# ATMOSPHERIC MERCURY SCIENCE PROGRAMS BEING UNDERTAKEN IN NORTH AMERICA

Dr. Gary J. Foley*
Director, National Exposure Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Dr. Donald C. McKay*
Director, Air Quality Research Branch
Atmospheric Environment Service
Environment Canada
Downsview, Ontario M3H 5T4

## Abstract

National and international concern about the health effects and continued use of mercury (Hg) as well as other metals has defined the need for estimates of the long term risks to ecosystems and human health from Hg released from human activities. The atmosphere is one of the mechanisms by which Hg is transported throughout the environment. This presentation will provide an overview of what efforts are being undertaken within the U.S. and Canada to improve our understanding of the processes governing the atmospheric concentrations of mercury, the temporal and spatial variability of atmospheric mercury, and the sources and sinks of atmospheric mercury.

## Introduction

Mercury is ubiquitous in the environment, being derived from a wide variety of natural as well as anthropogenic sources. Over the last 25 years, much effort has been expended to frequently update and continuously improve anthropogenic mercury emission inventories in the United States, Canada and many other industrialized countries[1-5].

Due to the highly volatile nature of prevalent environmental species of this heavy metal (especially elemental mercury, $Hg^0$, and dimethyl mercury, $CH_3HgCH_3$), the atmosphere acts as a major environmental vector for their distribution once they have been mobilized or released – either naturally or by human activities – into the major compartments of the biosphere. At least since the beginning of the Industrial Revolution, human activities have significantly perturbed the natural biogeochemical cycle and pre-industrial environmental distribution of this heavy metal. Because of the propensity for Hg to be methylated in aquatic and terrestrial environments, the mobilization of Hg into the biosphere sets the stage for this toxic heavy metal to become biomagnified (up to a million-fold or

more) in the tissue of living organisms. Ecologically and economically important target organisms are fish and piscivorous mammals or birds, some of which also serve as an important source of food for humans. In the case of environmental mercury contamination, ecologically represents the insidious human health link that can lead to deleterious health effects, especially in populations that are at special risk: viz., indigenous peoples, pregnant women and their children. Once mercury has been released/mobilized into the environment, and has begun cycling in the biosphere, there is no way to unequivocally distinguish its original source(s), whether anthropogenic or natural. This has profound implications for the development of regulatory policies, environmental/health protection strategies and control options for this persistent, bioaccumulative, toxic substance.

This paper will provide an overview of efforts being undertaken within the USA and Canada to improve our understanding of the processes governing the atmospheric concentration of mercury, the temperal and spatial variability of atmospheric mercury and the sources (natural or man made) and sinks of atmospheric mercury.

**Canadian Efforts**

Canada emits 12T, the USA 158T, and the world 2215T, into the atmosphere from human activities (1995 data).

Information on natural emissions of mercury in North America was compiled in the late 1980s, as part of a larger study of emissions, production and usage of 14 priority toxic chemicals in the Great Lakes ecosystem sponsored by the International Joint Commission (IJC)[6-7]. Citing the *National Inventory of Natural Sources and Emissions of Mercury Compounds for Canada*[8], these documents reported an estimate for natural emissions of elemental mercury ($Hg^0$) in Canada of 3,500 tonnes per year (t/yr), with the chief sources being emissions from vegetation, outgassing of soils and rocks, and emissions from freshwater surfaces and wildfires. In the *National Inventory* itself, the authors stated that 3500 t/yr is only an "order-of-magnitude approximation," serving to provide a framework within which new data may be incorporated.

The highest deposition rates of mercury in Canada occur in the Great Lakes Basin and Atlantic Canada. The location of sources, the chemical species of mercury emitted and the meteorology/climatology all contribute to mercury deposition. As of late, a number of research and monitoring efforts on atmospheric mercury have been initiated to understand the transport, deposition, and fate of mercury. The intent of this research and monitoring is to provide information that will aid in developing policies to reduce domestic anthropogenic mercury releases to the environment, to aid in seeking commitments from other countries for mercury reductions and to determine over time how well these policies have reduced man-made mercury.

