

Contributions of Global and Regional Sources to Mercury Deposition in New York State

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Project Location



Adirondack and Catskill regions outlined

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Keywords

- Dry deposition
- Gaseous divalent mercury (Hg [II])
- Gaseous elemental mercury (Hg [0])
- Long-range transport
- Particulate divalent mercury (Hg [p])
- Wet deposition

PROJECT FOCUS

The development of effective emission control strategies requires a rigorous assessment of the relative importance of local, regional, continental, and global sources of Hg deposition. However, since significant uncertainties remain in our understanding of the fate and transport of Hg in the environment, the attribution of Hg deposition to various sources must be qualified by any associated uncertainties. This project responded to these needs by:

- Assessing the contributions of local, regional, and global mercury sources to mercury deposition in New York State (NYS), and
- Identifying critical gaps in the data required to further refine these estimates.

CONTEXT

Mercury, a naturally occurring inorganic element, cycles in the environment as a result of both natural and human activities. The major contributors to atmospheric mercury include emissions from the combustion of mercury-containing fuels or materials and industrial processes, in particular, coal-burning electrical utilities, municipal waste combustors, commercial and industrial boilers, medical waste incinerators, chlor-alkali plants, hazardous waste combustors, lamp breakage activities, mining, and cement manufacture. Recent inventories indicate that ~150 tons of mercury are emitted from U.S. anthropogenic sources each year. The mercury transported through the air is deposited in water and on land, where humans and wildlife may be exposed to it as methylmercury. Since it accumulates in exposed aquatic organisms such as fish (bioaccumulation), mercury also poses a danger to organisms higher up in the food chain that consume a large amount of fish (biomagnification). When its concentrations reach high enough levels, mercury can act as a neurotoxin, impairing neurological development in fetuses and young children, and damaging the central nervous system of adults. Owing to the possible dangers posed by mercury contamination, 45 states have issued fish consumption advisories.

Mercury is present in the atmosphere in different forms with various lifetimes: as gaseous elemental mercury (Hg[0]), gaseous divalent mercury (Hg[II]), and particulate divalent mercury (Hg[p]). Hg(0) remains in the atmosphere for a few weeks, whereas Hg(II) and Hg(p) tend to be removed much more rapidly, with lifetimes on the order of a day and a week, respectively. The potential effects of atmospheric Hg emissions may range from the local impacts of species with shorter lifetimes, caused by the wet/dry deposition of Hg(II) and the wet deposition of Hg(p), to the regional and global impacts of species with longer lifetimes, caused by the long-range transport of Hg(0) and, under dry conditions, Hg(p). Conversion between the forms of mercury occurs in the atmosphere, particularly in the presence of clouds. The potential range of impacts of atmospheric mercury emissions thus depends on the Hg species involved, meteorological processes (e.g., wind and precipitation), and chemical transformations.

METHODOLOGY

A model was used to simulate the transport, transformation, and deposition of mercury. Three scenarios were considered: (1) a nominal or baseline scenario, (2) a scenario conducive to local deposition, and (3) a scenario conducive to long-range transport. The source areas considered were NYS; the continental United States (U.S.) not including NYS; Canada; Mexico; Europe; Asia; South America; Africa; Oceania; and natural sources. Scenarios 2 and 3 were designed to provide plausible Hg concentrations and deposition rates

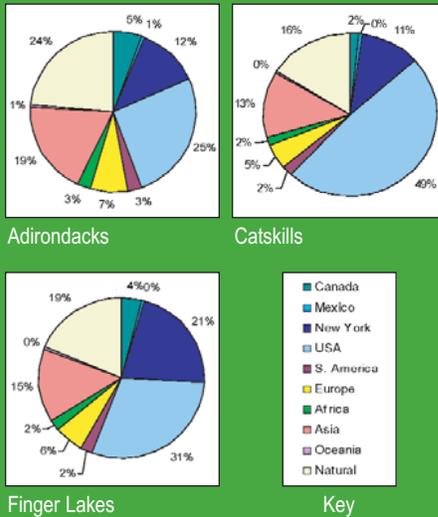


Atmospheric Fate and Transport of Mercury Species

PROJECT UPDATE

August 2005

Regional & Global Contributions to Total Hg Deposition at Three NYS Sites (Baseline Scenario)



