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Canadian Mercury Science Assessment **Executive Summary**



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Canadian Mercury *Science Assessment* **Executive Summary**

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INTRODUCTION

Mercury is a metal released into the ecosystem through both natural events, such as forest fires and volcanic eruptions, and through human activities, such as coal burning and metal smelting. In its elemental form, mercury is stable in the air and can travel far from emission sources. When deposited in the environment, mercury may be transformed by natural processes to its organic and toxic form, methylmercury. Methylmercury can accumulate in biota (living organisms such as plants and animals) and in humans at levels that can pose serious health risks. Mercury is a persistent global pollutant that is a threat to human and environmental health, and global action is needed to mitigate exposure risks.

Mercury exposure at elevated levels can have effects on human neurological, immune, and reproductive systems. The primary route of exposure to mercury for humans is through the consumption of fish and certain wildlife species. The pathway from emission sources (where pollutants are discharged to the environment) to accumulation in fish is complex; therefore, predicting how changes in sources will affect the level of mercury in fish requires considerable knowledge from many different fields of expertise. In Canada, mercury levels in various media (e.g., lake sediments, some biota) and some human populations have increased several-fold since the onset of the industrial era. Over 90% of the fish advisories in Canada are due to mercury, and many fish and fish-eating birds and mammals are at risk from mercury exposure. In the Arctic, levels of mercury remain high in some wildlife, and exposure to mercury through the consumption of traditional foods may pose health risks to northern Canadians. Overall, mercury remains a concern in many regions of the country.

This assessment is a synthesis of scientific research that has been undertaken in Canada over the past 20 years to understand the status of mercury in the Canadian environment and the impact of mercury on Canadian ecosystems and population. While several Arctic and global assessments specifically related to mercury over the past 10 years have identified this metal as an important environmental and health issue, the Canadian Mercury Science Assessment,

which includes up-to-date information on mercury in Canada as a whole, is the first comprehensive evaluation of mercury in the Canadian environment.

The Canadian Mercury Science Assessment presents science conducted under the Clean Air Regulatory Agenda (CARA) Mercury Science Program, led by Environment Canada, and the Northern Contaminants Program (NCP), led by Aboriginal Affairs and Northern Development Canada as well as scientific work funded by Health Canada, Natural Resources Canada, Fisheries and Oceans Canada, provincial and territorial governments, the Natural Sciences and Engineering Research Council, International Polar Year, and industry.

The CARA Mercury Science Program was created in 2007 to establish the scientific knowledge base to support regulatory decision-making on mercury. The intent of the program was to determine key indicators of environmental quality and risk to human health relevant to atmospheric emissions of mercury. Researchers were tasked with quantifying current and past levels of mercury in the environment as well as identifying gaps in the current state of knowledge of the transport routes from point of emission to exposure of wildlife, such as fish, and of humans. Researchers were also challenged to develop the capacity to predict changes in indicators (e.g., mercury levels in fish) that are associated with changes in levels of atmospheric emissions of mercury or changes in the receiving environment. Contributions from over 230 researchers are included in this assessment.

Despite a decrease in mercury emissions from sources in Canada, the United States, and Europe, global emissions of mercury are on the rise, mainly due to contributions from Asia, which currently account for approximately 50% of the total anthropogenic emissions (those originating from human activity).¹ Globally, over 2 000 tonnes (t) per year¹ of mercury is discharged into the air from anthropogenic sources. When emitted to the air, mercury can travel long distances before it is deposited onto the landscape. Reported Canadian anthropogenic atmospheric mercury emissions

1 UNEP, AMAP, 2013. Technical background report for the global mercury assessment 2013. Arctic Monitoring and Assessment Programme/UNEO Chemicals Branch, Oslo/ Geneva, p. 263 pp.

