

3.2 The Need for Mercury Emissions Reduction

Mercury is a naturally occurring metallic element and a potent neurotoxin.¹ Even small quantities of mercury in fish consumed by a pregnant woman can impair the neurological development of her fetus.² Young children are also vulnerable to mercury exposure, and it can create health risks for adults. Nationwide, mercury is the most common cause for state health departments to issue advisories warning against unrestricted consumption of certain locally-caught fish. All of the Great Lakes states have statewide fish consumption advisories for mercury. Mercury contamination problems are, in many cases, more serious in the inland lakes and rivers of the Great Lakes states than in the Great Lakes themselves [need source]. Moreover, mercury is a problem beyond the Great Lakes states; the highest mercury exposures result from consumption of seafood. In addition to exposure through eating contaminated fish, people can be poisoned by breathing mercury vapors. Mercury vapor can sometimes reach dangerous levels when mercury is spilled indoors; exposure to mercury vapor outdoors is not considered a significant risk in most circumstances.³

Scientists have determined that in many locations, including the Great Lakes, atmospheric deposition is the primary pathway by which mercury enters surface waters.⁴ Mercury is released into the air through both human activities and natural processes, and is eventually deposited into surface water and onto the land. Mercury emissions can travel long distances; while some emissions will deposit locally, some mercury emissions can remain in the atmosphere for six months or more, traveling around the globe. Mercury does not degrade, and it is not destroyed by combustion. In addition, it persists in the environment and bioaccumulates in the aquatic food chain, particularly in the organic form--methylmercury.

A number of factors affect the levels of mercury in fish, other than the mercury concentrations in the water. Water chemistry, sulfate deposition, and bacterial activity powerfully influence the amount of that methylates (and demethylates) in a water body; the trophic structure of the fishery, ecological factors, and fishing practices influence the degree to which methylmercury will bioaccumulate. As a result, it is frequently difficult to attribute temporal trends or spatial patterns in mercury fish concentrations to levels of mercury emissions and deposition. Nonetheless, scientists have concluded that, holding other factors constant, increased mercury deposition resulting from anthropogenic mercury emissions raises mercury concentrations in fish. The world expert panel titled, "Recovery of Mercury-contaminated Fisheries," assembled for the 2006 Mercury as a Global Pollutant Conference stated that, "The main conclusion drawn is that changes in mercury loading (increase or decrease) will yield a response in fish

¹ U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development. Mercury Study Report to Congress, Volume V: Health Effects of Mercury and Mercury Compounds; EPA-452/R-97-007 (December 1997).

² Water Quality Criterion for the Protection of Human Health: Methylmercury; EPA-823-R-01-001, EPA-823-R-01-001, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, January 2001.

³ U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development. Mercury Study Report to Congress, Volume VII: Characterization of Human Health and Wildlife Risks from Mercury Exposure in the United States; EPA-452/R-97-009 (December 1997), p 5-2, and National Institutes of Health, Office of Research Facilities, Development and Operations, "Mercury Health Hazards" (website), <http://orf.od.nih.gov/Environmental+Protection/Mercury+Free/MercuryHealthHazards.htm>.

⁴ U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development. Mercury Study Report to Congress, Volume III: Fate and Transport of Mercury in the Environment; EPA-452/R-97-005 (December 1997), p. 3-1.

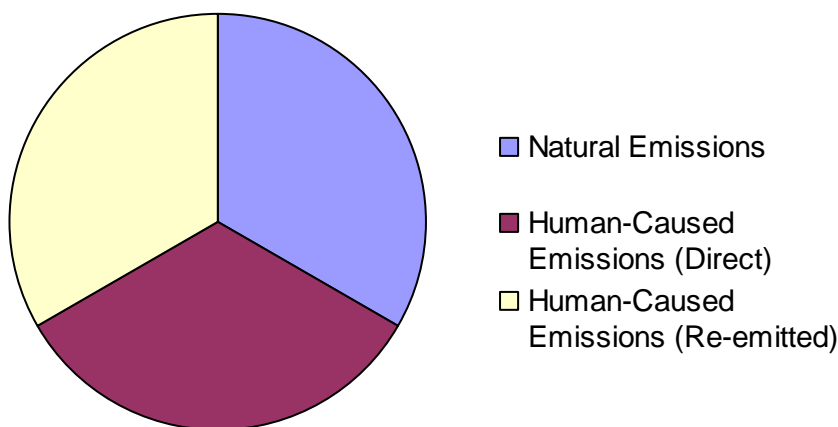
methylmercury, but that the timing and magnitude of the response will vary depending on ecosystem-specific variables and the form of the mercury load" (Munthe, et al., 2007). Other published studies have confirmed that increased atmospheric deposition of mercury will lead to an increase in methylmercury concentrations in fish (Harris, et al., 2007; Watras, et al., 2002 and 2006).

3.3 Sources of Mercury Emissions and Deposition to the Great Lakes Basin

3.3.1 Sources of Mercury in the Global Environment⁵

Mercury cycles in the environment as a result of natural and human (anthropogenic) activities. Natural sources of mercury, such as volcanic eruptions and emissions from the ocean, have been estimated to contribute about *one third* of current worldwide mercury air emissions, whereas anthropogenic emissions account for the remaining *two-thirds* (U.S. EPA, 2005d). Today, much of the mercury circulating through the environment is mercury that was released years ago, when mercury was frequently used in many industrial, commercial, and residential products and processes. Anthropogenic emissions are thought to be split roughly equally between these re-emitted emissions from previous human activity, and direct emissions from current human activity, as illustrated in Figure A. There is considerable uncertainty about how much of anthropogenic emissions are direct versus indirect.

Figure A: Contribution of Natural and Anthropogenic Worldwide Mercury Air Emissions.



Source: U.S. EPA, 2005d ⁶

Seigneur et al. (2004) compared three global emission scenarios for atmospheric mercury that varied in their distribution of background emissions of direct natural emissions and re-emissions of natural and anthropogenic mercury. For the base scenario, Seigneur assumed that 50 percent

⁵ This section is derived in large part from U.S. EPA and Environment Canada, 2006.

⁶ Website: www.epa.gov/mercury/control_emissions/global.htm

of deposited mercury is re-emitted to the atmosphere. A lower bound scenario assumed 33 percent is re-emitted, while the upper bound scenario assumed that 56 percent is re-emitted.

The global mercury budget comparison is illustrated in Table AA. Natural mercury emission estimates range from 1100 Mg/yr to 3201 Mg/yr. Natural land emissions (including re-emissions of natural mercury) range from 500 Mg/year to 1805 Mg/year (lower bound scenario), while natural emissions from oceans (including re-emissions of natural mercury) range from 600 Mg/year to 1396 Mg/year (lower bound scenario). Direct anthropogenic emissions range from 2143 to 2400 Mg/year. Re-emissions of anthropogenic mercury range from 1067 Mg/year (lower bound scenario) to 2670 Mg/year (upper bound scenario).

The ratio of current emissions to pre-industrial emissions, as well as the percentage of deposited mercury that is re-emitted from the Seigneur et al. base scenario, is consistent with Bergan et al. (1999) and Mason and Sheu (2002) values.

Table AA. Comparison of Recent Global Budgets for Atmospheric Mercury.

Emissions	Bergan et al., 1999	Mason and Sheu, 2002	Lamborg et al., 2002	Seigneur, 2004 base	Seigneur, 2004 lower bound	Seigneur, 2004 upper bound
Direct anthropogenic (Mg/year) ^c	2160	2400	4800	2143	2143	2143
Re-emitted anthropogenic (Mg/year)	2000	2090		2134	1067	2670
Natural from land ^a (Mg/year)	500	810	1000	1180	1805	878
Natural from oceans ^a (Mg/year)	1400	1300	600	954	1396	720
Total (Mg/year)	6060	6600	6400	6411	6411	6411
Re-emission/deposition (%)	50	47	NA ^b	50	33	56
Current/pre-industrial emissions	3	3.1	4	3	2	4

^a Including re-emission of natural mercury.

^b Not available.

^c Direct anthropogenic emissions of 2143 Mg/year consist of 246, 209, 176, 1138, 326, and 48 Mg/year for Africa, North America, Central and South America, Asia, Europe, and Oceania, respectively.

Source: Seigneur et al., 2004

Gustin and Lindberg (2005) estimate mercury inputs in line with those in Table AA (e.g., global emissions of 6000 to 6600 Mg/y and anthropogenic estimates of 2000 to 2400 Mg/y). However, the authors suggest that re-emission of previously deposited mercury may be greater than previously estimated. The more rapid re-emission of deposited mercury mean that there will be a

delay of many years before emissions controls lead to significant reductions in the global pool of mercury (Gustin and Lindberg, 2005).