Project Status

- Initiated 2001
- Completed 2002



Since 1975, the New York State Energy Research and Development Authority (NYSEERDA) has developed and implemented innovative products and processes to enhance the State's energy efficiency, economic growth, and environmental protection. One of NYSEERDA's key efforts, the Environmental Monitoring, Evaluation, and Protection (EMEP) Program, supports energy-related environmental research. The EMEP Program is funded by a System Benefits Charge (SBC) collected by the State's investor-owned utilities. NYSEERDA administers the SBC program under an agreement with the Public Service Commission.

compared to observations, thereby reflecting the sensitivity of the model to some changes in inputs. The wet and dry deposition rates of mercury were analyzed at three locations in NYS identified as potentially sensitive areas: the Adirondack Mountains, the Finger Lakes District, and the Catskill Mountains.

Further analysis assessed the major sources of uncertainty in model predictions of Hg deposition in NYS watersheds and bioaccumulation in the aquatic food chain. As part of this effort, existing databases were reviewed for atmospheric Hg concentrations and deposition, Hg concentrations in fish, and lake-watershed data.

RECENT FINDINGS

In all scenarios, U.S. emissions (non-NYS) were the largest source of total Hg deposition at all three sites in NYS. Overall, results from scenarios 2 and 3 (local deposition and long-range transport) vary only slightly from those of the baseline scenario.

BASELINE SCENARIO: U.S. emissions were the largest source of total Hg deposition at all three sites. Dry deposition: Dominated at all sites by NYS and U.S. emissions. Wet deposition: Much greater contribution from sources outside North America.

LOCAL DEPOSITION SCENARIO: An increase in contributions from U.S. and NYS sources to total deposition compared to baseline scenario. U.S. sources contributed the most, while NYS, Asian, and natural emissions constituted most of the remaining portion. Dry deposition: The impact of NYS and U.S. sources increased, while the impact of natural sources decreased. Wet deposition: The impact of NYS, U.S., and Canadian emissions generally increased, while that of the other emission sources decreased.

LONG-RANGE TRANSPORT SCENARIO: U.S. emissions were the largest source of total deposition at the NYS sites. Canadian and NYS contributions to total deposition decreased compared to baseline scenario, while the impact of sources outside North America increased. Dry deposition: Again dominated by NYS and U.S. emissions, though NYS impact decreased. Wet deposition: Continued to be more affected by sources outside North America.

UNCERTAINTIES AND DATA GAPS: Model performance was evaluated by comparing results to actual measurements of ambient Hg species concentrations and wet deposition rates. The comparison suggested that the model captures most of the processes that govern the atmospheric fate and transport of Hg. However, the results of source attribution must be seen as preliminary, as uncertainties remain in our understanding of the atmospheric fate and transport of mercury. Major sources of uncertainty include emissions (including Hg species), the dry deposition of Hg(II), and, for lake mercury cycling models, the sediment burial rate. Knowledge of atmospheric Hg chemistry is still incomplete; laboratory experiments are needed to identify and characterize the most important reactions. Finally, there is a great need for Hg measurements with which to evaluate the models, including ambient atmospheric concentrations of Hg(0), Hg(II), and Hg(p), and wet and dry deposition rates of mercury.

PROJECT IMPLICATIONS

An important concern in the case of mercury is how controls operating in one particular geographical area - e.g., in a specific state, region, or in the country as a whole - would affect mercury deposition in another area, such as NYS. To this end, it is vital to identify the major contributing sources of mercury deposition in a given area and to determine what regulatory regimes would operate most effectively in reducing mercury deposition on the regional, national, and international levels. Despite remaining uncertainties, this analysis represented the state of the science three years ago with regard to our understanding of the fate and transport of mercury. As such, it provided a useful indication of the relative contributions of local, regional, and global sources to Hg deposition in NYS. Recent developments in our understanding of the atmospheric fate and transport suggest that the results obtained in this study provide an upper limit to the contribution of local sources to mercury deposition in NYS. This information will be essential in evaluating the different policy proposals currently under discussion and in gauging the effectiveness of regulations implemented in the future. Policy options under discussion at the state and federal levels include mercury emissions trading, standards and caps, and greater enforcement of existing regulations. Currently, coal-fired power plants in the U.S., which are responsible for ~40% of U.S. industrial emissions, are the largest unregulated source of mercury emissions. In the absence of regulations and/or better control technologies, mercury emissions from coal-fired power plants are expected to increase as the demand for energy production and coal combustion increase.