Environment Canada
Environnement Canada

Mercury

Fishing for Answers

WPCD
Water Policy and Coordination Directorate

Canada

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Environment Canada
2003

Inside

Why is mercury an environmental concern?

Mercury, and particularly a form of it called methylmercury, is a human and environmental health concern because of its toxicity and ability to accumulate in fish and wildlife. The concern for human health is evident from the number of fish consumption advisories in effect. For example, in the Canadian Great Lakes, 22% to 66% of the fish consumption advisories are caused by mercury, and in all of Canada, 98% (2 572 of the 2 625) of advisories issued in 1997 were for mercury. Mercury is an environmental concern because its toxic effects can reduce wildlife populations. For example, on the Canadian east coast, common loons have twice as much mercury in their blood as loons elsewhere in North America; as a result these populations are having difficulty reproducing. The mercury in these loons comes from the mercury in the fish they eat. This report gives an overview of mercury in Canada and, in particular, discusses levels of mercury in fish that could be detrimental to the wildlife. For information on mercury and human health issues, contact Health Canada, the Canadian Food Inspection Agency, or your provincial or territorial health and environment ministries. (Links are provided on the last page of this report.)

What is happening?

Introduction to mercury

Mercury is commonly called liquid silver or quicksilver because it is metallic silver in colour and a liquid at room temperature.

The chemical symbol for mercury is Hg, which comes from its Latin name,* hydrargyrum, *meaning "liquid silver". As a metal, mercury is unique in that it is a liquid at room temperature.

Mercury forms tiny spheres that look like ball-bearings when spilled on a flat surface. These mercury spheres can be seen in the pores of rocks in some areas. This is not to say, however, that you can see little balls of mercury wherever it is present in the environment. Mercury bonds to other elements in the environment to form compounds that "dissolve" in water, much like the way table salt dissolves when added to a pot of water. Mercury can form both inorganic and organic compounds. In general, chemical compounds that contain carbon atoms are "organic", while those without carbon atoms are "inorganic".

Mercury ranks about 67th in abundance among the elements naturally found in rocks that make up the earth's crust. It is just slightly more common than gold, but less common than silver and uranium. Unlike gold and silver, mercury is not considered rare because it is found in highly concentrated deposits. Most of it occurs as cinnabar, a mineral composed of mercury sulfide. Small amounts of free metal may also be present in some rocks. Mercury is released slowly from rocks and minerals as they erode under normal weather conditions. Other natural sources of mercury include forest fires and other wood-burning events, volcanoes, and hot springs.

Mercury cannot be created or destroyed, however, humans introduce excess mercury into the global mercury cycle that would otherwise remain buried underground and for the most part remain inactive in environmental processes. Human, or anthropogenic, activities, such as mining, release more mercury from rocks and minerals than natural weathering processes. It is difficult to scientifically differentiate the amount of mercury released from natural sources from that released by human-related activities. Worldwide, the burning of fossil fuels (mainly coal) by humans contributes up to 11 900 tonnes of mercury per year. This amount is more than half of the total mercury released from all anthropogenic sources. In Canada, the main anthropogenic sources of mercury are metal smelting, coal-burning power plants, municipal waste incineration, sewage and hospital waste incineration, coal and other fossil fuel combustion, cement manufacturing, and mercury waste in landfills and storage. Overall, Canada's mercury emissions are decreasing (Figure 1).