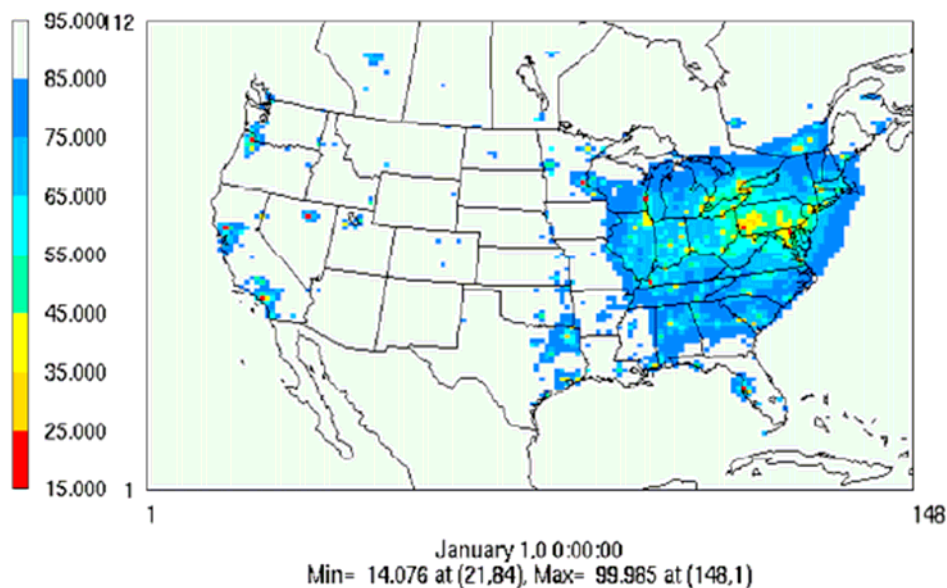
3.3.2 Sources of Mercury in Deposition in North America

The flux of mercury from the atmosphere to land or water at any one location is comprised of contributions from natural sources, human-caused activities, regional sources, and local sources (U.S. EPA, 1997). A variety of techniques can be used to estimate the relative contributions of different types of emission sources to mercury deposition at a given location. Deterministic models use an emissions inventory and model the movement of mercury in the atmosphere and the chemical reactions that influence the wet and dry deposition of mercury. These models are combined with meteorological inputs to produce estimates of total mercury deposition at a given location, as well as estimates of the mercury deposition caused by an individual source or group of sources.

USEPA utilizes two different deterministic models, the Community Multiscale Air Quality (CMAQ) model, and the Regional Modeling System for Aerosols and Deposition (REMSAD). Using CMAQ, EPA estimates that out of 144 tons of mercury deposited in the U.S., 23 tons or 16 percent, resulted from U.S. and Canadian anthropogenic mercury emissions. The remaining 84 percent, according to the model, comes from the global anthropogenic sources, natural sources, and re-emission of previously deposited mercury (U.S. EPA, 2005f).

However, these U.S. averages conceal a tremendous variation from place to place within the U.S. Figure AB shows the share of mercury deposition within the U.S. attributed to global (natural and non-U.S. or Canadian anthropogenic) sources. The places with the lowest share of deposition from the global source contribution, and therefore the highest share from the U.S./Canadian source contribution, are also the places with the highest total deposition. In some places, U.S. and Canadian sources account for most of the mercury deposition. Locations that are close to mercury sources, particularly to sources of reactive gaseous mercury (or oxidized mercury), which tends to deposit close to the source, are particularly likely to have high levels of mercury deposition. Waste incinerators were the largest sources of reactive gaseous mercury emissions in 1990; these emissions have subsequently been well controlled. Compliance with recently promulgated and forthcoming mercury rules is expected to reduce future U.S. deposition caused by U.S. sources, particularly in areas of highest deposition.

Figure AB: **Percent of Total Mercury Deposition Attributable to Global Sources: 2001.**



Source: U.S. EPA, 2005g

It is important to remember, in reviewing these results, that there are many uncertainties in both inputs and in the models themselves. Moreover, the model results may understate variation from place to place in local source contribution. The CMAQ modeling produces results averaged across 36 kilometer square grid cells, but there may be a large variation in actual deposition within a grid cell.

Previous U.S. EPA estimates had found a much larger contribution from domestic sources. According to the 1997 EPA Mercury Study Report to Congress, 60 percent of mercury deposited in the U.S. originated from anthropogenic mercury emissions within the U.S. The remaining 40 percent came from the global reservoir, which includes anthropogenic, natural and re-emitted sources. The downward revision in the estimate of the impact of U.S. sources on mercury deposition results in part from decreases in U.S. emissions, particularly the dramatic reduction in emissions of oxidized mercury from incinerators. The revised estimate also is based on a revised understanding of global emissions and of mercury behavior in the atmosphere, and from the use of a more sophisticated model.

Seigneur et al. (2004) utilized a deterministic model to estimate that North American anthropogenic sources contribute 30 percent to the total mercury deposition over the continental U.S.; other anthropogenic emission sources contribute 37 percent (with Asia contributing the most at 21 percent), while natural emissions account for the remaining 33 percent. This average conceals significant spatial variation; at selected receptors, the estimated contribution of North American anthropogenic emissions ranged from 9 to 81 percent. Seigneur et al. (2003) suggest that current models of the atmospheric fate and transport of mercury may overestimate the local and regional impacts of some anthropogenic emission sources. Therefore, according to Seigneur, the calculated contributions of anthropogenic North American emissions are likely to represent upper bounds of actual contributions.

Swain and Engstrom (1997) used sediment cores to measure mercury concentrations and assess deposition trends in eight lakes in rural Minnesota (four in the eastern portion and four in the western part of the state) and four urban lakes in western Minneapolis, Minnesota. They compared these deposition trends with trends derived from assessment of sediment cores in Alaska lakes. The study concluded that mercury deposition has declined slightly in the upper Midwest since peaking in the 1960s and 1970s, but that mercury deposition caused by globally-transported mercury has continued to increase. The decreased deposition observed in the Midwest was most likely triggered by reduced emissions from regional sources of mercury. The investigators estimated that roughly 40 percent of mercury deposited in the Midwest was from “regional anthropogenic contributions,” with 30 percent from “global anthropogenic emissions” and 30 percent from natural sources.

A 2006 study by scientists at the University of Michigan and U.S. EPA estimated the contribution of local and regional sources to mercury deposition in Steubenville, Ohio (in the Ohio River Valley, outside of the Great Lakes basin), using receptor modeling (Keeler, 2006). Receptor modeling, unlike deterministic modeling, begins with sampling of wet mercury deposition at a monitoring site, then combines measurements of trace elements and major anions with a multivariate statistical model and air mass trajectory analysis to assess the source of the mercury to the monitoring site. The Steubenville study utilized daily event-based wet deposition sampling and two different multivariate statistical models. It found that mercury deposition to this location was dominated by nearby sources, particularly coal combustion sources. Coal combustion sources were estimated to contribute 69-73 percent of deposition, while iron and steel production (or, in one model, nickel, iron and steel production) contributed 6-12 percent. In one model, incineration sources were estimated to contribute 12 percent of mercury deposition, while in the other, incinerator sources did not contribute significantly to mercury deposition. The Steubenville site is within 50 km of five large coal-fired electric utility boilers and within 100 km of 17 such boilers, and is also near to several steel production facilities.

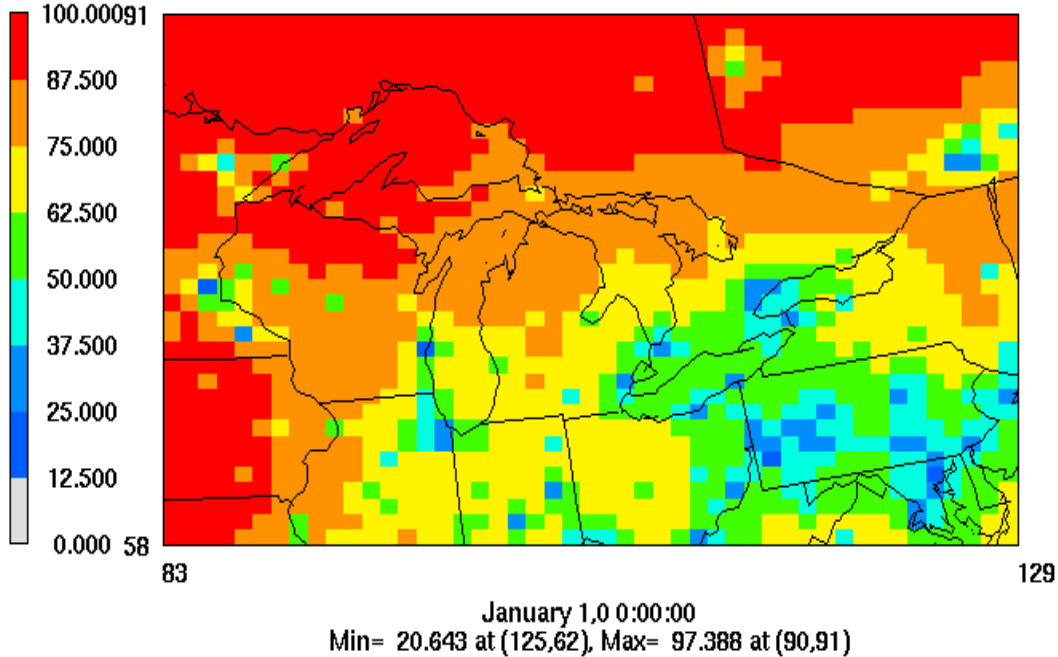
3.3.3 Mercury Deposition to the Great Lakes Region

U.S. EPA modeling using the CMAQ modeling system shows that the share of mercury deposition to the Great Lakes region resulting from sources outside of North America varies greatly, and is higher in the upper lakes than in the lower lakes. Figure AC shows that the non-U.S./Canada share for deposition to most of Lake Superior is estimated to be more than 87.5 percent. By contrast, the non-U.S. share of deposition to Lake Erie is less than 62.5 percent. CMAQ is a three-dimensional air quality model designed to estimate pollutant concentrations and depositions over large spatial scales (e.g., over the Great Lakes Basin). Because it accounts for spatial and temporal variations as well as differences in the reactivity of mercury emissions, EPA considers CMAQ to be the best available model for evaluating regulations which result in mercury deposition (US EPA, 2005c). The modeling shown in Figure AC is based on the 1999 U.S. emissions inventory, updated with 2002 data for medical waste incinerators, along with inventory data for Canada.

