilt switches along with possible locations and alternatives and Table 2 gives alternatives to tilt switches used in thermo-electrical operations.

Thermometers

Several mercury-free alternatives to mercury thermometers, including electronic (digital), expansion and aneroid versions, are readily available and should replace the use of mercury thermometers to reduce the risk of spills.

Manometers

Mercury-free manometers are readily available and should replace the use of mercury manometers to reduce the risk of accidental release of mercury to the environment. They are usually not more expensive than mercury manometers and can be easier to read. Table 3 lists the brand name, model and company contact for different mercury-free manometers, while Table 4 describes different alternatives to mercury-containing manometers.

Option 5: Conduct an inventory of mercury and mercury-containing devices

Manufacturers should conduct an inventory of mercury and mercury-containing devices to determine the presence of mercury in the facilities. This will alert equipment purchasers to the mercury so they may purchase alternatives when buying replacement devices. In addition, recycling activities will be enhanced through awareness of mercury-containing devices in the facility.

Three Northwest Indiana Steel Mills conducted a mercury inventory in 1999 as part of a voluntary agreement known as the Mercury Pollution Prevention Initiative in the Lake Michigan basin (see http://www.deq.state.mi.us/ead/p2sect/mercury/hghomepage.htm). The effort was divided into three parts; mercury was identified in: 1) purchased equipment and materials, 2) in use and in storage, and 3) in waste streams and (revert/recycled) outputs. Mercury was found in a variety of materials, with almost one half of the mercury present in the manufacturing plants (572 pounds) contained in equipment. 330 pounds of liquid mercury were found in temporary storage, including mercury removed from obsolete equipment. After the inventory was conducted, the three participating companies identified alternatives to mercury-containing equipment and materials and potential recycling options. Finally, they prepared mercury reduction plans in order to reduce risk of mercury spills; these plans included reduction goals and an implementation and reporting schedule for meeting those goals. The mercury reduction goals for the three steel mills are: to reduce mercury usage by 66% in the first five years and by at least 90% within 10 years of the project initiation.

Consumers Energy Company, a large power utility in Michigan, has also conducted a company-wide inventory of mercury which has alerted employees to the presence of mercury. Consumers Energy has also committed to a company pollution prevention effort, resulting in substantial reductions in mercury usage. Since the beginning of the mercury pollution prevention effort, Consumers Energy has:

- established a recycling program for old mercury-containing gas regulators,
- reduced stock mercury by 76.7%,
- replaced all mercury operated flame sensor switches with mercury-free alternatives, and
- established a replacement program for all failed mercury-containing equipment that provides for recycling of the old equipment and purchasing mercury-free alternatives.

Option 6: Emit less mercury in the manufacturing process by establishing a spill response plan

Mercury is an extremely hazardous substance. Mercury spills, therefore, can pose serious health risks (e.g., through vapor emissions or direct contact) and can be very difficult and costly to clean up. Small droplets of mercury can adhere to clothing, watches and gold (allowing the mercury to be transported to other locations) and become lodged in cracks and crevices in tile floors, counter tops and sinks.

Mercury spill prevention as well as proper spill response are important aspects of manufacturing facilities' mercury management policy. The following are some best management practices that will aid in spill prevention and response.

Mercury Spill Prevention and Response Practices

- Use mercury only in uncarpeted, well-ventilated areas. It is preferable to use mercury devices in rooms that do not have carpeting or other floor coverings that are not easily cleaned.
- Ask workers to remove all watches and other jewelry–especially gold jewelry since mercury readily combines with it.
- Prohibit smoking, eating and drinking in the area.
- Train all workers to understand the properties and hazards of mercury and to carry out safe handling procedures and specific policies related to mercury disposal.
- Clean and calibrate all mercury-containing equipment according to the manufacturer's recommended handling procedures and the formal procedures posed by your communications or safety program supervisors.
- Be prepared for a spill in any area where mercury-containing devices are used. Have a mercury vacuum sweeper and spill cleanup kit available. Never use a regular vacuum cleaner to clean up mercury–it will vaporize the mercury and release it into the air.
- Cleanup of mercury spills must be performed by specially trained staff.
- Create a formal mercury spill policy for your facility, considering the following factors:
  - availability of a staff person, trained in mercury spill cleanup
  - OSHA requirements
  - protective equipment and clothing for cleanup staff
  - type of flooring (linoleum, carpet, etc.)
  - determination of the type of equipment to be used for the size and type of spill
  - manufacturer's instructions for the equipment to be used
  - ultimate waste disposal, which may depend on the cleanup method
  - preparation of an incident report that describes the spill, the cleanup method used, unusual circumstances, and follow up

(Terrene Institute quoted by Wisconsin DNR)

Option 7: Properly dispose of and recycle mercury-containing items

Handle all mercury-containing lamps, batteries and devices as outlined in the Universal Waste Rule (40 CFR 273) and as in Management of Spent Mercury-Containing Lamps and Mercury-Containing Devices Destined for Recycling (62-737 F.A.C.). Handle all other mercury-containing items as hazardous waste under the Hazardous Waste Rule (62-730 F.A.C.). Additional information on proper recycling and disposal is provided below.

Fluorescent Bulbs

When a fluorescent bulb or a mercury vapor lamp burns out, carefully remove it from its fixture and store it in its original container or other box. Do the same with blue-tinted automotive headlamps; be sure to remove them before sending a retired vehicle to the scrap dealer. Mark the container "Mercury for Recycling" and take it to a local household hazardous waste collection site.

Never break or crush the bulbs. If a bulb is accidentally broken, air out the room and scoop the mercury-containing pieces and powder into a sealable, plastic container. Take the marked container to a local hazardous waste collection site.

Companies that recycle fluorescent lamps and other mercury containing devices are on the Internet at: http://www.state.in.us/idem/ctap/mercury/recyclers.pdf .

Switches

An inventory of mercury sources within Consumer's Energy revealed 408.5 pounds of mercury in switches, relays, timers and gauges–a significant amount! When the lifetimes of these devices are over, recycle them and purchase mercury-free alternatives.

When you replace an appliance, device or vehicle, remove switches and relays or ensure that they are removed, properly handled and recycled. Please be sure, however, never to remove the internal mercury switch from thermostats. Place the switch or relay in a sealable, plastic container and mark it "Mercury for Recycling". Take the container to a local mercury recycling site. (IDEM web site)

Call 1-800-345-6770 to determine how to recycle used mercury thermostats in your area (Wisconsin DNR) In addition, facilities should participate in the Honeywell Corporations's reverse distribution recycling program for mercury-containing thermostats. Contact Honeywell for more information at: (800) 468-1502.

Relays

Watlow Electrical Manufacturing has a recycling program for mercury displacement relays (MDRs) it makes or manufactures. In order to participate in this program, follow these procedures:

- Contact Watlow Controls at 507-454-5300 to establish an account and to obtain authorization to return the MDR
- Watlow will send the returned MDRs to a consolidator or recycler, who will remove and recycle the mercury and all other parts of the MDR that are recyclable or removable. Watlow will pay for the cost of collecting and disposing of the MDRs made or marketed by Watlow.
- MDRs eligible for this service are Watlow Series A, H, HG, KD, L, LD, M, and MD relays. (Watlow Electric Manufacturing)

If the MDR to be returned has one or more breached (open) poles, it must be sealed in a non-porous container to prevent the escape of liquid and gaseous mercury.

Acceptable non-porous containers are composed of high density polyethylene, or equivalent.

Watlow recommends the relay(s) be double-bagged in sealed Zip-Lock-type storage bags and further sealed with heavy duty packaging tape. Please ship the unit with adequate packing material in a corrugated cardboard box (minimum burst strength of 200 pounds). Breached relays must be shipped as hazardous material.

Please include the following information on the hazardous material shipping label:

- Proper shipping name: Mercury contained in manufactured articles
- Emergency contact number:800-800-2385 (Dynex Environmental Services)
- Hazard Class or Division:8

- Identification Number:UN2809
- Packing Group:1
- Type Label(s) and required information: Corrosive

For additional assistance, contact Watlow Controls at 507-454-5300 and ask to speak with the MDR product manager or site safety director. (Watlow web site)

Manometers

Each mercury manometer has a U-shaped plastic tube containing 0.781 pounds of mercury. This mercury can become contaminated by water, milk, dirt and cleaning chemicals and the plastic tube that holds the mercury can become discolored, which makes it difficult to read the manometer accurately. When this happens, the manometers must be repaired or replaced and the mercury disposed or recycled. A survey conducted in Minnesota revealed that 20 percent of the 2,357 dairy farms in the State use mercury manometers, containing about 1,825 pounds of mercury. In addition, 205 pounds of mercury are in storage or use at the dairy dealerships in Minnesota. (Wisconsin DNR) An inventory of mercury sources within Consumer's Energy revealed 368.9 pounds of mercury in manometers and barometers.

Develop procedures for disposing of/ recycling mercury-containing manometers. Some tips on disposing of and recycling your mercury-containing items:

- Label a container for mercury-containing items and place it in a convenient location.
- Mercury waste from servicing manometers should be stored in a covered, air-tight plastic container labeled "CONTAINS MERCURY" and send to a recycler.

B. INDUSTRIES THAT PUT MERCURY-CONTAINING DEVICES IN THEIR PRODUCTS

Automobile and appliance manufacturers are the two major industries that put mercury-containing devices in their products. This section addresses both industries.

1. Automobile Manufacturers

Background

Mercury may be in mercury switches, batteries and lamps used in automotive applications such as:

C hood and trunk lighting,
C anti-lock brake systems (ABS),
C air bags,
C active ride control,
C airbag sensors,
C radios,
C head lamps,
C remote transmitters,
C light switches and
C speedometer systems.

Ninety percent of mercury used in automobile manufacturing is in switches used for convenience lighting in trunks and hoods; therefore this discussion focuses on these types of mercury switches.

The mercury switch uses a liquid pool of mercury to activate an electric signal. In the mid-1990's, more than 9 metric tons of elemental mercury per year were supplied nation-wide for auto switch applications (M2P2 Task Force). In Minnesota alone, it is estimated that 86,000 mercury switches containing 152-190 pounds of mercury were contained in scrapped automobiles (Minnesota Pollution Control Agency). Mercury is released when autos are shredded or when scrap steel is melted to produce new steel.

Fortunately, suitable alternatives are currently available for mercury switches. The domestic automobile industry is actively practicing pollution prevention and achieving significant mercury reductions in the production process through the U.S. Automotive Pollution Prevention Project (see description later in section). However, recycling of mercury in automobiles is not as far along: while 94% of vehicles are recycled, the mercury switches in them are generally not. As a result, mercury is released into the environment.

Chrysler, Ford and General Motors have worked towards eliminating the use of mercury switches in automobile manufacturing. As a result, Chrysler vehicles are now mercury switch-free and Ford vehicles will be mercury-free by 2002. General Motors has taken some steps to reduce mercury use in vehicles.

In addition to these efforts, the Chrysler Corporation, Ford Motor Company, General Motors Corporation and the American Automobile Manufacturers Association joined forces in 1991 to form the U.S. Automotive Pollution Prevention Project (or, Auto Project). The Auto Project is currently a national effort and has developed 70 pollution prevention case studies (many of which pertain to mercury) and is helping to track emissions for the automobile industry of mercury and other toxic substances.

Attached to this section are: Table 5, which lists the mercury-containing products found in cars and some possible alternatives, and Tables 6 and 7 that name the domestic and foreign vehicles known to contain mercury-containing products.

In addition to mercury used in the mercury switches for convenience lighting in the automobile industry, manufacturers may also have other mercury-containing products at the facility that are used in the course of manufacturing such as fluorescent lighting, electrical equipment and displacement relays. For a full list of other mercury-containing items that may be in use at your facility and options that can be taken to reduce mercury pollution, refer to the previous section, "Manufacturing and Use of Mercury-containing Devices".

Options

- ***Discontinue use of mercury switches in convenience lighting and explore options for other uses as well.***
- ***Support programs to remove mercury switches from automobiles.***

Option 1: Discontinue use of mercury switches in convenience lighting and explore options for other uses as well.

For many of the current mercury sources, including mercury switches, there are acceptable mercury-free alternatives.

Table 5 lists mercury-containing products that may be used in automotive applications along with some suitable mercury-free alternatives. Major mercury-containing products are trunk and under-hood light switches (main source of mercury), ABS systems, HID head lamps and active ride control.

Option 2: Support programs to remove mercury switches from automobiles.

Automobiles are the most recycled product in the world: 94% of registered vehicles are recycled. During the recycling process, mercury can be emitted to the atmosphere when the vehicle is crushed or shredded, or when scrap is used to produced new steel.

This issue is just beginning to be addressed. The New York State Department of Environmental Conservation (NYDEC) has developed two different approaches that deal with recycling mercury switches from automobiles. The first type of program focuses on removing mercury switches while the auto is still in service. For example, in West New York, mercury switches are removed from government fleets. In addition, Valvoline dealers will replace mercury switches during an oil change. The second type of program targets the dismantlers and crushers and trains them to remove switches from the automobiles before crushing.

It is important to develop a standard procedure for dismantlers to follow when taking apart the car for recycling. In the meantime, the following instructions for removing mercury switches used in hood and trunk lighting are helpful. (Minnesota Pollution Control Agency)

- When vehicles are dismantled for parts, or when other wastes such as oil, battery and tires are removed, mercury switches should also be removed. If they are not removed during the dismantling, then they should be removed before crushing.
- To remove the switches, clip the wires and unscrew or pry the light fixture from the hood or trunk. Sometimes, the mercury switch will be found further along the wire towards the bottom of the hood or trunk. The mercury switch is a small, bullet-shaped metal or glass capsule that forms the base of the light socket and is visible once the bulb is removed. The capsule can usually be popped out of the fixture by pushing it through the socket from the base (wire) end. In some cases, the fixture will need to be cut open to remove the mercury-containing capsule.
- Be careful not to rupture the capsule (if this happens, consult your facility's mercury spill response procedure or the hazardous waste manager).
- If you hear and feel a soft rattle when the capsule is shaken, it contains mercury. Removing the mercury containing capsule from the light fixture will save on storage space and may also save on disposal costs as recyclers may charge by weight.
- Store the mercury switch and/or capsules in a leakproof, sealable container, and ship to a recycler.

2. Appliance Manufacturers

Appliance manufacturers, use mercury switches in appliances such as chest freezers and gas ranges. These switches are used for convenience lighting and for safety. Mercury-free alternatives should be used in the manufacturing of appliances.

C. MANUFACTURING AND USE OF MERCURY-CONTAINING CHEMICALS

This section discusses the manufacturing and use of mercury-containing chemicals, and outlines options chemical manufacturers can take to reduce mercury pollution. Mercury is used as a preservative in laboratory chemicals and pharmaceuticals, because of its anti-bacterial properties. Mercury is also used, in the case of chlor-alkali manufacturing (the largest chemical manufacturing source of mercury), as a cathode in an electrolytic cell used to manufacture chlorine and caustic soda. The resultant chlorine and caustic soda may become contaminated with mercury, which then contaminate other manufacturing facilities that use these chemicals (e.g., pulp and paper).

1. Chemicals Manufacturing (including pharmaceuticals)

Background

Chemical manufacturers use mercury compounds in a variety of settings. Chemical uses of mercury may occur in catalysts, cosmetics, explosives, fireworks, livestock and poultry remedies, packaging, pharmaceuticals, paints, fungicides, pesticides, pigments and dyes, poisons, preservatives, and special paper coatings. Commonly used mercury compounds include mercuric chloride (used in laboratories) and thimerosal (used as a preservative in contact lens solutions, nasal sprays and vaccines). See Table 8for a list of common mercuric compounds and solutions. Most of these uses of mercury have been phased out or are in the process of being phased out.

Chemical manufacturers may also have accumulated mercury in their sewer pipes and traps from historical disposal of mercury-containing chemicals down the drain. It is important to be aware of this possible source of mercury in a facility's wastewater, as the facility may still be releasing mercury even when all pollution prevention measures have been implemented.

Options

- ***Discontinue manufacturing of mercury-containing chemicals and make available and promote non-mercury alternatives***
- ***Emit less mercury in the manufacturing process by establishing a spill response plan***
- ***Participate in the development of a national mercury labeling requirement***
- ***Clean out the wastewater system to rid the facility of historical uses of mercury***

Option 1: Discontinue manufacturing of mercury-containing chemicals and make available and promote non-mercury alternatives

Chemical manufacturers should identify and produce alternatives to mercury-containing chemicals. The pharmaceuticals industry is actively pursuing this option in regards to the vaccine preservative, thimerosal.
The American Association of Pediatrics released a report indicating that thimerosal should be removed from vaccines typically administered to infants. Thimerosal is a very effective preservative that contains

ethyl mercury and has been used in vaccines to safeguard against bacterial contamination that may result in infant mortality. Although mercury levels in vaccines are within federal guidelines, Public Health Service agencies, the American Academy of Pediatrics and vaccine manufacturers agree that thimerosal should be reduced or eliminated in vaccines to make them safer. The pharmaceutical industry responded and is working on alternatives to thimerosal. In August 1999 the FDA licensed a thimerosal preservative-free hepatitis B vaccine, and other thimerosal-free vaccines are currently under review.

The risk of exposure to thimerosal versus the very large and devastating risk of childhood diseases (e.g., bacterial meningitis, whopping cough) leaves no question of whether to vaccinate the child. Parents and physicians should feel confident in the safety of the vaccines and continue to vaccinate their children according to the recommended schedule. This effort to reduce thimerosal in vaccines is making a small risk non-existent.

Option 2: Emit less mercury in the manufacturing process by establishing a spill response plan

Mercury is an extremely hazardous substance. Mercury spills, therefore, can pose serious health risks (e.g., through vapor emissions or direct contact) and can be very difficult and costly to clean up. Small droplets of mercury can adhere to clothing, watches and gold (allowing the mercury to be transported to other locations) and become lodged in cracks and crevices in tile floors, counter tops and sinks.

Mercury spill prevention as well as proper spill response are important aspects of manufacturing facilities' mercury management policy. The following are some best management practices that will aid in spill prevention and response.

Mercury Spill Prevention and Response Practices

C Use mercury only in uncarpeted, well-ventilated areas. It is preferable to use mercury devices in rooms that do not have carpeting or other floor coverings that are not easily cleaned.

C Ask workers to remove all watches and other jewelry–especially gold jewelry since mercury readily combines with it.

C Prohibit smoking, eating and drinking in the area.

C Train all workers to understand the properties and hazards of mercury and to carry out safe handling procedures and specific policies related to mercury disposal.

C Clean and calibrate all mercury-containing equipment according to the manufacturer's recommended handling procedures and the formal procedures posed by your communications or safety program supervisors.

C Be prepared for a spill in any area where mercury-containing devices are used. Have a mercury vacuum sweeper and spill cleanup kit available. Never use a regular vacuum cleaner to clean up mercury–it will vaporize the mercury and release it into the air.

C Cleanup of mercury spills must be performed by specially trained staff.

C Create a formal mercury spill policy for your facility, considering the following factors:

    < availability of a staff person, trained in mercury spill cleanup
    < OSHA requirements
    < protective equipment and clothing for cleanup staff
    < type of flooring (linoleum, carpet, etc.)
    < determination of the type of equipment to be used for the size and type of spill
    < manufacturer's instructions for the equipment to be used
    < ultimate waste disposal, which may depend on the cleanup method

< preparation of an incident report that describes the spill, the cleanup method used, unusual circumstances, and follow up

(Terrene Institute quoted by Wisconsin DNR)

Option 3: Participate in the development of a national mercury labeling requirement

For products or components which contain a significant percentage of mercury for its function or as an added ingredient, chemical manufacturers should work with environmental agencies to devise and implement a national mercury labeling requirement. This effort would allow consumers and businesses to make informed decisions about pollution prevention and environmental safety. (Minnesota Pollution Control Agency)

The Northwest Indiana Steel Mills attempted to identify the equipment in their facilities that contained mercury and found that is was a difficult and time-consuming process because each item had to be identified with the model number and plant purchase order in order to contact the vendor. If the mercury-containing equipment were labeled, the identification and replacement process would have been much quicker. (NW Indiana Steel Mills)

Option 4: Clean out wastewater system to rid your facility of historical uses of mercury

This option applies to all manufacturing facilities that use or make chemicals, including chlor-alkali and pulp and paper manufacturing facilities. Historical mercury use in chemical manufacturing facilities may have led to collection of mercury in those facilities' sewer pipes, sumps and traps. Even afer best management practices have been implemented, some facilities face violations of wastewater discharge standards due to the presence of mercury in their plumbing. By cleaning out sewer pipes, sumps and sink traps, it is possible to lower wastewater levels of mercury (M2P2 Task Force).

