Tracking Progress in Reducing Mercury Air Emissions

Compiled by the Northeast States for Coordinated Air Use Management (NESCAUM)

The Northeast states have taken steps since at least the 1990s to reduce and eliminate mercury emitted to the air from local sources. These steps occurred despite objections often raised against them asserting that they would be ineffective. The objections typically invoke the existence of a global pool of mercury created by mercury emissions from around the world that dominates local and regional mercury deposition. According to this argument, local and regional mercury emission reductions should have negligible benefits for the local and regional environment because the reductions will be overwhelmed by mercury deposition from the global mercury pool.

While a global mercury pool does exist, a wealth of real world observations shows that changes in local and regional mercury air emissions are in fact readily seen within fairly short time periods in the local and regional environment. This is indeed borne out by the results seen in the Northeast and elsewhere in the United States. The following sections present the results of scientific studies showing local and regional connections between changes in mercury air emissions and changes in mercury appearing in the environment. These are grouped according to the type of mercury emission source: 1) mercury from coal combustion, 2) mercury from waste incineration, and 3) mercury from smelters. While the main focus is on the Northeast, we include studies from outside the region to further illustrate the connections between changes in local and regional mercury emissions and changes in mercury found in the environment.

Mercury from Coal Combustion

A number of studies have linked mercury emissions from the burning of coal with mercury appearing in the environment. A recent overview of mercury in the Northeast has highlighted the important role of U.S. coal-fired power plants in contributing a large share of the mercury deposited in the region (Driscoll et al. 2007).

A 1997 study in Minnesota indicated a relationship between mercury deposition trends and regional coal combustion (as well as other possible sources) spanning a period of two centuries (Engstrom and Swain 1997). Sediment core sampling from rural lakes in eastern Minnesota indicated a growth in mercury deposited from the air since the first half of the 1800s, with the amount peaking in the 1960s and 1970s at 4.0 to 5.2 times higher than pre-industrial levels. Deposition then declined during the 1980s to levels 3.0 to 3.4 times greater than pre-industrial levels. By comparison, sediment core samples from remote coastal lakes in southeastern Alaska showed a general increase in mercury deposition since 1850 that continued increasing after the 1960s with no downward trend. If mercury deposition trends are largely driven by a global pool, one would expect to see the same trend profiles in the remote Alaska lakes as in the rural Minnesota lakes. Because the remote Alaska lakes showed no general decrease in mercury deposition, the downward trend in the Minnesota lakes likely occurred due to changes in regional rather than global mercury emissions. The Minnesota study identified two changes related to regional coal combustion that occurred at the same time as the decrease in mercury deposition to the lakes. These were the increase in use of technologies at coal-fired power plants (as well as metal smelters) that incidentally reduced mercury air emissions and a shift away from coal to natural gas and oil for commercial and residential heating. (Other changes that may have contributed to the decline in mercury emissions include the reduced industrial use of mercury and a decrease in emissions from waste incineration.)