Figure AC: Percent of CMAQ Mercury Deposition from Non-U.S./Canada Sources

Layer 1 $100 \cdot (\text{TDEP_HGj} - \text{TDEP_HGk}) / \text{TDEP_HGj}$

j=CCTM_04nov04.yearsum.dep.2001, k=cmp5_2001ae_hg_bcon_us36b.yearlysum.dep



Source: CMAQ Version 4.3 with Mercury, May 2005

U.S.EPA used another deterministic model, REMSAD, to evaluate mercury deposition within each of the lower 48 states, based on 2001 emissions. For each state, the location where within-state sources contributed the most mercury deposition was determined. The model then showed the percentage of mercury deposition at that location caused by sources within the state, within neighboring states, within non-neighboring states within the United States, within Canada and Mexico, by “background” sources (natural sources and anthropogenic sources outside of North America) and by re-emissions of previously-deposited mercury. The results of this exercise for each of the Great Lakes States are summarized in Table BB. It is important to note that these results represent the location of maximum mercury deposition caused by within-state sources, and that they do not reflect state-wide averages. In some cases, but not all, the location of maximum deposition was within the Great Lakes basin. (ICF International)

	Within-state	Neighboring States	Other U.S.	Canada/Mexico	Background	Re-emissions
NY	45.6	4.7	10.3	5.7	32.2	1.5
PA	89.8	1.6	1.2	0.1	9.2	0.4
IL	56.3	5.8	3.7	0.1	32.6	1.4
IN	56.7	7.5	3.4	0.1	35.3	1.9
MI	61.7	3.2	3.4	2.0	28.4	1.3
MN	55.4	0.4	3.3	0.2	39.2	1.5

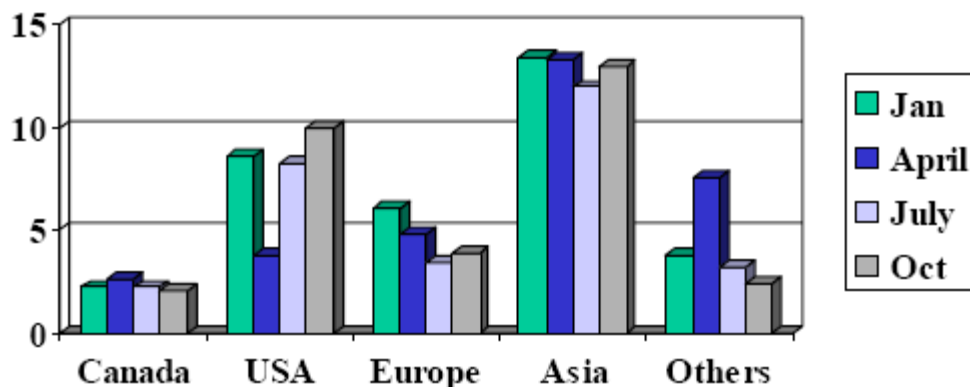
OH	42.2	10.2	4.5	0.2	45.7	3.1
WI	50.9	2.3	3.5	0.1	41.6	1.6

Table BB shows that there is considerable variation among states in the share of mercury deposition contributed by within-state sources at the site of maximum impact of these sources, ranging from nearly 90 percent in Pennsylvania to 42 percent in Ohio. In each Great Lake state, the combined impact of sources within the state and neighboring states was more than 50 percent at the site of maximum deposition impact of within-state sources. In every state except Pennsylvania, background sources and sources in Canada and Mexico accounted for at least 30 percent of deposition at these sites of maximum within-state impact.

The Meteorological Service of Canada (MSC) has utilized another model-- the global/regional atmospheric heavy metals model (GRAHM)-- to evaluate the sources of mercury deposition and atmospheric mercury concentrations (Dastoor and Larocque). Ashu Dastoor of MSC has provided the Great Lakes Binational Toxics Strategy mercury workgroup with this model's estimation of the impacts of global sources on the Great Lakes (Dastoor 2004 and Dastoor 2005) Figure BC shows the seasonal contributions from the different continents to surface air elemental mercury concentrations over the Great Lakes. Seasonal differences are noticeable. For example, while Asian contributions are the highest overall, during April, contributions from the 'others' category, which includes sources in the southern hemisphere, are high.

Figure BC: Percentage Contributions to Surface Air Elemental Mercury Concentrations Over the Great Lakes.

Percentage Contributions to Surface Air Elemental Mercury Concentrations over the Great Lakes

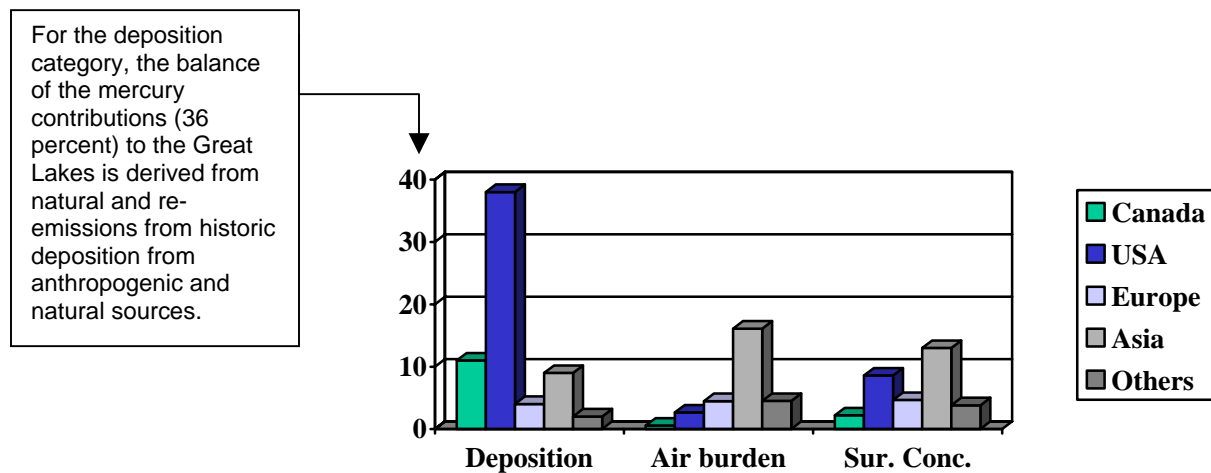


Note: "Others" is defined as other regions of anthropogenic emissions such as all Southern hemispheric emissions.

Source: Dastoor, 2004

Figure BD shows annual average contributions from global sources to the deposition, air burden [need to find definition for “air burden”] and surface air concentrations of mercury over the Great Lakes. This graph illustrates the importance of differences in contributions from global sources in different media. For example, contribution to the air burden is highest from Asia but deposition is highest from North American sources. The figure indicates that the largest percentage of deposition in 1995 was caused by North American emissions. However, experiments recently performed using year 2000 inventory data have determined that the contribution of mercury deposition from North American sources has decreased, while the contributions from Asia and other regions (excluding Europe) have increased (Dastoor, 2005).

Figure BD: Annual Average Mercury Contributions to the Great Lakes (1995).



Source: Dastoor, 2005

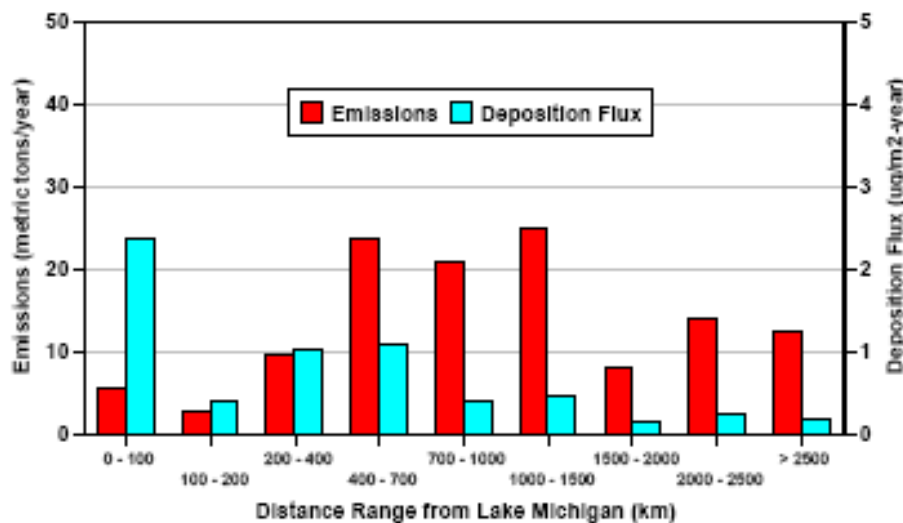
Seigneur et al. (2004) estimated that at Devil’s Lake, Wisconsin (MDN site WI31), North American anthropogenic emissions contribute 34 percent of mercury deposition with other global anthropogenic emissions contributing 40 percent, and natural emissions contributing 26 percent.