Although the cleaning process may be costly and time consuming, it is a good way of reducing mercury emissions from facilities and may help avoid regulatory actions. Once the plumbing has been cleaned, however, it is important to follow guidelines on managing mercury in order to avoid re-depositing mercury into the sewer system.

When sewer pipes, sumps and traps are cleaned, it is important to notify the plumber that the sludge may contain mercury. The sludge must be handled as hazardous waste unless demonstrated otherwise (i.e., through the Toxicity Characteristic Leaching Procedure).

Please consult Appendix O in the document prepared by the New York Monroe County Department of Health, "Reducing Mercury Use in Health Care", for procedures on cleaning traps and pipes. You can find the document "Reducing Mercury Use in Health Care" on the Internet at: http://www.epa.gov/glnpo/bnsdocs/merchealth/aboutmerhealth.html.

2. Chlor-Alkali Manufacturing

Background

In the chlor-alkali industry, mercury is used in an electrolytic process that converts sodium chloride into chlorine and sodium hydroxide (also known as caustic soda) which are sold as feedstock chemicals for several manufacturing processes, including paper, pharmaceutical and cosmetic production. Other common feedstock chemicals that may also contain mercury include hydrochloric acid, potassium hydroxide and sulfuric acid. These feedstock chemicals can be contaminated with low levels of mercury that can be passed on to wastewater treatment or as an air emission from waste boilers. Non-mercury, or clean, alternatives are available that can eliminate the potential for mercury release. (Minnesota Pollution Control Agency) See Table 9 for a list of the characteristics of different grades of caustic soda and Table 10 for mercury levels in the wastewater of facilities using caustic soda.

The chlor-alkali industry manufactures chlorine and caustic soda–two chemicals that are heavily used in the industrial sector. There are three types of technologies the industry uses to manufacture these chemicals: mercury cells, diaphragm cells, and ion-exchange membrane cells. In the U.S., the chlor-alkali industry uses the mercury cell process to make about 13% of the total amount of chlorine produced, while 75% is made in diaphragm cells and 11% in ion-exchange membrane cells. The trend in the chlor-alkali manufacturing industry in the U.S. is towards the non-mercury processes. (Wisconsin DNR)

When electricity is passed through a conducting ionic solution, the solution is decomposed into its constituents. This process occurs in an electrolytic cell which is composed of a cathode (negatively charged electrode), anode (positively charged electrode) and the conducting solution. In mercury cell chlor-alkali plants, mercury is used as the cathode in electrolytic cells, the anode is either carbon or metal, and the conducting solution is usually a sodium chloride brine.

Two reactions occur in the mercury electrolytic cell in the electrolyzer and the decomposer sections. In the electrolyzer section, a brine flows concurrently with the mercury cathode, providing a high current density between the cathode and the anode. As a result, chlorine gas forms at the anode while an alkali amalgam forms at the mercury cathode. The amalgam is then separated from the brine and enters the decomposer section, where water is added. In the decomposer, the amalgam undergoes another reaction which separates the mercury out of the amalgam. The recycled mercury is then re-used in the electrolyzer. Mercury emissions occur in this process when mercury leaks out of equipment and when equipment is opened for maintenance.

Options

- ***Modify chlor-alkali plant process***
- ***Improve operations in mercury cell plants to minimize mercury losses***

Option 1: Modify chlor-alkali plant process

Mercury emissions from chlor-alkali operations can be eliminated by converting from the mercury electrolytic cell to the membrane cell process, which is also more energy efficient. In a membrane cell, an exchange membrane separates the electrolytic reaction products: chlorine gas forms on one side of the membrane and is collected, while caustic soda and hydrogen gas form on the other side. The resulting caustic is purer and more concentrated than from other non-mercury technologies such as the diaphragm cell. The solution produced by membrane cells can be as much as 25 to 30 percent caustic by weight, which is then evaporated to produce a 50 percent product. (Report to Congress, Vol. 8)

When the mercury cell process is converted to the membrane cell, certain parts of the process remain the same. However, mercury levels that exceed 10 parts per million in the brine can hinder membrane performance, thus a mercury removal system is required. This system is necessary until the mercury is sufficiently purged from the brine (typically 1 or 2 years). The filters used for mercury removal can later be used for secondary brine treatment. (Horvath, 1986 quoted in Report to Congress, Vol. 8).

Because the membrane cell process is much more energy efficient than the mercury cell, electricity costs are lower after plant conversion. The estimated annual capital cost of converting a plant from the mercury to the membrane cell, according to the Mercury Report to Congress Vol. 8, is about $3.3 million (after deducting electricity savings), or about 12 percent of total annual expenditures. Additional savings would most likely result from avoidance of costs of recycling or disposing of mercury waste.

Option 2: Improve operations in mercury cell plants to minimize mercury losses.

The chlor-alkali industry has committed to reduce mercury use by 50% by 2005. The industry has to date achieved a 42% reduction through various measures to reduce mercury losses. (Chlorine Institute)

3. Pulp and Paper Manufacturing

Background

Mercury is potentially released to the environment by paper mills in three ways:

- as an ingredient or contaminant in feedstock chemicals and other laboratory chemicals (e.g., sulfuric acid and caustic soda),
- as a component in equipment (e.g., mercury tilt switches, thermostat and fluorescent lighting) (consult mercury-containing device section in "Use of Mercury-containing Devices in Manufacturing"), and
- through coal combustion (see Utilities section for ways to reduce mercury emissions due to coal combustion).

The pulp and paper manufacturing industry can reduce mercury release to the environment by replacing mercury-containing products with mercury-free ones and by using mercury-free feedstock chemicals.

Major mercury-containing products include feedstock chemicals (caustic soda and sulfuric acid) and electrical equipment. In addition to these products that may be used directly in the manufacturing process, manufacturers may also have other mercury-containing products at the facility. These include manometers and vacuum gauges, fluorescent and HID lamps for lighting, tilt switches, and thermostats.

Consult the "Manufacturing and Use of Mercury-Containing Devices" section for information about these products and options that will help reduce mercury release to the environment.

Options

- ***Substitute non-mercury or lower mercury feedstock chemicals***
- ***Clean out wastewater system to rid your facility of historical uses of mercury***

Option 1: Substitute non-mercury or lower mercury feedstock chemicals

Clean, mercury-free alternatives are available for purchase and can eliminate the source of mercury from feedstock chemicals through their use. This is a simple, very feasible and economical way to reduce mercury pollution in the environment. For example, mercury-free membrane grade caustic soda is no more expensive then the mercury cell grade, however, there may be some initial operational costs associated with switching chemicals. Interestingly, mercury cell caustic was found to be $30 per ton more expensive then the mercury-free membrane grade! (Potlatch) Low mercury sulfuric acid can also be obtained at no additional cost. One implementation issue is that the low mercury alternative may not be as effective as the mercury cell grade in all applications. For example, a membrane grade caustic soda does not perform as well as the mercury cell caustic in some demineralizer applications. However, for other applications there is no difference in performance. (Minnesota Pollution Control Agency)

Table 8 lists mercury compounds that may be used in pulp and paper manufacturing along with some suitable mercury-free alternatives. Table 9 lists the different grades of caustic soda, showing the mercury content of each. Table 10 shows the concentration of mercury in a facility's wastewater depending on the amount of mercury-containing caustic soda used per day and the rate of wastewater flow.

Option 2: Clean out wastewater system to rid your facility of historical uses of mercury

See option 4 of the Chemicals Manufacturing section.

D. INDUSTRIES THAT RELEASE MERCURY AS A BYPRODUCT OF MANUFACTURING

Many industries use raw materials that contain mercury, such as iron and copper ore, in their manufacturing processes, thereby unintentionally releasing mercury to the environment as a byproduct of operations. The following manufacturing processes contribute mercury to environment:

- Taconite Processing (iron ore processing)
- Portland cement manufacturing

There are many other industries that release mercury to the environment through burning coal for energy. Options that industries can take to reduce mercury emissions from burning coal are detailed in the Utilities section. Some of the industries addressed in this section also use coal-fired boilers; again, please consult the Utilities section for ways to reduce mercury emissions from burning coal.

1. Taconite Processing

Background

Taconite is a hard, banded, low-grade ore and is the predominant iron ore in the United States: ninety-nine percent of the crude iron ore produced in U.S. is taconite. Ninety-eight percent of the demand for taconite is from the iron and steel industry. Highly resource-intensive, taconite processing involves crushing and grinding the ore to liberate the iron-bearing particles, separating the particles from the waste material and concentrating it into taconite pellets. Mercury emissions result from fuel combustion or crushing and grinding the ore. Mercury emission reductions can occur with fuel switching as well as removing mercury from waste gases.

Options

- ***Use conventional controls to lower mercury emissions***
- ***Make plant area modifications to increase mercury rejection to the tailing and reduce the recycling effect of mercury in the beneficiation process***
- ***Substitute a mercury-free energy source for coal*** *(see Utilities section for discussion)*

Option 1: Use conventional controls to lower mercury emissions

Existing controls on pellet indurating furnaces for waste gases consist of electrostatic precipitators (ESPs), wet scrubbers, and multiclones. Through stack testing that has already been conducted by taconite facilities, some collection of mercury has been shown. One facility showed 87 percent control efficiency with an ESP while another demonstrated 35 percent control efficiency with a venturi scrubber. However, further testing is needed to determine what control efficiencies can be obtained from emission control equipment.

This option does not prevent mercury pollution permanently because it collects the mercury and transfers it to scrubber water which is then recycled back to the beneficiation (extraction) process. However, some mercury that is scrubbed out of the gas flows into the tailing basin. This mercury has been shown (September 1997 CMRL Study) to attach to solids and settle out in the basin. There is little biological activity in the solids that settle, therefore the re-volatilization of mercury should not occur.

Option 2: Make plant area modifications to increase mercury rejection to the tailing and reduce the recycling effect of mercury in the beneficiation process

This option calls for modifying the ore concentrating process to increase the mercury rejection to the tailing and for routing the scrubber water outside of the process to reduce the recycling effect of mercury in the beneficiation process. Increases in mercury separation in the iron concentration process will most likely come from improving the weight recovery of iron through additional stages of grinding and flotation. Flotation as well as increased sulfide levels in the ore may also increase the amount of mercury that is rejected to the tailing.

Option 3: Substitute a mercury-free energy source for coal

Refer to the Utilities section for discussion.

2. Portland Cement Manufacturing

Background

Portland cement manufacturing facilities release many hazardous air pollutants, including mercury. In 1999, EPA promulgated national emission standards for hazardous air pollutants (NESHAP) for new and existing sources in the Portland cement manufacturing industry.

Options

No reduction options beyond those required through regulation are currently available.

Resources used in creating this section

Bethlehem Steel Burns Harbor, Ispat Inland, and U.S. Steel. Binational Toxics Strategy Spring 2000 Stakeholders Meeting: Mercury Sources at Three Northwest Indiana Steel Mills, Update. May, 2000.

Center for Disease Control. Joint Statement Concerning Removal of Thimerosal from Vaccines. June 22, 2000. http://www.cdc.gov/nip/vacsafe/concerns/thimerosal/joint_statement_00.htm

Consumers Energy. Mercury Pollution Prevention–A Plan for the Management of Mercury Usage and Emissions and Report of Mercury Reduction Progress by Consumers Energy Company. March, 1999.

Department Of Health, Education, and Welfare Public Health Service, Food and Drug Administration. Inspection Technical Guide Subject: Electronic Relays http://www.fda.gov/ora/inspect_ref/itg/itg51.html July, 2000.

Meriam Instrument web site: http://www.meriam.com/vac-meas.htm. July, 2000.

Michigan Mercury Pollution Prevention Task Force. Mercury Pollution Prevention in Michigan: Summary of Current Efforts and Recommendations for Future Activities. April 1996. http://www.deq.state.mi.us/aqd/publish/m2p2.html

Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

Montgomery, Tim. Industrial Temperature Primer http://www.wici.com/technote/tmprmch3.htm Wilkerson Instrument Company, Inc.. July, 2000.

The Chlorine Institute, Inc.. Third Annual Report to EPA. May 3, 2000.

U.S. EPA. Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs. December 1997.

Watlow. Temperature Control: The Watlow Educational Series Book Five. 1995.

Watlow. Proper Disposal of Mercury Displacement Relays, Easy as 1-2-3. 1997. Http://www.watlow.com/news/NewsDetail.cfm?id=8168

Wisconsin Department of Natural Resources. Draft Wisconsin Mercury Sourcebook, 1997. http://www.epa.gov/glnpo/bnsdocs/hgsbook/index.html

Attachment 1: Types of Bulbs and Lamps that Contain Mercury, *Wisconsin Recycling Markets Directory*

- **Flourescent Lamps**: the tube-style were first used as overhead lighting in offices, now they also come in compact globe shapes for a variety of home and office uses
- **Mercury Vapor Lamps**: the first high intensity discharge (HID) lamps with blue-white light, originally used as farmyard lights
- **Metal Halide Lamps**: newer, more efficient HID lights used for sports and industrial lighting
- **High-Pressure Sodium Vapor Lamps**: white-yellow HID lights used for street lamps and outdoor security lighting
- **Neon lamps**: brightly colored lamps typically used in advertising; most colors contain mercury except red, orange and pink

Table 1: Alternatives to Mercury-Containing Electrical Equipment

Type of Switch	Where Equipment is Used	Possible Alternative
Tilt switch	–Airflow/fan limit control –Building security systems –Clothes iron –Fire alarm box –Fluid level, pressure or temperature control devices –Laptop computer screen shutoff –Lids of clothes washers and chest freezers –Silent light switch –Space heater –Thermostats	Mechanical switch
Float switch	–Bilge pumps –Septic tank -Sump pump	–Magnetic dry reed switch –Optic sensor –Mechanical switch
Thermostat	Temperature control device may have a mercury tilt switch	Electronic thermostat, snap switches
Reed relay	Low voltage, high precision analytical equipment such as electron microscope	–Solid state relay –Electro-optical relay –Dry reed relay
Plunger or displacement relay	High current, high voltage applications such as lighting, resistance heating, power supply switching	Mechanical switch
Thermostat probe	–Electric stoves –Hot water heaters	Non-mercury probe

Table 2: Alternatives to Tilt Switches Used in Thermo-Electrical Applications, *M2P2 Task Force*

Tilt Switch	**Quantity of Mercury**	**Available Alternatives**
Accustat ("mercury in glass thermostat," a calibrated device resembling a thermometer is used to provide precise temperature control for specialized applications)	~1000 mg	--
Flame Sensor (used in residential and commercial gas ranges, mercury is in capillary tube when heated mercury vaporizes and opens gas valve or operates switch. Used for both electrical or mechanical output.)	2500 mg	Hot surface ignition system for devices or products that have electrical connections.
Silent Switches (light switches prior to 1991)	2600 mg	mechanical switch

Table 3: Alternative Vacuum Gauges to Mercury Manometers, *Wisconsin DNR*

Brand	Model	Contact
Ashcroft	Ashcroft Digital Test Gauge Type 2530 and 2545	Dresser Industries Instrument Division Domestic HQ PO Box 5605 Newtown, CT 06470 203-426-3115
	Ashcroft Duralife Movement Pressure Gauge Type 1009, Grade 1A	
	Ashcroft Pressure Tester multi-purpose digital pressure indicator	
Bristol Babcock	Helicoid 900 Series Gauges	Bristol Babcock Helicoid Instruments 1100 Buckingham St. Watertown, CT 06795 860-945-2218
DCT Instruments	Series JK Digital Pressure Test Gauge	DCT Instruments 1165 Chambers Rd. Columbus, OH 43212 614-481-7777 800-328-1028
	Series TK Digital Pressure Test Gauge	
HAENNI	HAENNI 2 Inch Diameter Gauges liquid-filled stainless steel Bourdon tube pressure gauges	HAENNI Instruments, Inc. 1107 Wright Avenue Gretna, LA 70056 504-392-3344
	HAENNI 4 Inch Diameter Gauges liquid-filled stainless steel Bourdon tube pressure gauges	
OMEGA	General Service Gauges Type S	OMEGA Engineering, Inc. Worldwide Headquarters One Omega Drive PO Box 4047 Stamford, CT 06907-0047 800-826-6342

Table 4: Alternatives to Mercury-Containing Manometers

Type of Manometer	Cost	Comments
Electronic (digital)	Several hundred dollars	An order of magnitude more accurate than sphygmomanometers. Used in biomedical laboratory to calibrate other devices. A traceable calibration must be performed with a mercury manometer, onsite or offsite, on a regular schedule. The time interval depends on the manufacturer's recommendation.
Aneroid (Bourdon, diaphragm, piston or capsule types)	Price varies widely depending on accuracy and traceability required	Manufacturers recommend calibration at least annually. Schedule can be based on experience, with annual inspections as a minimum.
Liquid filled	Price varies widely depending on accuracy and traceability required	Inadvisable to move them from place to place. Manufacturers recommend calibration at least annually. Schedule can be based on experience, with annual inspections as a minimum.
Mercury	\$100-\$150 range	One meter tall. An order of magnitude more accurate than sphygmomanometers. Used in biomedical laboratory to calibrate other devices. Annual calibration recommended to ensure good performance.

Table 5: Mercury-Containing Products Found in Automobiles, *M2P2 Task Force quoted by Wisconsin DNR*

Mercury-containing products	**Quantity of Mercury**	**Known/Possible Use**	**Available Alternative**
airbag sensors	not confirmed	confirmed in certain models[25]	mercury-free versions
antilock braking systems (ABS)	~ 3000 mg	used on some four wheel drive vehicles; use on other ABS vehicles unknown[26]	
headlamps	0.5-1.0 mg	used in some high intensity discharge (HID) lamps[27]	standard halogen or tungsten filament headlights
radios	unknown	rechargeable batteries for radios in some imported vehicles	mercury free substitutes such as domestic alkaline batteries
active control	~1000 mg	in use by one or more manufacturer	
light switches	1000 mg	used to activate trunk and hood lighting	electro-mechanical switches
speedometer systems	< 40 mg	used in some Japanese imported vehicles	

[25] air bags are used to meet a required safety requirement

[26] anti-lock braking systems are used to improve vehicle safety

[27] HID headlamps: one manufacturer reported HID lamps allow for improved visibility, better aerodynamic shaping of the vehicle, resulting in better fuel economy; uses less energy than current headlamps, daytime running lights are not the same as HID headlamps.

Table 6: Mercury Switch Use in Domestic Automobiles, *M2P2 Task Force quoted by Wisconsin DNR*

Vehicle Make	**Vehicle Year(s)**	**Vehicle Model**
Ford	1974-1994	Tempo, Escort, LTD, F250, Ranger, Taurus, Crown Victoria, Thunderbird, Topaz, Bronco II, Cougar
Buick	1977-1990	LeSabre, Regal, Park Avenue, Celebrity, Skyhawk, Skylark, Century, Firenza
Pontiac	1984-1990	Sunbird, Bonneville, Grand Am
Oldsmobile	1977-1990	Cutlass Ciera, Cutlass Supreme, Calais, Toronado, Regency, Delta
Chevrolet	1981-1990	Beretta, Caprice, Lumina
Chrysler	1975-1994	New Yorker, Le Baron, Shadow, Cordoba, Laser, Reliant, Sundance, Aries
Cadillac	1979	DeVille, Cimarron
Audi	1984	Make Not Available

Table 7: Mercury Switch Use in Imported Automobiles, *M2P2 Task Force quoted by Wisconsin DNR*

Manufacturer	Model	Use	Period of Use	Phase-Out
BMW	All 7-Series	Batteries / Switches	Ended in 1992	
		Xenon Headlamps 1	1995-pres.	No current plans
Fiat	Alpha Romeo 164	None		
	Spider	None		
	Ferrari	None		
Honda	All	None		
Isuzu	All	None		
Land Rover	All	None (possibly batteries for keyless entry systems)		
Mazda	All	G sensor for ABS	Ended in 1992	
Mercedes	All	Acceleration sensors for airbags, ABS, seat belts, active suspensions	Ended in 1992	
Mitsubishi	Galant 4WD	ABS G sensor	1989-93	
	Expo 4WD	ABS G sensor	1992-94	
	Expo LRV 4WD	ABS G sensor	1992-94	
	3000 GT 4WD	ABS G sensor	1991-94	
Nissan	1996 Pathfinder 4WD	ABS sensor	With intro of standard ABS in 1996	end of 1996 MY
Porsche	944	Underhood Lamp Switch	1985-1991	
Rolls Royce	All	Underhood Lamp Switch	Ended mid-1960s	
		Batteries	Ended in 1993	

Saab	9000	Engine Comp. Light	Ended in 1991 MY	
	9000/900	Luggage Comp. Light	Ended in 1991 MY	
	900 Convertible	Heated Rear Window	Ended in 1991 MY	
Subaru	Legacy AWD (manual transmission)	G sensor for ABS	beginning of production	11/95
		G sensor for ABS	beginning of production	end of 1996 MY
Suzuki	All	None		
Toyota	All	Air Bag Sensor	ended in 1992	
Volvo	240/260	Eng. Comp Lamp	1975-1990	
		Luggage Comp Lamp	1975-1991	
	740/760	Eng. Comp Lamp	1982-1990	
		Airbag Sensor	1987-1992	
		Make-up Mirror 2	1986-1989	
	940	Make-up Mirror 2	1986-1991	
	744/764	Luggage Comp Lamp	1982-1991	
	940/960	Airbag Sensor	1987-1992	
	240	Airbag Sensor	1988-1993	

Table 8: Mercury-Containing Chemicals and Alternatives, *Wisconsin DNR*

Chemical	Alternative
Mercury (II) Oxide	Copper catalyst
Mercury Chloride	None Identified
Mercury (II) Chloride	Magnesium Chloride/ Sulfuric Acid or Zinc Formalin, Freeze drying
Mercury (II) Sulfate	Silver Nitrate/ Potassium/ Chromium-(III) Sulfate
Mercury Nitrate (for corrosion of copper alloys) for antifungal use (mercurochrome)	Ammonia/ Copper Sulfate Neosporin, Mycin
Mercury Iodide	Phenate method
Sulfuric Acid (commercial grade; mercury as impurity)	Sulfuric acid from a cleaner source
Zenker's Solution	Zinc Formalin

Table 9: Characteristics of Different Grades of 50% Caustic Soda (Sodium Hydroxide), *Chlorine Institute*

Properties are expected maximums. Typical levels of impurities may be substantially lower. Users should confirm this information with their supplier.

