Environment Canada
Transboundary Air Issues Branch

The Status of Mercury in Canada Report #2

A Background Report to the Commission for Environmental Cooperation North American Task Force on Mercury

May 2000

This report is the second Status Report on Mercury in Canada and is presented as Canada's input into the Phase II North American Regional Action Plan on Mercury. The status reports for Canada, Mexico, and the United States are an integral part of the three Parties' commitment to the North American Agreement on Environmental Cooperation, and in particular to the Mercury Action Plans formulated for the Sound Management of Chemicals Working Group, under the Commission for Environmental Cooperation. The status reports for the Phase I Mercury Action Plan provide a basis for comparison and serve as indicators of progress from 1997 to 1999.

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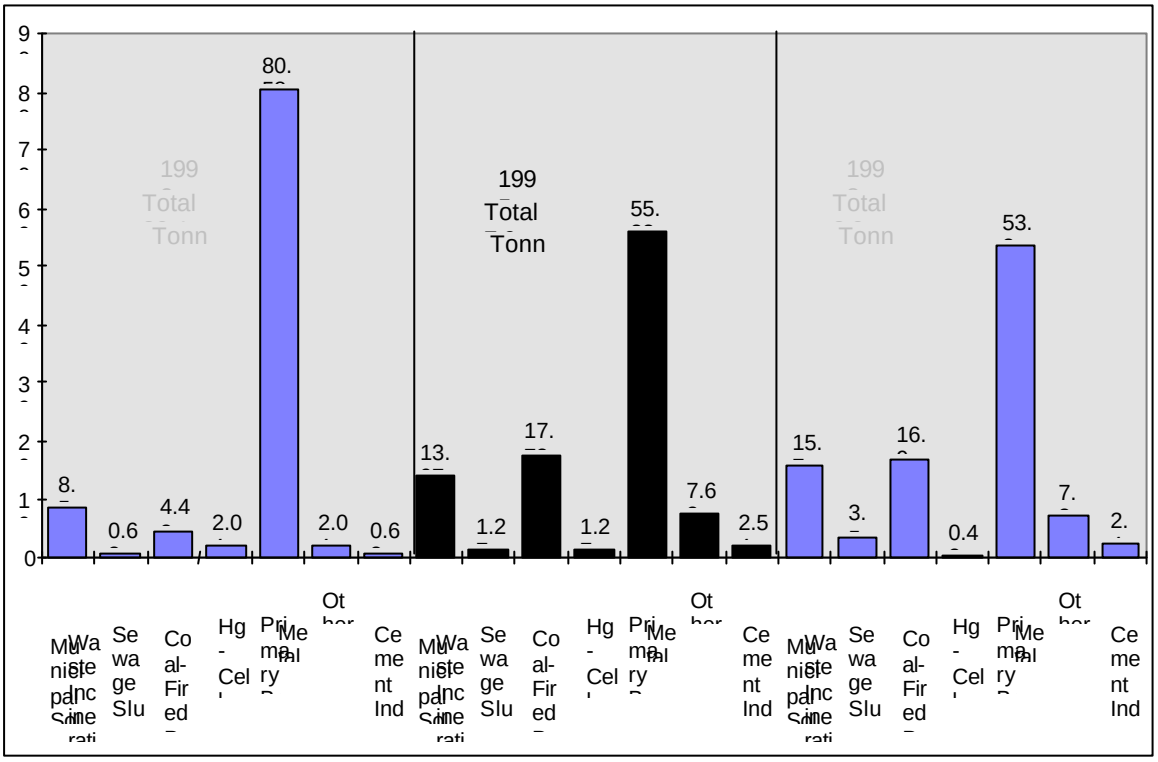
1.1 Emission Inventories

1.1.1 Anthropogenic (Human Activity) Sources

The Expert Panel on Mercury Atmospheric Processes recently published a report reviewing work completed on mercury in Canada as well as other countries. This report indicates that atmospheric mercury levels are still rising and 50–75 percent of this increase originates from anthropogenic sources (Expert Panel on Mercury Atmospheric Processes 1994). It has also been suggested that anthropogenic releases of Mercury to the atmosphere have caused a three-fold increase in its concentration in air and marine surface waters since the pre-industrial era (Allan 1996).

Canada's primary anthropogenic mercury sources are smelting, municipal waste combustion, sewage and hospital waste incineration, coal combustion and cement manufacturing (CEC Phase I Report). Preliminary emission data for 1994, 1995 and 1998 developed by federal experts within the Pollution Data Branch of Environment Canada and from the Canada-wide Standards Working Group, indicates that the largest industrial source of mercury emissions in Canada is the nonferrous (primary base-metals) industry, which, in 1995, contributed almost 50 percent of the total 11 tonnes of mercury emitted to the atmosphere by selected industrial sources. Coal-fired power plants are the second largest industrial source, contributing an estimated 13 percent of the total, followed by municipal solid waste incineration with 10 percent of the total (Neimi 1998).

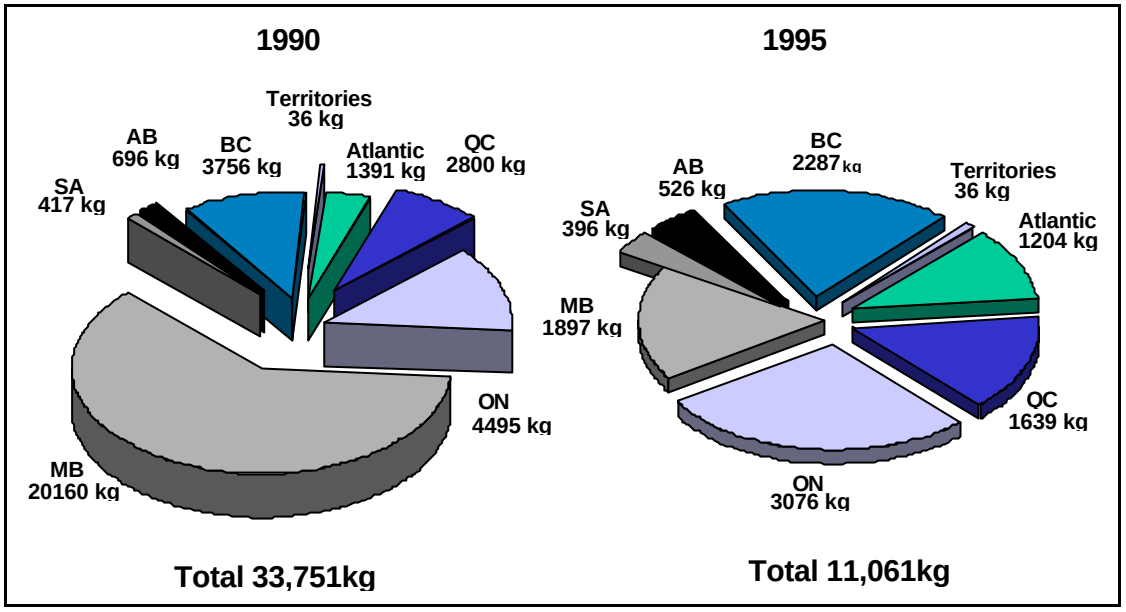
Figure 1: Canadian Atmospheric Mercury Emissions by Industrial Sector in 1990, 1995, 1998



Source: Neimi 1998

Until 1994 Canadian anthropogenic mercury emissions were mostly from one zinc/copper smelting facility in Manitoba which emitted over 20 tonnes of Canada's mercury emissions (Environment Canada 1996). Process upgrading has resulted in significant improvements since 1990. In the Manitoba example, a change from high temperature roasting to wet pressure extraction from the ore have helped Canadian anthropogenic emissions of mercury drop from the 1990 inventory of 32.7 tonnes to 11.1 tonnes in 1995 as shown below.

Figure 2: Mercury Releases By Province and Territory

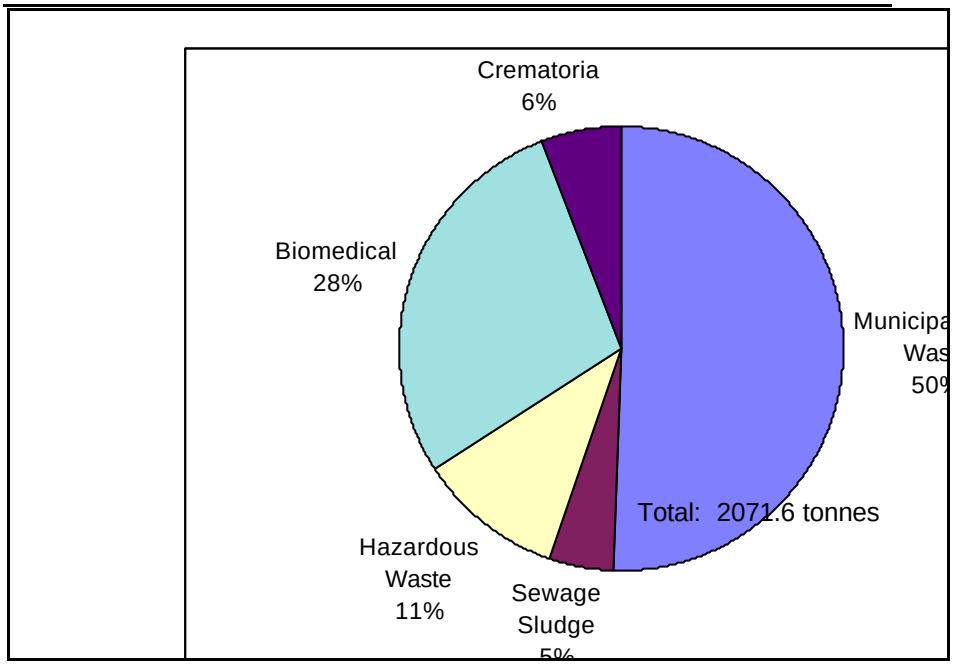


Data from a preliminary draft of the Canadian Emissions Inventory of mercury (1990 and 1995) prepared by Environment Canada's Pollution Data Branch.

1.1.1.1 Waste Incineration

In Canada, there are several types of waste incineration that may contribute to mercury emissions, including incineration of municipal solid waste, sewage sludge, hazardous waste, industrial and federal waste, biomedical waste, crematoria and wood waste. Figure 3 shows the contribution of each major incineration sector to the total emissions from incineration. Incineration of municipal solid waste, hazardous waste and biomedical waste are the largest contributors of mercury emissions.

Figure 3: 1995 Waste Incinerator Emissions by Sector



Data from a preliminary *draft* of the Canadian Emissions Inventory of mercury (1990 and 1995) prepared by Environment Canada's Pollution Data Branch.

Municipal solid waste (MSW) incineration resulted in mercury emission to air of 2502 kg in 1990, and 1047 kg in 1995. Ontario was the largest emitter of mercury from MSW incineration, emitting 730 kg or 29 percent of the national total in 1990, and 419 kg or 40 percent in 1995 (Environment Canada 1999).

There were 268 biomedical waste incinerators in Canada in 1990, 201 in 1995, and 160 in 1997, with Ontario being home to 35–40 percent of them (Environment Canada 1999). Emissions come from the incineration of mercury-containing wastes such as thermometers, sterility agents, some antiseptics, and materials used to clean up spilled mercury. More hospitals are beginning to manage their mercury on-site and alternatives to mercury have become increasingly common.

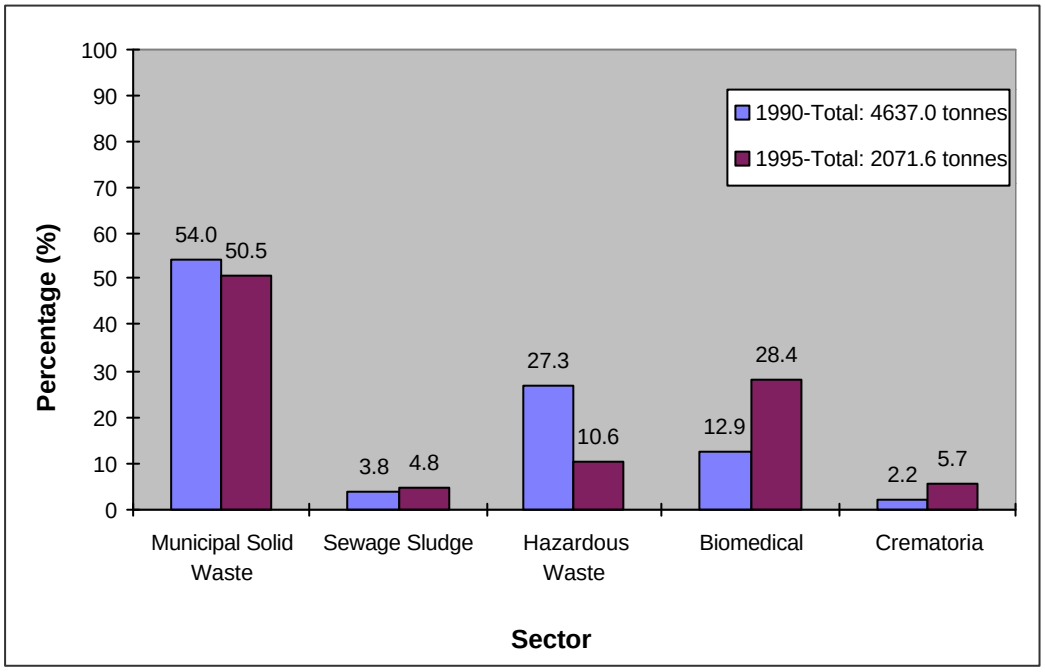
Nine sewage sludge incinerators in Canada contributed 100 kg or nine percent of mercury emissions from incinerators in 1995, down from 174 kg in 1990.

Crematoria accounted for six percent of emissions in 1995. The majority of their

emissions come from amalgam fillings. Emissions from incineration of hazardous waste dropped almost six-fold in the five-year period from 1990 to 1995. Wood waste contributed 17.8 kg in 1990 and five kg in 1995 of mercury emissions (Environment Canada 1999).

Emissions from industrial and federal incinerators are difficult to measure because of the wide variety of small incinerators in operation. As a result, the estimates are not very firm, but the emissions are fairly small so any errors would not significantly affect total emissions in Canada.

Figure 4: Waste Incinerator Emissions in 1990 and 1995



Data from a preliminary *draft* of the Canadian Emissions Inventory of mercury (1990 and 1995) prepared by Environment Canada's Pollution Data Branch.

1.1.1.2 Non-Utility Combustion of Fuel Oils

Non-utility combustion of fuel oils includes motor vehicle fuel use, residential, commercial and industrial boilers, and industrial process heating. No estimates for mercury emissions from vehicle exhaust were available. Using the EPA fire database emission factors, Doiron and Associates (1997) estimated 133.4 kg/yr of mercury were emitted from heavy and light fuel use.

