

## **PART 6. SUMMARY OF RESULTS**

### **6.1 Inventory of Mercury Releases to the Environment**

One SRFRS Committee goal was to improve the accuracy of the available estimates of mercury releases from sources in Minnesota (often referred to as an “emissions inventory”). The MPCA sent out a request for information to likely mercury sources and received submittals on 33 individual facilities, covering the vast majority of point-source air emissions in Minnesota. The facilities provided available information on mercury releases to land and water, in addition to air emissions. In addition, MPCA staff used other data, including mandated submittals from incinerators, data from the Electric Power Research Institute (EPRI) and the U.S. EPA, and special studies funded by the Legislative Commission on Minnesota Resources on wood combustion and taconite production.

In Minnesota, the mercury that contaminates fish is largely delivered to lakes and their watersheds by the atmosphere. About 6,000 lb. is deposited annually to the land and waters in Minnesota. About 10 to 20 percent of the mercury deposited to land makes its way to surface water. In contrast, available information indicates that relatively small amounts of mercury are directly discharged to surface waters from wastewater treatment plants and industrial discharges, on the order of 15 to 30 lb. per year in the state. Minnesota’s air emissions -- about 5,000 lb. per year in 1995 -- are more than 100 times higher. Point source discharge to surface water constitutes only 1 to 2 percent of the mercury load to surface water. MPCA staff members estimate that atmospheric deposition is responsible for the other 98 to 99 percent. Accordingly, it is more important to work towards reduction of atmospheric deposition than to reduce direct discharge. In addition, there are currently not obvious fish contamination problems resulting from direct discharge, as there had been in the early 1970s.

#### **6.1.1 Mercury Emission Inventory for Minnesota**

It is important to understand the sources of mercury to the atmosphere so that we can take appropriate action to reduce mercury emissions, mercury deposition to lakes, and the resulting fish contamination. To that end, MPCA staff has revised estimated emissions of mercury (the “inventory”) to the air for 1990 and 1995, and predicted future emissions in the years 2000 and 2005. Results are shown in Table 6.1. The inventory is subdivided into three main categories of emissions: (1) emissions that are incidental to energy production (the release of the trace mercury in fuels), (2) emissions that largely result from the purposeful use of mercury (volatilization during product disposal and incineration), and (3) emissions incidental to other activities (*e.g.*, processing natural resources that contain trace amounts of mercury, such as limestone and iron ore). Category 3 is distinct from category 1 (even though they are both incidental emissions) because once mercury is volatilized from geological material during processing, the product can be recycled without releasing additional mercury (except for that associated with energy consumption).

**Table 6.1 Inventory of mercury emissions, in pounds, in Minnesota for the years 1990, 1995, 2000, and 2005. (Estimates are subject to change as better information is received.)**

	confidence level	1990	1990	1990	1995	1995	1995	2000	2000	2000	2005	2005	2005
		(best)	Min.	Max.	(best)	Min.	Max.	(best)	Min.	Max.	(best)	Min.	Max.
<b>Incidental to Energy Production</b>													
coal (total) (1)	medium	1,526	1,145	1,908	1,462	1,096	1,827	1,493	1,320	1,666	1,735	1,533	1,938
electric utility coal	medium	1,416	1,062	1,770	1,332	999	1,665	1,335	1,201	1,468	1,544	1,390	1,699
commercial/industrial coal	medium	110	83	138	130	97	162	158	119	198	191	143	239
residential coal		0	0	1	0	0	1	0	0	1	0	0	1
petroleum refining (2)	low	0	0	0	0	0	0	0	0	0	0	0	0
Petroleum Sector (including refining and combustion of products)	low	250	125	250	250	125	250	250	125	250	250	125	250
wood (4)	medium	13	9	16	10	8	13	10	8	13	10	8	13
residual fuel oil (5)	low	3	1	5	2	1	4	2	1	4	2	1	4
natural gas (6)	low	0.2	0.1	0.5	0.28	0	1	0.28	0	1	0.28	0	1
<b>Subtotal incidental with energy production</b>		1,792	1,281	2,179	1,725	1,230	2,095	1,755	1,454	1,933	1,998	1,667	2,205
		21%			37%			47%			56%		
<b>Largely Resulting from the Purposeful Use of Mercury</b>													
Latex Paint Volatilization (7)	low	500	250	1,000	10	5	20	2	1	2	0	0	0
Municipal Solid Waste Combustion (8)	high	1,806	1,626	1,987	634	570	697	156	140	172	87	78	96
On-site Household waste incineration (9)	low	666	333	1,332	270	135	540	180	90	360	126	63	252
Medical Waste Combustion (10)	high	516	464	568	36	32	40	36	32	40	36	32	40
Sewage sludge Incineration (0.6 metro sludge (70% control in 2005) + Seneca)	med.	247	185	309	160	120	200	160	120	200	65	49	81
Fluorescent Lamp Breakage (12)	low	330	165	660	83	41	165	20	10	40	10	5	20
Class IV incinerators --1,000 closed by 1/96 (14)	low	55	28	110	28	14	56	0			0		
Crematories (15)	low	24	12	49	35	18	71	45	23	90	45	23	90
General Laboratory Use (16)	low	44	22	88	44	22	88	22	11	44	22	11	44
Dental Preparations (17)	low	24	12	48	12	6	24	6	3	12	3	2	6
Hazardous Waste incineration (18)	medium	5	4	6	5	4	6	5	4	6	5	4	6
Landfill volatilization (19)	low	13	6	25	3	2	7	13	6	25	13	6	25
Recycling mercury from Products within MN (20)	medium	4	3	4	35	26	44	50	38	63	65	49	81
Smelters that recycle cars and appliances (21)	medium	166	125	208	166	125	208	83	62	104	42	32	53
Volatilization from Dissipative Use (21.1)	low	2	1	4	2	1	4	2	1	4	2	1	4
Fungicide Volatilization (21.2)	low	86	43	172	25	13	50	5	3	10	5	3	10
Volatilization from spills and land dumping (21.3)	low	55	27	109	48	24	96	32	16	64	21	11	43
Volatilization during SW collection & processing (21.4)	low	1,304	652	2,607	432	216	864	288	144	576	192	96	384
Volatilization: land application of compost (23)	low	2	1	3	1	0	1	1	1	2	1	1	2
Volatilization: land application of sludge (24)	low	4	2	7	2	1	3	2	1	4	2	1	4
<b>Subtotal associated with purposeful use of mercury</b>		5,852	3,960	9,297	2,031	1,375	3,184	1,108	705	1,817	742	464	1,241
		69%			44%			30%			21%		
<b>Emissions Incidental to other Activities:</b>													
Taconite Processing (25)	medium	797	598	797	828	621	828	828	621	828	828	621	828
Pulp and Paper Manufacturing (26)	low	4	2	7	4	2	7	4	2	7	4	2	7
Soil Roasting (27)	low	13	7	27	13	7	27	13	7	27	13	7	27
<b>Subtotal emissions incidental to other activities</b>		814	606	831	845	629	862	845	629	862	845	629	862
		10%	10%	7%	18%	19%	14%	23%	23%	19%	24%	23%	20%
<b>GRAND TOTAL =</b>		8,457	5,847	12,307	4,600	3,235	6,140	3,708	2,788	4,612	3,585	2,761	4,307