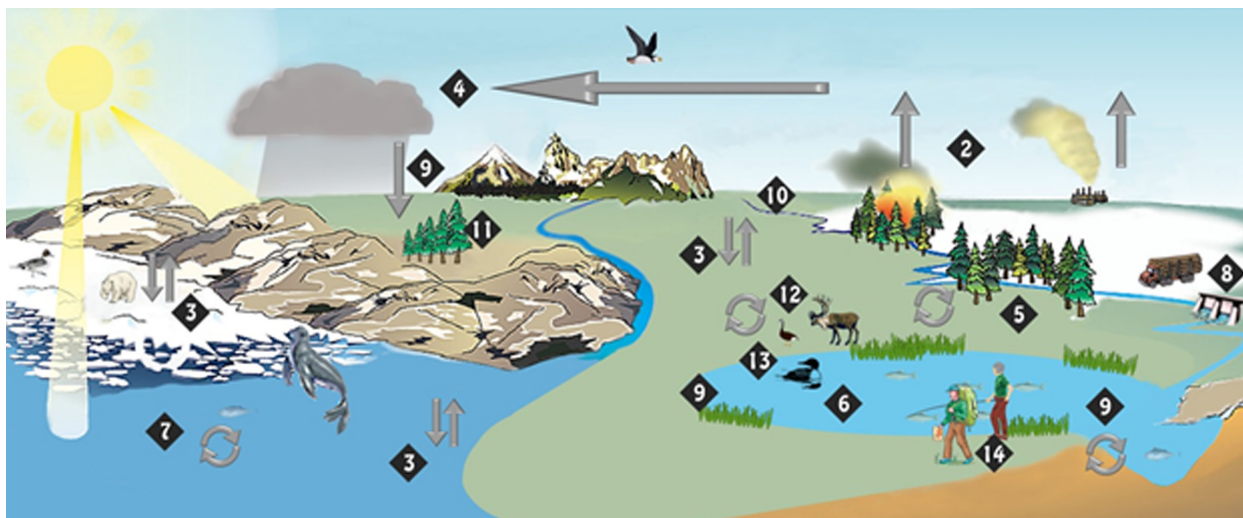


Figure 1: The movement of mercury through the ecosystem (as indicated by the arrows).

decreased 85% between 1990 and 2010² and currently account for a low percentage of the world's anthropogenic emissions of mercury to the air (<0.5%). Despite the decrease in domestic anthropogenic emissions of mercury, the concentrations of mercury in air and biota have not declined accordingly. Part of the reason for this discrepancy is that only a portion of the mercury measured in Canada is a result of Canadian emissions. As a whole, 95% of anthropogenic mercury deposition in Canada is derived from foreign emission sources. However, in areas close to point sources (such as coal-burning power plants and metal smelters) of mercury emissions, the local contribution of domestic emissions to mercury deposition can be much higher. Experimental studies and model projections indicate that, despite the relatively small contribution of domestic emitters to the atmospheric mercury burden in Canada, further reductions in mercury emissions from domestic sources would result in a decrease in mercury levels in biota such as fish and wildlife near these sources. These studies also show that emission reductions from foreign sources will further reduce mercury levels in biota in Canada. However, emissions reductions do not lower mercury levels in the Canadian environment following a linear relationship. Because of complex processes involved in the transport of mercury (see Figure 1) from emission sources to deposition, transformation,

and bioaccumulation, reductions in environmental levels of mercury can be delayed, particularly in regions distant from the sources.

Mercury is generally found in the air in three forms: elemental, reactive (or oxidized), and bound to particles. Gaseous elemental mercury is the dominant form in the air, and it can travel long distances from emission sources. Depending on the chemistry of the atmosphere and the amount of sunlight present, this elemental form can be transformed to oxidized or particle-bound mercury, which are more readily deposited from the atmosphere to landscapes and water bodies. Once deposited on plants, soil, or into bodies of water, mercury can either be transformed back to its elemental form and be released, or enter the ecosystem as oxidized or particle-bound mercury. The properties of the receiving environment (such as lakes, wetlands, forests, and oceans) govern the next steps in the mercury cycle that can lead to the production of methylmercury.

Methylmercury is a potent neurotoxin that can accumulate in the tissues of living organisms (bioaccumulation) and be magnified as organisms higher in the food chain consume mercury-containing prey (biomagnification), posing exposure risks to human consumers and the health of the organisms themselves. Climate change, emissions of other pollutants (for example, acid gases), changes in land

² Previous reports have stated a decrease of 90% since the 1970s (a longer time period than that reported here).

use, and the type of receiving environment can alter how mercury cycles within the environment and can determine whether it is converted to methylmercury and taken up by wildlife.

In terms of risk, certain populations of wildlife and humans are more vulnerable than others to mercury exposure. For wildlife, top predators, particularly those associated with aquatic food chains, are at greatest risk from high dietary exposure to mercury because they accumulate mercury from their prey, which can lead to high levels over their lifetimes (biomagnification). In Canada, fish at the top of the food web and fish-eating birds and mammals are most vulnerable to high mercury exposure. In humans, consumption of contaminated fish is the primary source of methylmercury exposure. Although the average exposure of Canadians is low, methylmercury remains a potential public health issue for populations who rely heavily on the consumption of large predatory fish and marine mammals for food, and for potentially susceptible groups including developing fetuses, infants, and children. The developing nervous system is considered to be the most sensitive to potential harmful effects of methylmercury; thus, infants and children have a higher risk of developing adverse health outcomes from exposure before and after birth. Various human health effects, including impaired neurological development, cardiovascular disease, and immune system dysfunction, have also been linked to methylmercury exposure. In fish and wildlife, exposure to methylmercury is associated with impairment of reproduction, growth, and health.