In 2007, the National Oceanic and Atmospheric Administration (NOAA) submitted a Report to Congress on Mercury Contamination in the Great Lakes (Cohen, 2007). It reported the results of atmospheric modeling of mercury emissions within the United States and Canada, including estimates of the impact of major individual sources and source sectors on mercury deposition to each of the Great Lakes. The NOAA modeling was based on 1999-2001 mercury emissions within the United States, and 1995-2000 mercury emissions within Canada, and did not estimate the impact of natural sources or global anthropogenic mercury sources.

This modeling showed that mercury emissions within the Great Lakes have a significant impact on mercury deposition to the Great Lakes. For instance, Figure CC shows estimated mercury deposition impacts to Lake Michigan, along with total mercury emissions, from North American sources at various distances from the Lake. The figure shows that the closer the emissions source, the larger the impact on a pound per-pound basis. Despite the relatively small amount of

mercury emissions from sources within 100 km of Lake Michigan, such sources had a large deposition impact. Sources within 100 km contributed more than 2 ug mercury per square meter of Lake Michigan surface area per year, according to the model; for context, total deposition flux to Lake Michigan is approximately 12.6 ug/m²/year.⁷ More distant sources contributed significantly as well, with total modeled deposition from sources between 100 to 700 km from Lake Michigan roughly equal to deposition from sources less than 100 km away. While roughly three-quarters of North American emissions occur more than 700 km away from Lake Michigan, these emissions account for only one-third of the deposition to the Lake caused by North American sources, according to the model. Similar patterns were found for Lake Erie and Lake Ontario, but a much smaller amount of mercury deposition to Lake Superior and Lake Huron is caused by sources within 100 km, because mercury emissions are much lower in the vicinity of these lakes.

Figure CC: Emissions and Deposition Arising from Different Distances from Lake Michigan



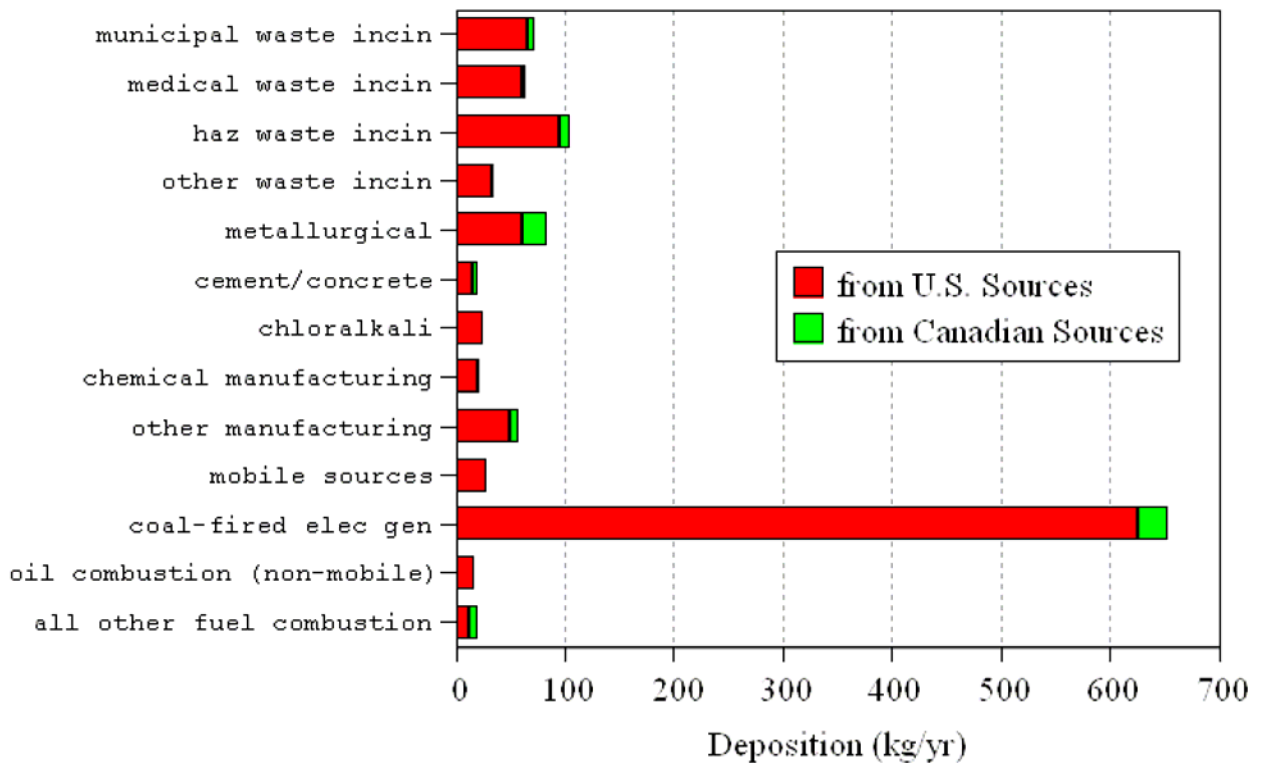
Source: Cohen, 2007, based on 1999-2001 emissions.

The NOAA Report to Congress also estimated that coal-fired power plants are the most important source sector causing mercury deposition to the Great Lakes. Figure CD shows estimated mercury deposition by source sector to the Great Lakes. Coal-fired power plants account for several times more deposition than any other source category, followed by hazardous waste incinerators, other types of waste incinerators (medical, municipal, and industrial) and metallurgical processes. The largest metallurgical contributions to the Great Lakes come from large gold mines in Nevada and Western Canada which, according to the model, have a larger deposition impact than closer but smaller metallurgical sources located within the Great Lakes states, such as taconite mines. Mercury emissions from the Nevada gold mines have been significantly reduced since the 1999 – 2001 inventory that the NOAA modeling is based on. It is important to note that the NOAA modeling is based on inventories that did not adequately quantify mercury emissions from electric arc furnaces and other facilities that melt auto scrap

⁷ Based on the finding of the Lake Michigan Mass Balance that total atmospheric loadings to the lake are 729 kg/year (see <http://www.epa.gov/glnpo/lmmb/results/loadmerc.html>), while the surface area of Lake Michigan is 57,800 square kilometers.

and other equipment that can contain mercury devices. Such facilities are the second largest source of mercury emissions after coal-fired power plants, according to the most recent inventories, but they are not a significant source in the inventories NOAA used.

Figure CD: Modeled Deposition to the Great Lakes from Different Source Sectors

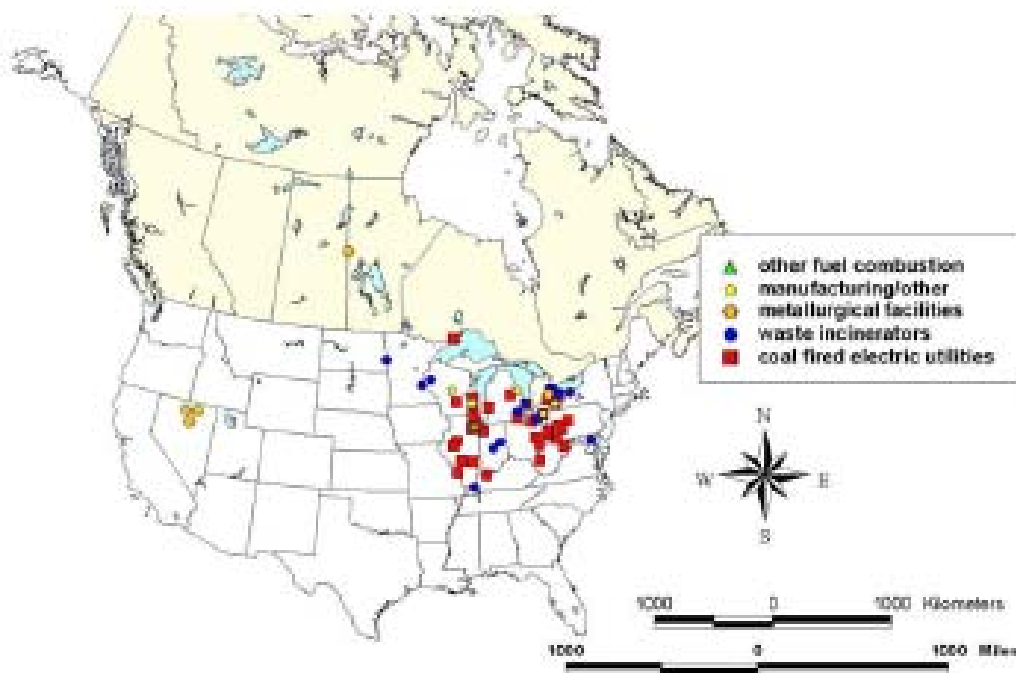


Source: Cohen, 2007, based on 1999-2001 emissions.

The NOAA study also shows the 25 individual sources that are believed to contribute the most deposition to each of the Great Lakes. These 25 largest contributors were responsible for between just over 20 percent (Lake Superior) to 40 percent (Lake Erie) of the modeled deposition from North American sources. For each of the Great Lakes, the majority of the top 25 sources are located in the Great Lakes states, and include a mixture of electric generation, incineration, metallurgical and other industrial sources. Figure CE is a map showing the

locations and source sectors of the sources that were in the top 25 for one or more of the Great Lakes.

Figure CE: Largest Modeled Contributors to the Great Lakes



3.3.4 Mercury Emissions Inventory for the Great Lakes States

The above survey of the scientific literature indicates that emissions sources within the Great Lakes have an appreciable impact on mercury deposition to the Great Lakes. A more detailed evaluation of these sources follows.