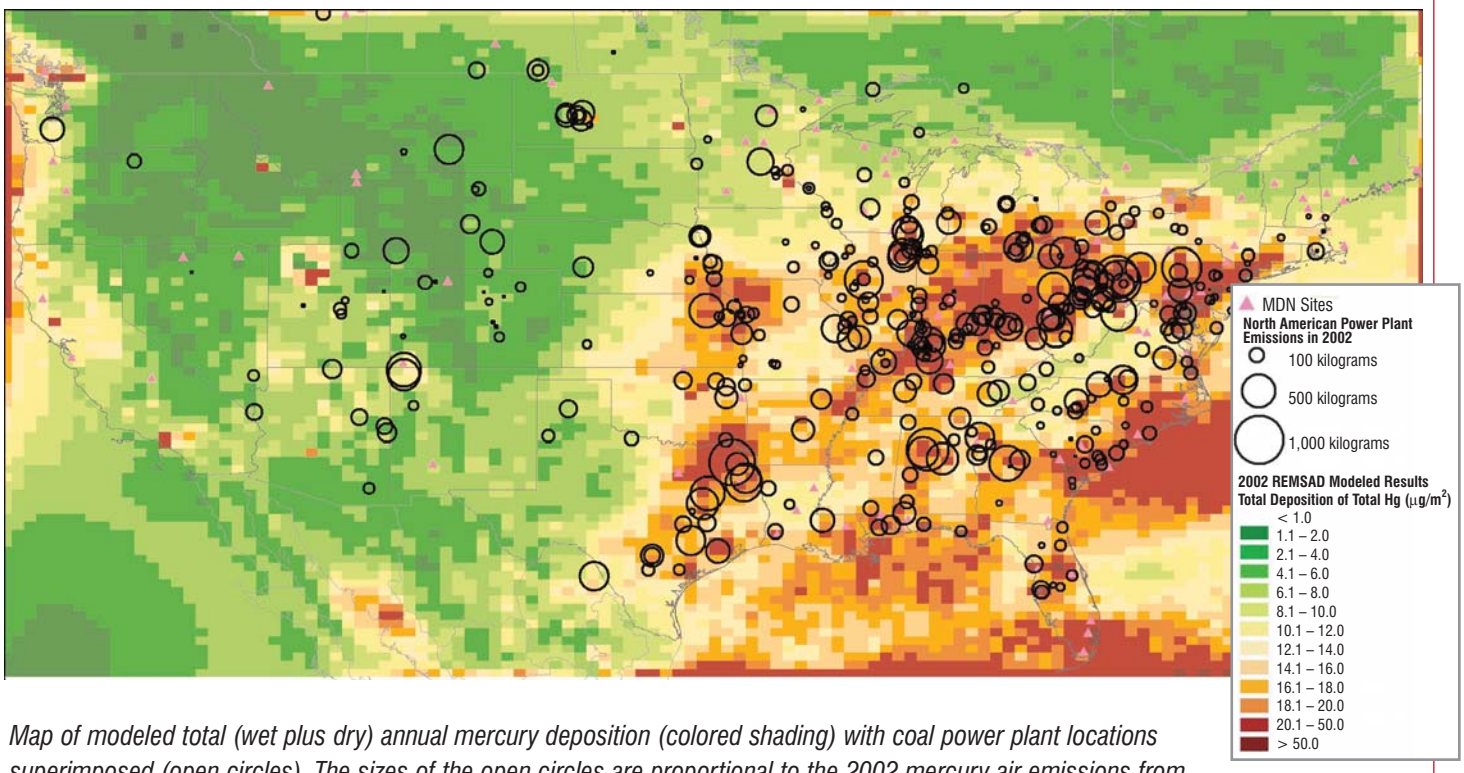
More recently, researchers from the University of Michigan and the U.S. Environmental Protection Agency found that coal combustion was the dominant source of deposited mercury (approximately 70 percent) in the Steubenville, Ohio, area over a two-year period from 2003 to 2004 (Keeler et al. 2006). Analyses of weather patterns indicated that the majority of deposited mercury came from local and regional mercury emission sources.

Consistent with the Steubenville results, researchers from Yale University identified inter-annual changes among regional power plants (particularly in the amount of coal consumed) as having a strong influence on observed ambient mercury concentrations in northwest Connecticut (Sigler and Lee 2006). The researchers determined the mercury source region influencing the Connecticut site encompassed most of New England and extended south into Maryland and west into Ohio.

Figure 1 displays the spatial correspondence of coal power plants with modeled annual mercury deposition in North America. The map in Figure 1 shows the modeled total (wet plus dry) annual deposition of mercury from all anthropogenic sources[1]. The darker red shading indicates higher amounts of mercury deposition. Superimposed on the modeled mercury deposition are open circles indicating the locations of coal-fired power plants in North America. The size of the circle is proportional to the amount of mercury emitted by the power plant in 2002. The map illustrates the local and regional association between the locations of coal power plants and the highest amounts of modeled mercury deposition.