Confidence level interpretation:

High +/- 10%; Medium +/- 25%; Low +/- 50% (except when best estimate cannot be exceeded).

**NOTES to Table 6.1**

- 1 Based on data submitted by facilities with stack tests (NSP, MP) and extrapolated to other coal combustors.
- 2 Based on a preliminary analysis of crude oils delivered to Minnesota refineries. The fate of the mercury in the refinery and various products is being investigated.
- 3 From Pang, S.M., 1997. Mercury in wood and wood fuels. Thesis. Master of Science. University of Minnesota.
- 4 Assumes the EPRI emission factor of 0.0008 lb./trillion Btu.

- 5 Nationally, 24.2 tons of mercury were added to paint in 1990 (Minnesota's economy is about 2% of the U.S. economy; 2% of 24.2 tons = 968 lb.). Half is assumed to volatilize the first year. The addition of mercury to paint was discontinued by 1992.
- 6 Based on stack tests.
- 7 Quantity is based on estimates by the Minnesota Office of Environmental Assistance. Municipal solid waste (MSW) is assumed to be 3.7 ppm in 1990 and 1.5 ppm in 1995.
- 8 Based on stack tests.
- 9 Based on sludge analyses and the analysis published by S. Balogh and L. Liang, 1995. Mercury pathways in municipal wastewater treatment plants. *Water, Air, and Soil Pollution*. 80:1181-1190.
- 10 Based on the proportion not recycled and industry figures on mg/lamp, assuming 25% is volatilized.
- 11 All of these small incinerators associated with grocery stores, etc. (about 1,000) closed by January 1996. It is assumed that they mostly burned cardboard with mercury at 0.2 ppm.
- 12 Assumes that each person has four amalgam fillings containing 0.5 gram of mercury each.
- 13 Estimate in the U.S. Environmental Protection Agency (EPA) Mercury Report to Congress.
- 14 Estimate in the U.S. Environmental Protection Agency (EPA) Mercury Report to Congress.
- 15 Estimate from Minnesota's only hazardous waste incinerator, 3M Chemolite.
- 16 0.1% of landfilled municipal solid waste (MSW) is assumed to volatilize to the air per year (based on studies of MSW emissions in Florida by S.E. Lindberg and J.L. Price, 1998).
- 17 Products within Minnesota. Estimate from Brian Golob, personal communication.
- 18 Automobile Shredder Residue Report. MPCA, 1995. It is assumed that 50% of mercury is emitted at steel smelters in Minnesota, and that the number of mercury switches (mostly from scrap automobiles) smelted along with scrap steel declines with time.
- 19 Mercury that dissipates into the environment (excluding fungicides): ritual uses, pharmaceuticals, etc.
- 20 Estimate of volatilization from fungicides applied to golf courses.
- 21 Estimate assumes that 8% of the mercury removed from service each year is spilled on the ground and that 5% of that amount volatilizes.
- 22 Assumes that the 5% of the mercury in solid waste is volatilized during collection, transportation and mechanical processing. Includes demolition, industrial and municipal solid waste (MSW) landfills, MSW and medical waste incineration, MSW compost, backyard burn barrels and steel-recycling facilities; fluorescent lamps calculated separately.
- 23 Assumes that 1.0% of mercury applied to the surface of the land volatilizes within a year.
- 24 Assumes that 1.0% of mercury applied to the surface of the land volatilizes within a year.
- 25 From Engesser et al., 1997. Mercury Emissions from Taconite Pellet Production. Univ. of Minnesota report to the MPCA.
- 26 From voluntary reports to the MPCA.
- 27 An average of 83,000 tons per year of surface soil is heated annually in Minnesota to remove organic contaminants. A background concentration of 0.08 ppm of mercury is assumed.

Establishing an inventory of mercury in products, the waste stream, fossil fuels and natural resources, such as iron ore and forest products, is problematic because there has been no driving force to collect the data until very recently. Better data exist for points of release of mercury to air and water because of traditional pollution control regulations concerning stacks and discharge pipes to water. Even air and water releases are not completely understood because of the relatively high expense of air emission measurements and EPA's failure to adopt a mercury analysis technique sufficiently sensitive for most surface water until June 1999 (the earlier EPA technique had a detection limit of 200 nanograms per liter, whereas Minnesota's surface water standard is 6.9 nanograms per liter).

The best information on the mercury content of the solid waste stream comes from stack testing of incinerator emissions prior to pollution-control devices, which often capture significant proportions of the mercury. Such information is invaluable for understanding the efficacy of pollution-prevention efforts for consumer product disposal.

Other ambiguities in the air emission inventory include variability in the mercury content of fossil fuels, the loss of mercury from products during use and disposal and subsequent emission to the atmosphere, and volatilization of mercury through reuse of byproducts that have been captured by pollution control equipment. One example is volatilization from land application of ash, sludges, and other wastes. Environmental contamination from product use and breakage is particularly poorly understood, and needs to be addressed adequately on a national scale. The EPA's *Mercury Report to Congress* does not even recognize products as a significant emission source, apart from emissions during incineration.