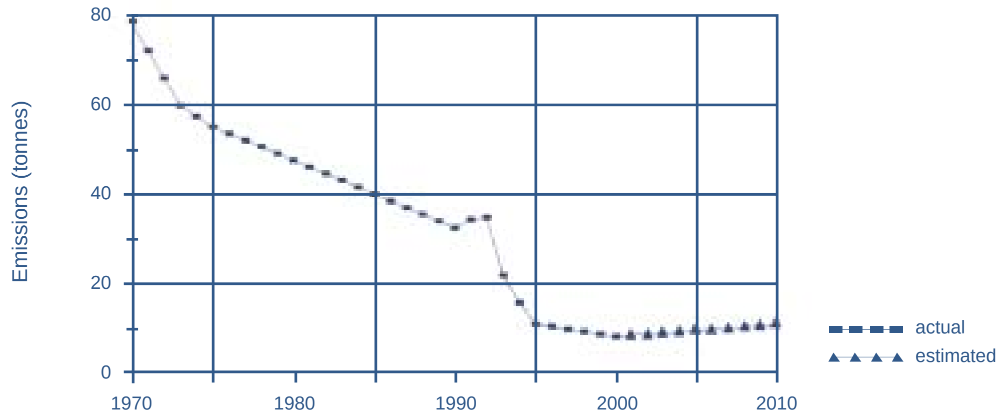


Figure 1: *Trend in Canada's mercury emissions*

Source: Pollution Data Branch, Environment Canada

Mercury is used in a variety of products, including thermometers, barometers, and electrical products such as dry-cell batteries, fluorescent lamps, and electrical switches. Cavities in teeth are filled with a dental amalgam, which is an alloy of silver and mercury. Although safe while in your mouth, improper disposal of used amalgams can result in mercury being released into the environment. Historically, mercury-based pesticides have been used to keep greens and fairways on golf courses free of moulds and fungi. Gold mining operations use mercury to separate gold from other minerals, although this practice no longer exists in Canada. Ultimately, these uses become conduits through which mercury can enter the environment when the items break, are removed from service, or, as in the case of pesticides, are released directly into the environment. Millions of discarded fluorescent lamps, for example, release collectively over 750 kilograms of mercury per year into the Canadian environment from landfills or by incineration.

When mercury enters the body, usually as an organic form called methylmercury, it moves into the bloodstream and is carried to the liver, kidneys, and brain. Mercury is a neurotoxicant, which means that it impairs the brain's normal functions, causing a variety of neurological symptoms. The expression "mad as a hatter" was born from the practice of using a form of mercury (mercury nitrate) in the making of felt for hats. Over the long term, industry workers who handled the mercury or who breathed it in suffered muscle tremors, irritability, headaches, and depression. Perhaps the most infamous case of mercury poisoning is the one that occurred in the Japanese fishing village of Minamata in the 1950s. Mercury released into the water from a chemical-manufacturing plant was taken up by fish and shellfish, which in turn were eaten by local residents. Over 100 people died and up to 2 800 people had symptoms of poisoning of the central nervous system. Before the source of the sickness was identified, affected people were said to have "Minamata disease".

The mercury cycle

Before the mid-1960s, mercury was believed to be relatively stable and inactive in the environment. It is now known that mercury has a complicated global cycle that involves movement among the various environmental compartments (living and non-living), long-range transport, and chemical transformations (Figure 2). In places where there is no direct source of mercury pollution, most of the mercury inputs come from rain, snow, and other forms of precipitation, as well as from dust and other minute solid particles in the air that settle to the earth's surface. Once on land or in water, some of this mercury may be altered chemically to a form that evaporates back into the air where it may travel long distances and be re-deposited elsewhere. Oceans and lakes receive additional mercury from rivers. Groundwater and runoff from the land also carry significant amounts of mercury to lakes, especially in wetland areas.

The "grasshopper effect" is the process by which certain types of chemicals, including mercury, can be carried around the world through repeated cycles of movement up into the atmosphere, transportation through the atmosphere, and return to earth in precipitation or in association with minute solid particles. It is this constant recycling of the mercury that makes it difficult for scientists to tell what mercury comes from natural sources and what mercury comes from human-related activities.

Mercury that enters salt (marine) and fresh waters can be chemically altered into two organic forms: methylmercury and dimethylmercury. Of these two forms, methylmercury is a greater environmental concern because it biomagnifies through food webs to levels that are toxic to fish and wildlife. The other form, dimethylmercury, evaporates into the air or is converted to methylmercury, especially in marine systems. The amount of methylmercury that is produced overall depends on many factors that are not yet completely understood. The amount of inorganic mercury that is present is an important factor because without it, methylmercury cannot be formed. Most of the methylmercury is formed in the top layer of sediment at the bottom of lakes. Certain types of bacteria can both make and degrade methylmercury, but methylmercury can also be made and degraded without the help of bacteria. Lake conditions such as shallow depth, low pH (acidic), warm temperatures, and low salinity, among other factors, favour the production of methylmercury. The amount of organic matter in sediments, such as decayed plants and animals, is very important because it serves as a food source for the bacteria. Water reservoirs created by damming a river and flooding the surrounding area are a special concern because these conditions favour the formation of methylmercury. Consequently, fish in reservoirs have relatively high levels of methylmercury for up to 20 years after damming.

