Great Lakes Commission
des Grands Lacs

ISSUE BRIEF

Mercury Contamination in the Great Lakes Basin

October 2021

Preface

This paper summarizes mercury contamination concerns and the state of research, mitigation, and policy efforts to address this issue in the Great Lakes basin. It was developed by the Great Lakes Commission's Ad Hoc Committee on Mercury Contamination. The committee's charge was to develop a policy resolution focusing on mercury monitoring, research and reduction, legislative priorities, and other needs in the Great Lakes-St. Lawrence River basin. This brief is intended to provide background information and context for the proposed resolution, based on progress over the past 10 years and remaining gaps, needs, and opportunities. It is not representative of all concerns and efforts related to mercury; however, it may serve as a guide to existing research, primary references, and the various key reports and agreements that address this issue in more depth.

I. Introduction

Transport and deposition of toxic contaminants such as mercury have broad implications for human health, environmental quality, and the use and development of Great Lakes water resources. For more than 15 years (from 1996 to 2011), the Great Lakes Commission (GLC) maintained an active program dealing with air pollution and air deposition in the Great Lakes. During this period, the GLC managed the U.S. Environmental Protection Agency (U.S. EPA) Region 5 multi-state Great Lakes Air Deposition (GLAD) program and its important Regional Air Pollutant Inventory Development System (RAPIDS). These programs, among other services to the jurisdictions, passed through grants and contracts to state agencies and academic institutions to address problems of deposition of mercury and other pollutants.

Some of the GLAD program priorities over the years included monitoring mercury deposition from rainfall events in Indiana, Michigan, and New York; evaluating the effects of conventional forest harvesting on mercury mobility and bioaccumulation in the northern forested region of the Great Lakes basin; identifying risks to humans from exposure to mercury along the St. Clair River; enhancing understanding of atmospheric cycling of persistent bioaccumulative toxic (PBT) chemicals in the Lake Superior watershed; estimating deposition rates for a class of emerging chemicals of concern across the Great Lakes; and assessing the effectiveness of recent chemical management policies on reducing levels of contamination in Lake Ontario's fish, among numerous other studies.

In 2008, the GLC sponsored a binational scientific synthesis effort through the GLAD program. The purpose of the synthesis project was to foster binational collaboration among mercury researchers and resource managers from government, academic, and nonprofit institutions to compile a wide variety of mercury data for the Great Lakes region, and to address key questions concerning mercury contamination, the bioaccumulation of methylmercury in food webs, and the resulting exposures and risks.

The synthesis effort involved more than 170 scientists and managers working to compile and evaluate more than 300,000 mercury measurements and to conduct new modeling and analyses. This synthesis provides a comprehensive overview of the sources, cycling, and impacts of mercury in the Great Lakes region. The primary results of this initiative have been published in a series of more than 35 scientific papers in the journals Ecotoxicology and Environmental Pollution and are distilled here for use by decision-makers and the public. Findings were summarized in the report Great Lakes Mercury Connections: The Extent and Effects of Mercury Pollution in the Great Lakes Region (Evers et al 2011).

During the 2009-10 U.S. congressional session, a "Comprehensive National Mercury Monitoring Act" was introduced in the Senate. The intent of this legislation was to provide funding to track mercury cycling in the environment to better inform local, regional, national and international mercury reduction polices and to track progress toward these goals. The legislation is consistent with recommendations outlined in the Great Lakes Regional Collaboration Strategy to Restore and Protect the Great Lakes and would have augmented efforts to reduce atmospheric pollution under the GLAD Program. Around the same time, the Great Lakes Restoration Initiative (GLRI) was established and led to the discontinuation of the GLAD program at the end of FY 2011.

The GLC adopted a resolution at its 2010 Annual Meeting titled Promoting Comprehensive Mercury Monitoring, Research and Reduction Efforts. The purpose of this resolution was to allow the GLC to participate in this important national dialogue, keep the states and provinces informed of these discussions, and to advocate for comprehensive mercury monitoring and reduction policies that would benefit the Great Lakes-St. Lawrence River basin. This bill did not pass in the 111th Congress and was not enacted into law. The bill was reintroduced in several subsequent sessions of Congress, most recently in 2021 by Senator Susan Collins (ME) – S. 1345 – and Representative Matt Cartwright (PA-8) – H.R. 2761. Both bills have been referred to committee; no other action has been taken.

Research, monitoring and risk reduction efforts for mercury and other toxic substances have continued since the GLC last acted on this issue in 2010. Despite progress, many of the needs identified by the GLC and other partners remain. Identification and quantification of emission sources and improved understanding of atmospheric pathways and environmental fate within and outside the Great Lakes basin are important and ongoing. In addition, changes in climate and weather patterns are likely to impact mercury cycling in the environment. Mercury contamination continues to impact the natural resources of the Great Lakes basin and negatively impact the health of communities throughout the region.

II. Sources of mercury in the Great Lakes basin

Mercury is a naturally occurring heavy metal found in the earth's crust. Natural sources of mercury released to the atmosphere include volcanoes, forest fires and weathering of mercury-bearing rocks. Anthropogenic sources include municipal and industrial discharges and burning of fossil fuels, particularly coal. Mercury

can exist as a pure element, form various salts (inorganic mercury) or bind with carbon and become methylated (organic mercury).

Sources of mercury in the Great Lakes basin include those that discharge directly to a water body through pipes or channels, such as wastewater treatment plants, industrial waste dischargers, and municipal stormwater discharge, as well diffuse sources that contribute through runoff or air deposition. The 2010 Great Lakes Mercury Emission Reduction Strategy (GLRC 2010) evaluated anthropogenic sources that contribute mercury to the Great Lakes and recommended actions to address them. Since that time, both the ECCC and U.S. EPA websites present updated and more detailed information and much of this information is summarized in the Great Lakes Binational Strategy for Mercury Risk Management (ECCC and U.S. EPA 2021). Generally, these sources include:

- Fossil fuel electric power generation
- Industrial, commercial & institutional Boilers
- Mercury cell chlor-alkali industry
- Metals production including mining and smelting
- Portland cement
- Waste incinerators
- Products and processes that deliberately use mercury
    - Crematories
    - Fluorescent lamps
    - Recyclers
    - Land application of biosolids
    - Mercury-added products (e.g., batteries, thermostats, switches, medical products)
    - Waste handling

The Great Lakes Binational Strategy for Mercury Risk Management (Binational Strategy) cites work by Evers, et al, 2011 identifying atmospheric emission and deposition as the greatest source to the Great Lakes. Both Canada and the United States have made significant strides to reduce mercury emissions through multiple actions listed in the Binational Strategy. In the Binational Strategy, table 4 presents total mercury emissions in Canada by sector, 1990-2015, and figures 2 and 3 depict similar information for the United States between 1990 and 2014. Each shows impressive declines in mercury emissions; however, deposition from global mercury emissions remain a concern.

The Canadian Mercury Science Assessment: Summary of Key Results (Science Assessment states that "Based on results from Environment Canada's Global/Regional Atmospheric Heavy Metals (GRAHM) model, an estimated 95% of the anthropogenic mercury deposited in Canada comes from sources outside of the country. These contributions are approximately 40% from East Asia, 17% from the United States, 8% from Europe, and 6% from South Asia" (ECCC 2016).

Sediments within the Great Lakes are an internal source of mercury cycling through the environment and contribute to fish consumption advisories. Lepak et al (2015) used mercury stable isotopes to assess mercury source contributions to Great Lakes sediment. Notably, sites influenced by the St. Louis River Estuary and Thunder Bay, the southern-most sites in Lake Michigan locations, and sites through lakes Erie and Ontario were dominated by industrial (or "legacy") and watershed sources. Additional mercury stable isotope work examining Great Lakes fish (Lepak et al 2018), and a recent Lake Superior study assessing mercury throughout the food chain (Janssen et al 2021) provide an evidential link between industrial and watershed sources in more local areas.

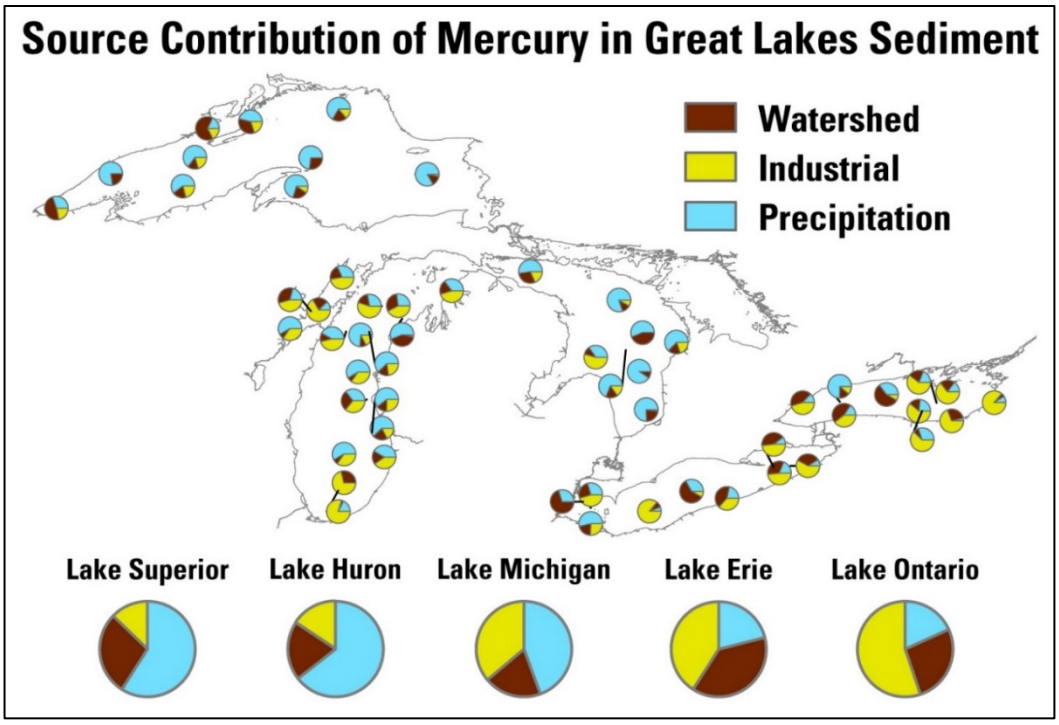


Figure 1. A map showing the relative concentrations of mercury sources which include watershed, industrial, and precipitation in Lake Superior, Lake Huron, Lake Michigan, Lake Erie, and Lake Ontario (Lepak et al 2015).

Identifying mercury sources to Minnesota and Lake Superior

Most of the mercury to Lake Superior is from atmospheric deposition: influenced by the amount of mercury emitted to the air. In terms of atmospheric loading, a long-term monitoring effort has been underway through the Mercury Deposition Network around the lake for over two decades. Minnesota tracks air emissions of mercury annually and breaks up air emission sources into 35 different categories. These are generally combined into three overall categories: mercury incidental to energy production, mercury due to the purposeful use of mercury in products, and mercury incidental to material processing.