1.1.1.3 Lime Manufacturing

Lime manufacturing plants operate in British Columbia, Alberta, Manitoba, Ontario, Québec and New Brunswick. Emissions are due to combustion of fuels and roasting of raw materials and are released from the rotary and shaft kilns. Production capacity is about 3.5 million tonnes/year. The annual mercury emissions were estimated to be 128 kg and 135 kg for 1990 and 1995, respectively.

1.1.1.4 Cement Manufacturing

Based on emission tests conducted at 15 Portland cement plants in 1993, the US EPA developed an emission factor of 0.87 g/tonne of clinker produced. Canada's total clinker production in 1996 was 8,570,000 tonnes. This yields an emission estimate of 745 kg of mercury.

1.1.1.5 Landfills

Estimates of mercury releases from landfills are still highly uncertain. A large number of mercury-containing products end up in landfills, including some sewage sludge containing mercury. In 1997, Sang and Lourie estimated that atmospheric mercury released from Ontario landfills was 1000 kg/year, or 24 percent of the atmospheric emissions in the province. In Ontario, atmospheric mercury concentrations measured over three dumps were 360–4.470 hg/m^3, compared to ambient mercury concentrations of 1.5–2.0 hg/m^3 across Canada (Pilgrim 1998). A more recent survey by Environment Canada indicated a concentration of approximately 10hg/m^3 of landfill gas. Environment Canada is presently engaged in a program to determine more accurately the mercury emission rates for Canadian landfills.

1.1.1.6 Foundries

Foundries manufacture metallic objects by cooling molten metal in a mold or die. Trace concentrations of mercury present in the feed materials may be emitted to the atmosphere during the melting process. According to the Canadian Foundries Association, the total foundry production in Canada is 708,700 tonnes of product per year.

Table 1: Foundry Emissions, 1997

Sector	Foundry Production	Hg Emission Factor	Quantity of Mercury Released
Foundries	**708,700 T/year**	**0.174 g/tonne of production**	**123.3 kg**

Source: Smith 1997

1.1.1.7 Wastewater

Emission estimates were determined by examining present populations, population served with water, population served with sewage treatment, measured water flow, and type of wastewater treatment, as detailed in Environment Canada's "Municipal Water Use Database (MUD)." This study assigned emission factors of 0.24 μg/L to wastewater streams which received no treatment, or primary treatment only, and 0.05 μg/L to wastewater which had secondary or tertiary treatment. Based on these emission factors, about 1,200 kg of mercury were discharged to water bodies from wastewater sources.

1.1.2 Natural Sources

Extensive geochemical surveys of remote areas of Canada have shown that mercury is a significant and highly variable natural constituent of bedrock, soil, freshwater sediments, water, biota and air. The principal natural sources of atmospheric mercury emissions in Canada are soil, freshwater and marine surfaces, vegetation, forest and bush fires. Globally, the four main natural sources of

mercury in the atmosphere are degassing from geological sources, including mineral deposits and emissions due to volcanic and seismic activities, soils, photo-reduction of divalent mercury in natural waters and biological formation from methylation of elemental or dimethyl mercury (Organization for Economic Cooperation and Development 1994). The role of submarine volcanism has yet to be quantified; however, it may be significant (see below).

Table 2: Natural Occurrence of Mercury

Source	Concentration (ppm)
Ultramafic igneous	0.004–0.5
Basaltic igneous	0.002–0.5
Granitic igneous	0.005–0.4
Shales and clays	0.005–0.51
Black shale	0.03–2.8
Limestone	0.01–0.22
Sandstone	0.001–0.3
Metal rich soils	1–7
Typical normal range in soil	0.008–0.19

Source: Thornton 1995

Geological situations and factors affect the natural background concentrations of mercury in environmental materials. The abundance of sulfide minerals in rock influences mercury concentration, as apart from being the major constituent of cinnabar, it is widely distributed in such sulfides as pyrite, pyrrhotite, chalcopyrite and sphalerite. In particular, black shale and some volcanic rocks exhibit elevated mercury concentrations.

New knowledge is continually being acquired that impacts the estimation of natural releases. For example, Canadian geologists involved in marine research have identified native mercury and sulfides on the sea floor in the western Pacific (Stoffers et al. 1999). It is estimated that each hot spring releases approximately one kg/yr of mercury to the sea floor. The number of such hot springs on the sea floor is unknown, but is certainly in the many thousands or tens of thousands. Such contributions to the submarine and surface environment may be significant locally, but the fate of the mercury has yet to be determined. Data is needed on how much

mercury is incorporated into ocean circulation patterns, and therefore transferred to the atmosphere. Similarly, new research concerning natural releases directly to the atmosphere are raising questions about the current global and North American models (Levin et al. 1999). This new knowledge is yet to be incorporated into current models for North American and global mercury cycling. As a result, mass balance models will keep evolving for the foreseeable future as natural sources are identified and quantified.

The relative contribution of natural sources of mercury to the environment as compared to anthropogenic sources continues to spark debate in the Canadian scientific community. While anthropogenic sources are relatively easily recognized and their releases can be quantified, natural contributions are almost always presented with the caution that they are "order of magnitude" estimates only. The reason for this is two-fold: not all natural sources have been identified or quantified and while anthropogenic releases are relatively predictable over time, such is not the case for natural emissions. This uncertainty is reflected in the range of the estimates for global natural emissions, from 40 to 190,000 tonnes per year. Recent estimates put the emission range at 2,000 to 3,000 tonnes per year (US EPA 1997). Therefore it has been approximated that natural emissions account for 40 percent of the total global emissions.

Current research in Canada is focusing on a number of issues, including the establishment of historical records of mercury deposition in ice and sediment cores, and biological archives (mammal teeth and trees, for instance); investigations into sediment cores from remote sites to determine the relative contributions of external input and internal diagenetic redistribution and other factors to observed concentration profiles; new tools (e.g., isotope ratios to assist in source apportionment determination); and studies of the processes that affect the rates of methylation and de-methylation in aquatic systems which play a key role in transforming mercury into bioavailable forms. Research on processes affecting the transformation of mercury to bioavailable forms is particularly important as the knowledge gained is key to developing appropriate risk management strategies.

It should be noted that although there is great uncertainty, most assessments have concluded that natural mercury emissions play a significant role in the overall global biogeochemical cycle and may account for up to half of the total loading. The relative mobility of mercury due to the ease of reduction of its compounds, coupled with its high volatility and low solubility in water, suggest that up to 2/3 of current atmospheric mercury emissions could be attributable to the recycling of past anthropogenic emissions (Doiron & Associates,C.C. 1996). Taking this into consideration, the relative contribution of natural mercury emissions may be closer to the low end of the range mentioned above.

At this time, the weight of scientific evidence indicates that the contribution to global flux of mercury is approximately equal for anthropogenic and natural sources. It must be noted that due to the spatial variability associated with both sources, either may be predominant at particular locations where mercury, whatever its source, is capable of being transformed to bioavailable species.

1.2 Ambient Monitoring

Canada has established and maintains national and regional databases that identify levels of metals in various media. For example, the National Geochemical Reconnaissance Database contains sediment and/or soil data for 25 percent of Canada's total area, 80 percent of which contains mercury data. This is discussed in greater detail in section 2.1.2 below (see also CEC Phase I Report). There are numerous provincial initiatives such as large databases for mercury in fish and baseline geochemistry programs. The Geological Survey of Canada is currently involved in a project in northern Ontario to determine mercury's post-deposition redistribution patterns and the variation of mercury levels through time. As well, the Canadian Arctic Contaminants Assessment Report (CACAR) is part of Canada's Northern Contaminants Program (NCP), written in response to the concern that toxic substances such as organochlorides, heavy metals and radionuclides are being discovered in relatively high concentrations in the Arctic environment. This is discussed further in section 2.1.2, under Risk Management.

There are also many published studies of historical mercury deposition patterns derived from dated peat and lake sediment cores in Canada and the United States. Analysis of this data needs to be incorporated into a weight of evidence approach to assist in understanding temporal trends in atmospheric mercury deposition.
The following federal and provincial departments have completed monitoring/inventory studies on mercury in the past or are presently doing so: i.e., Environment Canada; Department of Fisheries and Oceans; Natural Resources Canada; and the Ontario, Québec, New Brunswick, and Nova Scotia Ministries of the Environment. The Canadian Wildlife Service of Environment Canada has a long-term monitoring program that has been tracking mercury levels in seabirds since the early 1970s on the Great Lakes, and the Atlantic, Pacific and Arctic coasts (CEC Phase I Report).

1.2.1 General Ambient Monitoring

EMAN (Ecological Monitoring and Assessment Network)

The Ecological Monitoring and Assessment Network (EMAN) is a national program with the objectives of merging resources for programs across Canada that carry out independent monitoring activities. Its mandate is to “facilitate cooperation and a holistic approach to ecological inquiry and ecosystem understanding” (Environment Canada 1998). More specifically, the program’s goal concerning toxic chemicals is to detect and quantify them in the Canadian environment. The objective is “to understand the nature, extent and ecological implications of toxic chemicals in the Canadian Environment” (Environment Canada 1998).
The Indicators, Monitoring and Assessment Branch (IMAB) of Environment Canada proposes to assist the process by coordinating and facilitating certain assessments and by mobilizing the necessary EMAN resources to participate in the work. The intention is to prevent duplication of efforts, and collectively promote the production and use of environmental information.

Dorset Research Centre

The Ontario Ministry of the Environment extensively monitors mercury levels in lakes and watersheds across Ontario. Over 95 percent of the lakes surveyed have levels of mercury well above the suggested World Health Organization threshold level of 0.5–1.0 mg per kilogram of fish body weight, compelling the Ministry to issue local fish consumption advisories annually (CEC Phase I Report).

Hg Gas Phase Measurements

Canada monitors vapor phase mercury with the new Tekran® technology. Total Gaseous Mercury (TGM) measurement sites are located in New Brunswick, Nova Scotia, Québec, Ontario and the Northwest Territories. Typical ambient air concentrations for the Great Lakes, Québec and Atlantic Canada are in the range of 1.5 to 2 ng/m^3 (Blanchard 1997, Poissant 1997, Schroeder and Marks 1994, Beauchamp and Tordon 1997).

Mercury Wet Deposition

Local mercury deposition occurs between 0–100 kilometers of the source and regional deposition between 100 to 2,000 kilometers of the source (Iverfeldt 1995). A Canada/US Mercury Deposition Network has been established. Canadian sites, at present, are located at Kejimkujik National Park, Nova Scotia, the Huntsman Marine Science Centre, St, Anicet and Mingan, Québec and at the Dorset Environmental Sciences Centre in Ontario. A further four sites across Canada will be started in early 2000. An assessment of the data collected will be carried out to determine spatial/temporal trends and assist with source/receptor relationships (Environment Canada 1998).

Mercury Emissions

Mercury levels in industrial plumes are being studied using a research aircraft equipped to measure the different forms of mercury emitted from various industrial

sources. Measurements of mercury levels under winter conditions were completed early in 2000 and similar measurements are planned for late summer 2000.

Table 3: Estimates of mercury deposition to different regions of Canada and mercury deposition to the oceans based on sparse land measurements.

Regions of Canada	Land Mass (km^2)	Mercury Wet Deposition ($mg/m^2/yr$)	Mercury Wet Deposition (tonnes/yr)	Dry Deposition ($mg/m^2/yr$)	Dry Deposition (tonnes/yr)	Wet and Dry Deposition (tonnes/yr)
Arctic Canada	2,508,800	0.6	1.5	1.8	4.5	6.0
Northwest Central Canada	4,978,400	1.0	5.0	2.0	10.0	14.9
Northeast Canada	2,854,444	3.0	8.5	1.5	4.2	12.8
Southeast Canada	1,250,000	12.0	15.0	6.0	7.5	22.5
LAND (sub-total)	**11,580,533**		**30.0**		**26.2**	**56.2**
Pacific	165,384,000	5.0	826.9	2.5	413.5	1,240.4
Arctic	14,056,000	0.6	8.4	1.8	25.3	33.7
Atlantic	82,217,000	10.0	822.2	5	411.1	1,233.3
OCEANS (sub-total)	**261,657,000**		**1,657.5**		**849.9**	**2,507.4**
TOTAL	**273,273,533**		**1,687.5**		**876.1**	**2,563.6**

Source: Pilgrim 1998

1.2.2 Specific Ambient Monitoring

Canada has the capability to monitor, inventory, and analyze mercury found in the atmosphere, soil, and water. In the atmosphere, different standard methods are used. For total gaseous mercury measurements, vapor-phase mercury is amalgamated with gold, and for particulate-phase mercury measurements the mercury is passed through an air filter. Both of these methods are followed by cold-vapor atomic fluorescence spectrophotometry analysis. For mercury analysis in soil and water, a flux chamber is often used.

1.2.2.1 - Air

The most comprehensive air monitoring network in Canada is the National Air Pollution Surveillance Program (NAPS) It was established in 1969, and the network is operated by provincial and municipal cooperating agencies, and is coordinated by the Pollution Measurement Division of Environment Canada. As of 1993, NAPS consisted of over 117 stations in 57 urban regions across Canada where a variety of pollutants, including mercury, are monitored.

Researchers are now able to track the origin of atmospheric mercury back to its source over short distances and long-range transportation studies are beginning to meet with success. Research is still needed to develop accurate and precise measurements of mercury at lower concentrations. Currently, Canadian laboratories have the capability to detect mercury in air at 0.10 parts per trillion (CEC Phase I Report 1996).

The Ontario Ministry of Environment has recently developed a method for measuring mercury in its various forms from emissions. This method for analyzing speciated mercury has been verified and will be adopted by Canada, the United States and others as a recognized standard for this type of analysis.

To narrow the knowledge gaps on mercury cycling, internationally compatible networks are needed. Fitzgerald (1995) recognized the need for a global mercury network and proposed AMNET, a network designed to monitor elemental gas phase mercury on an international scale.

In 1996, a hemispheric mercury network (headed by Steven Lindberg of Oak Ridge National Laboratory) was proposed to measure wet mercury deposition within the Americas (Pilgrim et al. 1997).

Since the Americas network was envisioned, progress has been made in Canada. Two sites are supported by the US-Canada Gulf of Maine Council in the Atlantic Provinces, with a further two sites proposed by the Atmospheric Environment Directorate (AED) for Québec, and one now operating in Ontario giving a total of

five sites operating in Canada as one network using the National Atmospheric Deposition Program (NADP) as of 1998.

Gulf of Maine Mercury Wet Deposition Project

Establishment of four mercury deposition sites within the Gulf of Maine (GOM) airshed was proposed to the GOM Council, of which two sites were supported for one year of funding. The purpose of the GOM mercury deposition project is to quantify atmospheric mercury inputs at coastal sites within the GOM airshed and compare these results to other NADP sites across Canada and the United States forming a North American network. The GOM sponsored sites are located at St. Andrews in New Brunswick and at Kejimkujik National Park in Nova Scotia. The project is to run for five years to coincide with the NAPD/Mercury Deposition Assessment in 2001. The GOM Mercury Deposition study is a joint venture between EMAN, Atmospheric Environmental Service, Environment Canada, and the United States National Atmospheric Deposition Program/Mercury Deposition Network (US NADP/MDN).

