Executive Summary

A. Overview

Mercury is a toxic metal that exists as a trace element in the earth's crust. Once mobilized in the environment it can be transformed into methylmercury, a particularly toxic form of mercury that can bioaccumulate in fish and be ingested by fish-eating animals and humans. Evidence of elevated rates of mercury deposition from the atmosphere and of high levels of mercury contamination in non-commercial freshwater fish taken from waterbodies throughout the northeastern United States and eastern Canada has prompted concern about potential public health and environmental impacts. In response, all of the northeastern states and three eastern Canadian provinces have issued fish consumption advisories recommending limits on the consumption of potentially contaminated fish. Concern about mercury contamination has also led to a wide range of regulatory initiatives aimed at reducing mercury emissions within the region.

This regional Study was prompted by a desire to refine the results[1] of a recent national evaluation of atmospheric mercury emissions that was conducted by the United States Environmental Protection Agency (USEPA) in accordance with requirements of the 1990 Clean Air Act Amendments. Two of the findings contained in USEPA's *Mercury Study: Report to Congress*[2] are of particular relevance to this Study: (1) that a plausible link exists between past and present anthropogenic (i.e. human-caused) emissions and the increased concentrations of mercury that have been found in the environment and in freshwater fish; and (2) that rates of mercury deposition are likely to be higher in the northeastern U.S. relative to most other parts of the country.[3]

This Study reflects the combined contribution of state and provincial air, waste, and water management agencies throughout the Northeast states and eastern Canada.[4] It is intended to serve as an informational resource to these agencies and as a foundation for future regional initiatives, including the development of a coordinated Action Plan, to reduce the environmental and public health impacts of mercury pollution.

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1 Specifically, the Northeast states wished to refine the emission inventory figures developed by USEPA for the Northeast region.

2 The USEPA *Mercury Study: Report to Congress* was released in December, 1997.

3 Prevailing wind patterns, which tend to blow from west to east over the northeastern U.S. are probably important in determining broad-scale transport and deposition patterns.

4 USEPA also contributed vital technical and financial support, particularly with respect to the inventory assessment and deposition modeling components of this Study.

B. Mercury in the Environment

This Study, like USEPA's national assessment, focuses on mercury releases to the atmosphere which are thought to play an important role in the deposition of mercury throughout the region.[5] Mercury releases to the atmosphere occur when mercury-containing wastes and fossil fuels are burned; when mercury is used or emitted as a by-product in certain manufacturing processes; and when mercury in products such as paints or broken fluorescent lamps escapes to the atmosphere. Natural sources of atmospheric mercury emissions include volcanoes, forest fires,[6] and certain soils and weathering rocks. A third source of mercury in the atmosphere is the ongoing re-release of mercury that had previously been deposited on land and in oceans, lakes, and rivers.

Once mobilized in the environment, mercury can cycle through land, air, and water, undergoing a number of complex chemical and physical transformations. Of particular concern to public health and environmental officials is the deposition of mercury in aquatic ecosystems where it can be transformed into an organic form — methylmercury — that readily bioaccumulates up the food chain, providing a pathway of exposure for animals and humans that eat contaminated fish. Two other air pollution-related factors in the Northeast are thought to promote this process: (1) the acidified condition of many lakes, ponds, and streams (which is associated with high levels of methylmercury); and (2) elevated summertime levels of tropospheric ozone (which facilitates the conversion of elemental mercury in the atmosphere to chemical forms that are more susceptible to deposition).[7]

A combination of local, regional, and distant anthropogenic sources, natural sources, and re-emitted mercury (of either human or natural origin) from existing reservoirs of previously mobilized mercury may contribute to mercury deposition at a given location. Background concentrations of mercury in the atmosphere have increased by a factor of two to five since pre-industrial times,[8] suggesting a link between anthropogenic emissions and the increasing levels of mercury found in soils, sediments, and aquatic ecosystems.

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[5] Direct discharges of mercury to land or water may also be important on a local scale at some locations.

6 Some of the mercury released to the atmosphere during forest fires is likely to be of anthropogenic origin.

7 The acidification of lakes and streams in the Northeast is caused by acid precipitation (including acid rain, snow, and fog, etc.), primarily due to anthropogenic emissions of sulfur dioxide and nitrogen oxides. Tropospheric ozone, the same pollutant implicated in photochemical smog, is formed by reactions involving hydrocarbons and nitrogen oxides in the presence of sunlight.

8 Mason, R.P., W.F. Fitzgerald, F.M.M. Morel. 1994. The Biogeochemical Cycling of Elemental Mercury: Anthropogenic Influences. Geochim. Cosmochim. Acta. 58:3191-3198.