EPA compiles a National Emissions Inventory (NEI), based on state emissions inventories combined with national-level estimates. A summary of the 2002 NEI for mercury emissions in the Great Lakes States, aggregating broad source categories, is presented in Table DD. Utility boilers are by far the largest source of mercury emissions to the atmosphere in the Great Lakes states, accounting for 49 percent of total 2002 emissions. They are also the largest source of mercury emissions in each of the individual Great Lakes states except Minnesota and New York. Coal combustion at utility boilers resulted in an estimated 19.0 tons of mercury emissions in 2002; only 0.1 tons came from utility boiler oil combustion.

After utility boilers, the source sectors that account for most mercury emissions in the Great Lakes states are metals production (14 percent), waste incineration (11 percent), cement production (9 percent), non-utility fuel combustion (9 percent), and chlor-alkali production (three percent). This source sector breakout assigns hazardous waste incineration at Portland Cement

plants and lightweight aggregate kilns to the cement production category; assigning these emissions to the waste incineration category would raise this category's share of emissions to 15 percent.

Table DD: 2002 Mercury Emissions by Sector, Great Lakes States (tons)

	Great Lakes States	IL	IN	MI	MN	NY	OH	PA	WI
	Total								
Utility Boilers	19.1	3.9	2.7	1.8	0.7	0.5	3.6	4.8	1.1
Metals Production	5.4	0.8	0.8	0.5	0.6	0.1	1.3	1.2	0.1
Waste Incineration	4.4	0.4	0.1	0.1	1.6	0.7	0.1	1.3	0.1
Cement production	3.0	0.1	1.0	0.6	0.0	0.8	0.1	0.4	0.0
Non-Utility Fuel Combustion	3.5	0.5	0.4	0.4	0.4	0.4	0.7	0.4	0.4
Mercury Cell Chlor-Alkali Plants	1.2	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.5
Other	1.7	0.4	0.1	0.1	0.1	0.3	0.3	0.4	0.1
Total	38.3	6.0	5.9	3.5	3.5	2.8	6.7	8.5	2.2

These categories were derived by adding together emissions for the following NEI source categories.

--Utility boilers: Utility Boilers (coal) and Utility Boilers (oil)

--Metals production: Stainless and Nonstainless Steel Manufacturing (electric arc furnaces), Taconite Iron Ore Processing, Iron and Steel Foundries, Integrated Iron and Steel Manufacturing, and Ferroalloys Production.

--Waste incineration: Incineration (on-site commercial/institutional), Municipal Waste Combustors (small and large), Hazardous Waste Incineration (commercial), Sewage Sludge Incineration, Incineration (commercial and industrial solid waste), Hazardous Waste Incineration (on-site), Medical Waste Incinerators, Other Solid Waste Incineration.

--Cement-related: Portland Cement Manufacturing, Hazardous Waste Incineration (cement kilns), Hazardous Waste Incineration (lightweight aggregate kilns), Mineral Products (concrete batching).

--Non-Utility Fuel Combustion: Institution Boilers & Process Heaters (coal) and (oil), Residential Heating: Distillate Oil, Industrial/Commercial/ Institutional Boilers & Process Heaters - wood or waste, Industrial/Commercial/ Institutional Boilers & Process Heaters, Residential Heating (Bituminous/Subbituminous Coal), Residential Heating (Kerosene), Stationary Combustion Turbines – Oil, Residential Heating (LPG), Hazardous Waste Incineration: Liquid Fuel Boilers, Residential Heating (Anthracite Coal), Stationary Reciprocating Internal Combustion Engines – Oil, Stationary Reciprocating Internal Combustion Engines.

Source: 2002 NEI Version 3. Source categories amalgamated by authors.

Appendix Z shows a more detailed breakout of mercury emissions sectors, using NEI-designated source categories. The second-largest source category after coal-fired utility boilers is electric arc furnace steel production (3.7 tons). These emissions result from the use of mercury-contaminated scrap, as do the mercury emissions iron and steel foundries (0.5 tons). In addition, metals production results in mercury emissions from taconite production (0.4 tons) and integrated steel mills (0.3 tons).

The third-largest source in the 2002 NEI is Portland cement manufacturing (2.3 tons), which releases mercury as a result of mercury in raw materials (primarily limestone and, in some cases, coal combustion residues). Mercury emissions also results from the use of hazardous waste as a fuel in incinerators located at cement kilns (0.9 tons) and lightweight aggregate kilns (0.5 tons). The fourth-largest source is onsite waste incineration at commercial/industrial facilities (2.1 tons). There are numerous other incineration sources, including small municipal waste combustors (0.9 tons) large municipal waste combustors (0.6 tons), and commercial hazardous waste incineration (0.3 tons). The fifth-largest source is coal-fired industrial, commercial and

institutional boilers and process heaters (1.9 tons). Other significant non-utility fuel combustion sources include oil-fired industrial, commercial and institutional boilers and process heaters (0.7 tons), residential heaters using distillate oil (0.6 tons). The sixth-largest source is mercury-cell chlor-alkali plants (1.2 tons). Fluorescent lamp recycling (0.4 tons) is the only source greater than 0.3 tons not included in the categories described above.

The Michigan Department of Environmental Quality (MDEQ) and the Minnesota Pollution Control Agency have attempted to improve on the mercury emissions inventories developed under the NEI. Table DE shows estimates of mercury emissions in Michigan in 2002 according to MDEQ and to the NEI. The two inventories arrive at similar total emissions estimates for Michigan (within five percent of each other), and the two inventories both show that the largest sources in the state include coal combustion at electric utilities, cement manufacturing, various types of steel production, and various non-utility fuel combustion sources. However, there are some notable differences in some estimates, and also some areas where MDEQ estimates significant emissions but the NEI does not include an estimate. The NEI estimate for electric utility coal combustion is roughly 1000 pounds higher than Michigan DEQ's estimate, and the NEI's estimates for mercury emissions from industrial/commercial coal combustion is 270 pounds higher and its estimate for cement production is 435 pounds higher. There are also significant differences for industrial/commercial wood combustion, biosolids incineration, municipal waste combustion, and cremation. Emissions from Michigan crematories are only five pounds annually according to the NEI, which bases its estimate on emissions factors derived from a small number of emissions tests. Michigan DEQ estimates emissions of 126-189 pounds, based on a mass balance model of the fate of dental amalgam fillings. While in many (but not all) cases, the NEI estimates are higher than the MDEQ estimates, there are a number of source categories for which MDEQ estimates significant emissions but the NEI does not provide an emissions estimate. These source categories include natural gas combustion, taconite production, emissions from mercury-containing products during use and disposal, burn barrels, and remediation of contaminated sites.

Table DE: 2002 Estimates of Anthropogenic Hg Air Emissions in Michigan (pounds)

Emission Source	Michigan DEQ	NEI version 3
Coal Combustion		
Electric Utilities	2488	3477
Residential	1	0.01
Industrial/commercial	213	483
Oil Combustion		
Electric Utilities	51	51
Residential	36	51 distillate 6 kerosene
Industrial/commercial	2	23 Boilers & process heaters 1 stationary combustion turbines
Natural Gas Combustion		
Electric Utilities	9	--
Residential	95	--

Industrial/commercial	19	--
Stationary Internal Combustion	234	--
Wood Combustion		
Electric Utilities	7	--
Residential/Outdoor Wood Boilers	8	--
Industrial/Commercial	5	151
Petroleum Refining	5	0
Residential LPG Propane Combustion	4	0
Total Fuel Combustion	3177	
Biosolids Incineration	285	88 Sewage Sludge Incineration
Municipal Waste	100	179 MWCs: small 29 MWCs: large
Hazardous Waste Incineration	41	2 HWI: on-site
Hospital Waste	3	0.1 Medical Waste Incinerators
Cement Manufacturing	694	1129 Portland Cement Mfing
Taconite processing	88	0
Lime Manufacturing	73	12
Dental Amalgam Manufacturing	4	53
Brick Manufacturing	1	0.4
Coke Production	3	
Thermometer Manufacturing	0	
Medical Waste Autoclave	NA	
Blast/BOF Steel Manufacturing	396	437 Integrated Iron and Steel
EAFs-primary metal production	31	Included in EAFs below
EAFs-secondary metal production	282	432 EAFs
Secondary metal production excluding EAFs	228-237	223 Iron and Steel Foundries
EAFs & EIFs in Secondary metal production	7-28	Included in EAFs above
AREA SOURCES		
Hg Containing Products		
Dental Amalgam	141	--
Auto switch/auto shredding	117	--
Switches and relays (including thermostats)	96	--
Measurement and Control Devices	61	--
Consumer Use of Bulk Hg	20	--
Fluorescent Lamp Breakage	15	32.5
Fluorescent Lamp Recycling	4	0.01
Non-Fluorescent lamp Breakage	2	--
Waste Disposal		
Volatilization during solid waste collection and processing	887	--
Landfill volatilization	68	13
Burn Barrels	124	--
Cremation	126-189	10

Disposal of Bulk Hg to Clean Sweep Sites	7	--
Volatilization: land application of sludge	5	--
Contaminated Site Remediation	96	--
Mobile Sources	0.4-10.5	--
Emissions Categories Greater than One Pound Included in NEI but not in Michigan Inventory		
General Laboratory Activities		25
Asphalt Processing and Asphalt Roof Manufacturing		6.08
Gypsum Product Manufacturing		1.5
Total	7158-7269	6910

Source: Michigan Department of Environmental Quality and 2002 NEI.

