

**GREAT LAKES BINATIONAL TOXICS STRATEGY
MANAGEMENT ASSESSMENT FOR MERCURY**

**U.S. Environmental Protection Agency
Great Lakes National Program Office
Chicago, IL**

and

Environment Canada

February 2006

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EXECUTIVE SUMMARY

INTRODUCTION

The Great Lakes Binational Toxics Strategy identifies specific challenge goals for each Level 1 substance for the U.S. and Canada, with a timeframe that expires in 2006. As 2006 approaches, an analysis of progress and determination of next steps is needed to respond to the mandate set forth in the Strategy. A *General Framework to Assess Management of GLBTS Level 1 Substances* was developed to provide a tool to assist the Parties (Environment Canada and U.S. EPA) and stakeholders in conducting a transparent process to determine the appropriate management outcomes for the Level 1 substances. This report presents an analysis of mercury conducted using the general framework.

CHALLENGE GOAL STATUS

Both Canada and the U.S. have made significant progress in achieving reductions of mercury releases. Canada has reduced releases of mercury from anthropogenic sources in Ontario by approximately 84 percent (1988 baseline), against the goal of a 90 percent reduction. It is unlikely that Canada will meet its reduction goal by 2006. Mercury releases in Ontario have been cut by over 11,700 kilograms (kg) since 1988, based on Environment Canada's 2002 mercury inventory. The U.S. release challenge applies to the aggregate of air releases nationwide and to releases to the water within the Great Lakes Basin. According to the most recent National Emissions Inventory (NEI) estimates, U.S. mercury emissions decreased approximately 45 percent between 1990 and 1999, against a challenge goal of 50 percent. If an estimate of gold mining emissions is included in the 1990 inventory, the estimated reduction increases to 47 percent. By 2006, additional regulations and voluntary activities are expected to reduce U.S. mercury emissions by at least 50 percent (from the 1990 baseline), meeting the challenge goal.

Mercury use (or consumption) in the U.S. has declined significantly since 1995. However, the exact amount is difficult to quantify because the U.S. Geological Survey (USGS) stopped reporting estimated U.S. mercury consumption after 1997. On the basis of data reported by the chlor-alkali industry and the lamp industry, it is estimated that mercury use declined by more than 50 percent between 1995 and 2003. This assumes that mercury use by other sectors remained constant between 1997 and 2003. This may underestimate the actual decline, considering likely reductions in the use of mercury in measurement and control devices, switches and relays, and dental amalgam that have not been quantified.

ENVIRONMENTAL ANALYSIS

The consideration of mercury in the environment is complicated by the need to sort through contributions from natural sources, those associated with legacy sources, and currently occurring anthropogenic sources. GLBTS mercury efforts have been focused on currently occurring anthropogenic sources. The following points illustrate pieces of the mercury puzzle:

- Mercury levels continue to exceed risk-based criteria within the Great Lakes, most notably for methylmercury in fish and for sediment quality.

- Long-term trends (over 30 years) show a substantial decline (e.g., in herring gull eggs and sediments).
- Shorter term trends are less certain. In the past 10-20 years, mercury levels in fish, bald eagles, herring gull eggs, and atmospheric deposition have not declined.
- Mercury emissions decreased more than 40 percent in the U.S.
- Mercury releases in Ontario were reduced by 84 percent between 1988 and 2002.
- Mercury deposition data show no discernable decrease between 1995 and 2003.
- Mercury concentrations in biota are influenced not only by rates of mercury input into the environment, but also by factors that affect bioavailability and methylation of mercury.

One possible explanation for the lack of correspondence between the emissions trends and recent deposition trends is that reductions in deposition caused by North American emissions reductions have been offset by increases in deposition caused by global emissions. Trends of mercury concentrations in fish may not follow trends in mercury deposition, because mercury fish concentrations may be affected by mercury contributions from sediments, particularly in areas of past high direct water discharges.

Mercury is a major cause of fish consumption advisories in the Great Lakes Basin, with the highest mercury exposures caused by eating fish from certain inland lakes within the Basin. Therefore, continued efforts to reduce mercury inputs to the Great Lakes are warranted. Consumption of fish from the Great Lakes region adds to human body burdens of methylmercury, which often exceed health criteria. However, fish consumption also provides many health benefits, and in many cases Great Lakes fish are lower in mercury than other sources of fish. In the U.S., NHANES findings indicate that blood mercury levels in young children and childbearing-aged women usually are below U.S. EPA's reference dose; however, blood mercury analyses for 16 to 49-year-old women showed that approximately 6 percent of women in the survey had blood mercury concentrations greater than 5.8 ug/L, a blood mercury level equivalent to the current U.S. EPA reference dose, or the level, following application of an uncertainty factor, at which exposure is considered unlikely to cause appreciable risk. In Canada, exceedances of health guidelines for mercury are comparatively rare, because Canada's guidelines are less restrictive than U.S. guidelines.

Sources of Mercury

Mercury inputs to the Great Lakes environment have been reduced significantly. However, a wide variety of sources continue to impact the Great Lakes, especially atmospheric deposition. Mercury deposition results primarily from releases to the air from past and current anthropogenic sources, both in North America and globally. Mercury from natural sources, emissions from current human activities, and re-emission of historic anthropogenic mercury, each contribute to mercury levels in the Great Lakes. In Ontario, the largest air emissions sources of mercury include electric power generation, iron and steel production, municipal waste (primarily land application of biosolids), cement and lime manufacturing, and incineration. In the U.S., the largest air emissions source of mercury is now coal-fired electric power generation. The recent regulatory action in the U.S. and a proposed draft Canada-wide standard may result in substantial reductions from this sector. (The recently promulgated Clean Air Mercury Rule on coal-fired power plants in the U.S. is under legal challenge.) Other sources of mercury in the U.S. include

industrial boilers, production of gold and other metals, steel production using steel scrap, hazardous waste incineration, and chlorine production at mercury cell plants. In addition, mercury levels in some areas are elevated as the legacy of past contamination of water and sediments by direct water discharges of mercury.

MANAGEMENT ASSESSMENT

The GLBTS has identified a number of opportunities to reduce mercury releases to the Great Lakes Basin. Since mercury releases can be transported to the Great Lakes via the atmosphere from long distances, the GLBTS has also attempted to influence reductions across North America. The GLBTS can help promote reductions by continuing to share information about cost-effective reduction opportunities, tracking progress toward meeting reduction goals, including reductions achieved through various other programs and regulations, and publicizing voluntary achievements in mercury reduction. Particular attention will be paid to information-sharing in areas where mercury releases are significant but there are no existing federal regulations, or regulations are under development (e.g., contamination of metal scrap by mercury-containing devices, and their resulting emissions). The GLBTS will continue to encourage and track efforts to reduce mercury releases in sectors with regulatory systems in place or under implementation (e.g., mercury cell chlor-alkali plants and coal-fired power plants).

In addition, the GLBTS may have opportunities to promote mercury reduction beyond the U.S. and Canada, for instance by participating in the United Nations Environment Program's efforts to help developing countries identify sources of mercury and strategies for control. As North American releases decrease and global releases increase, an increasingly large share of mercury inputs to the Great Lakes Basin will come from overseas sources. The GLBTS has yet to determine if new reduction targets and challenge goals are appropriate.

MANAGEMENT OUTCOME

The final management outcome for mercury is continued Active Level 1 status with periodic reassessment by the GLBTS. The Mercury Workgroup will: 1) disseminate information about removal of mercury devices in auto scrap, appliances, and industrial equipment; 2) assist state, provincial, and local governments identify cost-effective reduction approaches for mercury releases from dental offices; and 3) participate in national and international mercury reduction programs.

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ACRONYMS

AOC	Areas of Concern
B(a)P	Benzo(a)pyrene
CAA	Clean Air Act
CAMNet	Canadian Atmospheric Mercury Measurement Network
CAMR	Clean Air Mercury Rule
CCME	Canadian Council of Ministers of the Environment
CDC	Centers for Disease Control and Prevention
CMAQ	Community Multiscale Air Quality
CWS	Canada Wide Standards
DFO	Department of Fisheries and Oceans
EC	Environment Canada
FDA	Food and Drug Administration
GLBTS	Great Lakes Binational Toxics Strategy
GLLFAS	Great Lakes Laboratory for Fisheries and Aquatic Sciences
GLNPO	Great Lakes National Program Office
GLWQA	Great Lakes Water Quality Agreement
H2E	Hospitals for a Healthy Environment
HCB	Hexachlorobenzene
Hg	Mercury
HUC	Hydrological Unit Code
IADN	Integrated Atmospheric Deposition Network
Kg	Kilograms
LaMP	Lakewide Management Plan
MAC	Maximum Acceptable Concentration
MACT	Maximum Achievable Control Technology
MCL	Maximum Contaminant Level
MDEQ	Michigan Department of Environmental Quality
MDN	Mercury Deposition Network
METAALICUS	Mercury Experiment To Assess Atmospheric Loading In Canada and the U.S.
MPCA	Minnesota Pollution Control Agency
NAS	National Academy of Sciences
NAPS	National Air Pollution Surveillance Network
NASM	Non-Agricultural Source Materials
NEI	National Emissions Inventory
NHANES	National Health and Nutrition Examination Survey
NLFTS	National Lake Fish Tissue Study
NLFA	National Listing of Fish Advisories
NOTL	Niagara-on-the-Lake
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
OAQPS	Office of Air Quality Planning and Standards
OCS	Octachlorostyrene
OSW	Office of Solid Waste
PCBs	Polychlorinated Biphenyls
PEC	Probable Effect Concentrations
PEL	Probable Effect Level

PM	Particulate Matter
RfD	Reference Dose
RGM	Reactive Gaseous Mercury
RIA	Regulatory Impact Analysis of the Clean Air Mercury Rule
SQG	Sediment Quality Guidelines
TEL	Threshold Effect Level
TGM	Total Gaseous Mercury
TRI	Toxics Release Inventory
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VNP	Voyageurs National Park
WLSSD	Western Lake Superior Sanitary District

MANAGEMENT ASSESSMENT FOR MERCURY

1.0 INTRODUCTION

The Great Lakes Binational Toxics Strategy (GLBTS) identifies specific reduction challenges or goals for each Level 1 substance for the U.S. and Canada. The time frame for achieving the Strategy's challenge goals expires in 2006. As 2006 approaches, an analysis of progress and determination of next steps is needed to respond to the mandate set forth in the Strategy. The *General Framework to Assess Management of GLBTS Level 1 Substances* was developed to provide a tool to assist the Parties (Environment Canada and U.S. EPA) and stakeholders in conducting a transparent process to determine the appropriate management outcomes for the Level 1 substances: mercury, polychlorinated biphenyls (PCBs), dioxins and furans, hexachlorobenzene (HCB), benzo(a)pyrene (B(a)P), octachlorostyrene (OCS), alkyl-lead, and five cancelled pesticides: chlordane, aldrin/dieldrin, DDT, mirex, and toxaphene. The framework presents a logical flow diagram for evaluating progress and the need for further action by the GLBTS on the Level 1 substances. Further details on the background and objectives of the framework are provided in Appendix A.

This report discusses the analysis of mercury using the *General Framework to Assess Management of GLBTS Level 1 Substances*. While the framework's flow diagram guides the discussion, the primary intent of the analysis is to present an overall evaluation of the status of the substance with respect to:

- Progress toward the GLBTS challenge goals;
- Levels in the Great Lakes environment; and
- Future management of the substance within the GLBTS.

A naturally-occurring element, mercury is a toxic persistent, bioaccumulative pollutant. Its most familiar form is liquid elemental mercury, a shiny, silver-gray, odorless metal, but it takes many different forms in the environment. Most environmental releases of mercury are inorganic, either in the elemental or ionic form. Most emissions of ionic mercury deposit within the region of the source, while elemental mercury enters a global atmospheric reservoir where it can remain and potentially travel long distances.

When released to the environment, inorganic mercury can be converted to methylmercury, an organic form of mercury, which can bioaccumulate and reach dangerous levels in fish at the top of the aquatic food chain. Mercury is a potent neurotoxin, capable of impairing neurological development in fetuses and young children and damaging the central nervous system of adults. People can be exposed to harmful quantities of mercury through consumption of fish contaminated with methylmercury, and the most vulnerable population is the developing fetus, exposed as a result of the mother's consumption of fish. Fish consumption advisories are in effect for mercury in thousands of lakes and rivers, including much of the Great Lakes ecosystem.

In addition to fish consumption and other dietary exposures, harmful exposures can also occur as the result of contamination of indoor air with elemental mercury vapor. Breakage of products that contain mercury, or otherwise spilling mercury, leads to evaporation of the exposed elemental mercury. If ventilation is insufficient, vapors can build up to levels that are dangerous,

potentially causing acute effects including respiratory failure, kidney damage, and neurological damage.

Section 2.0 of the report documents progress toward achieving the Strategy's challenge goals. Section 3.0 evaluates the impact of the substance on the Great Lakes basin using environmental and human health data. Section 4.0 evaluates the ability for the GLBTS to effect further reductions, and Section 5.0 arrives at a final management outcome for the GLBTS.

2.0 CHALLENGE GOAL STATUS

Have the challenge goals for the substance been met?

The GLBTS challenge goals for the U.S. and Canada, as stated in the 1997 Great Lakes Binational Toxics Strategy agreement, are:

Canadian Challenge: Seek by 2000, a 90 percent reduction in the release of mercury, or where warranted the use of mercury, from polluting sources resulting from human activity in the Great Lakes Basin.¹

U.S. Challenge: Seek by 2006, a 50 percent reduction nationally in the deliberate use of mercury and a 50 percent reduction in the release of mercury from sources resulting from human activity.

Both Canada and the U.S. have achieved reductions of mercury from sources resulting from human activity. However, despite the progress that has been made, both Canada and the U.S. continue to pursue their challenge goals outlined in the Strategy. A description of the progress made by each country is provided below. The GLBTS Mercury Workgroup is active; numerous mercury reduction activities are occurring in Canada to meet the goal of reducing releases of mercury in the Great Lakes Basin, and in the U.S. to meet the goal of reducing the deliberate use of mercury and releases of mercury nationwide.

Ontario: Progress Toward the GLBTS Challenge

In Ontario, releases of mercury have been reduced by approximately 84 percent between the 1988 baseline and 2002. Figure 2-1 illustrates the progress made toward the Canadian 90 percent reduction target. This figure shows that releases in Ontario have been cut by more than 11,700 kilograms (kg) since 1988, based on Environment Canada's 2002 mercury inventory. Figure 2-2 illustrates the 2002 sources of mercury releases in Ontario. This figure shows that the primary sources of releases are electric power generation, iron and steel, municipal (primarily land application of biosolids), cement and lime, and incineration.

¹ This target is considered as an interim reduction target and, in consultation with stakeholders in the Great Lakes Basin, will be revised if warranted, following completion of the 1997 COA review of mercury use, generation, and release from Ontario sources.

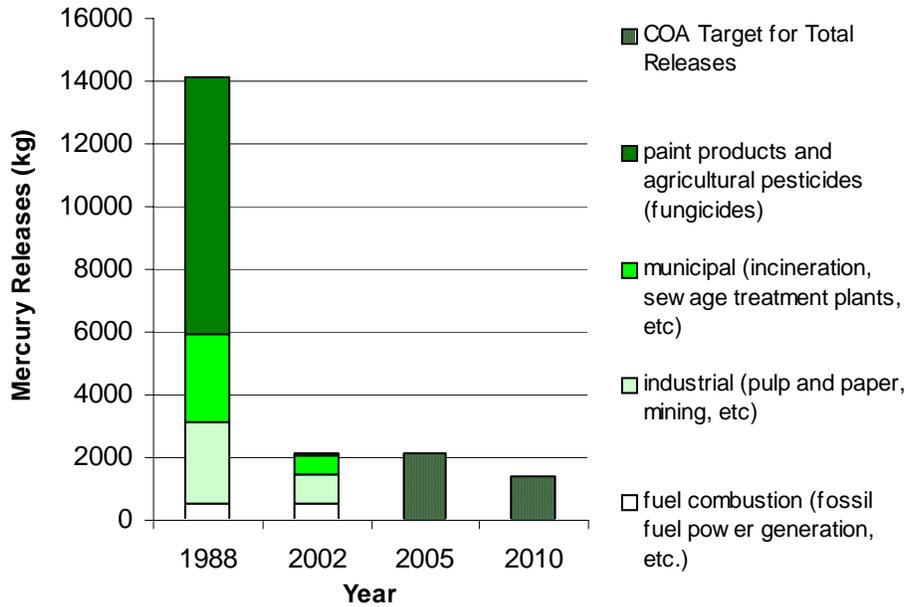


Figure 2-1. Reductions in Mercury Releases in Ontario from 1988 to 2002, by Sector.
 Source: Environment Canada, Ontario Region (2004)

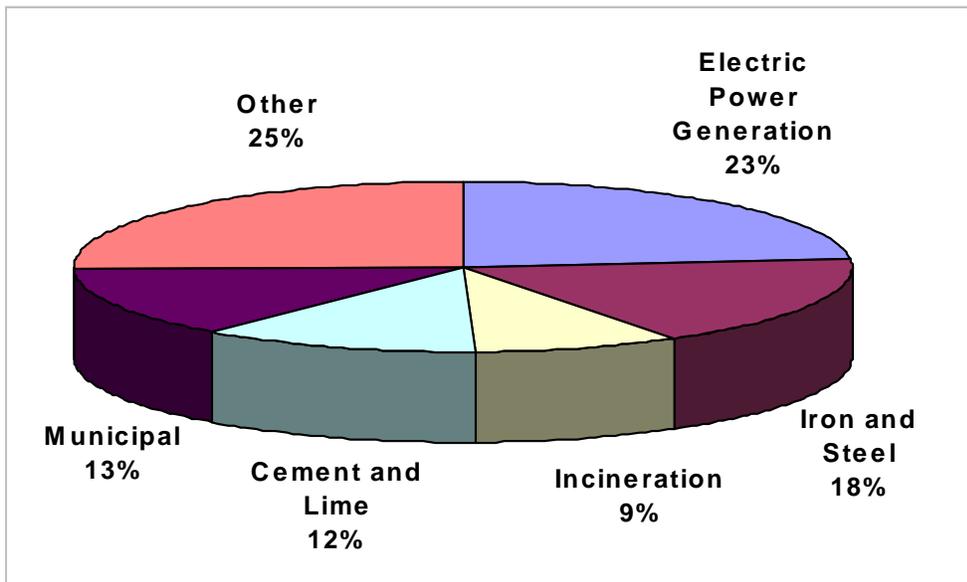


Figure 2-2. Sources of Mercury Releases in Ontario (2002).
 Source: Environment Canada, Ontario Region (2004)

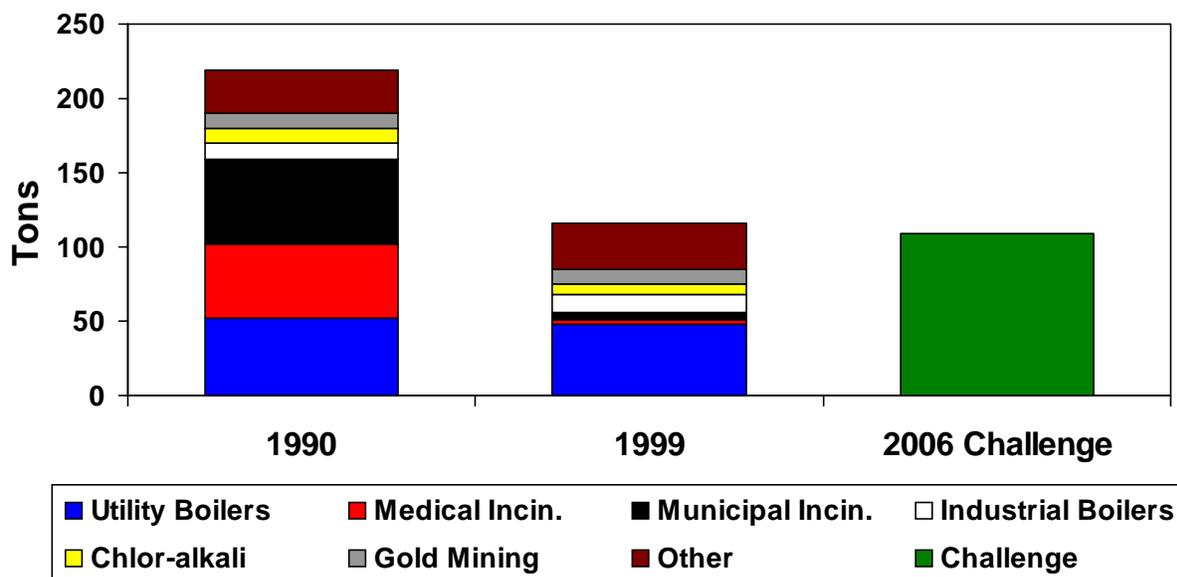
United States: Progress Toward the GLBTS Challenge

Because of the potential for mercury releases to be transported to the Great Lakes, the Mercury Workgroup has focused on nationwide mercury releases in the U.S. The U.S. release challenge

applies to the aggregate of air releases nationwide and of releases to the water within the Great Lakes Basin.²

According to the most recent estimates from the National Emissions Inventory (NEI), U.S. mercury emissions decreased approximately 45 percent between 1990 and 1999 (see Figure 2-3).³ It is likely that some additional reductions have occurred since 1999, particularly in emissions from municipal waste combustors and medical waste incinerators. Significant reductions in emissions from these sectors had already taken place by 1999, primarily from the use of Maximum Achievable Control Technology (MACT) standards enacted under the Clean Air Act (CAA). Compliance with emissions regulations for these categories was not required until after 1999. However, by 2006, additional regulations and voluntary activities are expected to reduce mercury emissions by at least 50 percent, thereby achieving the reduction challenge. Further discussion on sources of mercury is contained in Section 4.1.1.

Figure 2-3. U.S. Mercury Emissions: 2006 Challenge, 1990 Baseline.



Source: U.S. EPA, Office of Air Quality Planning and Standards

Although it is clear that mercury use has decreased since 1995, the trend is difficult to quantify because the U.S. Geological Survey (USGS) stopped reporting estimated U.S. mercury consumption after 1997. However, on the basis of data reported by the chlor-alkali industry and the lamp industry, it appears that mercury use declined more than 50 percent between 1995 and 2003, assuming that mercury use by other sectors has remained constant since 1997 (see Figure 2-4). The chlor-alkali industry accounted for an estimated 35 percent of mercury use in 1995, and its total mercury use decreased 76 percent between 1995 and 2003 (including the impact of plant closures). The fluorescent lamp industry has reported that mercury use in 2003 was 6 tons, compared with 32 tons estimated by the USGS for 1997 (see Table 2-1). These reductions are

² This target is considered as an interim reduction target and, in consultation with stakeholders, will be revised if warranted, following completion of the Mercury Study Report to Congress.

³ Note that there is uncertainty associated with all emissions inventories. For more discussion, see Murray and Holmes (2004).

the result of reductions in the mercury content of lamps sold in the U.S., as well as an increase in lamp imports and a decline in U.S. fluorescent lamp production. Lamp manufacturers use mercury both in lamps themselves and in the production process.

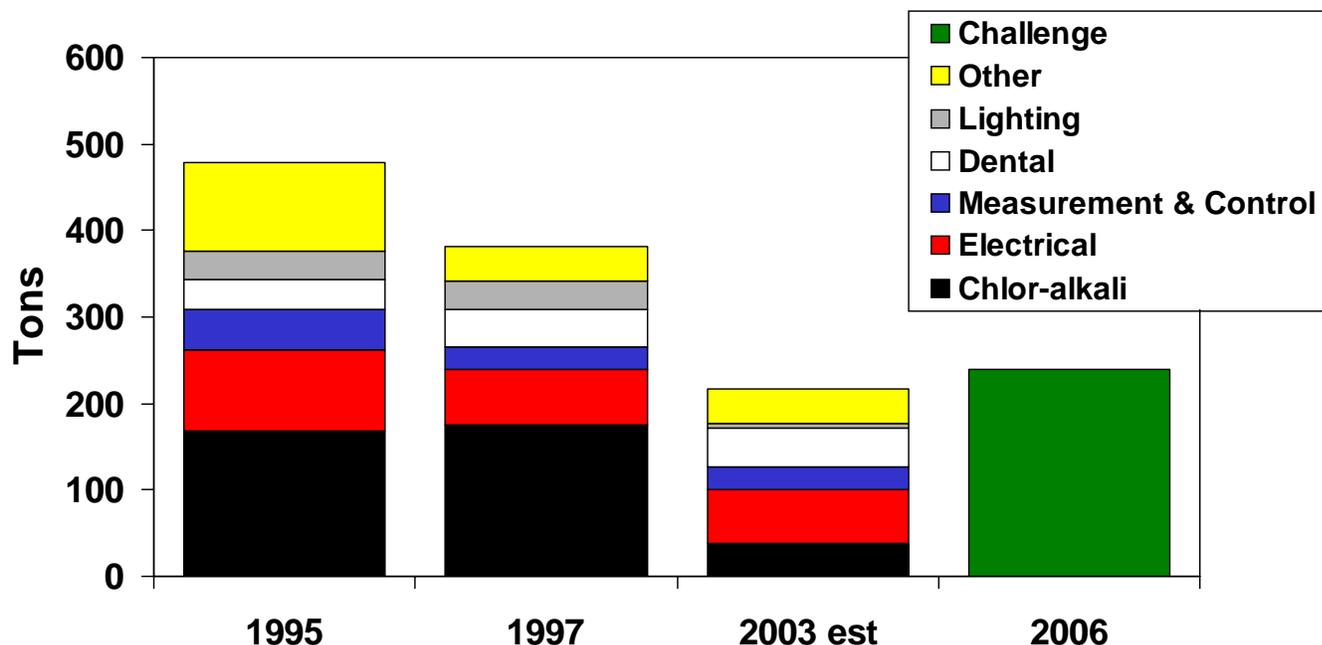


Figure 2-4. U.S. Mercury Use: 2006 Challenge, 1995 Baseline.

It is likely that mercury use has declined even more than portrayed in Figure 2-4, because mercury use in categories other than chlor-alkali and lamps also has decreased. While these reductions have not been quantified, reductions have been achieved in the use of mercury in measurement and control devices, switches and relays, and dental amalgam. These reductions are not visible in Figure 2-4.

Table 2-1. U.S. Mercury Use (tons).

Industry/Product Category	1995*	1997*	2003*
Chlor-alkali Production**	160	116	38
Wiring Devices and Switches	92	63	63
Measurement and Control Devices	47	26	26
Dental***	35	44	35
Lighting****	33	32	6
Other	102	40	40
Total	469	321	208

*Source for 1995 and 1997 (except chlor-alkali data): U.S. Geological Survey, *Minerals Yearbook*, 1995 and 1997 – converted to short tons. For 2003, assume that use has not changed, except in chlor-alkali, lighting, and dental categories.

**Chlorine Institute, *Seventh Annual Report to EPA*, July 22, 2004. Mercury “used” rather than mercury “purchased.” Under this definition of “use,” mercury purchased and placed in inventory or added to cells to increase working stock of mercury does not count as “use.”

*** Vandeven J, McGinnis SL. An Assessment of Mercury in the Form of Amalgam in Dental Wastewater in the United States. *Water, Air and Soil Pollution* 2005; 164:349-366.

**** Source of 2003 estimate: E-mail from Ric Erdheim, National Electrical Manufacturers Association, May 27, 2004.

3.0 ENVIRONMENTAL ANALYSIS

The environmental analysis presented in this section considers Canadian and U.S. monitoring data and established human health or ecological criteria as the primary basis for an objective evaluation of whether a substance imposes a negative impact on the Basin. Characteristics of acceptable monitoring data to assess the temporal, spatial, and population representativeness of a substance in the Great Lakes Basin ecosystem include (but are not limited to) basin-specific measures in water, air, sediment, soil, fish, biota, or human biological samples. In some cases, national data are presented.

3.1 ENVIRONMENTAL AND HUMAN HEALTH DATA



In most cases, there is sufficient environmental data to indicate whether mercury levels are or are not of concern in various media. However, in many cases, additional data is needed in order to assess trends or to better understand the sources of mercury and the behavior of mercury in the environment. Appendix C contains descriptions of additional monitoring programs that could not be included in the present report but would provide useful information for future assessments.

3.1.1 Whole Fish and Fish Tissue

Canadian Department of Fisheries and Oceans (DFO) Monitoring Program

The Canadian Department of Fisheries and Oceans (DFO) Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS) collects long-term (>25 years), basinwide monitoring data measuring whole body concentrations of contaminants in top predator (lake trout and/or walleye) and forage fish (smelt). DFO reports contaminant burdens annually in similarly aged fish (4+ to 6+ range).

U.S. National Lake Fish Tissue Study

The U.S. National Study of Chemical Residues in Lake Fish Tissue (or the National Lake Fish Tissue Study, NLFTS) is a four-year national screening-level freshwater fish contamination study. The National Lake Fish Tissue Study measures mercury and other contaminants in predator and bottom-dwelling fish tissue from lakes and reservoirs of the continental U.S. Sample locations were selected based on a stratified random sample to eliminate bias. U.S. EPA is releasing interim raw data each year of the study as it becomes available, but analysis of the data did not begin until January 2005 when U.S. EPA finished collecting the results for all four years. A final report is expected to be completed in 2006.

Data are currently available for the first two years of the study. The first and second year results consist of quality-assured raw data from analysis of fish samples collected from lakes and reservoirs during fall 1999 through 2001. The available data include more than half of the approximately 500 lakes and reservoirs being sampled in the study. The Great Lakes were excluded from the lakes selected for the study; however, lakes and reservoirs in the Great Lakes Basin were included.

Sampling locations included 77 sites (out of 250 sites nationally) in the Great Lakes States of Illinois, Indiana, Ohio, Michigan, Minnesota, New York, Pennsylvania, and Wisconsin. Mercury was detected in fish at all 77 sites, with the minimum and maximum concentrations measured being 24.8 ppb and 1,377 ppb, respectively. The method detection limit for mercury was 0.521 ng/g (ppb) (U.S. EPA, 2005e).