Minnesota is working with other Great Lakes partners on a number of projects to better understand the presence of mercury in the state, its sources and pathways. The GLRI has served as a critical resource to support achieving near-term goals. With the support of GLRI, the U.S. Geological Survey (USGS) is executing three priority projects related to mercury:

1. Tributary monitoring to determine the influence of ditched peatlands on methyl mercury loading to Lake Superior
2. Monitoring of more than 30 tributaries around Lake Superior to identify watersheds that deliver disproportionately large loads of methyl mercury to Lake Superior
3. Characterizing the source of atmospherically deposited mercury to Lake Superior through isotopic analysis of long-term data from the Mercury Deposition Network

Water discharges are a gap in knowledge. They will be addressed, at least in part, by the USGS study of tributaries this year. Minnesota has a very good database of mercury loads from permitted point sources, but they represent a small portion of the total mercury loading when compared to atmospheric deposition. There are still struggles with the unknowns between mercury deposition and methylmercury in fish. Mercury isotope research is expected to provide better knowledge of this relationship.

III. Impacts of mercury contamination

Human health

Mercury accumulates in waterbodies through atmospheric deposition, direct discharge, and precipitation runoff into streams and rivers. Mercury may then be converted to a much more potent and toxic form known as methylmercury. Most humans have some level of methylmercury in the blood, primarily due to the consumption of fish and shellfish that accumulate methylmercury in their muscle tissue. Methylmercury accumulates through the food chain and top predatory fish species may contain much higher concentration of mercury in muscle tissue than the surrounding environment. In humans, mercury is readily absorbed by the digestive system, remains in the bloodstream for six months to a year once exposure stops, and crosses both the blood-brain and placental barriers, where it can affect a developing fetus (Carrier et al 2001, Rice et al 2003, and Jo et al 2015).

Mercury is a potent neurotoxin and symptoms of acute exposure to inorganic mercury include tremors, emotional changes, muscle weakness, headaches, sensation disturbance and poor mental function. Higher exposures may also cause kidney effects, respiratory failure, and death (U.S. EPA 2021).

This exposure in the womb is especially concerning. Several studies have linked methylmercury exposure to permanent neurological deficits in children including attention deficits, loss of IQ, and decreased memory function. Examples of methylmercury poisoning are widely known. In Minamata, Japan, in the 1950s, thousands were poisoned by daily consumption of large amounts of fish and shellfish exposed to decades of direct discharge of industrial waste. Children were born with severe deformities including gnarled limbs, mental retardation, deafness, and blindness (Nabi 2014).

While exposures of this magnitude are rarely seen today, there is evidence that more subtle effects may be linked to levels of exposure in populations with high to moderate levels of dietary fish consumption. Some studies suggest low level methylmercury exposure has deleterious effects on the cardiovascular system (Genchi 2017).

Many health agencies around the country have issued guidance for fish consumers to limit methylmercury exposure from fish consumption. Most of this guidance is based on protecting a developing fetus. In general, fish consumption advice attempts to convey the message that fish is a good source of nutrition and has significant health benefits, but that consumers – particularly pregnant women, women of child-bearing age, nursing mothers, and young children – should avoid fish with high levels of methylmercury and limit their intake of fish with moderate levels of methylmercury. Great Lakes states generally advise the consumption of no more than one meal per week of small and moderate sized fish due to mercury contamination (Turyk et al 2012 and GLSFATF 1993).

Fish and wildlife

Harmful levels of mercury in animal tissues are found around the globe, from pythons invading the Florida Everglades to polar bears roaming far from any sources of pollution. Health impacts associated with high mercury levels in different species vary, but the primary effect is on wildlife reproduction and nervous system disruption, which can lead to behavioral abnormalities. Fish may have difficulty schooling and decreased spawning success; birds lay fewer eggs and have trouble caring for their chicks; and mammals have impaired motor skills that affect their ability to hunt and find food (NWF 2006). Some evidence indicates that elevated mercury levels also can adversely affect immune systems in wildlife. Potential

population effects in fish and wildlife resulting from dietary methylmercury exposure also vary by species, as well as regional differences in fish mercury concentrations, which are influenced by differences in mercury deposition and environmental methylation rates.

Common loons are a primary study organism for mercury studies due to their long lifespan (30 years or more), high status in the food chain, and complex behavior. Substantial evidence exists for adverse neurological, physiological, and reproductive effects to loons associated with environmental mercury levels. Neurotoxic effects of methylmercury in loons include reduced back-riding by chicks and lowered chick feeding rates by adults. Physiological responses to elevated methylmercury levels in loons include reduced diving frequency and the production of smaller eggs in the wild (Evers et al 2018). Population modeling suggests that reductions in mercury emissions could have substantial benefits for some common loon populations that are currently experiencing elevated methylmercury exposure (Scheuhammer 2007).

IV. Mercury contamination and environmental justice

Mercury exposure through fish consumption can be viewed as a textbook case of environmental injustice. Methylmercury contamination in Great Lakes fish is an environmental justice issue for indigenous communities that depend on fish as a large part of their diet. Subsistence and commercial fishing in indigenous communities not only provides affordable, high-quality protein for community members but also provides a direct connection to their history, culture and way of life or *bimaadiziwin* (Kuhnlein, H.V., 1996). Historical references indicate that as much as 65% of protein in Great Lakes Anishinaabeg diets was derived from locally caught fish (Unites States v. Michigan 1981). More recent studies include polling from communities in the northern Great Lakes that indicate amounts of fish eaten daily or weekly and include information on species and location of harvest (Dellinger 2004). Methylmercury levels vary in fish by location and species over time. The Chippewa Ottawa Resource Authority (CORA) and Great Lakes Indian Fish & Wildlife Commission (GLIFWC) have been monitoring contaminants in tribal commercial and subsistence fisheries, including mercury, for many years (Dellinger et al 2014 and Moses 2011). Both CORA and GLIFWC provide advice to tribal members on how to choose fish that are lower in contaminants including methylmercury (Dellinger et al, 2019, Madsen et al 2008, Moses 2018, Moses 2020a, and Moses 2020b).

Groups that rely on fishing for food, cultural identity, spiritual wellbeing, or economic prosperity are more vulnerable to mercury pollution. The vulnerability is heightened because sources and hotspots of mercury are found disproportionately in areas near communities of color, low-income and immigrant communities, and indigenous peoples (Bank 2012).

Similar environmental justice concerns apply to other subsistence fishing communities in the Great Lakes region. For example, significant Hmong and other Southeast Asian populations living in Green Bay, Sheboygan, and Milwaukee counties in Wisconsin have higher contaminant levels than the general population (Schantz et al 2010). Another Wisconsin-based study found higher levels of mercury exposure in Hmong Americans as compared to other communities, in part due to a preference or consuming fish species with higher levels of contamination (Stevens et al 2018). The Minnesota Family Environmental Exposure Tracking project studied Asian, East African, Latina and white pregnant women. Funded through the Minnesota Department of Health, this study found that Hmong women had the highest risk for mercury poisoning due to fish consumption and skin lightening products, followed by East African women.

In 2002, the U.S. EPA's National Environmental Justice Advisory Council released the report "Fish Consumption and Environmental Justice." In addition to providing a detailed analysis on the issue, the report proposed six overarching consensus recommendations to U.S. EPA, including establishing water quality criteria that account for specific uses; preventing and reducing the release of contaminants including, but not limited to, mercury; protecting communities with high exposure rates; ensuring that consumption advisories are a short-term measure; closer consultation with indigenous communities; and providing equitable funding and technical support to tribal programs. Ultimately, reducing the release of mercury into the environment would help eliminate the need for advisories (Gagnon, et. al 2018).

V. Examples of mercury contamination trends in the Great Lakes basin

Michigan

In Michigan, mercury use and emissions continue to decline. Significant emission reductions (67% less than 2005) are expected to occur by 2023 due to 14 coal fired power plants shutting down or converting to natural gas-fired electric generation. Mercury emissions were reduced by 84% from 1989 to 2011 and coal fired power plant mercury emissions decreased by 550 pounds from 2011 to 2017, a 20% reduction (Taylor Morgan et al 2017). The Michigan Department of Environment, Great Lakes, and Energy (EGLE) has been monitoring levels in fish from 22 sites in the Great Lakes and inland waters since 1990. At least two species were sampled at most of the Great Lakes sites and a total of 31 temporal trend data sets were generated. Overall, no change in mercury concentration was detected in 58% of the fish populations sampled (Taylor Morgan et al 2017).

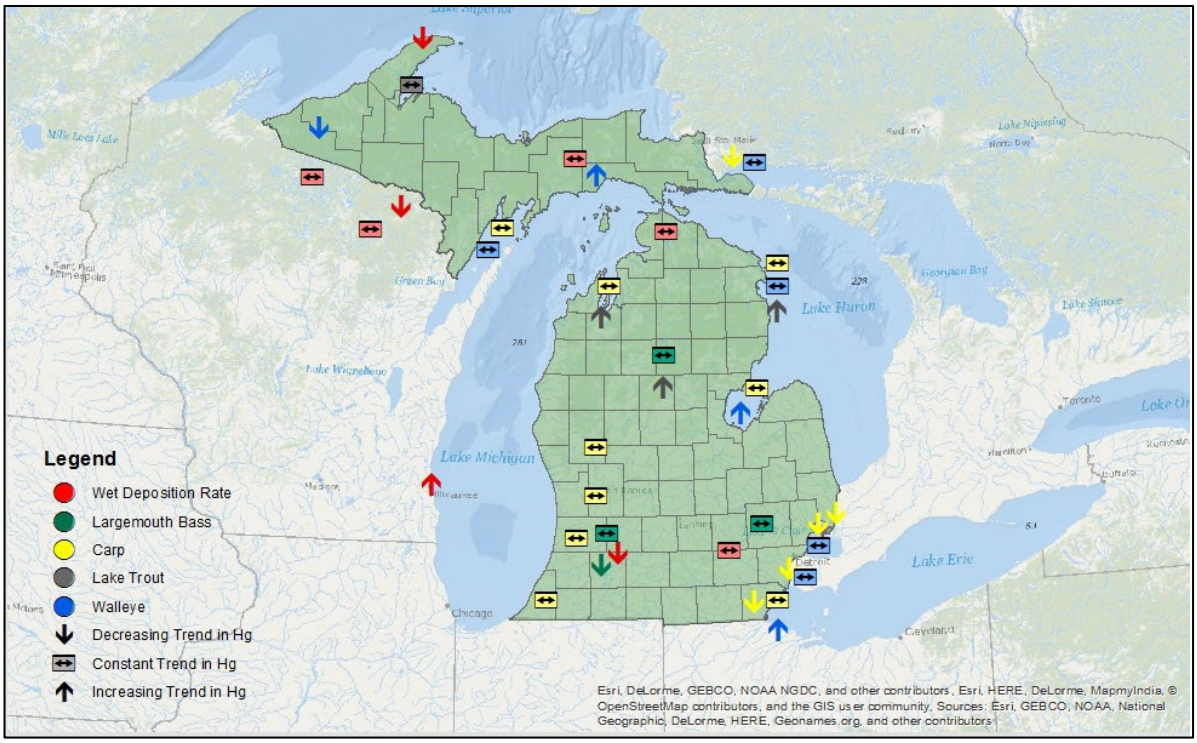


Figure 2. A map showing temporal trends in mercury wet deposition and fish tissue concentration in Michigan from 1990-2015 (Taylor Morgan et al 2017).