Properties (max values)	Membrane Process	Rayon Grade (Mercury Process)	Commercial Cell Grade (Diaphragm Process)	Purified (Diaphragm Process)
sodium hydroxide	51.5%	51.5%	52%	52%
sodium chloride	100 ppm	50 ppm	11,000 ppm	300 ppm
sodium chlorate	5 ppm	3 ppm	3000 ppm	10 ppm
sodium carbonate	500 ppm	1000 ppm	2000 ppm	1000 ppm
sodium sulfate	100 ppm	25 ppm	500 ppm	500 ppm
iron	3 ppm	3 ppm	10 ppm	5 ppm
nickel	0.3 ppm	0.3 ppm	3 ppm	4 ppm
copper	0.3 ppm	0.5 ppm	2 ppm	0.2 ppm
mercury	0.010 ppm	0.5 ppm	<0.01 ppm	0.005 ppm
heavy metals	10 ppm	10 ppm	10 ppm	10 ppm
silica	10 ppm	100 ppm	200 ppm	200 ppm

Table 10: **Mercury in Wastewater** (ppb), *Vulcan Chemicals quoted by Wisconsin DNR*

The following table shows the estimated mercury concentration [in parts per billion (ppb)] in wastewater given the usage of cause (in tons per day) and the average wastewater discharge (gpm).

	Wastewater Flow (pgm)			
Caustic Used (tons per day)	100	500	1000	5000
1	0.017	0.003	0.0016	0.0003
2	0.033	0.007	0.0033	0.0007
10	0.17	0.033	0.016	0.0033
20	0.33	0.066	0.033	0.0066

WASTE DISPOSAL

Background

The mercury that we use enters the waste stream and must be managed. Once mercury is used, it does not disappear, but eventually makes its way to the environment. It is important to handle mercury-containing waste in a way that it is not freely released into the air, water or land.

There are several types of facilities that may receive mercury-containing waste:

- Municipal Waste Combustors (MWCs)
- Municipal Waste Incinerators (MWIs)
- Medical Waste Incinerators
- Hazardous Waste Incinerators
- Wastewater Treatment Plants
- Publicly Owned Treatment Works
- Landfills

Each of these facilities has different ways of managing waste, depending on the source and the nature of it (e.g., solid, medical, hazardous, wastewater). Management of waste can lead to mercury pollution of the environment in several ways. MWCs, MWIs , Hazardous Waste Incinerators and Medical Waste Incinerators burn waste which releases any mercury contained in it into the air. The mercury in solid waste that is disposed of in landfills can volatilize. The process of soil roasting, which is the incineration of soils that are polluted with hydrocarbons, also releases mercury into the air. In wastewater treatment plants, various sludge handling processes are employed, including incineration and land application. The mercury in the sludge is then transferred to the air through incineration or volatilization from land application.

Options

- ***Separate waste material and manage properly***
- ***Use enhanced air pollution controls***
- ***Treat scrubber water from sludge incinerators at wastewater treatment plants***

Option 1: Separate waste material and manage properly

(this option applies to municipal waste, hazardous waste and medical waste)

Households, businesses, manufacturing facilities, and hospitals use many different mercury-containing items that should be separated out of the solid waste stream and managed or recycled properly. Common mercury-containing items are: fluorescent lighting, batteries, relays, switches, manometers, barometers, thermostats and thermometers. When these items are thrown into the trash, mercury escapes to the environment. Please refer to the manufacturing, medical, dental and consumer sections for specific information on the types of devices and items that contain mercury.

Many cities and counties have several types of material recovery facilities that separate and collect mercury as well as other hazardous waste items, for example:

- process separation recycling plants,
- household hazardous waste collection centers and
- appliance recycling facilities.

Once the material is collected and separated, it is then recycled or disposed of in compliance with special or hazardous waste rules. This results in removing mercury from the waste stream and is much more cost effective than separating mercury out of waste through controls at incinerators or wastewater treatment facilities. Household hazardous waste facility operators estimate a cost of $200 to $500 per pound of mercury emissions reductions through source separation compared to $3,400 to $7,600 per pound for air pollution controls (Minnesota Pollution Control Agency). These cost estimates include collection, recycling or disposal, and a share of the public education budget that supports successful source separation efforts.

It is important for those counties that do not have hazardous waste collection facilities to build such facilities. Capital assistance grants for building hazardous waste collection facilities may be available through the state government. In order to receive the benefit of a hazardous waste collection facility, a rigorous public education and outreach program is necessary.

Assuming an aggressive material separation program that diverts 50 percent of possible mercury in the waste stream, the Minnesota Pollution Control Agency estimated that the reduction potential in Minnesota would be:

- 580 lb/yr to air and 3,870 lb/yr to all media from all waste management activities and
- 130 lb/yr to air and 860 lb/yr to all media from waste combustors alone.

The Indiana Department of Environmental Management instituted a state-wide mercury collection project in 1998, which included the following key elements:

- Collection locations in every county for mercury and household products containing mercury by October;
- Statewide public education on the dangers of improper use and disposal of mercury;
- Two-year grants from IDEM to solid waste management districts that serve as processing hubs for other collection locations. The grants paid for 75 percent of the recycling, processing and transportation costs;
- Payment of all mercury recycling, processing and transportation costs during October for solid waste management districts that pledge to continue collecting mercury beyond October;
- Working with heating and ventilation contractors and suppliers to encourage recycling of used thermostats.

From October, 1998 to June, 1999, mercury collection events occurred in each of Indiana's 92 counties at which over 2,100 pounds of elemental and other mercury devices and debris were collected. In addition, ongoing mercury collection and education programs in 70% of Indiana's counties were created. (Indiana Department of Environmental Management)

Option 2: Use enhanced air pollution controls (APC)

There are several air pollution control technologies that can be employed in Municipal Waste Incinerators (MWIs), Municipal Waste Combustors (MWCs), Medical Waste Incinerators, and Hazardous Waste Incinerators. These include:

- carbon filter beds (Hazardous Waste Incinerators, MWIs);
- wet scrubbers (MWIs, MWCs, Medical Waste Incinerators);
- selenium filters (MWIs); and
- activated carbon injection (MWIs, Medical Waste Incinerators).

The following technologies may be used to filter out mercury from waste incinerators and combustors:

- Carbon filter beds have been developed in Europe for use as a final cleaning stage in MWCs and utility boilers to remove heavy metals (e.g., mercury), organic pollutants (e.g., dioxins and furans) and acid gases (e.g., sulfuric and hydrochloric acids). Carbon filter beds have not yet been put to commercial practice in the United States. Cost effectiveness studies indicate $513–$1,083 per pound mercury removed using carbon filter beds on MWCs. (Report to Congress, Vol. 8)

- Wet scrubbing systems are available in different designs and can be used to control acid gases, metals, PM, dioxins and furans in MWCs, MWIs and medical waste incinerators. A factor that determines the effectiveness of this control is the amount of water-soluble mercury in the flue gas stream–the less water-soluble mercury compounds, the less effective the technology (elemental mercury is not water soluble). A 90 percent reduction of mercury is possible with a wet scrubber on a MWC (Nebel et al., 1994 in Report to Congress, Vol. 8). Wet scrubbing systems have not yet been applied to MWCs in the United States, but have been used in MWCs in Europe and MWIs in the U.S.. Cost-effectiveness for this technology on MWCs is estimated to be $1,600–$3,320 per pound of mercury removed and on Medical Waste Incinerators, $2,000-$4000 per pound. (Report to Congress, Vol. 8)

- Selenium filters have been developed to remove elemental mercury from MWIs This technology is based on the affinity between mercury and metallic selenium. Selenium filters are effective on flue gas streams with inlet mercury concentrations of up to 9 mg/scm. At higher mercury concentrations, the lifetime of the filter is short and an alternative control system is recommended. Selenium filters have been applied mainly to smelter flue gas streams and crematories in Sweden. Cost effectiveness has not yet been estimated for this technology. (Report to Congress, Vol. 8)

- Activated carbon injection involves injection of powdered activated carbon into the flue gas upstream of an air pollution control device which adsorbs mercury onto its surface. After adsorption, the carbon is filtered out. This technology is used on MWCs and MWIs in Europe and the United States. U.S. test programs have shown mercury removals of 50 to 95 percent. The cost of removing mercury from MWCs using activated carbon injection is estimated to be $211–$870 per pound and from Medical Waste Incinerators, $2,000-$4000 per pound. (Report to Congress, Vol. 8)

Consult the Mercury Report to Congress, Volume 8 for more detailed description of the above options.

Each of these technologies transfers mercury from an air medium to an ash medium which is then stored in ash monofills. Based on available data, mercury is not readily released from the monofilled ash matrix. The reduction potential varies with each system and with the mercury concentration of the solid waste stream. As the concentration of mercury declines, the mercury removal efficiency decreases and the cost increases proportionately.

Regulatory standards are in place to control air toxics emissions from medical incinerators, municipal combustors, and hazardous waste combustors. According to the U.S. EPA, these standards should reduce emissions of mercury by 80 percent. The standards are based on the maximum achievable control technology (MACT) approach required by the Clean Air Act. MACT reflects the maximum degree of hazardous air pollutant reduction that can be achieved considering the availability, current use, costs, and non-air environmental impacts of emissions control technologies (U.S. EPA). The regulatory standards governing hazardous waste combusters were tightened in 1999, and focus on feed rate controls. Medical waste incinerator standards were issued in 1997; EPA expects that, because of the increased cost of on-site incineration under the final rules, these facilities are likely to switch to other methods of waste disposal such as off-site commercial waste disposal or on-site disinfection technologies.

Option 3: Treat scrubber water from sludge incinerators at wastewater treatment plants

This option calls for removing wet scrubber discharge and rerouting it for separate treatment. Wet scrubbers capture mercury and other particulate matter from sludge incinerators at wastewater treatment plants in order to control air emissions. The spent scrubber water containing elevated levels of mercury is recycled through the plant; the mercury eventually associates with the sludge which is then re-incinerated, thereby releasing mercury into the atmosphere. The Minnesota Pollution Control Agency estimated that 95 percent of mercury entering wastewater treatment plants is released to the atmosphere via incinerators.

A case study of the Metropolitan Council Environmental Services Metro plant in Minnesota indicated that approximately 120 fewer pounds of mercury per year would enter the atmosphere. Cost effectiveness was estimated to be $2,000–$20,000 per pound of mercury removed. (Minnesota Pollution Control Agency)

Resources Used in Creating This Section:

Indiana Department of Environmental Management. Pollution Prevention and Toxic Release Inventory Annual Report. 1999.

Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

U.S. EPA. Mercury Study Report to Congress, Volume VIII: An Evaluation of Mercury Control Technologies and Costs. December 1997.

MERCURY USE IN THE MEDICAL FIELD

Background

Mercury and/or mercury-containing products are used in a wide variety of settings in the medical field, including hospitals, clinics, nursing homes and veterinary clinics. Mercury is found in medical devices such as: blood pressure monitors (sphygmomanometers), thermometers, esophageal dilators (also called Maloney or Hurst bougies), Cantor tubes and Miller Abott tubes (used to clear intestinal obstructions), medical equipment batteries, and histology fixatives and stains. Many mercury-containing cleaners and lamps are found in medical facilities and some medicinal products such as eye drops and nasal sprays contain mercury. Mercury is also found in the sewer pipes of health care facilities–a remnant of the extensive use and improper disposal of mercury in past medical settings.

In order to reduce their mercury emissions, health care facilities must keep mercury-containing products out of the waste stream. There are two ways to ensure mercury does not enter either the wastewater or the incineration waste stream:

- substitute and/or replace mercury-containing products for mercury-free ones, and
- properly recycle and dispose of mercury-containing devices, products or substances.

Product substitution is at the heart of pollution prevention and is a viable option for many medical devices and products. A proper mercury spill response plan is also very important to ensure the safe handling and disposal of mercury.

Many health care facilities are actively pursuing pollution prevention and environmentally sound spill response plans and are also beginning to address mercury air emissions (from spills and medical waste incineration). Medical waste incinerators are a large contributor to mercury emissions, and are discussed in the Waste Disposal chapter. Pollution prevention will require significant initial educational and program implementation efforts, but can be successful at eliminating health care related mercury emissions. For pollution prevention efforts to be successful, there must be support from the health care facility management and/or a mercury reduction "champion" to lead the effort.

Options

- ***Substitute mercury-free products for mercury-containing ones***
- ***Devise a safe and environmentally sound mercury spill response plan***
- ***Recycle or dispose of mercury-containing products in an environmentally sound manner***
- ***Clean out the wastewater system to rid the facility of historical uses of mercury***

Option 1: Substitute mercury-free products for mercury-containing ones (while allowing health care professionals to exercise their judgement)

Mercury pollution prevention in health care facilities can provide many benefits, including:

- protection of human health and wildlife by reducing occupational exposures and releases of mercury to the air, water and land from wastewater discharges, spills, landfilling or incineration;
- avoidance of the costs associated with the use of mercury, such as disposal or recycling, collection and storage prior to disposal, paper work for tracking hazardous waste disposal, training and equipment for spill response, training for hospital employees who handle mercury-containing products, and liability for environmental problems or worker exposure;
- avoidance of increased regulation in the future;
- increase in the public's awareness about the dangers of mercury through publicity about the hospital's program; and
- enhancement of the positive public image of the medical facility due to publicity about success stories. (New York Department of Health)

For many of the current mercury sources there are acceptable mercury-free alternatives. According to a study conducted in Minnesota, 90% of intentional uses of mercury-containing products are avoidable.

One of the products that most often causes spills are thermometers. One way to increase the use of mercury-free thermometers is to hold a mercury fever thermometer exchange. This is an event at which participants turn in mercury fever thermometers and, in return, receive a non-mercury fever thermometer or a voucher for an alternative thermometer. In addition to decreasing the use of mercury, these exchanges educate people about the environmental and public health effects of mercury. Hospitals, schools, and communities are all possible settings for a mercury exchange event. For more information on how to hold a mercury thermometer exchange event, please refer to www.noharm.org.

Sphygmomanometers, like thermometers, are frequent causes of mercury spills. If you are going to use mercury sphygmomanometers, you need to have a clip to prevent the mercury tube from falling out. New Baum sphygmomanometers have them, but old ones do not. However, the safety clips (AKA "lever locks") are available from Baum for free. Refer to Baum's web site:
http://www.wabaum.com/Docs/blood.html

Tables 1-12 contain lists of medical products, laboratory tests and chemicals that use or contain mercury along with some suitable mercury-free alternatives. Major mercury-containing products are thermometers (measure temperature), sphygmomanometers (measure blood pressure) and Cantor tubes (dilates the esophagus).

Option 2: Devise a safe and environmentally sound mercury spill response plan

Mercury is an extremely hazardous substance. Mercury spills, therefore, can pose serious health risks (e.g., through vapor emissions or direct contact) and can be very difficult and costly to clean up. Small droplets of mercury can adhere to clothing, watches and gold (allowing the mercury to be transported to other locations) and become lodged in cracks and crevices in tile floors, counter tops and sinks. Many health care facilities have already instituted spill response plans and pollution prevention programs.

A safe and effective mercury spill response plan can lower health care facilities' mercury emissions to the environment and can save money. Examples of some costs of mercury spills include (Wisconsin DNR):

The Cost of Cleanup
A mercury-containing sphygmomanometer broken on a carpeted floor at Butterworth Hospital cost $2000 to clean up.

Labor Costs
It took Riverside Hospital 8 to 16 hours to clean up a mercury spill (the mercury had fallen in tile crevices).

Facility Down-Time
The room in which a mercury spill occurs will be unavailable for use until the site is decontaminated. Riverside Hospital found that their room was out of service for at least one day.

Equipment Loss
A mercury-containing switch in an oven in a University of Michigan Hospital cafeteria exploded. It cost $3500 to clean up the spill. The oven, a $25,000 piece of equipment, was irreparably damaged.

Training Time
Continuing to use mercury containing items can be expensive for your facility because of the needed staff training for spill response plans. However, if you are still using mercury-containing products, don't neglect training! An improperly managed spill can end up costing even more to decontaminate.

Mercury spill prevention as well as proper spill response are important aspects of health care facilities' mercury management policy. The following are some best management practices that will aid in spill prevention and response.

Mercury Spill Prevention and Response Practices

- Use mercury only in uncarpeted, well-ventilated areas. Provide troughs on smooth surfaced tables and benches to collect mercury spill. Never handle mercury over a sink. Reserve the room for mercury use only; restrict traffic in the area. It is preferable to use mercury devices in rooms that do not have carpeting or other floor coverings that are not easily cleaned.
- Ask workers to remove all watches and other jewelry–especially gold jewelry since mercury readily combines with gold–and have them wear a mercury vapor respirator and protective clothing: gloves, disposable gowns, and shoe coverings.
- Prohibit smoking, eating and drinking in the area.
- Train all workers to understand the properties and hazards of mercury and to carry out safe handling procedures and specific policies related to mercury disposal.
- Clean and calibrate all mercury-containing equipment according to the manufacturer's recommended handling procedures and the formal procedures posed by your communications or safety program supervisors.
- Be prepared for a spill in any area where mercury-containing devices are used. Have a mercury vacuum sweeper and spill cleanup kit available. Never use a regular vacuum cleaner to clean up mercury–it will vaporize the mercury and release it into the air.
- Cleanup of mercury spills must be performed by specially trained staff.
- Create a formal mercury spill policy for your facility, considering the following factors:

< round-the-clock availability of a staff person, trained in mercury spill cleanup
< OSHA requirements
< protective equipment and clothing for cleanup staff
< the circumstances that require patient, visitor and staff evacuation from
< how to determine when a room is "clean enough" to re-occupy
< type of flooring (linoleum, carpet, etc.)
< determination of the type of equipment to be used for the size and type of spill
< manufacturer's instructions for the equipment to be used
< ultimate waste disposal, which may depend on the cleanup method
< preparation of an incident report that describes the spill, the cleanup method used, unusual circumstances, and follow up
< mercury spills during a medical procedure

(Wisconsin DNR, New York Department of Health)

Option 3: Recycle or dispose of mercury-containing products in an environmentally sound manner

Proper management and disposal of mercury is always very important. It is important that staff are aware of the mercury-containing items in the facility and of the proper way to dispose of them. Mercury waste is different from regulated medical waste and must not be discarded in red sharps containers or other medical waste containers. Most regulated medical waste is incinerated at the present time and much of the mercury contained in the waste will be volatilized and released into the atmosphere.