State, Provincial, and Tribal Fish Consumption Advisories

The Great Lakes States, Ontario, and Tribes monitor mercury concentrations in fish for the purpose of developing fish consumption advisories. The National Listing of Fish Advisories (NLFA) database includes all available information describing state-, tribal-, and federally-issued fish consumption advisories in the U.S. for the 50 States, the District of Columbia, and four U.S. territories, and in Canada for the 12 provinces and territories. The database contains more than 91,500 samples of fish tissue contaminant data provided to U.S. EPA by the States, Tribes, territories, and Canada from 1967 to 2003.

The NLFA may be biased because samples are typically collected at sites that are known to be popular fishing spots, or sites suspected of having elevated levels of contamination. However, a comparison of the NLFA and NLFTS found that the two datasets are not statistically different except at the very upper end of the NLFA concentration distribution (e.g., 95th percentile), where there is a clear upward bias (U.S. EPA, 2005a).

Regulatory Impact Analysis of the Clean Air Mercury Rule

U.S. EPA's Office of Air Quality Planning and Standards (OAQPS) prepared a report, *Regulatory Impact Analysis of the Clean Air Mercury Rule*, or RIA, which analyzes the benefits and costs of the final Clean Air Monitoring Rule (CAMR) (U.S. EPA, 2005a). The RIA presents information on the impact of mercury on human health, ecosystems, and wildlife, including mercury concentrations in fish. Data on mercury concentrations in fish were obtained from the Mercury in Marine Life Database, the NLFA, and NLFTS. The data indicate a wide range of mercury contamination in finfish and shellfish from freshwater and saltwater sources in the U.S. The RIA states that "larger predatory fish in the higher trophic levels tend to have higher levels of methylmercury contamination in fish tissue."

3.1.2 Wildlife

Wildlife Studies on Loons, Minks, Otters, and Bald Eagles

Studies of mercury levels in wildlife have focused on the common loon (*Gavia immer*), mink (*Mustela vison*) and river otter (*Lutra canadensis*). Data is available from studies that measure the bioaccumulation patterns and temporal trends and effects of mercury exposure in loons, concentrations of mercury in the hair, brain, and liver tissues of river otter, and mercury concentrations in the brain, kidney, liver, and fur of mink. Dr. Michael Meyer of the Wisconsin Department of Natural Resources (WDNR) is leading a study of the impact of mercury exposure on the common loon population in northern Wisconsin. A dosing study is being conducted to quantify the level of mercury exposure associated with negative effects on survival and fitness of loon chicks.

In April 1999, the Michigan Department of Environmental Quality (MDEQ), Surface Water Quality Division, began monitoring mercury in bald eagles (*Haliaeetus leucocephalus*) and has continued and has continued each year since then. MDEQ has published annual reports from 2002 to 2004 that contain results of the samples collected in 1999, 2000, and 2001, respectively. Mercury data in nestling bald eagle feathers are available for 1999 and 2000; however, due to analytical difficulties, mercury data for 2001 and 2002 will be presented, as an addendum, in a future report to the MDEQ.

Canadian Wildlife Service Great Lakes Herring Gull Eggs

The Canadian Wildlife Service (CWS) measures mercury levels in herring gull eggs from fifteen colony sites on the Great Lakes. Eggs have been collected from up to eight water bodies within the Great Lakes Basin: the St. Lawrence, Niagara, and Detroit Rivers and Lakes Ontario, Erie, Huron, Michigan, and Superior. Mercury concentrations were first analyzed in 1974. The consistent monitoring of herring gull eggs by the CWS provides high-quality data with sufficient geographic coverage to assess the ecological impact of mercury in the Great Lakes. Study sites and methods are provided in Appendix B. Fish data from the Canadian DFO monitoring program described earlier can also be used to supplement herring gull data.

3.1.3 Sediments and Water

Screening Level Survey of Sediment Quality in Tributaries to the Lower Great Lakes

Over the period 2001-2003, Environment Canada conducted screening level surveys of sediment quality in 101 Canadian tributaries to Lake Erie, including those into the St. Clair and Detroit corridor and 211 Canadian tributaries to Lake Ontario, including the Niagara River and the St. Lawrence River. Surficial sediments (top 1-3 cm) were collected from one or more depositional reaches of each tributary, upstream of its mouth. The purpose of the surveys was to assess sediment quality in each tributary prior to discharge into their respective receiving waters. The study was designed to maximize the probability of detecting polychlorinated biphenyls, organochlorine pesticides, polycyclic aromatic hydrocarbons and metals in these tributaries, rather than to quantify contaminant loads.

Sediment Monitoring at U.S. Sites

The U.S. EPA has conducted or funded numerous assessments for mercury in contaminated sediments. Two such studies in the Great Lakes region are the Trenton Channel Project and the preliminary investigation of sediment contamination in Muskegon Lake. The Trenton Channel, a 9-mile stretch of the lower Detroit River, had been identified as containing contaminated sediments. From 1993 to 1996, the U.S. EPA and MDEQ took sediment cores from 84 stations in depositional areas of the Trenton Channel and analyzed the samples for a variety of parameters. Based on the results of this analysis, mercury was identified as a primary parameter of concern within contaminated areas (Ostaszewski, 1997).

Rediske et al. (2002) reported a preliminary investigation funded by the U.S. EPA Great Lakes National Program Office (GLNPO) of the nature and extent of sediment contamination in Muskegon Lake. Fifteen locations were selected for analysis. Surface sediments were collected using a Ponar dredge at all fifteen locations, and core samples were collected from twelve of these sites. All sampling took place in October of 1999.

Lake Michigan 1994 – 1996 Surficial Sediment Mercury

Sediment samples were collected from 118 stations in Lake Michigan between 1994 and 1996 (Rossmann, 2002). Samples were collected for the purposes of describing the spatial variation of mercury in surficial sediment and analyzing trends in mercury concentrations and fluxes.

St. Clair-Detroit River Corridor – Upstream/Downstream Water Quality Monitoring

Environment Canada initiated a whole-water monitoring program for the St. Clair and Detroit Rivers in 2001 to assess a wide range of organic and inorganic contaminants, including mercury. This monitoring effort is a component of Environment Canada's Great Lakes Surveillance and Connecting Channels program and supports the Lake Erie Lakewide Management Plan (LaMP) and Remedial Action Plans (RAPs) for the restoration of beneficial uses of the St. Clair and Detroit Rivers. The monitoring strategy adopted was to select a reference site for each river that was in the main headwater channel, upstream of all riverine inputs. The downstream sampling sites, which are intended to track and be responsive to changing toxic contaminant concentrations, are located below of all major contaminant inputs, in nearshore channels, off the east and west shores of the St. Clair and Detroit Rivers.

The Niagara River Upstream/Downstream Monitoring Program

Environment Canada's Niagara River Upstream/Downstream Program measures mercury in water and suspended solids at the head of the Niagara River at Fort Erie (FE) and at the mouth of the River at Niagara-on-the-Lake (NOTL). Monitoring began at NOTL in 1975 and at FE in 1983. Over the eleven-year period 1986/87 – 1996/97, sampling was conducted weekly. Since that time, the sampling frequency has been changed to biweekly. Sampling times at the two stations are offset by approximately 15-18 hours to allow for the travel time of water between the head and mouth of the river. Since the program analyzes two distinct matrixes (dissolved phase and suspended sediment), the concentration in the whole water is determined by calculation.

Open Lake Water Quality Monitoring

Mason and Sullivan (1997) report average total mercury concentrations in Lake Michigan waters using data collected in 1994 and 1995 as part of the Lake Michigan Mass Balance Study.

3.1.4 Atmospheric Deposition and Gaseous Mercury

Integrated Atmospheric Deposition Network

The Integrated Atmospheric Deposition Network (IADN) is a joint U.S./Canada atmospheric monitoring network that has been in operation since 1990.⁴ The IADN consists of five master stations, one near each of the Great Lakes, and several satellite stations. IADN measures concentrations of a number of organic pollutants and trace metals in ambient air (gas phase), suspended particles, and precipitation at each station, but does not include mercury at U.S. IADN stations. However, mercury in wet deposition is measured at two IADN sites co-located at Canadian Atmospheric Mercury Measurement Network (CAMNet) sites.

Canadian Atmospheric Mercury Measurement Network (CAMNet)

The CAMNet⁵ was established in 1996 to provide accurate, long term measurements of total gaseous mercury (TGM) concentration and the mercury deposition in precipitation (wet deposition) across Canada. The midlatitude sites are located in background or rural areas, with the latter occasionally impacted by emissions from urban areas. Wet deposition is measured at the CAMNet sites as part of the Mercury Deposition Network, which includes sites in the U.S., Canada and Mexico.

Mercury Deposition Network

The Mercury Deposition Network (MDN) is a set of North American wet deposition monitoring stations operated by States, Tribes, and universities that use a common sampling protocol and a single laboratory for mercury analysis. There are currently seven sites in Canada, approximately 80 sites in the U.S., and two sites in Mexico (see Figure 3-1). 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. Because it consists of weekly samples, the MDN only provides data on events when there is one single event during the weekly sampling period. In addition, the network does not include dry deposition monitoring. Dry deposition may be equivalent in magnitude to wet deposition.

U.S. EPA has developed a method for measuring the dry deposition of speciated mercury. The MDN is in the initial deployment stage of implementing dry deposition monitoring at ten to twelve sites. While dry deposition monitoring is expensive and difficult to measure, trial runs have been successful. Collaboration with MDN site operators and sponsors is needed to further deploy dry deposition monitoring at MDN sites (Gay, 2005).

⁴ Integrated Atmospheric Deposition Network (IADN) Web site:
<http://www.epa.gov/glnpo/monitoring/air/iadn/iadn.html>.

⁵ CAMNet Web site: www.msc.ec.gc.ca/arqp/camnet_e.cfm

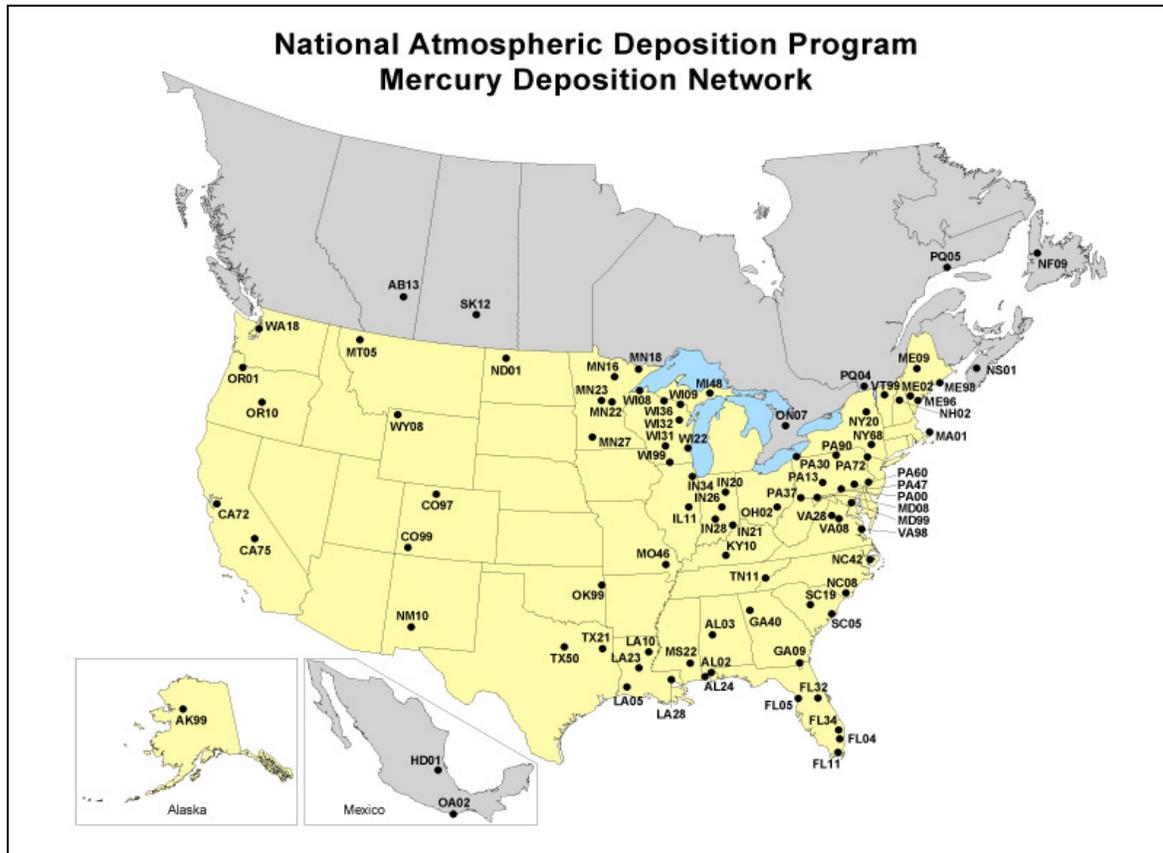


Figure 3-1. MDN Sites Currently in Operation (does not depict two new sites in Mexico).

Mercury Maps

The Mercury Maps project, undertaken by U.S. EPA Office of Water, attempts to relate changes in mercury air deposition rates to changes in mercury fish tissue concentrations. The project goal is to establish a tool to quantitatively evaluate the potential impact of air mercury emission reductions on fish tissue mercury concentrations, on a national (U.S.) scale.⁶ The tool applies fate and transport models to watersheds in which air deposition is the exclusive significant source. The project averaged mercury fish tissue concentrations across watersheds, using data from the 2001 NLFA, and estimated the percent reductions in air deposition load that would be needed to meet, on average, mercury fish tissue criteria. See Section 3.2.1 for a discussion of the project's results.

Deposition Monitoring in Michigan

The Michigan Mercury Deposition Network, run by MDEQ and University of Michigan Air Quality Laboratory (Dr. Gerald Keeler) has been in operation in some form since late 1994. The network monitors mercury in daily event-based precipitation samples at three urban and three rural sites in Michigan. Two sites also collect semi-continuous speciated atmospheric mercury measurements.

⁶ A peer reviewed final report is available at <http://www.epa.gov/waterscience/maps/report.pdf>.

Regulatory Impact Analysis of the Clean Air Mercury Rule

U.S. EPA's OAQPS prepared a report, *Regulatory Impact Analysis of the Clean Air Mercury Rule*, or RIA, which analyzes the benefits and costs of the final CAMR (U.S. EPA, 2005a). The RIA presents information on the impact of mercury on human health, ecosystems, and wildlife, including an analysis of mercury deposition using air quality monitoring. OAQPS used a photochemical air quality model to predict mercury deposition for a 2001 base year and in 2020, as a result of implementing mercury regulations.

3.1.5 Human Exposures

Health Canada Data on Blood Mercury Levels

Canadian studies to measure blood mercury levels in humans have focused specifically on fish-eating populations. National mercury monitoring programs have been conducted in First Nations populations for decades, but the most recent information on blood mercury levels in humans was released in 2004, when fish consumption and mercury data were analyzed for two groups of fish consumers in the Great Lakes Basin.

Cole et al. (2004) collected fish consumption data and blood samples from two populations – licensed anglers living in two Lake Ontario communities and a sample of sport-fish consumers living in five Great Lakes' Areas of Concern (AOC) – as part of a Health Canada-sponsored Great Lakes Health Effects Program to research contaminant exposures among Ontario fish consumers. Total mercury levels were above the detection limit in 87 percent of the whole blood samples taken from the angler population and in 100 percent of the blood samples taken from those eating fish within AOCs. A discussion of exceedances and trends follows in Sections 3.2 and 3.3.

National Health and Nutrition Examination Survey

Blood mercury levels in the U.S. population are currently being measured by the Centers for Disease Control and Prevention (CDC) in the National Health and Nutrition Examination Survey (NHANES). NHANES provides an ongoing assessment of the U.S. population's exposure to environmental chemicals by measuring chemicals or their metabolites in human specimens such as blood or urine. The CDC issued the first *National Report on Human Exposure to Environmental Chemicals* in March 2001, which presented exposure data for 27 chemicals from NHANES 1999. The CDC released the *Second National Report on Human Exposure to Environmental Chemicals* in January 2003, which presents biomonitoring exposure data for 116 environmental chemicals (including the 27 in the first report) from NHANES over the 2-year period 1999 to 2000. The *Third National Report on Human Exposure to Environmental Chemicals* was released in July 2005, with updated information on chemicals included in the second report, as well as new data on additional chemicals.

Results for mercury are included in all three reports. NHANES results for 1999-2002 update previously published information on NHANES 1999-2000 estimates of blood mercury levels. Although NHANES data are released and often analyzed as two-year periods, the estimates of blood mercury levels for 1999-2002 are the most reliable estimates of current exposure. The

four-year period provides greater geographic coverage, and estimates and sample errors are more stable, thus reducing variability caused by differing exposures to mercury across survey site locations.

For mercury analysis, whole-blood specimens were analyzed for total and inorganic mercury for children aged 1 to 5 years and women aged 16 to 49 years by automated, cold-vapor atomic absorption spectrophotometry in CDC's inorganic toxicology laboratory. The analytic method detection limit was 0.14 µg/L (ppb) for total mercury and 0.4 µg/L (ppb) for inorganic mercury in NHANES 1999-2002.

Regulatory Impact Analysis of the Clean Air Mercury Rule

U.S. EPA's OAQPS prepared a report, *Regulatory Impact Analysis of the Clean Air Mercury Rule*, or RIA, which analyzes the benefits and costs of the final CAMR (U.S. EPA, 2005a). The RIA presents information on the impact of mercury on human health, ecosystems, and wildlife, including an exposure modeling analysis. OAQPS used modeling approaches to determine the extent of mercury exposure due to consumption of fish; project the change in IQ of children due to mercury exposure *in utero*; estimate the value of future earnings losses associated with incremental losses of IQ; and evaluate the monetary value of improvements in IQ attributable to emissions reductions achieved through controls on U.S. coal-fired power plants.

3.1.6 Food Monitoring Programs

U.S. Total Diet Study

The Total Diet Study (TDS), sometimes called the Market Basket Study, is an ongoing program of the U.S. Food and Drug Administration (FDA).⁷ Since 1961, the TDS has been used to determine levels of various contaminants and nutrients in foods. Analyses are performed on foods that are prepared as they would be consumed (table-ready), so the final results can be used to provide a realistic measure of the dietary intake of analytes, including mercury (FDA, 2004). The foods collected in the TDS represent the major components of diet in the U.S. population. Analytical results are available for Market Baskets 1991-93 through 2002-04.

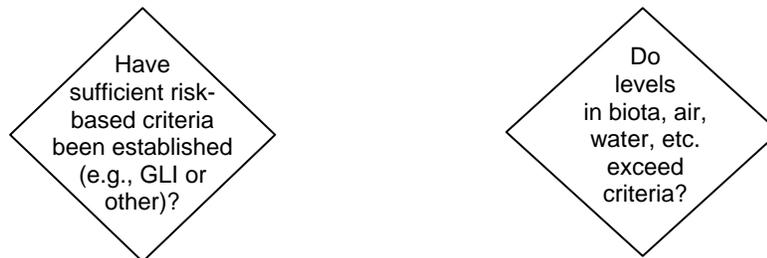
3.1.7 Biosolids

A number of States and communities in Ontario measure mercury in sewage biosolids. Two examples where mercury concentrations are measured include Michigan and the City of Toronto. The Michigan Department of Environmental Quality (MDEQ) encourages the use of biosolids (also known as sewage sludge) to enhance agricultural production in Michigan. Almost all biosolids that are recycled in Michigan are land applied at agronomic application rates to grow crops on sites approved by the MDEQ. Biosolids applications are controlled by the requirements of the provisions of a facility's National Pollutant Discharge Elimination System (NPDES) discharge permit for wastewater treatment or by a general permit. This includes monitoring and sampling of biosolids that are land applied.

⁷ A description of the TDS study design, foods, and consumption amounts can be found at <http://www.cfsan.fda.gov/~comm/tds-hist.html>

The City of Toronto has a Sewer-Use bylaw that requires installation of amalgam separators to capture waste dental amalgam at all dental clinics that place or remove amalgam fillings. Another requirement of the bylaw is a limit on the concentration of mercury (0.01 mg/L) in drains leaving the clinics and entering sewers. To measure the effect of the bylaw on mercury concentrations entering sewers, the City has tested biosolids at some of Toronto's sewage treatment plants. Also, as part of enforcement, the City is obtaining and analyzing samples from dental practices in Toronto.

3.2 CRITERIA



Criteria with which to assess the impact of mercury on the Basin are available for some but not all media. Criteria have been developed for mercury levels in whole fish, fish tissue, water, ambient air, bulk sediment, surface water, and biosolids. There is a wildlife criterion termed a “wildlife value” which is expressed in ambient water concentration terms. There are no criteria with which to judge levels of mercury in atmospheric deposition.

Current criteria information is sufficient to conclude that mercury levels have a continued adverse impact on the Basin. Current data collected in the Great Lakes indicate that mercury levels in fish are high enough in numerous cases to trigger fish consumption advisories, especially in inland lakes within the Great Lakes basin. It is likely that mercury levels in fish will still be of concern, even after significant reductions are made in U.S. sources. In addition, sediment quality criteria are frequently exceeded, and in some locations, water quality criteria are exceeded. Moreover, mercury levels in people exceed human health criteria in many cases. For example, 6 percent of women of child-bearing age in the U.S. have blood mercury concentrations at or above a level equivalent to EPA's RfD (CDC, 1999-2002).

For some environmental media, mercury levels are below existing criteria. Mercury levels in the Great Lakes Basin do not appear to exceed criteria for drinking water, outdoor ambient air, or biosolids. For some media, there are no mercury concentration standards, including wildlife and atmospheric deposition. A discussion of current criteria information for various media is presented below.

3.2.1 Whole Fish and Fish Tissue

The GLWQA criteria for mercury state that, “the concentration of total mercury in whole fish should not exceed 0.5 µg/g (wet weight basis) to protect aquatic life and fish-consuming birds.” All the DFO and EPA/GLNPO open lake analyses are conducted on whole fish, and the GLWQA criteria for mercury in whole fish apply. Whole fish contaminant levels are about 30 –

50 percent greater than edible portion sample (fillet) concentrations. Methylmercury traditionally represents from 70 to 95 percent of the total mercury concentration measured in fish tissue (whole fish or muscle tissue) (Whittle, 2005).

DFO collects lake trout and smelt from all lakes and walleye from Lake Erie. There are currently no exceedances of GLWQA criteria for mercury in smelt. Assuming they have stable populations, and even though they are not predator fish or popular sport fish, forage fish can be used as monitors of mercury contamination. Top predator fish, such as lake trout and walleye, can also be used as biological monitors of overall water quality and ecosystem health because contaminant concentrations in fish generally reflect overall contaminant levels in the environment. Unfortunately, data are not available for lake trout, but DFO-recorded concentrations of another predator fish, Lake Erie walleye, are below GLWQA criteria.

U.S. EPA has set a human health-based water quality criterion for methylmercury of 0.3 ppm methylmercury in fish (States can use this value in deriving water quality criteria, taking into account factors such as site-specific bioaccumulation). To determine exceedances, U.S. EPA's 0.3 ppm fish tissue criteria is compared to the average mercury concentration of all consumed fish in a water body and not just selected species. However, in the absence of species-specific screening levels for mercury, U.S. EPA uses 0.3 ppm as the threshold value for individual species.⁸

In addition to U.S. EPA standards, State health departments set criteria from which they generate fish consumption advisories. The Minnesota Department of Health uses the trigger of 0.2 ppm mercury in fish to advise women and children to eat fish less often than one meal per week. The Minnesota Pollution Control Agency has used the 0.2 ppm standard to assess lakes and rivers for impairment due to mercury for the last three years.⁹

Results of data from the first year (1999/2000) of the National Lake Fish Tissue Study show detection of mercury at all 77 sites in the Great Lakes States, and exceedances of U.S. EPA's human health-based water quality criterion for methylmercury of 0.3 ppm at 40 percent (31 out of 77 sites) of first and second year (2001) sites in the Great Lakes States. Table 3-1 lists fish tissue concentrations for first and second year fish samples that exceeded 0.3 ppm. All of the exceedances occurred in predatory fish. At one Indiana site in year one, a concentration of 1.38 ppm was measured for white bass, a significant exceedance over the water quality criterion.

⁸ Water quality criteria are one component of water quality standards – the other two being designated uses and antidegradation provisions.

⁹ Minnesota Pollution Control Agency, Proposed Water Quality Standards Rule Revisions <http://www.pca.state.mn.us/water/standards/rulechange.html>

Table 3-1. Mercury Concentration Exceedances in Fish Tissue for First (1999/2000) and Second Year (2001) Fish Samples in the U.S. National Lake Fish Tissue Study.

STATE	YEAR	SITE NAME	SPECIES	Fish Tissue Concentration (ppm)
Illinois	1	Unnamed Lake	Largemouth Bass	0.48
		Buck Lake	Largemouth Bass	0.37
	2	Otter Lake	Largemouth Bass	0.514
Indiana	1	Baire Lake	White Bass	1.38
Ohio	2	Darrell Rose's Pond	Smallmouth Bass	0.375
		Tom Porter's Pond	Largemouth Bass	0.367
Michigan	1	West Lake	Largemouth Bass	0.55
		Walloon Lake	Smallmouth Bass	0.32
	2	Torch Lake	Lake Trout	0.587
		Houghton Lake	Walleye	0.389
Minnesota	1	O'Dowd Lake	Walleye	0.82
		Namakan Lake	Walleye	0.58
		Lake Carlos	Largemouth Bass	0.53
		South McDougal Lake	Walleye	0.47
		Sturgeon Lake	Northern Pike	0.41
		Woman Lake	Walleye	0.34
		Charlotte Lake	Northern Pike	0.32
		Pokegama Lake	Northern Pike	0.32
	2	White Sand Lake	Northern Pike	0.32
		White Iron Lake	Walleye	0.613
		Fox Lake	Northern Pike	0.471
		First Lake	Northern Pike	0.384
		Mora Lake	Northern Pike	0.37
		North Turtle Lake	Northern Pike	0.337
New York	1	Little Wolf Pond	Smallmouth Bass	0.84
		Brant Lake	Largemouth Bass	0.76
Pennsylvania	1-2	All	All	< 0.3
Wisconsin	2	Castle Rock Flowage	Walleye	0.523
		Irogami (Fish) Lake	Largemouth Bass	0.402
		Turtle Flambeau Flowage	Smallmouth Bass	0.369

Note: Non-detects are assigned a value of zero. The NLFTS does not necessarily provide data that is representative of each State where sampling has occurred (e.g., in year 1 data, only four lakes were sampled in Michigan for mercury analysis).

In the U.S., the average mercury fish tissue concentration in a watershed in the NLFA is 0.29 ppm, and average watershed concentrations range from 0.001 ppm to over 4 ppm (U.S. EPA, 2005a). A query of the current NLFA database results in 3,183 water bodies with fish advisories for mercury in the U.S. and Canadian Great Lakes Basin (see Table 3-2). This includes fish consumption advisories for each of the Great Lakes and connecting water bodies (e.g., the St. Clair River, St. Mary's River, and Detroit River), as well as statewide advisories for certain fish species in all rivers and lakes in Wisconsin, Ohio, and Illinois; in all inland lakes in Michigan and Minnesota; and in all rivers in Indiana (U.S. EPA, 2005a). (Note that each water body may have more than one advisory for different species of fish.) Figure 3-2 illustrates the number of water bodies with fish mercury consumption advisories in the U.S. Great Lakes States.

Table 3-2. Number of Water bodies with Fish Consumption Advisories due to Mercury in the U.S. Great Lakes States and Ontario in 2003 (U.S. EPA, 2005a).

State/Province	Number of Advisories
Illinois	10
Indiana	172
Michigan	93
Minnesota	1,114
New York	39
Ohio	62
Pennsylvania	77
Wisconsin	85
Ontario	1,531
TOTAL	3,183

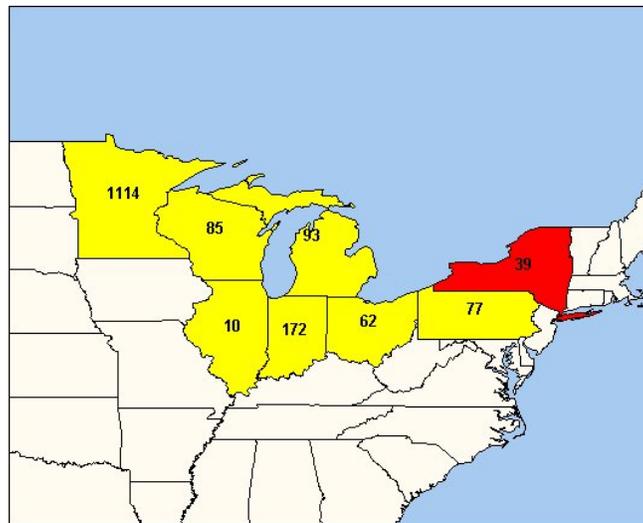


Figure 3-2. Number of Water bodies with Fish Consumption Advisories due to Mercury in the U.S. Great Lakes States (U.S. EPA, 2005b).

In preparing the RIA for the CAMR, U.S. EPA combined data for freshwater fish from the NLFTS and NLFA and normalized the data to control for variability from factors other than location (e.g., species, length, sampling method). Mean fish concentrations were calculated for watersheds, using the U.S. Geological Survey’s 2150 hydrological unit code (HUC) cataloging units. The mean fish mercury concentration for the U.S. was 0.25 ppm, with mean watershed fish concentrations ranging from 0 to 7.59 ppm. Average mercury concentrations in HUCs in the Great Lakes States were below 1 ppm with the exception of a few HUCs in Pennsylvania (U.S. EPA, 2005a).