Ohio and Lake Erie

Ohio has monitored fish tissue in Lake Erie since 1971 and a statewide consumption advisory due to mercury was established in 1997. Mercury levels decreased in the 1990s, but trends have stabilized since 2000, as show in Figure 3 below.

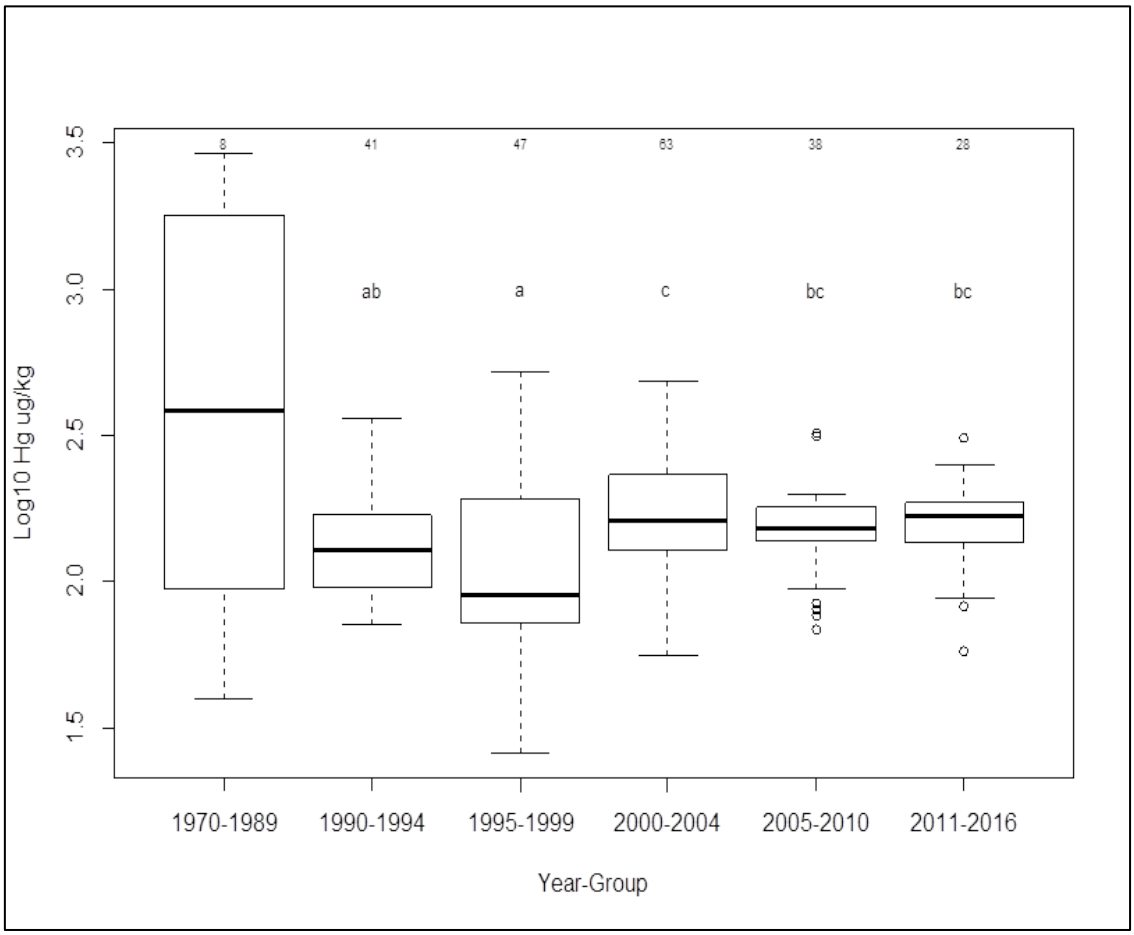


Figure 3. Log-transformed mercury concentrations in Lake Erie walleye from 1970-2016. The number at the top is N per binned timespans; letters (a-c) indicate significant differences among timespans. There is no significant difference in concentration from 2000 to 2016 (A. Rush, personal communication, September 17, 2021).

Lake Superior

Among the Great Lakes, Lake Superior has the highest mercury levels in fish and lowest levels in water and sediment. Studies conducted over the past 10 years have added to understanding of mercury in the Lake Superior ecosystem and yielded important insights. Previously, high methylmercury concentrations in tributary mixing zones relative to the open water of Lake Superior were thought to be a major source to fish. More recently, however, stable isotope analysis of mercury in lake trout and walleye has indicated the source of methylmercury to Lake Superior lake trout is inorganic mercury from atmospheric deposition methylated in the upper water column.

Another important recent finding is the increasing average age of lake trout in Lake Superior. Mercury concentrations in the fish typically increase with the size and age of fish. Because of the difficulty of

determining age in fish, length has been used as a surrogate for the age. A narrow mid-range of fish lengths have been the basis for evaluating mercury trends and it appeared the trend was upward over the period of study. The U.S. EPA's Great Lakes fish monitoring program investigated the trend in fish ages and discovered the average ages were increasing. When tissue concentrations were corrected for the change in fish age, mercury in lake trout showed a decline of 6-7% since 2003.

VI. Climate impacts

Emerging environmental stressors are also a concern for efforts to reduce mercury contamination and exposure. Rising global temperatures and increasingly intense storm events are releasing previously sequestered and naturally occurring mercury into waterways and are likely to impact patterns of deposition. Climate impacts to the physical characteristics and functions of the ecosystem will subsequently affect the biogeochemical cycle of mercury, potentially changing the rate of methylmercury formation within the environment and, subsequently, bioaccumulation in fish and wildlife (ECCC 2016). While some research has begun to look at these new risks, there is limited knowledge on the overall impact changes in climate will have to mercury cycling (Krabbenhoft and Sunderland 2013).

VII. Monitoring for mercury in the environment

For decades, jurisdictions within the Great Lakes basin have invested in mercury monitoring networks to better understand mercury cycling through the environment and the associated risks to both human health and biota. Reliable monitoring is needed to support science-based accountability systems and to better understand the critical linkages between mercury emission and environmental response and associated human health concerns. Both the Science Assessment and the Binational Strategy link monitoring to public policy decisions and evaluating effectiveness of those policies once implemented (ECCC 016 and ECCC and U.S. EPA 2021). Further, changes in global energy usage and changing climate conditions could have significant effects on mercury transport and cycling in the environment. Continued monitoring and research will be necessary to understand ecosystem responses.

The Binational Strategy identifies six monitoring, surveillance and research strategies (ECCC and U.S. EPA 2021). First among those strategies is multi-media environmental monitoring. Objectives for a comprehensive environmental monitoring include:

1. Quantifying concentration changes in the air, water, and key biota
2. Tracking mercury cycling in the environment including the effects of climate change,
3. Providing input into key models including bioaccumulation, global transport, and ecological risk
4. Distinguish between local and global sources
5. Optimized spatial and temporal resolution
6. Enhancing available monitoring tools

Understanding the sources for mercury entering the environment involves not only tracking emissions but also inventorying mercury-containing products and materials and tracking the operations with potential releases into the environment (e.g., transportation manifests and waste disposal). Overall, the Binational Strategy finds that "binational cooperation is needed to coordinate monitoring and surveillance efforts,

maximize research initiatives, and cost-effectively monitor and track mercury concentrations in multiple media (wastes, soil, water, air, tissues, etc.)" (ECCC and U.S. EPA 2021).

Resource constraints were recognized as affecting monitoring efforts in 2011 and budgets continue to be a limiting factor for monitoring now. As illustrated by the number of active versus inactive National Atmospheric Deposition Network sites, monitoring has decreased since observations began in 1996 and 2009 for the Mercury Deposition Network and Atmospheric Mercury Network, respectively (Figure 4).

In the last several sessions of the U.S. Congress, legislation has been introduced to establish a national mercury monitoring program. As previously noted, the most recent bills were introduced in 2021 by Senator Susan Collins (ME) – S. 1345 – and Representative Matt Cartwright (PA-8) – H.R. 2761. Despite bipartisan sponsorship, no action has been taken on the legislation to date. The objective of legislation is to establish "a comprehensive national mercury monitoring network to accurately quantify regional and national changes in atmospheric deposition, ecosystem contamination, and bioaccumulation of mercury in fish and wildlife in response to changes in mercury emissions would help policy makers, scientists, and the public to better understand the sources, consequences, and trends of mercury pollution in the United States."

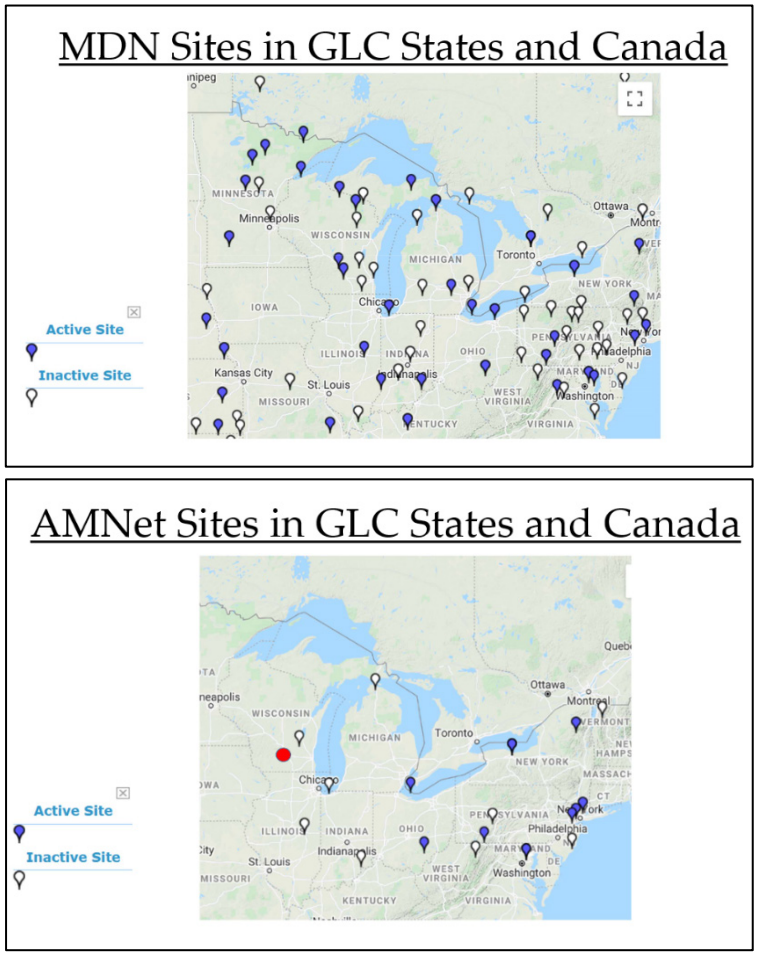


Figure 4. Locations of active and inactive monitoring sites in the National Atmospheric Deposition Network's Mercury Deposition Netowrk (MDN) and Atmospheric Mercury Network (AMNet) (National Atmospheric Deposition Network, http://nadp.slh.wisc.edu/NADP/networks.aspx, March 3, 2021).