3.3.5 Conclusion: Sources of Mercury to the Great Lakes

While there are still significant uncertainties about emissions inventories and the fate and transport of mercury in the environment, the following conclusions can be made with confidence:

- Air deposition of mercury is the primary source of mercury to the Great Lakes.
- Mercury deposition to the Great Lakes originates from both natural and anthropogenic sources, and from sources within the Great Lakes states as well as from more distant sources within North America and sources overseas.
- The share of mercury deposition caused by nearby sources varies greatly depending on location. In some cases, high mercury deposition levels occur near to significant sources, where nearby sources (within 100 km, or within the same state) are thought to account for well over half of mercury deposition. In areas of the Great Lakes basin that are more distant from concentrations of large mercury emissions sources, the contribution from nearby sources is relatively small; for instance, CMAQ modeling indicates that over most of the Lake Superior basin, all North American anthropogenic sources account for less than 12.5 percent of mercury deposition.
- The closer a mercury emissions source of a given size is to the Great Lakes, the more deposition it contributes.
- Most of the individual emissions sources that contribute most mercury deposition to the Great Lakes are within the Great Lakes states.
- Coal-fired power plants are by far the largest-emitting sector within the Great Lakes states. While there is some uncertainty in emissions estimates, there is general agreement that after coal-fired power plants, the largest sources of mercury emissions within the Great Lakes states include metals production (primarily from the use of mercury-contaminated metal scrap, but also from virgin raw materials), waste incineration, cement production, fuel combustion at non-utility stationary sources, and mercury cell chlor-alkali plants.
- Modeling indicates that coal-fired power plants within the Great Lakes states account for a significant share of mercury inputs into the Great Lakes.

- The share of mercury deposition to the Great Lakes contributed by global sources is growing, as emissions in Asia and Africa grow while emissions in North American decline.

3.4 Expected Changes in Mercury Emissions and Deposition

3.4.1 Expected Changes in Nationwide Mercury Emissions

Federal regulations and evolving technology are expected to result in changes in the mercury emissions inventory within the United States over the next decade. For some sectors, federal regulations had not been in effect as of the most recent (2002) national emissions inventory, but have come into effect since. For other sectors, regulations have been promulgated, but not fully implemented. For still other sectors, EPA has proposed regulations, or expects to propose regulations. These existing and prospective regulations will be described in section 5; here, we summarize the impacts of anticipated regulatory and technological changes on mercury emissions through 2020.

In a presentation to the Great Lakes Binational Toxics Strategy Mercury Workgroup in December 2007, Chuck French of USEPA's Office of Air Quality Planning and Standards provided projections of expected mercury emissions through 2020 (French 2007). These projections show a decline of approximately 50 percent in nationwide mercury emissions between 2002 and 2020, in addition to the 46 percent reduction that occurred between 1990 and 2002. However, two-thirds of the projected reduction from 2002 through 2020 was based on the anticipated impact of the Clean Air Mercury Rule (CAMR), a regulation meant to control mercury emissions from coal-fired utility plants beginning in 2010. However, in 2008 an Appeals Court found that USEPA had acted improperly in developing CAMR, and vacated the regulation. USEPA will develop a MACT standard [will need to change this if there's a Supreme Court challenge], but it is not clear what level of control such a standard will achieve; CAMR was expected to achieve a 70 percent reduction nationwide.

Mercury emissions at electric arc furnaces are also expected to decline approximately 70 percent nationwide between 2002 and 2020 as a result of federal air emissions regulations and reductions in the mercury content of equipment that gets scrapped. Additional reductions are expected from federal regulations controlling mercury emissions hazardous waste incinerators and federal regulations and plant closures or conversions of mercury-cell chlor-alkali plants. Further reductions in the mercury content of wastes are expected to lead to small additional reductions in mercury emissions from municipal waste combustors; emissions from these sources were already reduced more than 90 percent between 1990 and 2002. All of these nationwide sources are well represented in the Great Lakes states; therefore, it is anticipated that significant emissions reductions would occur in the Great Lakes states as a result of these regulations. Additional significant reductions are expected from gold mining sources, but all of these sources are located in the Western U.S., with none in the Great Lakes states.

3.4.2 Impacts of Possible Future Changes in Emissions on Mercury Deposition

While there has been no modeling of the deposition impacts of reducing mercury emissions in the Great Lakes states only, there have been efforts to determine the impact of reducing mercury emissions nationwide. USEPA performed dispersion modeling in 2005, using CMAQ, to

evaluate the mercury deposition impact of emissions reductions from coal-fired electricity generating units (EGUs) required by different potential versions of the forthcoming CAMR. While CAMR has since been vacated, this modeling is still useful in demonstrating the potential impact of policies that achieve significant reductions in mercury emissions. USEPA modeled mercury deposition under several different mercury emissions inventory scenarios, holding background natural and global emissions constant, changing only the U.S. emissions inventory.

First, USEPA compared deposition in 2001 with “baseline” 2020 deposition. Figure EE shows modeled mercury deposition in 2001. Modeled mercury deposition is high in the Ohio River Valley, eastern Ohio, across Pennsylvania, especially in Western Pennsylvania, and in the far Western and Southeastern parts of New York, as well as in the major cities of the Great Lakes basin. It is generally elevated in the southern part and eastern portion of the region, in comparison with the northern and western part. Nationwide, the maximum mercury deposition was an estimated 55 ug/m², the 90th percentile was 22 ug/m², and the mean was 16 ug/m².

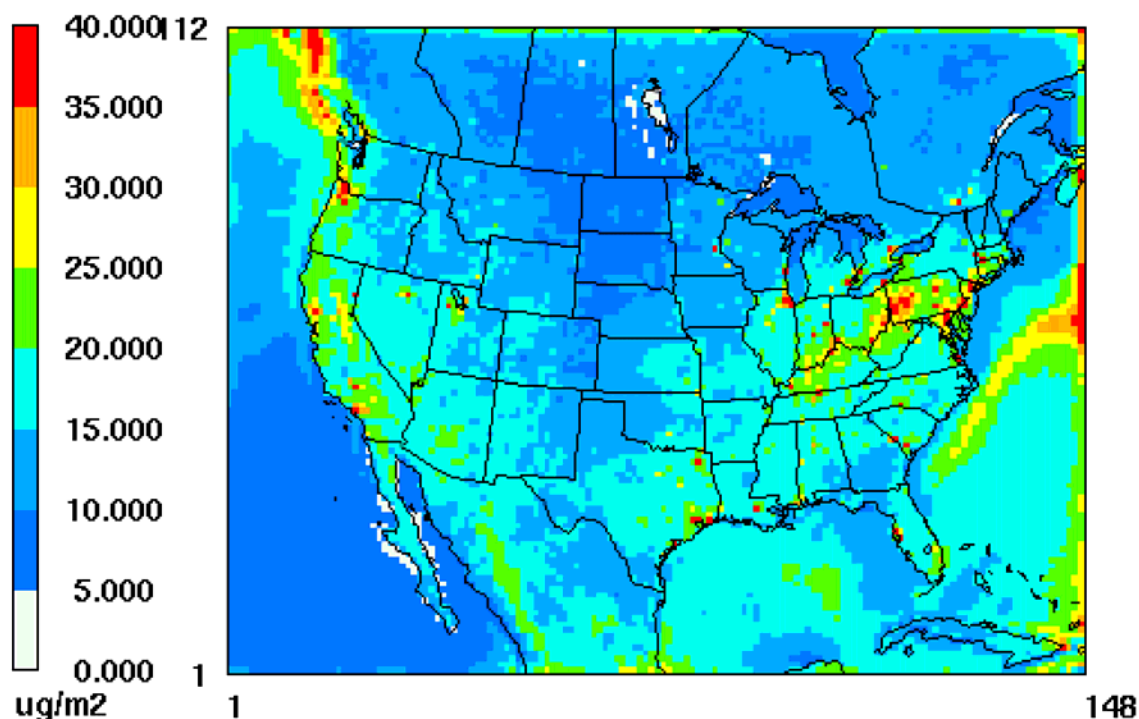


Figure EE: 2001 Mercury Deposition, With Total U.S. Mercury Emissions of 115 Tons
Source: USEPA, 2005c.

Under the 2020 baseline, U.S. mercury emissions would be lower than 2001 emissions by 27.7 tons, or 23.3 percent. Approximately half of these reductions would occur at coal-fired power plants as an incidental result of sulfur and nitrogen controls required under the Clean Air Interstate Rule (CAIR), and half would result from implementation of other regulations and predicted technology changes impacting other source sectors. CAIR, like CAMR, has subsequently been vacated by an Appeals Court. Figure EF shows the reductions in mercury deposition that would occur as a result of reducing mercury emissions by 2020 under the baseline scenario. This figure shows that anticipated emissions reductions would reduce deposition by less than 2 ug/m² in much of the country, including in most of the Northern and

Western parts of the Great Lakes basin. However, mercury deposition would decline at least 2 ug/m² in much of Illinois, Indiana, Ohio, and the lower peninsula of Michigan, and by up to 16 ug/m² in much of the Ohio River Valley and Western Pennsylvania.