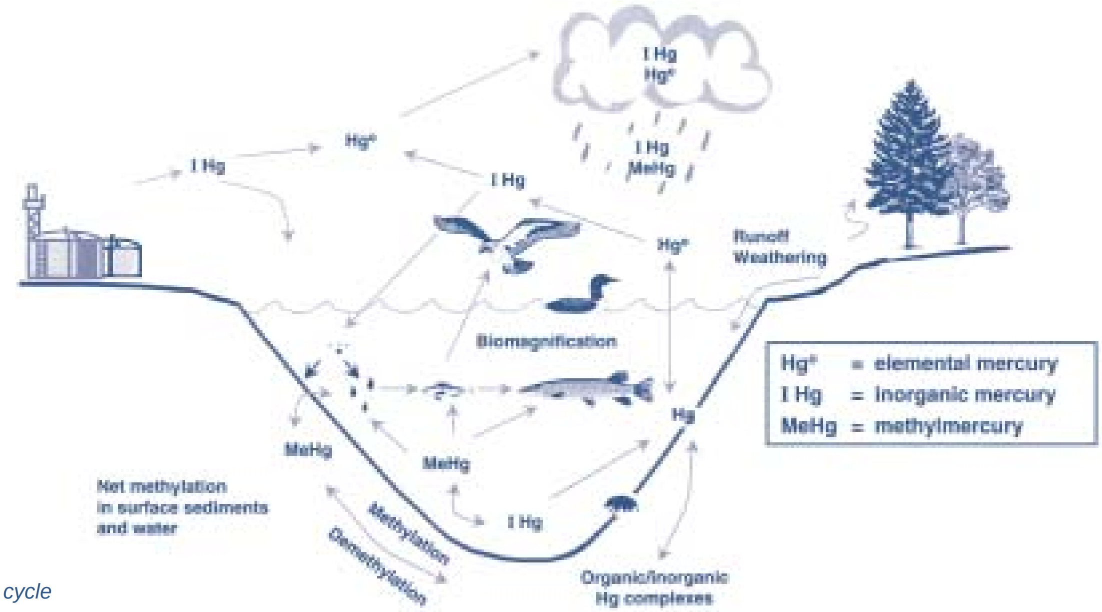


Figure 2: *The mercury cycle*

Bioaccumulation and biomagnification in fish and wildlife

Aquatic plants take up mercury compounds directly from the surrounding water, while aquatic animals, such as fish and shellfish, get mercury from water and from eating food contaminated with mercury. For large fish and for wildlife, essentially all of the mercury in their bodies comes from the food they eat. Animals accumulate mercury over time because they take it in faster than they can eliminate it from their bodies. Methylmercury accumulates in animal tissues more easily than other types of mercury compounds because it can bind to body proteins and pass through the digestive tract wall. The increase in the body burden of mercury as fish get longer and older is shown in Figure 3.

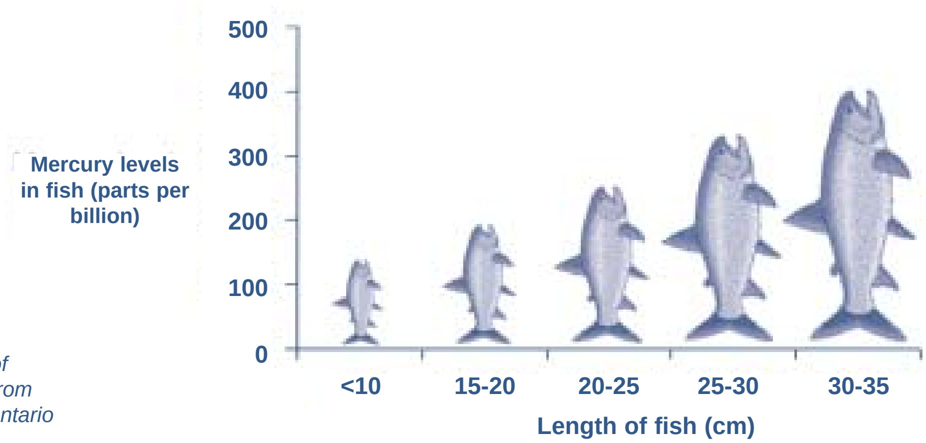


Figure 3: *Average levels of mercury in fish from Lake St. Clair, Ontario during the years 1990 to 1998*

Because of bioaccumulation and biomagnification, even a minuscule amount of mercury in the water can lead to high levels in fish and wildlife.