VIII. International and regional agreements

Over the past 40 years, several important agreements have been established that provide a framework and a commitment of the agreeing parties to take action on mercury and related concerns. Those agreements include:

- Minamata Convention on Mercury (2013): The Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury. Among other commitments, it includes a ban on new mercury mines, the phase-out of existing ones, the phase-out and phase-down of mercury use in a number of products and processes, control measures on emissions to air and on releases to land and water, and the regulation of the informal sector of artisanal and small-scale gold mining. The convention also addresses interim storage of mercury and its disposal once it becomes waste, sites contaminated by mercury, as well as health issues. The convention entered into force in 2017 and currently has 133 parties. Both Canada and the United States are parties to the convention.

- Great Lakes Water Quality Agreement (1972, 1978, 1987, 2012): The Great Lakes Water Quality Agreement (GLWQA) was first signed in 1972 to coordinate the actions of Canada and the United States. The purpose of the GLWQA is: "to restore and maintain the chemical, physical, and biological integrity of the Waters of the Great Lakes." Annex 3 of the 2012 Agreement addresses "Chemicals of Mutual Concern," including mercury. Through Annex 3, Canada and the United States have committed to "contribute to the achievement of the General and Specific Objectives of this Agreement by protecting human health and the environment through cooperative and coordinated measures to reduce the anthropogenic release of chemicals of mutual concern into the Waters of the Great Lakes." Implementation of Annex 3 is led by ECCC and the U.S. EPA. In 2021, the parties released the Great Lakes Binational Strategy for Mercury Risk Management that includes a compilation of 22 management options for mercury to achieve GLWQA commitments.

- Canada-United States Air Quality Agreement (1991): The Canada-United States Air Quality Agreement commits the two countries to significantly reducing emissions of pollutants that cause acid rain and contribute to smog. It established an Air Quality Committee to report every two years on progress. The last progress report was released in 2018.

- Great Lakes Toxics Substances Control Agreement (1986): The Great Lakes Governors signed the Great Lakes Toxic Substances Control Agreement to "establish a framework for coordinated regional action in controlling toxic pollutants entering the Great Lakes system; to further understanding of toxic contaminants and ways to control them; and to redirect our common goals, management practices and control strategies for toxic contamination to ensure a cleaner Great Lakes ecosystem." The agreement includes six principles and various commitments and guidance for implementing the principles. Implementation of the agreement eventually led to the establishment of the Great Lakes Protection Fund in 1989.

IX. Risk mitigation and management strategies

The Binational Strategy outlines numerous options that can be undertaken by the federal governments in the United States and Canada to achieve continuing and increased reductions of mercury in the Great Lakes basin, some of which are already underway (ECCC and U.S. EPA 2021).

State mercury programs

States undertake a wide variety of efforts to understand and reduce risks associated with mercury contamination. The following table summarizes various key elements of mercury strategies implemented in Great Lakes states. Additional detail on state programs is provided in Appendix B.

Jurisdiction	Overall Mercury Action Plan	Inventory Mercury Air Emissions Sources	Mercury Monitoring – Stack Testing	Mercury Monitoring – Air Deposition	Mercury Monitoring – Fish Consumption Advisory	Programs to Manage Mercury Containing Products	Mercury Dental Programs	State Requirements for Mercury Switch Recovery	Participant in National Vehicle Mercury Switch Recovery	Mercury Product Recycling	Mercury Pollution Prevention	Statewide TMDL
Illinois		X	X		X	X		X	X	X	X	*
Indiana	X	X	X	X	X	X	X	X	X	X	X	
Michigan	X	X	X	X	X	X	X		X	X	X	X
Minnesota	X	X	X	X	X	X	X		X	X	X	X
New York	X	X	X	X	X	X	X	X	X	X	X	**
Ohio		X	X	X	X	X	X		X			
Pennsylvania		X	X	X	X	X		X		X		
Wisconsin	X	X	X	X	X	X	X	X	X	X	X	

*Illinois has a U.S. EPA-approved mercury TMDL for Lake Michigan (nearshore).
**New York participates in a multistate TMDL approved by U.S. EPA in 2007 for a northeast regional coalition of states.

Impaired waters and mercury

The U.S. federal Clean Water Act (CWA) Section 303(d) provides for the listing of waterbodies that do not meet specific state standards for water quality. Thousands of waterbodies are listed as impaired due to mercury, often due to high mercury levels in fish. To address these impairments, states develop Total Maximum Daily Load (TMDLs) which set the maximum amount of a pollutant allowed in a waterbody and serves as the starting point or planning tool for restoring water quality. Michigan and Minnesota both established statewide TMDLs for mercury. In addition, a Northeast Regional TMDL is in place that includes New York. These TMDLs focus on reducing atmospheric deposition of mercury so that concentrations of mercury in fish can be reduced to healthier level.

Minnesota TMDL summary

In 2007, the MPCA finalized a statewide mercury TMDL study that determined the emissions reductions necessary to meet water-quality standards and protect people from consuming mercury-contaminated fish. The TMDL establishes a goal of 93% reduction in mercury from all human sources including emissions originating from outside of Minnesota. The MPCA is working to meet the 93% reduction in the state by following the mercury TMDL implementation plan, developed by stakeholders in 2009.

The Mercury TMDL Implementation Plan included guidelines for increased mercury emissions that result from new sources and modifications to existing sources. The original guidelines were revised in 2012 with stakeholder input. The Guidelines for New and Modified Mercury Emissions Sources are applied to ensure that increases to mercury emissions will not jeopardize the statewide reduction goal needed to meet water quality standards.

To accomplish the reductions specified in the TMDL and implementation plan, the MPCA proposed and later adopted rules regarding mercury reduction plans in Minn. R. 7007.0502. These rules established mercury emissions reductions for certain sources of mercury air emissions to bring both public and privately owned facilities into line with the statewide mercury reduction goals. In order to evaluate the progress of reducing mercury in our waters, mercury emissions inventories are developed and tracked, and the subsequent response in fish tissue is documented.

IX. Conclusion

Mercury is a legacy contamination issue in the Great Lakes region that continues to have damaging impacts today. Promulgation of regulatory standards and mitigation of nonregulated sources have significantly reduced domestic use and release of mercury. However, mercury remains present in the environment, impacting fish and wildlife and human health. Changing climate conditions threaten to exacerbate these issues. Thus, additional studies are needed to continue to identify and quantify pollutant loadings, pathways and sources to the basin, many of which are from other countries. The U.S. and Canada have an opportunity to lead and advance this work through engaging with international counterparts through the Minamata Convention; providing support to research, technology development, and monitoring programs; and partnering with the states, provinces and indigenous communities.

Data Resources

- U.S. EPA Mercury Homepage
  https://www.epa.gov/mercury
- Environmental Mercury Mapping, Modeling, and Analysis, U.S. Geological Survey
  https://www.usgs.gov/science-support/emmma
- Great Lakes Sources of Mercury, U.S. Geological Survey:
  https://www.arcgis.com/apps/MapJournal/index.html?appid=2320e50936c946a4a3a7be6ce28d56e6
- National Atmospheric Deposition Program - Mercury Deposition Network:
  http://nadp.slh.wisc.edu/mdn/

References

Anderson, H. A., Amrhein, J. F., Shubat, P., & Hesse, J. (1993). Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. Great Lakes Sport Fish Advisory Task Force.

Bank, M. S. (Ed.). (2012). Mercury in the environment: Pattern and process. Berkeley: University of California Press.

Carrier, G., Bouchard, M., Brunet, R. C., & Caza, M. (2001). A toxicokinetic model for predicting the tissue distribution and elimination of organic and inorganic mercury following exposure to methyl mercury in animals and humans. II. Application and validation of the model in humans. Toxicology and applied pharmacology, 171(1), 50-60. https://doi.org/10.1006/taap.2000.9113

Dellinger, J. A. (2004). Exposure assessment and initial intervention regarding fish consumption of tribal members of the Upper Great Lakes Region in the United States. Environmental Research, 95(3), 325-340. https://doi.org/10.1016/j.envres.2003.07.012

Dellinger, J. A., Moths, M. D., Dellinger, M. J., & Ripley, M. P. (2014). Contaminant trends in freshwater fish from the Laurentian Great Lakes: a 20-year analysis. Human and Ecological Risk Assessment: An International Journal, 20(2), 461-478. https://doi.org/10.1080/10807039.2012.759475

Dellinger, M. J., Lyons, M., Clark, R., Olson, J., Pingatore, N., & Ripley, M. (2019). Culturally adapted mobile technology improves environmental health literacy in Laurentian, Great Lakes Native Americans (Anishinaabeg). Journal of Great Lakes Research, 45(5), 969-975. https://doi.org/10.1016/j.jglr.2019.07.003

Evers, D.C., Wiener, J.G., Driscoll, C.T., Gay, D.A., Basu, N., Monson, B.A., Lambert, K.F., Morrison, H.A., Morgan, J.T., Williams, K.A., Soehl, A.G. (2011). Great Lakes mercury connections: The extent and effects of mercury pollution in the Great Lakes region. Biodiversity Research Institute. https://www.glc.org/library/2011-great-lakes-mercury-connections

Evers, D. C., Savoy, L. J., DeSorbo, C. R., Yates, D. E., Hanson, W., Taylor, K. M., ... & Fair, J. (2008). Adverse effects from environmental mercury loads on breeding common loons. Ecotoxicology, 17(2), 69-81. https://doi.org/10.1007/s10646-007-0168-7

Environment and Climate Change Canada (2016). Canadian mercury science assessment: Summary of key results. https://www.canada.ca/en/environment-climate-change/services/pollutants/mercury-environment/science-assessment-summary-key-results.html

Environment and Climate Change Canada and U.S. Environmental Protection Agency (2021). Great Lakes Binational Strategy for Mercury Risk Management. https://binational.net/wp-content/uploads/2021/06/20210615-Mercury-Strategy-FINAL.pdf

Gagnon, V.S., Gorman, H.S., Norman, E.S. (2018). Eliminating the need for fish consumption advisories in the Great Lakes Region. A policy briefing. Great Lakes Research Center. Contribution No. 50.

Genchi, G., Sinicropi, M. S., Carocci, A., Lauria, G., & Catalano, A. (2017). Mercury exposure and heart diseases. International journal of environmental research and public health, 14(1), 74. https://doi.org/10.3390/ijerph14010074

Great Lakes Regional Collaboration. (2010). Great Lakes Mercury Emission Reduction Strategy.