C. Health Effects and Fish Consumption Advisories

This Study does not attempt to undertake a comprehensive human exposure and health risk assessment for mercury. Rather it focuses on state and provincial responses to the health risks associated with methylmercury in freshwater sport fish. All the Northeast states and three eastern Canadian provinces have concluded that the elevated methylmercury levels currently found in some freshwater sport fish throughout the region pose plausible health risks and have issued advisories that recommend limiting consumption of potentially affected fish.[9] Such advisories typically recommend a greater level of caution for pregnant women, women of childbearing age, and young children based on evidence that the developing nervous system of a fetus/embryo or young child is especially sensitive to injury from mercury exposure.

Because some uncertainty exists about the health risks associated with low levels of methylmercury exposure, states and provinces have used somewhat different approaches in developing fish consumption advisories. Nevertheless, there is broad consistency among the advisories issued throughout the region. All the Northeast states believe methylmercury is of concern and, depending on the state, have issued consumption advisories for fish starting at contamination levels ranging from 0.3 to 1 part per million (ppm). The advisories are intended to protect sensitive individuals and segments of the population that frequently consume freshwater sport fish, as well as the general public. In issuing them, states and provinces have proceeded from a risk reduction rationale which recognizes that: (1) adverse developmental effects from low levels of methylmercury exposure may be subtle and difficult to detect; (2) these effects may not be reversible; (3) methylmercury is only slowly removed from the body and may therefore accumulate with repeated exposures; and (4) behavioral changes, including limiting consumption of potentially contaminated fish, may effectively reduce the health hazard.

To further refine current public health risk management strategies with respect to mercury, better information is needed on: actual fish consumption patterns, especially for certain subpopulations; the efficacy of fish consumption advisories in terms of affecting behavioral change; toxic effects associated with low level chronic versus high level short-term exposures; and integrated risk assessments that can account for potential exposure to mercury through other pathways, including the consumption of commercial and marine fish.

D. Fish Mercury Levels and Ecological Impacts

Efforts to monitor mercury levels in freshwater fish have been underway in the Northeast states since the 1970s. The results of these monitoring programs indicate that elevated levels of mercury, in some cases approaching and even significantly exceeding 1 ppm, are present in certain fish species and waterbodies throughout the region. Consistent with mercury's ability to

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9 A mercury-related U.S. Food and Drug Administration fish consumption advisory currently exists for swordfish and shark.

bioaccumulate, predatory fish that are high on the food chain and older, larger fish tend to exhibit higher concentrations. Conversely, smaller, younger fish that feed lower on the food chain generally exhibit lower mercury levels. A number of waterbody parameters also appear to correlate with fish mercury levels, including watershed area, surface area and depth, acidity, dissolved organic carbon, and conductivity. High water acidity, in particular, frequently correlates with higher concentrations of mercury in fish. Because of the multiple factors involved, fish contamination levels vary substantially in different species and waterbodies, even across relatively narrowly defined ecological subregions.

The ecological impacts of mercury could not be comprehensively assessed within the scope of this Study. This is an important area for further research, however, because the fish mercury levels documented in the Northeast states and eastern Canada are sufficiently high to pose risks to fish-eating wildlife based on available studies of mercury toxicity in animals. Adverse effects in exposed wildlife may include death, reduced reproductive success, impaired growth and development, and behavioral abnormalities. Reproductive effects are of particular concern because these may occur at levels of exposure well below those associated with symptoms of overt toxicity. Species that are more likely to be at risk for mercury exposure from fish consumption in the Northeast include top-level avian and mammalian predators such as eagles, loons, osprey, mink, and otter. Though data from available field studies are limited, elevated mercury levels and possible links to adverse reproductive effects have been documented in the region's loons and eagles.

E. Results of the Refined Emission Inventory

This Study refines and improves the emissions estimates for the Northeast states that were initially developed for USEPA's *Mercury Study: Report to Congress*. The resulting inventory of anthropogenic mercury emissions sources within the region is summarized in Table ES-1. It indicates that combustion sources, including municipal waste combustors and utility and non-utility boilers, contribute more than 80 percent of total anthropogenic mercury emissions within the Northeast states. Municipal waste combustors are by far the single largest source category within the region at present. Manufacturing sources (primarily chlor-alkali production, secondary mercury production, and cement manufacturing) account for approximately 7 percent of the inventory. Area sources (including paint use, fluorescent lamp breakage, general lab use, dental use, and crematories) account for approximately 6 percent. However, a number of potentially important sources are not included due to a lack of emissions information. As a result, the inventory is likely to understate total anthropogenic emissions in the Northeast.