Animals also have ways of eliminating mercury from their bodies. Some body organs (liver and kidneys) may be able to alter methylmercury to a form that is more easily passed from the body. In birds, methylmercury accumulates in feathers, so the natural process of moulting reduces the overall level of mercury in the body. Female animals pass at least some of their methylmercury on to their offspring. The amount of mercury eliminated in this way is not considered important for all fish and wildlife, but for loons the level of methylmercury in the eggs and in the brains of chicks may actually be higher

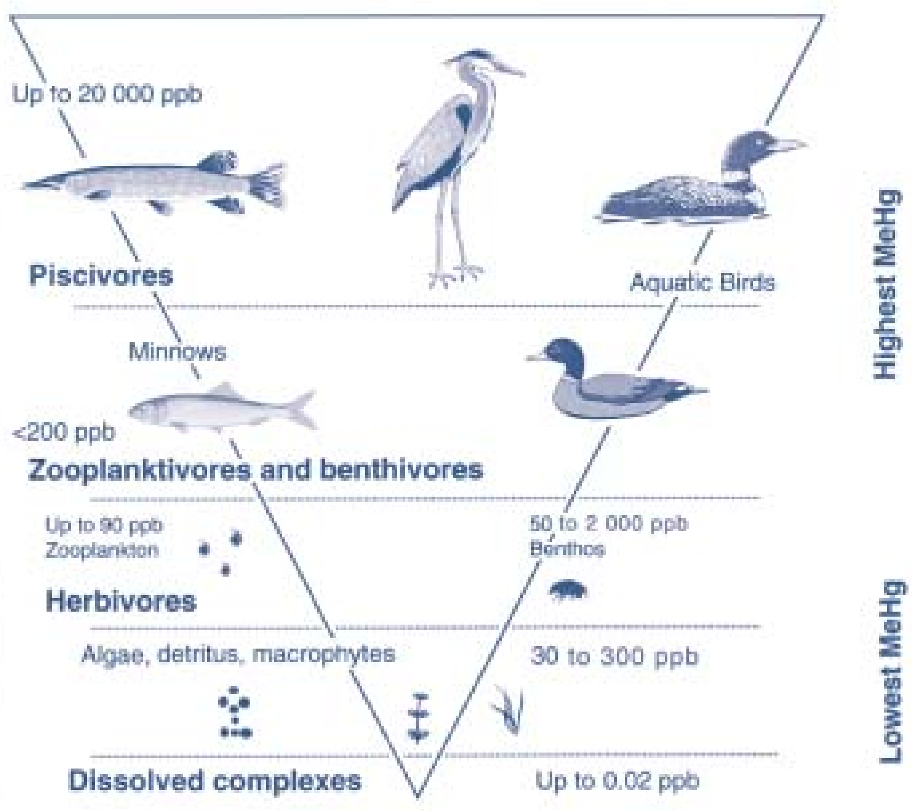


Figure 4: *Bioaccumulation and biomagnification of mercury*

than the level in the brain of the mother. Despite these ways to reduce its mercury body burdens, a predator such as a large fish, bird, or mammal generally has a greater amount of methylmercury in its body than its prey; this is called biomagnification (Figure 4). The proportion of total mercury that is methylmercury also gets bigger in larger and older predators. For example, only about half of the mercury in insects and other bugs is in the form of methylmercury, but nearly all of the mercury in large fish is methylmercury. Aquatic plants and animals that live in water polluted with mercury are more likely to be smaller (length and weight), have physical deformities, have problems reproducing, and die sooner than plants and animals not exposed to toxic levels of mercury. In water, the lowest level of mercury in an inorganic form that is known to harm aquatic life is 260 parts per trillion. Methylmercury is more toxic, with levels as low as 40 parts per trillion being toxic to some aquatic animals. Even at this low level, methylmercury may still accumulate in fish to a point that it threatens the health of wildlife that eat fish.

Mammals that accumulate toxic levels of mercury show signs of brain damage, including abnormal behaviour, eating disorders, loss of balance, lack of coordination, and paralysis of the legs. Methylmercury can make some mammals (e.g., mink) more sensitive to cold temperatures, causing them to die at low temperatures they would normally be able to tolerate. Birds exposed to mercury typically suffer from abnormal behaviour, and their young grow slowly and are less likely to survive. Selenium, which is an essential trace nutrient, can partially nullify the negative effects of mercury.

A trillion is written as 1 followed by 12 zeros. One part per trillion is equal to one drop of water in 50 Olympic-size swimming pools (each 50 m long x 20 m wide x 2 m deep). In metric units, 1 part per trillion is 1 nanogram per litre (1 ng/L) when measuring mercury in water or 1 nanogram per kilogram (ng/kg) when measuring mercury in sediment or fish.

Mercury levels in the Canadian environment

In general, levels of mercury in the aquatic environment are higher now and in recent history than they were in pre-industrial times. Testing for mercury in water has been limited by technology. The technology has improved in the past decade, but there are still only a few laboratories in Canada that can measure methylmercury in water samples. Globally, levels of mercury in fresh and marine water range from less than 1 to 20 parts per trillion. Based on information largely limited to Ontario and Quebec, levels of methylmercury are usually less than 1 part per trillion (ng/L) and account for less than 10 percent of all the mercury (organic plus inorganic forms) found in water.