Janssen, S.E., Hoffman, J. C, Lepak, R.F., Krabbenhoft, D.P., Walters, D., Eagles-Smith, C.A., Peterson, G., Ogorek, J.M., DeWild, J.F., Cotter, A., Pearson, M., Tate, M.T., Yeardley Jr., R.B., Mills, M.A. (2021). Examining historical mercury sources in the Saint Louis River estuary: How legacy contamination influences biological mercury levels in Great Lakes coastal regions. Science of the Total Environment, 779, 146284. https://doi.org/10.1016/j.scitotenv.2021.146284

Jo, S., Woo, H. D., Kwon, H. J., Oh, S. Y., Park, J. D., Hong, Y. S., Pyo, H., Park, K.S., Ha, M., Kim, H., Sohn, S.J., Kim, Y.M., Lim, J.A., Lee, S.-A., Eom, S.Y, Kim, B.G., Lee, K.M., Lee, J.H., Hwang, M.S., Kim, J. (2015). Estimation of the biological half-life of methylmercury using a population toxicokinetic model. International journal of environmental research and public health, 12(8), 9054-9067. https://doi.org/10.3390/ijerph120809054

Krabbenhoft, D. P., & Sunderland, E. M. (2013). Global change and mercury. Science, 341(6153), 1457-1458. https://doi.org/10.1126/science.1242838

Kuhnlein, H. V., & Receveur, O. (1996). Dietary change and traditional food systems of indigenous peoples. Annual review of nutrition, 16(1), 417-442. https://doi.org/10.1007/s10646-007-0168-7

Lepak, R. F., Yin, R., Krabbenhoft, D. P., Ogorek, J. M., DeWild, J. F., Holsen, T. M., & Hurley, J. P. (2015). Use of stable isotope signatures to determine mercury sources in the Great Lakes. Environmental Science & Technology Letters, 2(12), 335-341. https://doi.org/10.1021/acs.estlett.5b00277

Lepak,R.F., Janssen, S.E., Yin, R., Krabbenhoft, D.P., Ogorek, J.M., DeWild, J.F., Tate, M.T., Holsen, T.M., and Hurley, J.P. (2018). Factors affecting mercury stable isotopic distribution in piscivorous fish of the Laurentian Great Lakes. Environmental science & technology, 52(5), 2768-2776. https://doi.org/10.1021/acs.est.7b06120

Madsen, E. R., DeWeese, A. D., Kmiecik, N. E., Foran, J. A., & Chiriboga, E. D. (2008). Methods to develop consumption advice for methylmercury-contaminated walleye harvested by Ojibwe Tribes in the 1837 and 1842 ceded territories of Michigan, Minnesota, and Wisconsin, USA. Integrated Environmental Assessment and Management, 4(1), 118-124. https://doi.org/10.1897/IEAM_2007-026.1

Moses, S.K. (2018). Methods for 2018 update of GLIFWC's mercury maps for walleye consumption advice. GLIFWC Administrative Report 18-10. https://data.glifwc.org/archive.bio/Admin%20report%2018-10.pdf

Moses, S.K. (2020). Update of GLIFWC's mercury maps for walleye consumption advice. GLIFWC Administrative Report 20-03. https://data.glifwc.org/download/archive.bio/Admin%20Report%2020-03.pdf

Moses, S.K. (2020). An approach to developing mercury-based consumption advice for select species of Lake Superior fish: 2020 update. GLIFWC Administrative Report 20-06. http://data.glifwc.org/download/archive.bio/Lake%20Superior%20Mercury%20Map%202020%20Update%20Admin%20Rpt.pdf

Moses, S.K. (2011). 2009-2010 walleye total mercury analyses. GLIFWC Administrative Report 11-01. https://data.glifwc.org/download/archive.bio/Administrative%20Report%2011-01.pdf

Nabi, S. (2014). Toxic effects of mercury (Vol. 538). New Delhi, India: Springer India. https://doi.org/10.1007/978-81-322-1922-4_25

National Wildlife Federation (2006). Poisoning Wildlife: The Reality of Mercury Pollution. https://www.nwf.org/~/media/PDFs/Global-Warming/Policy-Solutions/NWF%20Poisoning%20Wildlife%20Report.ashx

Rice, D. C., Schoeny, R., & Mahaffey, K. (2003). Methods and rationale for derivation of a reference dose for methylmercury by the US EPA. Risk Analysis: An International Journal, 23(1), 107-115. https://doi.org/10.1111/1539-6924.00294

Schantz, S.l., Joseph C. Gardiner, Andréa Aguiar, Xiaoqin Tang, Donna M. Gasior, Anne M. Sweeney, Jennifer D. Peck, Douglas Gillard, Paul J. Kostyniak. (2010). Contaminant profiles in Southeast Asian immigrants consuming fish from polluted waters in northeastern Wisconsin. Environmental research, 110(1), 33-39. https://doi.org/10.1016/j.envres.2009.09.003

Scheuhammer, A. M., Meyer, M. W., Sandheinrich, M. B., & Murray, M. W. (2007). Effects of environmental methylmercury on the health of wild birds, mammals, and fish. Ambio, 12-18. https://doi.org/10.1579/0044-7447(2007)36[12:EOEMOT]2.0.CO;2.

Stevens, A. L., Baird, I. G., & McIntyre, P. B. (2018). Differences in mercury exposure among Wisconsin anglers arising from fish consumption preferences and advisory awareness. Fisheries, 43(1), 31-41. https://doi.org/10.1002/fsh.10013

Taylor Morgan, J., Drevnick, P. David, G., Bohr, J., McGeen, D. Hannan, F. (2017, July). Environmental Mercury Status and Trends in Michigan, USA. A Comprehensive Update of Environmental Mercury Releases, Usage and Levels in Air, Sediments and Fish. Poster presented at the International Conference on Mercury as a Global Pollutant, Providence, Rhode Island. https://www.michigan.gov/documents/egle/Mercury-Status-Trends-Michigan_736953_7.pdf

Turyk, M. E., Bhavsar, S. P., Bowerman, W., Boysen, E., Clark, M., Diamond, M., Mergler, D., Pantazopoulos, P., Schantz, S., & Carpenter, D. O. (2012). Risks and benefits of consumption of Great Lakes fish. Environmental health perspectives, 120(1), 11-18. https://doi.org/10.1289/ehp.1003396

United States vs. Michigan (1981). 471 F. Supp. 192 (W.D. Mich. 1979), aff'd 653 F.2d 277 (6th Cir. 1981), cert. denied, 454 U.S. 1124. https://case-law.vlex.com/vid/653-f-2d-277-596071742

U.S. EPA (2021, March 3). Health Effects of Exposures to Mercury. https://www.epa.gov/mercury/health-effects-exposures-mercury

Appendix A. Great Lakes Commission Ad Hoc Committee on Mercury Contamination: Charge and Membership

Charge

The charge to the Ad Hoc Committee on Mercury Contamination is to develop a policy resolution focusing on mercury monitoring, research and reduction legislative priorities and other needs in the Great Lakes-St. Lawrence River basin. This committee will present this policy resolution to the Great Lakes Commission (GLC) at its Annual Meeting in October 2021.

The committee is also asked to consider the overall needs of the basin and the GLC's near-term and long-term roles on this issue, and lay a foundation for associated activities going forward. Specifically, this will include:

- Developing a new draft policy on mercury monitoring, research and reduction for consideration at the 2021 Annual Meeting;
- Considering state and provincial priorities regarding mercury contamination and reduction;
- Addressing the federal role and federal legislative opportunities that will benefit the Great Lakes and St. Lawrence River;
- Evaluating the benefits of a Great Lakes air deposition and reduction program to the region.

Background

For more than 15 years (from 1996 to 2011), the GLC maintained an active program dealing with air pollution and air deposition in the Great Lakes. During this period, the GLC managed a U.S. Environmental Protection Agency (U.S. EPA) Region 5 program to manage the multi-state Great Lakes Air Deposition (GLAD) program and its important Regional Air Pollutant Inventory Development System (RAPIDS). These programs, among other services to the jurisdictions, passed through grants and contracts to state agencies and academic institutions to address problems of deposition of mercury and other pollutants.

Some of the GLAD program priorities over the years included monitoring mercury deposition from rainfall events in Indiana, Michigan, and New York; evaluating the effects of conventional forest harvesting on mercury mobility and bioaccumulation in the northern forested region of the Great Lakes basin; identifying risks to humans from exposure to mercury along the St. Clair River; enhancing understanding of atmospheric cycling of persistent bioaccumulative toxics in the Lake Superior watershed; estimating deposition rates for a class of emerging chemicals of concern across the Great Lakes; and assessing the effectiveness of recent chemical management policies on reducing levels of contamination in Lake Ontario's fish, among others.

During the 2009-10 U.S. congressional session, a "Comprehensive National Mercury Monitoring Act" was introduced in the United States Senate. The intent of this legislation was to provide funding to track mercury cycling in the environment to better inform local, regional, national and international mercury reduction polices and to track progress toward these goals. Authorization of this legislation was consistent with recommendations outlined in the "Great Lakes Regional Collaboration Strategy" report and would augment efforts being undertaken at the time to reduce atmospheric pollution under the GLAD Program and the new Great Lakes Restoration Initiative (GLRI). Importantly, because of the passage of the GLRI, the GLC was informed that the GLAD program would be discontinued at the end of FY 2011.

The GLC adopted a resolution at its 2010 Annual Meeting titled Promoting Comprehensive Mercury Monitoring, Research and Reduction Efforts. The purpose of this resolution was to allow the GLC to participate in this important national dialogue, keep the states provinces informed of these discussions and to advocate for comprehensive mercury monitoring and reduction policies that would benefit the Great Lakes-St. Lawrence River basin. This bill did not pass in the 111th Congress and was not enacted into law. The bill was reintroduced in 2011, 2015, and 2018 without action. It was reintroduced again by Senator Susan Collins of Maine during the 2019 legislative session but has not been referred to committee.

In addition to the federal legislation still being pursued, on March 30, 2020, U.S. EPA issued a new mercury inventory report that includes an updated inventory reporting rule. Further, mercury is an identified "Chemical of Mutual Concern" (CMC) under Annex 3 of the Great Lakes Water Quality Agreement.

The Resolutions Review Committee in its review of this 2010 resolution considered the importance of a program for the monitoring, research and reduction to the Great Lakes-St. Lawrence River basin and recommended that an Ad Hoc Committee be assigned the task of updating the 2010 resolution in time for the 2021 GLC Annual Meeting.

Membership

Illinois
John J. Kim, Director
Illinois Environmental Protection Agency

Indiana
Bruno Pigott, Commissioner
Indiana Department of Environmental Management

Michigan
Joy Taylor Morgan, Great Lakes Air Toxics Coordinator
Air Quality Division, Toxics Unit
Michigan Department of Environment, Great Lakes, and Energy

Minnesota
Hassan M. Bouchareb, Engineer
Environmental Analysis & Outcomes Division
Minnesota Pollution Control Agency

New York
Prabhat Mallik, Sr. Research Scientist
Division of Materials Management
New York State Department of Environmental Conservation

Ohio
Audrey Rush, Manager
Standards and Technical Support
Division of Surface Water
Ohio Environmental Protection Agency

Pennsylvania
Jim Grazio, Great Lakes Biologist
Office of the Great Lakes
Pennsylvania Department of Environmental Protection

Québec
Kerith W. Brand, Public and Governmental Affairs Attachée
Québec Government Office in Chicago

Marissa Gravel-Labelle,
Midwest Desk Officer – United States Division
Ministère des Relations, internationales et de la Francophonie

Wisconsin
Donalea Dinsmore, Quality Assurance and Funding Coordinator
Office of Great Waters
Wisconsin Department of Natural Resources

Chippewa Ottawa Resource Authority
Mike Ripley, Environmental Coordinator

Great Lakes Indian Fish and Wildlife Commission
Sara Moses, Environmental Toxicologist

Appendix B. State mercury program summaries

As submitted by members of the Great Lakes Commission Ad Hoc Committee on Mercury Contamination

Illinois

Illinois has multi-media regulatory programs and practices in place to address environmental concerns associated with mercury. In 2006, following extensive public outreach and internal research and development, the Illinois Environmental Protection Agency (Illinois EPA) proposed rules which implemented more aggressive mercury emissions standards that would obtain greater mercury reductions as compared to the federal Clean Air Mercury Rule. Though the federal rule would later be overturned, Illinois' rule remains in full effect. The rule requires 90 percent emissions reductions and prohibits coal-fired power plants from purchasing allowances, or trading emissions credits with other companies or states.