Figure 1 displays areas of elevated mercury deposition from the air. Elevated mercury in the environment, however, may occur not only because of relatively high levels of mercury being deposited from the air, but may also occur due to landscape features or water level management practices that result in higher mercury levels being concentrated in local fish, birds, or mammals relative to other places in the region. Recent work has described several of these "biological hotspots" in the Northeast using mercury data collected from yellow perch, largemouth bass, brook trout, loons, bald eagles, river otters, and mink (Evers et al. 2007).

FIGURE 1



Map of modeled total (wet plus dry) annual mercury deposition (colored shading) with coal power plant locations superimposed (open circles). The sizes of the open circles are proportional to the 2002 mercury air emissions from each power plant. Modeled deposition patterns used 1996 meteorology. [REMSAD modeling by NESCAUM; power plant data from the Commission for Environmental Cooperation (2004).]

1. Modeling results are from the Regional Modeling System for Aerosols and Deposition (REMSAD) v7.13 performed by NESCAUM. The REMSAD model used a 2002 mercury emissions inventory in the Northeast coupled with a 1996 mercury emissions inventory outside the Northeast that was supplemented with 1999 mercury emissions data for U.S. coal power plants collected by the U.S. Environmental Protection Agency. The meteorology used is for 1996.

TABLE 1 NESCAUM STATE MERCURY CONTROL PROGRAMS FOR COAL POWER PLANTS.*

STATE	RULES OR LEGISLATION – PROPOSED OR ADOPTED	PARTICIPATION IN NATIONAL TRADING PROGRAM?
CT	State statute requires 90 percent reduction or compliance with a mercury emissions limit of 0.6 lb/TBTU by July 1, 2008, with provision for an alternative if controls fail to achieve limitation. More stringent limits possible after July 1, 2012.	No
ME	All facilities (including electric generating units) have a mercury emission limit of 50 lbs/yr which drops to 35 lbs/yr in 2007 and to 25 lbs/yr in 2010. A mercury reduction plan is required for facilities emitting more than 10 lbs/yr.	Only one electric generating unit may be subject to Clean Air Mercury Rule and it emits less than 4 lbs/yr. Maine will let EPA administer the state program.
MA	Adopted rule requires 85 percent capture or 0.0075 lb/GWh by January 1, 2008, and 95 percent capture or 0.0025 lb/GWh by October 1, 2012. Averaging between units at the same facility allowed.	No
NH	Legislation passed House and Senate, signed by Governor. Calls for 80 percent reduction of mercury emissions from coal-burning power plants through installation of scrubber technology no later than July 1, 2013. Emission credits for SO_2 for early mercury reductions.	No
NJ	Adopted rule requires control efficiency of 90 percent or 3 mg/MWh by December 15, 2007, for coal-fired boilers of any size. A multi-pollutant approach can reduce the initial reduction required and extend compliance to December 15, 2012.	No
NY	Adopted rule for coal-fired electric utility steam generating units implements a Phase I emission cap for the years 2010-2014 and beginning in 2015 establishes a facility-wide emission limit for each applicable facility. Phase I imposes annual facility-wide mercury emission limitations, based upon the state mercury budget EPA distributed to New York. Facilities will not be permitted to generate and trade mercury reductions with other facilities or states. The annual facility-wide emission limitations will be in effect from 2010 to 2014. Starting in 2015, Phase II, in conjunction with other electric sector regulations such as the Regional Greenhouse Gas Initiative (RGGI) and the second phase of the Clean Air Interstate Rule (CAIR), will establish a unit-based emission limit of 0.6 lbs/10^{12} Btu for each applicable facility.	No
RI	Zero state budget for mercury under EPA's Clean Air Mercury Rule (CAMR).	No
VT	Zero state budget for mercury under EPA's CAMR.	No

**Information from the National Association of Clean Air Agencies (NACAA), "State Mercury Programs for Utilities," (January 23, 2007), available at http://www.4cleanair.org/Documents/StateTable.pdf (accessed February 26, 2007).*