U.S. EPA's Mercury Maps project averaged mercury fish tissue concentrations across watersheds using data from the 2001 NLFA (Figure 3-3).¹⁰ Average fish tissue mercury concentrations in HUCs in the Great Lakes are varied; Lake Michigan and portions of the Great Lakes States fall below the methylmercury in fish criterion of 0.3 ppm, while it appears that average mercury concentrations in Lake Superior and portions of Minnesota, Wisconsin, and Pennsylvania exceed the 0.3 ppm methylmercury fish criterion.

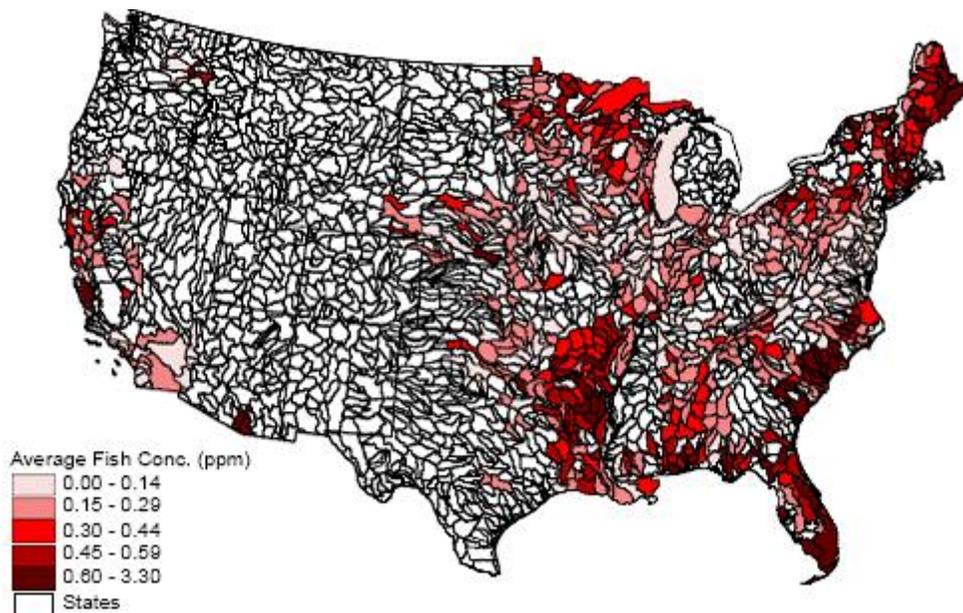


Figure 3-3. Fish Tissue Mercury Concentrations Averaged by Watershed. Source: U.S. EPA, 2001

Results of the Mercury Maps air deposition model illustrate the percent reduction in air deposition, by watershed, required to meet the 0.3 ppm methylmercury criterion (Figure 3-4). Watersheds colored red in Figure 3-4 indicate areas where fish concentrations exceed the criterion, while those colored green indicate watersheds in which no reductions are necessary and are unlikely to have a fish advisory. Watershed outlines with no color indicate no available fish tissue data. A significant portion of the HUCs in the Great Lakes currently meet the 0.3 ppm methylmercury in fish criterion, but in some watersheds, a large reduction in air deposition load is necessary to meet the 0.3 ppm methylmercury criterion. Given the strong influence of deposition from global sources (see Section 4.1), based on this analysis it is unlikely that even with deep reductions in U.S. and Canadian sources, criteria for methylmercury in fish cannot be met across the Great Lakes watershed without reductions in emissions from global sources.

¹⁰ Average value based on fillet samples only.

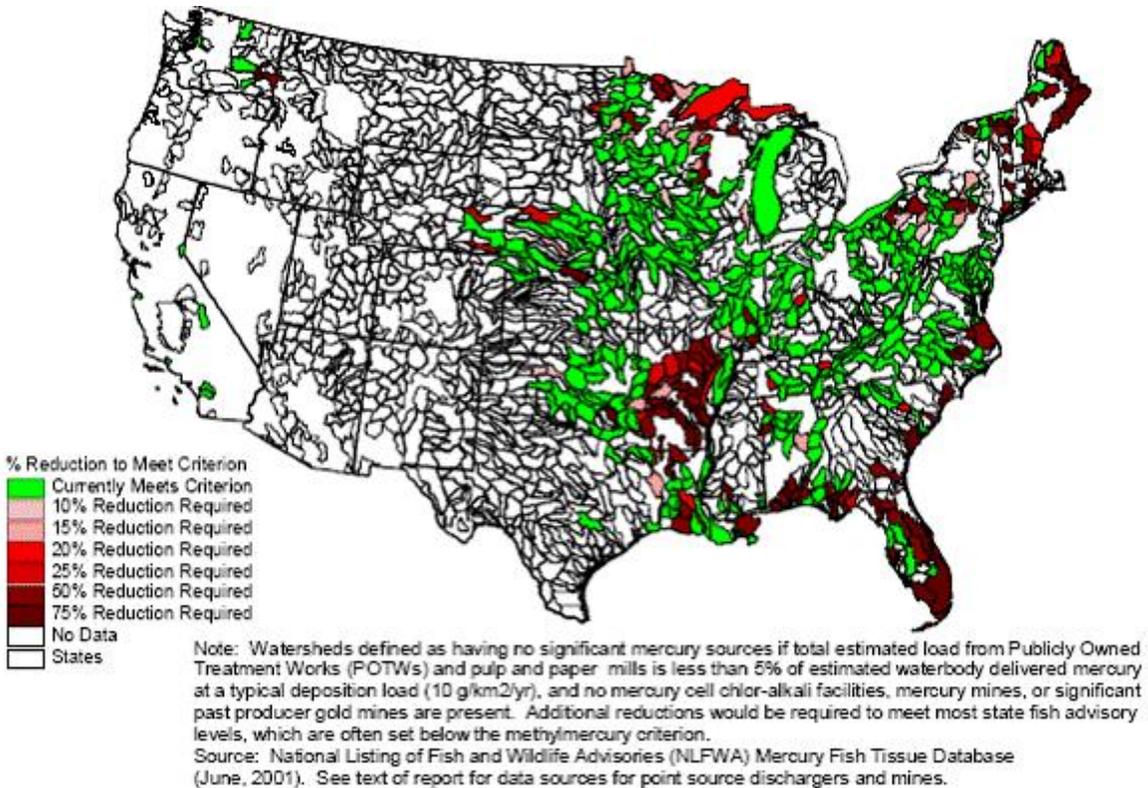


Figure 3-4. Percent Reduction in Air Deposition Load Necessary to Meet 0.3 ppm Methylmercury Criterion in Watersheds with No Other Significant Mercury Sources. Source: U.S. EPA, 2001

OMOE's *Guide to Eating Ontario's Sport Fish* is published bi-annually to provide guidance on interpretation of fish advisories monitored by OMOE (OMOE, 2005). The 2005-2006 edition of Ontario's *Guide to Eating Ontario Sport Fish* summarizes the causes of fish consumption restrictions for the general population attributed to mercury contamination in the Great Lakes and their connecting channels and inland locations. Four percent of all fish consumption advisories in Ontario are attributed to mercury contamination in Lake Superior, 9 percent in Lake Huron, 2 percent in Lake Erie, and 7 percent in Lake Ontario. OMOE also publishes a brochure for children and women of childbearing age, and another brochure, available in 19 languages, that explains how to use the *Guide to Eating Ontario's Sport Fish*.

Approximately 93 percent of consumption advisories for sport fish from inland lakes in Ontario are a result of mercury contamination. Sensitive populations have a higher percentage of restrictions caused by mercury (OMOE, 2005).

3.2.2 Wildlife

In the U.S., Great Lakes Basin States have set water quality standards for the protection of wildlife (see below). However, there are no criteria for mercury concentrations in wildlife itself. There is, however, some evidence that mercury may have a deleterious effect on some wildlife in the Great Lakes Basin.

Piscivorous (fish-eating) birds and mammals are more exposed to mercury than any other known component of aquatic ecosystems. Mercury contamination has been documented in populations of loons, eagles, and furbearers such as mink and otter. Adverse effects of mercury on birds and mammals include death, reduced reproductive success, impaired growth and development, and behavioral abnormalities. Correlative studies have concluded that common loons are sensitive to the toxic effects of mercury and that common loons are at risk of the greatest mercury exposure in many aquatic systems as they are long-lived, higher-trophic, obligate piscivores (Fevold et al., 2003).

Past studies on loon chicks in northern Wisconsin suggest that other factors, such as lake pH, might have more of an impact on chick survival and development than mercury exposure. Merrill et al. (2005) quantified prey and mercury consumption by loon chicks on 51 lakes and survival on 55 lakes ranging in pH from 4.9 to 9.5 in northern Wisconsin in 1995 and 1996. The authors concluded that loon chick survival in northern Wisconsin lakes is more likely related to prey availability than to mercury exposure (Merrill et al., 2005). Kenow et al. (2003) conducted a dosing study where common loon chicks in northern Wisconsin were fed fish with varying levels of methylmercury. The study suggests that while methylmercury did not seem to have an impact on loon chicks, *in ovo* exposures or other factors related to lake pH might have an impact on chick development.

Mierle et al. (2000) collected otter carcasses during the 1999 trapping season in south-central Ontario. Concentrations of mercury in hair, brain, and liver tissues of river otter were determined and analyzed. Mercury concentrations varied with respect to the age of otter; the mean age of otters with high mercury concentrations was about half the mean age of otters with low mercury concentrations. In areas where mercury levels are high, otters may have reduced survivorship because of mercury-induced stress on their health. Even subtle impairment of neurological health might reduce the ability to capture prey or avoid predators. Mercury is well known to have adverse effects on the immune system (Pollard and Hultman, 1997). In the wild, it may be the combination of mercury and an infectious stressor that affects their survivorship.

3.2.3 Surface Water

In the United States, EPA has set a national methylmercury water quality criterion for the protection of human health of 0.3 ppm methylmercury in fish. State governments can translate this methylmercury fish concentration to a criterion for water concentration of total mercury, based on the characteristics of water bodies within the State, including potential to methylate mercury and bioconcentration factors. Alternatively, States can avoid such a translation and manage impaired waters through *Waste Load Allocations*, eliminating the need to derive a water column concentration.

U.S. Great Lakes States have adopted stringent water quality standards for mercury under the Great Lakes Water Quality Guidance. For protection of wildlife, the water quality criterion is 1.3 ng/L. For protection of human health, the Great Lakes Water Quality Guidance initially set a criterion of 1.8 ng/L. However, subsequent to publication of the Guidance, U.S. EPA published a reference dose for methylmercury which, if used, would result in a criterion for mercury of 3.1 ng/L. Great Lakes States' adoption of 3.1 ng/L as the water quality criterion for protection of

human health for mercury was therefore considered consistent with the Guidance and was approved by U.S. EPA. Some States use this criterion, and others use 1.8 ng/L.

Mason and Sullivan (1997) reported an average total mercury concentration for Lake Michigan of 0.32 ng/L, which is below the Great Lakes Water Quality criteria.

Concentrations of mercury in whole-water samples were analyzed from thirteen surveys conducted in the St. Clair-Detroit River Corridor in 2001 and 2002. Table 3-3 indicates that mercury concentrations exceeded the Michigan water quality value (1.8 ng/L) in the Detroit River. Water quality guidelines have been established to serve as yardsticks for many environmental and health issues; however, exceedances of a particular guideline may not be sufficient to assess ecological or health impacts.

Table 3-3. Mean Whole-water Concentrations* in the St. Clair and Detroit Rivers, Based on 13 Surveys Conducted in 2001- 2002

Sampling Site	Mercury Concentration (ng/L)
St. Clair River	
Upstream Inlet (Nav. Ch.)	0.4
Downstream Roberts Landing	1.2
Downstream Port Lambton	1.8
Detroit River	
Upstream Fleming Channel	2.6
Downstream Trenton Channel	4.8
Downstream Amherst. Channel	4.7

* The reported mercury concentration is a calculated equivalent water concentration based on the concentration of mercury in the suspended sediment and the concentration of suspended sediment in the water.
Source: Waltho, 2005

3.2.4 Drinking Water

U.S. EPA sets Maximum Contaminant Levels (MCLs), for drinking water. For inorganic mercury, the MCL is 0.002 mg/L. Drinking water mercury concentrations are typically well below the MCL, and no recent exceedances have been recorded in the U.S. Great Lakes Basin.

For Canadian drinking water quality, Health Canada has adopted a Maximum Acceptable Concentration of 0.001 mg/L for total mercury. The Ontario Drinking Water Standard is also 0.001 mg/L for total mercury. A review of data contained in the Ontario Drinking Water Information Management System found no recent exceedances.

3.2.5 Sediment

Canadian Sediment Quality Guidelines (SQGs) identify a threshold effect level (TEL) and a probable effect level (PEL) for various analytes. The TEL is the level below which adverse biological effects are expected to occur rarely, and the PEL represents the level above which adverse effects are expected to occur frequently (CCME, 1999). For mercury in sediments, the TEL is 0.17 µg/g, and the PEL is 0.486 µg/g (CCME 1999; Persaud et al. 1993). Surficial sediment samples from Lakes Erie and Ontario were analyzed in 1998 for the presence of mercury and other contaminants, and results were compared against the Canadian SQGs (Marvin et al., 2002). In Lake Ontario, total mercury exceeded the PEL in 62 percent of the sites sampled; however, PEL exceedances were observed in only 6 percent of the stations in Lake Erie. Mercury concentrations exceeded the TEL at 87 percent of sites in Lake Ontario and 46 percent of sites in Lake Erie (Marvin et al., 2002).

The 1998 Lake Ontario data were used again in an assessment of the Laurentian Great Lakes. The assessment analyzed sediment samples taken by Environment Canada from each of the Great Lakes and from Lake St. Clair between 1994 and 2002 to see how recent contaminant levels differed from historical concentrations (Table 3-4) (Marvin et al., 2004). Environment Canada reported lake-wide average concentrations of mercury in sediment (along with the percentage of sites exceeding the Canadian PEL) for each of the lakes as follows:

Table 3-4. Total Mercury Concentrations (µg/g) and PEL Exceedances in the Great Lakes and Lake St. Clair.

Lake	Lake-Wide Average (µg/g)	% Exceeding PEL (0.486 µg/g)
Superior	0.088	0
Michigan	0.077	0
Huron	0.043	0
St. Clair	0.196	6
Ontario	0.586	62
Erie	0.187	6

Source: Marvin et al., 2004

Rossmann (2002) collected surficial sediment samples from 118 sites in Lake Michigan between 1994 and 1996. For the sites sampled, surficial sediment concentrations averaged 0.078 µg/g, in good agreement with the Lake Michigan value in Table 3-4. The range of concentrations measured 0.002 to 0.260 µg/g, indicating exceedances of the TEL but not the PEL.

Figure 3-5 illustrates mercury concentrations in suspended sediments within the St. Clair/Detroit River corridor, as measured under an ongoing Environment Canada monitoring program. The shaded boxes represent the annual mean concentration of mercury at each station, while the thin vertical bars represent the error or variation in the measurement. The numbers in the figure refer to station numbers. Exceedances of the PEL for mercury (486 ng/g) can be observed by comparing the height of the shaded boxes to the legend. The PEL for mercury is frequently exceeded throughout the entire length of the corridor. The consistency of the mercury distribution throughout the corridor, i.e., north to south, provides evidence of sources in the upper reaches of the St. Clair River. For example, comparison of the St. Clair River stations

with station 1167 in Lake Huron suggests that the upper reaches of the St. Clair River are a source of mercury.

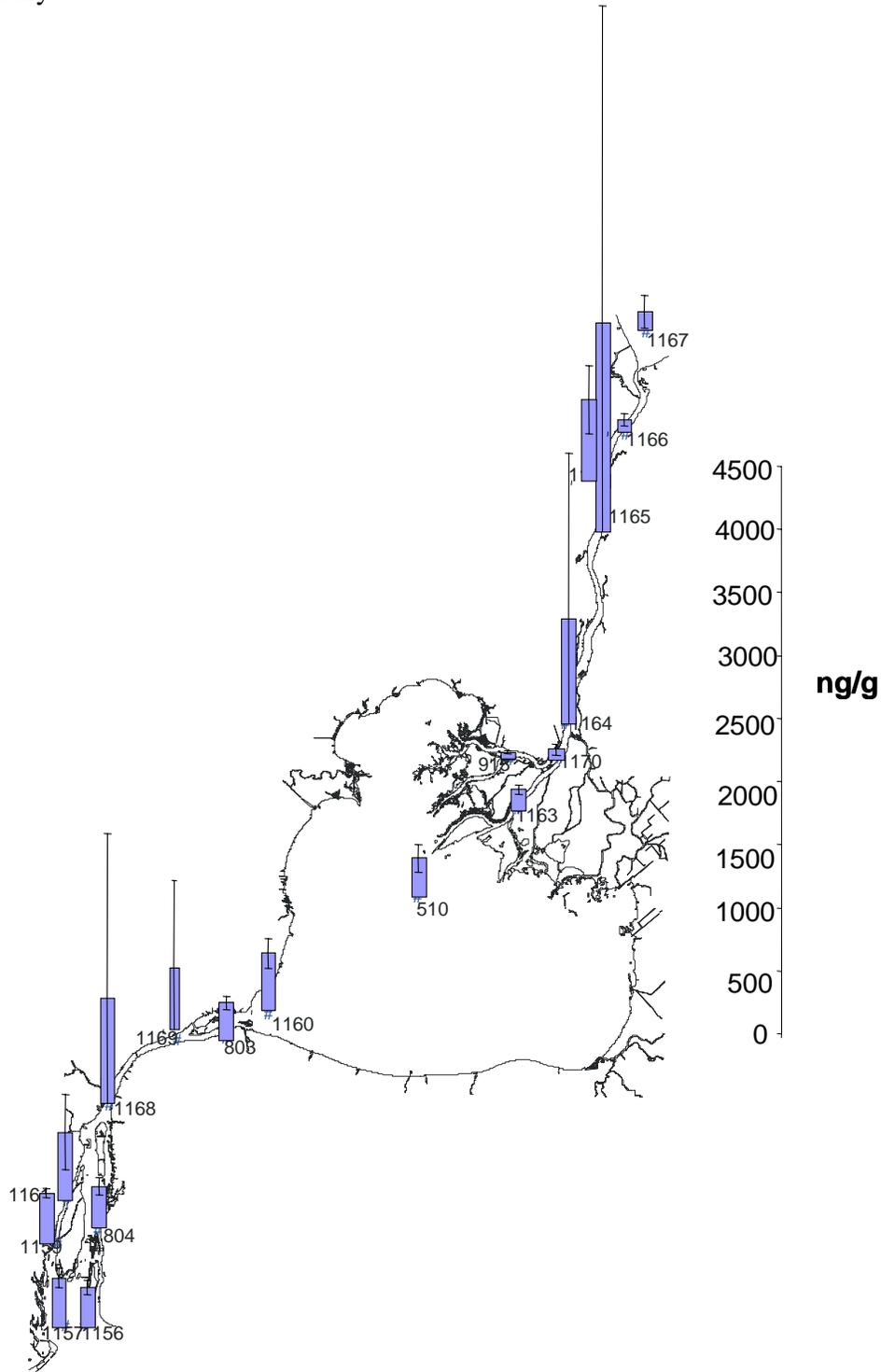


Figure 3-5. Mean Mercury Concentrations¹¹ in Suspended Sediments (ng/g) in the St. Clair / Detroit River Corridor. Source: Environment Canada

¹¹ The numbers in the figure refer to station numbers. Exceedances of the PEL for mercury (486 ng/g) can be observed by comparing the height of the shaded boxes to the legend.

Suspended sediment data collected through Environment Canada's Niagara River Upstream/Downstream Program at Fort Erie and Niagara-on-the-Lake from 1987 to 2000 can be compared to available sediment quality guidelines for mercury. No exceedances of the TEL (0.17 ug/g) were reported at Fort Erie. Exceedances of the TEL were reported in 1989-1990 at Niagara-on-the-Lake. No exceedances have been observed in Niagara River suspended sediments since 1990.

Guidelines known as Probable Effect Concentrations (PECs) were used to assess contamination of sediments in Muskegon Lake, Michigan. The International Joint Commission designated Muskegon Lake as an Area of Concern (AOC) because of severe environmental impairments related to industrial and municipal waste discharges. PECs are consensus-based guidelines (MacDonald et al., 2000) that represent the concentration above which there is a >75 percent probability that adverse ecological effects may be observed. The PEC for mercury is 1.06 mg/kg. Ponar samples collected from a Muskegon Lake study in October 1999 revealed two (out of 15) sampling locations had exceedances of the PEC for mercury (Rediske et al., 2002). Both exceedances yielded values of 1.7 mg/kg.

Onondaga Lake, in Onondaga County, New York, is a hazardous waste disposal site on U.S. EPA's National Priorities List (NPL). In July 2005 a remedy was selected to address areas of the lake where the surface sediments exceed a mean probable effect concentration quotient (PECQ) of 1 or a mercury PEC of 2.2 mg/kg. These criteria were developed specifically to address acute toxicity to the sediment-dwelling (benthic) community in Onondaga Lake. Many areas of the lake exceed the PEC (2.2 mg/kg), and exceedances reach as high as >150 times the PEC. The selected remedy (which includes dredging, isolation capping, targeted dredging, phased thin-layer capping, oxygenation, and monitored natural recovery) is expected to attain the PEC as well as a 0.8 mg/kg bioaccumulation-based sediment quality value for mercury on an area-wide basis for the lake and other applicable areas of the lake. Sediments are the primary focus of the remediation, but the selected remedy is also intended to achieve target fish tissue mercury concentrations (ranging from 0.3 mg/kg to 0.14 mg/kg) (NYSDEC and U.S. EPA Region 2, 2005).

3.2.6 Ambient Air

Potential risk from inhalation of mercury can be assessed using U.S. EPA's inhalation reference concentration (RfC) for elemental mercury. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of continuous exposure of a chemical to the human population through inhalation (including sensitive subpopulations), that is likely to be without risk of deleterious noncancer effects during a lifetime. The RfC for elemental mercury is 0.3 $\mu\text{g}/\text{m}^3$ (or 300 ng/m^3).

A pilot study of indoor elemental mercury exposure was conducted in 12 apartments and homes throughout Manhattan, Queens, Brooklyn, and Connecticut in 2000-2001 (Carpi and Chen, 2001). In this study, the mean indoor mercury exposure was 69 ng/m^3 , or 23 percent of the RfC of 300 ng/m^3 , and 8 percent of exposures were greater than the RfC (range 6.5-523 ng/m^3). Eleven of the 12 sites sampled in this study showed levels of airborne mercury that were significantly elevated over outdoor concentrations. This and other published research suggest

that up to 10 percent of households may have levels of airborne mercury above the U.S. EPA RfC due to historic spills of mercury-containing devices (Carpi and Chen, 2001).

While indoor air can frequently exceed the RfC, outdoor air is typically well below the RfC. The CAMNet monitoring program found an overall average median atmospheric concentration for TGM of $1.60 \pm 0.15 \text{ ng/m}^3$ for the ten Canadian sites from 1997-1999 by averaging together the site medians (Kellerhals et al., 2003). Higher variability of TGM concentrations at the sites in closer proximity to large urban areas appeared to be caused by the alternating exposure of these sites to anthropogenic TGM emissions, depending on wind direction and atmospheric mixing.

3.2.7 Atmospheric Deposition

There are no criteria for atmospheric deposition of mercury, either for concentration of mercury in wet deposition or for total deposition per unit of area. However, it is clear that atmospheric deposition is the primary input of mercury into the Great Lakes. U.S. EPA predicted the median total mercury deposition across U.S. watersheds to be $15.92 \text{ } \mu\text{g/m}^2$ in 2001, with a range of 6.99 to $54.54 \text{ } \mu\text{g/m}^2$. Ninety percent of HUCs are estimated to have mercury deposition below $22.16 \text{ } \mu\text{g/m}^2$ in 2001 (U.S. EPA, 2005a). The MDN web site (<http://nadp.sws.uiuc.edu/mdn/>) contains mercury deposition and concentration maps. Deposition and, to a lesser extent, concentration, tend to increase at lower latitudes, with highest deposition levels within the U.S. near the Gulf of Mexico. There appears to be a north to south gradient within the Great Lakes region as well, although this is less clear.

Generally, the concentrations of mercury in precipitation at rural sites in Canada are less than 30 ng/L, similar to the levels observed at border sites in the U.S. More frequent observations of high concentration episodes of mercury in precipitation ($>20 \text{ ng/L}$) were found at sites closer to urban centers, e.g., Egbert, in close proximity to Toronto and Barrie, than at more remote locations. The increased anthropogenic activity associated with highly populated areas may result in increased air concentrations of reactive gaseous mercury (RGM) and particulate matter (PM) which is more readily incorporated into cloud water and precipitation (Banic, 2005). Section 3.3 provides a discussion on trends in wet deposition.

3.2.8 Human Exposure

Both the U.S. EPA and Health Canada have estimated acceptable levels of mercury intake for diet and levels of mercury in blood. These levels differ between the two organizations. The U.S. EPA reference dose (RfD) for methylmercury is $0.1 \text{ } \mu\text{g}$ methylmercury per kg body weight per day ($\mu\text{g/kg/day}$). The RfD is a level believed to be without appreciable risk of harm. NHANES 1999-2002 findings indicate that blood mercury levels in young children and childbearing-aged women usually are below levels of concern. However, blood mercury analyses for 16-to-49 year old women showed that approximately 6 percent of women in the survey had blood mercury concentrations greater than $5.8 \text{ } \mu\text{g/L}$, a blood mercury level estimated to be equivalent to the RfD by U.S. EPA.

A provisional Tolerable Daily Intake (pTDI) of $0.47 \text{ } \mu\text{g/kg}$ of body weight/day for methylmercury (for the general population) was established in 1972 by the Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives

(JECFA) and was adopted by Health Canada. Through further studies, JECFA cautioned that pregnant women and nursing mothers likely had a greater risk from the adverse effects of methylmercury (WHO, 1989). Therefore, in 1998, the Foods Directorate of Health Canada reviewed new studies and lowered the maximum pTDI for methylmercury to 0.2 µg/kg of body weight/day for pregnant women, women of childbearing age and young children. A recent evaluation by JECFA (WHO, 2003) derived a similar value (provisional Tolerable Weekly Intake (pTWI) of 1.6 µg/kg of body weight/week or 0.23 µg/kg of body weight/day).

The U.S. Total Diet Study Market Baskets 1991-93 through 2002-04 analyzed a number of foods for mercury (document available at <http://www.cfsan.fda.gov/~comm/tds-res.html>, updated July 6, 2004). The analytical results show that mercury was not detected in 1,676 of 1,848 results, or 91 percent of samples. The mean concentration of mercury for all food samples was 0.006 mg/kg (or 6 µg/kg) and the median was 0 mg/kg, with a range of 0 to 0.322 mg/kg. The highest concentration was reported in tuna, canned in oil (0.322 mg/kg). Statistics were calculated using a value of zero for results below the limit of detection.

In 1998, Health Canada estimated the average daily intake of mercury from food for Great Lakes Basin residents using U.S. FDA Total Diet Study data (Health Canada, 1998). Table 3-5 presents the estimated daily intake of mercury via consumption of food for the Great Lakes Basin population of infants 0-6 months of age, preschoolers aged 7 months to 4 years, children aged 5-11 years, teenagers aged 12-19 years, and adults age 20 and over. Estimated daily mercury intakes expressed per kilogram of bodyweight were calculated using the average bodyweights listed in Table 3-5 for each age class. Estimated mercury exposures range from 0.06 ug/kg bw/day for members of the Great Lakes Basin population aged 12 years and older to 0.13 ug/kg bw/day for preschoolers aged 7 months to 4 years. These exposures are approximately half of Health Canada’s pTDI for methylmercury of 0.2 µg/kg of body weight/day for pregnant women, women of childbearing age, and young children.

Table 3-5. Estimated Daily Intake of Mercury via Consumption of Food for the Great Lakes Basin Population

	0-6 months	7 month-4 years	5-11 years	12-19 years	20+ years
Mercury exposure (µg/day)	0.608	1.66	2.907	3.668	4.134
Average body weight (kg)	7	13	27	57	70
Estimated daily intake (µg/kg bw/day)	0.087	0.128	0.108	0.064	0.059

Source: Health Canada, 1998

Health Canada developed blood guidelines for mercury in the 1970s. Blood levels below 20 µg/L of blood are classified as being in the normal acceptable range, 20-100 µg/L as “increasing risk”, and levels greater than 100 µg/L as “at-risk”. Total mercury levels in the whole blood of licensed anglers (n=232) were within the Health Canada acceptable range of less than 20 µg/L. The population eating fish within five Great Lakes AOCs (n=86) had two members having total blood mercury above the acceptable range, including one man with a blood mercury level of 26.0 µg/L. Six women of reproductive age in the Great Lakes AOCs sample (6 out of 35, or 25 percent) had total mercury levels above 10 µg/L, but were still classified as being in the normal acceptable range (Cole et al., 2004).

The biggest fisheries in the Great Lakes, especially the Lake Erie fishery, produce fish with lower mercury than the typical commercially-available fish. The highest levels are found in fish from certain inland lakes within the basin.

U.S. EPA's RIA estimates that the IQ of a typical child of freshwater fishers decreased approximately 0.06 to 0.07 points due to mercury exposure in 2001 (U.S. EPA, 2005a). The RIA also predicts that the total elimination of mercury emissions from power plants would reduce the 2001 impact on IQ by 13.2 percent.

3.2.9 Biosolids

U.S. EPA sets a pollutant concentration ceiling for mercury of 57 mg/kg in any land applied sludge; "exceptional quality" biosolids, which have fewer restrictions on their use, can contain no more than 17 mg/kg of mercury. The specific U.S. criteria for mercury in biosolids are as follows:

- ◆ 17 mg/kg (dry wt) and 17 kg/hectare cumulative loading for sludge applied on agricultural, forest and publicly accessible lands.
- ◆ 17 mg/kg (dry wt) and 0.85 kg/hectare annual loading rate for sludge sold or distributed for application to a lawn or home garden.
- ◆ 57 mg/kg (dry wt) for sludge sold or distributed for other types of land disposal.