Even though significant work remains in the quest to establish an accurate inventory of mercury uses, sources and releases to air, land and water (and such work should continue), MPCA staff believe that the information collected to date is sufficiently accurate to guide policy decisions.

### **6.1.2 Trends in Mercury Emissions**

It is clear that Minnesota's mercury emissions to the air declined by about 45% between 1990 and 1995— from about 8,500 lb. to 4,500 lb. Virtually all of the decline can be attributed to reducing emissions associated with the purposeful use of mercury. The major reductions were the elimination of mercury additives to latex paint (estimated reductions of about 500 lb.), source reduction and control at municipal waste incinerators (1,200 lb.) and on-site incinerators (about 500 lb.), and reductions from medical waste incinerators (about 500 lb.). Reductions at larger incinerators were due to both lower levels of mercury in waste (mercury in municipal solid waste declined from about 4 ppm in 1990 to about 1.5 ppm in 1995) and enhanced mercury control technology (for example, the Hennepin Energy Resource Company municipal waste combustor and the Mayo Clinic medical waste incinerator installed activated carbon injection systems). Further reductions in mercury use and additional emissions control will likely result in lower emissions from waste incineration, from 878 lb. emitted in 1995, declining to about

380 lb. in 2000 and 280 lb. in 2005. In addition, MPCA staff calculate that about 550 lb. less mercury were emitted to the air in 1995 simply because there was less mercury in products to volatilize when disposed of or accidentally spilled.

The trend for mercury emissions that are incidental to energy production and other activities, such as taconite processing, differs from the decreasing trend in purposeful use of mercury. Emissions from other sources stayed relatively constant between 1990 and 1995 and are projected to remain constant or increase between 1995 and 2005.

### **6.1.3 Mercury Emissions Associated with Electrical Production and Consumption**

In 1997, a new state law (Minn. Stat. §116.925) took effect that requires the producers and retailers of electricity to report on the amount of mercury emitted in generating electricity. The law requires the MPCA to summarize this emission information in its biennial air toxics report (first summarized in, *Toxic Air Pollutant Update: A Report to the Environment and Natural Resources Policy Committee of the Minnesota Legislature*, MPCA, February 1999).

For 1997, the MPCA received reports for 28 electrical generation units in Minnesota. The major fuel for most units was coal, although two facilities required to report depend on municipal solid waste for fuel (Hennepin Energy Resource Company and NSP Red Wing). In 1997, a total of 1,814 lb. of mercury air emissions, corresponding to the production of 33,721,787 megawatt-hours (MWh) of electricity, were reported. These estimates of mercury emissions associated with electrical production are consistent with the estimates provided in the emission inventory shown in Table 6.1.

### **6.1.4 How Mercury in Products gets to the Atmosphere**

Mercury has been used in many products for many reasons. Some products, such as pharmaceuticals and fungicides, dissipate the mercury into the environment as the product is used. Such uses have a relatively short life span, and then more mercury is purchased for that use. In contrast, mercury is used in some electrical switches that have an indefinite life span (lasting 40 years or longer) and may be encapsulated until the switch is decommissioned due to equipment changes. Most mercury uses in appliance and automobile switches and medical equipment, such as manometers, probably have life spans of 10 to 30 years. Tables 6.2 and 6.3 represent attempts to track the fate of mercury in products for the years 1990 and 1995 in Minnesota.

One of the primary motivating factors for the creation of Tables 6.2 and 6.3 was the need of the SRFRS to understand the relative importance of reducing mercury use in products as compared to the direct emission of mercury to the environment from point sources such as coal and waste combustors. These two categories are not mutually exclusive, because mercury in products is the source of the mercury to the waste combustors. These two tables track the fate of mercury to the solid waste stream, water waste stream, and estimates the quantity of mercury accidentally released to air, land, and water during

storage and use. For instance, in 1995 (Table 6.3) out of the 60 to 100 tons of mercury in use in Minnesota, about 4 tons (7,777 pounds) were discarded in about 2.5 million tons of solid waste. 44% of this waste (containing about 3,420 lb. mercury) went to landfills, of which MPCA staff estimate 5% (or 171 lb. mercury) was lost to the atmosphere before the waste was dumped out of the truck at the landfill (during waste collection, transportation, and mechanical processing). An additional 0.1%, or 3.3 lb. mercury, is estimated to be volatilized to the air at the landfill. 53% of the mercury in solid waste went to combustors in 1995, where 634 pounds were emitted to the air, and 3,282 lb. were captured for disposal in ash landfills. It is estimated that 206 pounds were volatilized on the way to the combustors. Some mercury makes its way to the atmosphere no matter how mercury-containing products are disposed of.

Once all possible fates of mercury-containing products are estimated, one can add all sources of mercury to air, land, and surface water. For 1995, MPCA staff estimate that, of the approximately 11,000 lb. of mercury removed from service that year, 15% (1,655 lb.) made its way to the atmosphere, 76% (about 8,400 lb.) is on the land or in landfills, 9% was recycled and 0.1%, or 17 lb., was discharged to surface water (Table 6.3). Encouragingly, these 1995 figures are considerably less than the corresponding figures for 1990, when almost three times as much mercury was disposed of, and more than three times as much was released to the atmosphere from purposeful use (Table 6.2). In 1990 about 20% of mercury used in products was released to the atmosphere, a proportion that declined to about 15% by 1995.