## Monitoring in Canada

In 1996, Environment Canada initiated the Canadian Atmospheric Mercury Measurement Network (CAMNet). The major objectives of CAMNet are:

- To improve the current understanding of the atmospheric transport, transformation and removal processes of elemental mercury and its ecologically significant compounds released into the environment.

- To establish spatial variability and temporal trends in Hg concentrations in the atmosphere and in precipitation on a regional/national basis.

- To identify major point and/or regional (area/line) sources of atmospheric mercury emissions.

- To define representative (characteristic) background ambient air concentrations in various parts of the country.

- To investigate trans-boundary atmospheric transport of this pollutant and to establish how Canadian concentrations in air and precipitation compare with those measured elsewhere.

- To provide input to and scientific data for validating numerical models describing the atmospheric pathways and characteristics of mercury species emitted into the environment.

- To provide scientific data for future health-based studies and risk assessments involving atmospheric aspects of mercury in the Canadian environment.

Currently there are 12 sites in the network with locations ranging from 43° to 82° N latitude and 62° to 123° W longitude.

Total Gaseous Mercury (TGM) concentrations are sampled either every 5 or 15 minutes and then converted to 1 hour or 6 hour means for subsequent data analysis and interpretation. Mercury in precipitation measurements are taken at 8 of the 12 sites adhering to the US NADP – Mercury Deposition Network (MDN) sampling protocol. Some preliminary results from the network on the temperal and spatial variability of total gaseous mercury in Canada have just been recently presented at the 25th International Conference on Heavy Metals in the Environment, Ann Arbor, Michigan, USA, August 6-10, 2000[9].

## Canadian Studies

In tandem with the Canadian monitoring efforts regarding the transport, deposition and fate of mercury in the atmosphere a number of field studies have been or are being undertaken. They include:

- **An Improved Natural Sources Inventory For Mercury**[10]

Elemental mercury vapor ($Hg^0$) is released into the atmosphere from a wide variety of natural and anthropogenic emission sources. Existing estimates of natural rates of $Hg^0$ emissions are poorly constrained due to the scarcity of temporally and spatially representative flux data. It is thus essential to determine natural volatilization flux values directly under a variety of environmental conditions, to properly understand, in qualitative as well as quantitative terms, the biogeochemical cycling of mercury in the environment.

Initial field studies were conducted from July 1996 to September 1997 to develop and apply insitu flux measurement technologies in natural settings. Natural mercury fluxes were monitored at five contrasting geochemical settings. Preliminary results indicated a strong positive relationship between total mercury concentrations in the substrate and flux of $Hg^0$ into the atmosphere. The work is continuing in order to determine if the relationship demonstrated at the five sites holds for a larger data set. Plans are to measure natural $Hg^0$ emissions from the Pinchi fault zone in British Columbia, from black shales in the Arctic and from bituminous glacial draft in Saskatchewan.

- **Mercury Emission from Wild Fires**

The Meteorological Service of Canada in collaboration with EPRI, NCAR, and the Canadian Forest Service (CFS) are undertaking studies to determine the mercury emitted from natural forest fires. Collaboration with EPRI has 2 components: (1) laboratory burns of fuel bundles; and (2) aircraft study of a small fire in Northern Ontario (spring and summer of 2000). Collaboration with CFS involved an aircraft study of gaseous mercury emitted from prescribed burns in the NWT (summer of 2000). No quality-controlled results from these studies are available as yet.

- **Mercury Species in Smelter and Power Plant Plumes**[11-12]

Smelters and coal-burning power plants can be important anthropogenetic sources of mercury. Mercury emission from these sources is mainly reported as total mercury. Because different chemical forms of mercury have different reactivities, bioavailabilities and toxicities, information on mercury speciation is required both for determining its transport, transformation and fate in the environment, and for assessing its toxicity and the influence on human health. In this study, TGM, TPM, and RGM in stack emissions and in ambient air were measured during January and February 2000. Two sources were studied: the Nanticoke coal-fired power generating station operated by Ontario Power Generation in Ontario, Canada and the Horne Smelter (copper) operated by Noranda Metallurgy in Quebec, Canada. The plumes were sampled at aging times of up to 1 hour using the National Research Council (NRC) DHC-6 Twin Otter aircraft. Ambient air was sampled by the aircraft and at a surface-based mobile laboratory (hereafter referred to as the ground site) located on a farm 19 km northwest of the Nanticoke facility and then on a small rise in the town of Rouyn 1.5 km southwest of the Horne Smelter.

