



Estimated Mercury Emissions in Minnesota for 2005 to 2018

Not Including Reductions Expected from the 2007-2008 Mercury TMDL Stakeholder Process

April 22, 2008

Introduction

This document contains estimates of mercury emissions to the atmosphere from human activity within Minnesota provide baseline information for the deliberations of the group of stakeholders that are working toward the implementation of the goals of Minnesota's mercury TMDL^a. A primary goal of the TMDL is to ultimately reduce Minnesota's anthropogenic mercury emissions to a total of 789 pounds (lb.) per year, an ambitious goal considering this document estimates 2005 emissions to have been about 3,300 lb. The TMDL requires that the state design an implementation plan that will result in the 75% reduction in emissions, from 3,300 to 789 lb. Specifically, the Mercury TMDL Stakeholder Process^b has the mission to identify mercury reduction strategies and to develop recommendations for the state's implementation plan.

The purpose of this document is to provide estimates of what mercury emissions would be if none of the new mercury reduction strategies that result from the TMDL stakeholder process are implemented. There are existing initiatives^c and social trends that will result in reduced total emissions, but projected reductions are not nearly sufficient to reach the TMDL emission goal. For instance, initiatives in the electric utility sector are projected to reduce those emissions by 76%, but no such initiatives yet exist for most other activities that emit mercury, some of which, without intervention, may increase emissions in proportion to economic activity or because of social trends. New and expanded point-source air emissions are only included in the estimates if they have received a permit from the Minnesota Pollution Control Agency (MPCA), but as a result of normal economic activity there will be additional proposed air emissions.

This document estimates that, in the absence of new mercury reduction strategies, mercury emissions will decline by about 40% by 2018, to about 2,000 lb., with negligible reason to decline further after 2018. The MPCA is asking stakeholders to identify reduction strategies that can decrease projected emissions by at least a further 60% — from the 2018 projection of about 2,000 lb. to the goal of 789, or lower. To facilitate economic change and growth, the stakeholders are also asked to recommend strategies that will accommodate new emissions without exceeding the statewide goal.

^a Statewide Mercury Total Maximum Daily Load (TMDL) Pollutant Reduction Plan.

<http://proteus.pca.state.mn.us/water/tmdl/tmdl-mercuryplan.html>

^b Mercury Total Maximum Daily Load Stakeholder Process. <http://www.mn-ei.org/projects/mercury.html>

^c Mercury. <http://www.pca.state.mn.us/air/mercury.html>

Table 1 Estimated mercury emissions (pounds) from human activity in Minnesota for the years 2005, 2010 and 2018

Mercury Emission Inventory for Minnesota (lb/year)

Updated by MPCA staff April 22, 2008

Categories	note	Confidence	estimated 2005 emissions	projected 2010 emissions	projected 2018 emissions	Likely change in same-facility emissions by 2018
Incidental to Energy Production						
Coal -- Electric Utility	1	high	1716.3	1041.0	410.3	specific reductions up 15% plus 4 lb Heron Lake may become significant
Coal -- Commercial, Institutional, & Industrial	2	medium	71.3	77.0	86.0	
Volatilization from coal ash	3	very low	0.0			
Petroleum Refining	4	medium	12.9	13.6	14.8	
Petroleum Product Utilization	5	very low	27.1	28.7	31.2	
Wood Combustion	6	medium	30.5	32.3	35.1	
Biomass other than wood	7	medium	0.0	2.1	2.1	
Natural Gas Combustion	8	medium	0.3	0.3	0.3	
Subtotal: Incidental with energy production			1858.4	1195.0	579.9	
% of total state emissions			56%	46%	30%	
Largely Resulting from the Purposeful Use of Mercury						
<i>Proportional to Hg content of Solid Waste</i>						
Volatilization: solid waste collection & processing	9	very low	169.0	152.8	126.8	down 25%
On-site household waste incineration	10	very low	40.0	36.2	30.0	down 25%
Volatilization from spills and land dumping	11	very low	24.0	21.7	18.0	down 25%
Landfill volatilization	12	very low	2.1	1.9	1.6	down 25%
Volatilization: land application of compost	13	low	0.2	0.2	0.2	down 25%
<i>Proportional to Hg content of Liquid Waste</i>						
Volatilization: land application of sludge	14	low	1.6	1.3	0.8	down 50%
<i>Recycling Activities</i>						
Shredders & smelters that recycle cars and appliances	15	low	138.7	24.1	11.4	80% removal of fewer switches
Recycling mercury from products within MN	16	very low	65.0	71.3	81.3	up 25%
Non-Ferrous metal recycling (Al, Pb,)	17	low	0.9	1.0	1.1	up 25%
<i>Dental Mercury</i>						
Dental Preparations	18	very low	62.4	56.4	20.1	down due to less use, traps
Cremation	19	low	80.0	105.0	126.7	increased deaths & % cremated
<i>Incineration</i>						
Municipal solid waste combustion	20	high	49.2	38.3	38.3	reductions at 2 facilities
Sewage Sludge Incineration	21	high	8.5	8.9	11.9	Up 13%; new Buffalo facility 2 lb
Medical waste incineration	22	high	0.4	0.6	0.8	up 100%
Hazardous waste incineration	23	high	0.3	0.3	0.3	none
Class IV incinerators	24	high	0.0	0.0	0.0	none
<i>Mfg & Use of Non-dental Mercury-containing Products</i>						
Mercury product manufacturing in Minnesota	25	low	42.0	38.0	31.5	down 25%
General Laboratory Use	26	very low	10.0	6.5	1.0	down 90%
Volatilization from dissipative use	27	low	0.8	0.6	0.4	down 50%
Subtotal: Associated with purposeful use of mercury			695.1	564.9	502.0	
% of total state emissions			21%	22%	26%	
Emissions Incidental to Material Processing						
Taconite Processing	28	high	734.8	840.6	840.6	several new facilities
(2005: includes 19.0 from dust + 6.6 lb from fuel)						(Keewatin controlled 28% in 2005)
Thermal treatment of soil	29	low	0.8	0.8	0.8	
Subtotal: Emissions incidental to material processing			735.6	841.4	841.4	
% of total state emissions			22%	32%	43%	
Difficult to Categorize (is the Hg from fuel or materials?)						
Asphalt Manufacturing	30	low	4.3	4.3	4.3	Unclear what trend is
Agriculture, Food, & Kindred Products	31	low	1.1	1.1	1.1	Unclear what trend is
Mineral Products	32	low	13.8	13.8	13.8	Unclear what trend is
Miscellaneous Industrial Processes	33	low	0.2	0.2	0.2	Unclear what trend is
Wood, Pulp & Paper, & Publishing Products	34	low	5.1	5.1	5.1	Unclear what trend is
Subtotal: Emissions difficult to categorize			24.6	24.6	24.6	
% of total state emissions			1%	1%	1%	
GRAND TOTAL=			3,314	2,626	1,948	

Abbreviations: NA = Not Applicable; NQ = Not Quantified;

Confidence intervals: High +/- 10%; Medium +/- 25%; Low +/- 50%; Very Low +/- 100% or more.