Across Canada, levels of mercury in the sediments of lakes and streams are about a million times higher than in water, occurring in the range of part per million (mg/kg). More mercury is found in sediment than in water because mercury compounds are attracted to and may attach to the small grains and particles (including decayed plants and animals) that make up the sediment. Levels of mercury in the sediments of lakes range from 0.005 to 21 mg/kg, while levels in the sediments of streams and rivers range from 0.005 to greater than 99 mg/kg. In estuaries and coastal waters not directly influenced by human activity, sediments have mercury levels from 0.01 to 2.22 mg/kg, while sediments from sites known to be polluted have levels up to 23 mg/kg. Mercury levels in fish are extremely wide ranging, from something less than can be measured to over 20 mg/kg. The amount of mercury that a fish accumulates depends on many factors. As explained above, more mercury is generally found in large fish than in small fish. Even fish of the same size living in the same lake may have different body burdens of mercury. Many factors, such as what species they are, how old they are, what they eat, and where they swim, determine the amount of mercury in their bodies. Although mercury is toxic to fish, mammals and birds that eat fish are generally more sensitive to mercury than the fish themselves. That is, fish contaminated with mercury may not have noticeable ill effects, but mink that eat these fish over their lifetime may develop health problems, or their offspring may.

Table 1: *Unit conversions*

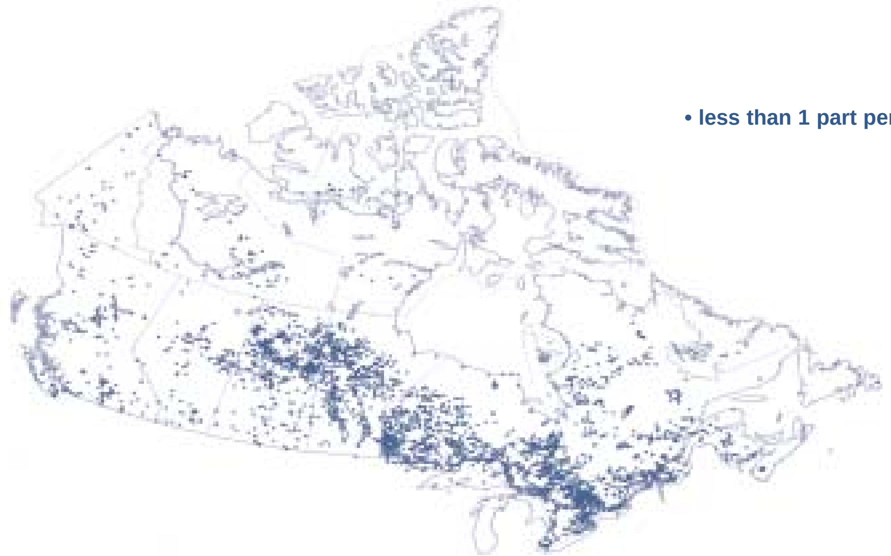
Système international (metric)				
part per million	ppm	=	milligram per kilogram*	mg/kg
part per billion	ppb	=	microgram per kilogram	µg/kg
part per trillion	ppt	=	nanogram per kilogram	ng/kg
1 milligram (mg)	= 1 000 micrograms (µg)		= 1 000 000 nanograms (ng)	
1 ppm	= 1 000 ppb		= 1 000 000 ppt	

*Because one litre (1L) of water weighs about one kilogram (1kg), then a ppm is also equal to a milligram per litre, and so on.

The Canadian tissue residue guidelines (TRGs) are the maximum levels of methylmercury in fish to protect wildlife that eat fish and other aquatic life. Kingfisher, heron, osprey, and mink each have their unique tissue residue guidelines because they eat different kinds and amounts of fish and other aquatic life as food.