More than half of sewage sludge generated in the U.S. is land applied (Diroff and Thomas, 2003). Typically, sewage sludge concentrations are well below these limits. U.S. EPA's 1988-1989 National Sewage Sludge Survey found only a small number of sewage sludges that had concentrations above 17 mg/kg, and mercury levels in sludge have declined since then. For instance, a study of trace metal levels in New England sludge found average levels of 1 to 2 mg/kg in 1999 and 2000 (NEBRA). A 2003 National Academy of Sciences report found no evidence that U.S. EPA's regulation of land applied sewage sludge has failed to protect public health, but recommended that the regulations be updated using current scientific data and risk assessment methods, including consideration of the species of mercury that might be present in sludge, or released from sludge (Diroff and Thomas, 2003).

In Ontario, the Ontario MOE has established the following criteria for mercury in biosolids:

- ◆ 5 mg/kg (dry wt) to be applied up to 22 dry tonnes per hectare per 5 years;
- ◆ 11 mg/L (dry wt) to be applied up to 8 dry tonnes per hectare per 5 years;
- ◆ 11 mg/L (dry wt) for other non-agricultural source materials (NASM) containing more than 1 percent total solids;
- ◆ 0.11 mg/L for other NASM containing less than 1 percent total solids.

In addition, total mercury loadings to soil cannot exceed 0.09 kg per hectare per five years, and the soil which receives sewage biosolids and NASM cannot exceed 0.5 mg/kg soil (dry wt).

Table 3-6 presents data on mercury concentrations measured in biosolids samples collected at sewage treatment plants (STPs) in southern Ontario and in the near North Ontario (Bonte-Gelok, 2005). The size of STPs studied range from small STPs to large STPs with <20 percent

industrial inputs. The data show that mercury concentrations in biosolids at Ontario STPs are generally below the Ontario MOE standard of 5 mg/kg (dry wt).

Table 3-6. Mercury Concentrations in Biosolids at Ontario STPs.

Parameter	Hg (mg/kg, dry wt) (Equiv to ppm)
Median Conc	1.5
Avg Conc	1.6
Standard Deviation	1.0
Min – Max Concentration	0.2 – 5.6

No. of STPs = 25
 No. of Biosolids samples = 235
 Source: Bonte-Gelok, 2005

Criteria Summary

Table 3-7 presents an overview of risk-based criteria for mercury and exceedances observed in environmental and human health data.

Table 3-7. Environmental and Human Health Data.

DATA	RISK-BASED CRITERIA	EXCEEDANCES
WHOLE FISH AND FISH TISSUE		
Canadian Department of Fisheries and Oceans (DFO) Monitoring Program ¹	GLWQA: Concentration of total mercury in whole fish should not exceed 0.5 µg/g (wet weight basis)	None. Data consistently below criteria
U.S. National Lake Fish Tissue Study (NLFTS)	U.S. EPA water quality criterion for methylmercury is a mercury concentration of 0.3 ppm in fish tissue for protection of human health.	Exceedances of 0.3 ppm confirmed in 40% of sites sampled in the Great Lakes States in the 1 st year (1999/2000) and 2 nd year (2001) of study.
National Listing of Fish Advisories (NLFA)	Various Great Lakes States have established criteria as well (i.e., Minnesota, 0.2 ppm)	3,183 advisories in the Great Lakes States and Ontario
WILDLIFE		
Canadian Wildlife Service's Great Lakes Herring Gull Monitoring Program	N/A	--
SURFACE WATER		
St. Clair-Detroit River Corridor Upstream/Downstream Water Quality Monitoring	MDEQ Water Quality Values 0.0018 µg/L (HNV "drink" and "non-drink") 0.0013 µg/L (Wildlife Value)	Exceedances at Detroit River sampling sites

DATA	RISK-BASED CRITERIA	EXCEEDANCES
Niagara River Upstream/Downstream Monitoring Program 1987-2000 Fort Erie-Dissolved Phase NOTL-Dissolved Phase	N/A N/A	-- --
Mason and Sullivan, 1997	Ambient Water ¹² : 1.8 ng/L water quality criteria for protection of human health 1.3 ng/L water quality criteria for protection of wildlife 1.694 µg/L for protection of aquatic life (acute) 0.908 µg/L for protection of aquatic life (chronic)	No exceedances in Lake Michigan.
DRINKING WATER		
U.S. EPA data	U.S. EPA MCL for inorganic mercury is 0.002 mg/L	No recent exceedances of MCL recorded in the U.S. Great Lakes Basin
Ontario Drinking Water Surveillance Program	Health Canada Maximum Acceptable Concentration for total mercury is 0.001 mg/L	No recent exceedances of MAC
SEDIMENT		
EC Water and Sediment Contaminant Monitoring Programs	Provincial Sediment Quality Guidelines (SQG) (dry weight): PSQ LEL: 0.2 µg/g; PSQ SEL: 2 µg/g	
Screening Level Survey of Sediment Quality in Tributaries to the Lower Great Lakes	Canadian Sediment Quality Guidelines (SQG) for mercury: SQG TEL 0.17 µg/g SQG PEL 0.486 µg/g	TEL: Exceedances at 87% of sites in Lake Ontario & 46% of sites in Lake Erie PEL: Exceedances at 62% of sites in Lake Ontario & 6% of sites in Lake Erie
Ostaszewski, 1997	No risk-based criteria were identified in the Trenton Channel study.	N/A
Rediske et al., 2002	PEC for mercury is 1.06 mg/kg	2 exceedances of the PEC (1.06 mg/kg) for mercury were found in ponar samples in 1999
Rossmann, 2002	SQG TEL 0.17 µg/g SQG PEL 0.486 µg/g	PEL: No exceedances TEL: Maximum concentration collected from sites in Lake Michigan indicates exceedances.

¹² Final Water Quality Guidance for the Great Lakes System established water quality criteria for 29 pollutants, including mercury. (40 CFR 132) EPA 1995d.

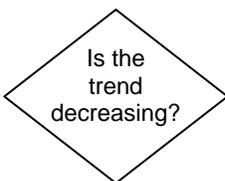
DATA	RISK-BASED CRITERIA	EXCEEDANCES
Niagara River Upstream/Downstream Monitoring Program 1987-2000		
Fort Erie-Suspended Sediment	SQG TEL 0.17 µg/g	None
NOTL-Suspended Sediment	SQG TEL 0.17 µg/g	Exceedances in 1989-1990 ¹³
Onondaga Lake, NY	Onondaga Lake PEC of 2.2 mg/kg	Exceedances in many areas of lake, some reaching as high as >150 times the PEC
AMBIENT AIR		
Carpi and Chen (2001)	RfC for elemental mercury is 0.3 µg/m ³ (or 300 ng/m ³)	An estimated 10% of households exceed the RfC
ATMOSPHERIC DEPOSITION		
Integrated Atmospheric Deposition Network (IADN)	N/A	--
Canadian Atmospheric Mercury Measurement Network (CAMNet)	N/A	--
Mercury Deposition Network (MDN)	Criteria do not exist. Water quality criteria apply to surface waters, but not to wet precipitation.	--
HUMAN EXPOSURE		
Cole et al. (2004)	Health Canada considers the "normal acceptable" range of total blood mercury to be <20 µg/L.	Blood mercury levels exceeded the 20 µg/L limit for two members of the AOC population (n=86). Six women of reproductive age within the AOC group had total mercury levels >10 µg/L
U.S. National Health and Nutrition Examination Survey (NHANES) 1999 – 2002	RfD for methyl mercury is 0.1 µg/kg/day	Yes, approximately 6 percent of childbearing-aged women had levels at or above a blood level equivalent to the RfD (≥5.8 µg/L)
Health Canada (Enforced by the Canadian Food Inspection Agency)	Established a guideline of 0.5 ppm for mercury in commercial fish	
Health Canada (1998)	pTDI for pregnant women, women of child-bearing age, and young children is 0.2 µg/kg bw /day	No exceedances in the Great Lakes Basin population
Inorganic Mercury Reference Dose (RfD)	RfD for inorganic mercury (mercuric chloride) is 0.3 µg/kg/day	
BIOSOLIDS		
Sludge (biosolids)	U.S. Limits: 17 mg/kg (dry wt) and 17 kg/hectare cumulative loading for sludge applied on agricultural, forest and publicly accessible	Federal U.S. biosolids criteria are being met

¹³ Most stringent risk based criteria, according to jurisdiction, used for determination of exceedances.

DATA	RISK-BASED CRITERIA	EXCEEDANCES
	<p>lands.</p> <p>17 mg/kg (dry wt) and 0.85 kg/hectare annual loading rate for sludge sold or distributed for application to a lawn or home garden.</p> <p>57 mg/kg (dry wt) for sludge sold or distributed for other types of land disposal</p> <p>Ontario Limits: For sewage biosolids to be applied up to 22 dry tonnes per hectare per 5 years: the maximum mercury concentration is 5 mg/kg dry wt.</p> <p>For sewage biosolids to be applied up to 8 dry tonnes per hectare per 5 years: the maximum mercury concentration is 11 mg/L dry wt.</p> <p>For other non-agricultural source materials (NASM) containing more than 1 percent total solids: the maximum mercury concentration is 11 mg/L dry wt.</p> <p>For other NASM containing less than 1 percent total solids: the maximum mercury concentration is 0.11 mg/L.</p> <p>Total mercury loadings to soil cannot exceed 0.09 kg per hectare per 5 years and the soil which receives sewage biosolids and NASM cannot exceed 0.5 mg/kg soil, dry wt.</p>	
OCCUPATIONAL EXPOSURE		
OSHA workplace standard	Permissible Exposure Limit (PEL): 0.1 mg/m ³	
Health Canada Occupational Exposure limits	Threshold Limit Value--Time-Weighted Average for elemental and inorganic Hg: 0.025 mg/m ³	

Agency Toxic Substances and Disease Registry (ATSDR) <http://toxprof.crcpress.com/default.asp?cc=77>

3.3 TRENDS



Analysis of sediment cores indicates that mercury levels in the Great Lakes have increased since the pre-industrial age, peaking in the 1940s-1970s, and generally declining since then. Mercury levels in Great Lakes herring gull eggs and fish likewise show a general decline since the 1970s. However, trends in environmental levels of mercury after the mid-1980s are less clear. In the past 10-20 years, mercury levels in fish, bald eagles, herring gull eggs, and atmospheric deposition have not declined. Blood mercury levels among women of childbearing age in the U.S. declined in the past five years, but the decrease was not statistically significant.

3.3.1 Whole Fish and Fish Tissue

Mercury concentrations have declined in a number of fish species, including most of those monitored by the DFO, since the late 1970s. Table 3-8 compares the most recently measured concentrations of mercury with the highest recorded concentrations in four of the five Great Lakes for the Canadian DFO fish collections. The changes are often lake specific and relate to both the specific characteristics of the substances involved and the biological conditions of the fish community surveyed. Additional graphs are provided in Appendix B (Figures B-1 through B-4) that illustrate the trends in total mercury levels collected by the DFO monitoring program in Lake Ontario, Lake Erie, Lake Huron, and Lake Superior from 1977 to 2003.

DFO smelt data in Lake Superior display a steady decline in mercury concentrations between 1981 and 2002. Lake Huron DFO smelt data show that mercury concentrations have fluctuated considerably between 1979 and 2003. Mercury concentrations between 1999 and 2003 are lower than the concentrations between 1979 and 1982, but there is no clear trend after 1982. In Lake Ontario, DFO smelt data show a significant decrease in mercury concentration in the early 1980s, but little change in the annual mean mercury level since the 1985. For Lake Erie, smelt show considerable variation, and are lower in the late 1980s and early 1990s than in previous years or subsequent years. Mercury concentrations in Lake Erie walleye declined rapidly from 1977 through 1983, but have remained steady since. On the whole, the DFO data seem to show a decrease in the late 1970s and early 1980s, but the trend since then becomes less clear.¹⁴

¹⁴ As confirmed by regression analysis (unpublished data; Whittle, 2005).

Table 3-8. Percent Change in Total Mercury Concentrations for DFO Fish Collections, Based on Whole Fish Samples (Age Range 4+ - 6+)^a.

Lake	Contaminant	Species	Highest Recorded Concentration		Most Recently Measured Conc'n		% of Highest Recorded Concentration
			Year	Value (µg/g)	Year	Value (µg/g)	
Superior	Mercury	Smelt	1981	0.10	2002	0.02	20%
Huron	Mercury	Smelt	1980	0.07	2003	0.05	74%
Erie	Mercury	Walleye	1977	0.37	2003	0.12	32%
	Mercury	Smelt	2002	0.05	2003	0.02	40%
Ontario	Mercury	Smelt	1982	0.09	2003	0.04	44%

*All concentrations based on whole fish samples. Concentration data are the mean of samples analyzed for a species from each lake for a specific year.

a) This does not apply to smelt – not aged.

Source: Whittle, 2005

To illustrate whole fish trends, Figure 3-6 shows the trend in total mercury levels in Lake Erie walleye from 1977 to 2003. For Lake Erie, after a period of rapid decline from 1977 through 1983, mercury concentrations in Lake Erie walleye appear to be decreasing at a much slower rate through 1996. After 1996, the frequency of annual measurements of mercury burdens in walleye by DFO was reduced. The mean of two recent measurements made in 1999 and 2003 was approximately 15 percent greater than the five-year mean of the period 1992 through 1996, and roughly the same as in 1983.

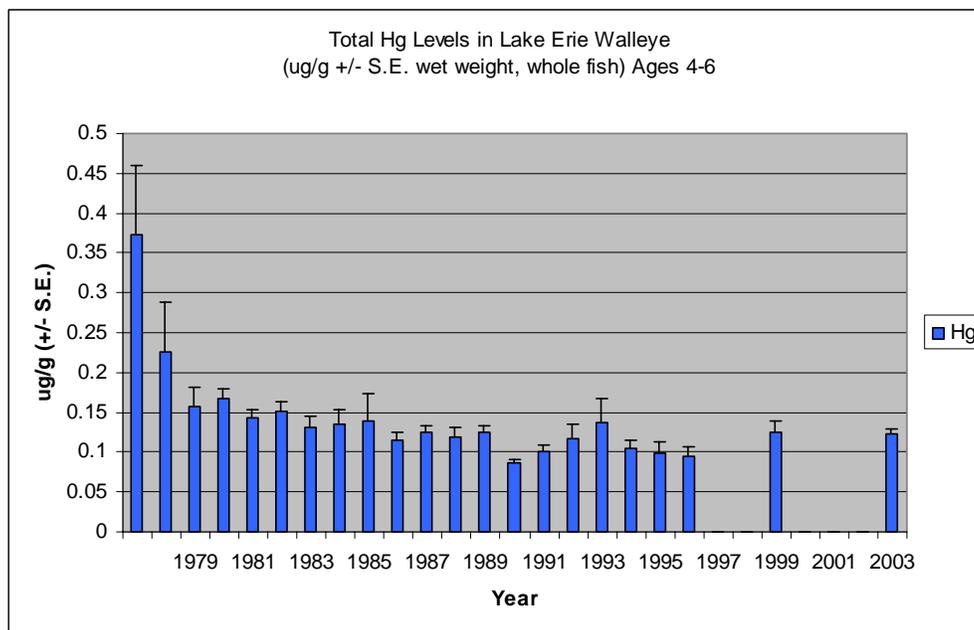


Figure 3-6. Total Mercury Levels in Lake Erie Walleye (1977-2003). Data Source: DFO/GLLFAS

According to the Lake Superior LaMP, the Ontario Sport Fish Contaminant Monitoring Program reports that mercury concentrations in Lake Superior lake trout have decreased 64 percent since 1976, to an average of 0.19 ppm (Lake Superior Binational Program, 2004). The Lake Huron Binational Partnership reports that the long term trend in mercury concentrations in Lake Huron top predator fish is “declining,” but with a recent “leveling off” (Lake Huron Binational Partnership Action Plan, 2004). The Lake Ontario LaMP reports a gradual declining trend from 1978 through 2000 in Coho Salmon from the Credit River, though a lack of reported data between 1995 and 1998 makes the more recent period difficult to interpret (Lake Ontario Lakewide Management Plan, 2004).

MPCA has examined recent temporal trends in fish mercury concentrations in Minnesota inland lakes using the fish tissue concentration in standard size northern pike and walleye.¹⁵ Changes over time in fish mercury concentrations within lakes were evaluated by comparing a recent sample year to an earlier year, which were at least five years apart. Recent sample years were 1995 or later and at least three fish (or composites) were analyzed each year. Of the 176 lakes meeting these criteria, 87 lakes (49 percent) showed a decrease in mercury concentrations, 44 lakes (26 percent) had increased fish-mercury, and 45 lakes did not show a significant difference between years (Figure 3-7). A Chi-square statistical test shows that significantly more lakes declined in fish contamination than increased ($p < 0.01$). During the 1990s, there was a general decline in fish mercury concentrations of slightly more than one percent per year. There have been noticeable reductions in fish mercury levels that correspond with reductions in mercury emissions and deposition. The MPCA has a goal to continue that trend through the next decade (i.e., 10 percent reduction in fish tissue mercury concentration by 2010 compared to 2000).

Hrabik and Watras found significant reductions in mercury concentrations in fish in two different basins of Little Rock Lake, Wisconsin, based on measurements taken during the summers of 1994 and 2000. The researchers attribute a 30 percent reduction in fish mercury concentrations to a decrease in atmospheric mercury deposition measured for the Little Rock Lake basin. They attribute an additional 30 percent reduction in fish mercury concentration in one basin, and a 5 percent reduction in the other basin, to de-acidification. They believe that reduced deposition of SO_4 has reduced the methylation of available mercury by sulfate-reducing bacteria, and the amount of mercury available for methylation has decreased because of reduced deposition of ionic mercury (Hrabik and Watras, 2002). However, while Hrabik and Watras found significant reductions in mercury deposition to the Little Rock Lake basin, such reductions have not been found elsewhere in Wisconsin. MDN data in Wisconsin for the period 1996 through 2001 show no apparent trend (see Figure 3-10).

While concentrations of mercury in fish have been trending downward, the number of fish consumption advisories has been increasing. In the U.S., fish consumption advisories for mercury increased by 222 in 2003 with almost 60 percent of these new advisories being issued in Minnesota (U.S. EPA, 2004). The increased number of advisories primarily reflects an increase in the number of assessments of fish and wildlife tissues.

¹⁵ Minnesota’s Total Maximum Daily Load Evaluation of Mercury in Fish Tissue, (Preliminary Draft) December, 2004. <http://www.pca.state.mn.us/publications/wq-iw4-01b.pdf>

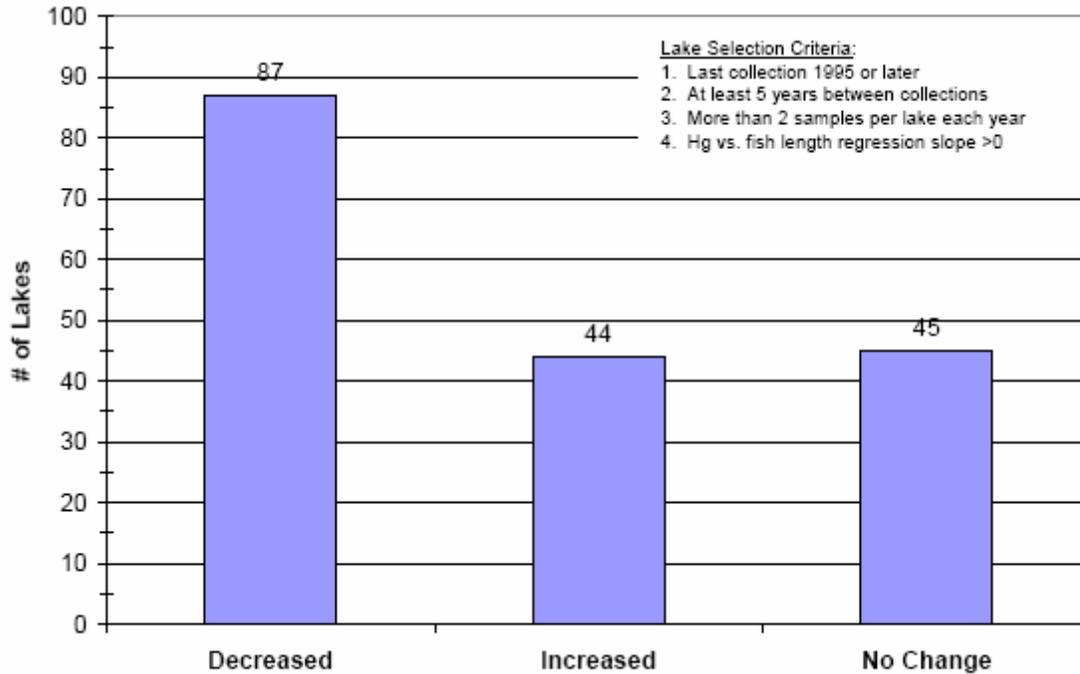


Figure 3-7. Comparison between Recent and Historical Fish Mercury Levels in 176 Minnesota Lakes (Northern Pike and Walleye; Standard Lengths)¹⁶.

3.3.2 Wildlife

Mercury concentrations declined in herring gull eggs in the 1970s and early 1980s, and have been roughly constant since the mid-1980s. However, mercury levels in loons appear to have decreased in the 1990s, while trends in bald eagles are uncertain.

Herring Gull Eggs

Percent declines from 1974 to 2003 in mercury levels in herring gull eggs collected from Great Lakes water bodies range from 15.2 percent to 50.6 percent. U.S. EPA analyzed mercury trends in Canadian Wildlife Service data. Figure 3-8 shows the decline at Lake Ontario sites from 1974 to 2003. Charts depicting the declines at other Great Lakes sites are presented in Appendix B (Figures B-6 through B-11). In all charts, trend lines for each colony were plotted using linear, power, or exponential regression, depending on which gave the best R^2 value. Most of the colonies have seen an overall decline in mercury concentrations since the 1970s, with the exceptions of Middle Island and Channel-Shelter Island.

¹⁶ Ibid.

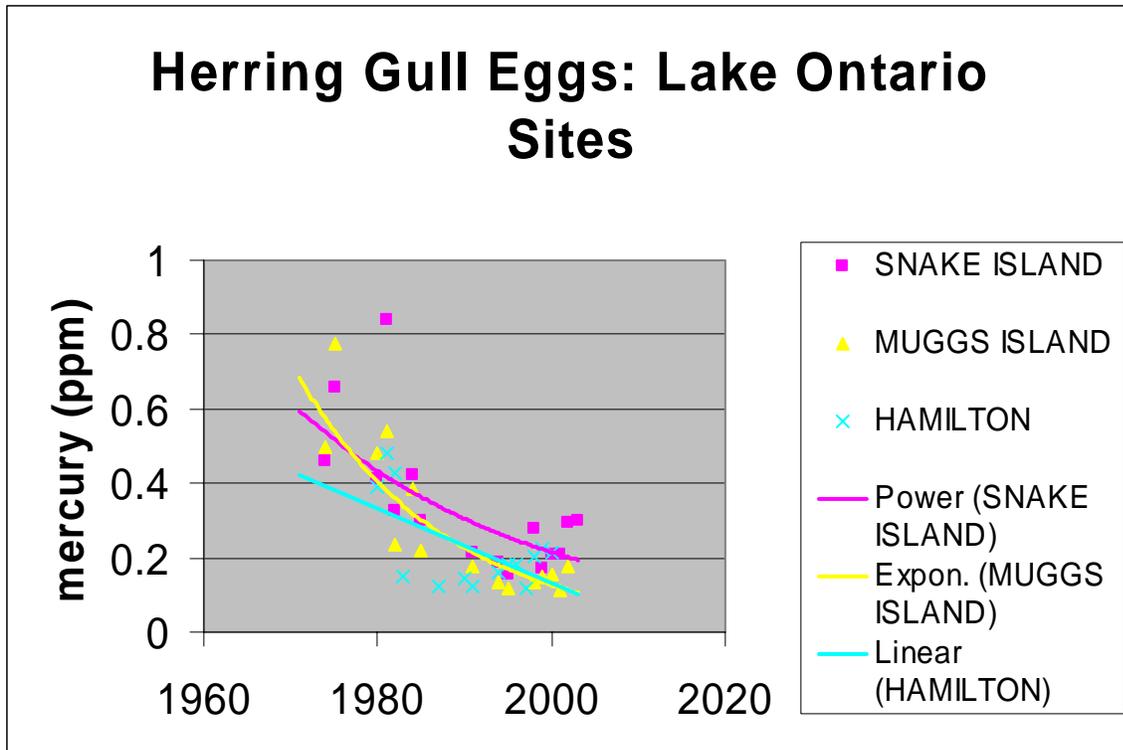


Figure 3-8. Trend in Mercury Concentrations in Herring Gull Eggs at Lake Ontario Sites, 1974-2003. Data Source: Canadian Wildlife Service

To more closely examine trends in herring gull eggs since the early 1980s, U.S EPA analyzed herring gull egg data from 1984-2003 (data prior to 1984 was excluded from the analysis). Regression analysis showed no declining trend, with slight increases in mercury concentrations at several colonies. These results indicate that mercury levels have not decreased in herring gull eggs in the past 20 years.

Loons and Bald Eagles

Fevold (2003) found that loon chick blood mercury levels declined by 4.9 percent annually for chicks sampled on 33 lakes in northern Wisconsin during the period 1992-2000; it is the first reported evidence showing a recent regional annual decrease in common loon mercury exposure.

Nestling bald eagle feathers were collected during the period of 1985-1989 from inland and Great Lakes breeding areas as well as from Voyageurs National Park (VNP), Minnesota (Table 3-9). To compare mercury concentrations to the 1999 and 2000 data, samples associated with Lake Michigan and Lake Huron were combined. The 1999 data appear to show a decline in mercury concentrations in each region. However, the 2000 data are roughly equivalent to the data for 1985 and 1989, except for a decrease at VNP and an increase for the Upper Peninsula breeding area (MDEQ, 2003). Therefore, based on available data, an overall trend in bald eagle mercury concentrations cannot be established.

Table 3-9. Geometric Mean for Mercury Concentrations ($\mu\text{g/g}$ dry weight) in Nestling Bald Eagle Feathers Collected in Michigan from 1985-1989, 1999, and 2000. Source: MDEQ, 2002, 2003

Location	1985-1989	1999	2000
Inland-Lower Peninsula	8.8	7.4	8.9
Inland-Upper Peninsula	8.1	6.2	11.1
Lake Superior	8.7	6.4	9.1
Lake Michigan and Lake Huron	8.0	5.4	7.8
Voyageurs National Park	20.1	NL	9.9

NL: Not listed

3.3.3 Sediment

Mercury concentrations in Great Lakes sediments have decreased from the peaks reached during the 1940s through 1970s. Environment Canada has investigated spatial and temporal trends in mercury contamination of sediments throughout the Great Lakes Region by comparing recent surveys with historical data. In 1998, Environment Canada revisited 66 sites in Lake Ontario that were originally sampled in 1968 by Frank et al. (1979) to analyze surficial sediment contamination relative to the Canadian SQGs. Mercury concentrations were observed to have decreased between 1968 and 1998, from 0.79 $\mu\text{g/g}$ to 0.59 $\mu\text{g/g}$ (Marvin et al., 2003).

Trends in mercury contamination of sediments in the Great Lakes were observed by Marvin et al. (2004) over the periods for which data were available for each of the lakes. Reductions in mercury concentrations in sediments, observed by comparing the most recent surveys with historical surveys, ranged from 25 percent for Lake Ontario to 80 percent for Lake Huron. As described above, the mean Lake Ontario concentration decreased from 0.79 $\mu\text{g/g}$ in 1968 to 0.59 $\mu\text{g/g}$ in 1998 (Marvin et al., 2004). In Lake Erie, the mean concentration decreased from 0.610 $\mu\text{g/g}$ in 1971 to 0.190 $\mu\text{g/g}$ in 1997-1998. Lake Michigan levels decreased from 0.110 $\mu\text{g/g}$ in 1975 to 0.078 $\mu\text{g/g}$ in 1994-1996 (Marvin et al., 2004). Mercury concentrations also declined in Lake Huron, from 0.220 $\mu\text{g/g}$ in 1969 to 0.043 $\mu\text{g/g}$ in 2002 (Marvin et al., 2004). The lake-wide average mercury concentration for Lake Superior in 2000 (0.088 $\mu\text{g/g}$) remained virtually unchanged from the level recorded in 1973 (0.083 $\mu\text{g/g}$) (Marvin et al., 2004).

The core profiles shown in Figure 3-9 represent the general trend in mercury accumulation in Great Lakes sediments over the past 150 years. Trends are tied to sediment layers as newer layers are less contaminated than older layers. Based on profiles of cores sampled during recent lakewide sediment surveys, the maximum accumulation of mercury in sediments of western Lake Erie, Lake Ontario, and Lake Superior occurred during the period 1964–1970 (Marvin et al., 2004).

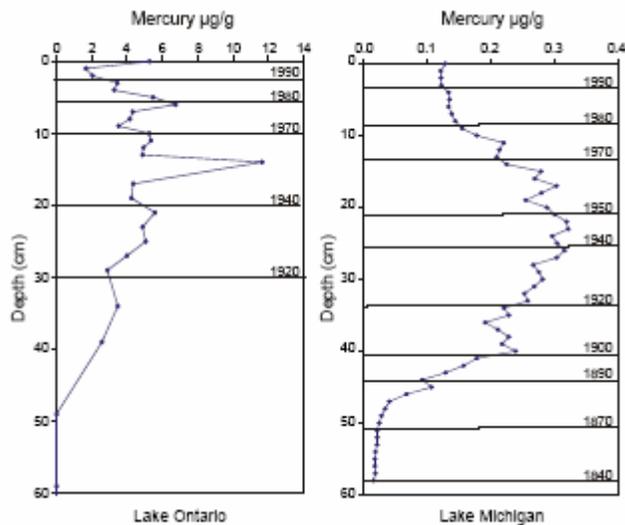


Figure 3-9. Profile of Mercury ($\mu\text{g/g}$) in a Benthos Core from the Central Area of the Mississauga (Central) Basin of Lake Ontario and Lake Michigan.
Source: Marvin et al., 2004

Rossmann (2002) confirms these trends for mercury levels in Lake Michigan. Based on comparisons of samples taken in 1994 through 1996 with samples taken in 1969-1970 and 1975, mercury concentrations in Lake Michigan surficial sediments are decreasing (Rossmann, 2002). Lake Michigan sediment cores show significant increases in mercury concentration between the era prior to 1800 and the present, but decreases after 1970.