Notes to Table 1, estimated mercury emissions in Minnesota, 2005-2018.

Emissions Incidental to Energy Production

1. Coal — Electric Utility

Based on data submitted by electric utilities; projections are based on reduction goals and the U.S. Environmental Protection Agency's (U.S. EPA) Integrated Planning Model (IPM) projections for unit utilization.

Table 2 Mercury emissions from coal-burning electric utilities

Owner	Plant name	Unit ID	Capacity (MW)	Total Hg emissions 2005 (lb)	Total Hg emissions 2010 (lb)	Total Hg emissions 2018 (lb)
Laurentian Energy Authority	All Virginia & Hibbing units	All units		12.8	8.0	8.0
Municipal	Austin Northeast	NEPP	29	8.3	10.9	11.8
Municipal	Springfield	4	4	0.0	0.0	0.0
Municipal	Willmar	1	3	0.0	1.0	1.0
Municipal	Willmar	3	19	3.7	6.5	6.5
Cleveland Cliffs	Silver Bay Power	BLR1	36	1.3	0.7	0.7
Cleveland Cliffs	Silver Bay Power	BLR2	69	1.7	1.3	1.3
Minnesota Power	Clay Boswell	1	69	3.0	3.1	3.3
Minnesota Power	Clay Boswell	2	69	3.0	3.4	3.6
Minnesota Power	Clay Boswell	3	350	90.0	9.9	9.9
Minnesota Power	Clay Boswell	4	426	184.0	13.5	14.3
Minnesota Power	Syl Laskin	1	55	21.0	12.5	12.5
Minnesota Power	Syl Laskin	2	55	0.0	12.6	12.6
Minnesota Power	Hibbard	3		3.0	3.0	3.0
Minnesota Power	Hibbard	4		3.0	3.0	3.0
Minnesota Power	Taconite Harbor Energy Center	1	65	22.0	2.4	2.4
Minnesota Power	Taconite Harbor Energy Center	2	67	17.9	2.0	2.0
Minnesota Power	Taconite Harbor Energy Center	3	68	17.0	2.0	2.0
Ottertail	Hoot Lake	1	8	0.0	0.0	0.0
Ottertail	Hoot Lake	2	62	39.4	17.3	18.3
Ottertail	Hoot Lake	3	84	0.0	23.8	25.2
Rochester	Silver Lake	1, 2, 3, 4	110	3.9	6.0	6.0
Xcel	Allen S King	1	571	60.6	8.8	8.8
Xcel	Black Dog	3	120	32.2	57.8	57.8
Xcel	Black Dog	4	186	65.1	80.8	80.8
Xcel	High Bridge	5		23.1	0.0	0.0
Xcel	High Bridge	6		36.6	0.0	0.0
Xcel	Minnesota Valley	4	50	0.0	0.0	0.0
Xcel	Riverside	8		60.2	0.0	0.0
Xcel	Riverside	6/7		45.5	0.0	0.0
Xcel	Sherburne County	1	762	333.7	352.5	35.2
Xcel	Sherburne County	2	752	314.0	356.0	35.6
Xcel/SMMPA	Sherburne County	3	936	310.3	42.0	44.5
		Total		1716.3	1041.0	410.3

Table 3 This electrical generating project has the potential to emit mercury, has been proposed, but has not yet received a permit (and is not included in the emission calculations):

Project	Type	Start-up date	Lb/yr	Status
Mesaba Energy	EGU	2010	54	Environmental Impact Statement

2. Coal — Commercial, Institutional and Industrial

Future emissions from non-electric utility coal combustion are projected to grow by 15% by 2018, as a result of normal economic growth in Minnesota.

Table 4 Mercury emissions from coal combustors that are not electric utilities

Facility	Unit	2005 mercury emissions (lb/yr)
Southern Minnesota Beet Sugar Coop	Boiler No. 1	8.70
University of MN - SE Plant	Boiler No. 5	8.50
American Crystal Sugar - E Grand Forks	Boiler No. 1	7.92
American Crystal Sugar - E Grand Forks	Boiler No. 2	7.82
ADM - Mankato	Boiler No. 5	6.08
Verso Paper Co - Sartell Mill	Bros Boiler	5.93
Verso Paper Co - Sartell Mill	B & W Boiler	3.59
American Crystal Sugar - Crookston	Boiler #1	2.84
American Crystal Sugar - Crookston	Boiler #2	2.84
American Crystal Sugar - Moorhead	Boiler #1, North	2.69
American Crystal Sugar - Moorhead	Boiler #2, Center	2.36
American Crystal Sugar - Moorhead	Boiler #3, South	2.31
ADM Corn Processing - Marshall	Coal Boiler #1	2.16
ADM Corn Processing - Marshall	Coal Boiler #2	2.16
American Crystal Sugar - Crookston	Boiler #3	1.59
District Energy St Paul Inc-Hans O'Nyman	Boiler 2	1.03
District Energy St Paul Inc-Hans O'Nyman	Boiler 3	0.78
Order of St Benedict/St John's Abbey	Boiler #4	0.72
Order of St Benedict/St John's Abbey	Boiler #1	0.30
University of Minnesota - Crookston	Boiler 4	0.25
Order of St Benedict/St John's Abbey	Boiler #2	0.24
University of MN - Twin Cities	SG201	0.16
Duluth Steam Cooperative Association	Boiler 1	0.09
Wausau Paper Printing & Writing LLC	Boiler 4	0.08
Wausau Paper Printing & Writing LLC	Boiler 3	0.08
Duluth Steam Cooperative Association	Boiler 2	0.06
Duluth Steam Cooperative Association	Boiler 4	0.06
Wausau Paper Printing & Writing LLC	Boiler 2	0.02
	Total	71.35

The following new facility is expected to contribute mercury emissions by 2010, but is not yet up and running (and is included in emission calculations):

Table 5

Facility	Unit	Potential mercury emissions (lb)
Heron Lake (ethanol plant)	Boiler	4

The following electrical generating project that has the potential to emit mercury has been proposed but has not yet received a permit (and is not included in the emission calculations):

Table 6

Project	Type	Start-up date	Lb/yr	Status
Agassiz Energy	Industrial Boiler - Ethanol	2010	4	EIS

3. Volatilization from Coal Ash

Although emissions from coal ash are thought to be virtually zero in 2005, this category is included because changes in pollution control equipment and the utilization of coal ash may make this a significant category. In 2005 coal combustion constitutes the majority of mercury emissions in Minnesota, at least partly because very little of the mercury contained in coal is retained by pollution control equipment. Major consumers of coal in Minnesota have committed to controlling mercury emissions, an effort that has the potential to greatly increase the mercury content of coal ash. There also has been a great deal of interest in the beneficial utilization of coal ash in a variety of ways, including soil stabilization for building construction, paved and unpaved roads, as flowable fill, as a raw material for livestock pads, and as an agricultural amendment. It is unclear whether mercury-enriched coal ash will be used in a way that allows for the volatilization of the mercury from the utilized ash, and, if so, what the rate of release would be. The MPCA has worked with Dr. Mae Gustin of the University of Nevada to predict mercury volatilization rates from coal ash. Most current coal ash contains very little mercury, so additional work will be needed to assess volatilization potential if there are proposals to utilize coal ash that is enriched in mercury.