The modeled total mercury deposition pattern in the United States using 1996 meteorology is qualitatively similar to the measured mercury wet deposition patterns from the national Mercury Deposition Network (MDN) *(http://nadp.sws.uiuc.edu/mdn/)*. That is, the highest levels of observed mercury wet deposition typically occur in the Ohio River Valley and the Southeast where there are the greater concentrations of mercury-emitting coal-fired power plants. It is interesting to note that a national study of mercury levels in largemouth bass, a fish widely distributed across the United States, found a strong positive relationship between mercury levels in the bass and the amount of mercury wet deposition measured in the state where the fish were sampled (Hammerschmidt and Fitzgerald 2006). This indicates that the influence of regional mercury emissions is discernable in an important freshwater sport fish living within the same region.

States in the Northeast have acted to reduce mercury air pollution from coal power plants through measures that are more aggressive than federal requirements. Table 1 lists the state requirements in adopted or proposed regulations or as given in legislation.

Mercury from Waste Incineration

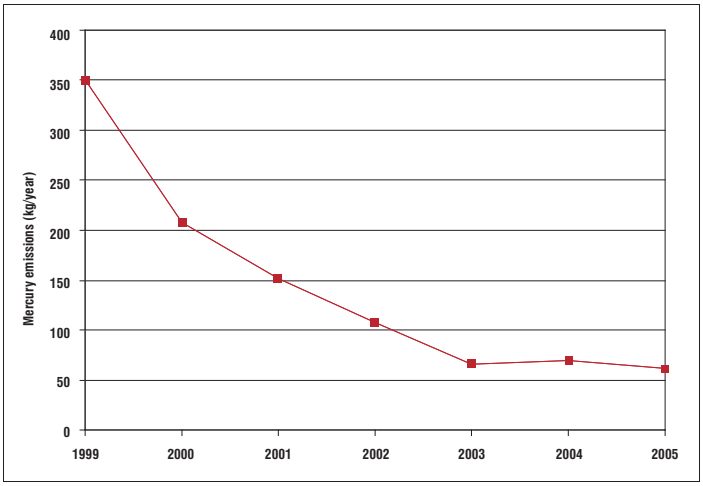
Reductions in mercury emitted to the air have been dramatic in the Northeast since the 1990s when the Northeast states began adopting aggressive mercury emission limits for municipal and medical waste incinerators. Across the NESCAUM region, states with large municipal waste incinerators adopted a mercury emission limit of 28 micrograms per dry standard cubic meter (µg/dscm) – almost three times more stringent than the current federal new source performance standard of 80 µg/dscm (NESCAUM 2003; CFR 2006). As a result, mercury emissions from municipal waste incinerators decreased by 85 percent from 1998 to 2002 (the most recent year NESCAUM has a mercury inventory for the entire region).

Mercury emissions from medical waste incinerators decreased by over 95 percent during the same period. For the New England states, mercury from municipal waste incinerators decreased from 6,800 lbs in 1998 to 840 lbs in 2002. Mercury from medical waste incinerators declined from 988 lbs in 1998 to only 5 lbs in 2002, a decrease of over 99 percent.

As an illustrative example of the extent of mercury reductions achieved in the Northeast, Figure 2 shows the downward trend in mercury emissions from municipal waste incinerators in Connecticut. Mercury emissions from these Connecticut sources decreased by over 80 percent from 1999 to 2005.