There are several Illinois laws which authorize programs that regulate and limit or prohibit mercury content in certain products. Products which have restrictions related to mercury content include thermometers, cosmetics, novelty products, K-12 grade school instructional equipment, electrical switches and relays, barometers, hydrometers, and flow meters. Automobile switches containing mercury must be removed prior to the vehicle being crushed or otherwise processed, with the switches required to be properly recycled. Illinois is included among several states that prohibit the sale and distribution of new mercury switch thermostats used for heating and cooling in buildings.

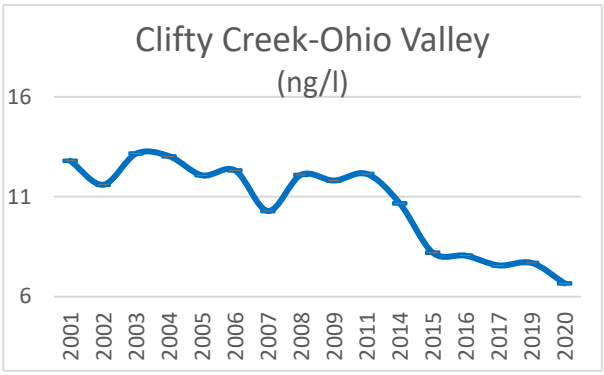
Illinois EPA administers periodic household hazardous waste collection programs, on its own and in partnership with counties and local governments, to accept bulk mercury and mercury-containing items from citizens and households. The collection programs have proven to be very successful and effective in providing a safe means of disposal that would otherwise not exist for many residents.

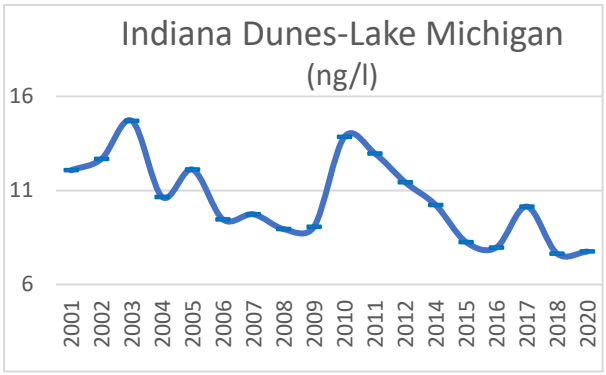
The state's Fish Contaminant Monitoring Program (FCMP) tests mercury levels in fish tissues through the coordinated efforts of several state agencies. The Illinois Department of Natural Resources collects fish for testing and passes them on to the Illinois EPA. Following Illinois EPA's analysis of mercury in fish tissue, the Illinois Department of Public Health issues any appropriate fish advisories.

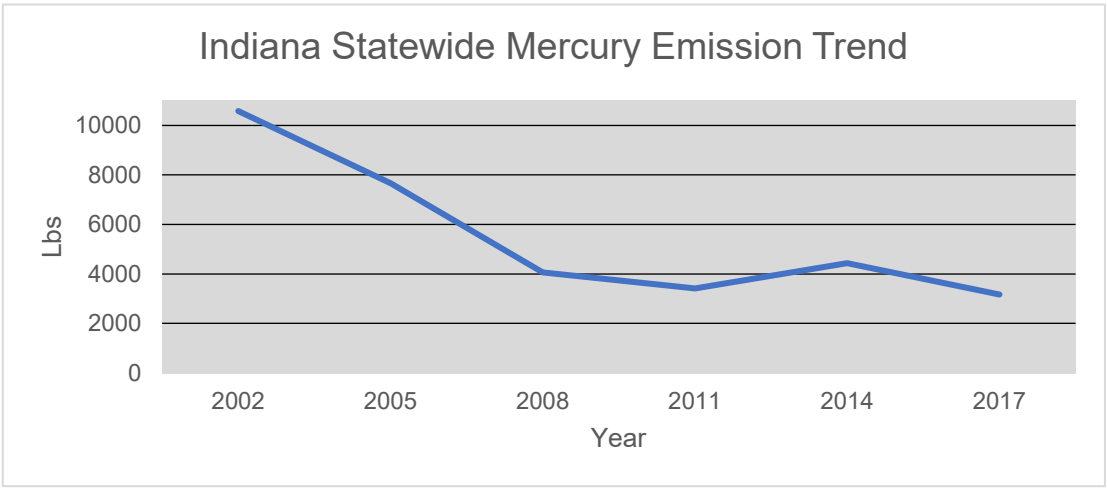
The FCMP also served as a basis for the development of a Total Maximum Daily Load (TMDL) report which addresses mercury impairments in 56 waterbody segments located in the Illinois Lake Michigan nearshore. This TMDL uses the target fish tissue concentration from the FCMP as the starting point for issuing a "one meal per week" advisory. This was used to set a reduction target for atmospheric mercury loading in order to achieve compliance with the fish consumption use.

Indiana

Although many voluntary and regulatory actions have led to reductions in mercury emissions over the past two decades, there are three measures that led to substantial reductions in Indiana. The first is the Mercury and Air Toxics Standards (MATS) which was promulgated in 2011 and significantly reduced mercury emissions from coal-fired power plants. The second is the Major Source Boiler Maximum Achievable Control Technology (Boiler MACT) that reduced mercury emissions for commercial, industrial, and institutional boilers, which was first promulgated in 2013 and strengthened since. Lastly is Indiana's mercury switch removal law, which requires automobile recyclers to remove mercury switches prior to processing scrap metal. This significantly reduces mercury emissions from steel manufacturing processes.







The charts reflect the trend associated with wet deposition monitoring concentrations of mercury in Indiana from 2001 through 2020 for the most southern and northern sites in Indiana. The Clifty Creek monitoring site is located just north of the Ohio River and has collected data that reflects a reduction in mercury concentrations of 48% since 2001. The Indiana Dunes monitoring site is located on the southern shore of Lake Michigan and it has collected that that reflects a reduction in mercury concentrations of 36% since 2001. Also, as illustrated, Indiana statewide mercury emissions have declined by 70% over a similar period of time.

Michigan

Identification of mercury pollution dates back to the 1970s, first reductions were concentrated on direct water discharges followed by focused efforts on air emission reductions in the 1990s. A State-wide Mercury Pollution Prevention Task Force completed their report in 1996 followed by a Michigan Mercury Action Plan and a state-wide Michigan Mercury Strategy Report in 2008 (www.michigan.gov/eglemercury) with a goal of eliminating anthropogenic mercury use and releases in Michigan. The Department of Environment, Great Lakes and Energy (EGLE) developed air pollution control rules in 2009 to reduce mercury emissions from coal-fired electric generating units (EGUs). These rules required a 90% reduction from 1999 baseline levels (Michigan Air Pollution Control Rules). All Michigan EGUs were in compliance with these rules when they went into effect on April 16, 2015. Companies were able to meet these requirements by installing air pollution controls and by meeting the requirements of 40 CFR Part 63 Subpart UUUUU – National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Utility Steam Generating Units (Mercury and Air Toxics Standard or MATS) (Mercury and Air Toxics Standards (MATS) | US EPA) converting to natural gas-fired electric generation or in some cases older EGUs were shut down.

In 2018 EGLE completed, and EPA subsequently approved, a state-wide mercury total maximum daily load (TMDL) to address mercury-impaired waters as required by the CWA. The TMDL addressed Michigan's inland waters not meeting water quality standards due to atmospheric deposition. According to the TMDL, anthropogenic atmospheric sources of mercury from Michigan must be reduced by 81% from 2001 levels to meet this goal (www.michigan.gov/eglemercury). Progress in achieving this goal in Michigan will be tracked using air emissions from the year 2002 as the baseline, since a complete emissions inventory for the baseline year 2001 is not available. Mercury fish tissue concentrations will also continue to be monitored to determine future progress. Mercury emission inventories have been developed for 2005, 2008, 2011, 2014 and are on the EGLE mercury web site under "mercury air issues" and a draft 2017 mercury emissions inventory has just been developed and should be posted to the EGLE Mercury Webpage by 2022.

Under the National Pollutant Discharge Elimination System (NPDES) permitting program in Michigan, dischargers are subject to a 1.3 nanograms per liter (ng/L) effluent limit. If a permittee qualifies for and is approved for inclusion under Michigan's Multiple Discharger Variance for Mercury, they can have a variance from an effluent limit of 1.3 ng/L, resulting in a higher mercury limitation in their permit. Any permittee with a higher limitation in their permit is required to implement a pollutant minimization program, which focuses on reducing sources of mercury. Michigan has seen great success utilizing pollutant minimization programs for mercury. During the last request to USEPA for approval of Michigan's Multiple Discharger Variance for Mercury (dated August 27, 2019), 95% of dischargers covered under the NPDES permitting program had average effluent concentrations equal to or less than 5.0 ng/L and 45% had average effluent concentrations equal to or less than 1.3 ng/L. Michigan's Multiple Discharger Variance for Mercury can be found at this link: https://www.michigan.gov/documents/egle/egle-wrd-michiganmultipledischargervariance-20202024_674158_7.pdf.

Minnesota

A number of efforts are in place to reduce mercury emissions in Minnesota. State statutes and rules, along with national standards for mercury and air toxics emissions from coal-fired utility boilers, have resulted in significant reductions in emissions of mercury and other pollutants in Minnesota. In 2006, Minnesota passed the Mercury Emissions Reduction Act (MERA), which set a schedule for the largest coal-fired utility boilers in the state to reduce mercury emissions by 90% from 2005 levels. As of 2015, all Minnesota utilities have achieved full compliance with MERA. To get there, they retrofitted some coal plants with improved pollution controls, switched some to natural gas, and shut down others.

The Minnesota Mercury Reduction Plan rules (Minn. R. 7007.0502) required certain sources of mercury to prepare and submit a mercury reduction plan to reduce mercury emissions. Facilities that emit more than 3 pounds of mercury were required to complete a mercury reduction plan. Briefly:

- Ferrous mining or processing facilities were required to reduce mercury emissions by 72% from 2008/2010 emission levels by January 1, 2025.
- Boiler owners/operators with individual emissions greater than 5 pounds were required to comply with the applicable federal regulations and ensure that a reduction of at least 70% was achieved by January 1, 2018.
- Iron and steel melters were required to reduce mercury emissions to less than 35 milligrams per ton of iron/steel produced by June 30, 2018.
- Mercury emission sources with processes that individually emit three or more pounds of mercury per year were required to reduce emissions by at least 70% by January 1, 2025.