Preliminary results at NADP sites in Atlantic Canada show an average volume weighted concentration of 7.44 ng/L with higher values recorded in the summer (Pilgrim 1998). Concentrations and deposition were also highest in summer and lowest in winter. Deposition is a function of concentration of mercury in precipitation and the amount of precipitation. The annual deposition rate for 1996 and 1997 was between 8.2 and 8.7 $\mu g/m^2/yr$ (Pilgrim 1998).

Wet Deposition Measurements in Québec

Wet deposition mercury was measured at St. Anicet from July 1995 to July 1996 along the St. Lawrence River between Cornwall, Ontario and Montréal, Québec by Environment Canada (Poissant & Pilote 1997). They reported concentrations of total mercury in rain ranging between 0.81 and 21.29 ng/L. The median concentration was 6.58 ng/L and the volume-weighted mean concentration was 6.98 ng/L. The total precipitation amount recorded at the station during the sampling period was 1085 mm giving a deposition of mercury of 7.6 $\mu g/m^2/yr$. Poissant

suggested that 26 percent of the mercury in rain was associated with the particulate phase, which would imply a nearby source. The dissolved mercury in precipitation should be approximately 0.02 ng/L (Poissant 1997). The Atmospheric Environment Directorate of Environment Canada and the Québec Ministry of Environment are now working toward establishing sites in Québec as part of the NADP.

1.2.2.2 - Water

Many federal and provincial departments monitor mercury levels in water throughout Canada. For mercury, some analytical chemistry studies are underway to find methods to determine the speciation and concentrations of the various phases of mercury in water.

For example, the Ontario Ministry of Environment (MOE) operates the Ontario-Provincial Water Quality Monitoring Network, a system of stations across the province that collect ambient water quality data from rivers and streams throughout Ontario. This network has operated since 1964 and collects information at more than 1,900 locations. Some sites have only a few years of historical data while others have substantial data/time series spanning years.

Mercury in water can be detected reliably at the 0.5 parts per trillion or 0.5 ng/g level (CEC Phase I Report).

Fisheries Act

The Chlor-alkali Liquid Effluent Regulations under the Fisheries Act require the plant owner to monitor the concentration of mercury in the effluent according to methods outlined in the regulations. The regulations were promulgated under the Fisheries Act in March of 1972, revised in July of 1997, and last amended in September of 1995 (Fisheries Act, online, 1997).

Experimental lakes area work is underway to develop a research program using various isotopes of mercury to track the pathways of mercury deposited to soil through to its ingestion by biota. The project, named “Metallicus,” is being initiated by Fisheries and Oceans Canada and will be conducted in northern Canada.

1.2.2.3 - Soils and Sediment

The National Water Research Institute (NWRI) is responsible for the Sediment Remediation Project. Emphasis is placed on studies relevant to the assessment of sediment quality and cleaning of contaminated sediments (Allan 1996).
Currently, mercury levels in soils and sediments can be analyzed to levels as low as 5 μg/kg (Environment Canada and Natural Resources Canada 1996).
Sediment cores provide extremely valuable information on anthropogenic influences (Electric Power Research Institute 1996). Sediment profiles in the boreal region of Québec were collected in the deepest part of ten remote lakes and evaluated. Cores were also taken from four hydroelectric reservoirs. For all sampled lakes, sedimentation rates ranged between 0.1 to 0.3 cm/yr (Pilgrim 1998). Lucotte estimated that the ratios of the surface to baseline mercury concentrations (Anthropogenic Sedimentary Enrichment Factor, ASEF) averaged 2.3 for the Québec lakes and are independent of latitude. Lucotte showed that an increase in mercury deposition rates above background levels occurred for all lakes located north of 47 degrees latitude in the early 1940s, and reported that this was consistent with undisturbed lakes of southern Québec and for one headwater lake in Newfoundland.

1.2.2.4 - Biota

Mercury concentrations in plants, invertebrates, fish, and wildlife are monitored by a number of Canadian institutions, chiefly Health Canada, Environment Canada, and the Department of Fisheries and Oceans. Provincial institutions are also involved in this monitoring process. Analytical methods for determination of total inorganic mercury and methylmercury concentrations in fish and wildlife tissues are routine and the detection limit for mercury is 20 ng/g (CEC Phase I Report).
Concentrations of mercury in the range of 0.5 ppm in the diet of piscivorous birds have been shown to produce reproductive and behavioral effects (Scheuhammer 1995). The difficulty of trying to develop a reference dose for fish-eating birds is that

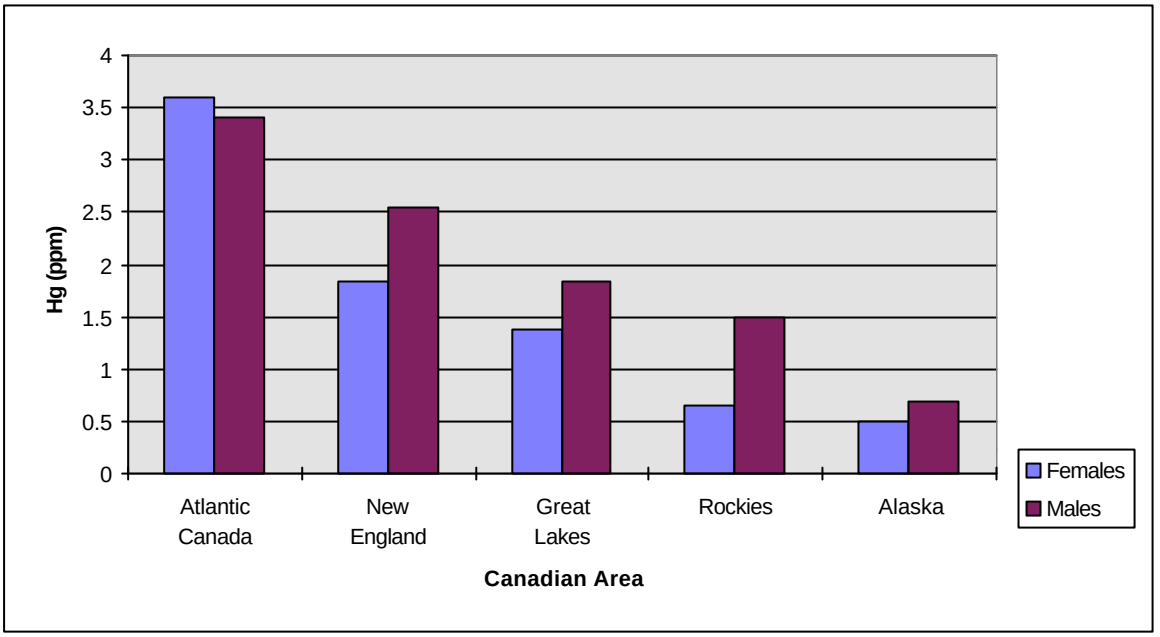
the species of interest (loons or kingfishers) can not be kept for extended periods in a laboratory, so extrapolations from one species to another are used. The role of chemical species such as selenium in detoxification of methylmercury also need to be more clearly defined. Piscivorous species in regions with higher mercury deposition, and in areas that favor methylation such as partially acidified watersheds, watersheds with large wetlands high in dissolved organic carbon, and reservoirs, are likely most at risk from mercury contamination.

A variety of fish-eating birds and mammals bioaccumulate mercury and carry body burdens that are considered a hazard to their health and offspring by laboratory standards. Some populations may have always had higher mercury concentrations than others. The geographic trends in different populations with mercury concentrations of interest are important in understanding the mercury issue. For example, it has been shown that belugas and ringed seals from the eastern arctic have lower levels of mercury than they do in the western arctic and the suggestion has been made that this is related to geology (Wagemann 1995).

Loons

In a recent survey of mercury in loons from five regions across the United States and Canada it was shown that blood mercury concentrations increased from west to east, with highest levels in southeast Canada (Evers et al. 1998). The Canadian Wildlife Service (Burgess 1998) reported a mean of 3.5 ppm of mercury in the blood of some adult loons from Atlantic Canada. Wider-scale studies to determine the effects on population now need to be conducted.

Figure 5 Mean Mercury Levels in Loon Blood



Source: Burgess 1996; Evers et al. 1998

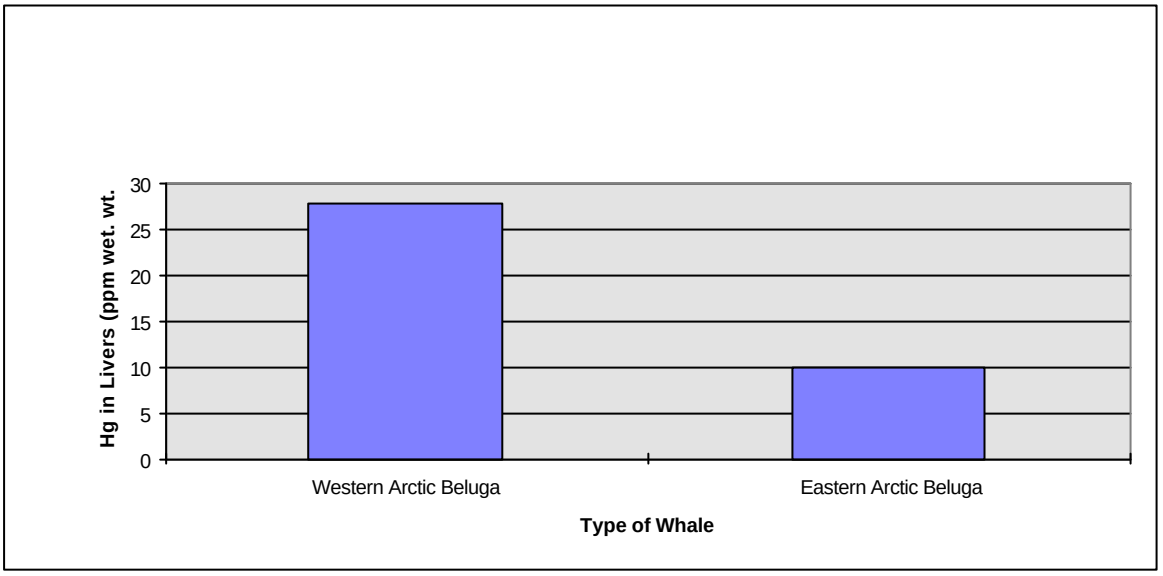
There are numerous anecdotal accounts of declines in the southern parts of the loon's breeding range in Canada over the past 100 years. These are supported by reports of reduced breeding success due to human development and the recreational use of lakes, acid precipitation and other pollutants. Lowered breeding success of common loons is suggested to occur when mercury concentrations in their prey average 0.1 ppm or more (Canadian Lake Loon Survey 1997). Approximately 30 percent of Ontario lakes sampled contained prey of a size suitable for loons with mercury concentrations greater than 0.3 ppm (Canadian Lake Loon Survey 1997).

Whales

The graph below suggests that different whale populations of the same species and approximate age do accumulate different levels of mercury. The spatial east to west mercury trend shown here for beluga whales is opposite to that shown in loons. The increase in mercury in the environment since the dawn of the industrial age, and the levels reported in fish and fish-eating creatures have not produced, with any degree

of confidence, statistical evidence of declines in wildlife populations. This tends to confound researchers but places greater emphasis on the need for work on subtle neurological impacts and the assessment of lowest observable effects levels for mercury.

Figure 6: Mercury in Eastern and Western Arctic Beluga, 1993–1994



Source: Wagemann 1995

1.3 Trends Data

In Canada, the Department of Natural Resources annually surveys production of industrial mercury at the first processing stage. Prior to 1992, mercury consumption was reported in two main categories: (i) electrical apparatus, industrial and control instruments and (ii) electrolytic preparation of chlorine and caustic soda and other uses. Because of the reduction of industrial use in each category, only total consumption is reported to protect commercial confidentiality. Canada's mercury consumption peaked in 1948 at 236.9 tonnes, and averaged about 80 tonnes until the late 1980s (CEC Phase I Report). In 1996, Canada's consumption was about 6.3 tonnes and dropped further to 2.9 tonnes by 1998 (Natural Resources Canada 1998).

1.3.1 Domestic Consumption

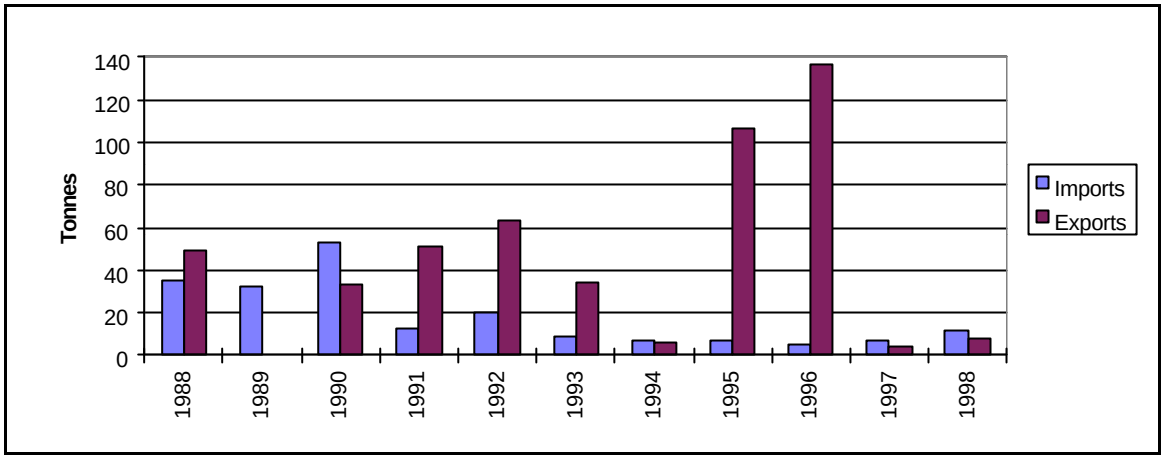
1.3.1.1 Imports

Imports of mercury have declined since the late 1980s, falling to between 5 and 7 tonnes in 1996 and 1997, before rising to approximately 11 tonnes in 1998 as shown in Figure 7 (Natural Resources Canada 1998). Over 90 percent of Canadian imports of mercury are from the United States. Imports of mercuric oxide have also fallen drastically to 0.466 tonnes in 1998 (Natural Resources Canada 1998). This is down from 214 tonnes in 1995, and 1,742 tonnes in 1991 (CEC Phase I Report). Mercury ores and concentrates are no longer imported (Natural Resources Canada 1998).