A recent study in Massachusetts observed significant declines in mercury in fish in Massachusetts lakes, which coincided with a steep decline in mercury air emissions from incinerators. The Massachusetts Department of Environmental Protection (MA DEP) has established a network of lakes for the long-term monitoring of mercury concentrations in the edible tissue of two fish species. This network provided the state with an indication of changes in fish tissue mercury concentrations over six years from 1999 to 2004 in seventeen lakes (MA DEP, 2006). Over this period, statistically significant decreases in mercury concentrations were seen in the sampled fish in a number of the network lakes located in the northeastern part of the state. This decline of mercury in fish tissue coincided with a significant decrease, approximately 87 percent, in mercury air emissions in the same local region due to new pollution controls on and closures of municipal and medical waste incinerators. This part of the state was known as a "hot spot" of mercury air emissions due to the relatively high number of incinerators in the area. The fish tissue samples in northeast Massachusetts were also higher than the state on average, indicating it was a mercury deposition hotspot as well as an emissions hotspot. The results show that significant decreases in edible fish tissue mercury concentrations can occur within 36 to 48 months of the adoption and implementation of comprehensive state and regional mercury controls. This indicates that mercury levels in fish living in these types of lakes can be reduced in a fairly short period of time in response to aggressive mercury controls at the local and regional level.

FIGURE 2

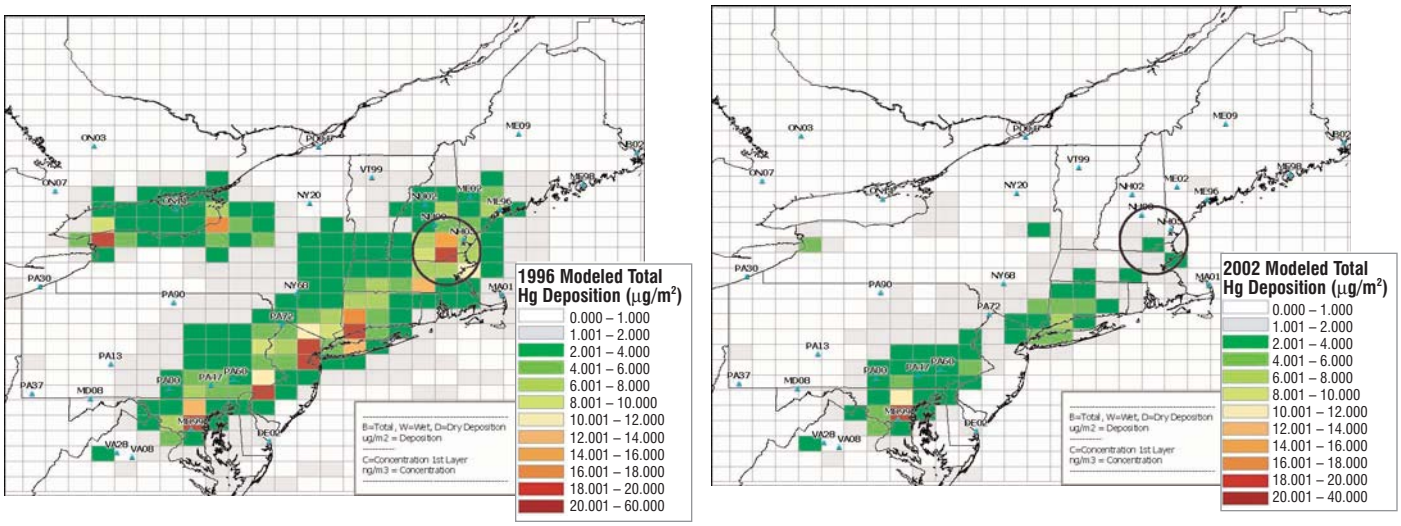


Annual trend in mercury emissions from municipal waste incinerators in Connecticut from 1999 to 2005, based on stack testing results. Data provided by the Connecticut Department of Environmental Protection.

The mercury trends in the fish tissue samples from northeast Massachusetts are consistent with mercury deposition modeling done by NESCAUM as well as modeling work by Evers et al. (2007) for this location. Figure 3 displays the NESCAUM modeling results for mercury deposition attributable to municipal and medical waste incinerators in the Northeast. In 1996, there was a locally high area of total mercury deposition in northeast Massachusetts that corresponded to a high density of municipal and medical waste incinerators in the same locale. The mercury emissions in this area greatly decreased since 1996 due to more stringent mercury emission controls on incinerators, mercury reductions in waste streams, and incinerator shutdowns. The model results for 2002 (after the decrease in local mercury emissions) show a corresponding decrease in mercury deposition from these sources, consistent with the findings from the fish tissue samples.