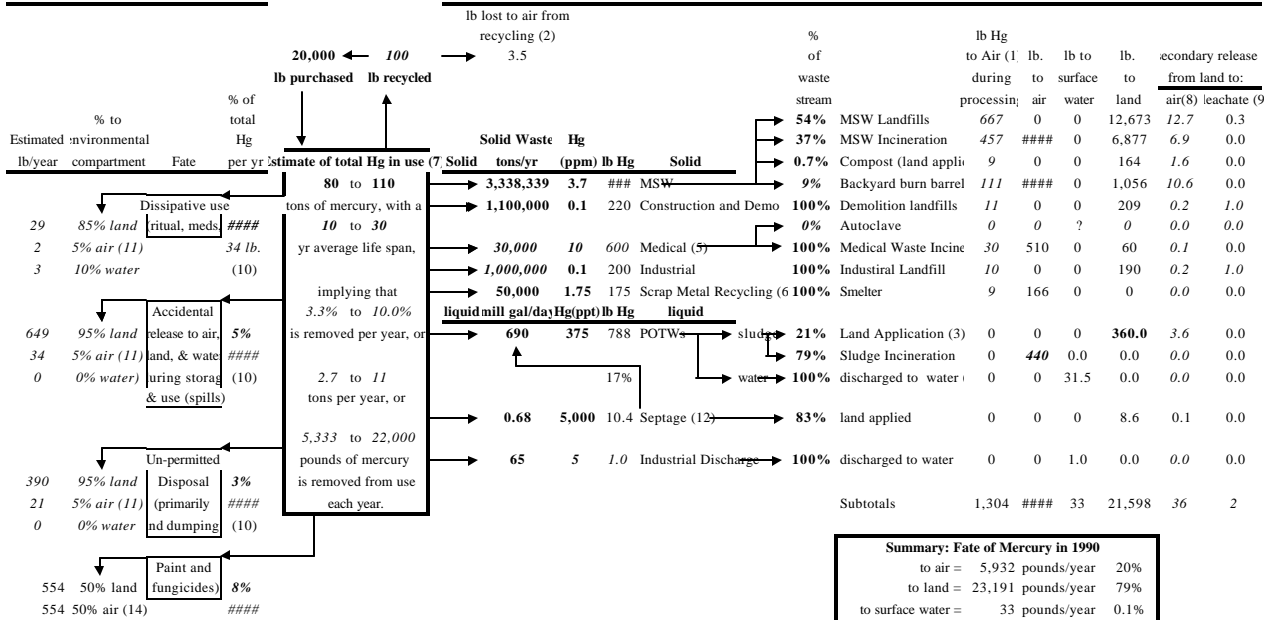
The 15% figure can be used as a conversion factor between mercury used in products and mercury emitted to the atmosphere. Assessment of the cost of reducing mercury releases to the atmosphere by reducing use in products versus controlling emissions from coal-fired utilities or taconite plants showed that, in general, the cost per pound to reduce emissions is lowest by reducing mercury use in products and improper disposal – even when costs are multiplied by 6.7 (the inverse of 15%) to calculate the cost of reducing releases to the atmosphere.

**Table 6.2. Analysis of the fate of mercury used in products in Minnesota, for 1990.**

10/2/98 Draft. Please direct comments to Edward Swain 651-296-7800; edward.swain@pca.state.mn.us

**Mercury not Recycled and Disposed to Waste Streams**

**Mercury Disposed in Solid or Liquid Waste Streams**



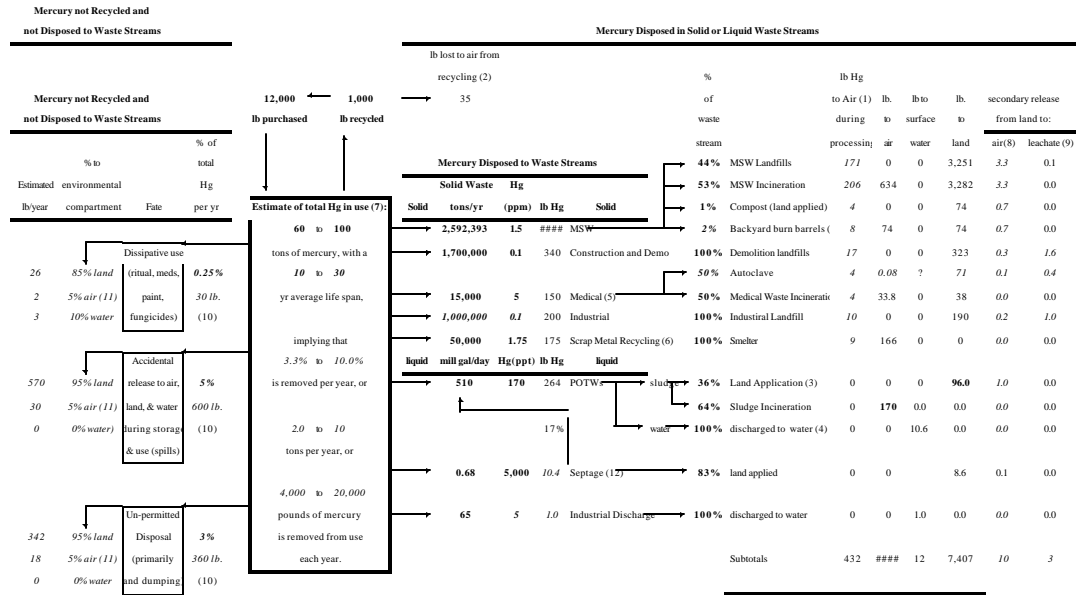
**Summary: Fate of Mercury in 1990**  
 to air = 5,932 pounds/year 20%  
 to land = 23,191 pounds/year 79%  
 to surface water = 33 pounds/year 0.1%  
 recycled = 100 pounds/year 0%  
**TOTAL = 29,255 pounds/year 100%**