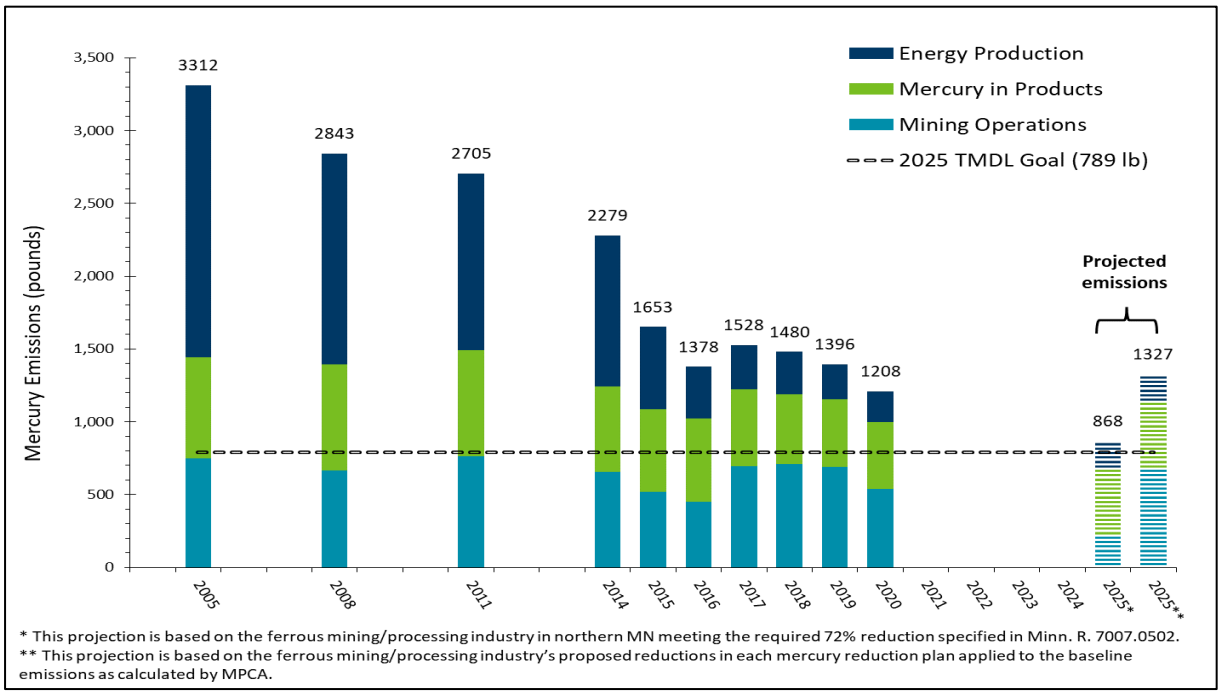


Figure. Mercury emissions from Minnesota sources; 2025 emission projections are based on measured and calculated inventories in previous years and the emission estimates contained in the mercury reduction plans submitted by the ferrous mining/processing facilities in northern Minnesota.

Additionally, some municipal and industrial wastewater dischargers are required to submit a mercury minimization plan as part of their National Pollutant Discharge Elimination System (NPDES) permit. This plan focuses on measuring mercury concentrations, evaluating the reduction potential of the facility and its users, a summary of reduction activities implemented in previous five years, and creating an implementation plan for mercury management/reduction for the next five years.

All the waters in the state will benefit from the statewide mercury reduction plan, but not all waters respond the same to reduced emissions. The primary goal is to substantially lower mercury in fish and make them safer to eat. Minnesota's Draft 2020 Impaired Waters List includes 5,774 water quality impairments in 3,416 different bodies of water. Of the waters tested, mercury is the cause of 1,653 impairments in 1,245 different lakes and rivers. About 73% of our waters will reach the goal if the plan is fully implemented. For the remaining 27%, more work is needed to understand why these waters remain high in mercury despite lower emissions.

New York

Regulations and Monitoring:

The 1990 Amendment of Clean Air Act required that the USEPA assess the US Hg emission source and impact on human health and environment. In accordance with that, in 1995, officials from New York State, eastern Canadian Province and other North Eastern States started developing a program to study on Hg. In 1998, the major conclusion from the study was that 47% of the Hg deposition in the Northeast is due to regional source, 30% to US sources are outside the region and 23% comes from global atmospheric reservoir. Since 1998, New

York State took multi-step approach to control the release of Hg in the environment by promulgating several laws rules and regulations.

In 2007, for Northeast United States, based on calculation in the Total Maximum Daily Load (TMDL), 98% of the mercury load to surface waters is the result of atmospheric deposition and the remaining 2% is due to effluent discharges. According to the TMDL, a 98% reduction in atmospheric deposition of mercury is needed in order to meet water quality goals - which is set at a standard of 0.7 ng/L (6NYCRR Part 703.5).

Air emissions of Hg, which is at present is the major anthropogenic source of global Hg, was controlled from the coal-fired electric utility power plant through several phases. In 2006, Part 246 of 6 NYCRR was promulgated to reduce the Hg emission approximately 50% by the year 2010 and by 90% by 2015. In the second phase, in 2015, NYSDEC implemented a plant-wide average emission limit for each power plant facility equivalent to 0.6 lb Hg/trillion Btu - which is stricter than proposed by USEPA. Regulations finalized to phase out coal fired power plants in New York by end of 2020, is the latest one.

Other important areas which are regulated include: require dental amalgam separator, ban sale of Hg in (thermostats, switches, relays, fever thermometer, measuring devices, manometers, sphygmomanometers, toys etc.), limit quantity of Hg in vehicle component to 15mg, lamp disposal ban and ban purchase of Hg products in school.

Atmospheric Hg deposition in NY State is monitored from five sampling locations through Mercury Deposition Network. Trough 2015-2018 the average Hg concentration was 7.6 ng/L across the five sites. Surface water Hg is sampled through the NYSDEC's Rotating Integrated Basin Studies (RIBS) program, in which two to four of the State's 17 major drainage basins are sampled each year over a 5-year cycle. Ninety-five percent (95%) of the RIBS samples collected from 2015-2018 contained Hg at levels above 0.70ng/L and yielded statewide average and median concentrations of 2.28 ng/L and 1.6 ng/L, respectively.

The New York State Department of Health (NYSDOH) regularly issues fish advisories for New York waterbodies to warn consumers of potential hazards.

Research and Findings:

To understand the present status of mercury in environment, to inform policy makers and for public understanding New York State Energy Research and Development Authority (NYSERDA) sponsored a program in New York State on Hg. This effort resulted in the publication of 23 papers in Ecotoxicology in the year 2020. Authors focused on Hg in atmospheric deposition, water, fish and wildlife - to address the questions of Hg in relation to biotic and abiotic factors in spatial and temporal pattern. Some of these papers included data available from 1969 through 2017. All data comprise the NYSERDA's "Synthesis of Environment Mercury Loads in New York State (1969-2017)" is available in Open NY (https://data.ny.gov/Energy-Environment/Synthesis-of-Environmental-Mercury-Loads-in-New-Yo/v475-sje9). From the findings of some of these papers provides an assessment of the impact of Hg in Great Lake Region.

Much of the Great Lakes basin in New York State is a net sink for Hg inputs, with more Hg entering into the basin through emissions and deposition than leaving to the atmosphere or drainage losses (Denkenberger et al. 2012). Study by Ye et al. (2020) suggested that New York State in-state emissions and the Northeastern US emission reductions from 2005 to 2011 did not significantly alter Hg wet and dry deposition in the two Great Lakes (Ontario and Erie) adjacent to New York State (NYS), and rural land areas of Upstate New York, when averaged over time and space. A three yearlong study (Zhow et al. 2019), on Rochester, NY shows that the

ambient mercury in the area was a non-local source. Due to the closure of a coal-fired power plant and promulgation of several fuel quality policies reduced local mercury emissions making long distance transport the major source of Hg in Rochester.

Fish Hg concentration is generally declining in Great Lakes since 1980. But a study from 2004 through 2015 on lake trout and walleye shows a declining trend in all Great Lakes except for Lake Erie and Lake Ontario (Fig. 1, Zhou et al. 2017). Fish Hg concentrations for Lake Erie and Lake Ontario over the past three decades, remain on average above the 0.22 ppm (ww) advisory threshold. Top nine species out of 15 species analyzed in these two lakes are above this limit (Fig. 2, Evers et al. 2020).

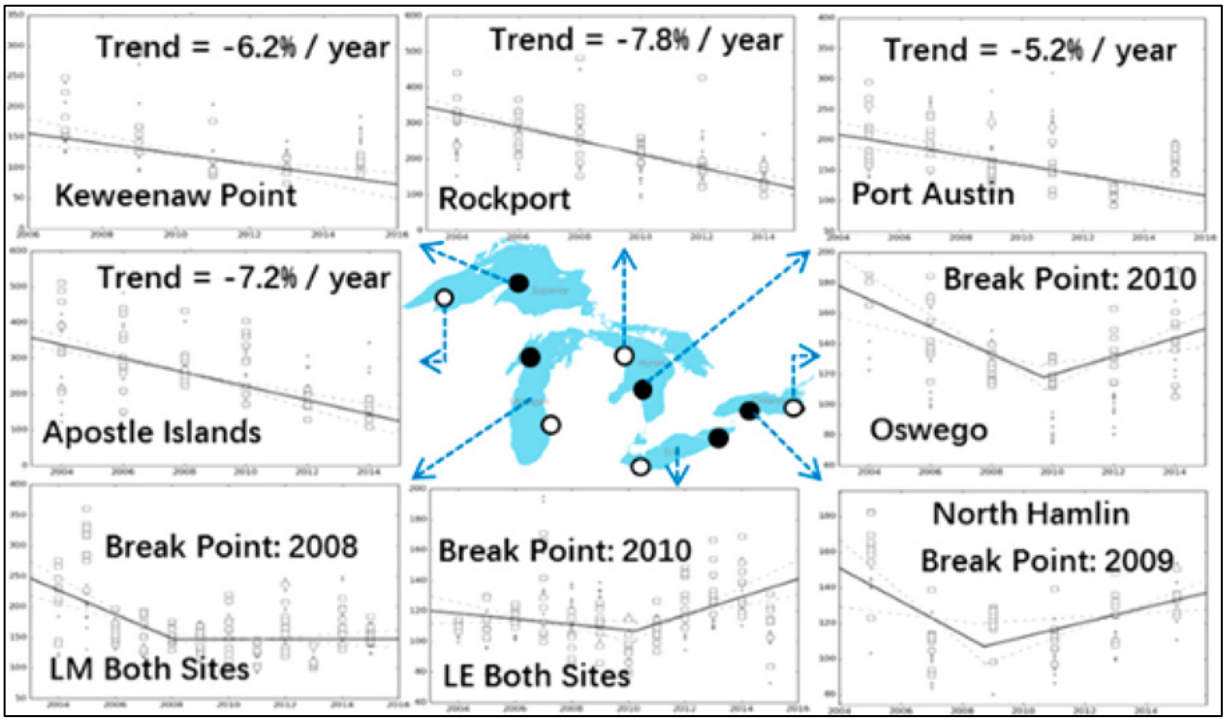


Figure. Hg temporal trend in top predator fish of the Laurentian Great Lakes from 2004 - 2015 (Zhou et al. 2017).