Table ES–1
Mercury Emission Inventory by Source Category
for Anthropogenic Emissions Sources within the Northeast[(a)]

Source Type	kg/year	Percent of Total In-Region Inventory
Municipal Waste Combustors	7,207	45%
Non-Utility Boilers[b]	2,877	18%
Electric Utility Boilers	2,008	13%
Manufacturing Sources	1,117	7%
Area Sources	1,001	6%
Sewage Sludge Incinerators	893	6%
Medical Waste Incinerators[c]	800	5%
TOTAL	**15,903**	**100%**

[a] Inventory figures are reported to the nearest kilogram (kg), however, estimates for some source categories are highly uncertain. In addition, the inventory does not include source categories for which information was not available, such as refineries, mobile sources, landfills, hazardous waste sites, and the thermal treatment of contaminated soils at hazardous waste sites. Some of these sources may be significant emitters of mercury.

[b] Non-utility boilers include boilers and other fossil-fuel combustion systems in commercial/industrial and residential settings.

[c] Medical wastes may also contribute to mercury emissions from municipal waste combustors and sewage sludge incinerators.

The total estimated inventory of 15,903 kilograms of mercury per year (kg/yr) for the Northeast states compares with an estimated national inventory of 144,000 kg/yr, as reported in USEPA's *Mercury Study: Report to Congress*. Based on a comparison with USEPA's national figures, there are important differences between the Northeast and other areas of the country in terms of the relative contribution of various source sectors to the total inventory. Utility boilers represent a much greater portion of the mercury inventory outside the region (roughly 35 percent versus 13 percent in the Northeast), while municipal waste combustors contribute a much larger share of the in-region inventory (45 percent of total emissions compared to 15 percent out-of-region).[10] These differences are likely due to a greater reliance on coal by utilities outside the region and to the fact that a greater percentage of municipal waste is burned in the Northeast compared to most other parts of the U.S.

F. Mercury Deposition in the Northeast

The Regional Lagrangian Model of Air Pollution (RELMAP) was used to explore patterns of mercury transport and deposition in the Northeast as a result of mercury emissions

[10] Northeast emissions were subtracted from national emissions in the calculation of these percentages.

from U.S. sources.[11] Results suggest that measurable quantities of mercury are being deposited throughout the Northeast states — including in remote areas — and that in-region sources, out-of-region sources, and the global reservoir all contribute to this deposition. Specifically, the results suggest that approximately 47 percent of modeled deposition in the Northeast is attributable to sources in the region, while approximately 30 percent is attributable to U.S. sources located outside the region. The remaining 23 percent comes from the global atmospheric reservoir.[12]

In terms of the contribution of specific source categories, the model results suggest that municipal waste combustors account for more than half of the mercury deposited regionally from all anthropogenic sources (both inside and outside the Northeast). Another third of the total is attributable to utility and non-utility boilers. Utility boilers outside the Northeast contribute more to in-region deposition than do utility boilers within the region.

Because current modeling tools are imprecise, these results should be understood as best available estimates. Key areas of uncertainty include the quantity and chemical speciation of actual emissions from different sources. Speciation is important because mercury is released in different forms that exhibit very different dispersion and depositional patterns, with some being more susceptible to long-range airborne transport than others. In addition, the modeling analysis does not include emissions sources in Canada that also contribute to the regional deposition of mercury, both within Canada and in the Northeast states. Nevertheless, a comparison of field measurements and model results suggests that RELMAP provides a reasonable estimate of annual wet deposition rates in the Northeast.

Current modeling tools can — in spite of their uncertainties — provide useful insights regarding general patterns of deposition and the relative contribution of different source categories. However, they do not provide quantitative information on the level of mercury already present in the environment, the effect of current emissions on environmental concentrations, or the magnitude of effect that controls on current sources will have on these concentrations and in what timeframe. Consequently, it is not possible at this time to quantify the public health benefits that might accrue as a consequence of further limiting airborne mercury emissions.

G. Strategies to Reduce Mercury Emissions

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[11] RELMAP was also used in the deposition modeling for USEPA's *Mercury Study: Report to Congress*.

[12] RELMAP assumes a constant background level of atmospheric mercury to account for global re-emissions from land and ocean surfaces. However, the model does not account for local or regional variation in such re-emissions, which may be elevated over certain geological formations or coastal areas, such as Long Island Sound. As a result, RELMAP may underestimate the role of re-emitted mercury — of both natural and

A number of federal and state regulatory initiatives have been undertaken to reduce atmospheric mercury emissions. Among them are federally mandated mercury emissions limits for municipal waste combustors and medical waste incinerators; state and federal legislation that has dramatically reduced mercury content in batteries, historically past anthropogenic origin — in determining overall deposition rates in the Northeast. the chief source of mercury in municipal solid waste streams; and programs to separate and collect mercury-containing wastes under state and federal hazardous waste management regulations. Northeast states are currently collaborating to implement USEPA's Universal Waste Rule to facilitate recycling efforts and to expand that program to a greater number of mercury-containing products. Finally, states have initiated a variety of assistance and outreach programs to promote awareness of and support for pollution prevention[13] efforts to reduce mercury emissions.