The data demonstrated that it is possible to use an aircraft platform to determine 3 different species of mercury in emissions from anthropogenic sources at distances of several tens of km from the source. Analysis of the winter data set will continue, with a focus on the influence of sunlight and aging time on the speciation of mercury. A summer field study is to follow in 2000.

- **Arctic Studies**[13]

The Arctic ecosystem is showing increasing evidence of contamination by persistent toxic substances including metals such as mercury that accumulate in organisms. Since 1995, continuous surface-level measurements of total gaseous mercury in the air have been taken at Alert. These measurements have shown that during the Spring there were frequent episodic depletions of mercury vapor concentrations strongly resembling depletion of ozone in Arctic surface air following polar sunrise. The studies are continuing (Arctic 2000) and some of the conclusions are that springtime conversion of mercury vapor produces one or more mercury species with shorter atmospheric residence time than $Hg^0$. This as yet undefined chemical oxidation mechanism provides an important environmental pathway for the introduction of mercury into the biosphere, thus potentially affecting large areas of the Northern Hemisphere at a time of the year when biota are preparing for peak summertime activity.

**U.S. Efforts**

The 1997 U.S. Mercury Study[14] acknowledged and quantified the role of the atmosphere in transporting Hg throughout the environment, by stating that *"a computer simulation of long-range transport of mercury suggests that about one-third (~ 52 tons) of U.S. anthropogenic emissions are deposited, through wet and dry deposition, within the lower 48 states. The remaining two-thirds (~ 107 tons) is transported outside of U.S. borders where it diffuses into the global reservoir. In addition, the computer simulation suggests that another 35 tons of mercury from the global reservoir is deposited for a total deposition of 87 tons."*

In addition, *"the highest deposition rates from anthropogenic and global contributions for mercury are predicted to occur in the southern Great Lakes and Ohio River valley, the Northeast and scattered areas in the South, with the most elevated deposition in the Miami and Tampa areas. The location of sources, the chemical species of mercury emitted and the climate and meteorology are key factors in mercury deposition. Humid locations have higher deposition than arid locations."*

And finally, *"a plausible link exists between past and present, human-cause, atmospheric emissions of Hg in the US and increase concentrations of Hg that have been found in the environment and freshwater fish."*

Thus, the next steps involve providing monitoring data and transport and fate models of that help answer a key policy-relevant scientific question that is well stated in the EPA Mercury Research Strategy[15].

*How much methyl mercury in fish consumed by the U.S. population is contributed by U.S. emissions relative to other sources of mercury (such as natural sources, emissions from sources in other countries, and re-emissions from the global pool); how much and over what time period, will levels of methyl mercury in fish in the U.S. decrease because of reductions in environmental releases from United States sources?*

Over the last five years, a number of research and monitoring efforts on mercury transport, deposition and fate have been started or enhanced by the U.S. Federal Agencies. This paper will identify some of these and the roles that they are playing to help answer the above question.

## Monitoring of Atmospheric Hg in the U.S.

Monitoring of atmospheric mercury includes measurement of concentrations the air, in precipitation and in dry deposition. Monitoring data is most often used for determining long-term geographic and temporal trends and, in particular, demonstrating the effectiveness of emission reductions. Also, the data can be critical to two types of models–source apportionment models and transport/deposition models–both of which can be used to develop and evaluate any planned emission reduction strategies. However, these latter uses require more rigorous monitoring, including speciation of the mercury and increased spacial and/or temporal resolution. There are three efforts are underway in the U.S. that are worth looking at.

## The Mercury Deposition Network[16]

The Mercury Deposition Network (MDN), which is part of NADP[1] currently has over 35 sites and is proposing to add more. MDN was formed in 1995 to collect weekly samples of precipitation that are analyzed for total mercury. The objective of the MDN is to develop a national database of weekly concentrations of total mercury in precipitation and the seasonal and annual flux of total mercury in wet deposition. However, no speciation of Hg in the rainfall is done. The data can be used to develop information on spatial and seasonal trends in mercury deposited to surface waters, forested watersheds, and other sensitive receptors and to look at the effectiveness of emission reductions.