4. Petroleum Refining

The mercury content of crude oil is poorly known, so estimates of emissions have low confidence. Minnesota has two refineries: Flint Hills Resources (formerly Koch Petroleum Group) Pine Bend Refinery and Marathon Petroleum's St. Paul Park Refinery. Flint Hills Resources has conducted two mass balance studies of the mercury flow through its facility, and its most recent study (2004) concluded that inputs of crude oil were 42.5 lb., emissions at the facility 9.6 lb., and products contained 15.9 lb., of which 10 lb. is associated with sulfur, which is sold as a commodity. Because virtually all of the sulfur is exported from Minnesota, none of the mercury in the sulfur is assumed to be emitted in Minnesota. An additional 15.7 lb. could not be accounted for in Flint Hills Resources' mass balance, which, until clarifying information is obtained, are assumed in this analysis to have been emitted at the facility. For the 2005 TRI report, Flint Hills reported mercury emissions of 9.6 lb. from its Pine Bend facility. For the 2005 TRI report, Marathon Petroleum reported 3.3 lb. mercury emissions at its facility. If one scales the inputs to Marathon to Flint Hills, one would predict inputs of 11.0 lb. to Marathon, and that 5.5 lb. mercury might be in the products from Marathon.

The Flint Hills Refinery refines a much greater quantity of crude oil than the Marathon facility. In 2007, Flint Hills Resources' Pine Bend refinery in Minnesota completed a project that increased its crude oil processing capacity by about 19%, from 270,000 to 320,000 barrels per day. The refinery primarily refines Canadian crude oil, which it processes into petroleum products such as gasoline, diesel, propane and butane^d. Marathon's facility has a capacity of 70,000 barrels per day. Crude oil from Canada and the United States is processed at the refinery into gasoline, diesel, fuel oil, jet fuel, kerosene, propane and asphalt.^e

Future emissions from this sector are projected to be proportional to change in capacity, which in 2007 increased 15% from 340,000 to 390,000 barrels per day.

5. Petroleum Product Utilization

From the calculations presented in note 4 (above), non-sulfur products, including mercury missing from the mass balance, produced by Flint Hills Resources may contain as much as 21.6 lb. mercury, and products produced by Marathon Petroleum may contain 5.5 lb., a total of 27.1 lb. mercury. These estimates are quite uncertain, and it is not clear where these products are consumed and if all the mercury contained in products is emitted to the atmosphere. For the purposes of this state-wide mercury emission inventory, it is assumed that all the mercury that may be in products is emitted in the state. A more detailed estimate of mercury emissions from petroleum products would require data on all imports and exports of petroleum products from the state, the mercury content of those products, and the fate of that mercury upon use of the product, including fuels and sulfur. Such data are not available, so the simple analysis presented here will be used. Future emissions from this sector are projected to grow by 15% by 2018 from 2005, in parallel to Minnesota's increase in refining capacity.

^d <http://www.fhr.com/refining/minnesota.aspx>

^e http://www.marathon.com/Global_Operations/Refining_Marketing_and_Transportation/Refining/St_Paul_Park_Minnesota/wq-iw1-21

6. Wood Combustion

Table 7

Facility	Unit	Unit size mmBtu/hr	Lb Hg
Sappi Cloquet LLC	Power Boiler #9	430	5.0
District Energy St. Paul Inc. - Hans O'Nyman	Boiler 7	563	9.6
Sappi Cloquet LLC	Power Boiler #7	300	7.0
Boise White Paper LLC - Intl Falls	Boiler #2		2.9
Norbord Minnesota	Wellons Burner		1.1
Blandin Paper/Rapids Energy Center	Boiler #6	270	0.7
Blandin Paper/Rapids Energy Center	Boiler #5	270	0.7
Georgia-Pacific - Duluth Hardboard	Boiler 4	52	0.4
ISD 146 - Barnesville High School	Wood/Bark Waste		0.3
Norbord Minnesota	Konus Burner 2		0.2
Norbord Minnesota	Konus Burner 1		0.2
Foldcraft Co	Primary Boiler		0.2
Georgia-Pacific - Duluth Hardboard	Boiler 5	17	0.2
Boise White Paper LLC - Intl Falls	Boiler #2		0.2
Potlatch Forest Products Corp Lumbermill	Steam Boiler		0.1
St Gabriel's Hospital	Wood/Bark Waste		0.1
Alltrista Consumer Products Co.	Boiler 1		0.1
Alltrista Consumer Products Co.	Boiler 2		0.1
Alltrista Consumer Products Co.	Boiler 3		0.1
Alltrista Consumer Products Co.	Boiler 4		0.1
23 other smaller facilities			1.1
Total			30.5

7. Biomass Other Than Wood

New facilities that combust biomass other than wood are beginning to be constructed in Minnesota. Fibrominn, which combusts turkey litter waste is operational. Koda Energy received an air emission permit from the MPCA in August 2007 and is under construction. Koda Energy will build a 308.18 MMBtu/hr combined heat and power biomass boiler to produce on average, 120,000 lb./hour of steam for process heat at Rahr Malting and 17.8 MW of electricity. Koda Energy will burn oat hulls and other biomass byproducts from the RAHR facility.

Table 8

Project	Type	Startup date	Estimated lb Hg/yr	Status	Hg emission range in TSD for Air Permit
Fibrominn	EGU	2007	0.1	Operational	
Koda Energy	EGU & steam	2010	2	Under construction	1.8 to 8.1
Total			2.1		

8. Natural Gas Combustion

This estimate is based on an emission factor of 0.0008 lb. mercury/trillion Btu (Electric Power Research Institute. Mercury in the Environment - A Research Update. TR-107695. Palo Alto, December 1996). Future emissions from natural gas consumption are projected to grow by 15% by 2018, but due to the extremely low emission factor, total projected emissions will remain at 0.3 lb./year.

Emissions Largely Resulting from the Purposeful Use of Mercury

Proportional to Hg Content of Solid Waste.