While mercury continues to be present in the solid waste stream, timely and effective state implementation of these programs should significantly reduce future emissions from municipal waste combustors — presently the dominant in-region source — as well as from other in-region sources. However, there are currently no federal and only limited state requirements that apply to mercury emissions from utility boilers, the dominant source of mercury emissions on a national basis. Federal action will likely be necessary to further address this source category.

Opportunities for further state action to reduce mercury deposition in the Northeast may include additional efforts to: manage fluorescent lamp disposal; expand household hazardous waste collection; expand recycling and pollution prevention programs; reduce mercury content in a wider range of products (such as switches and manometers); promote public awareness of appropriate disposal options; and explore improved emissions control options for some source categories.

While this Study is focused on mercury emissions to the atmosphere, mercury is a persistent pollutant that also cycles through other environmental media (such as water and soil). Mercury that is captured in a pollution control device or diverted from an incinerator may still be released to the environment unless it is properly managed. The global dimensions of the mercury issue must also be emphasized because human activities around the planet are contributing to increased background levels of elemental mercury in the atmosphere. A comprehensive approach to the mercury issue must therefore recognize the persistent, global, and multi-media nature of this pollutant and must seek to reduce the amount of mercury mobilized by human activity in the first place, rather than merely seeking to redistribute emissions.

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13 "Pollution prevention" refers to any practice which reduces the amount of a pollutant entering the waste stream or otherwise released to the environment prior to recycling, treatment, or disposal. It can include a wide range of activities, such as toxics use reduction, material substitution, process or equipment modification, and better management practices.

H. Mercury in the Eastern Canadian Provinces

Recognizing the transboundary, international dimension of atmospheric mercury transport and deposition, the scope of this Study includes the eastern Canadian provinces of New Brunswick, Newfoundland and Labrador, Nova Scotia, Prince Edward Island, and Québec. A summary of the Canada-specific data is presented separately, in Chapter VIII of this Study. The eastern Canadian provinces, like the Northeast states, are measuring elevated mercury concentrations in lake sediments and aquatic biota. Mercury levels above 0.5 ppm have been found in several fish species, while mercury levels in the common loon of Atlantic Canada are the highest in North America. The modeling conducted as part of this Study suggests that long-range transport of mercury emissions from the U.S. is contributing to deposition in Atlantic Canada. Other research indicates that transport also occurs in the opposite direction, with Canadian emissions sources contributing to atmospheric mercury concentrations over the northeastern U.S. While the deposition of mercury from Canadian sources was not modeled as part of this Study, it is evident that further binational efforts will be necessary to effectively address the issue of environmental mercury contamination across the Northeast states/eastern Canada region.

I. Recommendations

A number of recommendations concerning future efforts and research priorities emerged in the process of developing this Study. They address the need for further pollution prevention efforts as well as for additional research to fill gaps and resolve uncertainties in our current understanding of mercury emissions and their environmental and public health impacts. A partial list of some of the broad recommendations developed as part of this Study follows; a complete list may be found in Chapter IX. As the Northeast states and eastern Canadian provinces work together to develop a coordinated Mercury Action Plan for the region, these recommendations will be reviewed and prioritized in light of available resources and other constraints.

Establish a Mercury Task Force to foster cooperation and coordinate regional and international mercury assessment and control efforts.

- Reduce mercury emissions from sources located in the region through a combination of strategies, including pollution prevention and source reduction programs, recycling, and improved emission controls.

- Seek reductions in mercury emissions from sources outside the region that contribute to mercury deposition in the northeastern U.S. and eastern Canada.

- Collect additional data on fish mercury levels and fish consumption rates and continue refining fish consumption advisories.

- Conduct additional research on the cycling and bioavailability of mercury in aquatic ecosystems and on the ecological impacts of elevated fish mercury levels, particularly for fish-eating wildlife such as eagles, loons, osprey, otter, and mink.

- Collect additional data on the quantity and speciation of mercury emissions from different sources, including some sources that remain poorly characterized at present, and continue to refine available modeling tools.

- Evaluate the expanded use of innovative multi-media programs, including public-private partnerships to promote reductions in mercury emissions.

- Develop education and outreach programs that communicate the best current information on mercury to policymakers and the public, including the results of this and other studies.