Notes

1. Pounds of Hg in this waste stream that is lost to air during collection, transportation, & mechanical processing, assuming that 5% is lost during those processes.
2. The Mercury Report to Congress estimates 0.4 tons per year lost to air from recycling, while USBM data indicate about 220 tons is recovered per year, or about 0.2 percent.
3. Total sludge land spread in Minnesota is about 50,000 dry tons, with an average mercury content in 1990 of about 3.6 ppm (360 lb), and 1.8 ppm in 1995, or 180 lb.
4. This calculation assumes that 4% of the mercury entering a POTW is discharged to surface water, and that the rest associates with sludge (Balogh and Liang 1995, Water, Air, and Soil Pollution 80: 1181-1190).
5. About 7,500 tons/year medical waste is incinerated at the two large facilities (6,900 t/yr) and 20 small units (600 t/yr) (P. Torkelson, pers. com.). The amount accepted by autoclaves is unknown.
6. Automobile Shredder Residue Report. MPCA. 1995. The largest scrap metal smelter in MN is North Star Steel; it is assumed that 50% of Hg is emitted, and that the rest is emitted when the fly ash is refined for its zinc content in another state.
7. Based on pro-rated estimated of U.S. installed base, not counting chlor-alkali plants (S.M. Jasinski, 1995. The materials flow of mercury in the United States. Resources, Conservation, and Recycling 15:145-150).
8. The following rates are assumed for air emissions from land: 1%/yr from surface application; 0.1%/yr from other landfilled material (0.1% is based on studies of MSW emissions in Florida by S.E. Lindberg and others).
9. Leachate (assumed to be 0.002%/yr, based on concentration x leachate volume), is either land applied (through spray irrigation) or transported to a POTW. Median concentration is 0.7 ppb (Land Treatment of Landfill Leachate, MPCA, 1993, pg. 27).
10. Based on the mean quantity of mercury estimated to be removed from the installed base per year (in this case, the mean of 5,333 and 22,000 pounds per year = 13,666.5 pounds).
11. Consistent with Note number 1, 5% of these materials is assumed to become volatilized within a year of disposal. There may be continuing release in subsequent years, which is not accounted for in this estimate.
12. Concentration from document provided by Joe Carruth.
13. It is assumed that half of the mercury burned in a backyard burn barrel is volatilized immediately, and half is buried in the land. The quantity of solid waste disposed of in this manner is estimated from data collected by the Office of Environmental Assistance.
14. Mercury use in paint and golf-course fungicides was discontinued by 1992. It is estimated that half the mercury used each year was volatilized.

**Table 6.3. Analysis of the fate of mercury used in products in Minnesota, for 1995.**

11/19/98 Draft. Please direct comments to Edward Swain 651-296-7800; edward.swain@pca.state.mn.us



**Notes**

- Pounds of Hg in this waste stream that is lost to air during collection, transportation, & mechanical processing, assuming that 5% is lost during those processes.
- The Mercury Report to Congress estimates 7.4 tons per year lost to air from recycling, while USBM data indicate about 220 tons per year, about 3.5 percent.
- Total sludge land spread in Minnesota in 1995 was 46,668 dry tons with an average mercury content of 1.83 ppm, or 171 lb (R. Wirth, pers. com.).
- This calculation assumes that 4% of the mercury entering a POTW is discharged to surface water, and that the rest associates with sludge (Balogh and Liang 1995, Water, Air, and Soil Pollution 80: 1181-1190).
- About 7,500 tons/year medical waste is incinerated at the two large facilities (6,900 t/yr) and 20 small units (600 t/yr) (P. Torkelson, pers. com.). The amount accepted by autoclaves is unknown.
- Automobile Shredder Residue Report. MPCA. 1995. The largest scrap metal smelter in MN is North Star Steel; it is assumed that 50% of Hg is emitted, and that the rest is emitted when the fly ash is refined for its zinc content in another state. After 1995 North Star Steel asked suppliers to remove mercury switches before delivering scrap.
- Based on pro-rated estimated of U.S. installed base, not counting chlor-alkali plants (S.M. Jasinski, 1995. The materials flow of mercury in the United States. Resources, Conservation, and Recycling 15:145-179.)
- The following rates are assumed for air emissions from land: 1%/yr from surface application; 0.1%/yr from other landfilled material (0.1% is based on studies of MSW emissions in Florida by S.E. Lindberg and J.L. Price, 1998).
- Leachate (assumed to be 0.002%/yr, based on concentration x leachate volume), is either land applied (through spray irrigation) or transported to a POTW. Median concentration is 0.7 ppb (Land Treatment of Landfill Leachate, MPCA, 1993, pg. 27).
- Based on the mean quantity of mercury estimated to be removed from the installed base per year (in this case, the mean of 4,000 and 20,000 pounds per year, or 12,000 pounds).
- Consistent with Note number 1, 5% of these materials is assumed to become volatilized within a year of disposal. There may be continuing release in subsequent years, which is not accounted for in this estimate.
- Concentration from document provided by Joe Carruth.
- It is assumed that half of the mercury burned in a backyard burn barrel is volatilized immediately, and half is buried in the land.

## **6.2 Options for Reducing Mercury Releases**

### **6.2.1 Summary of Options**

Summaries of the mercury reduction options identified by the SRFRS Committee are in a series of tables. Table 6-1 shows the options identified for each source category, along with data, where available, regarding cost-effectiveness, reduction potential, permanence, and current availability of the option. Note that this information was deemed current in the Fall of 1998 and may not reflect the latest advances in control technologies. This table summarizes the option descriptions provided in Part 8 of this report.

Table 6-2 is a matrix in which mercury reduction options have been arranged to show relative cost-effectiveness and reduction potential. The division in Table 6-2 between “low, medium, and high” categories was selected to divide the options into thirds for comparison purposes only. The values shown do not represent a judgment by the Advisory Council or SRFRS Committee regarding, for example, the cost that would be considered an acceptable cost, or one that would be considered too high.

### **6.2.2 Data Gaps**

Data gaps affect identification and description of reduction options in four main ways:

- 1) there may still be significant unidentified mercury sources;
- 2) there are options which have been suggested but not yet researched to determine if they are feasible or cost-effective;
- 3) there may be options which have not been identified at all; and
- 4) lack of data, inaccuracies of data and incomplete data all of which influence cost and reduction potential estimates.

The estimates of cost and reduction potential for most of the options are very rough, due mainly to lack of data. For taconite processing options, no cost or reduction potential estimates are available at all due to data gaps (taconite processing as a source of mercury was relatively recently discovered.)

Examples of data gaps affecting options include:

- The “mercury in products fate model” explained in Part 6.1.2 was used to estimate the annual decrease in mercury releases to the environment (i.e., reduction potential) which results from most of the pollution prevention strategies for products (e.g., reducing the amount of mercury contained in new products purchased, or from taking mercury-containing items off the shelf in schools or homes). The assumptions made regarding how and when products are disposed, especially the amount spilled or illegally disposed of via “back yard” burning, are very rough.