3.3.4 Total Gaseous Mercury

Trend analyses were conducted for TGM data collected in Ontario between 1997 and 2001 at Egbert and Point Petre (Blanchard et al., 2002). The results indicate that for both sites, there was no clear trend for TGM. Kellerhals et al. (2003) observed that a slight seasonal trend for TGM was seen with higher concentrations observed in winter and spring, and lower concentrations in summer and fall. This is further demonstrated for all years of CAMNet data. Seasonal cycles in TGM observed elsewhere also show a winter maximum in concentration. For example, measurements of TGM in Scandinavia (Iverfeldt, 1991) found median concentrations in winter to be 33 percent higher than in summer. Several factors might contribute to this behavior (Blanchard et al., 2002), including differences in meteorological conditions and scavenging processes between summer and winter (e.g., reduced mixing heights and higher wind speeds in winter, increased oxidation and larger removal from the atmosphere by wet and dry deposition during warmer months). One other contributing factor might be the northern hemispherical wintertime increase in coal combustion for domestic heating purposes (Rotty, 1987).

3.3.5 Atmospheric Deposition

The most comprehensive data on wet mercury deposition show no trend since the mid-1990s. Other efforts to characterize trends in deposition have shown mixed results. A study of a Wisconsin lake showed decreasing mercury deposition in the 1990s. However, a study of wet deposition in Minnesota and North Dakota showed increasing mercury during the early 1990s.

Over the longer term, atmospheric mercury deposition, as measured in sediment cores from lakes whose only inputs are atmospheric, appears to have decreased from the peaks reached in the 1960s and 1970s.

Wet mercury deposition, as measured at Mercury Deposition Network sites, shows no trend since the mid-1990s. The next three graphs break out the data by year for 15 Great Lakes' sites (including sites in the U.S. and Ontario). Figure 3-10 shows the trend in mean weekly mercury deposition from 1996 to 2001 at four Wisconsin sites (WI08, Brule River; WI09, Popple River; WI36, Trout Lake; WI99, Lake Geneva). Overall, there is no apparent trend in mercury deposition over the time period 1996-2001 at these sites (Thomas, 2003).

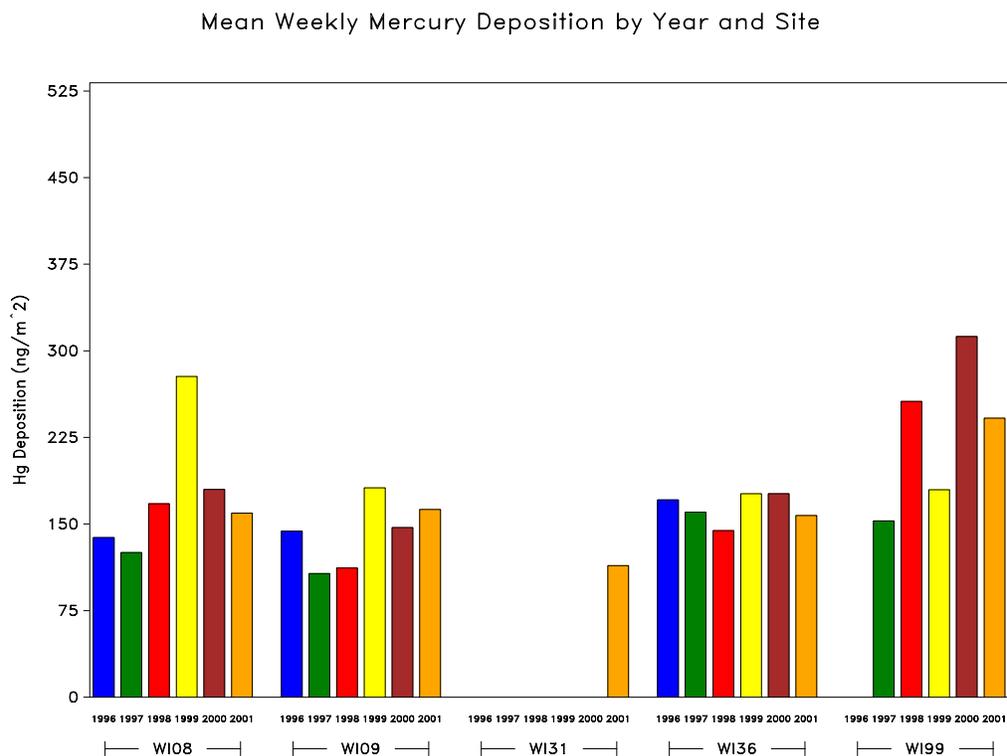


Figure 3-10. Trend in Mean Weekly Mercury Deposition from 1996 to 2001 at Four Wisconsin Sites. Source: Thomas, 2003

Figure 3-11 illustrates the available MDN data at one site in New York, two sites in Ontario, and two sites in Pennsylvania. There is no apparent trend in mercury deposition at the site with five years of data (PA90). Data are insufficient to determine trends over the time period 1996-2001 at the other sites shown in Figure 3-11 as well.

Mean Weekly Mercury Deposition by Year and Site

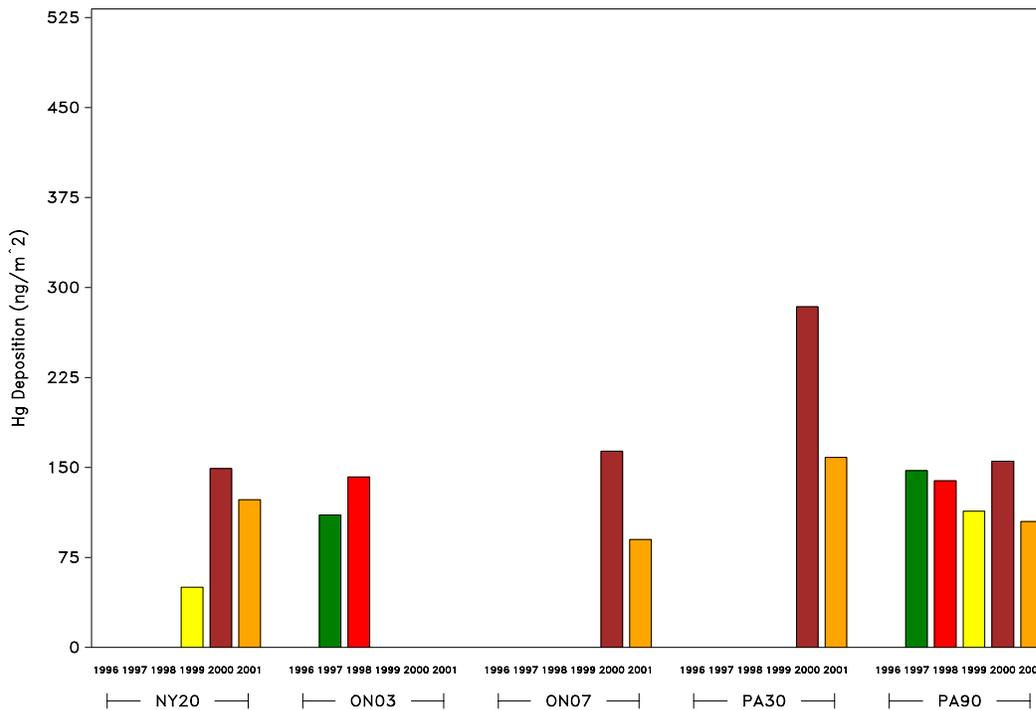


Figure 3-11. Trend in Mean Weekly Mercury Deposition from 1996 to 2001 in New York, Ontario, and Pennsylvania. Source: Thomas, 2003

Figure 3-12 shows the available MDN data at two sites in Indiana and three sites in Minnesota. Data are insufficient to determine trends at the two Indiana sites. Data for 1996-2001 show varying mercury deposition with no discernable trend at the three Minnesota sites (MN16, Marcell Experimental Forest; MN18, Fernberg; MN23, Camp Ripley).

U.S. emissions inventories indicate that mercury emissions decreased more than 40 percent between 1990 and 2000. However, MDN data do not show a discernable decrease nationally between 1995 and 2003. One possible explanation for the lack of correspondence between the emissions trends and the deposition trends is that reductions in deposition caused by U.S. emissions have been offset by increases in deposition caused by global emissions. Further analysis should be carried out to see whether global emissions increases are sufficiently large to make much of a difference. Other explanations for the lack of measurable decline in wet deposition, despite apparent reduction in emissions, include that the measurement timeframe may be too short to establish trends or that emissions reductions have impacted primarily unmeasured dry deposition, not wet deposition.

Mean Weekly Mercury Deposition by Year and Site

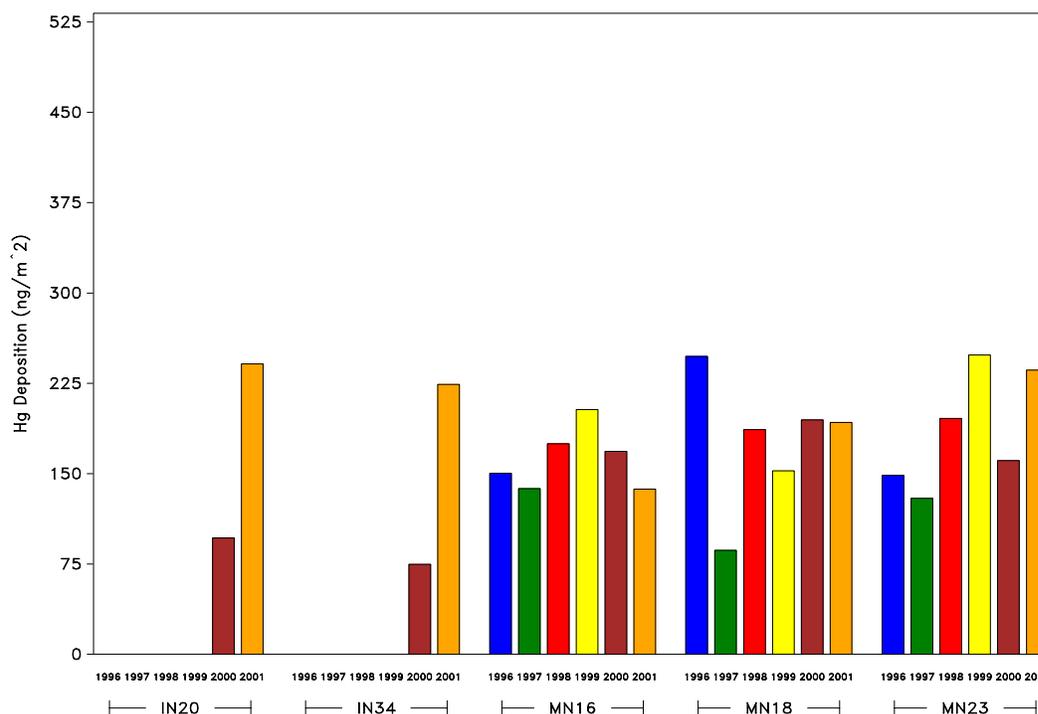


Figure 3-12. Trend in Mean Weekly Mercury Deposition from 1996 to 2001 in Indiana and Minnesota. Source: Thomas, 2003

A study of wet mercury deposition showing increasing mercury deposition levels in upper Midwestern U.S. States was conducted from 1990 to 1995. Total wet mercury deposition was monitored weekly at six sites in the States of Minnesota and North Dakota to assess spatial and temporal patterns, along with mercury contributions to surface waters. The study showed increased trends averaging $0.60 \mu\text{g}/\text{m}^2\text{-year}$ (or 8 percent per year) over the six year period. Significant variations were observed in annual wet mercury deposition between sites. Wet deposition of methylmercury averaged approximately $0.18 \text{ ng}/\text{L}$ in rain (representing 1.5 percent of total mercury); these measurements were strongly correlated with total mercury and precipitation depth (Glass and Sorensen, 1999). The average annual wet mercury deposition among the six long-term monitoring sites was $7.4 \mu\text{g}/\text{m}^2\text{-year}$ and showed significant variations between sites.

The Wisconsin Department of Natural Resources and the Electric Power Research Institute funded an effort to assess temporal trends in mercury deposition at a precipitation-dominated lake in northern Wisconsin. Little Rock Lake is a seepage lake situated in a sparsely populated area far removed from industrial activities. Investigators collected samples in the southern-most basin of the lake between 1988 and 1999. Over that 10-year period, concentrations of aqueous mercury and aqueous methylmercury in wet deposition declined by approximately 40 percent and 50 percent, respectively, in the surface waters of Little Rock Lake. Decreased mercury in bulk precipitation was also observed through atmospheric monitoring (Watras et al., 2000).

The results of a Swain and Engstrom (1997) sediment core study that investigated trends in mercury deposition at various U.S. locations 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 measured mercury concentrations in sediment cores from lakes in watersheds where there were no activities that discharge mercury to assess atmospheric 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.

Pirrone et al. (1998) found that mercury deposition to the Great Lakes peaked in the 1940s and again in the 1960s, based on evaluation of sediment cores taken from the eastern basin of Lake Ontario, the eastern basin of Lake Erie, and the southeastern basin of Lake Michigan. They found that these peaks were associated with peaks in modern North American industrial emissions, but not with peaks in emissions during the period between 1800 and 1920 when North American mines emitted significant amounts of mercury in the recovery of gold and silver. Even though estimated North American mercury emissions were higher during the 19th century than present, the emissions from 19th century mines were predominantly in the elemental form, and entered the global pool of atmospheric mercury without having a significant impact on deposition to the Great Lakes.

3.3.6 Human Exposure

Among childbearing-aged women, the geometric mean for blood mercury measured by NHANES and the share of women with levels ≥ 5.8 $\mu\text{g/L}$ declined from the 1999-2000 period to the 2001-2002 period. The percentage of women with blood mercury levels ≥ 5.8 $\mu\text{g/L}$ was 3.9 percent in 2001-2002, compared with 7.8 percent in 1999-2000 (Schober et al., 2003). However, the declines were not statistically significant. At least 2 more years of data are needed to best determine whether mercury exposure has declined among women of childbearing age in the U.S. (CDC, 2004).

3.3.7 Biosolids

Available data show that mercury concentrations in biosolids are decreasing, providing evidence that pollution control efforts have had some measurable impact on releases. About 50,000 dry tons of sewage treatment plant biosolids are land applied in Minnesota each year (after correcting for water content). The mercury content of the sludge has declined over time. Sludge averaged 3.6 ppm of mercury in 1990, 1.8 ppm in 1995, and 1.4 ppm in 2000.¹⁷

Mercury concentrations declined in Pennsylvania biosolids from 1984 to 1997. Evidence is strongest that maximum annual levels are declining, and declines are more evident for the 1980s than for the 1990s.¹⁸

¹⁷ Minnesota Pollution Control Agency (2004) <http://www.pca.state.mn.us/publications/reports/mercury-emissionsreport-0304.pdf>

¹⁸ Land Application of Sewage Sludge in Pennsylvania (1999) <http://pubs.cas.psu.edu/FreePubs/pdfs/uc164.pdf>

Data on biosolids from some of Toronto’s sewage treatment plants show reductions in the concentration of mercury entering the city’s treatment plants (see <http://www.ec.gc.ca/mercury/images/coa-e.pdf>). For example, Figure 3-13 illustrates the decline in mercury concentrations in biosolids at Toronto’s Ashbridges Bay Treatment Plant from 1990 to 2004. Recent decreases may be related to Toronto’s Sewer-Use bylaw, which required installation of amalgam separators at dental offices by the end of 2001.

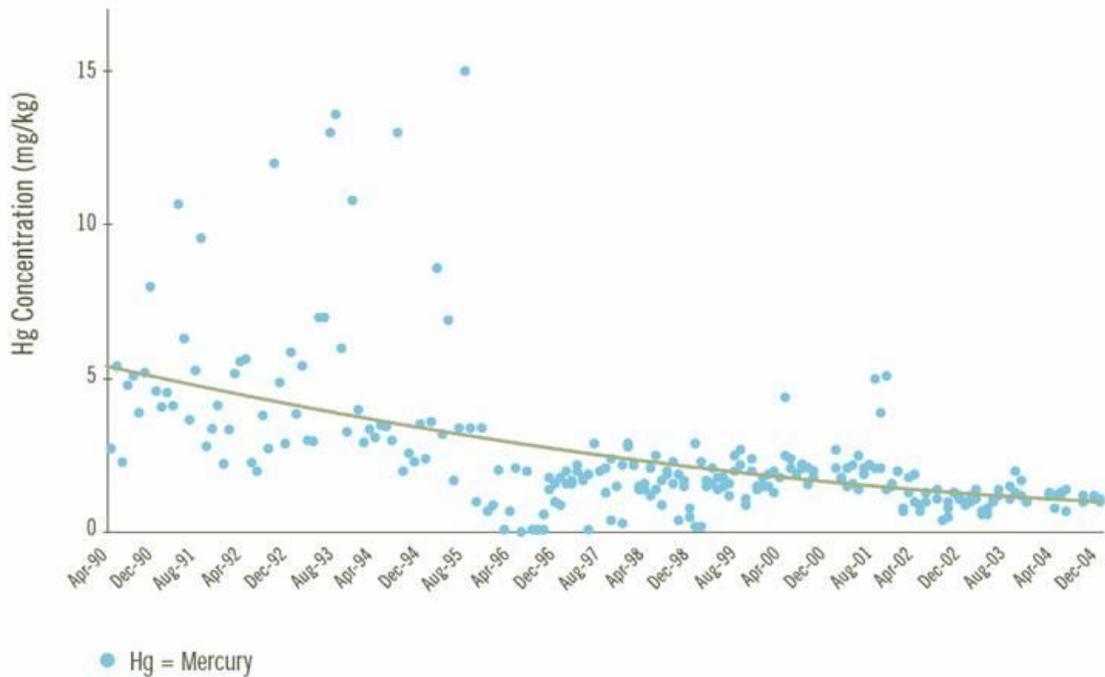


Figure 3-13. Trend in Mercury Concentrations in Biosolids at Toronto’s Ashbridges Bay Treatment Plant, 1990-2004. Source: Toronto Water Annual Report 2004

Trends Summary

Table 3-10 identifies trend information available from monitoring programs and studies that have collected data on mercury concentrations.

Table 3-10. Mercury Trends in Environmental and Human Health Data.

DATA	TRENDS
WHOLE FISH AND FISH TISSUE	
Canadian Department of Fisheries and Oceans (DFO) Monitoring Program	Declines observed from 1997 to 2003, though specific trends in smelt, walleye, and trout vary per Lake. (See Appendix B for graphs.)
National Listing of Fish Advisories (NLFA)	Advisories for mercury have increased steadily, by 247% (from 899 advisories in 1993, the baseline, to 3089 advisories in 2003 in the U.S. Trends in the number of fish consumption advisories issued may not reflect changes in levels of fish contamination Ref: http://epa.gov/ost/fishadvice/mercupd.pdf and http://www.epa.gov/ost/fish/advisories/factsheet.pdf
Minnesota Study	Of the 176 lakes meeting the criteria, 87 lakes (49 percent) showed a decrease in mercury concentrations, 45 lakes (26 percent) had increased fish-mercury, and 44 lakes did not show a significant difference between years. A Chi-square statistical test shows that significantly more lakes declined in fish contamination than increased.
WILDLIFE	
Canadian Wildlife Service's Great Lakes Herring Gull Monitoring Program	Percent declines of 15% to 50% across Great Lakes from 1974 to 2003. Overall declines observed at most colonies since the 1970s, with the exceptions of Middle Island and Channel-Shelter Island. Strong declines occurred prior to 1984. No declining trends after the mid-1980s.
Fevold et al., 2003	Study finds that loon chick blood Hg levels declined by 4.9% annually for chicks sampled on 33 lakes during the period 1992-2000. This is the first evidence we are aware of showing a recent regional annual decrease in common loon Hg exposure.
MDEQ 2002, 2003	No clear trend observed in inland and Great Lakes breeding areas; decreasing trend at VNP.
SEDIMENT	
Marvin et al., 2004	Declines in Great Lake sediment ranging from 25% in Lake Ontario to 80% in Lake Huron. No change in Lake Superior Hg levels from 1973 to 2000.
Ostaszewski et al., 1997	No trends were noted for mercury contamination in the Trenton Channel study.
Rediske et al., 2002	No trends for mercury contamination were noted in this study
Rossmann, 2002	Based on comparisons of samples taken in 1994 through 1996 with samples taken in 1969-1970 and 1975, mercury concentrations in Lake Michigan surficial sediments are decreasing.
Niagara River U/D Monitoring Program 1987-2000	

DATA	TRENDS
Fort Erie-Suspended Sediment	No clear trend, 1987 – 2000 ¹⁹
NOTL-Suspended Sediment	No clear trend, 1987 – 2000
TOTAL GASEOUS MERCURY	
CAMNet	No clear trend, 1997 – 2001
ATMOSPHERIC DEPOSITION	
MDN	No apparent trend at Great Lakes sites, 1996 – 2001.
Glass and Sorensen, 1999	Increasing trend in Minnesota, 1990 – 1995
Watras et al., 2000	Decreasing trend in Little Rock Lake (WI), 1988 – 1999
Swain and Engstrom, 1997	Slight decline in Minnesota since 1960s–1970s but increasing deposition from global sources
Pirrone et al., 1998	Deposition to Lakes Ontario, Erie, and Michigan peaked in 1940s and 1960s
HUMAN EXPOSURE	
U.S. National Health and Nutrition Examination Survey (NHANES)	No reliable trend data available yet.
BIOSOLIDS	
MPCA Data	Declining trend in Minnesota, 1990 – 2000
Pennsylvania Data	Declining trend in Pennsylvania biosolids, 1984 – 1997
City of Toronto	Mercury concentrations declining in biosolids at Toronto sewage treatment plants as a result of the City of Toronto Sewer-Use bylaw

3.4 ENVIRONMENTAL ASSESSMENT CONCLUSIONS

Most available data in the Great Lakes show that levels of mercury in the environment have declined in sediments, biosolids, fish, herring gull eggs, and loons. A long-term historic downward trend is evident in U.S. and Great Lakes sediment cores. While contaminant levels in Great Lakes herring gull eggs have shown a declining trend, the majority of the decline occurred in the 1970s and early 1980s; shorter term trends in the 1990s into the turn of the century are not declining. Mercury concentrations in bald eagles have also remained stable between 1985 and 2000 in the Lake Michigan area. Long-term temporal trend information is not available for mercury levels in open water and human biomonitoring.

Mercury is a cause of Great Lakes fish advisories. The highest mercury exposures are derived from eating fish from certain inland lakes within the Basin. Consumption of Great Lakes fish adds to human body burdens of methylmercury, which often exceed health criteria. The biggest fisheries in the Great Lakes, especially the Lake Erie fishery, produce fish with lower mercury than the typical commercially-available fish.

In addition to human body burdens and fish, exceedances of mercury criteria are observed in sediments and water in some areas of the Great Lakes. In other media, mercury levels are below relevant criteria (e.g., biosolids, drinking water, food). No criteria with which to assess mercury

¹⁹ Trend analysis and percent changes were calculated using the LifeReg model developed by A.H. El-Shaarawi. Reference: SAS-Based Program for Trend Analysis of Niagara River Toxic Contaminants Monitoring Data, El-Shaarawi, A. H., Ventressca, B., March 1998

levels in wildlife and atmospheric deposition have been established. However, high mercury levels may adversely affect populations of minks, otters, and loons in the Great Lakes.

Despite apparent long-term downward trends in mercury levels in the environment and significant reductions in emissions, current trends in some environmental media (such as wet deposition) are less clear. While U.S. emissions inventories indicate that mercury emissions decreased more than 40 percent between 1990 and 2000, MDN data show no discernable decrease nationally between 1995 and 2003. One possible explanation regarding the lack of correspondence between emissions trends and recent deposition trends is that reductions in deposition caused by North American emissions reductions have been offset by increases in deposition caused by global emissions. Trends of mercury concentrations in fish may not follow trends in mercury deposition, because mercury fish concentrations may be affected by mercury contributions from sediments, particularly in areas of past high direct water discharges.

4.0 GLBTS MANAGEMENT ASSESSMENT

The key question to consider in the GLBTS management assessment of a Level 1 substance is whether the GLBTS can effect further reductions. An important part of the assessment involves consideration of whether the identified reduction opportunities are significant enough to merit the effort. To answer this question, the following sections briefly summarize sources of mercury, current regulations and programs, and reduction opportunities.

4.1 SOURCES

4.1.1 Current Known or Inventory Sources

Global Emissions

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 *a third* of current worldwide mercury air emissions, whereas anthropogenic emissions account for the remaining *two-thirds* (U.S. EPA, 2005d). These estimates are highly uncertain. 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 roughly split between these re-emitted emissions, from previous human activity, and direct emissions from current human activity, as illustrated in Figure 4-1.

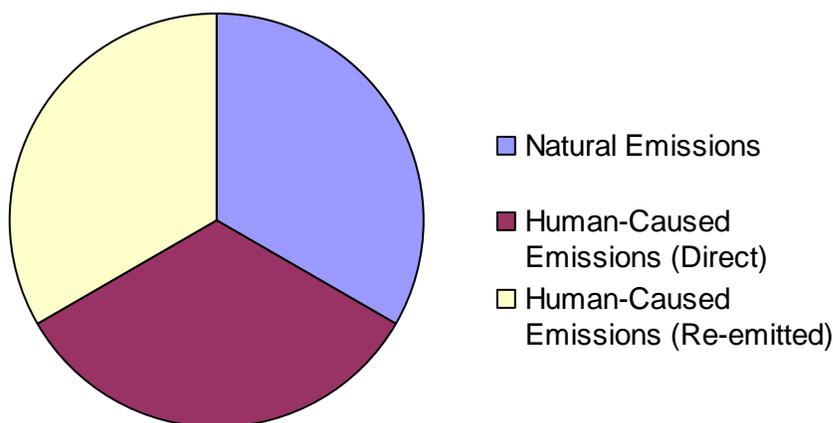


Figure 4-1. Contribution of Natural and Anthropogenic Worldwide Mercury Air Emissions. Source: U.S. EPA, 2005d²⁰

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

²⁰ Website: www.epa.gov/mercury/control_emissions/global.htm

of deposited mercury is reemitted 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 4-1. Direct anthropogenic emissions range from 2143 to 2400 Mg/year. 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). 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 4-1. 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

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). 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 4-2 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 global source contribution, and therefore the highest 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. Compliance with recently promulgated mercury rules is expected to reduce future U.S. deposition caused by U.S. sources, particularly in areas of highest deposition. The results are based on the Community Multiscale Air Quality (CMAQ) model, which U.S. EPA considers the best available for evaluating mercury deposition.

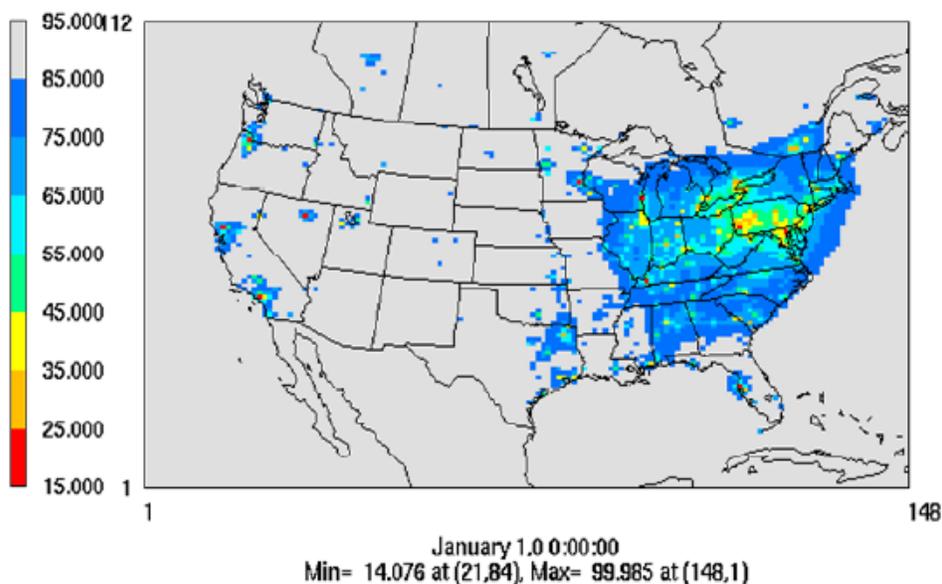


Figure 4-2. Percent of Total Mercury Deposition Attributable to Global Sources: 2001. Source: U.S. EPA, 2005g

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 ionic 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) estimated that North American anthropogenic sources contributed 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. 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.

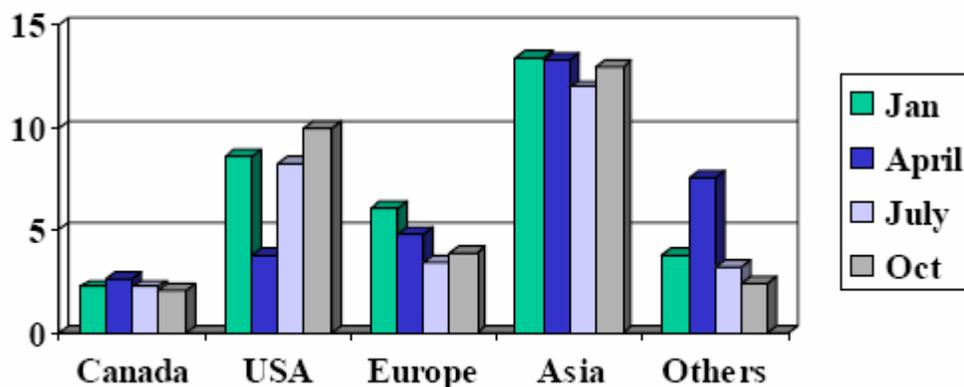
Gustin and Lindberg (2004) estimate mercury inputs in line with those in Table 4-1 (e.g., global emissions of 6000 to 6600 Mg/y and anthropogenic estimates of 2000 to 2400 Mg/y). However, the authors suggest that re-emission of previously deposited mercury is an *unquantified* source adding to the global mercury pool. The rapid re-emission of deposited mercury, they propose, may increase the residence time of mercury in the atmosphere. As a result, it might require years before emissions controls lead to significant reductions in the global pool of mercury (Gustin and Lindberg, 2004).