9. Volatilization: Solid Waste Collection and Processing

This estimate is based on the assumption that 5% of the mercury in solid waste is volatilized during collection, transportation and mechanical processing. This estimate includes municipal solid waste (MSW) that is landfilled, incinerated and composted, but does not include Problem Materials Not Recycled (PMNR; washing machines, oil filters, tires, etc.), waste that is recycled (newspaper, glass, cans), demolition, medical waste incineration, MSW compost or backyard burn barrels. Emissions from steel-recycling facilities is calculated separately (see note 15). Future emissions from solid waste volatilization are projected to decrease by 25% by 2018 because of decreased availability and disposal of mercury-containing products.

Table 9

Fate of Municipal Solid Waste	1990	1995	2000	2005
Recycling	1,381,690	1,766,528	2,267,952	2,490,000
MSW Compost	30,000	67,997	21,092	20,000
Resource Recovery (combustion)		1,379,329	1,228,830	1,240,000
Landfill	800,000	1,145,067	1,909,152	2,120,000
Problem Materials Not Recycled		110,868	110,841	120,000
On-site Disposal	110,000	95,226	96,064	80,000
TOTAL (tons)		4,565,015	5,633,932	6,250,000
Mercury Content (ppm) (calculated from incinerators)	3.66	0.97	0.62	0.5
Total landfilled, combusted, composted (tons)	2,200,000	2,592,393	3,159,074	3,380,000
Mercury content (lb) of Solid Waste (excluding recycling, PMNR)	16,104	5,029	3,917	3,380
Volatilization during handling and transport (lb) (5% of landfill, combustion, composting)	805	251	196	169
Emissions from on-site combustion, also known as "Burn Barrel emissions" assuming 50% is emitted.	403	92	60	40
Volatilized during landfilling, assuming 0.1% is emitted	5.9	2.2	2.4	2.1
Volatilized during and composting, assuming 1% is emitted	2.2	1.3	0.3	0.2

From MPCA SCORE reports:

www.pca.state.mn.us/publications/reports/lrp-p2s-3sy07.pdf

Report on 2005 SCORE Programs

A summary of waste management in Minnesota (December 2006)

10. On-site Household Waste Incineration

It is thought that a significant quantity of solid waste produced by households in Minnesota is not introduced into any organized collection system, but rather is burned on site. This practice could be a significant source of mercury emissions, given that there is no pollution-control equipment and that we know from testing at large municipal solid waste incinerators that household waste contains mercury. Much of household waste is paper, cardboard, and plastic, materials that have a mercury concentration that is much lower than the calculated average for waste. Therefore, the average mercury concentration must be maintained by the occasional introduction of high-mercury items, such as older batteries, broken thermometers, fluorescent lamps, thermostats, etc. In rural areas, on-site disposal often takes the form of an outdoor "burn barrel." In urban and suburban areas, older houses and apartments were often designed with a basement incinerator, although the use of these incinerators has undoubtedly decreased since regulation in the early 1970s. The MPCA estimates the quantity of waste not collected in Minnesota, which is thought to be burned on site, commonly in burn barrels. The following table outlines available data on the production and fate of MSW in Minnesota, and estimates mercury emissions. These figures imply that about 2% of MSW is burned on site. This may be an underestimate, given that at least two studies have shown much higher rates of on-site incineration. Zenith Research Group (1997) found that 11% of residents in the Duluth area affirmed that they use a burn barrel. A 2000 Zenith study of Minnesota residents in the Duluth area found that 18% of residents surveyed admitted to the practice (Zenith Research Group. 2000. Increased Awareness. Prepared for Western Lake Superior Sanitary District.). Future emissions from burn barrels are projected to decrease by 25% by 2018 because of educational initiatives, a decrease that could be accelerated if additional incentives are provided.

Table 10

	1990	1995	2000	2005
Emissions from on-site combustion, "Burn Barrel emissions" assuming 50% is emitted.	403	92	60	40

(See Table in Note 8 for calculations)

11. Volatilization from Spills and Land Dumping

The MPCA estimates that large quantities of mercury are in use in Minnesota, and that a portion that is removed from service each year (8%) is spilled, and that 5% of the mercury that is spilled volatilizes:

Table 11

Year	Hg in use (lb)	Hg removed from use (lb)	Spilled (%)	Hg volatilized (lb)
1990	190,000	13,667	8.0	54.7
1995	160,000	12,000	8.0	48.0
2000	130,000	12,000	8.0	48.0
2005	70,000	6,000	8.0	24.0

It may appear unlikely that such large amounts of mercury are being removed from use, yet these estimates are supported by mercury content of the solid waste stream, as quantified by stack tests at solid waste incinerators. Based on stack tests, the solid waste stream contained at least 16,000 lb. of mercury in 1990, 5,000 lb. in 1995, and 4,000 lb. in 2000. Although it is likely that more mercury was properly disposed of after 1990, it also seems likely that as long as mercury is in use, it will be accidentally spilled and volatilized.

12. Landfill Volatilization

0.1% of mercury in 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. (Lindberg, S. E.; Price, J. L. Airborne emissions of mercury from municipal landfill operations: a short-term measurement study in Florida. *J. Air & Waste Manage. Assoc.* 1999, 49, 520–532.) See table in Note 9 for calculations.

13. Volatilization: Land Application of Compost

See table in Note 9 for calculations.

Proportional to Hg Content of Liquid Waste

14. Volatilization: Land Application of Sludge

After correcting for the water content, about 50,000 dry tons of sewage sludge are land applied in Minnesota each year. This estimate assumes that 1% of the mercury applied to the surface of the land volatilizes within a year, but does not attempt to calculate any carryover from previous years. The mercury content of the sludge has been declining over time. Sludge averaged 3.6 ppm of mercury in 1990, 1.8 ppm in 1995, 1.4 ppm in 2000, and 0.7 ppm in 2005. Future emissions from land-applied sludge are projected to decrease by 50% by 2018 because of continued efforts to reduce mercury discharge to sanitary sewers, especially by dentists.

Recycling Activities

15. Shredders and Smelters That Recycle Cars and Appliances

Mercury is released by the recycling of cars and major appliances because of the presence of mercury switches in some of these products. There are several shredding facilities in Minnesota that process vehicle and appliance scrap, including Gerdau Ameristeel, Schwartzman Co. and Bay Side Recycling Corp. Emissions from shredders have only been characterized at one Minnesota facility (Gerdau Ameristeel, 10 lb./year) and further study is needed to identify all facilities and characterize their practices. In 2007 Gerdau processed the equivalent of 64% of the vehicles retired in Minnesota.