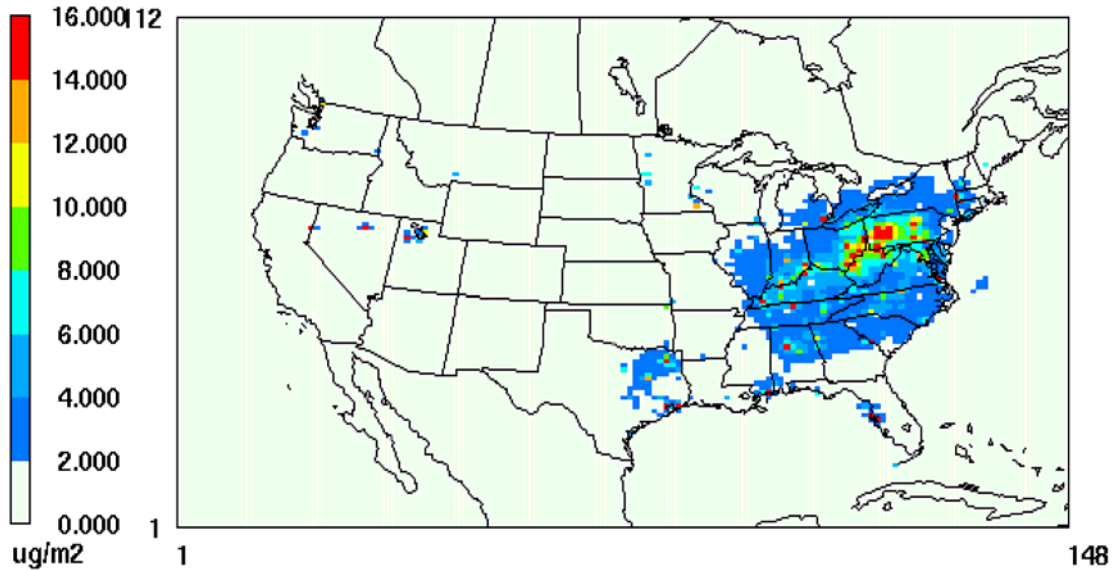


Figure EF: Baseline 2020 Mercury Deposition Compared with 2001 Deposition (Results of a 28 ton Reduction in U.S. Emissions)

Source: USEPA, 2005c.

Figure EG shows the remaining predicted mercury emissions in 2020 under the baseline emissions inventory scenario. The modeling shows that while anticipated emissions reductions would significantly reduce mercury deposition in the Eastern United States, particularly in the areas of highest deposition, mercury deposition would continue to be elevated in the southern part of the Great Lakes basin, and particularly in the vicinity of major cities, including Minneapolis, Milwaukee, Chicago, Indianapolis, Detroit, Cincinnati, and Pittsburgh.

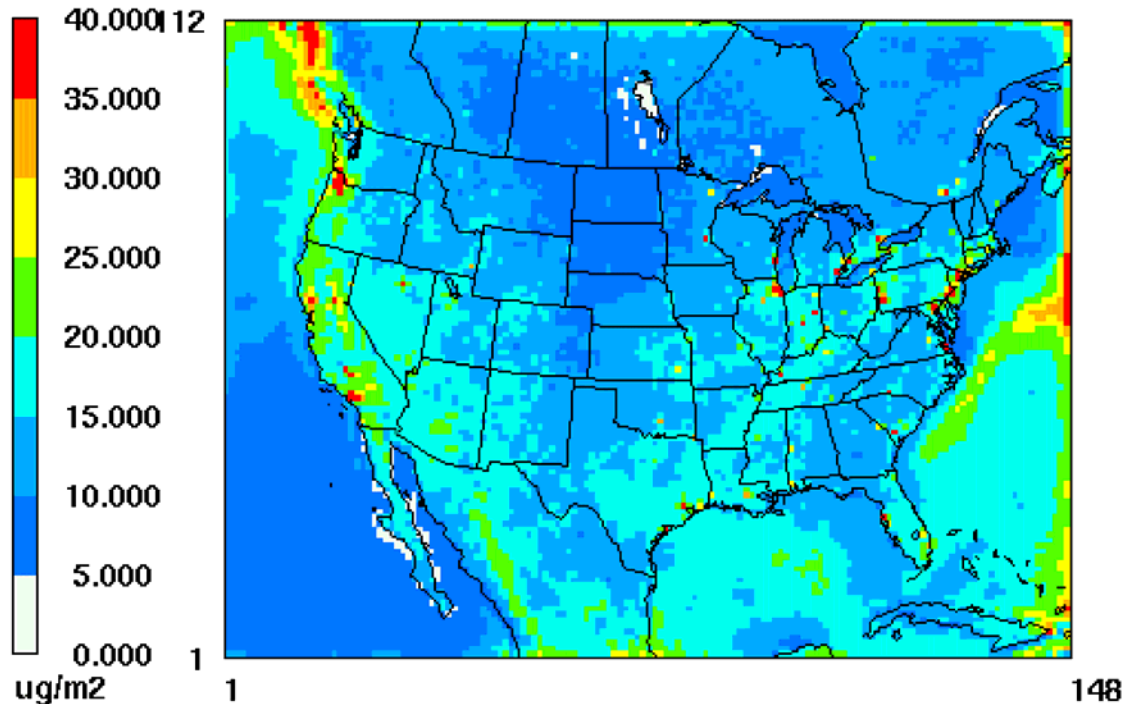


Figure EG: 2020 Mercury Deposition, With U.S. Mercury Emissions Reduced 28 Tons from 2001 levels

Source: USEPA, 2005c.

USEPA compared this 2020 baseline for mercury deposition with two additional scenarios:

- “CAMR Control Option 1,” in which non-EGU emissions would be identical to the 2020 baseline, while EGU emissions would be 9.37 tons lower than under the 2020 baseline. Total emissions would be 37.07 tons lower than in 2001.
- “CAMR Control Option 2,” in which non-EGU emissions would be identical to the 2020 baseline, while EGU emissions would be 13.59 tons lower than under the 2020 baseline. Total emissions would be 41.29 tons lower than in 2001.

Figures EH and EI show the additional reductions in mercury deposition under CAMR Option 1 and CAMR Option 2 that would occur relative to the 2020 baseline. In most of the country, deposition would be reduced less than one ug/m² by the reductions beyond the baseline. In the Great Lakes states, reductions of 1-4 ug/m² are predicted for a few scattered areas, primarily in Pennsylvania. According to the USEPA modeling, the impact on mercury deposition of the additional emissions reductions beyond the 2020 baseline achieved by CAMR would be much less significant than the predicted reduction in deposition caused by the initial emissions reduction between 2001 and the 2020 baseline. This result occurs for two reasons. First, the incremental emissions reductions below the 2020 baseline are only 9-14 tons under the CAMR options, while the initial emission reduction between 2001 and the 2020 baseline is greater-- 28 tons. Second, USEPA predicts that the CAMR options would result primarily in incremental reductions of elemental mercury, with relatively little of the reduction (14 -19 percent) coming from emissions of reactive gaseous mercury. By contrast, the anticipated reductions between 2001 and 2020 would be primarily (57 percent) from emissions of reactive gaseous mercury.

Since reactive gaseous mercury emissions tend to deposit close to the source while elemental mercury has a long atmospheric residence time and therefore can be transported globally, reduced emissions of reactive gaseous mercury have a much bigger impact than equivalent reductions in elemental mercury emissions. USEPA expects that initial efforts to control mercury emissions are likely to affect primarily reactive gaseous mercury emissions since emissions control equipment, for instance at coal-fired power plants, more easily capture this form of mercury. The CAMR control options would require deeper reductions in emissions from coal-fired power plants beyond the relatively easy-to-capture reactive gaseous mercury, leading to significant reductions in emissions of elemental mercury.

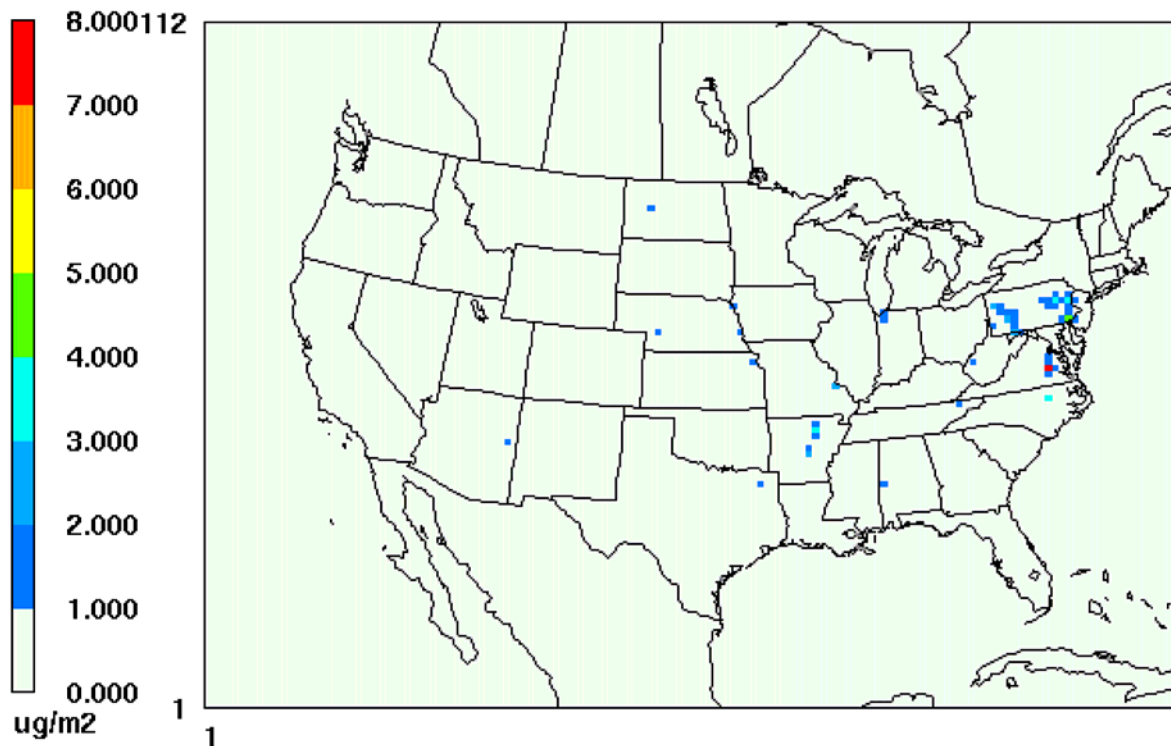


Figure EH: CAMR Option 1 Compared with Baseline 2020 Mercury Deposition (Results of a 9 ton Reduction in U.S. Emissions)

Source: USEPA, 2005c.