- The reduction potential of switching coal sources must be evaluated on a site-specific basis to determine the resulting mercury emission change.
- The potential for “re-emission” of mercury from ash and activated carbon used to collect mercury from combustion source flue gases has not been determined. As a result, the permanence of options that rely on end-of-stack controls to prevent air emissions is unknown.

A number of options also list “research needs” as part of the detailed option descriptions provided in Part 8.

### **6.3 Strategies for Reducing Mercury Releases**

#### **6.3.1 Summary of Existing Strategies**

A number of state and federal actions have already reduced the rate of anthropogenic mercury releases to the environment in Minnesota. These actions have all related to the intentional use of mercury or management of mercury-containing products. These programs have very effectively reduced releases from many sources, as shown in the emission inventory (see Part 6.1). The main reductions have occurred at waste combustors, which reduced emissions by approximately 50 % between 1990 and 1995, with the decrease continuing to the present. Another large decrease resulted from ceasing to use mercury as a fungicide in latex paint.

A summary of mercury reduction strategies employed in Minnesota since 1990 is shown in Table 6-3. In addition to these programs, other programs have also resulted in reduced mercury releases as a side benefit, including “demand side management” used by utilities to reduce energy demand.

#### **6.3.2 Summary of Potential New Strategies**

The SRFRS Committee has prepared a list of 50 potential strategies for reducing mercury releases. These strategies are summarized in Table 6-4, and described in detail in Part 9 of this report. The strategies list includes a range of strategy types. Some are strictly voluntary, others are regulatory or mandatory (mandatory strategies have regulatory components, even if they do not specifically require mercury reductions; fees or reporting requirements are useful examples). Most of the strategies that have been used to reduce levels of other pollutants in the environment are included in some form.

Some strategies are applicable to a specific source type (e.g., an emission limit on coal-fired boilers). In other cases, strategies apply to a number of different source types (e.g., an early reduction credit system). Some strategies are included which apply to all of the currently known, significant sources of mercury releases in Minnesota. Some strategies are also structured so that they are applicable to any newly discovered, significant mercury source types.

The strategies differ in the degree to which they directly or indirectly lead to reducing mercury contamination. Strategies can be:

- 1) direct: strategies that require that actions be taken (e.g., emission caps, emission limits);
- 2) indirect: strategies that provide economic incentives for actions that reduce mercury (e.g., deposit/refund systems) or increase knowledge about mercury releases or reduction options (e.g., education, reporting requirements, deposit/refund systems), thereby encouraging mercury reduction activities; and
- 3) indirect and deferred: strategies which may eventually lead to a reduction of mercury or which provide a foundation for future reduction activities. Examples include research on human health and wildlife impacts of mercury, or research and development of control technology.

The Advisory Council's Criteria Committee developed a review process that favored strategies that encourage implementation of options with high reduction potential that are cost effective and preferably permanent (reference the Criteria Committee report for definitions of these). The detailed strategy descriptions include cost and reduction potential estimates. It is more feasible to estimate cost, reduction potential, and cost-effectiveness (\$ per pound) for direct strategies. Rough estimates have been made for some indirect strategies as well. Although program cost estimates can be made, it is not relevant to estimate reduction potential and cost-effectiveness for the indirect and deferred strategies.

It should also be noted that the list of options is not complete, i.e., there are a few strategies which call for actions that are not specifically described in an option. For example, the cap and trade strategy includes petroleum refineries as affected sources, however, no reduction options for that sector have been developed, and mercury emissions from refineries are not well quantified.

A summary of strategies, ranked in order of cost-effectiveness is shown in Table 6-4. The table covers only those strategies that have cost and/or reduction potential estimates.

### **6.3.3 Strategy Financing Mechanisms**

Nearly all proposed strategies will impose new costs on someone. Finance methods or funding sources were requested to be part of each strategy proposal. Although some proposers did not suggest funding sources, the budget suggestions that were made fell into two general classes: a) systems based on fees or fee-like methods and b) systems that rely on general revenue sources, such as sales and income taxes.

Fee-based systems would impose costs on people or organizations that use mercury or release it into the environment. The other financing proposals would spread program or project costs over broader populations. Suggested general finance sources include: the MPCA's general budget, EPA grants, LCMR grants, the environmental trust fund, and

the state's general fund. Revenue for these sources comes from taxpayers who have a less direct connection to mercury releases, although many taxpayers do use and discard mercury containing products which can lead to environmental releases.

The Criteria Committee's definition of the fairness criterion calls for cost distributions roughly proportional to contributions to the mercury release inventory. The Screening and Evaluation Committee and Advisory Council will need to consider funding mechanisms of a strategy as one component of their fairness assessment.

#### **6.3.4 Missing Information**

Data gaps that limit the ability to thoroughly describe strategies with accuracy include:

- Data gaps pertaining to estimating the costs and reduction potential of options which may be implemented as a result of a given strategy also limit the ability to predict the costs likely to be incurred as a result of the strategy. These data gaps are described above under Part 6.2.2.
- In addition to the costs associated with options, strategies entail other costs such as the administrative costs associated with oversight of a strategy by state or county government. The amount of staff time needed has been roughly estimated.
- The potential secondary environmental benefits and costs of strategies, i.e., the reduction or increase in emissions of pollutants other than mercury, have not been rigorously identified nor quantified for most strategies. Those known are noted in strategy descriptions under "implementation issues."

### **6.4 Potential for Management of Mercury in the Environment**

The subcommittee formed to assess potential for managing mercury that is already in the environment came to the following conclusions:

There are numerous ways that mercury in the environment might be managed so as to minimize the amount that bioaccumulates in fish. The options include:

- 1) decreasing the amount of mercury deposited (e.g. reducing ozone or other pollutants in the air; minimizing dry deposition by reducing forest cover);
- 2) reducing how much mercury deposited to land makes its way to water bodies (e.g. reducing soil erosion, reducing use of storm sewers);
- 3) reducing the efficiency of methylation (e.g. reducing sulfate deposition, eliminating wetlands; adding selenium compounds to water);
- 4) removing mercury from the biosphere so that less is available (e.g. sediment dredging, fish removal, soil removal);

5) reducing mercury cycling in the biosphere (e.g. covering contaminated soil or sediment with materials that inhibit release to overlying water or air).