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[1]The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is a nationwide network of precipitation monitoring sites to collect accurate and precise weekly data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. The network is a cooperative effort between many different groups, including the State Agricultural Experiment Stations, US Geological Survey, and US Department of Agriculture, EPA, and numerous other governmental and private entities.

Concentrations of total mercury in rain are usually between 0 and 25 ng/L with a volume-weighted mean concentration for the network of about 10 ng/L in 1998. Weekly wet deposition of mercury depends on both concentration and total rainfall. The average wet deposition value for the network is about 200 ng/m$^2$/year or 10 μg/m$^2$/year. Mercury deposition is highest in the summer and lowest in the winter at most sites in eastern North America. This is attributable to both higher mercury concentrations and higher precipitation amounts during the summer months. The average wet deposition of mercury tends to be highest in south Florida and lowest in New England and eastern Canada.

**Mercury Monitoring in the Great Lakes States**

Individual Great Lakes states, notably Minnesota and Wisconsin[17], are engaged in considerable mercury monitoring. Michigan, Ohio, Illinois, and Indiana DEM are considering development/expansion of ambient mercury monitoring program, including deposition monitoring and vapor and particulate monitoring. In addition, states are expanding their source monitoring capacity with purchase of Tekrans, Lumex, and other devices.

Engstrom and Swain (1997)[18] analyzed sediment core data from the midwest to detect recent trends in mercury emissions and levels in the Midwest and found that, for a number of Minnesota lakes, mercury deposition peaked in the 1960s and 1970s and then declined. These declines were not seen in remote lakes in southeastern Alaska, indicating that deposition from the global pool had not declined. The decline in deposition inputs to the Minnesota lakes can be attributed to reduced emissions from regional and local sources, which are believed to have declined because of increasing application of controls to sources of mercury emissions (particularly waste incinerators).

**Mercury Monitoring in R-EMAP**

EPA has established a Regional Environmental Monitoring and Assessment Program (R-EMAP) project[19] which is measuring trace elements in precipitation and aerosol samples, using back trajectory analysis with emission signatures and conducting source apportionment to define local, regional, and inter-regional sources. Other related projects include: a source receptor project that provides observational data on precipitation events from a number of municipal solid waste incinerators in a small geographic area for a 200 mile corridor in the Lower Merrimack Valley and Adjacent Coastal Areas of Michigan; and an assessment of sediment contaminants, including mercury, in the Colorado, Rio Grande tidal, East Bay Bayou, and Corpus Christi Bay estuarine watersheds.

**More Mercury Monitoring is Needed**

A recent peer review (December 1999) of EPA's Draft Mercury Research Strategy[20] emphasized the need for additional monitoring of mercury in the environment. The reviewers offered several reasons why such monitoring is necessary, such as to validate the findings of fate and transport models and emissions inventories, to quantify the effectiveness

of future control strategies and regulations, to provide information on both baseline and changing levels of mercury in the global environment, and to characterize the success or outreach and risk communication efforts.

**U.S. Regional Mercury Studies**

Mercury contamination is an issue in many geographic locations in the United States. The U.S. "fish advisories"[21] give a good picture of the magnitude of the problem. In addition, the USGS[22] has identified the mercury "hot spots."

In any of these geographic analyses, research and monitoring efforts on mercury transport, deposition and fate can help provide some scientific direction to those dealing with the issues from the policy perspective. There are five possible contributors of mercury through the air pathway. Not all of these may be important in any geographical region.

The contributions from regional background. *Addressed by the mercury monitoring networks.*

The contributions from specific local sources. *May be addressed by local "source apportionment" or "source attribution" studies, including GLAMAP.*

The contribution of specific long-distance sources . *Addressed by mercury modeling combined with data from monitoring.*

The emissions from major water bodies, including snow pack, and how much is redeposited back to themselves. *Addressed through specific air-surface exchange measurements at the water body, such as that being done in the Lake Michigan Mass Balance Study.*

The contribution of the "urban plumes" as they pass over a large receptor, such as the Great Lakes. *Addressed by an urban plume study, such as AEOLOS, the Chicago Urban Plume Study.*

With this in mind, an examination of the mercury transport, deposition and fate studies in each of the three important U.S. geographical areas -- the Everglades, the Great Lakes and the Alaskan Arctic -- is worthwhile.