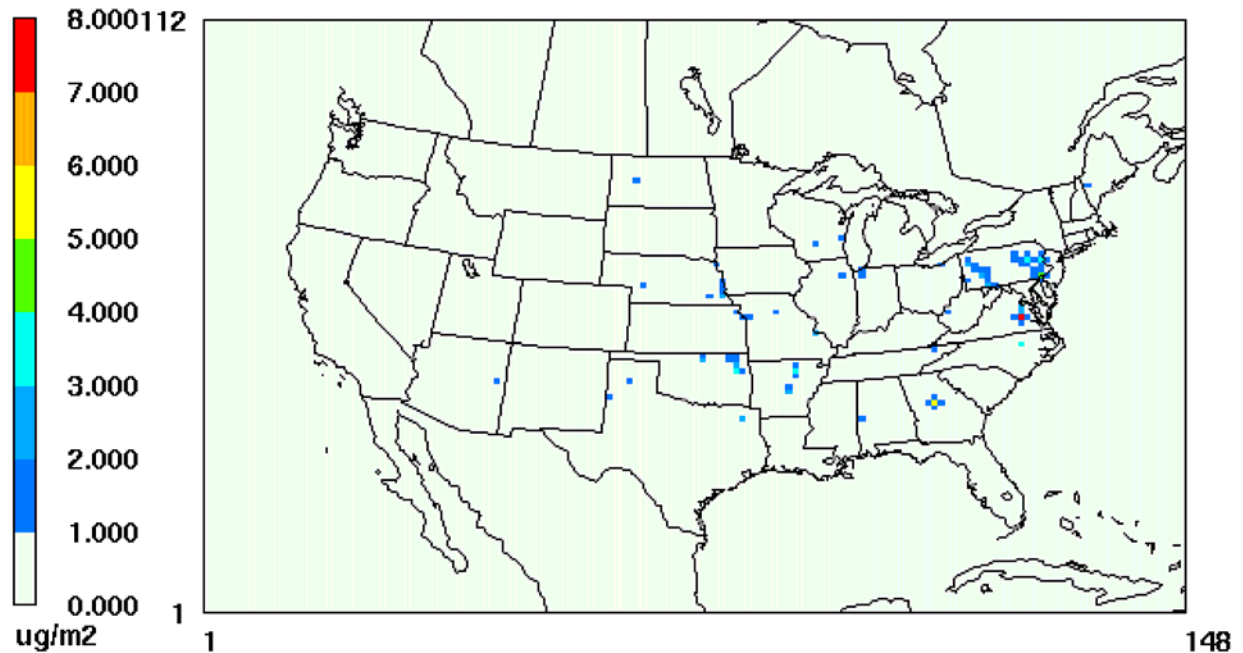


Figure EI: CAMR Option 2 Compared with Baseline 2020 Mercury Deposition (Results of a 14 ton Reduction in U.S. Emissions)
 Source: USEPA, 2005c.

3.4.3 Potential Global Benefits of Mercury Emissions Reduction within the Great Lakes States

In addition to the reductions in mercury deposition to the Great Lakes region that could result from reducing mercury emissions within the Great Lakes states, such reductions can have benefits beyond the Great Lakes states. The benefits beyond the Great Lakes states are most important when considering potential reductions in elemental mercury emissions, given elemental mercury's long atmospheric residence time and global atmospheric distribution. While reducing emissions of elemental mercury in the Great Lakes states is not expected to have a significant impact on mercury deposition within the Great Lakes states themselves, it will have a small impact on reducing mercury deposition to the oceans and to other places where mercury contamination is driven primarily by emissions from global sources rather than nearby sources. While these global deposition reductions would be small, they would be spread out over a broad area and would benefit many people who consume mercury-contaminated seafood.

Global direct mercury emissions from all natural and anthropogenic sources and excluding re-emitted anthropogenic emissions, total approximately 4000 metric tons per year (see table AA). Therefore, reducing mercury emissions within the Great Lakes states by an additional ten tons, for example, beyond the reductions that will be achieved through federal regulations, would reduce global primary mercury emissions by approximately 0.25 percent. Ten tons represents 25 percent of 2002 mercury emissions within the Great Lakes states. While such a reduction would not be detectable in global mercury deposition monitoring, it would be a real reduction and would represent a small contribution from the Great Lakes states towards reducing global mercury contamination problems. Only through numerous similar contributions from many

different regions can the global mercury problem be addressed. Moreover, efforts in the Great Lakes could help inspire similar reduction efforts in other places, helping to promote global reductions that will reduce mercury deposition to the Great Lakes and globally.

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Appendix Z [this shows everything over 0.1 tons—should we expand it to include all 96 sources, down to 2.2×10^{-8} tons?]

2002 NEI Version 3 (tons)	Great Lakes States Total	IL	IN	MI	MN	NY	OH	PA	WI
Utility Boilers: Coal	19.0	3.9	2.7	1.7	0.7	0.5	3.6	4.7	1.1
Stainless and Nonstainless Steel Manufacturing: Electric Arc Furnaces (EAF)	3.7	0.7	0.4	0.2	0.1	0.1	0.9	1.2	0.1
Portland Cement Manufacturing	2.3	0.1	1.0	0.6	0.0	0.3	0.0	0.3	0.0
Incineration: On-site: Commercial/Institutional	2.1	0.0	0.0	0.0	1.1	0.2	0.0	0.8	0.0
Industrial/Commercial/Institutional Boilers & Process Heaters – coal	1.9	0.4	0.3	0.2	0.3	0.0	0.6	0.1	0.1
Mercury Cell Chlor-Alkali Plants	1.2	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.5
Hazardous Waste Incineration: Cement Kilns	0.95	0.00	0.73	0.00	0.00	0.00	0.10	0.11	0.00
Municipal Waste Combustors: Small	0.87	0.00	0.00	0.09	0.32	0.13	0.00	0.28	0.05
Industrial/Commercial/Institutional Boilers & Process Heaters – oil	0.67	0.08	0.11	0.01	0.02	0.04	0.05	0.12	0.24
Municipal Waste Combustors: Large	0.64	0.00	0.01	0.01	0.03	0.38	0.00	0.18	0.01
Residential Heating: Distillate Oil	0.56	0.00	0.01	0.03	0.02	0.29	0.01	0.18	0.03
Iron and Steel Foundries	0.49	0.10	0.26	0.11	0.00	0.00	0.01	0.00	0.00
Hazardous Waste Incineration: Lightweight Aggregate Kilns	0.48	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00
Taconite Iron Ore Processing	0.38	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00
Fluorescent Lamp Breakage	0.37	0.02	0.01	0.02	0.02	0.24	0.04	0.02	0.01
Hazardous Waste Incineration: Commercial	0.29	0.22	0.00	0.00	0.00	0.00	0.07	0.00	0.00
Integrated Iron & Steel Manufacturing	0.28	0.00	0.06	0.22	0.00	0.00	0.00	0.00	0.00
Ferroalloys Production	0.26	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00
Dental Amalgam Production	0.18	0.03	0.02	0.03	0.00	0.04	0.02	0.02	0.02
Secondary Lead Smelting	0.17	0.00	0.06	0.00	0.08	0.01	0.00	0.01	0.00
Sewage Sludge Incineration	0.17	0.00	0.00	0.04	0.10	0.00	0.00	0.01	0.01
Inorganic Pigments Manufacturing	0.16	0.11	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Incineration: Commercial and Industrial Solid Waste	0.15	0.10	0.00	0.00	0.06	0.00	0.00	0.00	0.00
Primary Metal Products Manufacturing	0.14	0.00	0.09	0.00	0.01	0.00	0.04	0.00	0.00

Industrial/Commercial/ Institutional Boilers & Process Heaters - wood or waste	0.14	0.00	0.00	0.08	0.03	0.00	0.01	0.00	0.02
Lime Manufacturing	0.10	0.06	0.00	0.01	0.00	0.00	0.01	0.03	0.00
Electrical and Electronics Equipment Manufacturing: Electric Lamp Bulb and Part Manufacturing	0.10	0.01	0.00	0.00	0.00	0.00	0.09	0.00	0.00
Utility Boilers: Oil	0.10	0.00	0.00	0.03	0.00	0.03	0.00	0.03	0.00
Other	1.15	0.24	0.16	0.03	0.10	0.07	0.19	0.31	0.04
Total	39.1	6.0	5.9	3.5	3.5	2.8	6.7	8.5	2.2