As with Massachusetts, Florida has seen relatively rapid decreases of mercury in biota corresponding to local decreases in mercury emissions from waste incineration. Decreases in mercury levels on the order of

FIGURE 3



Maps showing the decrease in modeled total (wet plus dry) mercury deposition from municipal and medical waste incinerators in the Northeast between 1996 (left) and 2002 (right). Darker red shading shows areas of highest mercury deposition. The open circles in each map indicate the location of the northeast Massachusetts lakes where significant declines in measured mercury levels from fish tissue samples occurred, consistent with the modeling results (REMSAD).

80 percent were reported in largemouth bass and great egret nestlings living in the Florida Everglades (Atkeson et al. 2003). This coincided with an estimated decrease of over 90 percent in local mercury air emissions from 1991 to 2000 due to mercury reductions at local municipal and medical waste incinerators. Supporting the observation that local sources of mercury air emissions were the major contributors to local mercury deposition in south Florida is the study by Dvonch et al. (1999). This study found that over 70 percent of mercury wet deposition in south Florida during 1995 to 1996 could be attributed to local urban point sources, such as medical waste incinerators.

Reinforcing the Everglades results are long-term mercury trends in bird feathers from southern Florida obtained from museum collections with samples dating back to the early 1900s (Frederick et al. 2004). Feathers after 1990 came from live birds. When comparing the older museum feather samples with those collected from live birds, a five- to seven-fold increase in mercury concentration was observed. Most of the increase occurred after the late 1970s, with mercury concentrations in feathers being relatively stable in the preceding years. Based on global mercury emission trends and the differences in migratory behavior of the different bird species used in the study, the researchers suggested that the large increase in bird feather mercury concentrations after 1980 occurred due to local mercury emissions and deposition, rather than global. The study did not present results on any observed decreasing trends in the most recently collected feathers, but a separately published study by some of the same researchers found a decrease of over 70 percent in total mercury in the feathers of nestling great egrets collected in southern Florida between 1994 and 2000 (Frederick et al. 2001). The researchers suggested the decline could be due to controls on municipal and medical waste incinerators in Florida that were mandated during the early 1990s.

Mercury from Metal Smelters

Researchers from the Massachusetts Institute of Technology (MIT) measured mercury in fine particulate matter (diameter < 2.5 µm) in the ambient air across New York State over a two-year period from 1992 to 1993 (Olmez et al. 1998). Based on air mass trajectories, the researchers concluded about 55 percent of the mercury particulate came from smelters in Ontario and Quebec, and 25 percent from a mix of sources in the midwestern United States. The MIT researchers did not monitor elemental or reactive gaseous mercury, so it is possible that the relative contributions to these other mercury species could differ. During the study, the researchers observed a decline in mercury particulate beginning in February 1993. While the researchers could not be definitive, they theorized that the decrease in observed particulate matter could be due to changes in processes and implementation of controls that occurred at some of the Canadian smelters at about this time.

Summary

While a global pool of mercury exists, measures to reduce local and regional mercury emissions to the air clearly have local and regional benefits, and occur within a relatively short period of time. Real world observations present a strong correspondence between local and regional mercury air emissions and mercury appearing in the local and regional environment. These observations range from local "hot spots," as seen with waste incinerators in northeast Massachusetts, to regionally broad elevated mercury levels, as seen with coal combustion in and across many states of the eastern United States. Mercury deposition modeling that is consistent with observed mercury trends in the environment lends confidence that these tools give directionally correct guidance for making decisions about future control efforts.

The Northeast states have established an impressive track record in aggressively reducing mercury air emissions. The result is not only reduced amounts of mercury released through smokestacks, but also reduced amounts of mercury appearing in the Northeast environment. While mercury contamination continues to persist, a sense of accomplishment should be felt in what has been done, while a sense of mission can be derived from what can still be achieved. ■

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