**Great Lakes**

GLAMAP

The Great Lakes Atmospheric Mercury Assessment Project (GLAMAP) was begun in 1994 to obtain a region-wide assessment of the spatial and temporal variations in atmospheric mercury levels for the Great Lakes basin. An international monitoring network was established with more than 10 sites located in 7 states and provinces across the Great

Lakes region. Measurements of gas- and particle-phase mercury were performed simultaneously at all of the sites and were collected for a period of two years.

Atmospheric mercury monitoring was added to the five Integrated Atmospheric Deposition Network (IADN)[2] master stations located on the shores of each of the five Great Lakes. Five additional network locations were chosen to complete the spatial coverage of the region so that areas typically upwind of the Great Lakes were also represented by a site.

The spatially averaged QTBA field for the sites in the *east* and *south* sub-regions (Figures 5.5a) indicates that on average, source areas within the southern half of the Great Lakes region contributed 23 to 27 $pg/m^3$ of particle-phase mercury to the region represented by these sites. The source areas contributing the highest concentrations on average (25- 27 $pg/m^3$) included the entire Lake Erie and the western Lake Ontario basins, as well as the upper and lower Ohio River valley areas. Located within these areas are several of the major urban/industrial centers for the Great lakes region, including Cleveland, Buffalo, Toronto/Hamilton, and Pittsburgh. The other major urban/industrial centers for the region (Detroit, Chicago/Gary, St. Louis) were located within the source areas that contributed 23 to 25 $pg/m^3$ on average to these sites.

The monitoring data from GLAMAP was analyzed under the study named "Mercury Methods Development for Investigating Sources, Transport and Deposition in the Great Waters (*NTIS Report Number Not Available*) and resulted in the following findings

- Mercury concentrations in Chicago urban rain was about 2 times higher than concentrations in rain collected at Sleeping Bear Dunes. Also, atmospheric mercury concentrations in vapor phase and attached to particles were higher in urban areas.

- Wet deposition is the dominant pathway for atmospheric deposition of mercury into Lake Michigan (900 kg/yr) followed by vapor phase (400 kg/yr) and particle phase (60 kg/yr) deposition. About 490 kg/yr vaporized from the lake.

- Tributary loads of mercury were estimated to be about 20% of the net air loads of mercury.

- Gas phase mercury concentrations were higher (approximately 25%) in the southern and eastern portions of the Great Lakes basin than in the northern and western portions. The same trend was apparent for particulate phase mercury; only the difference was greater by a factor of 3.

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[2]Integrated Atmospheric Deposition Network (IADN) addresses US/Canada Surveillance and Monitoring Obligation; GLNPO, EC (AES, NWRI, EC-Ont, EHD), and OME. The network consists of air and precipitation monitoring stations around the Great Lakes. IADN determines the atmospheric loadings of toxic substances to the Great Lakes System by quantifying the total and net atmospheric input of toxic chemicals and also defines the temporal and spatial trends in atmospheric deposition of toxic chemicals.

- Mercury source trajectory models were used to identify source regions. Sources in the Ohio River valley and urban areas in the Great Lakes basin contributed the most mercury to the Great Lakes airshed. These models will be used to push for MACT standards for utilities.

AEOLOS

In June 1998, a workshop was held in Chicago to allow scientists to provide an overview of some of the key findings from the EPA sponsored studies on the Urban Contamination of the Great Waters: Atmospheric Exchange over Lakes and Oceans Study (AEOLOS)[23]. The study had the objective to determine the influence of the Urban/Industrial Chicago/Gary areas (i.e. the combined urban plume) to atmospheric fluxes by route/means of deposition and by source.

Although this study did not specifically focus on mercury, the research, in general, found that:

- Urban areas contribute relatively large loads of PCBs, PAHs, and mercury (Hg) compared to "background" areas.

- A mass balance model that fails to consider the impacts of urban areas will underestimate atmospheric loads of heavy metals and organic pollutants to the "Great Waters."