The results of a Swain and Engstrom (1997) study that investigated trends in mercury deposition at various U.S. locations 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 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.

To address uncertainty regarding the role of sources of mercury as well as its fate and transport, U.S. EPA and EC rely on the use of computer models to describe the environmental fate of mercury. An example of this is the development of a global mercury model by Dr. Ashu Dastoor at Meteorological Service of Canada (MSC) who uses atmospheric mercury data from IADN sites. Global scale modeling is an appropriate tool to address questions such as budgets, long-range transport, trans-boundary exchanges and polar pollution related to mercury in the atmosphere. Environment Canada's MSC has developed a high resolution Global and Regional Atmospheric Heavy Metals model (*GRAHM*) to investigate atmospheric mercury on a global scale. A new version of *GRAHM* was developed which includes a limited area model (*LAM- GRAHM*) for mercury. Canadian efforts continue on further development, testing and application of the global model for atmospheric transport of mercury.

Dastoor highlighted the impacts of global sources on the Great Lakes in a talk at the Mercury Workgroup meeting at the GLBTS Stakeholder Forum on June 17, 2004. Figure 4-3 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.

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.

Figure 4-3. Percentage Contributions to Surface Air Elemental Mercury Concentrations Over the Great Lakes.
Source: Dastoor, 2004

Figure 4-4 shows annual average contributions from global sources to the deposition, 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).

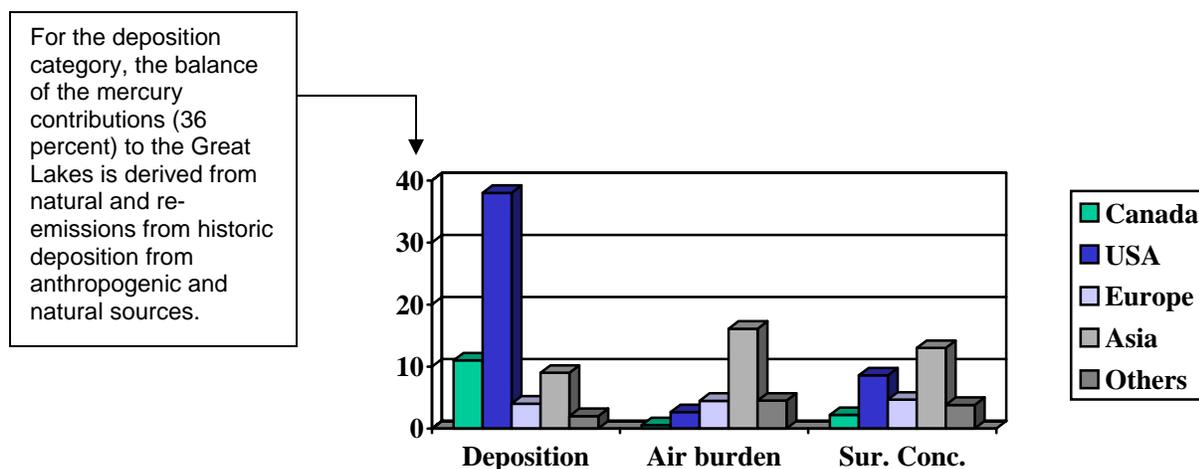


Figure 4-4. Annual Average Mercury Contributions to the Great Lakes (1995).
Source: Dastoor, 2005

Great Lakes Basin Impacts

There are continuing sources of mercury release within the Great Lakes basin. Sources close to the Great Lakes likely have a bigger impact on mercury deposition to the Great Lakes than more distant sources that emit equivalent amounts of mercury. In particular, sources that emit ionic mercury close to the Great Lakes are likely to have the greatest impact. Incinerators were believed to be the biggest sources of ionic mercury in the early 1990s; these sources have been well controlled.

Additionally, modeling efforts are underway to determine the relative importance of different sources of contamination in the Great Lakes Basin.

- ◆ Through modeling, Dr. Mark Cohen of the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory has been attempting to determine the relative contributions of different sources and source regions to the overall atmospheric deposition to any given receptor (e.g., the Great Lakes). In 2003, Dr. Cohen gave a presentation regarding the atmospheric deposition of mercury to the Great Lakes at an International Joint Commission (IJC)-organized symposium. Cohen et al. (2004) reported that sources up to 2000-km from the Great Lakes contributed significant amounts of mercury through atmospheric transport and deposition and, while there were significant contributions from incineration and metallurgical sources, coal combustion was generally found to be the largest contributor to atmospheric mercury deposition to the Great Lakes. Seigneur et al. (2004) suggested that, at selected receptors, the contribution of North American anthropogenic emissions ranged from 9 to 81 percent.
- ◆ Mercury cycling monitoring in the Devil's Lake, Wisconsin, Total Maximum Daily Load (TMDL) pilot project has been conducted to allow verification of an EPA model. The monitoring project is one of two atmospheric deposition pilot projects in the U.S. Data from the project is not yet available. 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.
- ◆ 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 the U.S. and Canada varies greatly, and is higher in the upper lakes than in the lower lakes. Figure 4-5 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, CMAQ is the best available model for evaluating the impacts of the CAMR on mercury deposition (US EPA, 2005c). The modeling shown in Figure 4-5 is based on the 1999 U.S. emissions inventory, updated with 2002 data for medical waste incinerators.

Layer 1 $100*(TDEP_HGj-TDEP_HGk)/TDEP_HGj$

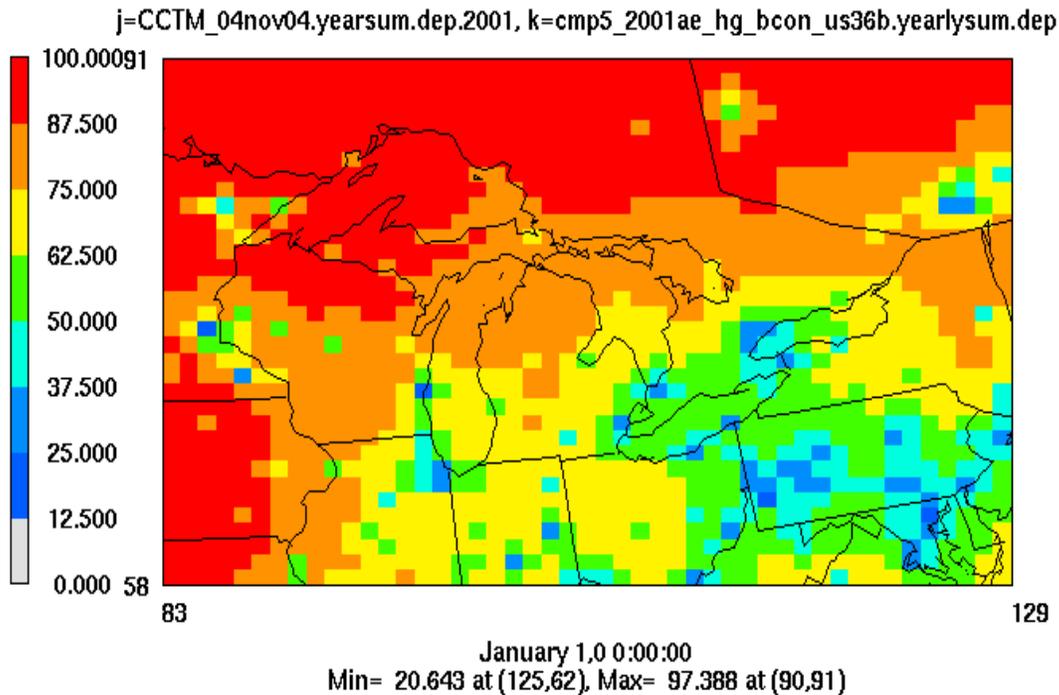


Figure 4-5. Percent of CMAQ Mercury Deposition from Non-U.S./Canada Sources
Source: CMAQ Version 4.3 with Mercury, May 2005

Given the importance of global sources and the fact that, in some watersheds within the Great Lakes Basin, deep reductions in mercury deposition are needed in order to meet criteria for fish consumption, it is likely that even deep reductions in U.S. and Canadian sources will not be sufficient. Mercury emissions from global sources will need to be reduced as well.

- ◆ A research project entitled Mercury Experiment To Assess Atmospheric Loading In Canada and the U.S. (METAALICUS) is studying what happens to mercury concentrations in fish when the rate of atmospheric deposition to the ecosystem is changed. Initial results indicate that the concentration of methylmercury in fish responds quickly (within a month) to additions of directly deposited mercury and that newly-deposited mercury is more bioavailable than older reservoirs of mercury bound in sediment (Goodrich-Mahoney, 2003).

4.1.2 Ontario Inventory

A number of industrial processes contribute to mercury releases in Canada. In Ontario, the largest sources of mercury are:

- Electric power generation
- Iron and steel production
- Municipal (primarily land application of biosolids)
- Cement and lime manufacturing
- Incineration.

Table 4-2 illustrates the sources of mercury releases in Ontario in 2002. Source information presented in the Canada-Ontario Agreement (COA) Inventory continues to be reviewed and quantified.

Table 4-2. 2002 Sources of Ontario Mercury Releases.
Source: Canada-Ontario Agreement (COA) Inventory, 2002

Source Sectors	Mercury Releases (kg/yr)			
	Air	Water	Soil	Total
Thermal Power Generation (fossil fuel)	527	0.72		528
Iron & Steel	347.14	2.5		350
Cement Manufacture	208.41			208
Sludge Land Application	10		172	182
Sewage Treatment Plants	0	100		100
Hazardous Waste (incineration)	94			94
Ferrous Foundries (iron/steel/alloys)	84			84
Lime Manufacture	79			79
Sewage Sludge (incineration)	95			95
Consumer Products Use	73			73
Residential Combustion (coal/oil)	72			72
Glass Industry	58			58
Landfills	50			50
Mining & Smelting	46.66	0.3		47
Cremation	42			42
Electrical Products Industry	31.36			31
Pulp & Paper	24.85	5.32		30
Nonferrous (smelting/refining)	23.2			23
Asphalt	17			17
Municipal Solid Waste (incineration)	40			40
Carbon Black Manufacture	13.94			14
Petroleum Refining	13.77	0.05		14
Industrial Combustion (coal/oil)	11			11
Vehicle/Parts Manufacture	6.68			7
Residential Combustion (wood)	6			6
Federal/Industrial Waste (incineration)	4			4
Industrial Combustion (wood)	4			4
Miscellaneous (Industry)	2.27	0.05		2
Rail/Marine	2			2
Biomedical/Hospital Incinerators	1.01			1
Waste Wood (Incineration)	1			1
Chemical Production	0.95			1
Total	1981	109	172	2261

4.1.3 United States Inventory

In the U.S., the baseline year for assessing reductions in mercury releases is 1990, the year of the most recent mercury emissions inventory available at the time the Binational Toxics Strategy was signed (the draft Mercury Report to Congress 1990 emissions inventory). The U.S. EPA subsequently updated its 1990 estimates in a National Toxics Inventory. EPA also developed a National Emissions Inventory (NEI) for mercury for 1999. The 1999 inventory has been revised several times. The most recent data are summarized below. Based upon the 1990 inventory,

about 210 tons per year (tpy) of mercury were emitted to the air in the U.S. by human-generated sources in the 1990 time frame. Based on the 1999 NEI, about 116 tons were emitted from anthropogenic sources in the U.S. Table 4-3 presents U.S. air emissions of mercury, by source category, from the 1990 and 1999 inventories.

Table 4-3. U.S. Air Emissions of Mercury (tons), by Source Category.

Source Category	Emissions (tons)	
	1990	1999
Utility Boilers	52.09	48.41
Coal-fired boilers	(51.05)	(47.91)
Oil-fired boilers	(1.04)	(0.5)
Industrial Boilers	11.83	11.91
Gold Mining	0.16	11.52
Hazardous Waste Incineration*	6.57	6.58
Mercury Cell Chlor-alkali Plants	9.96	6.53
Municipal Waste Combustion	56.73	5.10
Medical Waste Incineration	49.73	2.84
Portland Cement Manufacturing	2.35	2.35
Refuse Systems	0.08	2.11
Pulp and Paper Production	1.9	1.62
Stationary Reciprocating Internal Combustion Engines	0.15	1.33
Industrial Inorganic Chemicals, NEC	0.25	1.2
Residential Heating: Distillate Oil	1.27	1.15
Petroleum Refineries, Catalytic Cracking and Reforming and Sulfur Plant Units	1.41	1.17
Lamp Breakage	1.5	1.01
Lime Manufacturing**	0.1	1
Sewerage Systems	1.8	0.9
Primary Lead Smelting	1.3	0.0001
Hydrochloric Acid Production	2.98	0.0005
Other	7.38	8.84
Total	209.57	115.59

NEC – Not elsewhere Classified

Sources: U.S. EPA National Emissions Inventory 1999 and 1990 National Toxics Inventory

*Emissions from burning hazardous waste at cement plants are included here.

**Emissions from feed material, primarily mercury in limestone

Total estimated emissions decreased 45 percent between 1990 and 1999. In some cases, these data may present a somewhat misleading estimate of the trend in mercury emissions; for some source categories, changes in emissions may reflect changes in estimating techniques or improved knowledge about a source category, rather than actual changes in emissions. In addition, there may be greater confidence in the 1999 estimates than the 1990 estimates because there was less measured data on which to base the 1990 estimates. In the gold mining category, the apparent increase in emissions between 1990 and 1999 is clearly the result of improved estimating, not a real increase in emissions. If we assume that mercury emissions from mining have held steady in relation to gold mine production, 1990 mercury emissions from this source would be an estimated 9.9 tons, in comparison with the 11.5 tons estimated for 1999. If this amount is added to the 1990 total, making a new baseline of 219.31 tons, mercury emissions declined 47 percent between 1990 and 1999 (Table 4-4).

Table 4-4. U.S. Air Emissions of Mercury, Revised with 1990 Gold Mining Estimate (tons).

Source Category	Emissions (tons)	
	1990	1999
All Sources other than Gold Mines	209.41	104.07
Gold Mining	9.90	11.52
Total	219.31	115.59

However, this estimate also does not include some recent information about mercury emissions from iron and steel foundries and electric arc furnaces. These facilities melt scrap, including vehicles, appliances, and other machinery contaminated with mercury-containing devices. U.S. EPA's Office of Air Quality Planning and Standards (OAQPS) has completed an emissions standard for iron and steel foundries, and is developing a standard for electric arc furnaces. As part of these efforts, OAQPS has developed emissions estimates for these sectors which were not included in the 1990 or 1999 inventories. Including these estimates, adjusted to reflect likely changes in the mercury content of scrap between 1990 and 1999, yields an estimate of a 44 percent reduction in total mercury emissions between 1990 and 1999 (Table 4-5).

Table 4-5. U.S. Air Emissions of Mercury, Revised with 1990 Gold Mining Estimate and Estimates for Electric Arc Furnaces and Iron and Steel Foundries (tons).

Source Category	Emissions (tons)	
	1990	1999
All Sources other than Gold Mines and Steel Production	209.41	104.07
Gold Mining	9.90	11.52
Electric Arc Furnaces ¹	10.70	10.70
Iron and Steel Foundries ²	1.40	1.75
Total	231.41	128.04

¹ Data from 1999 is based on preliminary estimate of current emissions by U.S. EPA's OAQPS. The 1990 data is based on assumptions that mercury content of scrapped appliances and industrial equipment is declining, but that this decline is offset by an increase in the mercury content of end-of-life vehicles. Evidence suggests that mercury content of new vehicles declined between 1990 and 1999; there is also some evidence to suggest that mercury content of scrapped vehicles may have increased between 1990 and 1999.²¹ The Alliance of Auto Manufacturers believes that mercury content of scrapped vehicles has not increased, but this evaluation assumes a doubling in mercury content of scrapped vehicles in order to be conservative and to avoid over-estimating mercury emissions reductions. In any case, mercury content of end-of-life vehicles has likely started to decrease since 1999.

² The 1999 estimate is based on data collected during development of the final air emissions standard for iron and steel foundries (implied by estimate that rulemaking will achieve 80 percent reduction from current emissions or 1.4 tons of reduction). See 69 FR 21910. 1990 data is based on assumption that 50 percent of emissions from these facilities are caused by mercury in vehicles, and that 50 percent of emissions are from appliances and industrial equipment, and that the amount of mercury in such equipment that gets disposed of improperly, ending up in these facilities, has declined roughly 50 percent since 1990.

²¹ http://www.cleancarcampaign.org/Mercury_April_2004.pdf

4.2 OPPORTUNITIES TO ACHIEVE FURTHER REDUCTIONS

This section considers current programs and regulations in place to address sources of mercury and assesses potential opportunities for the GLBTS to effect further reductions. An important part of the assessment involves consideration of whether the identified reduction actions offer an opportunity for the GLBTS to add value beyond existing activities.

4.2.1 Opportunities with Known or Inventory Sources

In the U.S., total annual mercury releases from 1999 inventory sources are currently estimated at 116 tons (from Table 4-3). The U.S. and Canada have pursued the control and management of mercury releases through major program areas (e.g., air, water); collectively, these actions place regulatory controls on all of the major well-defined industrial and municipal sources of mercury in the U.S. and Ontario.

Mercury releases to the air are controlled under regulations promulgated by U.S. EPA under authority of the Clean Air Act (CAA) and its amendments, which require emissions limits for mercury and other hazardous air pollutants based on “maximum achievable control technology” (MACT). With full implementation of the MACT rules, the major/significant categories of commercial, municipal, and medical waste combustion are under direct regulation for their mercury emissions. Mercury releases to water are managed through a combination of risk-based and technology-based tools established under the Clean Water Act. Clean-up of mercury-contaminated soil and sediment is an important part of the U.S. EPA Superfund and RCRA Corrective Action programs.

A number of initiatives are expected to reduce mercury releases even further by the end of 2005. These include Canada-Wide Standards (CWS) for sewage sludge incineration, dental amalgam, and fluorescent lamps. Table 4-6 identifies current programs or regulations and reduction opportunities for known sources of mercury.

Table 4-6. Reduction Opportunities for Known Sources of Mercury.

Known Source Category or Source	Current U.S. or Canadian Regulations or Programs	Opportunity for GLBTS to Achieve Further Reductions
Utility coal boilers	On May 18, 2005, U.S. EPA published the world's first regulations limiting mercury emissions from coal fired power plants. Under the Clean Air Mercury Rule (CAMR), states are required to implement regulations that will reduce power plant mercury emissions 21 percent nationally by 2010, and 69 percent eventually. States can choose to participate in a national mercury emissions allowance trading program, or to achieve required reductions through emissions standards. Under the allowance trading program, power plants will be able to "bank" unused emissions allowances for later use, creating an incentive for reductions beyond the required 21 percent between 2010	Opportunities: Facilitate discussion about state implementation of regulations and about the impact of federal regulations and possible trading.

Known Source Category or Source	Current U.S. or Canadian Regulations or Programs	Opportunity for GLBTS to Achieve Further Reductions
	<p>and 2017. Use of these banked allowances after 2018, when the emissions "cap" is lowered to 15 tons (69 percent below the current level), will allow emissions to exceed the cap for some years beyond 2018. Trading of emissions allowances could cause emissions reduction amounts in some states to differ from the national average.</p> <p>Some state agencies also are implementing their own rules (e.g., Wisconsin Department of Natural Resources finalized a regulation limiting mercury emissions from the state's power plants).</p> <p>In June 2005, the Canadian Council of Ministers of the Environment (CCME) accepted in principle a draft CWS that would significantly reduce mercury emissions from the coal-fired electric power generation (EPG) sector. Final endorsement of the CWS by ministers is expected in early 2006.</p> <p>This CWS consists of two sets of targets:</p> <ul style="list-style-type: none"> • Provincial caps on mercury emissions from existing coal-fired electric power generation plants, with the 2010 provincial caps representing a 65 percent national capture of mercury from coal burned, or 70 percent including recognition for early action. • Capture rates or emission limits for new plants, based on best available control technology, effective immediately. Capture rates and emission rates are based on coal type. A 75 percent capture rate has been established for sub-bituminous coal and lignite, and an 85 percent capture rate has been established for bituminous coal and blends. <p>In Ontario, the 2010 CWS cap (kg/yr) is 0, and in June 2005 the Ontario provincial government also released a plan to phase out all coal-fired plants in Ontario. The first of five plants was closed in April 2005. Three of the remaining four plants will close in 2007, with the remaining station, Nanticoke GS to close in early 2009. Once all plants have been closed, a 100 percent reduction of emissions from this sector will be achieved in Ontario.</p>	
Industrial boilers	<p>A MACT standard has been developed for U.S. industrial and commercial boilers. This standard was finalized during 2004, with compliance required within three years. Compliance with the standard as proposed would reduce emissions from this category to 10 tons from 12 tons currently. This reduction, however, will likely not be required until after 2006.</p>	<p>Possible opportunities to promote energy efficiency programs that can be applied to industrial boilers.</p>

Known Source Category or Source	Current U.S. or Canadian Regulations or Programs	Opportunity for GLBTS to Achieve Further Reductions
Gold mining	A voluntary project between Nevada Department of Environmental Protection, U.S. EPA and four Nevada gold mining companies has set a goal of achieving 50 percent reduction by 2005 in emissions from operations at the four mining companies. It is expected that a 50 percent reduction from the gold mining sector has already been exceeded.	Despite not being a regional source, there is the possibility for GLBTS to share general lessons learned on mining with a global audience.
Primary non-ferrous metals smelting	<p>In Canada, emissions from the primary non-ferrous base metal smelting sector had decreased from 23.7 metric tons in 1990 to 4.4 metric tons in 1995.² By 2000, emissions had dropped to approximately two metric tons.³ Canada established environmental source performance guidelines for base metal smelters. For existing facilities, the guideline is 2 g Hg/metric ton of finished metal, while for new and expanded facilities, the performance guideline is 0.2 g Hg/metric ton of finished zinc, nickel and lead, and 1 g Hg/tonne of finished copper.</p> <p>The U.S. does not currently have air emissions regulations for non-ferrous metals smelters. Area source standards are under development. A zinc smelter in Illinois reported more than 500 pounds of mercury emissions in 2003.</p>	The workgroup could push for better information about mercury emissions from primary non-ferrous metals smelting globally and within the Great Lakes Basin.
Hazardous Waste	<p>A MACT for hazardous waste combustors was finalized in 1999. As a result of court challenges, U.S.EPA will promulgate a revised standard by 2005. In the meantime, interim standards went into effect in September 2003. These interim standards are expected to reduce mercury emissions by less than 50 percent.</p> <p>The CWS compliance date for mercury emissions from hazardous waste incinerators was December 31, 2003. In Ontario the limit (50 µg/Rm³) was incorporated into the Certificates of Approval (legal instruments) for all 6 facilities. Emissions from hazardous waste incinerators have been reduced by approximately 200 kg since 1988.</p>	
Chlor-alkali	<p>As a result of plant closures, chlorine production capacity at U.S. mercury cell plants declined 22 percent between the end of 1999 and the end of 2002, and by 27 percent between 1998 and 2002.</p> <p>A MACT standard for this sector was finalized, and is expected to achieve a 74 percent reduction (1500 pounds) from point source emissions within chlor-alkali plants, and unquantified reductions from mercury cell rooms and other sources. Compliance will not be required until the end of 2006, but factories may move toward early compliance. U.S. EPA expects the MACT standards will cut total mercury emissions from these facilities by about</p>	<p>Possible opportunity to continue to publicize voluntary achievements in mercury reduction.</p> <p>Continue reporting: The Chlorine Institute's <i>Seventh Annual Report to EPA</i> reports the chlor-alkali industry has reduced mercury consumption and purchases significantly since 1995 with small increases in mercury consumption by this industry between 2001 and 2003.</p>

Known Source Category or Source	Current U.S. or Canadian Regulations or Programs	Opportunity for GLBTS to Achieve Further Reductions
	<p>11 percent from 1999 emissions levels.</p> <p>Canada does not have any chlor-alkali plants operating in the Great Lakes Basin.</p>	
Municipal Waste	<p>Compliance with MACT standards for large municipal waste combustors was not required nationwide until November 2000, although compliance was required earlier in some States. Nationwide compliance with MACT standards at small municipal waste combustors was required in 2005. As a result of full implementation of these standards, mercury emissions from municipal waste combustors are expected to decline to 4 tons annually. In 2005, these two regulations are projected to reduce U.S. MWC emissions by 91 percent from 1990 emission levels.</p> <p>The CWS compliance date for mercury emissions from existing municipal waste incinerators is December 31, 2006. In Ontario there is one operating facility that is currently required (Certificate of Approval) to meet the limit (20µg/Rm³). In Ontario, mercury emissions from this sector have been reduced by over 1500 kg since 1988.</p>	<p>Continue to publicize voluntary achievements in mercury reduction, and to support efforts to reduce mercury use in products and improve management of mercury-containing wastes.</p> <p>Additional reductions are being achieved through household hazardous waste collections and decreased use of mercury in products.</p>
Medical Waste	<p>For medical waste incinerators, compliance with US EPA MACT standards was not required nationwide until September 2002. Full implementation reduced estimated emissions from this category to 1 ton annually.</p> <p>All existing hospital incinerators were closed by regulation (Ontario Regulation 323/02) by December 15, 2003. In Ontario there is one commercial operating facility that is currently required (Certificate of Approval) to meet the limit (20µg/Rm³). In Ontario, emissions from medical waste incineration have decreased by approximately 250 kg since 1988.</p>	<p>Hospitals for a Healthy Environment (H2E)⁴ is a voluntary program whereby health care facilities pledge to eliminate mercury and reduce waste, consistent with the overall goals of H2E. The program continues to grow and has enlisted 539 new partners in the last year.</p> <p>Compliance information indicates that mercury emissions from U.S. medical waste incinerators are 95 percent less than in 1990.</p>
Iron Foundries and Electric Arc Furnaces	<p>The MACT standard for iron foundries will go into effect in 2005. Industry compliance with work practice standards prohibiting the use of auto scrap unless mercury lighting switches have been removed is required beginning in 2005.</p> <p>U.S. EPA is beginning to develop a proposal for regulating mercury emissions from electric arc furnace steel plants; the work practice standard for the electric arc furnace regulation may go into effect during 2006.</p> <p>The auto industry has steadily reduced the mercury content in its vehicles; phasing out mercury switch use over the 1990s (completing the phase out in 2003 model year), and is presently working with suppliers on alternatives to mercury in the remaining components which</p>	<p>Opportunity to publicize voluntary achievements in mercury reduction. Also can help spread compliance assistance information.</p> <p>Opportunity to help steel plants with work practice standards.</p>

Known Source Category or Source	Current U.S. or Canadian Regulations or Programs	Opportunity for GLBTS to Achieve Further Reductions
	contain only trace amounts (high intensity discharge headlamps and flat panel displays). ⁵	
Mercury-Containing Lamps	<p>The Association of Mercury and Lamp Recyclers reports that lamp recycling has increased. The Association of Lighting and Mercury Recyclers (ALMR)'s annual report estimates that the national recycling rate for all lamps in 2003 was 23 percent, up from 22 percent in 2001.</p> <p>The goal of the CWS for fluorescent lamps is a 70% reduction in the mercury content of lamps by 2005 and an 80% reduction by 2010. Electro Federation Canada reported a 73.5% reduction in the mercury content of lamps between 1990 and 2003. The 1990 baseline was 43 mg/lamp, and the 2003 average mercury content is 11.4 mg/lamp.</p>	Continue to publicize achievements in mercury recycling.
Dental Amalgam Waste	<p>American Dental Association Promotes Best Management Practices (Available at: http://ada.org/goto/amalgambmp). With the ongoing public water fluoridation and a continuing emphasis on improved oral health, tooth decay is expected to decrease, resulting in fewer dental restorations. A proposed standard procedure for dental amalgam waste recycling in dental offices is being developed by the ADA Standard Committee on Dental Products.</p> <p>State mercury minimization programs have been implemented (e.g., installation of amalgam separators in dental practices). The overall mercury reduction effort has resulted in effluent values approaching GLWQA standards. States may also have regulatory requirements to follow.</p> <p>The CWS compliance date for waste dental amalgam was December 31, 2005. Dental clinics⁵ where amalgam is placed, repaired or removed were required to install amalgam separators by regulation (Ontario Regulation 196/03) by November 15, 2003. Implementation of the regulation is expected to reduce releases of mercury from dental clinics by 95%.</p> <p>Best Management Practices Document was released in 2005 to the dental community in Ontario. The document was developed with input from dental organizations, dental schools, MOE and EC.</p>	Possible opportunities to continue to publicize achievements in mercury reduction efforts.
Mercury-containing thermostats	1) Thermostat recycling by Thermostat Recycling Corporation (TRC). In 2004, TRC increased the rate of thermostat collections from heating, ventilation, and air-conditioning (HVAC) wholesalers by 36 percent and mercury recovery by 23 percent over collection rates in 2003. The TRC has collected nearly 300,000 thermostats and processed over 2,600 pounds of mercury from HVAC contractors since it began operations in 1998. Over this same	<p>Opportunity to continue to publicize achievements in mercury recovery and collection efforts.</p> <p>Support efforts to identify mechanisms to increase the collection rate.</p>