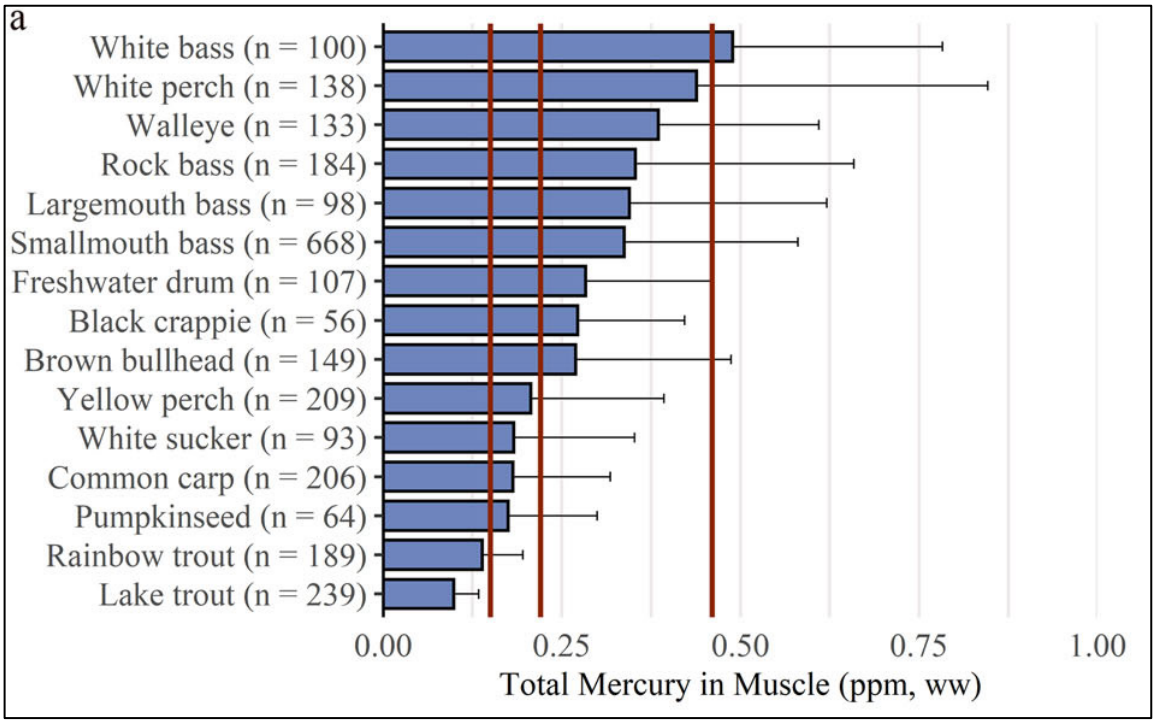


Figure. Mean concentrations and standard deviation of Hg in fish of Lake Erie and Lake Ontario of New York State (n=2633). Three vertical lines indicate consumption advisory levels. The 0.15 and 0.46 ppm vertical lines bracket the USEPA advisory levels. The mean Hg concentration of 9 of 15 species exceed the 0.22 ppm health threshold suggested by the Great Lakes Consortium (Evers et al. 2020).

References:

- Denkenberger JS, Driscoll CT, Branfireun BA, Eckley CS, Cohen M, Selvendiran P (2012) A synthesis of rates and controls on elemental mercury evasion in the Great Lakes Basin. Environ Pollut 161:291–298
- Evers DC, Sauer AK, Burns DA, Fisher NS, Bertok DC, Adams EM, Burton MEH, Driscoll CT (2020) A synthesis of patterns of environmental mercury inputs, exposure
- and effects in New York State. Ecotoxicology 29:1565–1589
- Ye Z, Mao H & Driscoll CT (2020) Impacts of anthropogenic emissions and meteorology on mercury deposition over lake vs land surface in upstate New York. Ecotoxicology 29:1590-1601
- Zhou C, Cohen MD, Crimmins BA, Zhou H, Johnson TA, Hopke PK, Holsen TM (2017) Mercury Temporal Trends in Top Predator Fish of the Laurentian Great Lakes from 2004 to 2015: Are Concentrations Still Decreasing? Environ. Sci. Technol 51:7386−7394
- Zhou H, Hopke PK, Zhou C, Holsen TM (2019) Ambient mercury source identification at a New York State urban site: Rochester, NY. Science of the Total Environment 650:1327–1337

Ohio

Fish Consumption

Lake Erie fish were first collected and analyzed for mercury in 1971 and the Ohio Fish Consumption Advisory has been in place since 1992. The statewide advisory in Ohio is one meal per week. However, several species from many tributaries, reservoirs and Lakes throughout the state are restricted to one meal per month due to mercury contamination. Steelhead trout, brown bullhead, and smallmouth bass have a one meal per month advisory for Lake Erie due to mercury.

NPDES permits

There are approximately 200 facilities with permit limits or monitoring requirements in the Lake Erie Basin. Although mercury dischargers have declined over the decades, facilities' total load to the Lake Erie watershed is approximately 2.5 Kg/yr. A general mercury variance has been included in Ohio's rules to offer NPDES permittees an opportunity for relief from installing costly end-of-pipe treatment in order to comply with low average water quality-based mercury limits (12 ng/L). The average cost to remove mercury through end-of-pipe treatment is in excess of ten million dollars per pound of mercury removed. As of 2018, there were approximately 150 facilities that utilize the mercury variance.

Solid Waste

In December 2000, mercury containing equipment (MCE - thermostats, barometers, manometers, temperature and pressure gauges, and mercury switches, such as light switches in automobiles) was added by rule to the definition of universal waste (MCE as universal waste). This rule allows consolidation of MCE waste at central locations making it easier for small users to collect and recycle at various locations throughout Ohio. Prior to adding MCE to the universal waste rule, such materials were not regulated when recycled.

Dental Amalgam Standard

In August 2017, Ohio EPA published a dental amalgam factsheet as part of the NPDES pretreatment program in response to federal rule and guidelines. This rule requires dental offices including large institutions such as dental schools and clinics, that discharge to a POTW, to install dental amalgam separators. Once captured by the separator, dental amalgam can be recycled and is a common-sense solution to managing mercury that would otherwise be released to air, land and water.

Pennsylvania

Pennsylvania has a number of programs designed to monitor and reduce toxic pollutants like mercury throughout the Commonwealth. Like other states, Pennsylvania enforces National Emissions and Performance Standards in its Air Quality permitting and compliance monitoring programs and has incorporated uniform Great Lakes Initiative criteria for toxic pollutants including mercury into its enforceable Water Quality Standards. The Commonwealth has a number of unique programs designed to proactively reduce the use of mercury at the source. These include a Small Business Assistance Program and Energy and Technology Development initiatives. In addition, on Oct. 9, 2008, Act No. 97 (HB 44), the Mercury-Free Thermostat Act, was signed into law. The law requires manufacturers of mercury thermostats that have been sold in the state to establish and maintain a collection and recycling program for out-of-service mercury thermostats from wholesalers, contractors, retailers, service technicians and homeowners.

The Commonwealth also has monitoring programs that track levels of mercury and other toxics in the ambient air and fish tissue. Pennsylvania participates in the National Air Deposition Program with a network of 21 fixed ambient air monitoring stations. A Mercury Deposition Network monitoring station on Presque Isle State Park within Pennsylvania's Lake Erie watershed was monitored from 2000-2020 (Figure 1). During this period of

time mercury levels in monitored deposition decreased significantly from over 9 ng/L to approximately 6 ng/L (Figure 2).

Despite this encouraging trend, this persistent, bioaccumulative, toxic (PBT) metal is remains present in the aquatic environment (along with other PBTs) in sufficient quantities to warrant fish consumption advisories for certain fish species in the Pennsylvania waters of Lake Erie and elsewhere in the Commonwealth.

Figure. National Air Deposition Monitoring Site PA 30 on Presque Isle State Park, Erie, Pennsylvania.

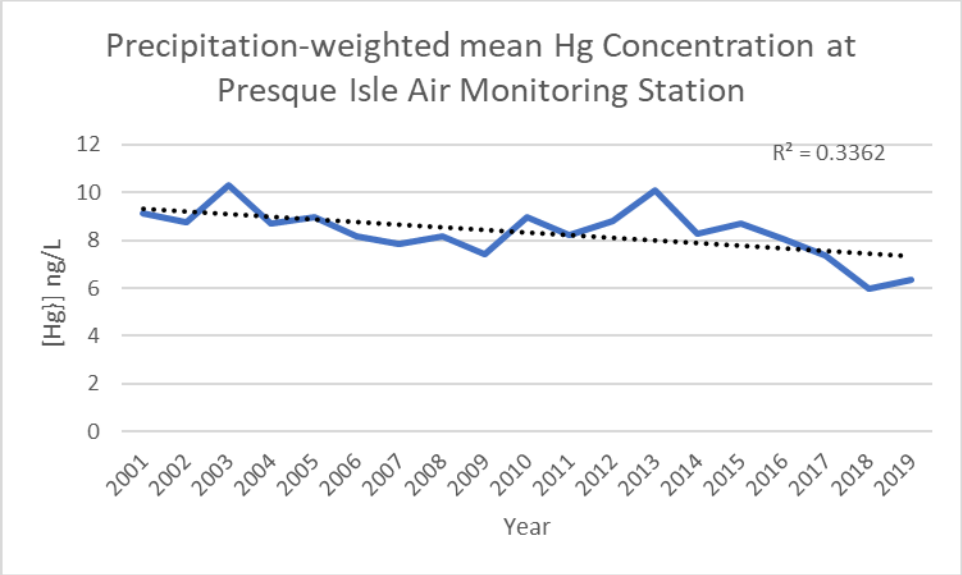


Figure. Mercury concentrations in atmospheric deposition have decreased significantly (p=0.009) at the Presque Isle Mercury Deposition Network Monitoring Station over the last two decades

Wisconsin

As a pollutant that is regulated or managed under multiple programs, information about those efforts is collected on a Mercury topics page on the WDNR websites. Wisconsin's efforts to manage and control mercury emissions and discharges have evolved over the past three decades. Early work included developing clean sampling techniques for obtaining reliable water quality and adapting those sampling techniques implement water quality-based mercury limits into the wastewater permits program. Wisconsin Wisconsin's statewide safe-eating guidelines consider that fish in all Wisconsin waters contain mercury. DNR issues waters-specific advice where fish have higher concentrations for mercury (published advice is based on the highest contaminant of concern).

Administrative rules for controlling mercury air emissions have been in place since 1997, with revisions in 2008 and 2014 that include provisions for 90 % mercury reductions for coal-fired power plants. With these regulatory controls plus reductions in the number of coal-fired power plants and a manufacturing process shift at a chlor-alkali to eliminate the mercury cell, between 2008 and 2017 mercury air emissions were reduced by 75%. The Air Management Program actively participates in the National Atmospheric Deposition Network (NADP) operated by the Wisconsin State Laboratory of Hygiene. Five MDN sites operate in Wisconsin, including one site operated by the Forest County Potawatomi.

Wisconsin enacted a mercury ban in 2009, regulating the sale, distribution and use of specific mercury and mercury-containing devices, with some exemptions (e.g. there is no reasonable alternative). Administrative rules effective September 1, 2000 replaced the hazardous waste identification and listing rule and update definitions of solid waste and revised rules associated with handling hazardous materials that include recycling materials that contain mercury. Successful waste minimization efforts have reduced the number of hazardous waste generators and the quantities generated. Pollution prevention efforts include the Clean Sweep, a grant program administered by the Department of Agriculture, Trade and Consumer Protection to collect household and agricultural hazardous waste and very small quantities of hazardous waste generated by businesses. In addition, consumers are encouraged to recycle light bulbs. Many communities have multiple options for recycling, including a retailer take back program. Focus on Energy, a partnership with Wisconsin utilities, maintains an on-line Find a Retailer tool.