Lake Michigan Mass Balance Study

The Lake Michigan Mass Balance (LMMB) Study focuses on four chemicals: PCBs, *trans*-nonachlor, atrazine, and mercury. These substances are being studied because they are representative of classes of pollutants (e.g., pesticides, herbicides, metals, etc.) of environmental significance in Lake Michigan and throughout the Great Lakes.

The Lake Michigan Mass Balance Workplan[24] identifies four specific objectives:

- Identify Chemical Loading Rates – To identify relative loading rates of critical pollutants from major media (air, tributaries, sediment resuspension) to the Lake Michigan Basin in order to better target future load reduction efforts.

- Establish Baselines – The LMMB loading rates will establish a baseline against which to gauge progress in meeting reduction goals.

- Predict Benefits – The mass balance models will deliver predictive ability to resource managers to assist in choosing management strategies for Great Lakes toxic chemicals. Specifically, managers will determine the environmental benefits of specific load reduction scenarios for toxic substances and the time required to realize those benefits.

- Understand Ecosystem Dynamics – To improve our understanding of key environmental processes governing contaminant cycling and availability within relatively closed ecosystems.

The data verification and validation portion of the Lake Michigan Mass Balance project is scheduled to be finished in 2000, although analysis and modeling of the data will continue after that. In addition to the loadings data above, the results, when completed, will be described here by media (water, air, sediment, and biota) and by contaminant (PCBs, *trans*-nonachlor, mercury, and atrazine). In the meantime, many of the principal investigators have published their results in peer-reviewed scientific journals.

HYSPLIT & CMAQ Modeling

The IJC International Air Quality Advisory Board (IAQAB) is coordinating a project to assemble information relevant to BTS policy[25] . The project involves three phases, for each of the substances of concern. The first is the determination of the availability and adequacy of US and Canadian emissions inventories. The second phase involves the identification of control/prevention actions. The third phase involves an attempt to determine the relative contributions of different sources and source regions in the inventory to the Great Lakes atmospheric deposition, i.e., to estimate source-receptor relationships. In this latter phase, U.S.-Canadian effort chose the NOAA HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory) computer model to simulate the atmospheric fate and transport of pollutants from sources in the United States and Canada to the Great Lakes. The applicability of this model for screening-level estimates of source contributions to Lake Michigan and Lake Superior was demonstrated for three pollutants--dioxins/furans, cadmium and atrazine. It will next be used to simulate mercury transport and deposition to these lakes.

In order to help identify the air emission sources responsible for this atmospheric deposition of mercury, new Community Multi-Scale Air Quality (CMAQ)[26] software has been developed by EPA to simulate the emission, transport, chemical and physical transformation, and wet and dry deposition of atmospheric mercury. The new pollutant species added to CMAQ for atmospheric mercury are: elemental mercury ($Hg^0$), mercuric chloride ($HgCl_2$), mercuric oxide gas (HgO(g)), mercuric oxide aerosol (HgO(a)), and a general mercuric aerosol (HgA) resulting from the evaporation of cloud water containing various dissolved mercury compounds.

This version of the CMAQ mercury model must be qualified as "experimental" at this time due to serious scientific uncertainties regarding: (1) the rates and physical/chemistry forms of mercury emitted from various industrial sources; (2) the rates and forms of mercury emitted from soils, wetlands and water bodies previously contaminated by human activity; (3) the rates and forms of mercury from truly natural sources, and (4) the actual physical and chemical processes of the atmosphere that transform mercury to and from the forms known to effectively deposit to the earth's surface. Nonetheless, this new CMAQ modeling framework for mercury can be used now along with supporting observational data to help identify the most important uncertainties in the context of our present understanding of

atmospheric mercury cycling. As our understanding of atmospheric mercury improves, these advances can be efficiently incorporated into the modular CMAQ modeling framework.

**South Florida**

Recent and continuing Florida Atmospheric Mercury Studies focus on understanding reactive gaseous mercury and particulate mercury in Florida's atmosphere, building on the South Florida Mercury Monitoring Study and coordinated with the Florida Department of Environmental Protection. These studies have shown that atmospheric deposition is the predominant source of mercury to the Everglades. Ongoing work focuses on determining the sources of this mercury, and includes flights with a specialty instrumented aircraft. Measurements of reactive mercury in the ambient atmosphere and its dry deposition, along with particulate-bound mercury, are critical to evaluating the sources and transport of mercury in the Everglades. Development of advanced models has begun for atmospheric transport and deposition of mercury to incorporate new information on species and forms of mercury and related gases. These models will be able to include south Florida's specific meteorology while representing processes, which can be generally applied to other areas.