Subcommittee members found that none of these options are practical for addressing the general problem of elevated mercury in the environment, but a subset may be of practical use for addressing site-specific mercury contamination problems that resulted from local pollution. For instance, option number 5 may be practical for dealing with contaminated sediments in certain situations of limited spatial extent.

## SUMMARY TABLES

### Abbreviations, Terms and Assumptions

Hg = mercury  
CE = cost effectiveness  
MWI = medical waste incinerator  
MWC = municipal (solid) waste combustor

RP = reduction potential  
TF = technically feasible  
WWTP = waste water treatment plant  
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?	
					+ comments	
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?		+ comments
New Natural Gas	Utilities	under development	55-58	Y	Y	Y	CE doesn't include pipeline extension, RP for replacing 1 mid-size plant
Coal source switching	Utilities	unknown	unknown	Y	Y	Y	TF to the extent that facilities can burn lower Hg coal
Lower exhaust temp.	Utilities	25,000-125,000	375	N	Y	Y	RP assumes 10% reduction
No or low-Hg emitting new generation sources	Utilities	unknown	Unknown	Y	Y	Y	RP given as 0 near term, 100s long term
substitute lower mercury feedstock chemicals	industrial/commercial facilities	?	100	Y	Y	Y	
Energy source substitution/fuel switching	Taconite Plants	175,000	1	Y	Y	Y	TF must maintain ability to burn alternative fuels
Chemicals/additives replacement	Taconite Plants	unknown	9	Y	U	U	
Laboratory pollution prevention	school, hospital, commercial laboratories	700-6,600	10-25	Y	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	Y	
Waste material separation and proper management	all product users, material recovery facilities	200-500	580	N*	Y	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	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	Y	
Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y	Y	RP: 1000 to air, 7,000 to all media
reduce use of Hg dental amalgam	Dental	?	?	Y	Y	Y	

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

OPTION	SOURCES	COST EFFECTIVENESS \$ per pound	REDUCTION POTENTIAL pounds per year
<b>Lower cost</b>			
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
<b>Medium cost</b>			
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
<b>Higher cost</b>			
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**

<b>Program Type</b>	<b>Description</b>	<b>Results, Costs, etc.</b>	<b>Contact Person</b>
<b><i>Voluntary Programs</i></b>			
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 scrapyards 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
<b><i>Regulatory Programs</i></b>			
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

<b>Program Type</b>	<b>Description</b>	<b>Results, Costs, etc.</b>	<b>Contact Person</b>
<i>State Laws</i>			
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
<b>STATE STRATEGIES - INFORMATION/RESEARCH</b>						
<i>Minnesota Mercury Inventory</i>	none	All sources	N/A	N/A	N/A	Y
<i>Minnesota Mercury Research</i>	none	potentially all sources	N/A	N/A	N/A	Y
<i>Minnesota Mercury Research, fees assessed</i>	none	potentially all sources	N/A	N/A	N/A	Y
<b>STATE STRATEGIES - MANDATORY</b>						
<i>Improve compliance with product labeling</i>		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
<i>Label existing "installed" mercury-containing products</i>		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
<i>Performance-based limits for significant air emitters</i>		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 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

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
<b>BACT and BMP on all significant air emitters</b>		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
<b>Hg reduction plans for primary sources</b>		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
<b>Require BMPs by primary sources</b>		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
<b>Hg Emission Cap</b>		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
<i>Hg Emission Cap, 4 largest source sectors</i>		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
<b>Outstanding Resource Waters designation for more lakes</b>	potentially all options	potentially all sources	unknown	unknown	Y/N	U
<b>TMDL (Total Maximum Daily Load) Pilot Project</b>	potentially all options	potentially all sources	unknown	unknown	Y/N	U
<b>Equipment recordkeeping</b>		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
<b>Public Disclosure - Utilities</b>		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 generation sources	Utilities	unknown	Unknown	Y	Y
<b>Cap-and-Trade</b>	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 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
<i>state buys Hg free energy</i>		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
<i>Subsidies</i>	Subsidies could encourage any option to be implemented	all	unknown	unknown	Y/N	Y/U
<i>License bulk Hg buyers and sellers</i>		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
<i>License buyers and sellers of encapsulated Hg</i>		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
<i>Enforce existing state disposal bans</i>		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
<i>Expand existing Hg product disposal bans</i>		auto manufacturers and scrap yards, households	unknown	unknown	?	?
<i>Sales fee on products</i>		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
<i>Utility fee and awards for development of control technologies</i>		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
<i>fees on utilities, award first to implement</i>		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
<i>fees on multiple industries, award first to implement</i>		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 - existing	Taconite Plants	unknown	unknown	N	Y
	Conventional controls - new and emerging technology	Taconite Plants	unknown	unknown	N	U
<b>Deposit and refund</b>						
		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
<b>Mandatory product stewardship</b>						
		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
<b>Clean air investment fund</b>						
		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
<b>Clean air Investment fund - Revenue neutral fees</b>						
	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
<i>green electricity through competition</i>		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
<b>National Strategies</b>						
<i>Total Hg content hazardous waste limit</i>		all	unknown	?	?	?
<i>National Mercury Research</i>	None	all?	N/A	N/A	N/A	Y
<i>Change TRI reporting protocol</i>	None	all?	N/A	N/A	N/A	Y
<i>Tax electricity</i>	Demand side management/energy efficiency	Utilities, other electricity generators, energy users	unknown	0-6000	Y	?
<i>International Hg management plan</i>	Options related to intentional use of mercury, waste management	Potentially all sources, users, consumers	0.20-infinity	0-360,000	?	?
<i>MN Hg outreach position</i>	cost effective options, largely related to source reduction	all?	unknown	?	?	?
<i>MWI, MWC lower emission limits</i>	primarily control technology options for MWI, MWC	MWI, MWC	7,400-infinity	0-200*	?	?
<i>Lower limits for sewage sludge incineration</i>	source reduction, waste segregation, and controls for sludge incinerators	sludge incinerators	unknown	100*	?	?
<b>State Strategies - Voluntary</b>						
<i>Voluntary Hg Use Reduction</i>		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
<b>Voluntary reduction from energy sectors</b>		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
<b>Early Reduction Credits</b>	potentially all options, mainly low cost options	all sources	unknown	0-800??	Y/N	Y
<b>Promote labeling of "installed" Hg products</b>		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
<i>reduce Hg in buildings</i>	(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
<i>state procurement policy</i>		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
<i>Increase HHW collection programs to include business</i>		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
<i>ID reduction programs via sludge reporting</i>		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 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
	Install additional amalgam capture equipment	Dental	15,000-618,000	17	N*	U