Known Source Category or Source	Current U.S. or Canadian Regulations or Programs	Opportunity for GLBTS to Achieve Further Reductions
	<p>period, the TRC has collected more than 175,000 thermostats containing over 1,400 pounds of mercury in the Great Lakes States.</p> <p>2) Product Stewardship Institute Mercury Thermostat Project</p>	
Auto Switches	<p>Efforts to reduce mercury in auto scrap - use of mercury-containing switches in automobiles produced for the North American market ceased with the 2003 model year.</p> <p><i>Switch Out</i>, a voluntary program that encourages auto recyclers to remove mercury-containing switches from end of life vehicles, has been operating in Ontario since 2001. Almost 31,000 switches (~24 kg mercury) have been collected in Ontario.</p> <p>Environment Canada has set-up a working group, including representatives of the auto and steel industries, to create a national strategy to promote the removal and recycling of mercury-containing switches from end of life vehicles.</p>	<p>Opportunity to continue to publicize achievements in mercury reduction efforts.</p> <p>Provide outreach connection and compliance assistance with steel makers. Opportunity to help comply with work practice standards.</p> <p>U.S. EPA has begun a dialogue with various stakeholders, including representatives of the auto and steel industries, in an effort to create a voluntary national program to promote the removal and recycling of auto mercury switches.</p> <p>Several Great Lakes States are implementing programs to remove mercury switches already placed in autos (e.g., Michigan Department of Environmental Quality and the Alliance of Automobile Manufacturers will fund outreach to auto dismantlers as well as the cost of transporting mercury-containing switches to state recycling locations).</p>
Uncontaminated elemental mercury sources (e.g., thermometers, manometers, barometers, and sphygmomanometers)	Statewide Household Hazardous Waste (HHW) Collections	<p>Opportunity to continue to publicize achievements in mercury reduction efforts.</p> <p>Sources of elemental mercury have been removed from locations throughout Ohio, Indiana, southern Michigan, and western Pennsylvania.</p>
Industrial users of mercury-containing devices	<p>Mercury Agreement Reduction Program⁷</p> <p>US EPA OSW's National Partnership for Environmental Priorities (NPEP) Program</p>	<p>Opportunity to continue to publicize achievements in mercury reduction efforts.</p> <p>Since 1998, three Northwest Indiana steel mills have worked through the Lake Michigan Forum and cooperated with the Indiana Department of Environmental Management (IDEM) to inventory mercury uses/sources within these mills and develop a clean sweep/pollution prevention initiative to inventory, recycle, and substitute, to the greatest extent practical, mercury at their facilities. To date,</p>

Known Source Category or Source	Current U.S. or Canadian Regulations or Programs	Opportunity for GLBTS to Achieve Further Reductions
		3,751 pounds of mercury, or 80 percent of mercury inventoried at the three mills, has been removed.
Municipalities	EC has developed a <i>Municipal Actions to Reduce Mercury</i> document. The document provides information on developing a municipal mercury elimination policy and plan, and on developing municipal mercury programs including re-naming, mercury switch and sensor removal, and mercury collection programs.	
Button Cell Batteries	A Chinese company, New Leader, is making mercury-free button cells. ⁸	Opportunity to continue to provide outreach and publicize achievements in mercury reduction efforts

References:

- ¹ U.S. EPA (2005). Clean Air Mercury Rule. <http://www.epa.gov/air/mercuryrule/>
- ² Environment Canada, "Submission by Canada to UNEP Global Mercury Assessment" (September 2001).
- ³ Based on Canadian air emissions inventory at [http://www.ec.gc.ca/MERCURY/ SM/EN/sm-cr.cfm?SELECT=SM](http://www.ec.gc.ca/MERCURY/SM/EN/sm-cr.cfm?SELECT=SM) as of August 1, 2005. This inventory shows a total of 8025 kg, of which 25 percent is from base metal smelting.
- ⁴ H2E Web site: <http://www.h2e-online.org/>
- ⁵ Review comment, Cass Andary, Alliance of Automobile Manufacturers, May, 2005.
- ⁶ Members of the Royal College of Dental Surgeons of Ontario are required to comply with the "Standard of Practice: Amalgam Waste Disposal."
- ⁷ Mercury Agreement Reduction Program Web site: <http://www.epa.gov/region5/air/mercury/nwindianareport3-17-04.pdf>.
- ⁸ Mercury Use in Button Batteries (March 2005) Web site: http://mainegov-images.informe.org/dep/rwm/mercury/pdf/button_batteries/batteryreport.pdf

Because of the potential for mercury releases to be transported to the Great Lakes, the Mercury Workgroup has focused on nationwide mercury releases in the U.S. The workgroup continues to focus on sharing information about cost-effective reduction opportunities, tracking progress toward meeting reduction goals, and publicizing voluntary achievements in mercury reduction. Particular attention is paid to information-sharing in areas where mercury releases are significant but there are no existing federal regulations or regulations are under development. For instance, the Mercury Workgroup will attempt to focus on the contamination of metal scrap by mercury-containing devices, and the resulting emissions, and provide a forum for discussing cost-effective approaches to address this problem. In addition, the workgroup will focus on the issue of mercury releases from dental offices and will help state, provincial, and local governments identify cost-effective reduction approaches for this sector.

4.3 OTHER SUBSTANCE-RELATED OPPORTUNITIES FOR THE GLBTS

There may be additional opportunities for the GLBTS to reduce exposure to mercury and to facilitate tracking of mercury release and use in the environment.

A potential opportunity for the GLBTS Mercury Workgroup is to work with state and local health departments in dealing with broken products (e.g., thermometers) and minimizing indoor air exposures when handling or cleaning up mercury spills. When products break, mercury can evaporate, thus creating a risk of dangerous exposures to mercury vapor in indoor air.

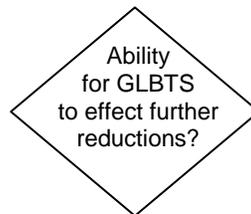
Another opportunity may exist for the GLBTS Mercury Workgroup to share general lessons learned with a global audience, especially helping developing countries identify sources of

mercury and strategies for control. Sharing experiences and lessons learned at a global level could contribute to reducing global source deposition to the region.

Other opportunities for the GLBTS Mercury Workgroup could include:

- ◆ disseminating information developed by national and international programs to the Great Lakes region,
- ◆ influencing funding priorities for grant programs, and
- ◆ influencing national/international priorities for mercury reduction.

4.4 GLBTS OPPORTUNITY ASSESSMENT CONCLUSIONS



The Mercury Workgroup continues to seek reductions in mercury use and release in the Great Lakes Basin. While significant reductions have been achieved in both Canada and the U.S., **a number of opportunities for further GLBTS action are identified** in Sections 4.2 and 4.3.

Despite the opportunities and benefits identified, it is also important to consider the effectiveness of pursuing these activities under the GLBTS, such as engaging interested stakeholders, the level of input expected from workgroup members, resource availability and value-added under the GLBTS to conduct studies and programs, status or strategy of the U.S. and Canadian national mercury programs, and status of international mercury programs.

5.0 MANAGEMENT OUTCOME

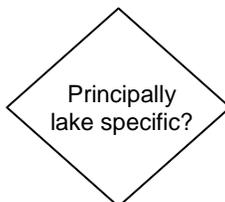
This section considers the environmental analysis in Section 3.0 and the GLBTS opportunity assessment presented in Section 4.0 to arrive at a final management outcome in Section 5.4.

5.1 REFERRAL OR PARTICIPATION IN ANOTHER FORUM

An increasing number of national, regional, binational, and sector or product-specific efforts pursue goals similar to those of the GLBTS. For instance, Lakewide Management Plans include mercury reduction efforts, and a variety of organizations, such as the Northeast Waste Management Officials Association, sponsor information-exchange forums on mercury. Moreover, a variety of sector-specific and product-specific mercury information-exchange opportunities have developed, beyond the Binational Toxics Strategy. In addition, there is a mechanism for sharing information about mercury among the governments of Canada, U.S. and Mexico. As part of the Sound Management of Chemicals Program, the North American Commission for Environmental Cooperation (CEC) developed a North American Regional Action Plan (NARAP) on Mercury (Phase II- March 2000). The tri-lateral **NARAP** on Mercury is one of a number of such regional undertakings that stem from the North American Agreement on Environmental Cooperation between the governments of Canada, the United Mexican States and the United States of America. Implementation of the NARAP on Mercury is based upon building existing initiatives such as the GLBTS, which has fostered relationships with the CEC and may continue to advocate GLBTS interests in this forum.

Moreover, there are increasing opportunities to share information about mercury on a global scale. After considering the key findings of the Global Mercury Assessment report, the United Nations Environment Programme (UNEP) Governing Council concluded that further international action to reduce the risks to humans and wildlife from the release of mercury to the environment was warranted. Subsequently, a **UNEP mercury programme** was established to facilitate national, regional and global actions to reduce or eliminate uses and releases of mercury, thereby significantly reducing the adverse impacts on humans and the environment. An immediate objective is to encourage all countries to adopt goals and take actions, as appropriate, to identify at-risk populations, minimize exposures through outreach efforts, and reduce human-generated mercury releases. The GLBTS could provide support and advocate GLBTS interests and opportunities in this forum.

5.2 NUMBER OF LAKES IMPACTED



The problem of mercury use and mercury release in the environment is **not specific** to any one of the Great Lakes.

5.3 NEW CHALLENGE GOALS



The data presented in Section 2.0 suggest that the U.S. has met the goal of reducing mercury use by 50 percent. The U.S. is expected to meet the goal of reducing mercury emissions by 50 percent by 2006. Canada is close to meeting its challenge goal of a 90 percent reduction in the release of mercury. However, it is likely that significant reduction efforts will need to continue, even after the U.S. and Canadian challenge goals have been met.

5.4 FINAL RESULT

The recommended final management outcome for mercury is continued active Level 1 status with periodic reassessment by the GLBTS because the Mercury Workgroup still has the ability to influence mercury issues. The Mercury Workgroup will continue its efforts to share information about cost-effective reduction opportunities, track progress toward meeting reduction goals, and publicize voluntary achievements in mercury reduction, where possible. While stringent regulatory standards and guidelines are in place, a variety of additional pollution prevention measures need to be taken to further reduce mercury use and release. The workgroup will focus on disseminating information about auto scrap, appliances, and industrial equipment. The workgroup will help state, provincial, and local governments identify cost-effective reduction approaches from dental offices. Finally, the workgroup will participate in national and international mercury reduction programs.

Other potential Mercury Workgroup actions could include:

- Facilitate discussion about state implementation of regulations on power plant emissions and about the impact of federal regulations and emissions allowance trading;
- If a sector or industry presented itself, the workgroup could seek additional voluntary commitments, for instance mercury reduction partnerships to increase the presence of mercury-free building materials and consumer products;
- Taking on more explicit efforts to influence national/international actions (i.e., development of GLBTS “issue papers” on policy issues) to share knowledge gained in the Great Lakes region with a global audience; and
- Coordination with the CEC Sound Management of Chemicals Program to manage mercury in North America and share general lessons learned with a global audience.

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**APPENDIX A: GENERAL FRAMEWORK TO ASSESS
MANAGEMENT OF GLBTS LEVEL 1 SUBSTANCES:
BACKGROUND, OBJECTIVES, AND DOCUMENTATION**

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General Framework to Assess Management of GLBTS Level 1 Substances: Background, Objectives, and Documentation

BACKGROUND

Over the past thirty years, the governments of Canada and the United States have joined together with industries, citizen groups, and other stakeholders in a concerted effort to identify and eliminate threats to the health of the Great Lakes ecosystem resulting from the use and release of persistent toxic substances. A major step in this process was the enactment of the *Revised Great Lakes Water Quality Agreement (GLWQA) of 1978* which embraced, for the first time, a philosophy of “virtual elimination” of persistent toxic substances from the Great Lakes. In 1987, the GLWQA was amended, establishing Lakewide Management Plans (LaMPs) as a mechanism for identifying and eliminating any and all “critical pollutants” that pose risks to humans and aquatic life. In 1994, the International Joint Commission’s *Seventh Biennial Report* under the GLWQA called for a coordinated binational strategy to “stop the input of persistent toxic substances into the Great Lakes environment.” This led to the signing of the *Great Lakes Binational Toxics Strategy* (GLBTS, or Strategy) in 1997. The Strategy specifies Level 1 substances, each targeted for virtual elimination and each with its own specific challenge goals, along with Level 2 substances targeted for pollution prevention. The substances were selected on the basis of their previous nomination to lists relevant to the pollution of the Great Lakes Basin, and the final list was the result of agreement on the nomination from the two countries. The specific reduction challenges for each substance include individual challenge goals for each country, within a time frame that expires in 2006.

Significant progress has been made toward achieving the Strategy’s challenge goals. As 2006 approaches, an analysis of progress and determination of next steps is needed to respond to the mandate set forth in the Strategy. The purpose in developing the *General Framework to Assess Management of GLBTS Level 1 Substances* is to provide a tool to assist the Parties (Environment Canada and U.S. EPA) and stakeholders in conducting a transparent process to assess the Level 1 substances.

OBJECTIVE

The framework presents a logical flow diagram for evaluating progress and the need for further action by the GLBTS on the Level 1 substances in order to meet the following objective:

Evaluate the management of GLBTS Level 1 substances with the following potential outcomes:

- 1) Active Level 1 Status & Periodic Reassessment by GLBTS**
- 2) Consider Submission to BEC²² for New Challenge Goals**
- 3) Engage LaMP Process**

²² The Binational Executive Committee (BEC) is charged with coordinating implementation of the binational aspects of the 1987 Great Lakes Water Quality Agreement, including the GLBTS. The BEC is co-chaired by EC and U.S. EPA and includes representatives from the Great Lakes states and the Province of Ontario, as well as other federal agencies in Canada and the U.S.

4) Suspend GLBTS Workgroup Activities. Where warranted, refer to another program and/or participate in other fora. Periodic Reassessment by GLBTS, until Parties determine substance has been virtually eliminated.

Additional outcomes that may result from the framework are:

- **Recommend benchmark or criteria development as a high priority; and**
- **Recommend additional environmental monitoring as a high priority.**

The framework is intended to serve as a guide in determining the appropriate management outcome(s) for the Level 1 substances: mercury, polychlorinated biphenyls (PCBs), dioxins and furans, hexachlorobenzene (HCB), benzo(a)pyrene (B(a)P), octachlorostyrene (OCS), alkyl-lead, and five cancelled pesticides: chlordane, aldrin/dieldrin, DDT, mirex, and toxaphene. The framework is not intended to specify details of how a Level 1 substance should be addressed once a management outcome is determined.

STRUCTURE OF THE FRAMEWORK

The framework is set up in a hierarchical fashion to allow efficiencies in the decision process. The hierarchy of the framework is to first consider progress toward the challenge goals committed to in the Strategy, then to conduct an environmental analysis and finally, a GLBTS management assessment which leads to various potential management outcomes for a substance.

The environmental analysis (depicted in green) and the GLBTS management assessment (depicted in blue) comprise the two main parts of the framework. The environmental analysis considers available Canadian and U.S. monitoring data and established human health or ecological criteria as the primary basis for an objective evaluation of a substance's impact on the Basin. For substances lacking sufficient risk-based criteria or environmental monitoring data, the framework recommends the development of benchmarks or criteria and additional monitoring as a high priority. While the environmental analysis places emphasis on good monitoring data, evidence of use, release, exposure, or precautionary concerns may also be considered.

If the environmental analysis concludes that there is no basis for concern, GLBTS workgroup activities may be suspended, with periodic reassessment of the substance until the Parties determine that the substance has been virtually eliminated. If, on the other hand, the environmental analysis concludes that there is a reason for concern, the GLBTS management assessment evaluates the ability for the GLBTS to effect further improvements in and out of the Basin. The GLBTS management assessment also considers whether the impact of a substance is basinwide or restricted to a single lake. In cases where the GLBTS can effect further reductions, consideration will be given as to whether new Strategy challenge goals can be established. Virtual elimination is an underlying tenet of the Strategy and should be kept in mind throughout the assessment process.

The GLBTS management assessment can result in a number of potential management outcomes; the outcomes provided in the framework allow a substance to remain in active Level 1 status or GLBTS workgroup activities to be suspended. The outcomes also recognize that it may be appropriate to more actively involve a LaMP process, to refer a substance to another program, to represent GLBTS interests in other fora (e.g., international programs), or to consider proposing new challenge goals. All outcomes include a periodic reassessment by the GLBTS (approximately every two years).

While it is recognized that the Parties have an ongoing responsibility to promote GLBTS interests in other arenas, a potential outcome of the framework is to recommend referral to another program and/or GLBTS representation in other fora. In the GLBTS framework, this option is presented when there is no evidence of Basin effects, or when the GLBTS cannot effect further significant reductions on its own, but can advocate substance reductions in other programs and in international fora.

It should be noted that, in using the framework to conduct assessments for the Level 1 substances, it may not be possible to definitively answer “YES” or “NO” to all questions. It is not necessary to have a definitive answer to proceed in the framework. For example, in assessing whether there is environmental or health data to assess the impact of the substance in the Basin, it may be determined that, while additional data would be helpful, there is some data on releases and environmental presence in certain media with which to assess the status of the substance. In this case, judgment is needed to decide whether these data are sufficient to proceed along the “YES” arrow or whether the available data are not adequate and the analysis should proceed along the “NO” arrow, placing the substance on a high priority list for monitoring. As a general guide, the framework allows flexibility and judgment in interpreting environmental data and in determining the most appropriate management outcome(s).

Each decision node, or shape, in the framework is illustrated below along with a brief explanation that describes, in further detail, the question to be assessed.

GLBTS Level 1 Substances

Have the challenge goals for the substance been met?

All 12 Level 1 substances will be assessed.

The first question to consider in assessing the GLBTS status and future management of a Level 1 substance is whether the challenge goals agreed to in the Strategy have been met. The answer to this question informs the subsequent assessment in many ways, not only indicating progress, but also revealing issues associated with the ability to pursue further reductions. Progress toward the U.S. and Canadian goals will be considered jointly. Challenge goals will be evaluated with the best data presently available. Note that some challenge goals target “releases” of a substance while others target its “use”. As a result, different types of data may be required to evaluate challenge goal status (e.g., “use” data vs. environmental “release” data). The framework continues with both the environmental analysis and GLBTS management assessment, notwithstanding the status of the challenge goals.

ENVIRONMENTAL ANALYSIS



High Priority for Monitoring

Characteristics of acceptable monitoring data to assess the temporal, spatial, and population representativeness of a substance in the Great Lakes Basin ecosystem include (but are not limited to) basin-specific measures in water, air, sediment, soil, indoor environments (e.g., dust), fish, biota, or human biological samples. If necessary, use or release data may be used as surrogates (e.g., in the case of alkyl-lead).

“What gets measured gets managed.” Substances entering this box will be recommended as a high priority for monitoring to the Parties. The intent is that these GLBTS substances will be considered by a wide range of government or private agencies when they make decisions regarding which analytes to monitor in the environment. As sufficient monitoring data is developed, substances will be re-evaluated.

Have sufficient risk-based criteria been established (e.g., GLI or other)?

Relevant criteria include, but are not limited to:

- Water quality criteria
- Fish tissue concentrations
- Ambient or indoor air standards
- Sediment or soil standards
- Limits based on reference doses
- Health-based standards for human biota measurements

High Priority for Benchmark or Criteria Development

If there are no criteria against which to evaluate current levels, the GLBTS will consider whether there is a need for the Parties to recommend the development of human health or ecological criteria. This box effectively creates a GLBTS list of substances that are in need of human health or ecological criteria with which to identify exceedances in the environment.

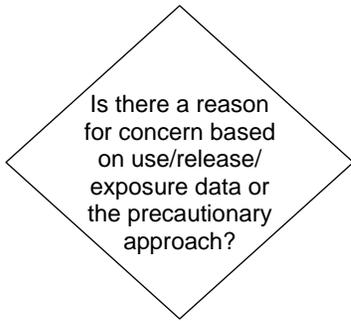
Do levels in biota, air, water, etc. exceed criteria?

As the framework is intended to be flexible in its implementation, the choice of criteria to use in answering this question may vary. For example, the most strict criteria in one or more media may be used to evaluate environmental levels.

Is the trend decreasing?

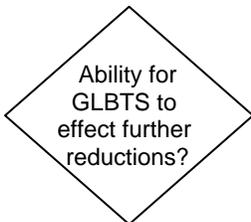
If there are no criteria, or if current levels do not exceed criteria, this box considers whether there is a decreasing trend. A decreasing trend could be defined as a statistically significant negative slope. If the trend is decreasing, the substance is evaluated for evidence of concern based on use, release, exposure, or the precautionary approach. If a decreasing trend cannot be established, then the substance moves directly to the GLBTS management assessment to determine the ability of the GLBTS to effect further reductions.

* Note that, in the event that there are established criteria and the GLBTS substance is below those criteria but not decreasing in trend, further analyses may be required to estimate when criteria might be exceeded.

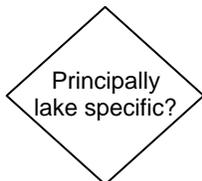


In cases where sufficient monitoring data is not available, or where environmental trends are decreasing and criteria have either not been established or are not being exceeded, the relevant question is whether there is evidence of Basin effects based on documented use, release, or exposure data, or from a precautionary point of view. An example of a precautionary point of view would be documented evidence of significant impact in another geographic location with the same sources and use patterns as in the Basin, or because the effects of a pollutant would be significant by the time it was able to be measured through monitoring.

GLBTS MANAGEMENT ASSESSMENT



Answering this question involves an accelerated version of the first three steps of the GLBTS 4-step process,²³ looking at sources and current programs and regulations to see where the reduction opportunities lie. Part of the assessment will involve consideration of whether the reduction opportunities will be significant enough to merit the effort.



Based on a joint GLBTS-LaMP determination that the impact of a substance is restricted to a single lake, the appropriate LaMP will be engaged for coordination of leadership for reduction actions to be undertaken by the responsible organizations.



The GLBTS will assess the practicality of setting forth new challenge goals.

²³ The GLBTS four-step process to work toward virtual elimination is: 1) Information gathering; 2) Analyze current regulations, initiatives, and programs which manage or control substances; 3) Identify cost-effective options to achieve further reductions; and 4) Implement actions to work toward the goal of virtual elimination.

GLBTS MANAGEMENT OUTCOMES

Active
Level 1
Status &
Periodic
Reassessment
by GLBTS

The substance will continue as a Level 1 with reduction actions addressed by the appropriate process and with periodic reassessment, approximately every two years, using the *General Framework to Assess Management of GLBTS Level 1 Substances*.

Consider
Submission
to BEC for
New
Challenge
Goals

The GLBTS will consider recommending new challenge goals to BEC. The justification for new challenge goals will incorporate the findings of the framework analysis and will include assessment of the desired environmental improvement and feasibility. If the GLBTS decides to propose new challenge goals, the recommendation to BEC will include a reduction percentage, reduction timeline, and baseline for the proposed new challenge goals.

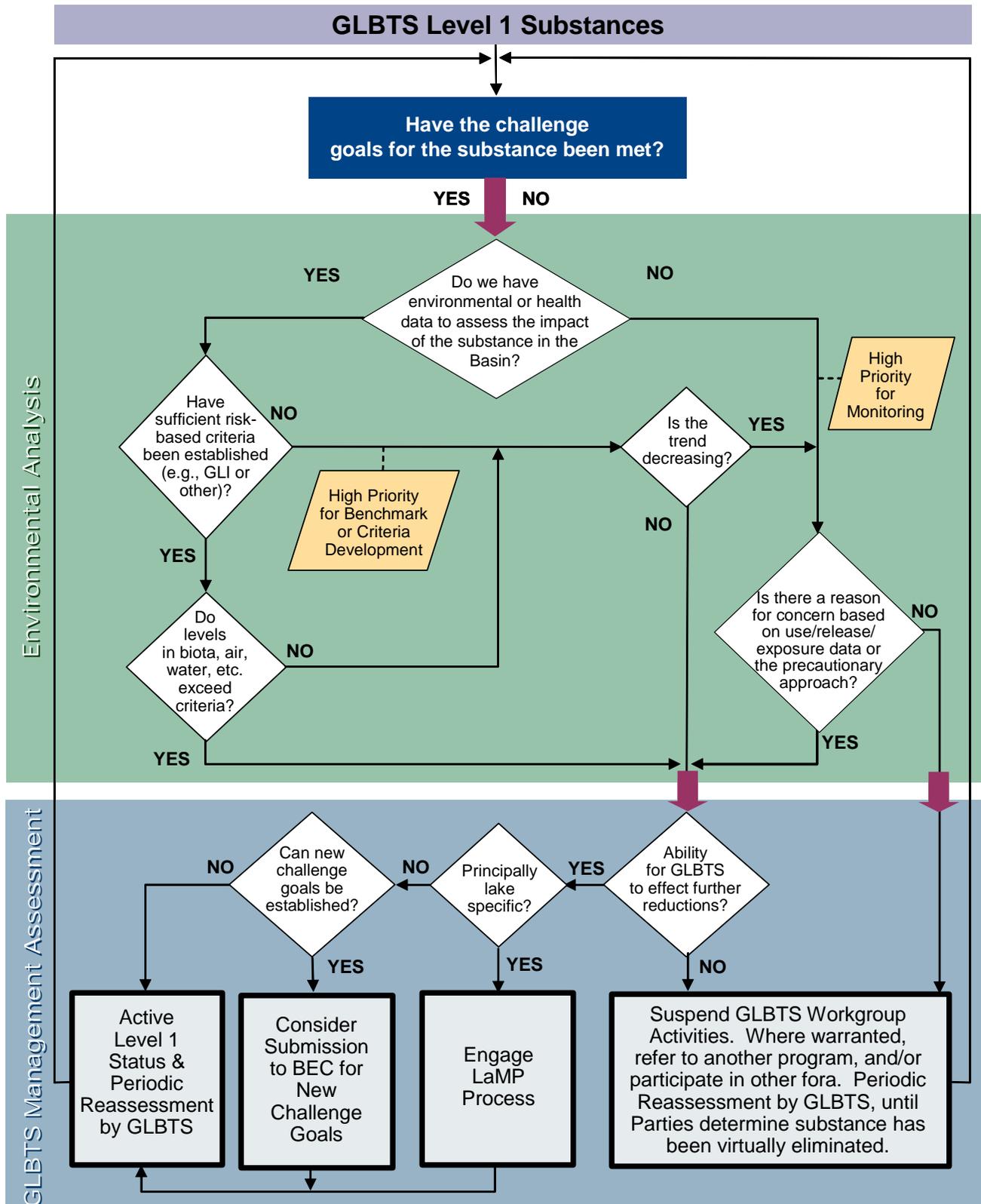
Engage
LaMP
Process

For substances whose impact is lake-specific, the appropriate LaMP will be engaged to coordinate substance reduction activities with continued support from the GLBTS, recognizing the limited direct implementation capacity of the LaMPs. It is understood that much of the actual implementation would be carried out by the agencies with responsibility to address these substances. A joint review of progress would be undertaken periodically.

Suspend GLBTS Workgroup Activities. Where warranted, refer to another program, and/or participate in other fora. Periodic Reassessment by GLBTS, until Parties determine substance has been virtually eliminated.

In the event that the GLBTS is not able to effect further reductions, or there is no evidence of Basin effects, GLBTS workgroup activities will be suspended. Where warranted, a recommendation will be made to a) refer reduction efforts for the substance to another program, and/or b) represent GLBTS interests in other fora (e.g., Commission for Environmental Cooperation, United Nations Environment Programme). There will be no ongoing workgroup involvement with these substances, though each one will undergo periodic reassessment, approximately every two years, using the *General Framework to Assess Management of GLBTS Level 1 Substances*, until the Parties determine that virtual elimination has been reached.

General Framework to Assess Management of GLBTS Level 1 Substances



APPENDIX B: ENVIRONMENTAL/HEALTH DATA

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Whole Fish Tissue: Supplemental DFO Data

The following figures provide temporal trends in total mercury levels collected by the DFO monitoring program from the late 1970s to 2003. Figure B-1 illustrates the trend in total mercury levels in Lake Ontario rainbow smelt from 1977 to 2003. DFO smelt data in Lake Ontario show that there has been very little change in the annual mean mercury level reported for smelt since the mid-1980s. Conversely, the 2003 level of 0.04 $\mu\text{g/g}$ is the highest mercury concentration in smelt samples recorded since 1984 (0.67 $\mu\text{g/g}$).

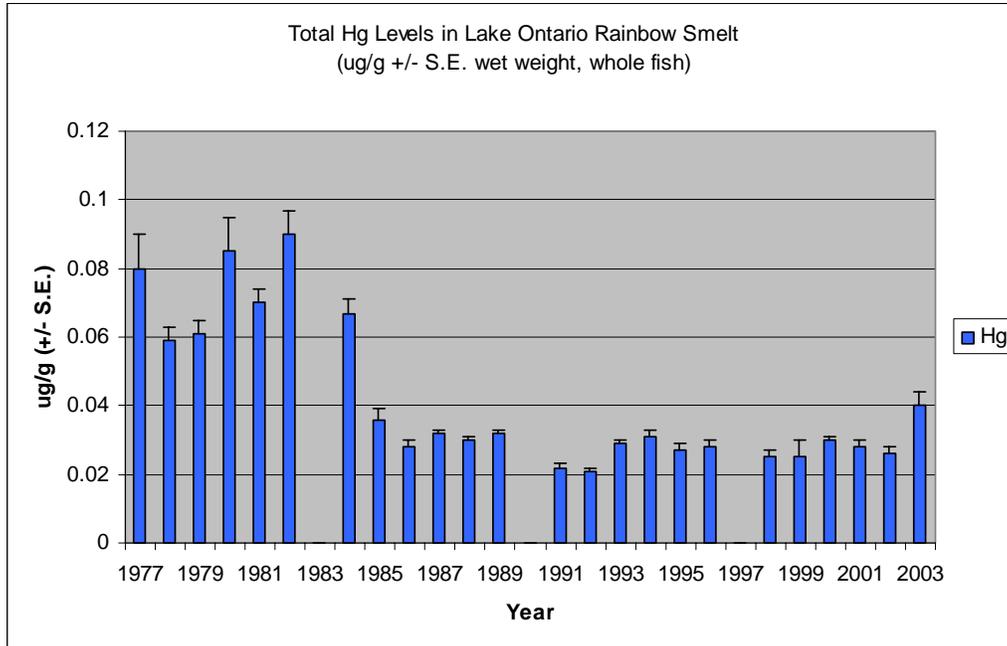


Figure B-1. Total Mercury Levels in Lake Ontario Rainbow Smelt (1977-2003). Data Source: DFO/GLLFAS

Figure B-2 illustrates the trend in total mercury levels in Lake Erie rainbow smelt from 1977 to 2003. DFO smelt data for Lake Erie show that concentrations of mercury measured in samples collected in 2002 had the highest concentrations reported since the whole lake survey was initiated in 1977. Subsequently, the 2003 concentrations were the second lowest concentrations reported since 1977.