1.3.1.2 Exports

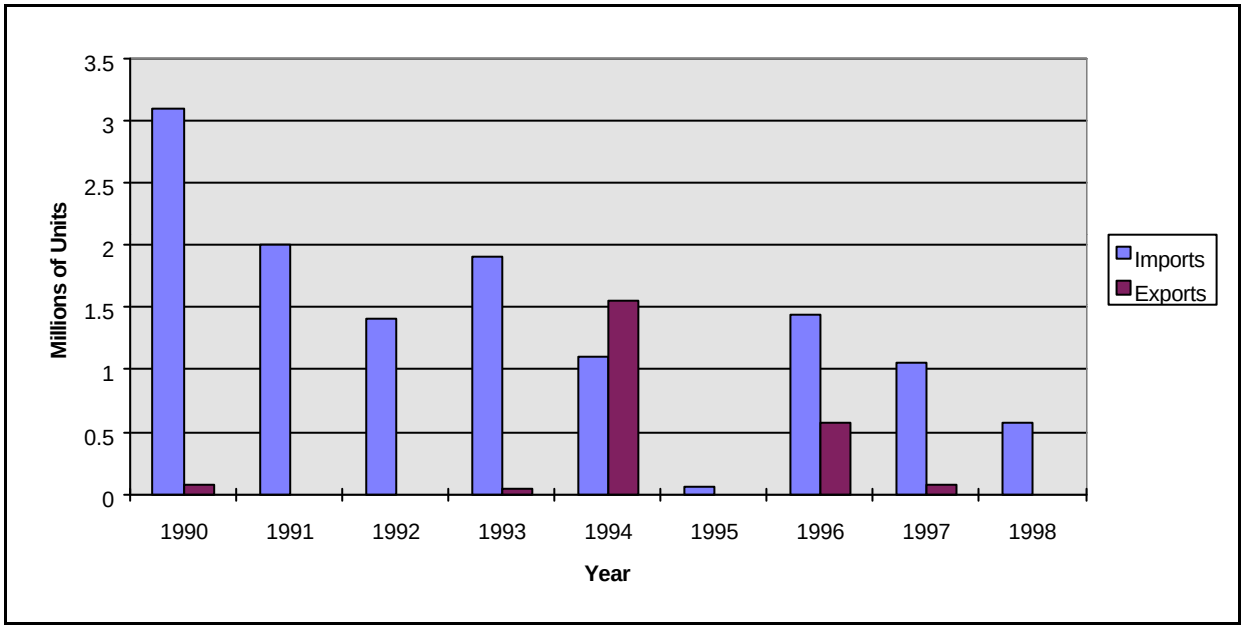
Since 1990, Canada has been a net exporter of mercury, with the exception of 1994 when net exports were almost nil (CEC Phase I Report). The United States has taken 100 percent of Canadian exports since 1994. While Canadian exports increased in 1995 to 107 tonnes, the source of these exports is unclear at this time (CEC Phase I Report). In 1996 exports rose to 137 tonnes, but have since dropped in 1997 and 1998 to 4 and 8 tonnes respectively (Natural Resources Canada 1998). Canadian mines do not report mercury production at this time (CEC Phase I Report).

Figure 7: Mercury Trade in Canada: Imports and Exports



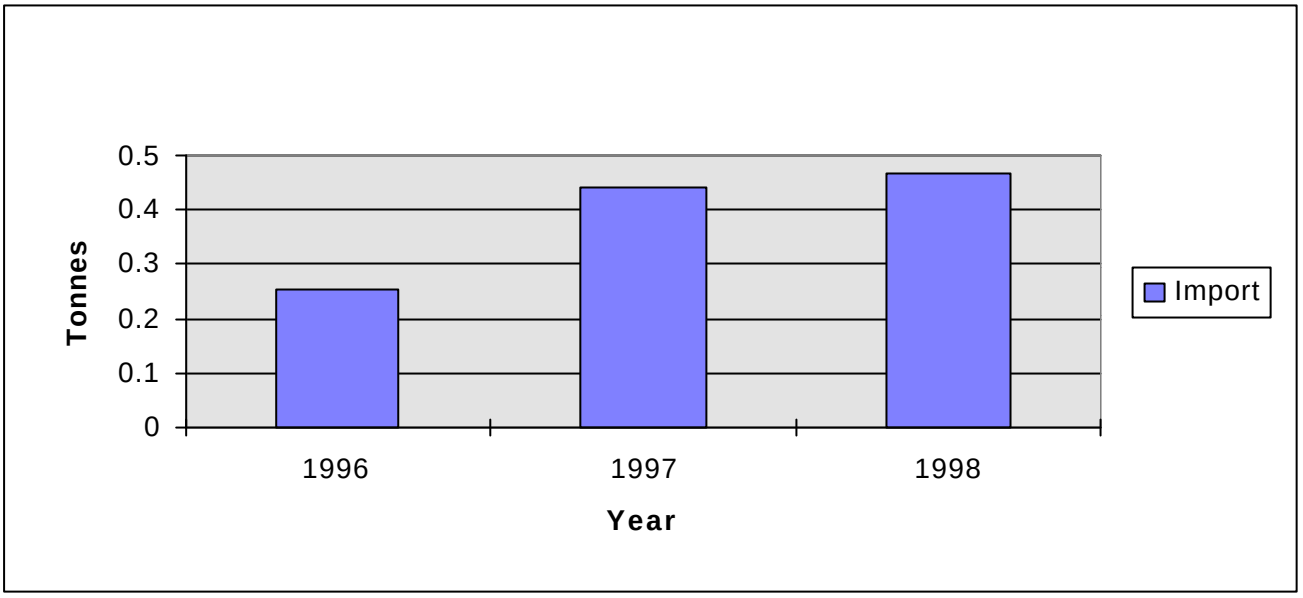
Source: Natural Resources Canada 1998

Figure 8: Trade in Mercuric Oxide Primary Cells and Batteries



Source: Natural Resources Canada 1998 and Statistics Canada 1996, 1997, 1998

Figure 9: Imports of Mercury Oxides in Canada



Source: Natural Resources Canada 1998

1.3.2 Use Patterns

Until the 1960s, mercury was used primarily as a flowing mercury electrode for the electrolysis of an aqueous sodium chloride solution to yield chlorine and caustic soda. Process losses to the environment became a concern and many mercury cell chlor-alkali plants were either closed or converted to diaphragm cell or ion exchange technologies. Worldwide demand of this application continues to be the single largest use of mercury, but it is declining as older facilities are being closed and replaced with mercury-free technology (Natural Resources Canada 1998). Battery production is another major market for mercury that is experiencing a decline as manufacturers switch to alternative metals.

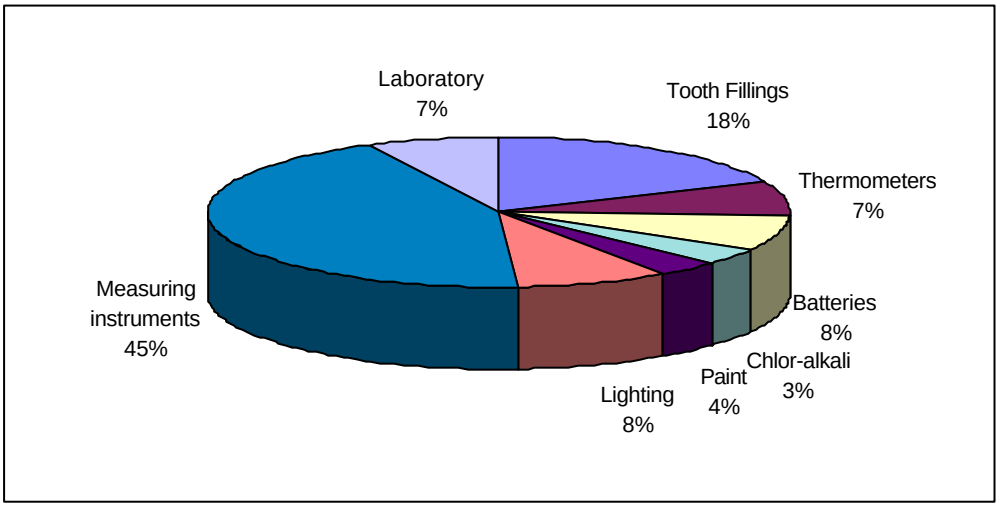
The third major use for mercury is in electrical applications. Uses range from metallic mercury switches in thermostats to mercury-vapor discharge lamps. Other uses include dental amalgams, temperature and pressure measuring devices, detonators, and pharmaceuticals (Natural Resources Canada 1998).

Increased concerns related to the risks of exposure to human health and the environment have led to increased restrictions on the uses of mercury; however, its

unique properties will likely guarantee its use in some key sectors in the foreseeable future.

Canada's reported consumption of metallic mercury for electrical apparatus, industrial and control instruments and the one remaining mercury cell chlor-alkali plant fell to six tonnes in 1994 (CEC Phase I Report). This number continued to fall as various uses for mercury in aspects such as battery manufacture were phased out. In 1995 metallic mercury consumption was approximately three tonnes and in 1996 it increased to approximately six tonnes (Natural Resources Canada 1998).

Figure 10: Mercury use in Canadian Products, 1994



Source: OECD 1994

Because of its obligations under the Canada-Ontario Agreement, Ontario has collected a substantial amount of information on mercury use patterns. Use of mercury in various other products has been severely limited or banned. These restrictions include mildew-proofing paint additives, pigments in paint and use of mercury in cosmetics (Canada-Ontario Agreement, online,1994).

1.3.2.1 Use in devices for sensing pressure or temperature

Thermometers

Mercury-containing thermometers contain approximately 0.5 to 2.25 grams of elemental mercury in a small vacuum tube of uniform bore with a mercury-containing chamber at one end and a temperature scale on the side. During the manufacture process, elemental mercury is sealed in the chamber, where it expands during heating. Elemental mercury has the unique characteristic of having a liquid physical state at ambient temperature ranges, making it ideal for this application. It is estimated that 29.5 tonnes of mercury associated with fever thermometers was discarded in 1985, 15.3 tonnes in 1995, and 15.2 tonnes will likely be discarded in the year 2000 (Environment Canada 1998). Substitutions for mercury-containing fever thermometers began to appear in 1984, and mercury use has continued to decline since then (Environment Canada 1998).

Thermostats

Most mercury-containing thermostats are a specialized use of silent/tilt switches. Thermostats are temperature control devices that usually contain a temperature-sensing element, an electrical switch that activates heating and cooling equipment, and a mechanism for adjusting normal temperature (Sass et al. 1994). Most residential and appliance thermostats are an on/off (two wire) device with a bimetal temperature-sensing element consisting of two different metals welded or brazed together with different thermal expansion coefficients (Sass et al. 1994). Another type of temperature sensing element in thermostats is the gas-filled diaphragm that expands when heated and contracts when cooled. Normally, a gas refrigerant is used. These sensors are used in air-conditioning equipment more than in heating. They are more popular in Canada and Europe than in the United States (Sass et al. 1994).

Mercury silent/tilt switches commonly used in thermostats consist of a hermetically sealed glass tube with two electrodes sealed into the glass at one end. The glass tube is filled with approximately three mg of mercury and an inactive gas such as nitrogen (Giannetas and Lourie 1999) The mercury switch thermostat operates quietly and efficiently, does not require a power source, and needs little to no maintenance. The device has a typical service life of 30 to 40 years and it keeps temperature fluctuations in a room within one degree, saving energy of up to 12 percent over most alternative technologies, excluding the electronic thermostat (Giannetas and Lourie 1999).

Thermostat probes containing mercury may be found in gas-fired appliances that have pilot lights such as: ranges, ovens, clothes dryers, water heaters, furnaces, or space heaters (Doiron & Napier 1998).

There are many thermostats that do not contain mercury switches. They operate on other principles, such as the mechanical snap-acting switch, the open-contact magnetic snap switch, the sealed-contact magnetic snap switch and the electronic thermostat.

Table 4: Comparison between Mercury Switch Thermostat and Alternatives

Switch Type	Performance	Applications	Hg Content*	Thermostat Price ($US)
Mercury tilt switch	Accurate, reliable, long life service	Premium residential heating/cooling	3mg	$40–80
Mechanical snap-acting switch	Inexpensive, less reliable	Electric strip heating, ventilation	zero	$10–30
Open Contact magnetic snap switch	Accurate, reliable, long service life	Premium residential heating/cooling	zero	$60–100
Electronic thermostat	Accurate, reliable, unproven service life	Premium residential heating/cooling programmable features	zero	$70–140

Sources: Sass et al. 1994, * Gianettas and Lourie 1999.

Heating/Cooling Systems

The mercury safety valve/mercury flame sensor detects the presence of a pilot light for a concealed gas burner and controls the gas flow to the burner if a pilot light is out. These devices are used both in standing and electronically ignited pilot flames and are found nearly universally in residential and commercial ranges and ovens (Gilkeson 1999).

In Canada, safety shut-off valves must be approved by the Canadian Standards Association (CSA). It is difficult to determine if a specific shut-off valve contains mercury or how commonly used the valve is because, although one can get a list of certified values; for proprietary reasons the certifying bodies will not disclose information on construction and will only certify that the piece of equipment has been approved for its intended use (Cautillo 1999).

Mercury safety valves were first used in the early 1950s when standing pilot oven burners were introduced. Hot Surface Ignitors (HSI) were introduced in the early 1970s and are only found on appliances with electrical connections.

1.3.2.2 Use in electrical storage devices

Canada has Environmental Choice Guidelines concerning mercury in batteries (see section 2.5.2). The following reduction levels of mercury in batteries have been targeted: a) Zinc-air batteries for hearing aids: a maximum of 40 mg/Ah (milligrams per Amperehour) rating on mercury content; b) cylindrical batteries: a maximum of 0.02 percent mercury by weight and c) alkaline manganese buttons or coin batteries, 25 mg per cell (Pilgrim 1998).

The Canadian Household Battery Manufacturers' Association (CHBA) eliminated the deliberate addition of mercury to household alkaline, zinc-carbon, and zinc-chloride batteries as of January 1997 (Antler 1996). The only major type of mercury-containing battery available in Canada may be mercury-oxide batteries. Mercury is used primarily to control off-gassing, which can lead to leakage and possible ruptures. New technologies have been introduced such as: removing or decreasing

impurities which cause gassing; using other formulations to suppress gas production; and redesigning batteries to allow gases to escape more quickly (Binational Toxics Strategy 1999).

1.3.2.3 Use in health care sector

Hospitals

There are 159 biomedical incinerators in Canada (SENES Consultants 1998). Biomedical waste incinerators destroy infectious and noninfectious wastes generated from facilities involved in medical/veterinary care or research activities. These facilities include hospitals, medical and veterinary clinics, nursing homes, medical laboratories, medical/veterinary schools and research units and funeral homes (SENES Consultants 1998).