Develop procedures for disposing of mercury-containing thermometers, sphygmomanometers, laboratory chemicals, batteries, lighting, electrical equipment, thermostat probes in gas appliances, industrial thermometers and laboratory manometers. Some tips on disposing of your mercury-containing items:

C Make sure the procedure for disposing of thermometers is convenient for nursing personnel. Label a container for mercury-containing thermometers and place it in the collection station. All mercury-containing thermometers should be packed in a tightly closed container in a manner that prevents breakage for delivery to a hazardous waste collection facility.
C Contact your hazardous waste manager for details on labeling, storing and transporting mercury sphygmomanometers that are specific to your facility.
C Mercury waste from servicing manometers should be stored in a covered, air-tight plastic container labeled "CONTAINS MERCURY" and sent to a recycler.
C Thermostat probes and electrical equipment (including lamps) that contain mercury should be stored in a covered container, labeled and transported to the hazardous waste collection facility. Do not break lamps: mercury vapor is released. If a lamp is accidently broken, store pieces in a sealed container and transport to the hazardous waste collection facility.
C Batteries should be sent to the hazardous waste collection facility. It may be easier for staff to collect all batteries and send to the hazardous waste management coordinator who will be responsible for determining which batteries can be recycled. Some battery manufacturers offer recycling programs for mercury-containing batteries. Check with the battery suppliers to determine if they have collection plans.
C Incorporate the importance of keeping mercury out of the wastewater when training laboratory staff on the disposal of hazardous substances. Make sure laboratory staff are aware of the

products that contain mercury by posting a list of mercury-containing products in the laboratory. It is important to keep laboratory chemicals that are ready to recycle or dispose of in separate containers to minimize the amount of hazardous waste generated. Check with your local sewer district to determine the proper disposal of mercury-contaminated rinse water. Contact your hazardous waste manager for the proper way to recycle unused mercury-containing laboratory chemicals.

(New York Department of Health, Wisconsin DNR)

Option 4: Clean out the wastewater system to rid the facility of historical uses of mercury

Historical mercury use in medical facilities may have led to collection of mercury in those facilities' sewer pipes, sumps and traps. Even afer best management practices have been implemented, some facilities face violations of wastewater discharge standards due to the presence of mercury in their plumbing. By cleaning out sewer pipes, sumps and sink traps, it is possible to lower wastewater levels of mercury (M2P2 Task Force).

Although the cleaning process may be costly and time consuming, it is a good way of reducing mercury emissions from facilities and may help avoid regulatory actions. Once the plumbing has been cleaned, however, it is important to follow guidelines on managing mercury in order to avoid re-depositing mercury into the sewer system.

When sewer pipes, sumps and traps are cleaned, it is important to notify the plumber that the sludge may contain mercury. The sludge must be handled as hazardous waste unless demonstrated otherwise (i.e., through the Toxicity Characteristic Leaching Procedure).

Please consult Appendix O in the document prepared by the New York Monroe County Department of Health, "Reducing Mercury Use in Health Care", for procedures on cleaning traps and pipes. You can find the document "Reducing Mercury Use in Health Care" on the Internet at: http://www.epa.gov/glnpo/bnsdocs/merchealth/aboutmerhealth.html.

Resources Used in Creating This Section:

Department of Health, Monroe County, New York. Reducing Mercury Use in Health Care. 1999. http://www.epa.gov/glnpo/bnsdocs/merchealth/index.html

Michigan Mercury Pollution Prevention Task Force. Mercury Pollution Prevention in Michigan: Summary of Current Efforts and Recommendations for Future Activities. April 1996. http://www.deq.state.mi.us/aqd/publish/m2p2.html

Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

Wisconsin Department of Natural Resources. Draft Wisconsin Mercury Sourcebook, 1997. http://www.epa.gov/glnpo/bnsdocs/hgsbook/index.html

Table 1: Mercury Sources in a Health Care Environment, *Wisconsin DNR, compiled from City of Detroit, MPCA, Terrene Institute*

Product	**Applications**	**Alternatives**
Analytical Instruments (mercury chloride as reagent)	SMAC AU 2000	ISE (Ion Selective Electrode)
Barometer	weather condition	
Batteries: Mercuric Oxide and Silver Oxide	Ë hearing aides Ë pacemakers Ë defibrillators Ë fetal monitors Ë hofler monitors Ë pagers Ë picker caliber Ë spirometer alarm Ë telemetry transmeter Ë temperature alarm Ë blood analyzer	lithium, zinc, alkaline
Blood Gas Analyzer Reference Electrode	Radiometer (brand)	
Cathode ray Ocilloscope	cathode ray tube	
Dental Amalgams	tooth restoration	gold, silver, porcelain, and polymer
DC Watt Hour Meters	e.g., Duncan, no longer manufactured but may still be in use	
Displacement/Plunger Relay	power supply switching (1 to 4 poles, NO, NC, many voltage and current ratings, generally for high current, high voltage applications	
Electron Microscope	mercury used as a vibration dampner	
Esophageal Dilators (also called Maloney or Hurst Bougies)/ Cantor tubes/ Miller Abbot Tubes/ Feeding Tubes	mercury is used as a weight at the bottom of the tube	tungsten, water (used as a weight) Anderson Tube can replace the Cantor Tube

Flame Sensor/ Safety Valve	Ë some infrared heaters (Robertshaw and Harper-Wyman) Ë some furnaces (White Rodgers)	
Hitachi Chem Analyzer	Hitergent Reagent has 65 ppb mercury	
Lead Analyzer Electrode	ESA (brand) model 3010B	
Commercial-Industrial-Laboratory manometers	Many types and uses	
Sphygmomanometers	blood pressure	electronic vacuum gauge, expansion, aneroid
Lamps	Ë flourescent –bilirubin blue –general purpose straight –U-bent, circline, compact –high output Ë germicidal lamps –cold cathode –hot cathode –slimline Ë metal halide Ë high pressure sodium vapor Ë ultra-violet (TB patient) Ë spectral lamps Ë high intensity discharge	ordinary glow lights; opticals; high-energy, long-lasting lights Ë low pressure sodium Ë forced draft and well lighted room can be designed for the TB patient
Thermometers	Ë blood bank Ë clerget sugar test Ë fever/temperature Ë incubator/water bath Ë minimum/maximum Ë tapered bulb (amored)	electronic (digital), expansion, aneroid
Thermostats	Ë ovens (laboratories) Ë nursing incubators Ë room temperature control Ë refrigerators	thermostat with bi-metallic strip or with other alternatives

Switches	Displacement/ Plunger Relays: Ë high currant/voltage lighting Ë power supply switching Ë tungsten lighting Ë wetted reed relay/wetted reed switch: test, calibration, measurement equipment Tilt Switches: Ë airflow/fan limit control Ë building security systems Ë chest freezer lid switches Ë fire alarm box switch Ë fluid level control Ë lap-top computer–screen shut off when close Ë pressure control Ë silent light switches Ë washing machine lids	Ë silent light switches believed to be totally discontinued (GE in 1991), reportedly also manufactured by Leviton, which now produces a non-mercury device Ë mechanical switches

Table 2: Mercury Sources in Health Care Laboratory Tests, *Wisconsin DNR, compiled from City of Detroit, MPCA, Terrene Institute*

Test Type	Reagent	Mercury	Alternative
Albumin	Million's reagent	Thimerosal; Mercury-Nitric Acid Solution	
ANA	Buffer		
Anti-Bacterial Agent	Mercurochrome		OTC Neosporin, Sulfa
Anti-fungal/ Anti-infective/ Bacteriostatic Enzyme/ Ammonia	Merthiolate Mercury Nitrate	Thimerosal (26% of mercury)	Neosporin, Mycin Ammonia/ Copper Sulfate
Ammonia Nitrogen	Nessler's Solution Channing's Solution	Mercury Potassium Iodide	
Arsenic-Calcium Reagent		Mercury 260 ppm	
Blood Bank Saline	Immu-Sal		
BUN Test Enzyme Non Protein Nitrogen	Nessler's Solution		
CA 125		Thimerosal	
Cleaning Supply (commercial grade)	Caustic Soda		
Clostridium Difficile EIA		Thimerosal	
Colorimetric Chloride Analysis			Ion-Selective Electrode Method
CPK Reagent		Mercury 2.7 ppm	
Cytology	Mucolexx	Thimerosal	
Drugs of Abuse	All	Thimerosal	
Epstein Barr Virus	Buffer		

Fixatives	B 5 Fixative Zenker Solution Helly Ohlamacher Carnoy-Lebrun Shardin	Mercuric Chloride (11)	
Flame Photometer (obsolete use)	Mercury (11) Sulfate		Silver Nitrate, Potassium Sulfate, Chromium (111) Sulfate
FTA	Buffer		
Ganglion Cell	Cajol's		Possible substitute is Proclain for mercury compound
Giardia EIA		Thimerosal	
Group A Stap ID		Thimerosal	
Harris Hematoxylin	Mercuric Oxide		Sodium Idoate,
HBFT	Alum Hematoxylin (Solution A)	0.25 mg mercury in 100 ml	
Hepatitis B Core		Thimerosal	
Hepatitis C		Thimerosal	
Hepatitis B AG & AB		Thimerosal	
Herpes EIA	Buffer	Thimerosal	
Histology	Stains: Carbol-Fuchin Mercury Chloride Carbol Gentian Violet Gomori's	Mercuric Chloride or Thimerosal	Possible substitute is Proclain for mercury compound
HIV		Thimerosal	
Identification of White Cell	Camco		
Lithium	Cesium Internal Std.	2.5 ppb	
Lyme	Buffer		
Mercurial Diuretic (known as mercupurin)	Mercurophylline		

Microbiology	Stain: Gram Iodine	Mercuric Chloride or Thimerosal	
pH	Buffer		
Pharmaceutical Preservative	Phenol Mercuric Acetate		
Progesterone		Thimerosal	
Protain Test (contain Hydroxy phenol group)	Millon's Reagent		
Sodium/Potassium		Thimerosal	
Takata-ara	Takata's Reagent		
Thyroid Antibodies	Buffer		
Urine Analysis	Stabilur Tablets	Mercuric Oxide	
Use in delineating nerve cell	Golgi's		

Table 3: Mercury-Containing Chemicals and Alternatives, *Wisconsin DNR, compiled from City of Detroit, MPCA, Terrane Institute, Michigan M2P2 Task Force*

Chemical	**Alternative**
Mercury (II) Oxide	Copper catalyst
Mercury Chloride	None Identified
Mercury (II) Chloride	Magnesium Chloride/ Sulfuric Acid or Zinc Formalin, Freeze drying
Mercury (II) Sulfate	Silver Nitrate/ Potassium/ Chromium-(III) Sulfate
Mercury Nitrate (for corrosion of copper alloys) for antifungal use (mercurochrome)	Ammonia/ Copper Sulfate Neosporin, Mycin
Mercury Iodide	Phenate method
Sulfuric Acid (commercial grade; mercury as impurity)	Sulfuric acid from a cleaner source, Zenker's Solution, Zinc Formalin

Table 4: Alternatives for Mercury-Containing Thermometers, New York Department of Health

Type of thermometer	**Cost**	**Accuracy**	**Time for Reading**	**Calibration Frequency**	**Comments**
Electronic (digital): oral/rectal	Thermometer: approx. $300 Disposable probe covers: pennies apiece. Take-home can be <$5	Comparable to mercury	Oral: seconds Rectal: seconds	Every 6 mo. to 1 year (some need initial testing only)	Requires batteries
Electronic (digital): tympanic (also called infrared thermometer)	Thermometer: approx. $300. Disposable probe covers: pennies apiece.	Comparable to mercury	Seconds	Every 6 mo. to 1 year (some need initial testing only)	Requires batteries. Must use “pull and tug” method to get correct placement. Can select to give equivalent oral/rectal reading.
Chemical strip, single-use disposable (plastic or paper strips with dots filled with different chemical mixtures, each formulated to melt and change color at a given temperature.	Pennies apiece	Comparable to mercury	Oral: 1 minute Axilla: 3 minutes	None required	Does not record temperatures below 35EC (95EF)

Glass filled with alloy of gallium, indium and tin; a liquid at room temperature	Approximately $3.00	Comparable to mercury	3 minutes	None required	Breakable
Mercury	Approximately $0.40	Considered to be the "gold standard" for accuracy comparisons	Oral: 5 minutes Axilla: 7 minutes	None required	Breakable. Average life expectancy 80 days in hospital setting, if reused. Disposal is expensive.

Table 5: Alternatives for Mercury-Containing Sphygmomanometers, New York Department of Health

Type of Sphygmomanometer	**Cost**	**Comments**
Aneroid	Wall model adult: $50-$80; portable model adult: $30-$35	Needs calibration annually. Accuracy comparable to mercury.
Electronic	On the order of $2000	Common where long-term continuous monitoring is needed, such as intensive care.
Mercury	Wall model adult: $60-$70 portable model adult: $60-$70	Requires annual refilling and calibration. Easily breakable. Disposal is expensive. Not recommended for carpeted areas.

Table 6: Alternatives for Mercury-Containing Gastrointestinal Tubes, New York Department of Health

Type of GI Tube	**Mercury-Free Alternative and Effectiveness**
Bougie tubes (esophageal dilators)	Tungsten. Considered to be as effective as mercury.
Cantor tubes (used to trace the GI tract)	Tungsten. Can be purchased empty of weighting and hospital adds the weighting material, either mercury or tungsten. Some feel tungsten weighting is not as effective as mercury because it is not as heavy.
Miller Abbott tubes (used to clear intestinal obstructions)	Tungsten. Can be purchased empty of weighting and hospital adds the weighting material. Tungsten replacement is considered to be as effective as mercury
Feeding tubes	Tungsten. Considered to be as effective as mercury.

Table 7: Alternatives for Mercury-Containing Laboratory Chemicals, New York Department of Health

Compound	**Possible Alternatives**
Histological fixatives (such as B5 and Zenker's Solution) with mercury (II) chloride as a tissue preservative	Zinc formalin; other products are available that are both mercury-free and formaldehyde-free.
Mercury (II) chloride as an oxidizer in hematoxylin	Sodium iodate as oxidizer.
Chemical used for acidic drug analysis of barbiturates and benzodiazepines by thin layer chromatography (such as Toxi-Dip B3)	Gas chromatography/mass spectrometry method. A hospital may need to send samples to a lab that has the equipment and the specially trained staff required.
Thimerosal (Trademark Merthiolate) as a preservative in stains and other products in the pH neutral range	Methyl paraben, propyl paraben

Table 8: Pharmaceutical Uses of Mercury, New York Department of Health

Product	**Notes**
Merbromin/water solution	Used in plastic/reconstructive surgery as a disinfectant and marker
Ophthalmic and contact lens products	May contain mercury preservatives: thimerosal, phenylmercuric acetate, phenylmercuric nitrate
Nasal Sprays	May contain mercury preservatives: thimerosal, phenylmercuric acetate, phenylmercuric nitrate
Vaccines	May contain thimerosal (primarily in hemophilus, hepatitis, rabies, tetanus, influenza, diptheria and pertussis vaccines

Table 9: Alternatives for Mercury-Containing Batteries, New York Department of Health

Battery	Quantity of Mercury	Use	Voltage	Available Alternatives
Button batteries: Zinc air	Contains on average 9 mg. per cell. Manufacturers use this standard for all button batteries.	Medical	Multiples of 1.4 v	None
Button batteries: Alkaline-manganese	11 mg mercury on average.	Consumer	Multiples of 1.5 v	Silver oxide (lasts longer, costs more, does not come in a full range of sizes)
Button batteries: Silver oxide	Contains on average 3.5 mg. per cell.	Consumer	Multiples of 1.5 v	None

Table 10: Mercury-Containing Electrical Equipment, New York Department of Health

Type of Switch	**Where Equipment is Used**	**Possible Alternative**
Tilt switch	–Airflow/fan limit control –Building security systems –Clothes iron –Fire alarm box –Fluid level, pressure or temperature control devices –Laptop computer screen shutoff –Lids of clothes washers and chest freezers –Silent light switch –Space heater –Thermostats	Mechanical switch
Float switch	–Bilge pumps –Septic tank -Sump pump	–Magnetic dry reed switch –Optic sensor –Mechanical switch
Thermostat	Temperature control device may have a mercury tilt switch	Electronic thermostat
Reed relay	Low voltage, high precision analytical equipment such as electron microscope	–Solid state relay –Electro-optical relay –Dry reed relay
Plunger or displacement relay	High current, high voltage applications such as lighting, resistance heating, power supply switching	Mechanical switch
Thermostat probe	–Electric stoves –Hot water heaters	Non-mercury probe

Table 11: Alternatives for Mercury-Containing Industrial Thermometers, New York Department of Health

Type of Thermometer	Approximate Cost	Accuracy	Comments
Digital	$39	Within 1% of scale range	Light-powered, no battery required; interchangeable with mercury thermometer as to threading and well
Bimetal	$45-$47	Within 1% of scale range	Contains a glass "window" but glass does not contain a liquid; *not* interchangeable with mercury as to threading and well
Alcohol-filled	$40	Within 1% of scale range	Red-colored alcohol in glass tube; interchangeable with mercury thermometer as to threading and well
Mercury	$32	Within 1% of scale range	Mercury in glass tube

Table 12: Alternatives for Mercury-Containing Laboratory Manometers, New York Department of Health

Type of Manometer	**Cost**	**Comments**
Electronic (digital)	Several hundred dollars	An order of magnitude more accurate than sphygmomanometers. Used in biomedical laboratory to calibrate other devices. A traceable calibration must be performed with a mercury manometer, onsite or offsite, on a regular schedule. The time interval depends on the manufacturer's recommendation.
Aneroid (Bourdon, diaphragm, piston or capsule types)	Price varies widely depending on accuracy and traceability required	Manufacturers recommend calibration at least annually. Schedule can be based on experience, with annual inspections as a minimum.
Liquid filled	Price varies widely depending on accuracy and traceability required	Inadvisable to move them from place to place. Manufacturers recommend calibration at least annually. Schedule can be based on experience, with annual inspections as a minimum.
Mercury	$100-$150 range	One meter tall. An order of magnitude more accurate than sphygmomanometers. Used in biomedical laboratory to calibrate other devices. Annual calibration recommended to ensure good performance.

MERCURY USE IN THE DENTAL FIELD

Background

Dental amalgam (silver filling) is an alloy that results from mixing powdered silver, tin and copper (and sometimes zinc, palladium or indium) with elemental liquid mercury which quickly hardens into a strong and durable substance. Silver amalgam has been used as a dental restorative material for over 150 years, making it one of the oldest materials used in oral health care, second only to gold.

Amalgam is popular because:

- it is extremely durable and has good long-term performance (even when the patient does not have good oral health care);
- it has minimal placement time (in only one appointment);
- it is easy to manipulate by the dentist and is the least technique-sensitive of all restorative materials;
- it is very economical and can be applied to a wide range of clinical situations; and
- it is the only material that can be used in areas of the mouth that can not be kept dry during placement.

Disadvantages of amalgam include:

- destruction of some healthy tooth structure;
- poor aesthetic qualities;
- marginal breakdown of the tooth; and
- local allergic potential in sensitive individuals.

Currently, the main source from the dental field of mercury release into the waste stream is in the placement and replacement of amalgam fillings. During the placement procedure, excess material is removed from the restoration and evacuated from the mouth into the wastewater stream. When an amalgam is replaced, the dentist drills it out of the tooth, releasing dust and large particles from the old filling into the air and wastewater. Chairside traps catch about 65% and vacuum system filters 30% of the amalgam waste produced during dental procedures so that it does not clog up the system. Some dental offices send excess amalgam as well as waste from the traps to recycling facilities, but many throw the filtered material out. Most amalgam waste, therefore, is fated to the sewer system, a landfill or an incinerator. Mercury is thus found in the sewer pipes of dental facilities–a remnant of the extensive use and improper disposal of mercury in past dental settings.

Another source of mercury release is through spills. The large majority of dentists use a pre-capsulated amalgam alloy to prepare the amalgam. Pre-capsulated amalgam alloy is beneficial to dentists because it makes a more consistent and better quality amalgam. Mercury spills and other types of discharges have been greatly reduced through the use of the premixed alloy powder. A minority of dentists, however, still use bulk mercury in amalgam preparation.

Use of dental amalgam has declined since the 1970s due to a general decline in dental caries (cavities), improvements in dental techniques, the availability of alternative restorative materials and dietary modifications. Patterns of the occurrence of dental caries have also changed as a greater emphasis is placed on preventative oral health care, including such practices as the use of flouride, sealants and improved oral hygiene practices and products.

> The total amount of mercury used in the dental industry is 31 Mg (34 tons), including mercury in all dental equipment and supplies (Plachy 1997–Report to Congress, Vol. 8).

> In 1990, dental amalgam accounted for approximately 96 million out of 200 million restorative procedures–a 38 percent reduction since 1979 (Public Health Service 1993).