There is one electric arc furnace (EAF) mini-mill in Minnesota that melts steel from recycled cars and appliances, Gerdau Ameristeel, formerly North Star Steel. In the national TRI, Gerdau Ameristeel reported emissions of 255.3 lb. for 2005, which the MPCA believes overestimates true emissions because (a) it was based on a 1999 stack test when vehicles contained 15% more mercury switches and (b) the stack test was extrapolated to the total number of hours the bag houses were running rather than the hours that melts of scrap metal occurred — the bag house fans were left on when mercury was not being volatilized. Adjusting for just the hours that the melting was occurring, total facility emissions for 2005 are now estimated to have been 138.7 lb., including 10 lb. from the shredder. While 138.7 may be a 15% overestimate (21 lb.) for Gerdau facility alone because it is based on the 1999 stack test, 138.7 may be a fair 2005 estimate for Minnesota as a whole when including emissions from other shredders, and so that number is used as a statewide estimate.

Data from the National Vehicle Mercury Switch Recovery Program (NVMSRP) project a 59% decline in the quantity of mercury switches in the autos that are retired in Minnesota from 2005 to 2018, and 89% decline from 2005 to 2025 (Figure 1).

A 59% decline in mercury switches alone would imply that state-wide emissions would be 56.9 lb. in 2018 and 15.3 lb. in 2025. However, the recent Electric Arc Furnace NESHAP Area Source Rule for mercury, which includes the National Vehicle Mercury Switch Recovery Program (NVMSRP) goal of 80% removal of switches from vehicles *prior to shredding*, means that statewide emissions are projected to be 24.1 lb. in 2010, 11.4 lb. in 2018 and 3.1 lb. in 2025 (Table 13).

Future emissions are projected to decline from a combination of (1) reduced mercury in auto scrap due to the NVMSRP and, and (2) a parallel reduction in the number of switches in other scrap because the use of switches in appliances, such as washing machines, gas ovens, freezers and residential boilers, was halted. The NVMSRP effort is scheduled to end on a national basis after 2017, when 90% of the switches originally installed in vehicles are projected to have retired. Figure 1 shows the estimated amount of mercury in vehicles available for recovery in Minnesota, the estimated amount contained in Gerdau Ameristeel's annual input, and the effect of 80% recovery under the NVSMRP.

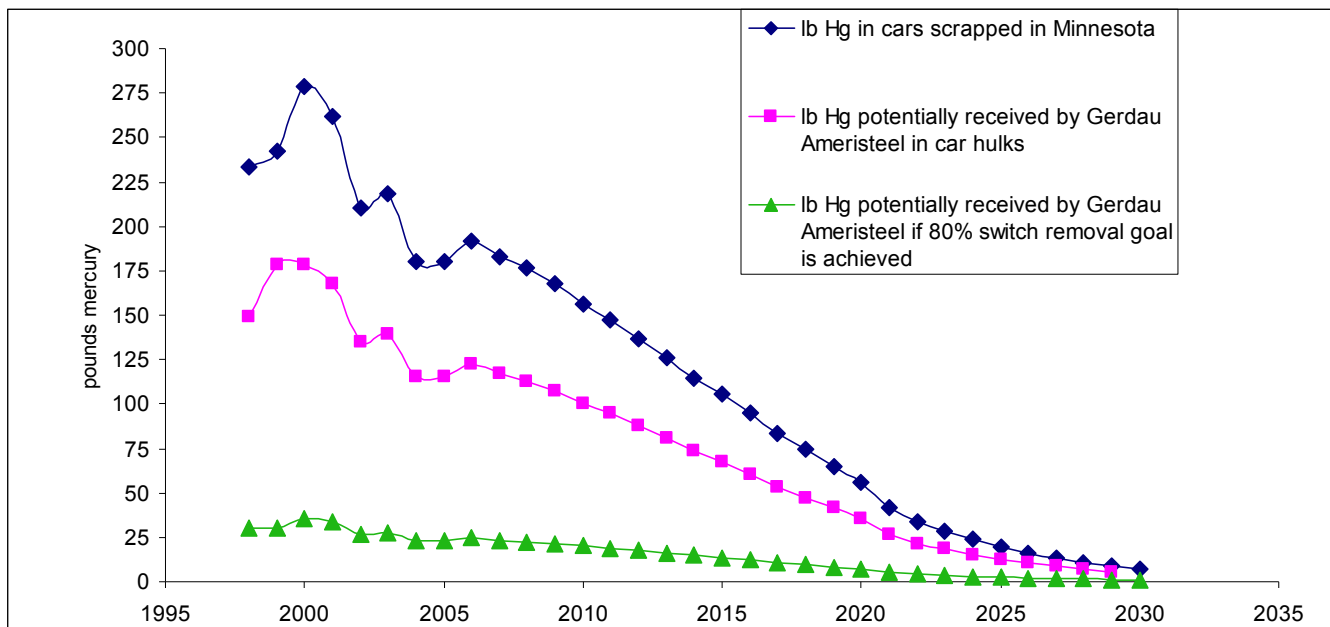


Figure 1 Modeled calculations of the mass of mercury available for recovery from vehicles retired each year in Minnesota and contained in vehicle scrap inputs to Gerdau Ameristeel. The source of the data is NVMSRP Measurement Subcommittee, assuming that Gerdau Ameristeel receives 64% of vehicles retired in Minnesota. Data, supporting information and references are available at www.elvsolutions.org/model.html. Switch retirement forecasts are based on several sources, including Polk vehicle registration data, vehicle population and retirement studies and models from the Federal Reserve Bank, the Department of Energy, the Society of Automotive Engineers, and the Michigan Mercury Switch Study.

Table 12

Year	Lb Hg in cars scrapped in Minnesota	Lb Hg potentially received by Gerdau Ameristeel in car hulks	Lb Hg potentially received by Gerdau Ameristeel if 80% switch removal goal is achieved	Statewide Hg emissions (lb) reflecting switch decline and 80% removal after 2008
2000	278.3	178.1		
2005	180.1	115.2		138.7
2010	156.6	100.2	20.0	24.1
2018	74.2	47.5	9.5	11.4
2025	19.8	12.7	2.5	3.1

16. Recycling Mercury from Products Within Minnesota

It is difficult to estimate the emissions associated with recycling mercury in Minnesota because it is unclear what the emission factor is for recycling mercury. This estimate was made in the late 1990s by Brian Golob, who at the time was employed by one of the three mercury recycling companies in Minnesota. Future emissions from mercury recycling are projected to increase by 25% by 2018 because of increasingly aggressive efforts to remove mercury from use and recycle it.