The South Florida Mercury Monitoring Study will define the magnitude, extent and trend of mercury contamination in the Florida Everglades, as well as provide information for the initial phase of the ecological risk assessment. Extensive data collection supported the development of the South Florida Restoration Project models. The information was used in developing a mathematical biogeochemical model of mercury cycling in the Everglades, in performing ecological risk assessments, in determining human health and ecological risks and in developing remediation or regulatory strategies.

The South Florida Ecosystem Assessment Project (Phase I) was a large-scale intergovernmental monitoring and assessment program designed to measure current and changing conditions of ecological resources in South Florida using an integrated approach. The ultimate goal of this program is to provide decision-makers with sound ecological data needed to improve environmental management decisions for the restoration of the Everglades ecosystem. This project addresses multiple issues that are thought to be critical to the restoration of the ecosystem and addresses the interactions among issues. These issues include mercury contamination, eutrophication, marsh habitat alteration, and hydroperiod modification. Phase II of this project began in 1999. Time series monitoring will identify changes occurring since Phase I. Increased emphasis will be placed on vegetation, phosphorus and mercury assessment, providing data for input to various ecosystem models such as an Everglades mercury cycling model. The Phase I technical report and database is located on the EPA Region 4 website[27].

**Alaskan Arctic**

EPA, NOAA, and DOE's Oak Ridge National Laboratory are working together to investigate the nature and geographical extent of a phenomenon termed the "Arctic Sunrise" where atmospheric elemental gaseous mercury levels have been shown to drop drastically,

well below global background levels, during the Arctic Spring when sunlight returns. Although the majority of atmospheric mercury is present in elemental form, differentiation is important due to the greater local impact of reactive forms. Measurements of Hg2+ and HgP during arctic sunrise will help elucidate the transformation processes leading to the Hg0 depletion. The understanding of the processes controlling the transformation and deposition of mercury species in the Arctic may shed light on what is happening in the other regions as well.

Lindberg et al[28] noted that while mercury levels in Arctic wildlife are known to be elevated, there are no known Arctic sources that would explain this. Therefore, long-distance sources must be considered. They point out that one hypothesis, that they will look at in the study, is that elemental mercury from these faraway sources is transformed into reactive gaseous species that deposit locally. Some of the initial measurements are presented, of which the measurements of the snow pack is most interesting. The snow pack appears, in the preliminary measurements, to behave similar to a large water body, accumulating mercury for periods of time and releasing at other times. Special measurements to confirm this are being undertaken in the study.

**Conclusions**

After looking at the above U.S./Canadian programs, the following observations can be drawn:

- Both countries have established monitoring sites that are providing data in mercury levels in precipitation which should be continued. However, more effort is needed on the measurement of atmospheric levels of mercury, including the speciation between total gaseous mercury, total particulate mercury, and reactive mercury.

- Models now exist for predicting the transport and deposition of mercury both on a global and regional scale. However, they are not generally applicable to all regional studies. In each study, they need to be carefully evaluated with monitoring data collected from that region to determine their validity for the intended application.

- Comprehensive studies using state-of-the-art measurements and models, such as those in South Florida, the Great Lakes, the Arctic, and in the western and central prairies of Canada are the appropriate type of effort to understand the transport, deposition, and fate of the atmospheric species of mercury. These studies will also identify the major sources of mercury contributing to these regions.

*Disclaimer*

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16. ABSTRACT

National and international concern about the health effects and continued use of mercury (Hg) as well as other metals has defined the need for estimates of the long term risks to ecosystems and human health from Hg released from human activities. The atmosphere is one of the mechanisms by which Hg is transported throughout the environment. This presentation will provide an overview of what efforts are being undertaken within the U.S. and Canada to improve our understanding of the processes governing the atmospheric concentrations of mercury, the temporal and spatial variability of atmospheric mercury, and the sources and sinks of atmospheric mercury.

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