Options

- ***Use alternative restorative materials***
- ***Recycle amalgam waste from chairside traps and vacuum system filters***
- ***Recycle bulk mercury and use pre-capsulated amalgam***
- ***Install additional amalgam capture equipment***

Option 1: Use alternative restorative materials

Current alternatives to mercury amalgam include composites, sealants, glass ionomers, gold, cast metal (gold, platinum, and palladium), metal-ceramic and ceramic. The decision to use a particular material depends on several variables: the location of the defect in the tooth, the extensiveness of the defect, the location of the afflicted tooth in the mouth, the amount of stress placed on the targeted area, the ability to keep the tooth dry during the placement of the filling, and the cost of the material.

Although several alternatives to amalgam are available, for a variety of reasons, the preferred material is often amalgam. Cold silver and gallium techniques are currently among the most promising alternatives to amalgam, but are still in the developmental phase. Most dentists favor amalgams over composites and glass ionomers when the filling is in a stress-bearing area, when moisture control during placement is poor, and when cost is an over-riding concern (composite can cost up to twice as much as amalgam). Gold is often thought by dentists to be a better restorative material than amalgam because it is more durable, healthier for the tissue, and the margins corrode less. However, the cost of gold fillings may be prohibitive: gold fillings cost 4-5 times as much as silver amalgam.

While the potential to completely eradicate the use of mercury in the dental field exists with this option, it will not be realized for some time due to the favorable properties of amalgam in many cases for tooth restoration. Some people predict that technological advances will allow for the phase-out of mercury in the next couple of decades, however, because a large part of the population has amalgam restorations, proper handling of the wastes will be an issue for some time.

See Table 1 for a comparison of restorative materials according to critical parameters such as longevity of the material, relative surface wear, resistance to fracture, marginal integrity, conservation of tooth structure, aesthetics, cost to patient and indications such as occlusal stress, age of patient and extent of caries.

Option 2: Recycle amalgam waste from chairside traps and vacuum system filters

Chairside traps capture about 65% of amalgam waste and vacuum system filters capture about 30% of amalgam waste produced during dental procedures in order to keep the system clean; however, the collected waste is not always recycled properly. Proper recycling is an easy and effective way of preventing mercury releases into the environment: every dentist should properly dispose of amalgam waste. Although only relatively small amounts of material are generated, the mercury that is released to the environment by all the dental offices in an area can be substantial. It has been estimated that in the metropolitan Seattle area, the approximate 1650 dental offices contribute 14 percent of the mercury in the wastewater system. In San Francisco, dental offices contribute an estimated 12 percent of the mercury in the wastewater system (Wisconsin DNR).

Recycling amalgam is very inexpensive; the Western Lake Superior Sanitary District estimated that the cost of recycling chairside traps is approximately $3.50 per pound, or less than $20 per practice per year (Wisconsin DNR). If the quantity of amalgam is sufficient, many recycling companies will pay for it, or accept it free of charge. However, most express courier companies will charge a small fee (less than $10) because amalgam is considered a hazardous material.

For a contact list of amalgam recyclers and the materials accepted, product requirements, preferred packaging and price, refer to: http://www.p2pays.org/ref/01/text/00020b.htm

Information about the proper procedures for managing the traps and filters in order to ensure recycling of mercury from the waste is described in Attachment 1.

Option 3: Recycle bulk mercury and use pre-capsulated amalgam

Since 1984, the American Dental Association's Council on Dental Materials, Instruments and Equipment, as part of its dental mercury hygiene recommendations, has recommended that dentists discontinue the use of bulk mercury and bulk amalgam alloy and that they only use pre-capsulated amalgam alloy in their practices. The use of these pre-mixed capsules decreases the potential for spills and occupational exposure and lessens the overall amount of mercury being used. The majority of dentists use pre-capsulated amalgam alloy as opposed to mixing the amalgam from scratch with bulk mercury. Measurement of the ratio of liquid mercury to amalgam powder is much more exact with the pre-capsulated technique, which makes a more consistent and better quality amalgam. Consequently, spills and other forms of liquid elemental mercury discharge are greatly diminished.

All bulk mercury should be sent to the local recycler/reclaimer. In some cases, government environmental agencies may have recycling programs. The Michigan Department of Environmental Protection has conducted a bulk mercury collection program; on a smaller scale, the Western Lake Superior District has also conducted a bulk mercury collection program. Check your state environmental agency for information about recycling services in your area. This Environmental Protection Agency web site provides links to most state and local environmental regulatory agencies in the nation: http://www.epa.gov/epapages/statelocal/envrolst.htm

For government agencies considering starting recycling programs, the cost effectiveness of a bulk mercury collection program was estimated in a Minnesota study to be $125/lb for air reductions and $20/lb for reductions to all media. Costs include labor for handling collections, "disposal" costs, and promotional printing and mailing costs. (Minnesota Pollution Control Agency) To estimate how much mercury such a program could yield in your town, assume 7% of dentists provide an average of 3.375 pounds of mercury each (based on MI/WLSSO experience). Nationally there are 149,350 active practicing dentists, which equates to nearly 17.6 tons of mercury!

Option 4: Install additional amalgam capture equipment in dental offices

A variety of technologies have been developed for capturing amalgam waste that has not been captured by chairside traps and vacuum system filters, including sedimentation columns, centrifuges and complete capture units. The American Dental Association Board of Trustees has identified the following technologies for handling amalgam waste:

- lowest tech: filters (secondary screens with finer mesh sizes, if technically practical)
- low tech: holding tanks (if prototypes are made commercially available)
- high tech: separators (the commercially available models, e.g., from Europe)
- higher tech: electrical and chemical approaches (which could address all of the discharge and not just the particulate)
- amalgam alternatives (would still need to address removals of existing amalgams)
- closed systems (if feasible)

(Wisconsin DNR)

These technologies range in price from $100 to several thousand dollars and in capture efficiency from 90% to 99+% of the total mercury generation in a dental office (Minnesota Pollution Control Agency).

Amalgam capture equipment options are quite new to the market and are largely untested in terms of effectiveness and cost effectiveness. The ability of dental office vacuum systems to work compatibly with the emerging technologies is a key question for dental offices. Also, issues of maintenance, wear and tear on existing equipment, and the availability of collection and recycling systems are all key questions that need to be addressed. New technologies will be accepted in the marketplace only when adequate testing and information is available to dentists. (Minnesota Pollution Control Agency) Dentists should check with a dental association or dental school before making a purchase.

For a list of amalgam separation vendors, visit: http://www.p2pays.org/ref/01/text/00020b.htm

Resources Used in Creating This Section:

Department of Health and Human Services, Public Health Service. Dental Amalgam: A Scientific Review and Recommended Public Health Service Strategy for Research, Education and Regulation: Final Report of the Subcommittee on Risk Management of the Committee to Coordinate Environmental Health and Related Programs. 1993.
http://www.health.gov/environment/amalgam1/ct.htm

Michigan Mercury Pollution Prevention Task Force. Mercury Pollution Prevention in Michigan: Summary of Current Efforts and Recommendations for Future Activities. April 1996.
http://www.deq.state.mi.us/aqd/publish/m2p2.html

Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

The Naval Dental Research Institute. Dental Mercury Environmental Issues. 2000.
http://www.dentalmercury.com

Wisconsin Department of Natural Resources. Draft Wisconsin Mercury Sourcebook, 1997.
http://www.epa.gov/glnpo/bnsdocs/hgsbook/index.html

Table 1: Comparison of Restorative Materials

Critical Parameters in Evaluating Posterior Restorative Materials	AMALGAM	COMPOSITE	GLASS IONOMER	GOLD FOIL	GOLD ALLOY (CAST)	METAL-CERAMIC CROWNS
Median Longevity Estimate[28]	8-12 years	6-8 years when used in conservative non-stress bearing situations	No data: 5 years predicted	No data: 10-15 years estimated	12-18 years	12-18 years
Relative Surface Wear	Wears slightly faster than enamel	Excessive wear in stress-bearing situations	Excessive wear in stress-bearing situations	Excessive wear in stress-bearing situations	Wears similar to enamel	Porcelain surface may wear opposing tooth
Resistance to Fracture	Fair to excellent	Poor to excellent	Poor	Fair to Good	Excellent	Excellent
Marginal Integrity (leakage)	Fair to excellent Self-sealing through corrosion products	Poor to excellent Polymerization shrinkage can cause poor margins	Poor to excellent	Poor to excellent	Fair to good Depends on fit and type of luting agent used	Poor to excellent Depends on fit and type of luting agent used
Conservation of Tooth Structure	Good	Excellent	Excellent if initial restoration, not if replacement	Good	Poor	Poor
Aesthetics	Poor	Excellent	Good	Poor	Poor	Excellent

[28]Longevity estimates reflect medians from published studies; however, under different clinical situations many restorations will last longer. For materials which have emerged in the last decade and gold foil, estimates are speculative.

Indications: Age range **Occlusal stress** **Extent of caries**	All ages Moderate stress Incipient to moderate size cavity	All ages Low stress-bearing Incipient to moderate size cavity	All ages Adult-Class V and low-stress primary teeth Class I and II child incipient to moderate size cavity	Adult Class III and V and crown repair Incipient to moderate size cavity	Adult High-stress areas Severe tooth destruction	Adult High-stress areas Severe tooth destruction or esthetic considerations
Cost to Patient[29]	1X	1.5X	1.4X	4X	8X + gold	8X

[29]Relative cost to patient, in relation to amalgam (1X). There may also be considerable geographic variation.

Attachment 1: Procedures for Collecting Mercury and Mercury Amalgams, *Michigan Dental Association, "HHR Update," March 1996 + WLSSD handout*

I Disposable Traps

Recycling facilities recover mercury from amalgam or amalgam traps for recycling. The following techniques will properly collect, store, and transport the chair-side traps to a recycler. Following these simple procedures, you can reduce the amount of mercury released to the environment.

1. Flush the vacuum system with line solution before changing the chair side trap. The best method is to flush the line the last thing before you go home, and then change the trap first thing the next morning.

2. Use barrier techniques such as gloves, glasses, and mask when handling the chair side trap. Choose utility gloves intended for cleaning and handling wastes for this procedure.

3. Do not place gloves, plastic bags, or paper towels into the recycling container. These add the volume of waste crated and cause problems with recycling equipment. Unless saturated with blood, dispose of gloves, plastic bags and paper towels in the garbage.

4. **A. Chair-Side Traps**

Place the trap in widemouth plastic container. Label the container: Amalgam for recycling. Keep the container covered.

Only traps on chairs used for amalgam placement or removal need special handling. Place traps from chairs dedicated to hygiene in regular garbage.

B. Vacuum Pump Traps

Reusable Traps: Empty the trap's contents into a widemouth plastic container. Keep the container covered.

Disposable Traps: Replace the cover after use. Place the trap in the original box for shipment to a recycler.

II Reusable Amalgam Traps

First, disinfect the trap for 24 hours using a minimum amount of disinfectant. Then, remove all visible amalgam and store it in an airtight container, labeled "WASTE AMALGAM". The disinfected trap can then be reused. Recycle the waste amalgam as outlined for scrap amalgam.

III Secondary Filters on the Vacuum Pump

Change these filters at least once a month, or more frequently if needed. DO NOT dispose of the filters as regulated medical waste. Place facial tissue or towels inside to absorb the liquid.

IV Scrap Amalgam

Excess amalgam remaining at the end of the procedure should be stored in an air-tight container labeled "SCRAP AMALGAM". The American Dental Association recommends that the scrap amalgam container be stored under a small amount of photographic fixer. Most reclaimers/recyclers will only accept dry amalgam, so you may need to decant off the fixer and blot the amalgam dry with a paper towel.

MERCURY USE IN SCHOOLS AND LABORATORIES

Background

Mercury is often found in equipment and chemical solutions used in educational institutions (middle, high school and university) and laboratories (educational, medical and commercial laboratories). Laboratories have elemental mercury and many mercury-containing chemicals that are regularly used in a wide variety of tests and applications. Laboratories also have thermometers, barometers and other scientific instruments that may contain mercury. Refer to Table 1 for a list of mercury-containing chemicals and their alternatives.
In schools, mercury is often found in the science laboratory supply room as elemental mercury or as various mercuric compounds which are not always properly stored or labeled. Science laboratories may also use mercury thermometers. Mercury thermometers, sphygmomanometers, nasal spray and contact lens solution are found in the nurse's office and school medical centers as well. In middle and high schools, students are not as careful with chemicals, therefore, allowing students to handle dangerous chemicals poses an unnecessary health and environmental risk. Schools should consider removing all mercury and mercury-containing items in order to avoid such a risk. Some states have special programs to help schools get rid of mercury (e.g., Vermont and Indiana). Please visit the Mercury K-12 Organization web site to obtain tools for teaching about mercury and other information about mercury in homes and schools: http://www.mercury-k12.org/hgspill.htm.

Schools and laboratories also utilize flourescent lighting, electrical and heating equipment, cleaners and batteries that contain mercury. Refer to the electrical manufacturing section for suggestions on how to manage these mercury-containing items in order to minimize pollution and ensure safety.

In order to reduce their mercury emissions, schools and laboratories must keep mercury-containing products out of the waste stream. There are two ways to ensure mercury does not enter either the wastewater or the solid waste stream:

- substitute and/or replace mercury-containing products for mercury-free ones, and
- properly recycle and dispose of mercury-containing devices, products or substances.

Product substitution is at the heart of pollution prevention and is a viable option for many types of equipment and laboratory chemicals. In addition, students and laboratory personnel should be educated about the proper handling of mercury to ensure personal and environmental safety. A proper mercury spill response plan is also very important to ensure the safe handling and disposal of mercury.

Options

- ***Substitute mercury-free products for mercury-containing ones***
- ***Devise a safe and environmentally sound mercury spill response plan***
- ***Recycle or dispose of mercury-containing products in an environmentally sound manner***

T ***Practice sound laboratory management: reduce waste***

T ***Clean out the wastewater system to rid the facility of historical uses of mercury***

Option 1: Substitute mercury-free products for mercury-containing ones

For many of the current mercury sources there are acceptable mercury-free alternatives. According to a study conducted in Minnesota, 90% of intentional uses of mercury-containing products are avoidable. In particular, mercury can be replaced with a safe alternative in the context of schools and classrooms. The cost of purchasing mercury-free items in place of mercury-containing ones or of replacing mercury-containing items at the end of their lives have not been quantified, but is expected to be relatively low. Replacing mercury-containing items before the end of their life (e.g., mercury switches, thermostats, gauges) has been estimated to cost up to $1000 per pound. (Minnesota Pollution Control Agency)

The following mercury-containing items may be found in schools:

laboratories
- pure mercury
- mercury compounds
- thermometers

nurse's office
- thermometers
- sphygmomanometers (blood pressure measuring device)
- nasal spray
- contact solution

buildings
- thermostats
- "silent" light switches
- fluorescent light bulbs

Science classrooms, especially in middle and high schools, sometimes use mercury in experiments and demonstrations of chemical principles and of the particular properties of mercury. Demonstrations of chemical principles can be done with less dangerous substances and demonstrations of the properties of mercury can be accomplished with video tapes.

Table 1contains lists of mercury-containing chemicals along with some suitable mercury-free alternatives. Besides chemicals and elemental mercury, major mercury-containing products in labs are thermometers (measure temperature) and manometers (measure pressure).

Option 2: Devise a safe and environmentally sound mercury spill response plan

Mercury is an extremely hazardous substance. Mercury spills, therefore, can pose serious health risks (e.g., through vapor emissions or direct contact) and can be very difficult and costly to clean up. Small droplets of mercury can adhere to clothing, watches and gold (allowing the mercury to be transported to other locations) and become lodged in cracks and crevices in tile floors, counter tops and sinks.

Thermometers are often sources of spills in laboratory settings. Examples of spill incidents are reported by the Mercury K-12 Organization at: http://www.mercury-k12.org/hgspill.htm. Some incidents involve children playing with mercury and contaminating their homes and schools, sometimes requiring HAZMAT response. Residents of the contaminated homes can become very ill, requiring hospitalization if the spill is not detected immediately. Schools have been shut down for several days and residents evacuated from their homes for months while cleanup activities occur.

A safe and effective mercury spill response plan can lower laboratories' mercury emissions to the environment and can save money. Mercury spill prevention as well as proper spill response are important aspects of laboratories' mercury management policy. The following are some best management practices that will aid in spill prevention and response.

Mercury Spill Prevention and Response Practices

- Use mercury only in uncarpeted, well-ventilated areas. Provide troughs on smooth surfaced tables and benches to collect spilled mercury. Never handle mercury over a sink. Reserve the room for mercury use only; restrict traffic in the area. It is preferable to use mercury devices in rooms that do not have carpeting or other floor coverings that are not easily cleaned.
- Ask people to remove all watches and other jewelry–especially gold jewelry since mercury readily combines with gold–and have them wear a mercury vapor respirator and protective clothing: gloves, disposable gowns, and shoe coverings.
- Prohibit smoking, eating and drinking in the area.
- Train all workers to understand the properties and hazards of mercury and to carry out safe handling procedures and specific policies related to mercury disposal.
- Clean and calibrate all mercury-containing equipment according to the manufacturer's recommended handling procedures and the formal procedures posed by your communications or safety program supervisors.
- Be prepared for a spill in any area where mercury-containing devices are used. Have a mercury vacuum sweeper and spill cleanup kit available. Never use a regular vacuum cleaner to clean up mercury–it will vaporize the mercury and release it into the air.
- Cleanup of mercury spills must be performed by specially trained staff.
- Create a formal mercury spill policy for your facility, considering the following factors:

    - availability of a staff person, trained in mercury spill cleanup
    - OSHA requirements
    - protective equipment and clothing for cleanup staff
    - type of flooring (linoleum, carpet, etc.)
    - determination of the type of equipment to be used for the size and type of spill
    - manufacturer's instructions for the equipment to be used
    - ultimate waste disposal, which may depend on the cleanup method
    - preparation of an incident report that describes the spill, the cleanup method used, unusual circumstances, and follow up

(Wisconsin DNR, New York Department of Health)

If you spill mercury, there are certain precautions you need to take to safeguard your health as well as procedures that should be followed to prevent mercury pollution in the environment. Remember to always get help with dealing with large mercury spills. See Attachment 1: “Guidance for Household Mercury Spills”.

Option 3: Recycle or dispose of mercury-containing products in an environmentally sound manner

A school lab and nurse's office could most likely clean out all mercury-containing items and send them to a hazardous waste collection facility. This would eliminate the environmental and safety issues involved with having mercury on site.

In laboratories that do not have the option of completely ridding the facility of mercury, proper management and disposal of mercury is very important. It is important that staff are aware of the mercury-containing items in the facility and of the proper way to dispose of them.

Develop procedures for disposing of mercury-containing thermometers, laboratory chemicals, batteries, lighting, electrical equipment, thermostat probes in gas appliances, industrial thermometers and laboratory manometers.

Properly cleaning out manometers and disposing of the mercury is very important. Follow these guidelines from the University of California at San Diego for cleaning out the mercury in a laboratory manometer.

Procedure for Cleaning out a Mercury Manometer
Prior to beginning, make sure you are familiar with the hazards involved, are working in a fume hood, have acid resistant gloves and apron, wear safety goggles (or safety glasses and a face shield) have a well stocked spill kit prepared for both mercury and acids and have plenty of clear space to work.

1. Carefully pour out the mercury in to a prepared, labeled container for evaluation for reuse.
2. With compressed air, gently blow out the inside of the glass tube into a collection vessel to get the rest of the mercury out.
3. Mix a solution of aqua regia (HCl & $HNO3$) and place in contact with the 'crud' inside the glass tube.
4. Carefully agitate the acid in a fashion which encourages the 'crud' to dissolve. This can be accomplished by 'rocking' the glass tube back and forth, allowing the liquid to pass over the surface repeatedly.
5. If the contaminants appear to be organic in nature, rinse with a degreasing solvent, such as methylene chloride.
6. Neutralize any used, or left-over aqua regia.
7. Place all mercury contaminated waste in a properly labeled waste container for EH&S to pick-up.
8. With compressed air, gently blow the clean manometer dry.
9. Clean up any mess and re-fill the manometer with clean mercury.

Some more tips on disposing of your mercury-containing items

C Make sure the procedure for disposing of thermometers is convenient. Label a container for mercury-containing thermometers and place it in a convenient location. All mercury-containing thermometers should be packed in a tightly closed container in a manner that prevents breakage for delivery to a hazardous waste collection facility.