The 2014 Canadian Mercury Science Assessment consists of 2 documents: the **Summary of Key Results** (including this Executive Summary) and the **Science Assessment**. This Executive Summary is a short document highlighting the results from the science assessment and prominent issues relating to mercury in Canada. The Summary of Key Results contains the most significant scientific results, recommendations for future work, and answers to policy-relevant science questions. The Science Assessment is a comprehensive scientific review of knowledge of environmental mercury in Canada. It provides an in-depth knowledge baseline against which future changes in mercury levels in the environment can be attributed to changes in mercury emissions and climate. This assessment

further identifies key gaps in our understanding of how mercury travels, where it ends up, the impact of human activities and changes in mercury pollution.

The information provided in this assessment is also intended to inform both national governments and international organisations on mercury science in Canada. Canada has identified mercury and its compounds as a toxic substance under the *Canadian Environmental Protection Act (1999)*. The Government of Canada's actions to manage risks associated with mercury are summarized in the *Risk Management Strategy for Mercury*.³ Canada has signed the United Nations Environment Programme's Minamata Convention on Mercury (October 2013), which has as its primary goal the protection of human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.

This assessment reflects the research undertaken in Canada within the past 20 years related to the following:

- Releases of mercury from anthropogenic sources
- Releases of mercury from soils, streams, sediments, and vegetation
- Atmospheric trends, transport, transformation, and deposition of mercury
- Cycling of mercury in the terrestrial, aquatic, and marine environments
- Influence of human activities on mercury processes in the environment
- Numerical modelling (i.e. simulation) of mercury processes, from the air to the ecosystem
- Distribution of mercury levels in biota in Canada over space and time
- Biological effects of mercury on biota
- Ecological risk assessment of mercury to wildlife
- Human health issues relating to mercury in Canada

³ Canada, G.O., 2010. Risk Management Strategy for Mercury. Environment Canada and Health Canada, Ottawa.

HIGHLIGHTS OF SCIENTIFIC FINDINGS

In Canada:

- Mercury remains a risk to Canadian ecosystems and human health.
- In humans, the average exposure of Canadians to mercury is low; however, methylmercury remains a potential public health issue for vulnerable populations who rely heavily on the consumption of predatory fish and traditional wildlife food items (“country food”) and potentially susceptible groups, including developing fetuses, infants, and children.
- Significant global-scale reductions in mercury emissions are predicted to be required to reduce mercury levels in fish below those currently observed across Canada.
- There are aquatic environments in Canada where average mercury levels in biota are high enough to be of concern. The species at greatest risk for impaired health and reproduction from mercury exposure include large predatory fish, fish-eating mammals, and fish-eating birds.
- In terrestrial and aquatic biota in Canada, the highest levels of mercury are reported in southeastern Canada and in some locations in the western and high Arctic. Lower mercury levels in biota are found in southwestern Canada. Levels of mercury over the last 40 years have increased in 31% of Canadian wildlife populations studied, decreased in 21%, and remained stable in 48%. Of all the populations that report increases, 83% are from the Arctic, and the greatest increases have been seen in seabirds.
- Mercury levels in common loons were high enough to cause risks of abnormal behaviour and of impaired reproduction in 36% and 10% of the Canadian lakes studied, respectively. As well, risks to reproduction in predatory fish were found in 82% and to fish health in 73% of Canadian lakes studied.
- Mercury emissions from the waste sector have been reduced by 76%, electric power generation by 30%, iron and steel industries by 54%, and chemical industries by 95%. Due to the steady increase in development of the oil sands, the upstream petroleum sector has shown increases

in mercury emissions and currently accounts for approximately 4.6% of the total Canadian mercury emissions.

- Further controls to achieve domestic and international mercury emission reduction, added to those currently in place, are predicted to benefit Canadian ecosystems. These reductions will ultimately result in lower levels of mercury in fish than if no new emissions reduction controls were put in place. It is predicted that, without additional emissions controls, future fish mercury levels will rise above current levels.⁴
- The “best case scenario” of global emission reductions, using all of the best technologies of today would result in a 20%–50% reduction in mercury deposited to ecosystems and up to 30% lower levels mercury in fish after 150 years when compared with a scenario of no new emission reductions.
- Reported emissions of mercury to the air in Canada have decreased by 85% from 1990 to 2010. However, measured mercury levels in the ambient air have decreased, on average,⁵ by 18% (range from 10% to 26%⁶) (1995–2011) and vary across the country. Levels closer to emission sources show greater declines than in areas farther away from sources, and the Arctic shows significantly smaller declines than temperate regions of Canada.
- Numerical modelling predictions suggest that over 95% of the anthropogenic mercury deposited in Canada comes from sources outside of the country (40% from East Asia, 17% from the United States, 8% from Europe, and 6% from South Asia). While Canadian emissions are predicted to decrease, global emissions are predicted to increase.
- Human activities such as the creation of reservoirs, mining, previous chlor-alkali production⁷ that used mercury cells, and

4 This result reflects the lakes modelled in the Science Assessment.

5 Average decrease is based on monitoring results from 10 different sites in Canada with a minimum of 5 years of data, with a mean range of 12–24%.