17. Non-ferrous Metal Recycling (Al, Pb)

These emissions are calculated by the MPCA air emission inventory staff:

0.55	Industrial Processes	Secondary Metal Production	Aluminum	Burning/Drying
0.36	Industrial Processes	Secondary Metal Production	Lead	Blast Furnace (Cupola)
0.91	Total			

Dental Mercury

18. Dental Preparations

Dentists have used mercury amalgam for over 150 years in the United States. Mercury amalgams typically contain between 42 and 50% mercury. The mercury employed in the amalgam has a variety of pathways to the atmosphere, including direct volatilization during preparation in the dental office, from the patient’s mouth, after removal in the dental office, during transit in wastewater pipes, from sewage sludge, from crematoriums, and a variety of more subtle pathways. In this estimate, the MPCA includes direct volatilization from the dental office, from the consumer, and during transit in wastewater pipes, but excludes all other pathways, which are included in other emission categories. The MPCA based the estimates on information in the report *Substance Flow Analysis of Mercury in Products* (August 2001, www.pca.state.mn.us/air/mercury-mn.html#publications). However, the MPCA reduced volatilization during transit from 10 to 5%, although no data on the subject are presently available. 2005 projections are based on data from Cain et al. 2007, using the MPCA assumptions that transit loss is 5% and that otherwise Minnesota can be estimated as 2% of national figures.

Table 13

	1990	1995	2000	2005	2018
Dental office (lb)	46.2	46.2	46.2	31.8	15.9
Customer breathing (lb)	11	12.1	13.2	6.4	3.2
Transit loss (lb)	46.2	40.7	35.2	24.2	1.0
Total Emissions (lb)	103.4	99	94.6	62.4	20.1

19. Crematories

Cremation can release significant quantities of mercury because of the mercury amalgam that is present as dental fillings, and cremation probably releases all of this mercury to the atmosphere. The MPCA estimates for this source are based on calculations presented in Substance Flow Analysis of Mercury in Products (August 2001, www.pca.state.mn.us/air/mercury-mn.html#publications), which calculates that an average of 2.63 grams of mercury are emitted per cremation. Cremations are expected to significantly increase in the future and the number of mercury fillings in people’s teeth will decline after about 2025 due to better dental care (Fig. 2). Therefore emissions to the atmosphere are projected to increase until about 2025 before declining (Fig. 3).

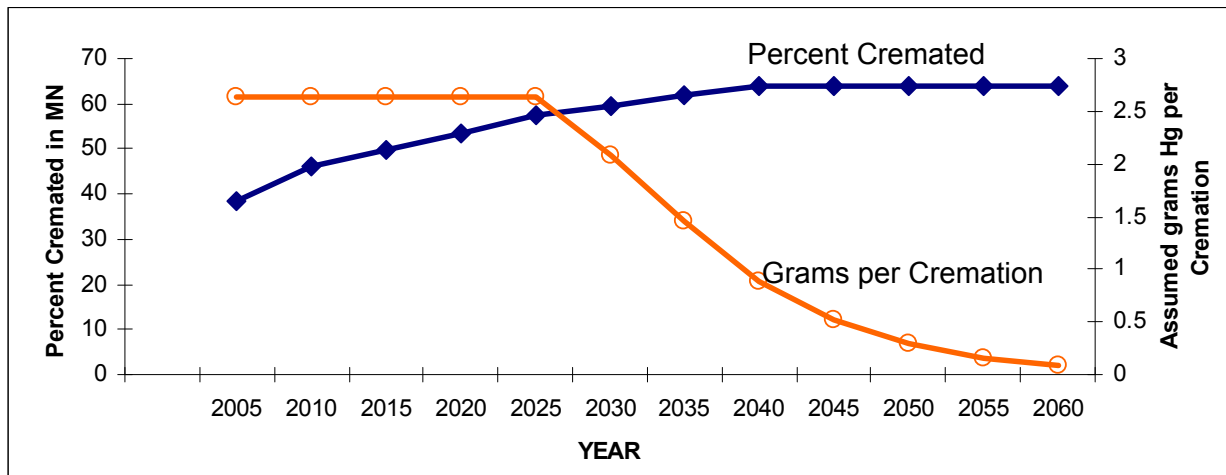


Figure 2

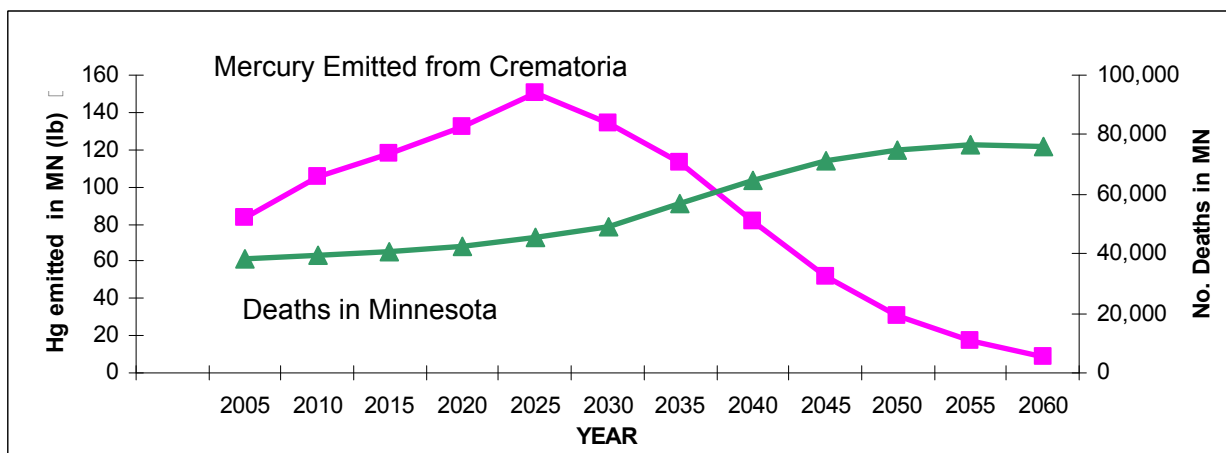


Figure 3

Table 14

Year	MN Hg cremation emissions (lb)	% Cremated in MN	Deaths in MN	Assumed g Hg per cremation	Change in Hg from 2005 (Brown et al. 2002)
2005	83	38	38,200	2.63	
2010	105	46	39,400	2.63	
2015	118	50	40,800	2.63	
2020	133	54	42,800	2.63	
2025	151	57	45,400	2.63	
2030	134	60	49,200	2.08	-21%
2035	113	62	57,000	1.45	-30%
2040	81	64	64,800	0.89	-39%
2045	52	64	71,000	0.52	-42%
2050	31	64	75,000	0.29	-44%
2055	17	64	76,400	0.16	-46%
2060	9	64	76,000	0.08	-48%

Notes:

Brown, L. J., Wall, T. P., and Lazar, V. 2002. Trends in caries among adults 18 to 45 years old. *J. American Dental Assoc.* 133:827-834

Bold numbers are from literature, others are interpolated.

CANA (Crematoria Association of North America) predicts that the national cremation rate will reach 64% in 2040, which may be an underestimate for Minnesota, which in the past has exceeded national rates by about 7%.