- Contact your hazardous waste manager for details on labeling, storing and transporting mercury-containing items.
- Mercury waste from servicing manometers should be stored in a covered, air-tight plastic container labeled "CONTAINS MERCURY" and sent to a recycler.
- Thermostat probes and electrical equipment (including lamps) that contain mercury should be stored in a covered container, labeled and transported to the hazardous waste collection facility. Do not break lamps: mercury vapor is released. If a lamp is accidently broken, store pieces in a sealed container and transport to the hazardous waste collection facility.
- Batteries should be sent to the hazardous waste collection facility. It may be easier for staff to collect all batteries and send to the hazardous waste management coordinator who will be responsible for determining which batteries can be recycled. Some battery manufacturers offer recycling programs for mercury-containing batteries. Check with the battery suppliers to determine if they have collection plans.
- Stress the importance of keeping mercury out of the wastewater when training laboratory staff on the disposal of hazardous substances.
- Make sure staff are aware of the products that contain mercury by posting a list of mercury-containing products in the laboratory. It is important to keep laboratory chemicals that are ready to be recycled or disposed of in separate containers to minimize the amount of hazardous waste generated.
- Check with your local sewer district to determine the proper disposal of mercury-contaminated rinse water.
- Contact your hazardous waste manager for the proper way to recycle unused mercury-containing laboratory chemicals.

(New York Department of Health, Wisconsin DNR)

Option 4: Practice sound laboratory management: reduce waste

There are many ways laboratories can cut down on waste. Reducing the amount of mercury and mercury-containing chemicals lowers the amount of mercury that must be disposed of.

Some ideas:

- Be careful in your purchasing of stock chemicals. Up to 40 percent of hazardous waste generated from labs is from unused chemicals.
- Make sure chemicals are properly stored and labeled. Many high school laboratories store chemicals alphabetically, with no thought to potential reactions among chemicals.
- Order chemicals in smaller quantities in order to reduce stockpiling of chemicals.
- Use chemicals that are already available in your stockroom and use older chemicals first.
- Purchase cylinders that vendors will accept back when empty.
- Try some new chemistry–see if changing some standard operating procedures can reduce waste.
- Use the same reaction vessel for a number of reaction steps in order to save waste created by purification and cleaning steps.
- Use smaller reaction vessels.
- Use analytical procedures that produce less waste, e.g., use microanalytic scale techniques.
- Clean up.
- Recover, Recycle and Reuse. Mercury can be recovered.
- Use a surplus chemical exchange program. Return unused chemicals to a central stockroom. The requirements are that the bottle is more than half full, properly labeled and the container is

clean.

C Convert waste into product.

Option 5: Clean out the wastewater system to rid the facility of historical uses of mercury

Historical mercury use in laboratory facilities may have led to collection of mercury in those facilities' sewer pipes, sumps and traps. Even afer best management practices have been implemented, some facilities face violations of wastewater discharge standards due to the presence of mercury in their plumbing. If mercury in your wastewater is still a problem after implementing best management practices, it may be possible to lower your wastewater levels of mercury by cleaning out sewer pipes, sumps and sink traps.

Although the cleaning process may be costly and time consuming, it is a good way of reducing mercury emissions from facilities and may help avoid regulatory actions. Once the plumbing has been cleaned, however, it is important to follow guidelines on managing mercury in order to avoid re-depositing mercury into the sewer system.

When sewer pipes, sumps and traps are cleaned, it is important to notify the plumber that the sludge may contain mercury. The sludge must be handled as hazardous waste unless demonstrated otherwise (i.e., through the Toxicity Characteristic Leaching Procedure).

Please consult Appendix O in the document prepared by the New York Monroe County Department of Health, "Reducing Mercury Use in Health Care", for procedures on cleaning traps and pipes. You can find the document "Reducing Mercury Use in Health Care" on the Internet at: http://www.epa.gov/glnpo/bnsdocs/merchealth/aboutmerhealth.html.

Resources Used in Creating This Section

Department of Health, Monroe County, New York. Reducing Mercury Use in Health Care.
http://www.epa.gov/glnpo/bnsdocs/merchealth/index.html

Indiana Department of Environmental Management, Office of Pollution Prevention & Technical Assistance. Mercury Links and Information http://www.state.in.us/idem/ctap/mercury/index.html

Michigan Mercury Pollution Prevention Task Force. Mercury Pollution Prevention in Michigan: Summary of Current Efforts and Recommendations for Future Activities. April 1996.
http://www.deq.state.mi.us/aqd/publish/m2p2.html

Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

Stanford University. Replace Your Thermometers Before They Break
www.stanford.edu/group/water/hg-therm.htm

Wisconsin Department of Natural Resources, Mercury in Your Community and Environment
http://www.epa.gov/glnpo/bnsdocs/merccomm/

Wisconsin Department of Natural Resources. Draft Wisconsin Mercury Sourcebook, 1997.
http://www.epa.gov/glnpo/bnsdocs/hgsbook/index.html

Table 1: Mercury-Containing Chemicals and Alternatives, *Wisconsin DNR, compiled from City of Detroit, MPCA, Terrane Institute, Michigan M2P2 Task Force*

Chemical	**Alternative**
Mercury (II) Oxide	Copper catalyst
Mercury Chloride	None Identified
Mercury (II) Chloride	Magnesium Chloride/ Sulfuric Acid or Zinc Formalin, Freeze drying
Mercury (II) Sulfate	Silver Nitrate/ Potassium/ Chromium-(III) Sulfate
Mercury Nitrate (for corrosion of copper alloys) for antifungal use (mercurochrome)	Ammonia/ Copper Sulfate Neosporin, Mycin
Mercury Iodide	Phenate method
Sulfuric Acid (commercial grade; mercury as impurity)	Sulfuric acid from a cleaner source
Zenker's Solution	Zinc Formalin

Attachment 1: Guidance for Mercury Spills, *Indiana Department of Environmental Management*

1. **Safe mercury clean up is important:**
   Mercury can be found in a variety of household items. When liquid mercury is spilled, it forms droplets that can accumulate in the tiniest places; these droplets can emit vapors into the air that we cannot see or smell. Mercury vapor in the air can be very toxic. Families have been poisoned from mercury spills in the home which have not been properly cleaned up. Children [and pregnant women] are at highest risk. **The small amount of mercury in fever thermometers, thermostats and fluorescent bulbs is not likely to cause serious health problems, but it should be cleaned up.**

2. **When a mercury spill occurs, NEVER do this:**
   - C NEVER use an ordinary vacuum or shop vacuum to clean up mercury. The vacuum will put mercury vapor into the air and increase the likelihood of human exposure. The vacuum cleaner will be contaminated and have to be disposed of properly with the spilled mercury.
   - C NEVER use a broom or paint brush to clean up mercury. It will break the mercury into smaller beads and spread them around.
   - C NEVER pour or allow mercury to go down a drain.
   - C NEVER allow people whose shoes or clothing may be contaminated with mercury to walk around.

3. **Steps to take before cleaning up a spill:**
   - C [Remove all jewelry, especially gold. Mercury readily binds with metals]
   - C Contain the spill. Dike mercury (using rags, [cardboard] or other disposable item) to prevent spreading. Divert from drains, cracks and crevices.
   - C Keep children [and pregnant women)] and others away from spill area to prevent the spread of contamination.
   - C Close doors to other indoor areas. Immediately ventilate spill area–open doors, windows, use fans that exhaust to outdoors. Keep air flowing through room with mercury spill–but make sure it is ventilating outside.
   - C Turn off heating, ventilating or air conditioning systems that circulate air from the spill area to other parts of the house.
   - C If you or any other person have come in contact with the mercury stay in the area so as not to spread the contamination. Put contaminated clothing/shoes into a trash bag, wipe off any visible mercury beads into the bag, then shampoo and shower well after cleanup is complete.

4. **Questions to ask when a call comes in:**
   - C Are there children in the home? Remove them from the area.
   - C How much spilled?
     - < Big or little spill? (big is anything over 10 grams of mercury. A thermostat ampule contains ~5 grams) If big, homeowner should call contractor. If small (consumer product) follow cleanup directions below:
   - C What type of surface(s) is the spilled mercury on?
     - < Hard or porous? Cracks or crevices? If surface is hard, cleanup may be easier.

A porous surface may be more difficult to clean, because the mercury can seep into porous surfaces, cracks and crevices. In this case, the mercury cannot be completely removed and, if possible, should be sealed into the surface with epoxy paint or other sealing agent.

- < Accessible or difficult to reach? Can make the clean-up job a bit more difficult.
- < Disposable item? If item is removable, e.g. carpeting, rug, furniture cover, it should be removed and disposed of properly through the mercury recycling center closest to caller.

C What have you already done to try to clean up the mercury? Work through the spill section with them.

C Did you use a vacuum cleaner on the spilled area?

- < How long used? The shorter, the better.
- < What size room? The bigger the better, if vacuum cleaner was used.
- < What do with vacuum and bag? It cannot be cleaned and it must be trashed. Unplug it and cut the cord at base so no one will use it. Triple bag with plastic, bring to local mercury collection site.

C Is your water disposal on a city sewer line or on a septic system?

- < If you are on a city sewer, your local wastewater treatment plant can handle small amounts of mercury if you accidentally get some down the drain or if small amounts go down after rinsing mercury off your skin.
- < If you are on a septic system, all mercury-contaminated materials (including any water used) need to be cleaned up and collected. If mercury accidentally goes down a septic system, stop using the system and contact a professional.

5. Suggested equipment and supplies for a small spill clean up:

Stress that all supplies used will be contaminated and cannot be cleaned and reused. These items must be disposed of properly after use and taken to the mercury recycling center.

- C rubber squeegee
- C plastic dust pan
- C plastic trash bags
- C zipper-shut plastic bags
- C flashlight
- C wide-mouth plastic container with tight lid
- C large tray or box
- C facial tissues, toilet paper, or paper towels
- C eye dropper
- C index cards, playing cards, or other disposable heavy paper
- C plastic wrap
- C sulfur powder
- C zinc or copper flakes

6. Clean Up Methods:

ANYTHING which comes in contact with mercury should be disposed of!

C Push small mercury beads together with a card, stiff paper, or squeegee to form larger droplets and to push them into a plastic dust pan or use an eye dropper to pick up the balls of mercury. Collect all mercury into a leak-tight plastic bag or wide-mouthed sealable plastic container.

- Work from the outside of the spill area toward the center. Work over a tray or box that is lined or covered with plastic wrap when pouring mercury. Mercury's high density and smoothness cause it to roll fast.
- Use a flashlight to look all around in the areas of the spill. The light will reflect off the shiny mercury beads and make it easier to see them.
- Sprinkle sulfur powder on the spill area after cleaning up beads of mercury; a color change from yellow to brown indicates that mercury is still present and more cleanup is needed.
- Sprinkle zinc flakes or copper flakes (available at hardware stores) to amalgamate any small amounts of mercury which remain.

7. Follow-up checklist:

- Wash your hands. Shower or bathe if other parts of your body may have contacted mercury.
- Continue to air out the room with outside air for two days if weather permits.
- If mercury is spilled in a regularly used area, you should consult your family doctor or local health department regarding mercury testing for your family.
- Take all elemental mercury, mercury devices and mercury-contaminated items to the nearest mercury recycling center.

Remember: Get an experienced professional to clean up large spills!

CONSUMER MERCURY USE

Background

The public uses many mercury-containing products. Common consumer products that may contain mercury are batteries, flourescent lighting, clothes irons, vintage toys, paints, pesticides, thermometers, detergents, appliances, art supplies, electrical switches and some medicinal products such as contact solution and nasal spray. Breaking thermometers or flourescent light bulbs, rinsing out paint cans, applying certain pesticides to lawns, and throwing away mercury-containing products into the trash or sinks are several ways mercury can be released to the environment. The main concern with most mercury-containing products is their disposal, not their use. Disposing of these products in an improper way can lead to serious environmental pollution and human health problems.

> Did you know that 0.5 grams of mercury from one broken thermometer can detectably pollute 5 million gallons of San Francisco Bay water? (www.stanford.edu/group/water/hg-therm.htm)

The Minnesota Pollution Control Agency (MPCA) estimates that about 90% of all current uses of mercury-containing products are avoidable. By purchasing non-mercury product alternatives, consumers can decrease the amount of mercury pollution. This will also help place market pressure on the manufacturing industry to reduce mercury use in products. In addition, proper recycling and disposal of mercury-containing products should occur to minimize releases of mercury into the environment.

Energy efficiency is another way to curtail mercury pollution. Energy production is the greatest contributor of mercury to the environment, mainly through the combustion of mercury-containing coal. By cutting back on your energy consumption through more efficient lighting, heating and appliances, and by curtailing wasteful energy-use practices, you can help reduce mercury pollution from power plants.

There are three main ways a consumer can help to reduce mercury pollution in the environment: 1) substitute mercury-free products for mercury-containing products, 2) dispose of and recycle mercury-containing products properly and 3) practice energy efficiency. These options are described in the remainder of this section.

Options

- ***Substitute mercury-free products for mercury-containing ones***
- ***Recycle or dispose of spilled mercury and mercury-containing products in an environmentally sound manner***
- ***Practice energy efficiency***

Option 1: Substitute mercury-free products for mercury-containing ones

There are a few commonly used products that contain mercury:

- thermometers (These are highly breakable and are a major cause of small spills. If not cleaned up properly they can pose an indoor air health threat. There are many effective electronic alternatives);
- thermostats (These are safe to leave in service until the end of their lives (when they must be disposed of properly), but can be replaced with energy-saving (ENERGY STAR®) programmable electronic models);
- fluorescent lamps (These are the exception to the rule: continue to use.);
- appliances (There are several types of appliances that may contain mercury, including some chest freezers with internal lights and gas ranges with standing pilot lights, plus others referred to in the attached Tables).

Mercury in jewelry or used in religious rituals or hobbies can also pose a spill risk and health threat. In addition, mercury in trace amounts is used as a preservative in the form of thimerosal in some medicines and pharmacy products such as contact lens solution and nasal spray.

Be aware of the products you use that may contain mercury and next time you buy them, look for the mercury-free alternatives. One exception to this rule is fluorescent lighting which contains mercury, but is still environmentally beneficial due to its energy efficiency (some fluorescent bulbs have less mercury than others–make sure to check). Most products that contain mercury have substitutes that do not cost any more money than the ones with mercury, such as batteries, detergents, paints, toys, and medicinal products. The Minnesota Pollution Control Agency estimates that 90% of consumer products have acceptable alternatives and by not using mercury-containing products consumers and businesses can permanently reduce mercury pollution by 7000 pounds per year in Minnesota alone!

Tables 1-4 and Attachments 1-2 list products that contain mercury and alternatives to mercury-containing items such as batteries, detergents and electrical switches.

Option 2: Recycle or dispose of mercury-containing products and spilled mercury in an environmentally sound manner

Do not throw away all of your mercury-containing products as it is mainly the disposal of these items that causes problems! When mercury is thrown in the trash or spilled down the drain, it does not just disappear, but eventually contaminates our water and air via waste incinerators, landfills and wastewater treatment facilities. However, when the use and/or lifetime of the product has ended, recycle it and replace it with a mercury-free alternative.

Take your mercury-containing products to your nearest household hazardous waste collection site for safe disposal and recycling. Find out the local contacts for household hazardous waste collection and mercury thermostat recycling; the sewage treatment plant or the Department of Public Works are good places to find out if there is a household hazardous waste collection program in your area.

For more information:

C Call 1-800-345-6770 to determine how to recycle used mercury thermostats in your area (Wisconsin DNR)

C Companies that recycle fluorescent lamps and other mercury containing devices are on the Internet at: http://www.state.in.us/idem/ctap/mercury/recyclers.pdf, and

C Mercury-containing products and what to do with them can be found at: http://www.state.in.us/idem/ctap/mercury/brochure.html

Mercury Spills

If you spill mercury, there are certain precautions you need to take to safeguard your health as well as procedures that should be followed to prevent mercury pollution in the environment. See Attachment 3: "Guidance for Household Mercury Spills".

Option 3: Practice energy efficiency

The large share of mercury that is released to the environment is from the burning of fossil fuels (especially coal) for energy. By reducing your energy consumption, in turn you can help lower the amount of mercury that is released into the environment via coal combustion. Using less energy can also sharply reduce your utility bill. Ways to lower energy consumption:

C Drive less, walk and bike more

C Carpool

C Use public transportation

C Use fluorescent lighting (but recycle properly)

C Use energy efficient products (with the ENERGY STAR® label), such as office equipment, home appliances, residential heating and cooling equipment, residential lighting fixtures, exit signs, and even new homes. Products with the ENERGY STAR® label save energy and money, perform better, and help prevent air pollution. A household can reduce its energy bill by up to 40% with the purchase of products with this label. The ENERGY STAR® web site is at: http://www.epa.gov/energystar.html

C Consult the Home Energy Saver page to determine what steps you can take to reduce energy consumption in your home and for a list of the most efficient appliances on the market: http://hes.lbl.gov/HES/about.html

C Consult the California Energy Commission's web site for suggestions on how to become more energy efficient: http://www.energy.ca.gov/consumer/home/home.html

Resources Used in Creating This Section:

Indiana Department of Environmental Management, Office of Pollution Prevention & Technical Assistance. Mercury Links and Information http://www.state.in.us/idem/ctap/mercury/index.html

Michigan Mercury Pollution Prevention Task Force.. Mercury Pollution Prevention in Michigan: Summary of Current Efforts and Recommendations for Future Activities. April 1996. http://www.deq.state.mi.us/aqd/publish/m2p2.html

Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.

Stanford University. Replace Your Thermometers Before They Break www.stanford.edu/group/water/hg-therm.htm

Wisconsin Department of Natural Resources, Mercury in Your Community and Environment http://www.epa.gov/glnpo/bnsdocs/merccomm/

Wisconsin Department of Natural Resources. Draft Wisconsin Mercury Sourcebook, 1997. http://www.epa.gov/glnpo/bnsdocs/hgsbook/index.html

Table 1: Household Products that Contain Mercury, *Wisconsin DNR*

Product	**Description**	**What to Do**	**Mercury-Free Alternative**
thermometers	silver liquid in tube	bring to Household Hazardous Waste Facility	alcohol or digital thermometer
thermostats	all non-electronic models	when it needs replacing, recycle–call the national thermostat recycling program	electronic "set back" models can help save on energy bills
fluorescent lights	light bulbs in the form of long or curved tubes	continue to use these, however recycle them at the Household Hazardous Waste Facility	none, although some newer bulbs have less mercury than others
old alkaline batteries	bought before 1990	bring to Household Hazardous Waste Facility	rechargeable batteries
mercurochrome	an old time antiseptic for cuts and scrapes	bring to Household Hazardous Waste Facility	new antiseptics do not contain mercury
maze toys	contain blob of mercury	bring to Household Hazardous Waste Facility	mercury-free games
old toys that light up or make noise	may contain mercury button batteries	bring to Household Hazardous Waste Facility	toys that do not light up or make noise
shoes that light up when you step	bought before June, 1994	bring to Household Hazardous Waste Facility	sneakers that do not light up
chemistry sets	may contain mercury compounds	bring mercury or mercury compounds to Household Hazardous Waste Facility	other mercury-free toys
contact lens solution	may contain thimerosal or other mercury compounds	check the label, then use it up	other brands that do not contain any mercury compounds

vials of mercury	small containers of mercury used for ceremonial purposes	bring to Household Hazardous Waste Facility	none

Table 2: Batteries and Mercury Content

Type of Battery	Description	Example of Use	Mercury Content
Alkaline	Cylindrical or rectangular cells; the most commonly recognized battery. Labeled "alkaline".	Flashlight, radios, toys, calculators, remote controls, electronic games, portable radios and televisions, garage door openers	None currently. Mercury in alkaline batteries was phased out in 1994. *Alkaline manganese button cell batteries contain on average 11 mg. of mercury.
Zinc Carbon	Cylindrical or rectangular cells; labeled as 'General Purpose", "Heavy Duty", or "Classic".	Best used in slow drain applications like clocks, garage door openers, pagers, and smoke detectors. Have much shorter life span than alkaline batteries	Mercury in zinc carbon batteries was eliminated in 1994. Contain about 0.01% mercury per battery.
Silver Oxide	Button shaped. Identify by AG, KS or SR imprint.	watches, calculators, toys, greeting cards, musical books	Contain on average 3.5 mg. per cell. Mercury use in these batteries is expected to be discontinued.
Zinc Air	Usually button shaped. Identify by pin hole on one side.	hearing aids and pagers	Contain on average 9 mg. per cell.
Mercury Zinc (Mercuric Oxide)	Button shaped; larger mercuric oxide batteries look like 9-volt or fat AA batteries	hearing aids, watches, and other items requiring a small battery. In consumer applications, mercuric oxide batteries are being replaced by zinc-air button cells. The larger mercuric oxide batteries are often used in military, hospital or industrial uses.	Have not been sold since 1995. Phase-out began in1991.