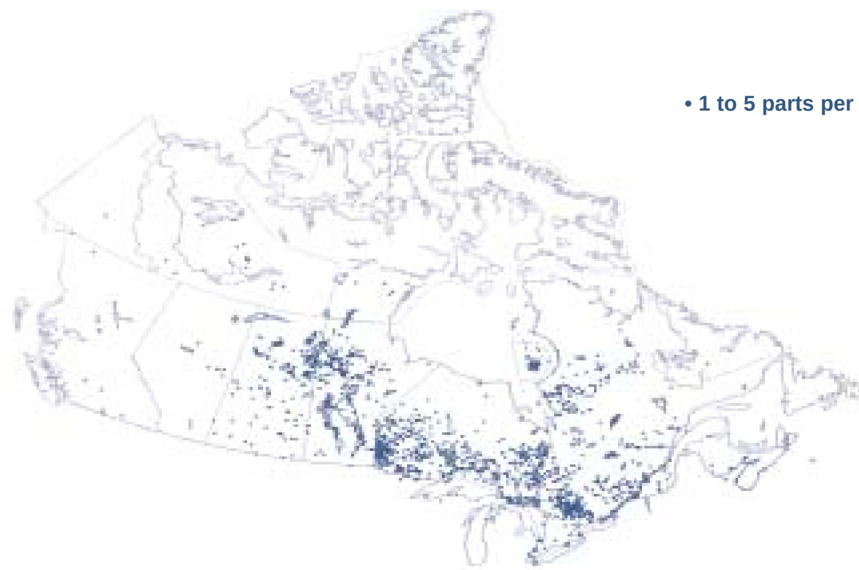
Canadian tissue residue guidelines, or TRGs for short, are estimated levels of mercury in fish that should protect *the wildlife that eat them*. Because not all wildlife are the same, TRGs were calculated for 10 species of mammals and 28 species of birds that eat fish or other forms of aquatic life. TRGs for other wildlife species may be calculated when specific scientific information about their diet is known. These guidelines are alert levels or benchmarks to help identify where there might be environmental problems because of mercury pollution (see Environment Canada 2002).

In a case study, the TRGs for three birds (belted kingfishers, great blue herons, and osprey) and one mammal (mink) were compared to mercury levels in fish across Canada. These wildlife were selected because they are common throughout much of Canada and because freshwater fish form a main part of their diet. In addition, the size of fish normally eaten by each of these species is different. Generally speaking, kingfishers eat small fish (10–15 cm), while osprey eat larger fish (30–35 cm). Mink eat fish that are 15–20 cm, and herons eat fish that are 20–25 cm.



• less than 1 part per million

Figure 5: *Mercury levels in fish*



• 1 to 5 parts per million

● greater than 5 parts per million

The Canadian National Database for Mercury Levels in Freshwater Fish has information for over 3 200 locations. The type, size, and number of fish samples varies from site-to-site making national comparisons difficult. Also, at most sites, data are not available for consecutive years. Many areas have naturally high levels of mercury due to local geology or other factors.

Common loons in Kejimkujik National Park, Nova Scotia, have the highest level of mercury in their blood found anywhere in North America. But loons elsewhere in Nova Scotia and in nearby New Brunswick have mercury levels similar to those living in New England and the Great Lakes. Fewer nests are made by loon populations with high mercury levels in their blood and fewer chicks seem to hatch from those nests. The main food source for these loons is yellow perch, 10 to 15 cm in length. Recognizing that mercury levels vary from fish to fish, the mercury levels are around 100 ppb, 220 ppb, and 270 ppb in yellow perch from New Brunswick, Kejimkujik National Park, and Nova Scotia, respectively. The fact that the tissue residue guideline for loons is 172 ppb demonstrates that it could be a useful tool in identifying potential problem areas. (See Environment Canada 1998 and 2002 for more details.)

Species	TRG (ppb or µg/kg)
Belted Kingfisher	62
Heron	
male	148
female	141
Osprey	155
Mink	
female	92

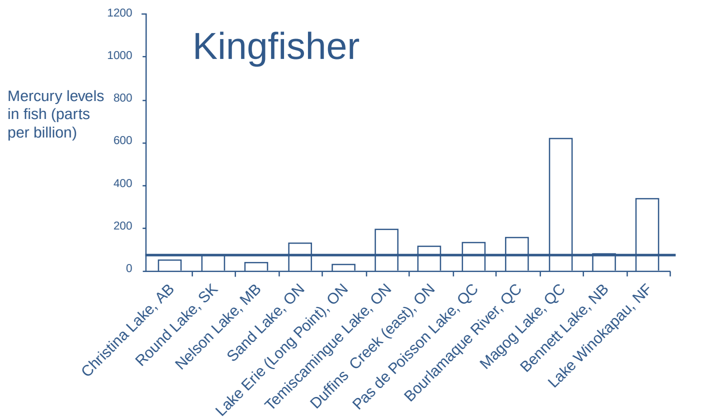
Table 2: *The Canadian tissue residue guidelines (TRGs)*

Next, the TRG for each species was compared to entries in the Canadian National Database on Mercury Levels in Freshwater Fish. The database includes information from all provinces and territories except Prince Edward Island. Altogether, 90 species of fish from over 3 200 locations are represented (Figure 5). Because kingfishers, herons, osprey, and mink eat different sizes of fish, their respective TRGs were compared only to those corresponding to the size of fish that each prefers to eat.