Incineration

20. Municipal Solid Waste Combustion

The mercury emissions in the following table are based on stack tests submitted to the MPCA

Table 15

Facility	Unit	Lb emitted
Mayo Waste Management Facility	Pathological Waste Incinerator	0.033
Xcel Energy - Key City/Wilmarth	Boiler #1 (with CE 001 scrubber and CE 002 baghous	1.814
	Boiler #2 (with CE 003 scrubber and CE 004 baghous	1.826
Xcel Energy - Key City/Wilmarth	MSW Incinerator Unit 1	0.216
Pope/Douglas Solid Waste Management	MSW Incinerator Unit 2	0.132
Xcel Energy - Red Wing Generating Plant	Boiler 1	5.310
Xcel Energy - Red Wing Generating Plant	Boiler 2	5.060
Red Wing Solid Waste Boiler Facility	Left and Right Incinerator and Common Auxiliary Bu	1.336
Covanta Hennepin Energy Resource Co LP	MSW Incinerator	5.360
Covanta Hennepin Energy Resource Co LP	MSW Incinerator	4.471
Enviro-Chem Inc - Plant 1	Recovering Metals	0.010
Enviro-Chem Inc - Plant 1	Recovering Metals	0.010
Enviro-Chem Inc - Plant 1	Recovering Metals	0.010
Enviro-Chem Inc - Plant 1	Recovering Metals	0.010
Olmsted Waste-to-Energy Facility	Municipal Waste Combustor Unit #1	1.785
Olmsted Waste-to-Energy Facility	Municipal Waste Combustor Unit #1	0.000
Olmsted Waste-to-Energy Facility	Municipal Waste Combustor Unit #2	0.524
Olmsted Waste-to-Energy Facility	Municipal Waste Combustor Unit #2	0.000
Perham Resource Recovery Facility	South MSW Incinerator	10.590
Fergus Falls Resource Recovery Facility	MSW Incinerator 1	2.522
Fergus Falls Resource Recovery Facility	MSW Incinerator 2	0.853
Polk Cnty Solid Waste Resource Recovery	Incinerator 1	2.262
Polk Cnty Solid Waste Resource Recovery	Incinerator 2	1.184
Polk Cnty Solid Waste Resource Recovery	Dump Stack for Incinerator 1	0.004
Polk Cnty Solid Waste Resource Recovery	Dump Stack for Incinerator 2	0.004
Great River Energy - Elk River	Unit 1 Boiler	0.460
Great River Energy - Elk River	Unit 2 Boiler	0.460
Great River Energy - Elk River	Unit 3 Boiler	0.723
Verso Paper Co - Sartell Mill	B & W Boiler	2.302
	Total	49.239

Perham experienced a malfunction of pollution control equipment in 2005, which allowed an unusual amount of mercury to be emitted. Projections after 2005 assume that Perham emits 2.0 lb./year.

The Olmsted facility has a permit to expand, and construction is underway in 2008. The Olmsted expansion is expected to increase mercury emissions at the facility by approximately 1.0 lb./year.

21. Sewage Sludge Incineration

Sewage sludge contains mercury from a variety of wastewater sources. There are two sludge

incinerators in Minnesota, the Metropolitan Plant, and the Seneca Plant. Based on data provided by the Metropolitan Council, the MPCA estimates that 247 lb. of mercury were emitted in 1990, 160 lb. in 1995, 112 lb. in 2000, and only 8.5 lb. in 2005. In late 2004 a new incinerator with about 97% mercury-control efficiency began operation at the Metropolitan plant (as calculated by Balogh and Nollet, 2007, Sci Total Environ. Mercury mass balance at a wastewater treatment plant employing sludge incineration with offgas mercury control.) In September 2007 the Buffalo Wastewater Treatment Plant (Buffalo, Minn.) received an amended permit to construct a sewage sludge incinerator that will control mercury emissions with activated carbon. It is unknown what actual emissions of mercury will be from this new facility. The Air Quality Permit limits mercury emissions to 4 lb./year, but emissions are likely to be much lower. For the purpose of projecting emissions, 2 lb./year are assumed at startup in 2008. To account for increased loading and emissions due to population growth, increases of 1% per year are projected.

Table 16.

Facility	1990	1995	2000	2005	2010	2018
Metropolitan Plant	212	136	95	2.4	2.5	2.7
Seneca Plant	35	24	17	6.1	6.4	6.9
Buffalo Plant					2.0	2.2
Total emitted (lb)	247	160	112	8.5	11.0	11.8

21. Medical Waste Incineration

Emission data are based on stack tests submitted to the MPCA, as summarized in the following table.

Table 17

Facility	1990	1995	Lb Hg/ton	2000	Lb Hg emitted	2005	
	Lb Hg emitted	Lb Hg emitted		Tons burned		Tons burned	Lb Hg emitted
Mayo Foundation, Rochester	115	1	7.71E-05	5,292	0.40	5,300	0.4
Medical Safety Systems, Cannon Falls	33	25	3.10E-03	1,851	5.70	0	0.0
Small Class IV incinerators at hospitals (about 80 in 1990, 20 in 1995, 6 for part of 2000)	368	10	2.10E-04	200	0.04	0	0.0
Total mercury emitted	516	36			6.14		0.4

Notes:

After 1990, the Mayo Foundation Incinerator was replaced with a new facility that controls mercury emissions with activated carbon injection.

The Medical Safety Systems facility in Cannon Falls closed permanently in August 2000.

Most hospital (Class IV) incinerators were required to close by February 2000 due to federal regulations; those still operating in 2000 are listed below:

Table 18

Date operation ceased	Hospital
January 2000	Fairmont Community Hospital
February 2000	Worthington Regional Hospital
February 2000	St. Cloud Hospital
June 2000	Lakewood Health Center, Baudette
October 2000	NW Medical Center, Thief River Falls
November 2000	Northcountry Regional Hospital, Bemidji

23. Hazardous Waste Incineration

Minnesota has only one hazardous waste incinerator, 3M Chemolite. Based on data submissions from that facility, MPCA estimates annual mercury emissions of 5 lb. per year. 3M did not submit any data recently, and 5 lb. may be an overestimate.

23. Class IV Incinerators

Small incinerators were once commonly used at grocery stores and other small businesses to incinerate waste, largely cardboard. All of these small incinerators, of which there were about 1,000 in 1990, closed by January 1996 because of new state regulations to reduce particulate emissions. It is assumed that they mostly burned cardboard with mercury at 0.2 ppm. The MPCA estimates that Class IV incinerators burned about 138,000 tons in 1990 and 70,000 tons in 1995.