Table 3: Mercury Content in Detergents and Cleaners, *Massachusetts Water Resources Authority/ MASCO*

Product	**Mercury Content (ppb)**
Ajax Powder	0.17
Comet Cleaner	0.15
Lysol Direct	<0.011
Soft Scrub	<0.013
Kodak Fixer	6.9; 3.7
Kodak Developer	2.65; 6.0
Alconox Soap	0.004 mg/kg 0.005 mg/kg <0.0025 mg/kg
Derma Scrub	<5.0 <2.5
Dove Soap	0.0027
Ivory Dishwashing Liquid	0.061
Joy Dishwashing Liquid	<0.01
Murphy's Oil Soap	<0.012
Soft Cide Soap (Baxter)	8.1
Sparkleen Detergent	0.0086
Sunlight Dishwashing Detergent	<0.011

Table 4: Mercury Switches in Electrical Applications, *M2P2 Task Force, 1996*

Switch	**Quantity of Mercury**	**Available Alternatives**
Tilt Switch		
Thermostats	3000–6000 mg	electronic type and snap switches
Float Control (septic tank and sump pumps)	--	magnetic dry reed switch, optic sensor, or mechanical switch
Freezer light	2000 mg	mechanical switch
Washing Machine (power shut off)	2000 mg	mechanical switch
Silent Switches (light switches prior to 1991)	2600 mg	mechanical switch
Thermo-Electrical Applications		
Accustat ("mercury in glass thermostat," a calibrated device resembling a thermometer is used to provide precise temperature control for specialized applications)	~1000 mg	--
Flame Sensor (used in residential and commercial gas ranges, mercury is in capillary tube when heated mercury vaporizes and opens gas valve or operates switch. Used for both electrical or mechanical output.)	2500 mg	Hot surface ignition system for devices or products that have electrical connections.

Attachment 1: Types of Bulbs and Lamps that Contain Mercury, *Wisconsin Recycling Markets Directory*

- **Flourescent Lamps**: the tube-style were first used as overhead lighting in offices, now they also come in compact globe shapes for a variety of home and office uses
- **Mercury Vapor Lamps**: the first high intensity discharge (HID) lamps with blue-white light, originally used as farmyard lights
- **Metal Halide Lamps**: newer, more efficient HID lights used for sports and industrial lighting
- **High-Pressure Sodium Vapor Lamps**: white-yellow HID lights used for street lamps and outdoor security lighting
- **Neon lamps**: brightly colored lamps typically used in advertising; most colors contain mercury except red, orange and pink

Attachment 2: Where to Find Tilt Switches, *Wisconsin DNR*

- "silent" wall switches, single pole and three way (believed to be totally discontinued in 1991)
- airflow/fan limit controls
- building security systems (tilt and trembler devices)
- chest freezer lid switches (for light)
- cameras (still, video, film: over-ridable position sensor to protect CCD from sunlight damage)
- fire alarm box switch
- laptop computer (screen shut-off when closed)
- portable phone (mute/privacy switch when phone is in horizontal position)
- temperature control
- washing machine lids (for spin-cycle shut-off)

Attachment 3: Guidance for Household Mercury Spills, *Indiana Department of Environmental Management*

Safe mercury clean up is important:

Mercury can be found in a variety of household items. When liquid mercury is spilled, it forms droplets that can accumulate in the tiniest places; these droplets can emit vapors into the air that we cannot see or smell. Mercury vapor in the air can be very toxic. Families have been poisoned from mercury spills in the home which have not been properly cleaned up. Children [and pregnant women] are at highest risk. **The small amount of mercury in fever thermometers, thermostats and fluorescent bulbs is not likely to cause serious health problems, but it should be cleaned up.**

1. When a mercury spill occurs, NEVER do this:

C NEVER use an ordinary vacuum or shop vacuum to clean up mercury. The vacuum will put mercury vapor into the air and increase the likelihood of human exposure. The vacuum cleaner will be contaminated and have to be disposed of properly with the spilled mercury.

C NEVER use a broom or paint brush to clean up mercury. It will break the mercury into smaller beads and spread them around.

C NEVER pour or allow mercury to go down a drain.

C NEVER allow people whose shoes or clothing may be contaminated with mercury to walk around.

3. Steps to take before cleaning up a spill:

C [Remove all jewelry, especially gold. Mercury readily binds with metals]

C Contain the spill. Dike mercury (using rags, [cardboard] or other disposable item) to prevent spreading. Divert from drains, cracks and crevices.

C Keep children [and pregnant women)] and others away from spill area to prevent the spread of contamination.

C Close doors to other indoor areas. Immediately ventilate spill area–open doors, windows, use fans that exhaust to outdoors. Keep air flowing through room with mercury spill–but make sure it is ventilating outside.

C Turn off heating, ventilating or air conditioning systems that circulate air from the spill area to other parts of the house.

C If you or any other person have come in contact with the mercury stay in the area so as not to spread the contamination. Put contaminated clothing/shoes into a trash bag, wipe off any visible mercury beads into the bag, then shampoo and shower well after cleanup is complete.

4. Questions to ask when a call comes in:

C Are there children in the home? Remove them from the area.

C How much spilled?

    < Big or little spill? (big is anything over 10 grams of mercury. A thermostat ampule contains ~5 grams) If big, homeowner should call contractor. If small (consumer product) follow cleanup directions below:

C What type of surface(s) is the spilled mercury on?

    < Hard or porous? Cracks or crevices? If surface is hard, cleanup may be easier. A porous surface may be more difficult to clean, because the mercury can seep

into porous surfaces, cracks and crevices. In this case, the mercury cannot be completely removed and, if possible, should be sealed into the surface with epoxy paint or other sealing agent.

< Accessible or difficult to reach? Can make the clean-up job a bit more difficult.

< Disposable item? If item is removable, e.g. carpeting, rug, furniture cover, it should be removed and disposed of properly through the mercury recycling center closest to caller.

C What have you already done to try to clean up the mercury? Work through the spill section with them.

C Did you use a vacuum cleaner on the spilled area?

< How long used? The shorter, the better.

< What size room? The bigger the better, if vacuum cleaner was used.

< What do with vacuum and bag? It cannot be cleaned and it must be trashed. Unplug it and cut the cord at base so no one will use it. Triple bag with plastic, bring to local mercury collection site.

C Is your water disposal on a city sewer line or on a septic system?

< If you are on a city sewer, your local wastewater treatment plant can handle small amounts of mercury if you accidentally get some down the drain or if small amounts go down after rinsing mercury off your skin.

< If you are on a septic system, all mercury-contaminated materials (including any water used) need to be cleaned up and collected. If mercury accidentally goes down a septic system, stop using the system and contact a professional.

5. Suggested equipment and supplies for a small spill clean up:

Stress that all supplies used will be contaminated and cannot be cleaned and reused. These items must be disposed of properly after use and taken to the mercury recycling center.

C rubber squeegee

C plastic dust pan

C plastic trash bags

C zipper-shut plastic bags

C flashlight

C wide-mouth plastic container with tight lid

C large tray or box

C facial tissues, toilet paper, or paper towels

C eye dropper

C index cards, playing cards, or other disposable heavy paper

C plastic wrap

C sulfur powder

C zinc or copper flakes

6. Clean Up Methods:

ANYTHING which comes in contact with mercury should be disposed of!

C Push small mercury beads together with a card, stiff paper, or squeegee to form larger droplets and to push them into a plastic dust pan or use an eye dropper to pick up the balls of mercury. Collect all mercury into a leak-tight plastic bag or wide-mouthed sealable plastic container.

C Work from the outside of the spill area toward the center. Work over a tray or box that is lined or covered with plastic wrap when pouring mercury. Mercury's high density and smoothness cause it to roll fast.

- Use a flashlight to look all around in the areas of the spill. The light will reflect off the shiny mercury beads and make it easier to see them.
- Sprinkle sulfur powder on the spill area after cleaning up beads of mercury; a color change from yellow to brown indicates that mercury is still present and more cleanup is needed.
- Sprinkle zinc flakes or copper flakes (available at hardware stores) to amalgamate any small amounts of mercury which remain.

7. Follow-up checklist:

- Wash your hands. Shower or bathe if other parts of your body may have contacted mercury.
- Continue to air out the room with outside air for two days if weather permits.
- If mercury is spilled in a regularly used area, you should consult your family doctor or local health department regarding mercury testing for your family.
- Take all elemental mercury, mercury devices and mercury-contaminated items to the nearest mercury recycling center.

Remember: Get an experienced professional to clean up large spills!

APPENDIX A: Excerpts from "Options and Strategies for Reducing Mercury Releases" by the Minnesota Pollution Control Agency

From 1997 through 1999, the Minnesota Pollution Control Agency (MPCA) worked with a variety of stakeholders on a Mercury Contamination Reduction Initiative, which included the development of options for mercury reduction from a variety of sources. A committee on Source Reduction Feasibility and Reduction Strategies developed a report (Options and Strategics for Reducing Mercury Releases) which evaluates various options for their cost effectiveness (cost per pound of mercury emissions reduced), reduction potential (total reductions achievable in Minnesota), technical feasibility, and permanence. The evaluation of permanence considered whether the option would result in pollution prevention, or the transfer of mercury from one medium to another, or re-introduction of mercury into commerce.

MPCA's evaluations of cost effectiveness and reduction potential are specific to Minnesota. Reduction potentials were, in most cases, calculated for Minnesota only. As a result, Minnesota's report includes no options for sectors, such as the chlor-alkali industry, that are not found in Minnesota. The cost-effectiveness evaluations for Minnesota could differ from cost-effectiveness that would be found in other areas of the country, in part because estimated emissions reductions are based on Minnesota-specific assumptions about the share of mercury-containing wastes that are incinerated versus land-filled. Nonetheless, the summary tables below present information that could be valuable in selecting reduction options throughout the United States. Details about the reduction options are available through the full report, which can be downloaded from http://www.pca.state.mn.us/air/mercury-mn.html.

The information below is taken directly from the Minnesota report (Minnesota Pollution Control Agency. Options and Strategies for Reducing Mercury Releases. Report to the Advisory Council of the Minnesota Pollution Control Agency Mercury Contamination Reduction Initiative, from the Source Reduction Feasibility and Reduction Strategies Committee. April 2000.).

SUMMARY TABLES

Abbreviations, Terms and Assumptions

Hg = mercury	RP = reduction potential
CE = cost effectiveness	TF = technically feasible
MWI = medical waste incinerator	WWTP = waste water treatment plant
MWC = municipal (solid) waste combustor	P = permanence

NIKE = less controversial strategies, "just do it" strategies.

COST EFFECTIVENESS = Note that the cost effectiveness of a strategy sometimes exceeds the cost of associated options because administrative costs (e.g., MPCA staff time) are included in strategy cost estimates.

REDUCTION POTENTIAL = Unless noted otherwise, the reduction potential estimates shown are reductions in air emissions of mercury. Except for strategies listed under "National," the reduction potential shown is for just the state of Minnesota. For national strategies, a national estimate is indicated. Note that the reduction potential for a given strategy is not equal to the sum of its associated options.

PERMANENCE:

Y = yes: used for options/strategies that lead to pollution prevention
N = not permanent because the option/strategy would lead to transfer of Hg from one medium to another (e.g., from air to land)
N* = not permanent because it encourages mercury recycling, not pollution prevention
Y/N = yes and no: strategies that would lead to both permanent and non-permanent options

TECHNICALLY FEASIBLE:

Y = yes, the option/strategy is technically feasible
U = unproven and/or not commercially available
N = no; options which are infeasible in the near future are excluded

ASSOCIATED OPTIONS = Options that could indirectly be encouraged by a given strategy are marked "(indirectly related)" to the left of the option. For example, enforcing labeling laws for mercury products may indirectly lead to manufacturers choosing to discontinue use of mercury in their product rather than labeling it.

Estimates assume that the permanence and technical feasibility of strategies was projected based on the associated options most likely to be implemented as a direct result of the strategy. If both permanent and non-permanent options are likely to result, the strategy is marked "Y/N." Similarly, if some associated options are technically feasible while the feasibility of others is unproven, the strategy is marked "Y/U."

Table 6.3: Summary of Options

OPTION	SOURCES	Cost - effectiveness (Per Pound)	Reduction potential pounds per year	Permanence	TECHNICALLY FEASIBLE? + commentsNOTES	
Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y	RP: 2-8 to air, 15-50 to all media CE: 125 for air, 20 for all media
collect raw mercury	School laboratories	10	1000	Y	Y	
Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y	RP: 580 to air, 3,900 to all media
Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y	RP: 10 to air, 60 to all media; CE: 700 for air, 100 for all media
Increase recycling of chairside traps	Dental	110	110	N*	Y	RP: 110 to air, 325 to all media; CE: 110 for air, 40 for all media
coal cleaning - intense conventional	Utilities	47,000	150	N	U	RP from air to land, Prof. multimedia transfer release rate unknown
coal cleaning- chemical	Utilities	46,000	425	N	U	RP from air to land, Prof. multimedia transfer release rate unknown
coal cleaning - chemical + conventional	Utilities	58,000	540	N	U	RP from air to land, Prof. multimedia transfer release rate unknown
use best available control technology to capture Hg	WWTP water discharge	5,500,000	31*	N	U	*RP to water
Demand side management/energy efficiency	Utilities	493,000-2,800,000	unknown	Y	Y	RP NSP only 6-17
carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-110,000	200	N	U	RP assumes 60% from air to land, P multimedia transfer, release rate unknown
Increase recycling of vacuum system filters	Dental	880	50	N*	Y	RP: 50 to air, 150 to all media; CE: 880 for air, 300 for all media
carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U	RP assumes 30% from air to land, P multimedia transfer, release rate unknown
Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U	RP: 17 to air, 50 to all media; CE: 15,000-618,000 to air, 5,000-210,000 to all media
Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U	Applies only to units w/ existing wet scrubbers
natural gas co-firing @ 20% gas	Utilities	410,000-922,000	280	Y	Y	CE based on incremental fuel costs only, RP assumes 20% replacement
carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-275,000	520	N	U	RP assumes 90% from air to land, P multimedia transfer, release rate unknown
wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y	RP assumes 10% replacement
co-generation	Utilities	unknown	Unknown	Y	Y	
Conventional controls - existing	Taconite Plants	unknown	unknown	N	Y	TF not necessarily for all plants due to operational constraints
Conventional controls - new and emerging technology	Taconite Plants	unknown	unknown	N	U	

Plant area modifications	Taconite Plants	unknown	unknown	N	U	
co-fire biomass @ 5-10%	Utilities	unknown	70-140	Y	Y	TF for certain conditions
OPTION	**SOURCES**	**Cost - effectiveness (Per Pound)**	**Reduction potential pounds per year**	**Permanence**	**TECHNICALLY FEASIBLE? + commentsNOTES**	
New Natural Gas	Utilities	under development	55-58	Y	Y	CE doesn't include pipeline extension, RP for replacing 1 mid-size plant
Coal source switching	Utilities	unknown	unknown	Y	Y	TF to the extent that faculties can burn lower Hg coal
Lower exhaust temp.	Utilities	25,000-125,000	375	N	Y	RP assumes 10% reduction
No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y	RP given as 0 near term, 100s long term
substitute lower mercury feedstock chemicals	industrial/commercial facilities	?	100	Y	Y	
Energy source substitution/fuel switching	Taconite Plants	175,000	1	Y	Y	TF must maintain ability to burn alternative fuels
Chemicals/additives replacement	Taconite Plants	unknown	9	Y	U	
Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y	RP: 10-25 to air, 1-5 to water, 70 to 170 to all media; CE: 700-6,600 for air, 100-1000 for all media
Enhanced air pollution control	Mass burn and RDF combustion	3,400-7,600	200	N	Y	
Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y	RP: 580 to air, 3870 to all media; CE: 200-500 to all media
Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y	RP: 1000 to air, 7,000 to all media, assuming eventually 90% of Hg uses are eliminated
Treat scrubber water	RDF/sludge incinerators	2,000-20,000	120	N	Y	
Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y	RP: 1000 to air, 7,000 to all media
reduce use of Hg dental amalgam	Dental	?	?	Y	Y	

Table 6.4: Options sorted for comparison, by relative cost-effectiveness

OPTION	SOURCES	COST EFFECTIVENESS $ per pound	REDUCTION POTENTIAL pounds per year
Lower cost			
Collect raw mercury	School laboratories	10	1,000
Reduce Hg use in consumer products	all product users	10-100	1,000
Purchase and use less Hg containing products	all product users	10-100	1,000
Increase recycling of chairside traps	Dental	110	110
Collect bulk Hg from dental offices	Dental	125	2-8
Waste material separation and proper management	all product users, material recovery facilities	200-500	580
Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580
Collect Hg chemicals and compounds in school labs	Schools	700	10
Increase recycling of vacuum system filters	Dental	880	50
Medium cost			
Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	20,394
Enhanced air pollution control	Mass burn and RDF combustion	3,400-7,600	200
Treat scrubber water	RDF/sludge incinerators	2,000-20,000	120
Carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520
Carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200
Install additional amalgam capture equipment	Dental	15,000-618,000	17
Carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55
Coal cleaning- chemical	Utilities	46,000	425
Coal cleaning - intense conventional	Utilities	47,000	150
Coal cleaning - chemical + conventional	Utilities	58,000	540
Higher cost			
Carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200
Lower exhaust temp.	Utilities	100,000-125,000	140
Carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55
Increase wet scrubber efficiency	Utilities	62,000-258,000	30
Carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520
Energy source substitution/fuel switching	Taconite Plants	175,000	1
Install additional amalgam capture equipment	Dental	15,000-618,000	17
Natural gas co-firing @ 20% gas	Utilities	410,000-922,000	280
Wind as replacement for energy from coal	Utilities	537,000-937,000	140
Demand side management/energy efficiency	Utilities	800,000-2,800,000	?
Use best available control technology to capture Hg	WWTP water discharge	5,500,000	31*

Table 6.5:Strategies used since 1990

Program Type	Description	Results, Costs, etc.	Contact Person
Voluntary Programs			
Health Care Outreach	Education to encourage proper Hg mgmt. and reduced use of Hg equipment, via video, slide show, posters, newsletters		Emily Moore Minnesota Office of Environmental Assistance 651/215-0201
Household Haz. Waste/Special Waste Collection	Many counties accept mercury and mercury-containing products from homeowners and to a lesser extent businesses as part of their HHW/Special waste collections	40 County programs accepting from homeowners throughout state and 5 programs for businesses in Duluth, Mankato, Rice County, other regions.	Ned Brooks, MPCA; Tim Tuominen, WLSSD; Rob Dunnette, Olmsted County
Dental Office Outreach	Effort begun in WLSSD area to educate dentists about need to collect amalgam waste for recycling; keep it out of MSW and infectious waste streams. Statewide and GL programs now in development.	Recycling fee for amalgam-containing waste is \$4/lb or less. Additional costs are incurred in the practice and for transportation and recordkeeping. Collection of bulk mercury highly cost-effective.	Tim Tuominen, WLSSD; Ned Brooks, MPCA; John Gilkeson, MOEA
Thermostat Take-Back	Through a reverse distribution system involving contractors and wholesalers, thermostat manufacturers take back out of service items	During Minnesota/ Honeywell-only pilot 1994-1997, over 23,000 units collected at a cost of less than \$1 each; per pound cost <\$100. TRC program now implemented in Region V and Florida (9 states).	Greg Swain, Honeywell (612) 954-2978
Mercury switches in automobiles	Law requires 'good faith effort' to remove mercury switches before auto crushing; included in PCA scrapyard training. MI and MN involved in P2 and mgmt discussions with auto mfrs.	Some scrapyards aware of issue and mgmt options; Northstar Steel accepts switches at no cost from scrapyards. Ford and GM on slow phaseout; Chrysler reportedly at 100% switch phaseout for 1999 model year. P2 cost a few cents per car for non-mercury switches; mgmt cost several dollars per switch for labor to identify and remove.	Rocky Sisk, Ned Brooks, MPCA; John Gilkeson, MOEA
Regulatory Programs			
Waste Combustor Standards (municipal solid waste and medical waste)	Sets air emission limits on Hg and requires preparation of Hg Reduction Plans	Emissions from MSW combustors have decreased >50% in 5 years, largely from reduced levels of Hg in products (batteries) and Hg product separation programs. One MWC and one MWI have installed PACI.	Anne Jackson, MPCA Ref. Minn. Rules 7011.xxxx
Water Discharge Standards	A few WWTP which had Hg detected above >0.2 ug/l have mercury discharge limits	Some of these facilities, such as WLSSD, have used source reduction to successfully lower mercury levels	Gary Kimball, MPCA