Sources of mercury in waste products include batteries, fluorescent and high intensity lighting fixtures, thermometers, specialty papers and films, and pharmaceutical materials and pigmented materials. Based on a 1990 emissions sampling program involving six hospitals in Ontario, it is estimated that, on average, 14 grams of mercury are emitted for each tonne of waste incinerated (Sang and Lourie 1997). Mercury emissions from medical waste incinerators in the northeast states are based on 20g/tonne for uncontrolled mixed waste, 16g/tonne for infectious (red-bag) material and 0.005 g/tonne for pathological material (Pilgrim 1998).

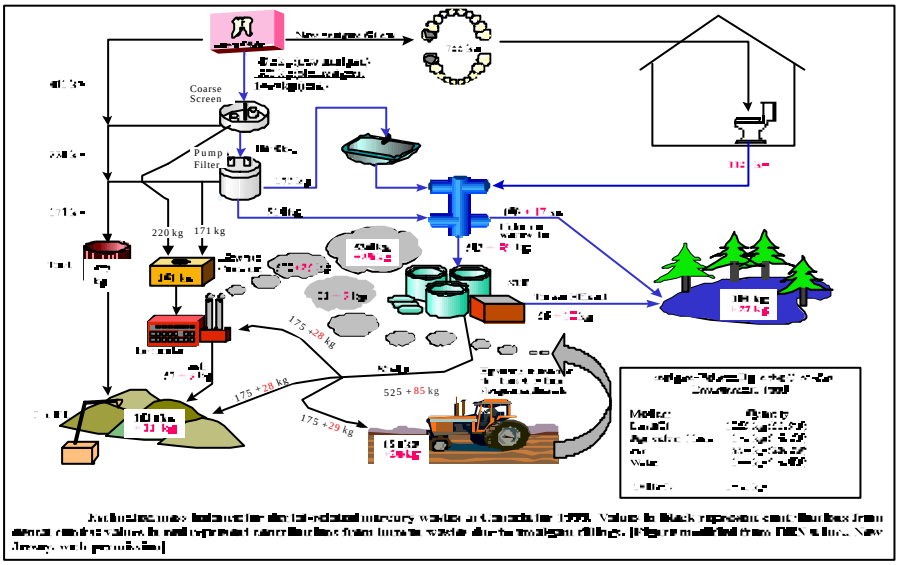
The total 1995 mercury emissions from the medical waste incinerators sector were 418 kg from the 159 facilities across Canada (SENES Consultants 1998).

Dental Use

Increasing knowledge about the risk of toxic effects caused by anthropogenic mercury accumulation in ecosystems has resulted in a growing pressure for reduction of the discharge of mercury-containing waste. Consequently, the mercury

waste problems of dental clinics have been given increased attention. Major amalgam particles from mixing surplus or those produced during the carving and burnishing of new amalgam restorations are generally collected in coarse filters. Beside the dental chair smaller amalgam particles released by production of new fillings or by removal of old restorations partially settle in tubes and drains. The remaining particles are carried to the wastewater stream and settle out in sewer pipes or flow to the local sewage works or septic tanks. According to recent investigations, dental clinics appear to be responsible for the major amount of mercury collected in the sludge generated in sewage plants (Amalgamlinks 1997). If threshold values for heavy metal content, including mercury, are exceeded, the sludge may be restricted for use as a fertilizer (Amalgamlinks 1997).

Figure 11: Estimated Mass Balance for Dental-Related Mercury Wastes in Canada for 1999



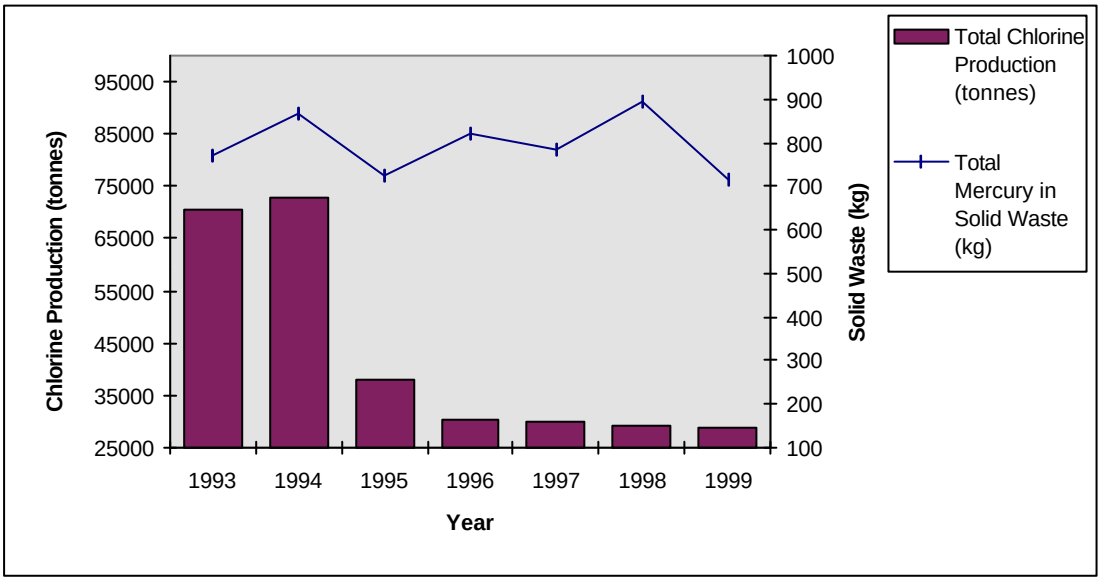
Source: O'Connor Associates Environmental Inc., 2000

1.3.2.4 Use in mercury cell chlor-alkali manufacture

The only remaining mercury cell chlor-alkali facility in Canada is the PCI Chemicals Canada Incorporated plant located in Dalhousie, New Brunswick. Monitoring data

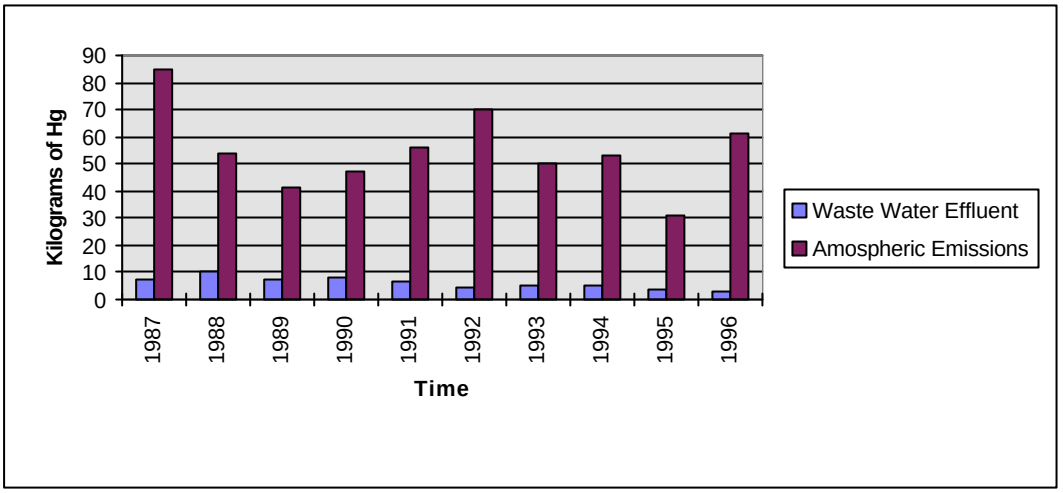
from 1993–96 indicate mercury emissions are within acceptable limits and that the average annual release in liquid effluent was 4.4 kg/year (Doiron et al. 1998). Atmospheric emissions are 15 times greater than discharges to water. In 1996, 62 kg/yr (4.9 percent of atmospheric emissions in Canada) were emitted to the atmosphere from the New Brunswick chlor-alkali plant (Doiron et al. 1998). Solid wastes containing low level mercury are disposed of on site, while high-level mercury waste is transported to hazardous waste management facilities. Figure 11 shows the amount of solid waste containing high level mercury that PCI has sent off site to1993 to 1999 as well as the amount of chlorine produced containing high level mercury.

Figure 12: Mercury-containing Solid Waste and Chlorine Production



Source: Audet 1999.

Figure 13: Mercury emissions to water and air from the chlor-alkali plant in Dalhousie, New Brunswick 1987–96



Source: Pilgrim 1998

The plant is regulated under the Canadian Environmental Protection Act, Chlor-alkali Mercury Release Regulations, the Chlor-alkali Liquid Effluent Regulations under the Fisheries Act, and a New Brunswick, Department of the Environment, Certificate of Approval under the Clean Environment Act (Dorion et al.1998).

1.3.2.5 Use in other devices

Environmental Manometers

In conjunction with the province of New Brunswick, Environment Canada operated 22 mercury manometer gauges containing approximately 500 grams of mercury per manometer (Giannetas and Lourie 1999). These were completely phased out of New Brunswick in 1996. Mercury manometer stations continue to operate in Nova Scotia and Newfoundland. Several hundred of these instruments were used across Canada and many mercury manometers still remain in operation at environmental stations. Mercury losses to the environment are minimal. However, at least one manometer was swept away during a spring flood on the Tobique River, in New Brunswick. It is estimated that approximately 3,000 kg of mercury is stored at

Environment Canada's flood stations throughout Atlantic Canada and a further 6,000 kg in Québec (Giannetas and Lourie 1999).

Agricultural Use of Mercurial Fungicides

Agricultural use of mercury fungicides peaked in Canada in the 1970s when ninety-five agricultural products containing 18 different mercury compounds were registered for use. Much of this mercury may remain in soils and may be volatilized into the air or washed into rivers and streams. The mercury used decades ago may still be involved in this circulation making it important to note the cumulative losses. Mercury compounds for the treatment of seed were introduced into Canada in 1929, but most had been deregistered by the early 1990s when only four mercurial fungicides were still registered for use in Canada, all of which were for turf application, (Sang and Lourie 1997), generally at golf courses.
The registration of all mercurial fungicides was discontinued on 31 December 1995, and retail stocks of these products were allowed to be depleted until the end of 1997. Sang and Lourie estimated that in 1997, 0.009 g/person or 90 kg/year of mercury was released through volatilization of mercurial fungicides in Ontario.

Fluorescent Lights and Fixtures

Mercury is used in the manufacture of various lamps and lighting fixtures, the main applications being fluorescent, mercury vapor, halide and high-pressure sodium lamps; wiring devices, and switches (see section 2.5.2). Sang and Lourie (1996) estimated that mercury emissions associated with the manufacture, breakage and disposal of mercury-containing lamps and light switches in Ontario are 240 kg per year. Extrapolating this data suggests that the value for Canada is approximately 719 kg/yr. Doiron and Associates pointed out that the Pollution Probe estimate is based on an assumption that 25 percent of the total mercury content of these lamp devices is volatilized.

Nationally, mercury releases from fluorescent light tube breakage are projected to have declined to an estimated 13.3 tonnes per year in 1995, and by the year 2000, releases are expected to be down to 10.5 tonnes as a result of recycling programs and changes in design technology (Environment Canada 1998). This data assumes that the mercury content in fluorescent tubes will be reduced to 15mg per standard tube by the year 2000. In Canada, the average mercury content in fluorescent lamps has fallen from 48.2mg in 1985 to 27mg in 1995, with an industry target to further reduce mercury content to 15mg (Bleasby 1998).

Table 5: Types of Mercury-Containing Lamps

Type of Lamp	Use
Fluorescent	Tube-style was first used as overhead lighting in offices, but now also found in compact globe shapes for variety of home and office uses.
Mercury Vapor	First high intensity discharge (HID) lamps with blue-white light, originally used as farmyard lights.
Metal Halide	Newer more efficient HID lights found in homes and offices.
High-Pressure Sodium Vapor	White-yellow HID lights used for street lamps and outdoor security lighting.
Neon Lamps	Brightly colored lamps typically used in advertising; most colors contain mercury except red, orange, and pink.

Source: Giannetas and Lourie 1999

Table 6: Mercury Content in Fluorescent Lamps

Year	Industry Average mg/unit
1985	48.2
1990	41.6
1994	28.0
1995	23.0
1999 (Phillips)	3.0 (low Hg lamp)
2000 (NEMA target)	12.0 (per lamp)

Source: Giannetas and Lourie 1999

According to Newdick (1998) an estimated 120 million fluorescent lamps are currently in use in Canada. According to Statistics Canada, in 1990 there were about 48,000,000 units of fluorescent hot cathode, other discharge and ultra-violet

or infra-red lamps sold in Canada (including imports) and approximately 60,000,000 sold in 1995.

Reduction of mercury content in lamps is reaching practical limits (Sass et al. 1994). Redesigning low dose mercury lamps can reduce leachable mercury and help them pass Toxicity Characteristic Leachate Procedure or TCLP tests. If the mercury contained is so low that successful operation is questionable, then there may be an increase in mercury use and release because of shorter life and poorer performance (Chong 1997). Although mercury content per lamp is decreasing, population growth and increased use and demand may result in an increase in total mercury use and release.

Paints

Major Canadian paint manufacturers have voluntarily removed mercurial compounds in latex paint. Mercury based antimicrobial pesticides, including those for exterior paints were phased out in 1998 (see section 2.5.2). In the1970s, approximately 15 tonnes/yr of mercury was used in Canadian paints (Pilgrim 1998). Although estimates vary, current information suggests that approximately two-thirds of this mercury was ultimately emitted to the atmosphere, and that painted surfaces contributed significantly to total atmospheric emissions of mercury in the recent past (Doiron & Associates 1997). Environment Canada estimated that paint application contributed 448 kilograms to Atlantic Canada's total mercury emission inventory in 1978 (Pilgrim 1998).

Switching Devices/Relays

Ignitrons, thyratrons and trigger-tubes containing mercury are used as an electronic switch via grid control (Sass et al. 1994). The development of the transistor in 1947 (solid state) has replaced most vacuum tubes and some gas filled tubes. However, applications requiring the amplification of high-power signals such as older model microwaves, radar installations, X-ray machines, and mercury-arc rectifiers still

require gas-filled tubes containing mercury vapor. The communications industry is currently researching fiber optic switching technology (Sass et al. 1994).
Silent/tilt switches are small tubes with an electrical contact at one end of the tube. As the tube tilts, mercury collects at the end where the electrodes are situated. These switches are used in numerous applications such as: light switches, sump pump float controls, automobile trunk lamps, chest freezer door lamps, and washing machine lift covers (Sass et al. 1994).
Reed switches are small circuit controls used in electronic devices that have mercury wetted electrical contacts. They are being replaced by electro-optical and solid state alternatives for applications in communications and circuit control (Sass et al. 1994).

Lighthouse Lenses

Canada had 6 tonnes of mercury stored in existing lighthouse facilities (Pilgrim 1998). This mercury is used to float the beacon lenses. There has been no estimate of environmental losses during de-commissioning of these sites. However, the Canadian Coast Guard has reported that recovered mercury has been sent to authorized agents for recycling of elemental mercury.

1.3.3 Production Patterns

1.3.3.1 Primary Production

Currently, there is no primary production of mercury occurring within Canada (Natural Resources Canada 1998).