6 This number is representative of data from 11 measurement sites with a minimum of 5 years of data. The number of years of data collected ranges from 5 to 17 years, with a minimum of no decline over 7 years (Genesee, AB), and a maximum of 34% over 11 years (Kuujuaupik, QP).

7 The last mercury cell chlor-alkali plant in Canada closed in 2008.

activities that release mercury to the atmosphere (coal burning, municipal waste incineration, cement production, and metals smelting) have contributed or are contributing to the observed mercury levels in Canada.

- Acid-impacted (acidic) and nutrient-deficient lakes, ponds, and wetlands tend to have higher methylmercury concentrations than nutrient-rich and lower-acidity bodies of water. The acidic lakes typically contain fish and fish-eating wildlife with relatively high mercury levels.
- Decreasing emissions of acidic and greenhouse gases are predicted to result in decreased formation of methylmercury and to reduce the bioaccumulation of mercury in wildlife.
- Continued and, in some cases, enhanced monitoring of mercury levels in key environmental compartments will be required to evaluate the contribution of domestic versus global sources of mercury emissions to the Canadian mercury burden and to assess the risk to biota and humans from mercury.

Knowledge Gaps

There are several overarching gaps identified in this science assessment, including gaps in knowledge of the impacts of climate change on the mercury cycle, in capabilities to predict future mercury levels, in knowledge of the impacts of mercury on the Arctic ecosystem and its vulnerability to mercury as well as on human health, and in information on mercury levels in the environment at sites across the country.

The most important knowledge gap is in our understanding of the impact of climate change on mercury cycling, methylation (i.e. how methylmercury is formed), and cumulative effects in Canada. Climate change can disrupt the physical characteristics and functions of the ecosystem, and these changes affect all of the processes in the biogeochemical cycle of mercury. Ecosystems in Canada that are especially vulnerable to climate change and mercury contamination include the Arctic, aquatic ecosystems, coastal regions, and wetlands. Other knowledge gaps that limit our understanding of the effects of climate change on mercury in the environment include the following: limited information on the processes driving emission of mercury from various surfaces and water bodies; lack of chemical identification of

different species of atmospheric mercury and quantification of their deposition to surfaces; lack of knowledge of the impact of acidity, temperature, and organic matter collectively on methylmercury production and bioaccumulation in freshwater aquatic systems; insufficient information on methylmercury levels and production in the marine environment; insufficient knowledge of factors promoting methylmercury in food webs; and a lack of information on the fate and transport of mercury within terrestrial ecosystems.

Current predictive capabilities are limited by a lack of understanding of regional differences in the biogeochemistry of ecosystems and of emission sources other than those currently reported. As well, capacity to predict the effect of changes in anthropogenic emissions on fish mercury concentrations at a national scale is impeded by a lack of information on the physical characteristics of individual watersheds and the hydrodynamics of these watersheds across Canada.

A significant portion of Canada is Arctic, and much is still unknown about mercury in this fragile ecosystem. Noteworthy gaps include an incomplete understanding of the disproportionate increase in mercury levels in biota in comparison with other regions, of the impact of sea ice conditions on the overlying atmosphere, and of the underlying ocean chemistry.

In regard to human health, there is a lack of in-depth information to understand the balance between the benefits of nutrients from the consumption of fish and the risks of methylmercury exposure. As well, the relationship between methylmercury exposure and other diseases is not fully understood.

There remain insufficient monitoring data to expand the scale of information about mercury trends and predictions across the country. Scaling up to the national level from regional data has been a challenge given the geographic size and the diversity of ecosystems in Canada. There is need for a national monitoring focus on targeted biota and abiotic (i.e. non-living) systems to identify areas at risk due to mercury exposure. Furthermore, there is a lack of complete and fully characterized mercury emission data to enable accurate predictive capabilities in Canada. There is a lack of data on mercury exposure of Canadian children, and, in particular, of First Nations children.

RECOMMENDATION

Efforts in the last 20 years have greatly improved our understanding of the sources, transport, fate, and effects of mercury in the Canadian environment. Environmental mercury pollution is complex, and future scientific work will require strong, coordinated, national leadership that engages multi-level partners from all aspects of human health, wildlife, and ecosystem research in an integrated approach.

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