Program Type	Description	Results, Costs, etc.	Contact Person
State Laws			
Fluorescent Lamp Disposal Ban	Requires businesses and households to recycle fluorescent lamps. Counties have established a variety of programs	A system for collecting and recycling lamps has been established in MN; Lamp manufacturers have reduced Hg levels in lamps. Market reflects state contract recycling price of 25¢/4 ft lamp. 70% estimated state recycling rate (10 million bulbs sold per year).	John Gilkeson, MOEA (651) 215-0199
Ban on disposal of Hg products	Requires households and businesses to recycle or properly manage hg wastes.	Several private and public recyclers and collection programs offer service.	Ned Brooks, MPCA
Dairy Manometer Ban and "Buy-back"	Law bans sale, installation, and repair of Hg-containing dairy manometers after 6/30/97 and use after 12/31/00 and offers up to $100 for turning in old gauge.	Take-back system utilizes dairy equipment suppliers and state coordinated disposal network to collect the estimated 2000 manometers in service. Each manometer is delivered with one pound of mercury.	Sandy Dunn, MDA 651-297-2133
Relay Manufacturer Responsibility	Requires manufacturers of mercury displacement relays sold in Minnesota to provide education and incentives as well as cover the costs of managing out of service relays	Law went into effect July 1, 1998.	Ned Brooks, MPCA
Battery Mercury Reduction	Bans Mercuric Oxide batteries (except in specialty applications and then requires manufacturer stewardship), Bans addition of Hg to alkaline batteries, 25 mg. limit in button batteries.	Significant reduction in Hg in MSW.	Ned Brooks, MPCA
Mercury components in major appliances	Research identifying mercury components in appliances, development of fact sheet and outreach to appliance processors about identification, removal, and proper management of components		John Gilkeson, MOEA
Mercury in construction/demolition	Law prohibits disposal; implied requirement for removal prior to demolition. Education and enforcement efforts for C&D contractors have begun recently.		John Gilkeson, OEA;

Table 6.6: Summary of strategies

STRATEGY	OPTIONS	AFFECTED SOURCES	Cost effectiveness $ per pound	REDUCTION POTENTIAL pounds per year	PERMANENCE	TECHNICALLY FEASIBLE
STATE STRATEGIES - INFORMATION/RESEARCH						
Minnesota Mercury Inventory	none	All sources	N/A	N/A	N/A	Y
Minnesota Mercury Research	none	potentially all sources	N/A	N/A	N/A	Y
Minnesota Mercury Research, fees assessed	none	potentially all sources	N/A	N/A	N/A	Y
STATE STRATEGIES - MANDATORY						
Improve compliance with product labeling		manufacturers and users of products	600	360	N*?	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
(Indirectly related)	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
Label existing "installed" mercury-containing products		All product users, recyclers except households	3,600	145	N*	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
(Indirectly related)	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
Performance-based limits for significant air emitters		Utilities, Taconites, MWC, MWI, Others	150,000	3,700	Y/N	Y/U
	coal cleaning - intense conventional	Utilities	47,000	150	N	U
	coal cleaning- chemical	Utilities	46,000	425	N	U
	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
	Demand side	Utilities	800,000-	?	Y	Y

	management/energy efficiency		2,800,000			
	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
	natural gas co-firing @ 20% gas	Utilities	410,000-922,000	280	Y	Y
	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
	wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y
	co-generation	Utilities	unknown	Unknown	Y	Y
	Conventional controls - existing	Taconite Plants	unknown	unknown	N	Y
	Conventional controls - new and emerging technology	Taconite Plants	unknown	unknown	N	U
	Plant area modifications	Taconite Plants	unknown	unknown	N	U
	co-fire biomass @ 5-10%	Utilities	unknown	70-140	Y	Y
	New Natural Gas	Utilities	under development	55-58	Y	Y
	Coal source switching	Utilities	unknown	unknown	Y	Y
	Lower exhaust temp.	Utilities	100,000-125,000	140	N	Y
	No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y
	Energy source substitution/fuel switching	Taconite Plants	175,000	1	Y	Y
	Chemicals/additives replacement	Taconite Plants	unknown	9	Y	U
	Enhanced air pollution control	Mass burn and RDF combustion	3,400-7,600	200	N	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
BACT and BMP on all significant air emitters		Utilities, Taconites, MWC, MWI, Others	unknown	unknown	Y/N	Y/U
	coal cleaning - intense conventional	Utilities	47,000	150	N	U
	coal cleaning- chemical	Utilities	46,000	425	N	U

	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
	Demand side management/energy efficiency	Utilities	800,000-2,800,000	?	Y	Y
	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
	co-generation	Utilities	unknown	Unknown	Y	Y
	Conventional controls - existing	Taconite Plants	unknown	unknown	N	Y
	Conventional controls - new and emerging technology	Taconite Plants	unknown	unknown	N	U
	Plant area modifications	Taconite Plants	unknown	unknown	N	U
	Coal source switching	Utilities	unknown	unknown	Y	Y
	Lower exhaust temp.	Utilities	100,000-125,000	140	N	Y
	Energy source substitution/fuel switching	Taconite Plants	175,000	1	Y	Y
	Chemicals/additives replacement	Taconite Plants	unknown	9	Y	U
	Enhanced air pollution control	Mass burn and RDF combustion	3,400-7,600	200	N	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
Hg reduction plans for primary sources		all primary sources, not households	6,000-18,000	375-1000	Y/N*	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U
	Substitute lower mercury feedstock chemicals	industrial/commercial facilities	?	100	Y	Y

	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
(Indirectly related)	collect raw mercury	School laboratories	10	1000	Y	Y
(Indirectly related)	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
Require BMPs by primary sources		all primary sources, not households	4,100-11,000	375-1000	Y/N*	Y
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U
	substitute lower mercury feedstock chemicals	industrial/commercial facilities	?	100	Y	Y
	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
(Indirectly related)	collect raw mercury	School laboratories	10	1000	Y	Y
(Indirectly related)	Replace mercury-containing items	Industrial/commercial facilities, schools	10-1000	580	Y	Y
Hg Emission Cap		Most air emitters	62,000	275	Y/N	Y/U
	coal cleaning - intense conventional	Utilities	47,000	150	N	U
	coal cleaning- chemical	Utilities	46,000	425	N	U

	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
	Demand side management/energy efficiency	Utilities	800,000-2,800,000	?	Y	Y
	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
	natural gas co-firing @ 20% gas	Utilities	410,000-922,000	280	Y	Y
	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
	wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y
	co-generation	Utilities	unknown	Unknown	Y	Y
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	Conventional controls - existing	Taconite Plants	unknown	unknown	N	Y
	Conventional controls - new and emerging technology	Taconite Plants	unknown	unknown	N	U
	Plant area modifications	Taconite Plants	unknown	unknown	N	U
	co-fire biomass @ 5-10%	Utilities	unknown	70-140	Y	Y
	New Natural Gas	Utilities	under development	55-58	Y	Y
	Coal source switching	Utilities	unknown	unknown	Y	Y
	Lower exhaust temp.	Utilities	100,000-125,000	140	N	Y
	No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y
	Energy source substitution/fuel switching	Taconite Plants	175,000	1	Y	Y
	Chemicals/additives replacement	Taconite Plants	unknown	9	Y	U
	Enhanced air pollution control	Mass burn and RDF combustion	3,400-7,600	200	N	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
Hg Emission Cap, 4 largest source sectors		utilities, taconites, MWC, MWI, sludge incinerators	60,000	240	Y/N	Y/U
	coal cleaning - intense conventional	Utilities	47,000	150	N	U
	coal cleaning- chemical	Utilities	46,000	425	N	U

	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
	Demand side management/energy efficiency	Utilities	800,000-2,800,000	?	Y	Y
	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
	natural gas co-firing @ 20% gas	Utilities	410,000-922,000	280	Y	Y
	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
	wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y
	co-generation	Utilities	unknown	Unknown	Y	Y
	Conventional controls - existing	Taconite Plants	unknown	unknown	N	Y
	Conventional controls - new and emerging technology	Taconite Plants	unknown	unknown	N	U
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	Plant area modifications	Taconite Plants	unknown	unknown	N	U
	co-fire biomass @ 5-10%	Utilities	unknown	70-140	Y	Y
	New Natural Gas	Utilities	under development	55-58	Y	Y
	Coal source switching	Utilities	unknown	unknown	Y	Y
	Lower exhaust temp.	Utilities	100,000-125,000	140	N	Y
	No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y
	Energy source substitution/fuel switching	Taconite Plants	175,000	1	Y	Y
	Chemicals/additives replacement	Taconite Plants	unknown	9	Y	U
	Enhanced air pollution control	Mass burn and RDF combustion	3,400-7,600	200	N	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
Outstanding Resource Waters designation for more lakes	potentially all options	potentially all sources	unknown	unknown	Y/N	U

TMDL (Total Maximum Daily Load) Pilot Project	potentially all options	potentially all sources	unknown	unknown	Y/N	U
Equipment recordkeeping		all	20,750	40	Y/N*	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
(Indirectly related)	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
Public Disclosure - Utilities		utilities	unknown	unknown	Y/N	Y/U
(Indirectly related)	coal cleaning - intense conventional	Utilities	47,000	150	N	U
(Indirectly related)	coal cleaning- chemical	Utilities	46,000	425	N	U
(Indirectly related)	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
(Indirectly related)	Demand side management/energy efficiency	Utilities	800,000-2,800,000	?	Y	Y
(Indirectly related)	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
(Indirectly related)	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
(Indirectly related)	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
(Indirectly related)	natural gas co-firing @ 20% gas	Utilities	410,000-922,000	280	Y	Y
(Indirectly related)	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
(Indirectly related)	wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y
(Indirectly related)	co-generation	Utilities	unknown	Unknown	Y	Y
(Indirectly related)	co-fire biomass @ 5-10%	Utilities	unknown	70-140	Y	Y
(Indirectly related)	New Natural Gas	Utilities	under development	55-58	Y	Y
(Indirectly related)	Coal source switching	Utilities	unknown	unknown	Y	Y
(Indirectly related)	Lower exhaust temp.	Utilities	100,000-125,000	140	N	Y
(Indirectly related)	No or low-Hg emitting new	Utilities	unknown	Unknown	Y	Y

	generation sources					
Cap-and-Trade	same options apply to each variation	Utilities, pet. refineries, taconites, industrial coal-burners	yr 2003/2012	yr 2003/2012	Y/N	Y/U
with opt-in					Y/N	Y/U
Variation 1 (0% red. from yr 2000)			under development	21/597		
Variation 2 (10% red. from yr 2000)			under development	21/832		
Variation 3 (25% red. from yr 2000)			under development	256/1184		
variation 2	coal cleaning- chemical	Utilities	46,000	425	N	U
all variations	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
variation 3	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
all variations	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
all variations	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
all variations	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
all variations	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
all variations	collect raw mercury	School laboratories	10	1000	Y	Y
all variations	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
all variations	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
all variations	Increase recycling of chairside traps	Dental	110	110	N*	Y
all variations	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
all variations	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U
all variations	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
all variations	reduce use of Hg dental amalgam	Dental	?	?	Y	Y
Without opt-in					N	U
Variation 1 (0% red. from yr 2000)			under	21/597		

			development			
Variation 2 (10% red. from yr 2000)			under development	21/832		
Variation 3 (25% red. from yr 2000)			under development	256/1184		
variation 2	coal cleaning- chemical	Utilities	46,000	425	N	U
all variations	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
variation 3	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
all variations	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
state buys Hg free energy		state of MN	unknown	40	Y	Y
	wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y
	New Natural Gas	Utilities	under development	55-58	Y	Y
	No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y
Subsidies	Subsidies could encourage any option to be implemented	all	unknown	unknown	Y/N	Y/U
License bulk Hg buyers and sellers		manufacturers, schools, bulk users	4,700??	50	Y	Y
(Indirectly related)	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
(Indirectly related)	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
(Indirectly related)	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
(Indirectly related)	collect raw mercury	School laboratories	10	1000	Y	Y
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
License buyers and sellers of encapsulated Hg		Hg buyers and sellers	4,000	30	Y/N*	Y
(Indirectly related)	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
(Indirectly related)	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y

(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
(Indirectly related)	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
Enforce existing state disposal bans		all	800	150	Y/N*	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	collect raw mercury	School laboratories	10	1000	Y	Y
	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
(Indirectly related)	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
(indirectly related)	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
Expand existing Hg product disposal bans		auto manufacturers and scrap yards, households	unknown	unknown	?	?
Sales fee on products		wholesalers/ retailers	500-3,300	360	Y	Y
	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
Utility fee and awards for development of control technologies		utilities, energy consumers	unknown	0-750	N	U
(Indirectly related)	coal cleaning - intense conventional	Utilities	47,000	150	N	U
(Indirectly related)	coal cleaning- chemical	Utilities	46,000	425	N	U
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
(Indirectly related)	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
(Indirectly related)	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U

(Indirectly related)	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
(Indirectly related)	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
(Indirectly related)	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
fees on utilities, award first to implement		Utilities	13,200	200	N	U
	coal cleaning - intense conventional	Utilities	47,000	150	N	U
	coal cleaning- chemical	Utilities	46,000	425	N	U
	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
fees on multiple industries, award first to implement		all?	unknown	unknown	N	U
	coal cleaning - intense conventional	Utilities	47,000	150	N	U
	coal cleaning- chemical	Utilities	46,000	425	N	U
	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	Conventional controls -	Taconite Plants	unknown	unknown	N	Y

	existing					
	Conventional controls - new and emerging technology	Taconite Plants	unknown	unknown	N	U
Deposit and refund		households, some businesses	Unknown	unknown	Y/N*	Y
(Indirectly related)	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
(Indirectly related)	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
Mandatory product stewardship		consumers and product manufacturers	1100-2500	450-900	Y/N*	Y
(Indirectly related)	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
(Indirectly related)	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Reduce Hg use in consumer products	all product users	10-100	1000	Y	Y
Clean air investment fund		All	500-7,500	500	Y/N	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	collect raw mercury	School laboratories	10	1000	Y	Y
	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
	Enhanced air pollution control	Mass burn and RDF combustion	3,400-7,600	200	N	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
Clean air Investment fund - Revenue neutral fees	Potentially all options	all	unknown	unknown	Y/N	Y/U

STRATEGY	OPTIONS	AFFECTED SOURCES	Cost effectiveness $ per pound	REDUCTION POTENTIAL pounds per year	PERMANENCE	TECHNICALLY FEASIBLE
green electricity through competition		utilities, electricity users	unknown	unknown	Y	Y
	wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y
	No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y
	co-fire biomass @ 5-10%	Utilities	unknown	70-140	Y	Y
National Strategies						
Total Hg content hazardous waste limit		all	unknown	?	?	?
National Mercury Research	None	all?	N/A	N/A	N/A	Y
Change TRI reporting protocol	None	all?	N/A	N/A	N/A	Y
Tax electricity	Demand side management/energy efficiency	Utilities, other electricity generators, energy users	unknown	0-6000	Y	?
International Hg management plan	Options related to intentional use of mercury, waste management	Potentially all sources, users, consumers	0.20-infinity	0-360,000	?	?
MN Hg outreach position	cost effective options, largely related to source reduction	all?	unknown	?	?	?
MWI, MWC lower emission limits	primarily control technology options for MWI, MWC	MWI, MWC	7,400-infinity	0-200*	?	?
Lower limits for sewage sludge incineration	source reduction, waste segregation, and controls for sludge incinerators	sludge incinerators	unknown	100*	?	?
State Strategies - Voluntary						
Voluntary Hg Use Reduction		All sources (including houses)	unknown	unknown	Y/N*	Y/U
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	collect raw mercury	School laboratories	10	1000	Y	Y
	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	substitute lower mercury feedstock chemicals	industrial/commercial facilities	?	100	Y	Y
	Chemicals/additives replacement	Taconite Plants	unknown	9	Y	U
	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y

	Reduce Hg use in consumer products	all product users	10-100??	1000	Y	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	reduce use of Hg dental amalgam	Dental	?	?	Y	Y
Voluntary reduction from energy sectors		Utilities, pet. refineries, industrial coal-burners	unknown	unknown	Y/N	Y/U
	coal cleaning - intense conventional	Utilities	47,000	150	N	U
	coal cleaning- chemical	Utilities	46,000	425	N	U
	coal cleaning - chemical + conventional	Utilities	58,000	540	N	U
	Demand side management/energy efficiency	Utilities	800,000-2,800,000	?	Y	Y
	carbon injection @ 60% overall Hg collection efficiency	Utilities	11,000-130,000	200	N	U
	carbon injection @ 30% overall Hg collection efficiency	Utilities	37,000-200,000	55	N	U
	Increase wet scrubber efficiency	Utilities	62,000-258,000	30	N	U
	natural gas co-firing @ 20% gas	Utilities	410,000-922,000	280	Y	Y
	carbon injection @ 90% overall Hg collection efficiency	Utilities	9,000-330,000	520	N	U
	wind as replacement for energy from coal	Utilities	537,000-937,000	140	Y	Y
	co-generation	Utilities	unknown	Unknown	Y	Y
	co-fire biomass @ 5-10%	Utilities	unknown	70-140	Y	Y
	New Natural Gas	Utilities	under development	55-58	Y	Y
	Coal source switching	Utilities	unknown	unknown	Y	Y
	Lower exhaust temp.	Utilities	100,000-125,000	140	N	Y
	No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y
Early Reduction Credits	potentially all options, mainly low cost options	all sources	unknown	0-800??	Y/N	Y
Promote labeling of "installed" Hg products		All product users, recyclers except households	3,300-6,400	0-145	N*	Y

	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
(Indirectly related)	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
(Indirectly related)	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
reduce Hg in buildings	(reduce Hg discards to MSW)	Manufacturers, suppliers, HVAC & demolition contractors, State	4,600-6,400	0-30	Y/N*	Y
	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
(Indirectly related)	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
state procurement policy		state of MN, sellers and manufacturers of Hg products	10,000	17	Y	Y
	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
Increase HHW collection programs to include business		All product users, recyclers except households	1,300	150	Y	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	collect raw mercury	School laboratories	10	1000	Y	Y
	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
ID reduction programs via sludge reporting		dischargers to sewers	?	?	Y	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	collect raw mercury	School laboratories	10	1000	Y	Y
	Replace mercury-containing	industrial/commerc	10-1000	580	Y	Y

	items	ial facilities, schools				
	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectivene ss $ per pound**	**REDUCTI ON POTENTI AL pounds per year**	**PE RM AN EN CE**	**TE CH NI CA LL Y FE ASI BL E**
	substitute lower mercury feedstock chemicals	industrial/commerc ial facilities	?	100	Y	Y
	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
	reduce use of Hg dental amalgam	Dental	?	?	Y	Y
ISO 14000 or equivalent Environmental Management System	potentially all options, mainly low cost options	All	unknown	unknown	Y/N	Y/U
Educate product users	product related options	some industry, schools, homes	200	500	Y	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	collect raw mercury	School laboratories	10	1000	Y	Y
	Replace mercury-containing items	industrial/commerc ial facilities, schools	10-1000	580	Y	Y
	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U
	substitute lower mercury feedstock chemicals	industrial/commerc ial facilities	?	100	Y	Y
	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
	reduce use of Hg dental	Dental	?	?	Y	Y

	amalgam					
Reduce dental amalgam use through research and changing insurance coverage		Dental	20,000-40,000*	25	Y	Y
	reduce use of Hg dental amalgam	Dental	?	?	Y	Y
Education and waste management program for dental offices		Dental	1,600-60,000	175	Y/N*	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
STRATEGY	**OPTIONS**	**AFFECTED SOURCES**	**Cost effectiveness $ per pound**	**REDUCTION POTENTIAL pounds per year**	**PERMANENCE**	**TECHNICALLY FEASIBLE**
	Increase recycling of chairside traps	Dental	110	110	N*	Y
	Increase recycling of vacuum system filters	Dental	880	50	N*	Y
	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U
reduce installed Hg via education and clean sweeps	clean sweeps?	all, start w/ households, schools, dentists	1,400	120	Y/N	Y
	Collect bulk Hg from dental offices	Dental	125	2-8	Y	Y
	collect raw mercury	School laboratories	10	1000	Y	Y
	Replace mercury-containing items	industrial/commercial facilities, schools	10-1000	580	Y	Y
	Collect Hg chemicals and compounds in school labs	Schools	700	10	Y/N	Y
	Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	Y
	Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y
Hg detecting dog, to identify Hg in labs and other places		labs, product users	400	250	?	?