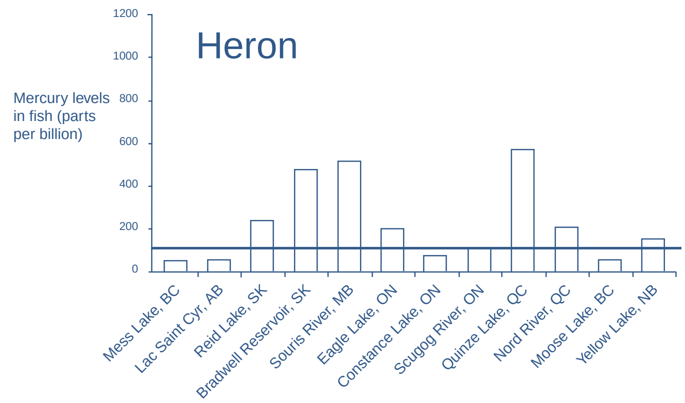
General conclusions about mercury levels in fish across Canada and over time are hard to make because information from case to case is different and is not always comparable. The information in the four graphs in Figure 6 shows that mercury is a potential problem throughout Canada. Where levels of mercury in fish are higher than the TRGs, it does not necessarily mean that wildlife in those locations have or will develop health problems. This is because the combination of factors and circumstances that may lead to health problems are unique to each location. For example, a slight difference in diet, particularly in the size or proportion of fish eaten, may put one bird population at higher risk over another. Professional advice should be sought when interpreting the results. Further investigation at these locations is likely warranted to determine if wildlife are indeed experiencing or are at risk of experiencing ill health effects.

What are Canadian governments doing about it?

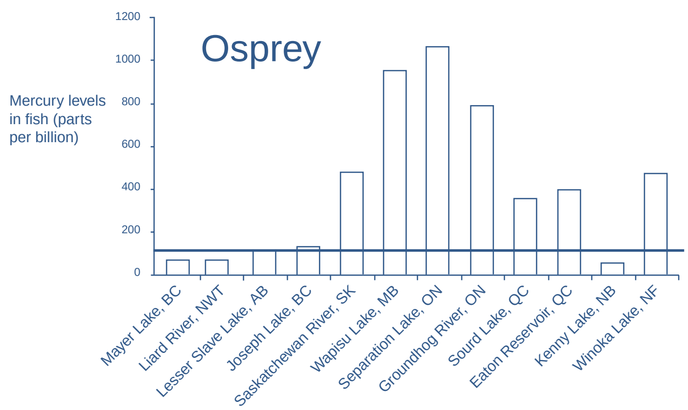
The management of mercury in the environment is a priority for the federal, provincial, and territorial governments in Canada. Many initiatives are currently in place to curb emissions. Nationally, the Canadian Council of Ministers of the Environment (CCME), a body made up of federal, provincial, and territorial environment ministers, is developing Canada-wide Standards (CWSs) for mercury in products and from industrial emissions in cooperation with industry and the public. In general, CWSs are intended to be achievable targets based on science, social and economic impacts, and technical feasibility. The federal



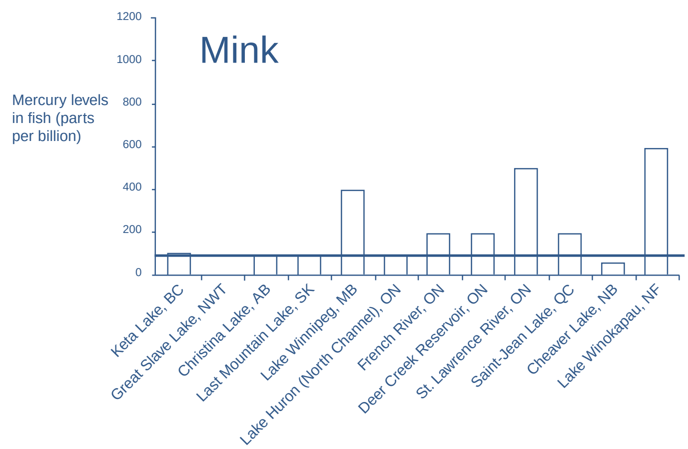
Levels of mercury in fish (10 to 15 cm in length) eaten by kingfisher. The horizontal line represents the tissue residue guideline of 62 parts per billion.