STRATEGY	OPTIONS	AFFECTED SOURCES	Cost effectiveness \$ per pound	REDUCTION POTENTIAL pounds per year	PERMANENCE	TECHNICALLY FEASIBLE
	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
	Purchase and use less Hg containing products	all product users	10-100??	1000	Y	Y
	reduce use of Hg dental amalgam	Dental	?	?	Y	Y
<b>ISO 14000 or equivalent Environmental Management System</b>	potentially all options, mainly low cost options	All	unknown	unknown	Y/N	Y/U
<b>Educate product users</b>	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/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
	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
	reduce use of Hg dental amalgam	Dental	?	?	Y	Y
	<b>Reduce dental amalgam use through research and changing insurance coverage</b>	Dental	20,000-40,000*	25	Y	Y
	reduce use of Hg dental amalgam	Dental	?	?	Y	Y
	<b>Education and waste management program for dental offices</b>	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
<i>reduce installed Hg via education and clean sweeps</i>	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
	<i>Hg detecting dog, to identify Hg in labs and other places</i>	labs, product users	400	250	?	?



## **PART 7. RECOMMENDATIONS RELATED TO STRATEGY EVALUATION AND SELECTION**

1. Options have not been developed for some mercury-emitting sources, such as industrial boilers, petroleum refineries, and households. Lack of developed options does not necessarily imply a lack of information, or lack of available means to reduce mercury from these sources. It is primarily due to limited resources and time to develop this information, and/or the limited knowledge of those who participated in developing this report. Current lack of option write-ups for these sources should not influence a decision on whether these sources should be addressed via the strategies.
2. Mercury is an issue that is global in nature. Although state strategies may be capable of reducing mercury contamination in fish, they could only do so to a limited extent. The potential for state-only strategies to lead businesses to relocate to outside Minnesota must also be considered. For these reasons, the SRFRS Committee encourages the Advisory Council to recommend in the final report the development of national strategies. This doesn't mean that Minnesota should wait for national action before taking any action. (Refer to Table 6-4 or Part 9.2.1 for a list of proposed national and international strategies.)
3. While SRFRS support a general preference for pollution prevention-type options, SRFRS recommend to the AC and SEC that options or strategies that do not provide permanent prevention should not be rejected for that reason alone.
4. The SRFRS Committee recommends that any strategies "package" (a group of strategies) include performance measures to allow determination of strategy effectiveness.
5. The SRFRS Committee recommends to the Screening and Evaluation Committee (SEC) that strategies that have more than one component can be split into separate strategies by the SEC, if it is deemed necessary.
6. Secondary benefits and/or impacts, i.e., reductions or increases in other pollutants, have not been accounted for in the primary cost-effectiveness estimates that are presented in the summary tables. They are identified briefly in the "Implementation Issues" section of option and strategy detailed descriptions. These benefits and impacts should be taken into account as part of economic impact evaluation and other evaluations as appropriate.
7. Although the Criteria Committee report called for providing estimates of reduction potential over a 20-year time period, the SRFRS Committee has provided annual reduction potential estimates and qualitative comments regarding the expected changes in reduction potential over time. Providing 20-year estimates proved to be too time consuming. This information could be important for assessing

contamination reduction potential. It should also be noted that some options result in one-time reductions vs. ongoing reductions for others.

8. Any reduction goals identified must take into account programs that have already been implemented; e.g., the dairy manometer program and MSW regulations.
9. It is difficult or, in some cases, not possible to estimate the reduction potential and cost-effectiveness for many of the voluntary strategies and information collection/research strategies. These strategies should not be rejected from consideration solely due to lack of cost-effectiveness and reduction potential estimates.
10. The committee asked itself if there were any strategies that committee members would be unlikely to oppose. They were identified as actions that seemed like someone should “just do it.” These are labeled as “Nike” strategies in Appendix B. In cases where strategies were suggested as “Nikes” but not unanimously accepted, the reasons for opposition are noted under “SRFRS Discussion” in Appendix B. The SEC and Advisory Council may find this information useful. It indicates that the likely “social/political” feasibility of these strategies is high. In addition, the SRFRS Committee recommends that evaluations for these NIKE strategies should be handled first, given their low controversy.
11. As part of the NIKE exercise, the committee also was asked if there were any strategies that everyone believed should be dropped from further consideration. No such strategies (termed “NOVAs”) were identified. A number of committee members did express opposition to considering strategies that pertain to utility deregulation, such as “Greening Electricity through Customer Choice, Supplier Competition, and Technological Innovation,” however, this was not a unanimously held position.
12. The SRFRS Committee likes the early reductions credit concept and supports further development. SRFRS expect it could be an appropriate part of a strategy alternative package. The strategy itself was not unanimously supported as a NIKE.
13. A main focus regarding reducing mercury emissions from utilities was on finding replacements for coal-fired electricity generation. These options would reduce multiple pollutants simultaneously. Creating incentives for using low-mercury energy sources for new power generation should be considered by the Advisory Council.
14. The SRFRS Committee believes that, although some strategies are more thoroughly described than others, strategy descriptions are sufficient to move forward to strategy evaluation. If the SEC finds that more detail is needed on specific strategies, questions should be referred to MPCA staff, who will refer them to the main strategy authors or to a subcommittee as appropriate.

15. Options that are incomplete, and sources for which options have not been developed at all, should be considered to the same degree as other sources and options. The SEC should request more information, as needed, from the MPCA. Further research may be needed for poorly defined options that are considered to be an integral part of viable strategies.