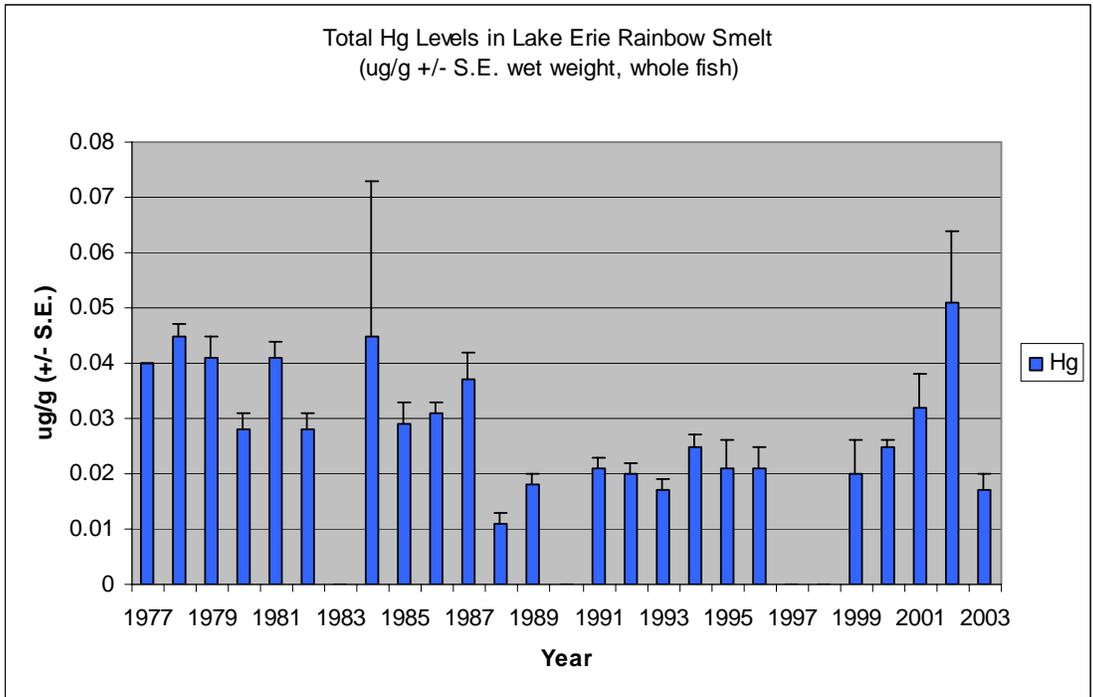


Figure B-2. Total Mercury Levels in Lake Erie Rainbow Smelt (1977-2003). Data Source: DFO/GLLFAS

Figure B-3 illustrates the trend in total mercury levels in Lake Huron rainbow smelt from 1979 to 2003. Figure B-3 illustrates the trend in total mercury levels in Lake Huron rainbow smelt from 1979 to 2003. Lake Huron DFO smelt data show that mercury concentrations have fluctuated considerably over the period between 1979 and 2003. However, samples collected in 2003 DFO smelt have the highest lakewide concentration recorded since 1984.

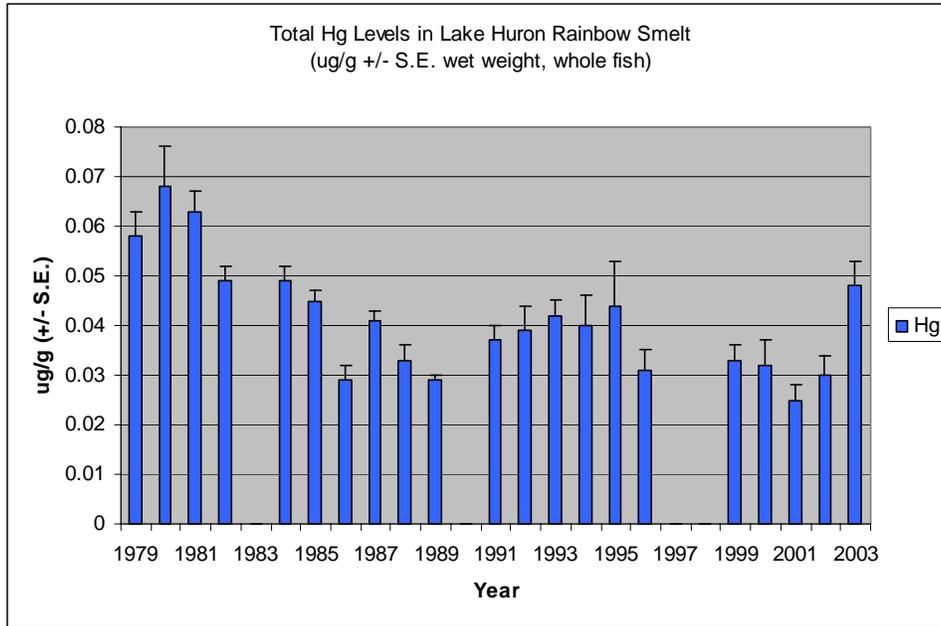


Figure B-3. Total Mercury Levels in Lake Huron Rainbow Smelt (1979-2003). Data Source: DFO/GLLFAS

Figure B-4 illustrates the trend in total mercury levels in Lake Superior rainbow smelt from 1981 to 2002. DFO smelt data in Lake Superior continue to display a steady decline in mercury concentrations through 2002.

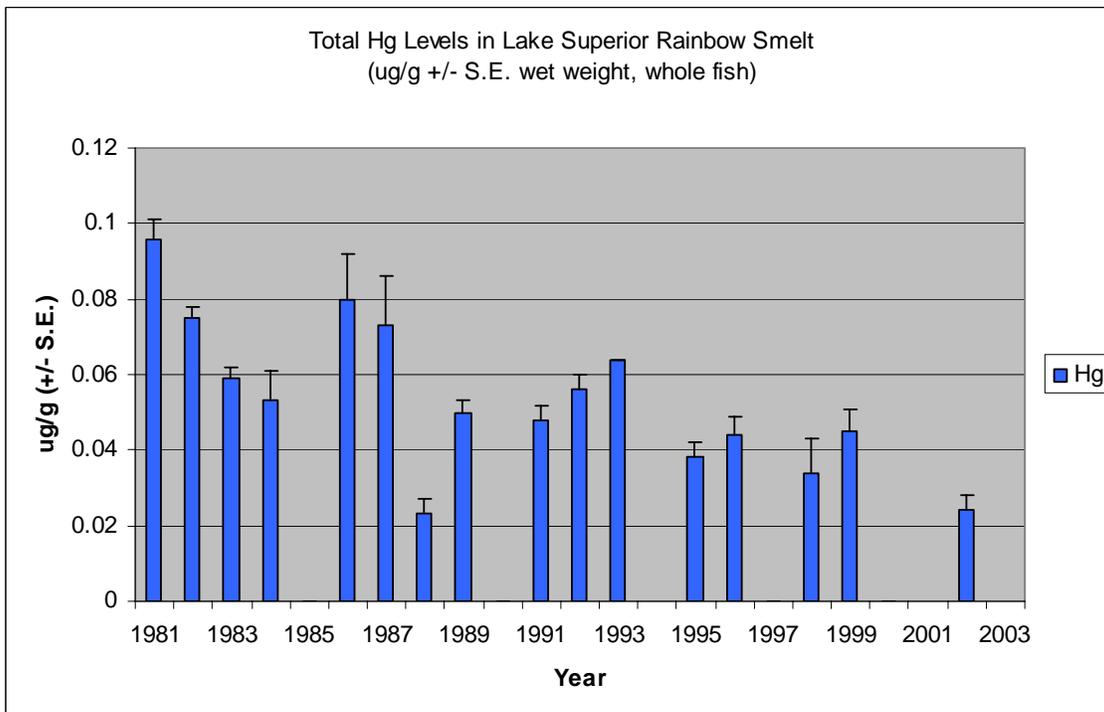


Figure B-4. Total Mercury Levels in Lake Superior Rainbow Smelt (1981-2002). Data Source: DFO/GLLFAS

Canadian Wildlife Service Herring Gull Egg Monitoring Program: Methods and Sampling Sites

The Canadian Wildlife Service (CWS) has analyzed temporal trends in contaminant levels in herring gull eggs from 15 colony sites on the Great Lakes. Eggs have been collected since the early 1970s from up to eight water bodies within the Great Lakes Basin: the St. Lawrence, Niagara, and Detroit Rivers and Lakes Ontario, Erie, Huron, Michigan, and Superior.

The methods and protocol for the Herring Gull Egg Monitoring Program have been described previously (Mineau et al., 1984; Ewins et al., 1992; DiMao et al., 1999). Briefly, 10-13 fresh herring gull eggs were collected, one per completed clutch, from the sites listed below. Collections were made in late April and early May. Eggs were sent to the CWS National Wildlife Research Centre, where they were refrigerated, prepared, and analyzed by gas chromatography within eight weeks of collection (Won et al., 2001). Prior to 1986, all eggs were analyzed individually. Although they are still prepared individually, since 1986 a subsample from each egg has been taken to form a single site pool, which is then analyzed.

Individual annual data for all compounds and sites can be found in Bishop et al. (1992), Pettit et al. (1994), Pekarik et al. (1998) and Jermyn et al. (2002).

Herring gull eggs were collected from the following sites (see Figure B-5):

- St. Lawrence River – Strachan Island (near Cornwall)
- Lake Ontario – Snake Island (near Kingston), Tommy Thompson Park (Toronto Harbour) and Neare Island (Hamilton Harbour)
- Niagara River - an unnamed island 300 m above Niagara Falls
- Lake Erie – Port Colborne Lighthouse and Middle Island
- Detroit River – Fighting Island
- Lake Huron – Chantry Island, Double Island (North Channel) and Channel-Shelter Island (Saginaw Bay)
- Lake Michigan – Big Sister Island (Green Bay) and Gull Island
- Lake Superior – Granite Island (Black Bay) and Agawa Rocks

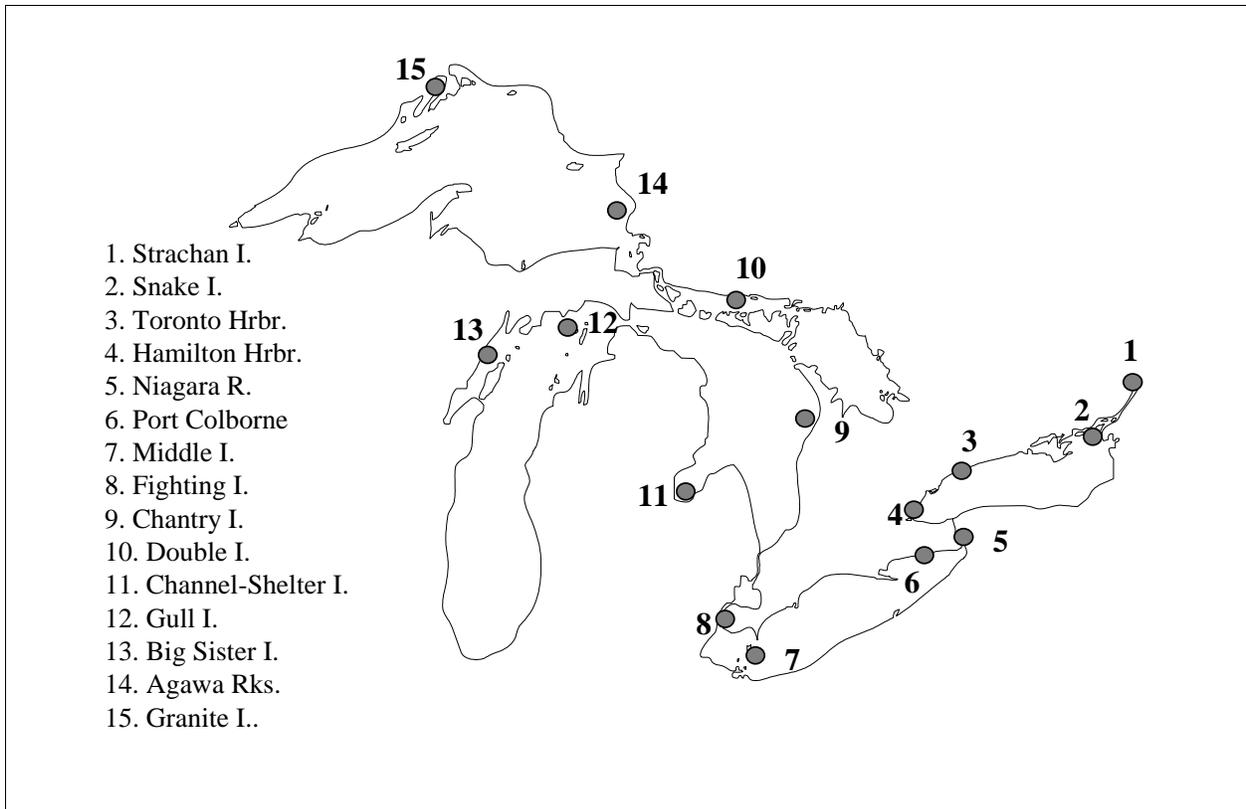


Figure B-5. Location of the 15 Herring Gull Egg Colonies in the Canadian Wildlife Service Herring Gull Egg Monitoring Program

Canadian Wildlife Service Herring Gull Egg Monitoring Program: Supplemental Charts

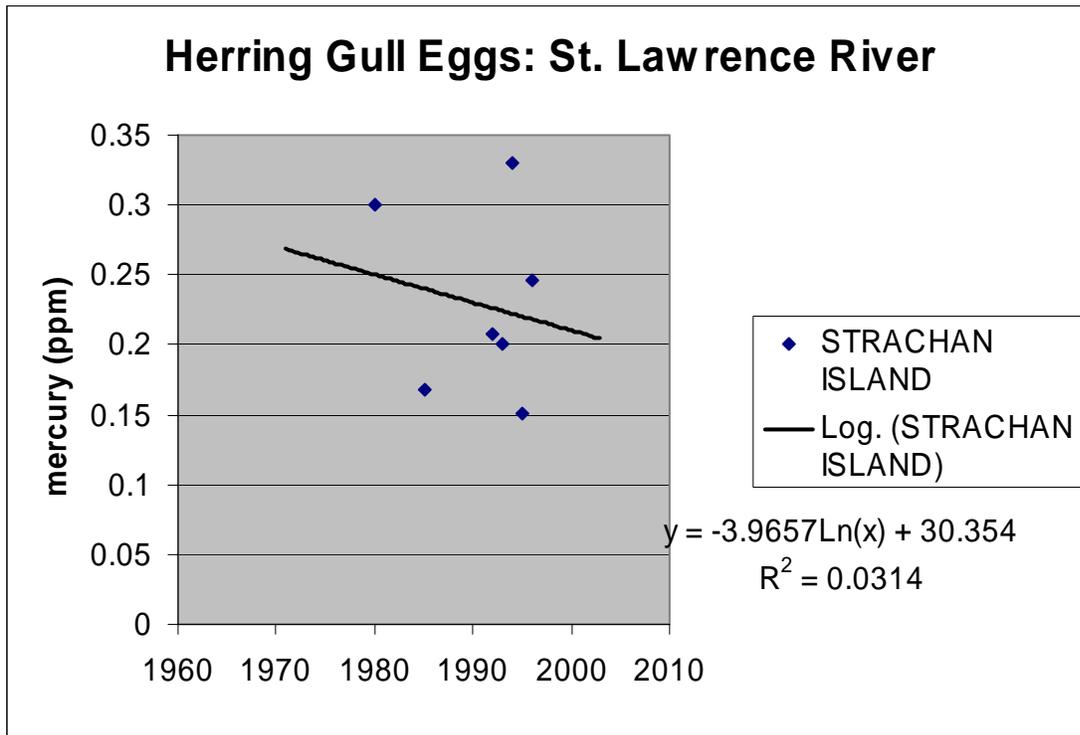


Figure B-6. Trend in Mercury Concentrations in Herring Gull Eggs at St. Lawrence River Sites, 1980-2003. Data Source: Canadian Wildlife Service.

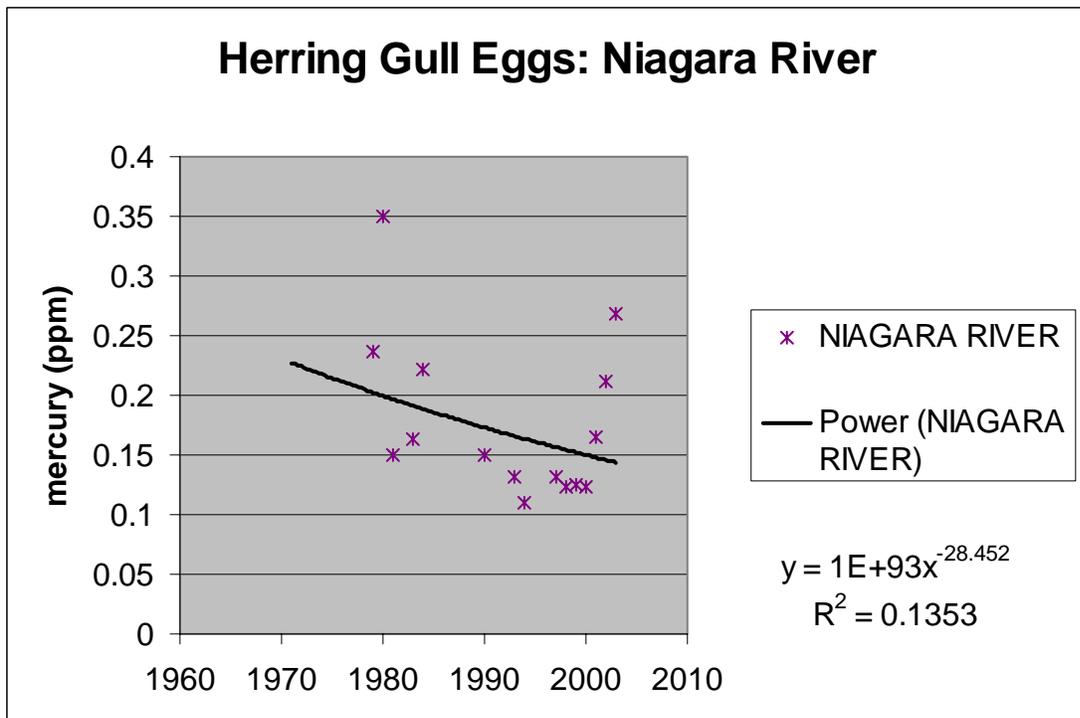


Figure B-7. Trend in Mercury Concentrations in Herring Gull Eggs at Niagara River Sites, 1979-2003. Data Source: Canadian Wildlife Service.

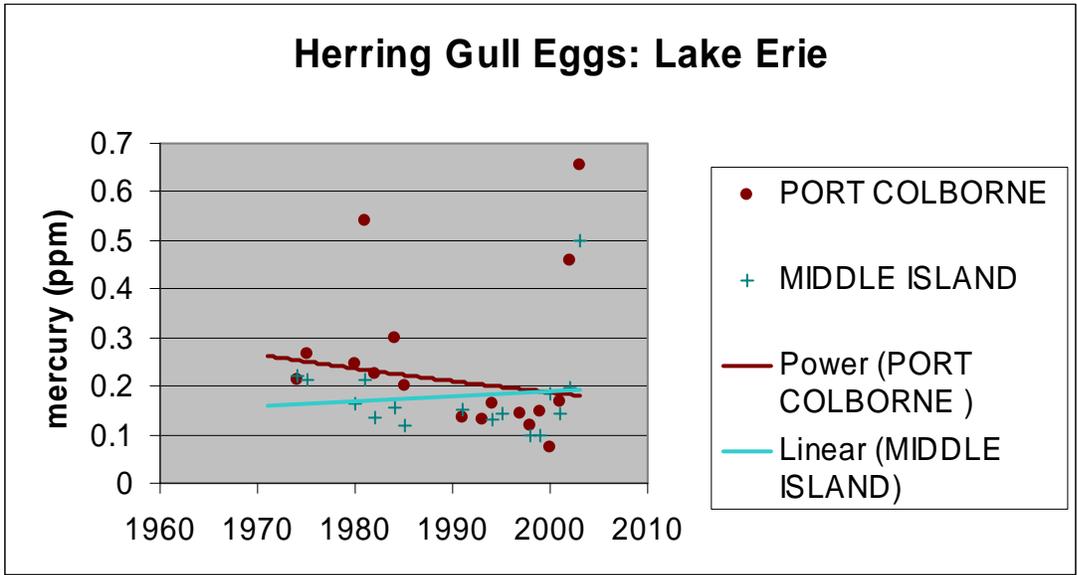


Figure B-8. Trend in Mercury Concentrations in Herring Gull Eggs at Lake Erie Sites, 1973-2003. Data Source: Canadian Wildlife Service.

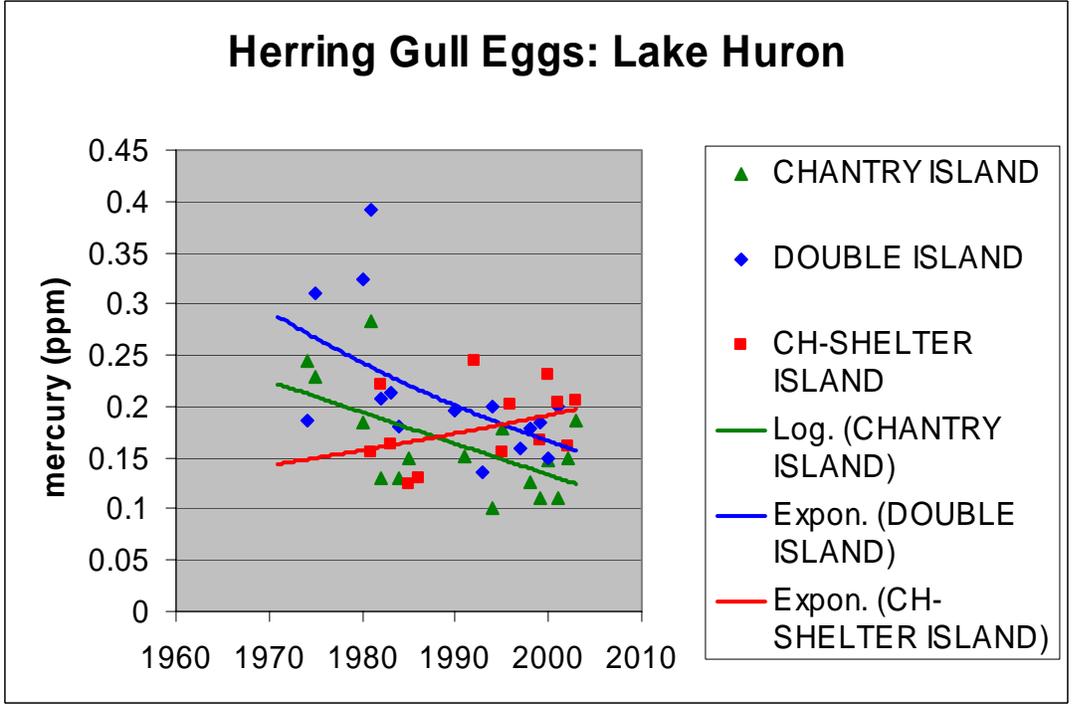


Figure B-9. Trend in Mercury Concentrations in Herring Gull Eggs at Lake Huron Sites, 1974-2003. Data Source: Canadian Wildlife Service.

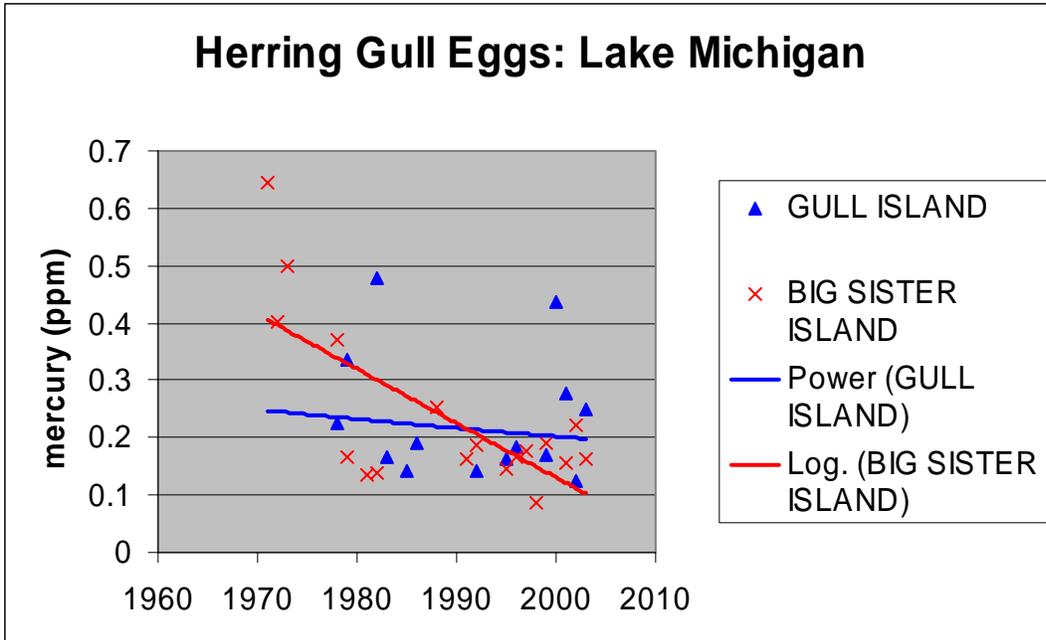


Figure B-10. Trend in Mercury Concentrations in Herring Gull Eggs at Lake Michigan Sites, 1971-2003. Data Source: Canadian Wildlife Service.

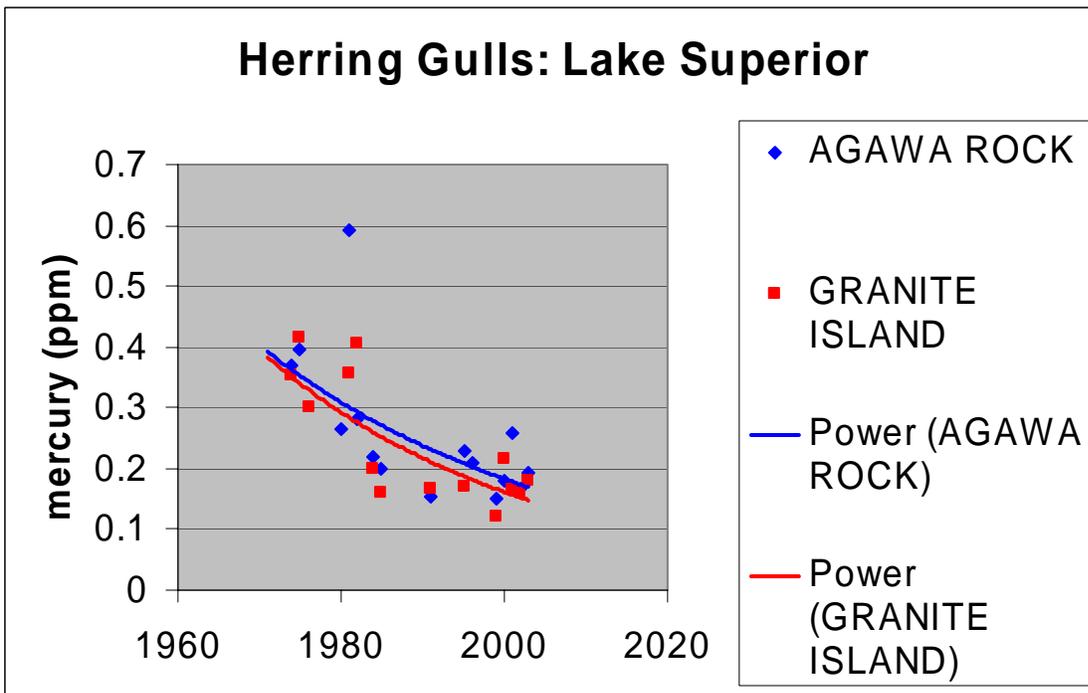


Figure B-11. Trend in Mercury Concentrations in Herring Gull Eggs at Lake Superior Sites, 1974-2003. Data Source: Canadian Wildlife Service.

**APPENDIX C:
ADDITIONAL PROGRAMS THAT
MONITOR MERCURY**

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APPENDIX C: ADDITIONAL PROGRAMS THAT MONITOR MERCURY

National Oceanic and Atmospheric Administration's (NOAA) Mussel Watch Project (U.S.)

NOAA's Mussel Watch Project began in 1986 with Great Lakes zebra mussel sampling not beginning until 1992 with five sites (total) in Saginaw Bay, Lake St. Clair and eastern Lake Erie. The Great Lakes portion of the Mussel Watch Project quantifies all the same contaminants in zebra mussels as the rest of the Mussel Watch Project, including mercury. There are currently 24 sampling sites in the Great Lakes (Lauenstein, 2005). All Mussel Watch data can be found at http://www8.nos.noaa.gov/cit/nsandt/download/mw_download.aspx.