Manufacturing & Use of Non-dental Mercury-containing Products

25. Mercury Product Manufacturing in Minnesota

Mercury is released from product manufacturing processes. According to the IMERC database of mercury product manufacturers, there are three mercury product manufacturing facilities located in Minnesota. These include Anchor Scientific, Long Lake; Electro-Sensors, Inc., Minnetonka; and SJE Rhombus, Detroit Lakes. SJE Rhombus is the only facility that has filed a TRI report for mercury. This mercury-switch manufacturing facility calculates that in 2005 it emitted 42 lb. mercury (TRI report). Because of progressive bans on the sale of mercury switches in states, now totaling about 15 states including Minnesota, SJE Rhombus projects a decline in the manufacture of mercury switches. MPCA conservatively projects a decline in emissions of 25% by 2018. The other two facilities have not filed TRI reports for mercury releases. Further information is needed.

In addition to these three companies, there is a neon lamp industry in the state, a product line that utilizes mercury. FMS Corporation (FMSneon.com, Minneapolis) manufactures a wide variety of neon sign components for national and international distribution, and in addition there are a number of small businesses engaged in neon lamp manufacturing for artistic and commercial applications. Use and emissions of mercury in this sector have not been studied and warrant further investigation.

26. General Laboratory Use

Chemical laboratories have traditionally used mercury for a variety of uses, including physical measurements and chemical analyses. The EPA Mercury Report to Congress (1997) estimated that in 1995, 2,200 lb. of mercury were volatilized from laboratories nationally. Given that Minnesota represents 2% of all economic activity nationally, the MPCA estimates that 44 lb. of mercury were emitted in 1990 and 1995, that this source declined to 22 lb. by 2000, 10 lb. by 2005, and 5 lb. by 2018. The decline is projected to occur as a result of continued education.

27. Volatilization from Dissipative Use

“Dissipative use” is the consumption of mercury in products that are meant to be used and absorbed into the environment, such as fungicides and preservatives. The largest use of mercury in this category was mercuric compounds used as a preservative in latex paints, a practice that was discontinued in 1992. Mercury was legally used in some cosmetics as a preservative (up to 65 ppm) until a Minnesota law banned the sale in January 2008.

Emissions Incidental to Material Processing

28. Taconite Processing

In Minnesota, the iron in taconite ore is concentrated and marble-size pellets are baked, or indurated, for ease of handling before they are shipped for smelting outside of the state. Induration volatilizes virtually all of the mercury that is present in the concentrate. For this volatilization estimate, emission factors (lb. per million long ton) are calculated from Jiang et al., 2000 (“Mercury Emissions from Induration of Taconite Concentrate Pellets – Stack Testing Results from Facilities in Minnesota.” A presentation at the U.S. Environmental Protection Agency conference, Assessing and Managing Mercury from Historic and Current Mining Activities, San Francisco, Calif., November 28-30, 2000.).

Table 19

Facility	2005	2010	2018
Northshore Mining Co - Silver Bay	7.3	7.3	7.3
US Steel Corp - Minntac	185.3	185.3	185.3
United Taconite LLC - Thunderbird Mine	1.1	1.1	1.1
Northshore Mining Co - Babbitt	0.1	0.1	0.1
Hibbing Taconite Co	227.1	227.1	227.1
Ispat Inland Steel Mining - Minorca	33.4	33.4	33.4
US Steel - Keewatin Taconite	146.9	105.8	105.8
United Taconite LLC - Fairlane Plant	133.6	133.6	133.6
Minnesota Steel Industries (MSI)	0.0	77.0	77.0
Mesabi Nugget	0.0	70.0	70.0
Total	734.8	840.6	840.6

Note: Keewatin Taconite had pollution-control equipment installed in Oct 2005, which reduces Hg emissions by 28% after 2005

The following mining projects that have the potential to emit mercury have been proposed but have not yet received a permit (and are not included in the emission calculations):

Table 20

Project	Type	Start-up date	Potential Hg emissions (lb)	Status
Polymet	Mining	2012	8	Env. Review
Keetac expansion	Mining	2013 est.	49 est.	Announced
Mesabi Nugget II	Mining	?	?	Announced

29. Thermal Treatment of Soil

An average of 5,000 tons of surface soil are heated annually in Minnesota to remove organic contaminants as a method of soil remediation. A concentration of 0.08 ppm of mercury is assumed in the soil, and it is assumed that all of the mercury in the soil is emitted to the atmosphere, releasing about 0.8 lb.

Difficult to Categorize (Is the mercury from fuel or materials?)

These four subcategories, totaling about 25 lb., are new to the mercury emission inventory, appearing as output from the MPCA's air toxics emission inventory. MPCA staff will investigate these categories to determine if emissions are mostly associated with energy consumption or material processing. With that knowledge, it may be appropriate to reassign the emissions to one of the three major categories above, resulting from Energy, Purposeful Use, or Material Processing. In addition, it may be possible to project time trends.

30. Asphalt Manufacturing

This category was responsible for the emission of 4.3 lb. of mercury in 2005, based on U.S. Environmental Protection Agency (U.S. EPA) emission factors from plants that prepare hot asphalt. In the plants tested by the U.S. EPA, it is not clear whether the mercury originated in the raw materials or the fuel that was used to heat the materials. With further investigation, it should be possible to assign these emissions to either of two major categories in this mercury emission inventory, Incidental to Energy Production or Emissions Incidental to Material Processing.

31. Agriculture, Food and Kindred Products

This category was responsible for the emission of 1.1 lb. of mercury in 2005, based on U.S. EPA fugitive emission factors for activities classified under SCC code 30288801, which is usually applied to facilities that handle grain. With further investigation, it should be possible to assign these emissions to either of two major categories in this mercury emission inventory, Incidental to Energy Production or Emissions Incidental to Material Processing.

32. Mineral Products

This category was responsible for the emission of 13.8 lb. of mercury in 2005, based on U.S. EPA emission factors for activities classified under SCC codes 30588801 (fugitive dust emissions, 10.0 lb.), 30501049 (wind erosion, 2.41 lb.), and 30500311 (firing of bricks, 1.42 lb.). With further investigation, it should be possible to assign these emissions to either of two major categories in this mercury emission inventory, Incidental to Energy Production or Emissions Incidental to Material Processing.

33. Miscellaneous Industrial Processes

This category was responsible for the emission of 0.2 lb. of mercury in 2005, based on U.S. EPA emission factors for activities classified under SCC code 39999999, for miscellaneous industrial processes.

34. Wood, Pulp and Paper, and Publishing Products

This category was responsible for the emission of 5.1 lb. of mercury in 2005, based on U.S. EPA emission factors for activities classified under SCC code 30700104 (emissions from Boise Cascade recovery furnace, 3.6 lb.), SCC code 30701010 (Oriented strandboard rotary dryer, 1.1 lb.), and SCC code 30700106 (Lime Kiln, 0.4 lb.). With further investigation, it should be possible to assign these emissions to either of two major categories in this mercury emission inventory, Incidental to Energy Production or Emissions Incidental to Material Processing.