1.3.3.2 Byproduct Production

While primary mercury metal is no longer produced in Canada, some mercury-containing compounds are produced as a result of the mining and smelting process. Mercury is often associated with base metal ores as well as gold and other precious

metals. During the smelting and refining process for base metal ores, trace amounts of mercury can be recovered during the treatment of sulfur-containing gases. The mercury is fixed with other compounds and sold for export for further recovery in the United States. Likewise, any mercury-containing compounds, together with any other trace elements that are left over during the refining stages of gold and other precious metals, are shipped for further treatment in the United States.

2. Risk Management Pollution Prevention

Canada is a signatory to a number of international, continental and domestic initiatives that target heavy metal contamination in the atmosphere, water and land. The strategies summarized below include a wide range of policies, action plans, programs and guidelines developed with the intentions of sustaining environmental and economic well being. Collectively, the initiatives encompass spatial, political and social dimensions. For example, monitoring programs across the country are in operation, while reduction plans contain reference to the far north, the marine environment, and fresh water bodies. Policies and acts emphasize the importance of metals for trade, but warn against their more dangerous properties. Many of the strategies address developmental and cultural needs.

2.1 National Policies

2.1.1 Federal Government Policy

Toxic Substances Management Policy (TSMP)

Canada's Toxic Substances Management Policy (TSMP) provides a framework for making scientifically valid decisions in regard to the effective management of toxic substances. This policy serves to ensure that pollution prevention principles are applied in those programs, while sustaining jobs and a healthy economy. The policy contains two key management objectives. The first key management objective is to virtually eliminate from the environment, toxic substances that result predominantly from human activity and that are persistent and bioaccumalative. These are

classified as Track 1 Substances. The second objective is life cycle management of other toxic substances and substances of concern throughout their entire life cycles, to prevent or minimize their release into the environment. These are classified as Track 2 Substances, and include naturally occurring substances, such as mercury. The TSMP establishes precautionary, proactive and accountability rules for dealing with toxic substances. It will be applied in all areas of federal responsibility. A Track 2 substance in the environment may be targeted for virtual elimination from the environment if it poses unacceptable risks to the environment or human health. Elements and naturally occurring substances, such as mercury, that are used or released as a result of human activity may be targeted for reduction to naturally occurring levels under Track 2.

Minerals and Metals Policy (MMP)

The Minerals and Metals Policy (MMP) of the Government of Canada describes, within areas of federal jurisdiction, the Government's role, objectives and strategies for the sustainable development of Canada's mineral and metal resources. It provides guidance for federal decisions on minerals and metals in the context of sustainable development. This includes: a responsive public policy framework; the role of the market mechanism; the role of regulation; the role of nonregulatory approaches; the importance of science; endorsement of the concept of pollution prevention; affirmation of the precautionary approach; and recognition of the polluter pays principle. The Policy introduces an approach to the responsible use and management of minerals and metals called the 'Safe Use Principle'. This principle takes a life–cycle-based approach to the use and management of minerals and metals, including the application of risk assessment and management strategies, in accordance with well established stewardship practices.

Federal Pollution Prevention Strategy

The federal Pollution Prevention Strategy stresses the need to shift from managing emissions to preventing pollution and commits the federal government to achieving a climate in which pollution prevention becomes a major consideration in private sector activities. It also indicates that techniques and practices for pollution prevention should focus on “substances of concern.” Based on available scientific information, mercury is a substance of concern.

2.1.2 Canadian Domestic Initiatives

Canadian Environmental Protection Act (CEPA)

The Canadian Environmental Protection Act has greatly evolved since its proclamation in 1988. In the past, its focus was on strict law enforcement and intergovernmental cooperation. In 1996 the Act was renewed and proclaimed into law on 31 March 2000. The focus of the revised Canadian Environmental Protection Act (CEPA) of 1999 is pollution prevention and the protection of the environment and human health in order to contribute to sustainable development. CEPA 1999 outlines many issues including controlling toxic substances (such as mercury), controlling pollution and managing wastewaters and enforcement law (CEPA, online, The New Canadian Environmental Protection Act 1999, <http://www.ec.gc.ca/cepa/english/index.htm/>).

The *Domestic Substances List*, established under *the Canadian Environmental Protection Act* identified 32 mercury compounds in commerce in Canada. Mercury compounds not on this list are deemed to be new to Canadian commerce and their introduction requires notification according to the New Substances Notification Regulations under CEPA. Mercury and all mercury compounds are included in Schedule 1, List of Toxic Substances of CEPA, giving the Minister the power to regulate its entry into the environment.

Strategic Options Process (SOP)

Under the Canadian Environmental Protection Act, a number of substances were assessed and declared toxic to human health and the environment. The Strategic Options Process (SOP) was developed to determine methods for the management of substances declared toxic under CEPA. The process consists of two phases, the first of which is “Information Gathering.” This first step involves the formation of an Issue Table to set the environmental and health objectives as well as the time for achieving them in the context of sustainable development. A critical task of the Issue Table is to ensure that the scientific, technical and socio-economic information necessary for the evaluation of strategic options is available. The second phase is “Options Identification and Evaluation.” The information that was gathered during the first step of the SOP is used to assess options for meeting the environmental and health objectives within the context of sustainable development. Voluntary action, information gathering, market-based measures and mandatory pollution reduction measures are all possible strategies the Issue Table considers. The cost-benefit analysis developed by SOP considers the feasibility of implementing different pollution control strategies taking into account the cost of implementing new technologies or processes. A summary document of the SOP Report, including final recommendations is prepared for review by ministers, who may act on the recommendations contained in the SOP reports.

The nonferrous base metal smelting and refining sector and the electric power generating sector were investigated to determine strategies to reduce mercury emissions. The Issue Table for the base metal SOP is recommending an 80 percent reduction of 1998 emissions of mercury, nickel, arsenic, lead and cadmium from smelters and refineries by 2008 (Davies 1997). Specific to mercury in the Electric Power Generation Sector, the SOP Report recommends a 5–30 percent reduction in mercury emissions from present values. Furthermore, it is recommending that environmental performance standards should be developed by 2000 for emissions, under the auspices of the CCME, and that site specific management plans should be developed (Environment Canada 1996).

National Pollutant Release Inventory (NPRI)

The National Pollutant Release Inventory (NPRI) provides the Canadian public with a database summary of pollutants released to the environment from Canadian industry and transportation sectors. In reporting their releases, industries must satisfy the following general criteria: 10 or more full time employees, and using an NPRI substance in concentrations greater than one percent weight and in quantities greater than 10 tonnes (Environment Canada 1996). Mercury manufactured, processed or otherwise used must be reported if it exceeds five kg. Dental offices are currently exempt. These firms are required to file a report with Environment Canada and identify any releases of NPRI compounds to air, water, and soil. In the case of byproducts, such as from the combustion of fuel, only values greater than the 10 tonne minimum requires reporting. Mining facilities are exempted from reporting, but facilities processing mined materials, such as smelting operations, are not. Environment Canada proposed changes to the NPRI for the 1997 reporting year. Among the proposed changes was the development of different reporting thresholds or other reporting criteria. In the case of mercury, the requirements for reporting have been reassessed so that lower quantities of the toxic substance could be included. The government has implemented changes, allowing for a more comprehensive reporting of toxins. Compliance, promotion and enforcement are being revised to ensure that facilities understand their legal requirement to report. In the past, mercury releases did not have to be reported if they were under the 10 tonne threshold. In December of 1999, mercury was listed under a new threshold criteria of five kg.

Environmental Assessment Act and Environmental Assessment Review Process

The process of Environmental Assessment compels the proponents of projects to consider the environmental and social ramifications of the project, and to seek the

input of the affected public. Where an environmental assessment is required under the Act, the review process must be undertaken early in the planning stages of the project before irrevocable decisions are made.

Canadian Council of Ministers of the Environment Accord on Environmental Harmonization and the Standards Sub-Agreement

The Canadian Council of Ministers of the Environment (CCME) is made up of the Ministers of the Environment for the Federal Government, the ten provinces and the three territories. In November 1996, the CCME approved the Canada-wide Accord on Environmental Harmonization (see below). The objectives of the Accord are to enhance environmental protection, promote sustainable development, and achieve greater effectiveness, efficiency, accountability, predictability and clarity of environmental management of Canada-wide issues. In order to achieve these objectives the governments have agreed to enter into multilateral subagreements on specific issues of concern.

Canada-wide Standards for Mercury

In November 1996, the Canadian Council of Ministers of the Environment, with the exception of the province of Quebec, approved an Accord on Environmental Harmonization. The Accord focused on coordinated management of environmental issues and was followed in 1998 by a number of sub-agreements, to harmonize environmental assessments, environmental inspections, and to establish Canada-wide Standards for several priority issues. Mercury was identified as one of the initial priority issues, and in November 1999, draft Canada-wide Standards to address the base metal smelting sector and the waste incineration sector was received for review by the Committee of Ministers. These draft standards were accompanied by proposals for initial actions by the federal, provincial and territorial governments to implement the Standards. Proposals for action are shown in Table 9. Additional Canada-wide Standards are under development for emissions from fossil-fuelled electric power generation facilities. Mercury-containing products have

also been recommended for consideration. Priority controls are aimed at fluorescent lamps and dental amalgams.

Table 7: Proposals for Action

	Existing Facilities	New/Proposed Facilities	Other Proposals
Canada	• develop implementation plans for existing federally owned, operated or managed incineration facilities		• establish a Strategic Options Implementation team that will monitor the progress of the implementation of base metal standards • maintain the RDIS or equivalent emissions database as a means of tracking emissions of mercury • support international action to reduce global anthropogenic mercury emissions • lead the federal/provincial coordination of reports to the Council of Ministers on progress by industry and jurisdictions in complying with the standards • support ARET and NPRI offices as a major public reporting mechanism for mercury emissions rates from various sectors
Alberta	• any existing facilities that fall under the standards will be subject to the requirements through regulatory and nonregulatory process • medical and municipal incineration facilities that are less than 120t/yr will be reviewed to determine best options for standard implementation	• any new facilities will be subject to the requ9irements through regulatory and nonregulatory processes	
British Columbia	• only one base metal smelting facility, and one existing municipal solid waste incineration facility which is subject to the CWS. These facilities will be monitored to ensure continued compliance with the standard	• there are no existing biomedical waste, hazardous waste incineration facilities or sewage sludge facilities which are subject to the CWS. If any are proposed the CWS will be implemented	
Manitoba	• develop and review	• implement standards	• Continue to participate in

	options for the implementation of incineration standards for applicable existing facilities	for new facilities through regulatory and nonregulatory processes	the implementation of the strategic option s process for base metal smelters
New Brunswick	• develop a schedule of compliance to implement the CWS for existing facilities	• implement standards for new facilities through the regulatory approval process	• stack testing for mercury for one of the coal-fired power facilities will occur • participation in the implementation of the Mercury Action Plan
Newfoundland and Labrador		• any new base metal smelters will be required to use BAT to meet proposed CWS • any new hazardous waste, sewage sludge or medical waste incinerators will be required to review the use of conical waste combustors and estimate their remaining life expectancy	
Northwest Territories		• any new smelting facilities will be required to comply with relevant approvals and standards including the CWS	• a new Environmental Guideline is being drafted under the Environmental Protection Act that will provide further information for institutional users to prevent mercury-containing wastes entering the municipal and biomedical waste streams
Nova Scotia	• one existing incinerator that burns both municipal and medical waste. This incinerator is currently in compliance with the proposed CWS	• mew base metal smelters or hazardous waste incinerators would be subject to the Environmental Assessment Regulations and CWS would be used when establishing emissions • all new municipal and medical waste incinerators will have to be in compliance	• participants in the implementation of the Mercury Action Plan

		with CWS	
Nunavut		• any new incineration or smelting facilities will comply with the CWS	
Ontario	• continue to participate in the Strategic Options process implementation for the base metal smelting standard and monitor facilities to ensure they continue to comply with the standard	• establish a reporting and monitoring system to monitor the performance and compliance with the standard by the incineration facilities • new and expanding facilities will be addressed during the Environmental Assessment and Approvals process	
Prince Edward Island		• establish a reporting system to monitor performance and compliance with the waste incineration standard for facilities • any proposed sewage sludge incinerators or base metal smelters will have to comply with existing legislation and the CWS	
Saskatchewan	• for medical waste facilities burning less than 120tonnes/yr, a partnership will be formed between the government and owners to document and implement a mercury diversion plan	• any proposed base metal smelting, municipal solid waste incinerators, hazardous waste incinerators or sewage sludge incinerators will be subject to applicable existing legislation during proposal, development and operational phases	
Yukon		• any proposed base metal smelting, municipal solid waste incinerators, hazardous waste incinerators or sewage sludge incinerators will be subject to CWS	• operates an annual special waste collection program where hazardous wastes are collected for proper disposals

Source: CCME 1999.

The Northern Contaminants Program (NCP) and the Canadian Arctic Contaminants Assessment Report (CACAR)

An initiative of the 1990 Canadian “Green Plan” was a program called the Arctic Environmental Protection Strategy (AEPS). The goal of the AEPS is to preserve and enhance the integrity, health, biodiversity and productivity of Arctic ecosystems for the benefit of present and future generations. The objectives of the Strategy’s Northern Contaminants Program are to reduce and wherever possible eliminate contaminants in country foods. Although the Green Plan and the AEPS have fulfilled their mandate for the NCP, research continues to be done. The product of the first reporting phase is the Canadian Arctic Contaminants Assessment Report (CACAR). This has been written in response to the concern that toxic substances such as organochlorides, heavy metals and radionuclides are being discovered in relatively high concentrations in the Arctic environment when there was no obvious local use or source of the contaminants. The objectives are to identify the contaminants and their locations, sources and effects on people and wildlife, with the goal of identifying means of minimizing the risk.

The concern for the indigenous Arctic communities is their dependence on wildlife, which, in some instances may have bioaccumulated unsafe levels of heavy metals and other contaminants in their meat and fat. The report concludes that more research is needed regarding the health effects of low level heavy metal contamination to adults, children and the unborn. A summary version of the CACAR report, entitled *Highlights of the Canadian Arctic Contaminants Assessment Report: A Community Reference Document*, is available to the public. The second phase of the NCP is currently in progress.

The National Air Pollution Surveillance (NAPS) network

Developed in 1970, the National Air Pollution Surveillance network is a database for monitoring air quality across the country. Originally intended for use in urban centers, the network gradually expanded to include some rural areas as well. NAPS was at first equipped to handle sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter and lead. Recently, testing capacity has expanded to include other pollutants, including mercury (Davies 1997). There are currently 155 NAPS stations in 55 cities throughout Canada (NAPS, online, 1998).