Levels of mercury in fish (20 to 25 cm in length) eaten by heron.The horizontal line represents the tissue residue guideline of 141 parts per billion.



Levels of mercury in fish (30 to 35 cm in length) eaten by osprey. The horizontal line represents the tissue residue guideline of 155 parts per billion.



Levels of mercury in fish (15 to 20 cm in length) eaten by mink. The horizontal line represents the tissue residue guideline of 92 parts per billion.

Figure 6: *Mercury levels in fish eaten by wildlife*

government is partnered with Ontario through the Canada–Ontario Agreement Respecting the Great Lakes Basin Ecosystems, which has set targets for emission reductions for mercury, among other commitments. Canada and the United States are partnered through the Great Lakes Binational Toxics Strategy, as well as the New England Governors and Eastern Canadian Premiers Mercury Action Plan to reduce mercury emissions by half in the region. In June 2000, Canada, the United States, and Mexico signed a Mercury Action Plan under the North American Agreement on Environmental Co-operation of the

North American Free Trade Agreement (NAFTA). Canada is an active participant in the Arctic Council, whose members represent the eight northern circumpolar nations. Mercury issues for this multi-national initiative are addressed under the Northern Contaminants Program. Canada signed and ratified the United Nations Economic Commission for Europe Heavy Metals Protocol for Cadmium, Lead, and Mercury in 1998.

Research initiatives include METAALICUS (Mercury Experiment to Assess Atmospheric Loading in Canada and the United States), an interagency research project to determine the relationship between the atmospheric loading of mercury to lakes and the methylmercury concentrations of fish. From 1995 to 1998, Environment Canada led a multi-disciplinary study of mercury sources, fate, and effects in Nova Scotia and New Brunswick. From 1999 to 2001, Natural Resources Canada led a collaborative research team to further investigate mercury sources and biogeochemical processes influencing the fate of mercury in Kejimkujik National Park, Nova Scotia.

What can you do to help?

There are many things you can do to help.

- Refrain from using items that contain mercury. Use rechargeable or mercury-free batteries and non-mercury thermometers. (Thermometers with red liquid are mercury-free.)

- When finished with mercury-containing items, take them to a designated hazardous waste depot instead of throwing them out with your regular garbage.

- Use fluorescent lighting because of its high energy efficiency, but dispose of used lamps at a designated hazardous waste depot.

- Ask your dentist to dispose of dental amalgams (cavity fillings) properly and consider mercury-free fillings for any replacement and new fillings.

- Observe general energy conservation practices to help curb pressure on electric power generators to burn more coal or to build larger hydro-electric dams.

Recommendations

Mercury levels in fish are high enough to put wildlife such as loons, kingfishers, herons, osprey, and mink at risk of adverse health effects. In general, little is known about the levels of mercury in fish eaten by wildlife. Improved monitoring of mercury levels in fish eaten by wildlife is needed to explain the observed effects in wildlife, to forecast future problems, and to evaluate the efficacy of pollution control measures taken to reduce mercury in the environment. In particular, studies on mercury levels in marine fish are needed because many wildlife species, including those discussed above, eat fish from the ocean for up to several months a year. In addition, studies on the long-term effects of mercury and on the combined effects of mercury and selenium in wildlife are needed to better understand the full impact of mercury.

The Government of Canada, under the *Canadian Environmental Protection Act*, is committed to the *precautionary principle*. In the spirit of this principle, there is enough information to know that mercury exists in Canada at levels that are causing deleterious impacts on wildlife; therefore, we should take action, and promote activities to reduce mercury pollution.

Further Information

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Environment Canada. 2002. Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota: Methylmercury. Scientific Supporting Document. Ecosystem Health: Science-based Solutions Report No.1-4. National Guidelines and Standards Office, Environment Canada, Ottawa.

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Links

Canadian Council of Ministers of the Environment *www.ccme.ca*

Canadian Food inspection Agency *www.inspection.gc.ca*

Conference of New England Governors and Eastern Canadian Premiers (Committee on the Environment)
www.scics.gc.ca/pdf/850084012_e.pdf

Environment Canada *www.ec.gc.ca*

Health Canada *www.hc-sc.gc.ca*

Northern Contaminants Program *www.inac.gc.ca/ncp*

METAALICUS *www.biology.ualberta.ca/metaalicus/metaalicus.htm*
www.umanitoba.ca/institutes/fisheries/METAALICUS1.html

Metals in the Environment Research Network *www.mite-rn.org*

United Nations Economic Commission on Europe (UNECE) Protocol on Heavy Metals *www.unece.org/env/lrtap/protocol/98hm.htm*