National Pesticides Use Database

Under CEPA and the Pest Control Products Act, this database is the result of a joint survey by Environment Canada and Health Canada on pesticides based on reported active ingredients. In 1990, the database indicated that some mercurous and mercuric chloride content was still present in fungicides used for turf management on golf courses. Actual quantities reported are considered confidential (Environment Canada 1996); however, as of 1997, any further use is prohibited, including use of remaining stockpiles.

Five Resource Department Memorandum of Understanding (MOU)

The MOU is among the Five Resource Departments on Science and Technology for Sustainable Development. This MOU establishes mechanisms for coordination and collaboration among 1) Agriculture and Agri-Food Canada, 2) Environment Canada, 3) Fisheries and Oceans, 4) Health Canada and 5) Natural Resources Canada, to support science and technology for sustainable development. The metals working group established under the MOU has been working on the scientific issues associated with Canada’s participation in the Heavy Metals Protocol under the United Nations Economic Commission for Europe’s Long-range

Transboundary Air Pollution (UN ECE LRTAP) Convention. Together, they have gathered a group of researchers and scientists who work cooperatively to explore issues and answer questions that will affect the policy making process.
Some of the key questions posed in regards to heavy metals are:

a) Are there measurable environmental effects that can be monitored due to off-site mine effluents and emissions?

b) What is needed to reverse them?

c) Does metal deposition from long-range transport cause effects deleterious to the environment, and if so, what reductions are needed?

d) What are the processes that control movement of metals in the environment within and between the biosphere, the atmosphere, the geosphere and the hydrosphere?

The five departments have contributed to a great number of activities designed to answer these questions. For example, there are five existing sites in Canada that measure metals loading via the atmosphere. Trends in heavy metal contamination rates are recorded by the Geological Survey of Canada (GSC), who measure loading in agricultural soils, sediments and even in tree cores. The GSC and the Meteorological Services Canada (MSC) are determining areas of primary heavy metal deposition around smelters by using soil/mass balance analyses and determining the speciation of metals in the air and in deposition around smelters.

Canada-Ontario Agreement (COA)

The COA for the Great Lakes Basin serves to coordinate activities and programs between the federal and Ontario governments to prevent and minimize pollution entering the Great Lakes ecosystem. The government of Canada and the province of Ontario have therefore agreed to virtually eliminate toxic and bioaccumulative substances from the Great Lakes ecosystem. Mercury is included in the list of substances to be eliminated. The specific goal for mercury is 90 percent reduction

by the year 2000 (Environment Canada 1996). The approach involves voluntary programs by industry and others to reduce the use of these substances. The COA program utilizes a number of existing initiatives to facilitate these reductions, and to report progress on these reductions.

Great Lakes, St. Lawrence River and Fraser River Action Plans

These Environment Canada initiatives embody an ecosystem management concept that empowers communities in the particular action plan area to foster environmentally responsible citizenship and promote sustainable development. Toxic metals are identified as a detrimental stress to ecosystems and are consequently targeted for appropriate management within the geographic focus of the action plan.

National Geochemical Reconnaissance Database

As part of an ongoing program to map the surficial chemistry of the Canadian landmass, the Geological Survey of Canada (GSC) continues to develop a geochemistry database. The data are used by the Canadian minerals industry and by governments to assist in resource development and appraisal studies, as well as by government agencies and other interested organizations concerned with environmental issues. The data, acquired on an ongoing basis since 1974, provide geochemical baseline information demonstrating spatial variability, which have implications in environmental monitoring and in understanding how humans interact with their environment. Variations in natural mercury concentrations in lake and stream sediments across Canada are being measured as part of the National Geochemical Reconnaissance. As of 1996, mercury concentration data have been available for 78,347 lake sediment sampling sites and 66,411 stream sediment sampling sites. These survey data cover more than 2.2 million square kilometers, almost 25 percent of Canada’s total area (Chevalier 1999).

2.2 International Protocols

2.2.1 International Initiatives

United Nations Conference on Environment and Development (UNCED), Agenda 21

Canada is a signatory to Agenda 21, which contains many commitments relevant to the strategy on mercury. It is a strategy for solving 39 environmental and development issues. Most notably, Annex I (the Rio Declaration) recognizes the importance of sustainable development and the precautionary approach. Furthermore, chapter 19 on the environmentally sound management of toxic chemicals recommends the adoption of pollution prevention approaches as a means of reducing the risks associated with toxic chemicals.

Since the conference, a Commission on Sustainable Development has monitored progress toward the goals stated by the Agenda. Two documents prepared by Canada in response to the Agenda report on toxic chemicals and initiatives for their reduction.

United Nations Economic Commission for Europe (UN ECE) Heavy Metals Protocol

The Executive Body to the UN ECE's Convention on Long-range Transboundary Air Pollution (LRTAP) has finalized negotiations on a protocol to control long-range atmospheric transport of heavy metals. The protocol focuses on mercury, lead, and cadmium and calls for stabilization, control and/or reductions in anthropogenic emissions of these metals. To meet these commitments, Parties to the protocol are required to declare how they intend to meet the "Base Obligations." These include setting emission limit values, capping or reducing emissions, the phase-out of polluting processes, and applying product restrictions.

OECD Risk Reduction Program

In 1990, the Council of the Organization for Economic Cooperation and Development (OECD) adopted an act to reduce risks that chemicals pose to the

environment, and/or to the health of the general public or workers. OECD member countries, which include Canada, chose mercury as a chemical for cooperative risk reduction.

Denmark, with a consultant from the Water Quality Institute, used Sweden's aid to begin data collection for the Mercury Risk Reduction Monograph in 1992. The following conclusions about 'Mechanisms of Risk Reduction' for each country were developed using compiled data. All member countries have laws about mercury emissions to water, air and land as well as prohibitions about adding mercury to seed dressing. The majority of OECD countries have also forbidden mercury in paint, created guidelines for occupational risk reduction, and developed regulations about levels of mercury in sewage sludge applied to agricultural land. Some countries disallow use of mercury in thermometers and dental fillings, have established agreements to reduce input of mercury to the marine environment and constructed databases to determine regions of high mercury levels (OECD 1994). Canada is involved with national risk reduction measures such as setting regulations for the use of mercury in batteries under the Canadian Environmental Choice Guidelines, and banning mercury use in paints applied to children's products. It also sets maximum mercury limits for water quality and chlor-alkali industry emissions and regulates mercury in pesticides.

Arctic Environmental Protection Strategy (AEPS)

The eight circumpolar nations—Canada, Denmark, Finland, Iceland, Norway, Sweden, the USSR, and the United States—are all stakeholders in the Arctic Environmental Protection Strategy. Created in 1991, it identifies shared circumpolar environmental problems and objectives and actions each country is committed to take to protect the Arctic Environment. In September 1996, the AEPS became part of the Arctic Council that was established at that time.

Programs such as Arctic Monitoring and Assessment Program (AMAP), Protection of the Marine Environment in the Arctic (PAME) and Emergency, Prevention,

Preparedness and Response (EPPR) have been developed to meet their objectives. Research priorities are given to Persistent Organic Pollutants (POPs), selected heavy metals, and radionuclides. The experience of the Arctic Council is instructive since it has demonstrated how a relatively informal agreement with very little dedicated funding can be most effective in stimulating international action in the relevant domestic and international affairs (CEC 1997).

The AMAP, established in 1991, is important because it has the role of monitoring and assessing the effects of anthropogenic pollutants in the Arctic. The first AMAP assessment report has been completed, and a second report to be released by AMAP is currently in progress (AEPS online 1997). Recent findings on mercury have indicated previously unknown properties of this element in relation to ozone and polar sunrise. Research in this area is ongoing.

2.2.2 Continental Initiatives

North American Agreement on Environmental Cooperation (NAAEC)
Commission for Environmental Cooperation (CEC)

As a consequence of concern for the environment, by North American Free Trade Agreement (NAFTA) signatories, a parallel side agreement known as the NAAEC mandated the establishment of a Commission for Environmental Cooperation. The CEC has a mission to “facilitate cooperation and public participation to foster conservation, protection and enhancement of the North American environment for the benefit of present and future generations, in the context of increasing economic trade and social links between Canada, Mexico and the United States” (CEC online 2000).

Concern about pollutants or their precursors that reside in the atmosphere for longer than two days was raised in the 1997 CEC review of transboundary pollutants. This includes two priorities for mercury research. The first is to assess the availability of atmospherically deposited inorganic mercury, and to relate these amounts to the methylating bacteria that converts it to the very toxic methylmercury form. The second is to determine the contribution of atmospherically deposited mercury to the

supply of methylmercury in freshwater ecosystems, linking it to the amount found in fish species used as human food (CEC 1997). They also recognize the need to obtain new information that will aid in defining the hazards of releasing anthropogenic mercury into the environment.

Great Lakes Water Quality Agreement (GLWQA)

This agreement was first signed in 1972, renewed in 1978 and amended in 1987. It has been developed to express commitment of Canada and the United States to the restoration and maintenance of the Great Lakes ecosystem in terms of its chemical, physical and biological integrity. This agreement is one of several through which the International Joint Commission assists the governments of Canada and the United States in fulfilling their commitments.

To address the continued concern about the deposition of toxic substances to the Great Lakes Basin, the 1987 amendments included Annex 15. This new annex concerns only airborne toxics and commits Canada and the United States to: (1) conduct research to determine the pathways, fate and effects of toxic substances (2) undertake surveillance and monitoring to determine the sources and inputs to the Great Lakes and (3) implement measures to control the sources of emissions of toxic substances.

Great Lakes Binational Toxics Strategy (GLBTS)

In keeping with the objectives of the 1987 Great Lakes Water Quality Agreement, on 7 April 1997, Canada and the United States signed the Great Lakes Binational Toxics Strategy: Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes, also known as the Binational Toxics Strategy, or BNTS. The purpose of the BNTS is to set forth a collaborative process by which Environment Canada (EC) and the United States Environmental Protection Agency (US EPA), in consultation with other federal departments and agencies, Great Lakes states, the Province of Ontario, Tribes and First Nations, and Great Lakes Basin stakeholders, will work toward the goal of virtual elimination

of certain targeted persistent toxic substances resulting from human activity in the Great Lakes Basin. The Strategy recognizes that the Great Lakes are an invaluable natural endowment for the residents, for the economy, and for many fish and wildlife species, and seeks to protect and ensure the health and integrity of the Great Lakes ecosystem. For Mercury, the Canadian challenge is to seek by 2000, a 90 percent reduction in the release of mercury, or where warranted, the use of mercury, from polluting sources resulting from human activity in the Great Lakes Basin. A reduction of 80 percent has been achieved by 1999. This target is considered as an interim reduction target and, in consultation with stakeholders in the Great Lakes Basin, will be revised if warranted, during the development of the renewed Lake Superior COA Agreement in 2000.

Lake Superior (COA Agreement)

A binational program to restore and protect Lake Superior was announced in 1991. The initiative involves the governments of Canada, the United States, Ontario, Michigan, Minnesota and Wisconsin. The program includes a binational pollution prevention program to deal with persistent toxic substances, including mercury.

New England Governors/Eastern Canada Premiers Mercury Action Plan

In June of 1997, the Governors of the Northeast (New England) States and the Premiers of the Eastern Provinces signed a resolution calling for cooperation in addressing the mercury issue. To this end, a report was developed discussing the various mercury issues in this region, to be used as a resource tool in developing a Regional Mercury Action Plan. The ultimate goal of this initiative is the virtual elimination of anthropogenic mercury emissions into the environment. A conference held in Fredericton NB, in 1998 concluded that aggressive and concerted actions are needed to reduce potential health risks attributable to mercury exposures and to expand scientific information on mercury sources, controls and environmental impacts. The Regional Mercury Action Plan identifies steps to address those aspects of the mercury problem in the region that are within their control or influence.

Recognizing that significant contribution of airborne mercury comes from outside the region, it is stated that the aggressive commitments embodied in the regional action plan will provide leadership to encourage similar actions to reduce mercury emissions nationally and internationally.

2.3 National Legislation, Regulations, Guidelines

Canada has federal legislation, regulations and guidelines relevant to the control or reduction of mercury in air, water, waste effluent, marine waste disposal, contaminated sites, transportation as product or waste, consumer products, pest control products, composting and for occupational health exposure.

2.3.1 Air

2.3.1.1 Occupational Exposure

The Threshold Limit Values (TLVs) for Chemical Substances in the Work Environment as determined by the American Conference of Governmental Industrial Hygienists are the criteria used for national occupational health standards in Canada.

The criteria are divided into two parts, Threshold Limit Value-Time Weighted Average (TLV-TWA) and Threshold Limit Value-Short Term Exposure Limit (TLV-STEL). The TLV-TWA is the maximum value that workers can be exposed to continuously over a 40-hour workweek. TLV-STEL is the maximum concentration that workers can be exposed to on a short-term basis (i.e., a 15-minute maximum exposure less than four times per day).

Table 8: Criteria for Maximum Occupational Exposure Limits to Mercury

Description	TWA (mg/m^3)	STEL (mg/m^3)
Mercury-alkyl compounds	0.01	0.03
Mercury-vapor	0.05	–
Mercury-aryl and inorganic compounds	0.1	–

Source: American Conference of Governmental Industrial Hygienists, 1991–1992.

2.3.2 Water

2.3.2.1 Drinking Water

The *Canadian Water Quality Guidelines*, as published by Health Canada and Environment Canada in 1995, includes prescribed maximum contaminant levels for different water uses and for the freshwater aquatic environment. The following table outlines the guidelines for mercury.

Table 9: Water Quality Guidelines for Mercury

Metal	Drinking Water (mg/L)	Freshwater Aquatic Life (mg/L)	Irrigation Water (mg/L)	Livestock Water (mg/L)
Mercury	0.001	0.0001	N/A	0.003

Source: Health Canada. Canadian Water Guidelines, 1995

2.3.2.2 Wastewater Effluent

National Guidelines on Physical-Chemical-Biological Treatment of Hazardous Wastes recommends maximum concentrations of mercury of 0.1 mg/L, 0.001 mg/L and 0.1 mg/L, respectively, in wastewater effluent (CCME 1997).

2.3.2.3 Inland Waters

The Fisheries Act includes a number of provisions to limit the quantities of metals that can be released to the water. Many of these provisions specifically target mining and related metal industries. The Metal Mining Liquid Effluent Regulations

regulate levels of metals in mining effluent discharged into water bodies, and in metal finishing liquid effluent, but mercury is not included in the suite of metals controlled under these regulations. The Fisheries Act does have some control over mercury in waters through the Chlor-alkali Liquid Effluent Regulations (see section 1.2.2.2).

2.3.2.4 Ocean Dumping

Canada controls waste disposal at sea and meets its international obligations under the London Convention (1972) by means of a permit system, in place since 1975. Part VII of CEPA (1999), the enabling legislation, contains provisions concerning Ocean Dumping (CEPA, online, 1988). These regulations permit dumping at sea for nonhazardous substances only, or if the regulatory body considers dumping at sea to be environmentally preferable and practical. The *Ocean Dumping Regulations* (1988) limit the concentrations of mercury in wastes that are dumped. CEPA regulations were amended in 1994 to prohibit sea disposal of industrial wastes (CEC Phase I Report).

2.3.3 Soil

The CCME has published *Recommended Canadian Soil Quality Guidelines* (1997). The criteria for these guidelines were based on consideration of the levels of metals in soil that would risk either human or environmental health.

Table 10: Criteria for Mercury in Soil

Metal	Mercury (mg/kg)
Agricultural	7
Commercial	24
Residential/Park land	7
Industrial	30

Source: CCME, March 1997

2.3.3.1 Composting

Centralized composting sites are becoming increasingly widespread as a result of recycling activities. The number of centralized, private and municipal composting facilities throughout Canada has more than quadrupled, from 30 sites in 1989 to over 120 sites in 1994. The maximum amount of mercury allowed in compost is five mg/kg under the Fertilizers Act, administered by Agriculture Canada (CEC Phase I Report).

Table 11: Criteria for Mercury in Compost Material

Metal	Maximum Amount (mg/kg)	Maximum Amount for Restricted Uses (mg/kg)
Mercury	0.5	5

Source: CCME, March 1996

2.3.3.2 Contaminated Sites

The CCME has established Canadian Environmental Quality Criteria for Contaminated Sites. These are limits for contaminants in soil and water intended to maintain, improve, or protect environmental quality and human health at contaminated sites (CCME 1996). Table 6-5 shows the limits for mercury. This is discussed further in section 3.2 of this report.

Table 12: Numerical Limits for Mercury Soil Contaminants

Assessment Criteria	**Mercury**
Soil	0.1 μg/g dry weight
Water	0.1 μg/L
Remediation Criteria for Soil	**Mercury**
Agriculture	0.8 μg/g dry weight
Residential/Park Land	2 μg/g dry weight
Commercial/Industrial	10 μg/g dry weight

Source: CCME, March 1997

2.3.4 General

2.3.4.1 Agriculture Chemicals

Pest control products are regulated by Health Canada under *the Pest Control Products Act* and the *Pest Control Products Regulations*. Formulations containing mercury as an active ingredient were previously approved as fungicides for control of plant diseases and as antimicrobial pesticides, e.g., as paint or wood preservatives. Mercury-based fungicides have been discontinued in Canada and mercury-based antimicrobials have been phased out. Manufacturing of these products ceased in 1996, sales were ceased by the end of 1997, and all use ended in 1998. There are presently no mercury-based pest control products registered for use in Canada.

2.3.4.2 Food

The Foods Directorate of Health Canada has compiled Guidelines/Tolerances of Various Chemical Contaminants in Canada. For mercury in food, there are guidelines for fish consumption. The maximum allowable limit for total mercury content in fish is 0.5 ppm (mg/l) set by the Bureau of Chemical Safety (CEC Phase I Report). Swordfish and shark and tuna are exempted from this guideline, but consumption of any or all of these species should be limited to a maximum of one meal per week by all consumers. Mercury contamination of foods is evaluated on a case-by-case basis. For those who consume large amounts of fish, such as aboriginal people, the Medical Services Branch has a limit of 0.2 ppm (mg/l) for total mercury content (CEC Phase I Report)

2.3.4.3 Consumer Products

The amount of mercury allowed in a consumer product is under the jurisdiction of Health Canada's Hazardous Products Act. In Canada, the selling, advertising or importing of toys, equipment or other products for use by a child in learning or play that have an applied decorative or protective coating containing mercury or its compounds is prohibited.

Recently proposed amendments to the Hazardous Products Act will include “a restriction on mercury compounds in interior consumer paints containing mercury” and “addition of a precautionary statement on exterior consumer paints containing mercury” (Canada Gazette 1997).

2.3.4.4 Transportation

The Transport of Dangerous Goods Regulations under the Transport of Dangerous Goods Act regulates the shipping of mercury and wastes containing these substances, as a corrosive/toxic substance. The regulations require precise labeling of all containers, packages, tanks, cylinders, and all vehicles carrying these toxic substances. This is in concert with a national tracking system that monitors all shipments of hazardous waste, including mercury.

The transport of radioactive mercury is regulated by the Federal Atomic Energy Control Act under the Transport of Radioactive Materials Regulations. The Pollutant Substances Regulations under the Canada Shipping Act prohibits discharge of mercury and mercury compounds into any Canadian territorial waters (see http://www.tc.gc.ca/actsregs/csa-lmmc/csa52.html).

2.3.4.5 Imports/Exports

Elemental mercury and all mercury compounds are expressly regulated by sections 185–192 of CEPA with respect to import and export of wastes. As described in section 2.3.4.4, transportation regulations also apply to import and export of toxic substances and wastes containing mercury (CEC Phase I Report).

2.4 Provincial Legislation, Regulations, Guidelines

In addition to federal regulations, a number of provinces have additional acts, regulations and guidelines covering liquid effluent, drinking water, and emissions from industrial sources.

Table 13: Provincial Regulations/Guidelines for Hg as Promulgated

British Columbia

Pollution Control Act (General)	Permit system. Prohibits waste discharge into all media unless approved					
Waste Management Act (General)	Prohibits disposal of pollution causing waste (with exceptions)					
Chem. & Petroleum Report (Air)	**Objectives For Emissions from Chlor-alkali and Sodium Chlorate Industries** New/proposed discharges 230.0 mg/m^3 Hg	Intermediate 345.0 mg/m^3 Hg	Immediate 575.0 mg/m^3 Hg			
Ambient Air Control Objectives (Air)	**Discharges to the Air:** 0.10–1.0 µg/m^3 Hg					
Objectives for Gaseous Particulate Emissions (Air)	**Discharges to the Air: Control Objectives** 0.03–0.27 mg/mol Hg					
Objectives for the Discharge of Final Effluents (Water)	**Marine and Fresh Waters** 0.00–0.005 mg/L dissolved Hg in effluent					
Chem. & Petroleum Report (Water)	**Objectives for Air Emissions from the Chlor-alkali and Sodium Chlorate Industries other than Petroleum Refineries**					
	HM	*New/proposed*		*Intermediate*		*Immediate*
		Marine	**Fresh**	**Marine**	**Fresh**	**Marine** **Fresh**
	Hg	0.002 mg/L	0.002 mg/L	0.05 mg/L	0.05 mg/L	0.05 mg/L 0.05mg/L
Effluent Standards for Special Waste Facilities (Water)		Discharges to the Environment/Storm Sewers		Discharges Directed to Municipal or Industrial Treatment Works		
	effluent Hg (total)	0.001%		0.1%		

Alberta

Clean Water Act	Minimum acceptable Levels for wastewater treatment: Hg = 0.0005 mg/L
Release of substances (General)	**Prohibition on Release** Prohibits release of substances that may have significant adverse effects on the environment

Saskatchewan

Specific Surface Water Quality Objectives	**Protection of Aquatic Life and Wildlife** 0.0001 mg/L Hg **Livestock Watering** 0.003 mg/L Hg (total)
Environmental Spill Control Regulations (Land)	Spills to be reported if amt. exceeds

Onsite	*Offsite*	*HM*	*Time Period*
1.0 kg	0.001 kg	Hg (all forms)	24 hrs

Manitoba

Classification Criteria Regulations	**Leachate Quality Criteria** Hg is a "leachable toxic substance" if it is equal or greater than concentration in waste extract 0.1 mg/L Hg
Regulatory Controls (General)	**Manitoba Environment Act** Includes basic scheme for emission control for all media, and for the development of an environmental management system. Also included is a system for environmental assessment.
Atmosphere Pollution Regulations	**Specific Prohibitions: Discharge of air contaminants** No owner shall discharge into the atmosphere from any source, an air contaminant having a weight in excess of nine-tenths of one gram per cubic meter of atmosphere calculated at a temperature of 20°C and a pressure of 760 mm of mercury. (STATS.MAN.:M.38:2)

Ontario

Ambient Air Quality Criteria Regulation (Air)	2.0 $\mu g/m^3$ (30 d. mean) Hg
Air Contaminants from Ferrous	10.0 $\mu g/m^3$ (1/2 hour average)

Foundries Regulations (Air)		
Air Pollution		*Conc. at pt. of impingement ½ hour avg.*
Regulations	Hg (alkyl) compounds/m^3 of air Hg in free and combined form/m^3 of air	1.5 µg 5.0 µg

Québec

Environmental Quality Act (General) (COMM:12:2)	Primary source of environmental protection and regulation. Principle component of the Act is section 20, which prohibits discharge of contaminants of quantities more than those regulated by the government, or that will affect human health or the environment.

New Brunswick

Clean Air Act	**Air Quality Regulations** Permission to develop or operate facility causing air contaminants required
Clean Water Act	**Water Quality Regulations** It is an offense to release contaminants into water without approval
Mining Act	The holder of the mining lease is required to carry out an environmental protection program

Nova Scotia

Nova Scotia Environment Act	This Act includes principles of sustainable development, polluter pays, pollution prevention and the precautionary approach. Permits required for activities that may harm the environment. The Act also includes sections on hazardous waste, contaminated sites, waste management and air quality.

Prince Edward Island

Basic Regulatory Scheme PEI Regulatory Controls (General) COMM: 15:3	**PEI Environment Act** Basic controls for pollution emission into abiotic and biotic environment. The act prohibits contaminants from being discharged into the environment, and defines the penalties involved in doing so. Note that the definitions for 'contaminant' and 'environment' are broad. The Minister ultimately decides whether the contaminants will threaten the environment.
Transboundary Pollution (Air/Water) COMM: 15:6	The Transboundary Pollution (Reciprocal Access) Act deals with interjurisdictional and choice-of-law issues relating to "pollution" discharged into the air or waters surrounding the Island (COMM: 15:6).
Water Courses COMM: 15:5	The federal CEPA gives the Minister some control over waste, water and water supply treatment.

Newfoundland

Department of Environment and Lands Act	**Water Pollution Control** (COMM: 16:3)The Act gives the Minister broad powers to prevent water pollution and control development within and around bodies of water under the jurisdiction of the province. These include any surface, ground and near-shore waters, whether fresh or salt. The Minister's powers are, however, subject to the powers of the Minister of Municipal and Provincial Affairs.
Department of Environment and Lands Act (Air)	**Air Pollution Control Regulations** free and combined form=2.0 $\mu g/m^3$ Hg free and combined form=0.5 $\mu g/m^3$ Hg (alkyl) compounds

Northwest Territories

Basic Regulation Scheme (General) COMM:6:1	CEPA (federal) serves as basis for NWT contaminant regulatory scheme. Environmental emissions prohibited except as regulated by the CEPA, or if permit is issued. Environmental Standards Objectives for contaminants developed on industry-by-industry basis. Not legally relevant except in permits issued under the Pollution Control Act. Arctic Water Pollution Prevention Act (federal) Waste deposit in Arctic water prohibited

Yukon

Yukon Environment Act COMM:5:1	Includes a range of environmental objectives Comprehensive: covers permits, special waste, assessment and planning. Environmental Bill of Rights: healthy environment is a right. Healthy environment is a right. Yukon Act regulation on federal land not within Yukon jurisdiction is subject to federal Yukon Waters Act and Territorial Lands Act. CEPA also applies.

Nunavut

Area Development Act	No person shall dispose of any garbage, sewage or other waste material except at a site and in a manner approved by an area development officer.

Sources: Cotton, Roger et al. (1991, including service issues 1992–1997);
Canadian Environmental Law, Eco/Log, 1999

Provincial governments also hold the responsibility of issuing health advisories for contaminated lakes in their area. The following provincial Departments of the Environment presently have health advisories for fish consumption due to high levels of mercury in their lakes: Manitoba, Ontario, Quebec, Alberta, New Brunswick, Nova Scotia, and the North West Territories. Alberta has 16 sites that have existing health

advisories due to mercury levels higher than 1.0 mg/L. Manitoba has issued health advisories for three sites that are dependent upon the size of the fish. Fish caught at these sites that are over 20 inches long may not be consumed and those under 20 inches may only be consumed once a week. Nova Scotia and New Brunswick have province wide fish advisories.

The recommended maximum concentration of mercury dissolved in effluent wastes is 0.001 mg/L (National Guidelines on Physical-Chemical-Biological Treatment of Hazardous Waste). The Special Waste Management Regulations in the province of British Columbia specify maximum mercury emission criteria of 0.2 mg/m^3 for hazardous waste incinerators. Recommendations for stack discharge limits and anticipated emissions for mercury are made in the Operating and Emission Guidelines for Municipal Solid Waste Incinerators, published by the Canadian Council of Ministers of the Environment (CCME). Provinces use these guidelines when issuing permits to facilities under their respective jurisdictions. Mercury emissions not exceeding 0.2 mg/m^3 are anticipated from municipal solid waste incinerators operating under good combustion conditions and equipped with dry scrubber fabric filter systems.

2.5 Voluntary Partnership Initiatives

2.5.1 Sector Specific

Accelerated Reduction/Elimination of Toxics

The Accelerated Reduction/Elimination of Toxics (ARET) is a voluntary emissions reduction program that includes representatives from industry, health, professional organizations, and the federal and provincial governments. Together, they have developed reduction objectives for toxic, persistent and/or bioaccumulative substances. There are four key components in the program: the ARET Substance List, the ARET Challenge to potential program participants, the response to the ARET Challenge where participants make a public commitment to achieve their goals and adopt an action plan, and the ARET participants' progress report.

The Mining Association of Canada (MAC) membership in the ARET program includes 29 mining and smelting operations, some of which are the largest in the world. Participation of MAC members in ARET is high, with 97 percent of members participating in the program. These companies are primary sources of metal emissions to the environment.

The ARET long-term vision is to virtually eliminate the emission of bioaccumulative and persistent toxic substances, and reduce other toxic emissions to harmless levels. By the year 2000, ARET hopes to reduce bioaccumulative and toxic substances by 90 percent and others by 50 percent (ARET 1999). These reductions are relative to a base year (between 1987 and 1994) and selected on a company-by-company basis.

Elemental and inorganic mercury compounds are included on ARET's B-2 list. Methylmercury is on the A-1 list of compounds, slated for virtual elimination of anthropogenic releases. The nonferrous metals sector is the largest emitter of anthropogenic mercury in Canada; however, commitments made by mining companies had resulted in an overall reduction in mercury releases of 58 percent by 1993, 82 percent by 1995, and 90 percent by 1997. This achieves the 90 percent reduction goal that was to be attained by the year 2000 (ARET 1999).

Responsible Care®[1]/National Emissions Reduction Master Plan

Companies in good standing with the Canadian Chemical Producer's Association (CCPA) accept a 'Statement of Responsible Care and Guiding Principles. The initiative is a response developed due to the public's distress about being exposed to environmental pollutants. Responsible Care® is concerned with 369 chemicals on the CCPA's chemical substance list, and 55 chemicals on its Optional Substance List. The lists include heavy metals, polyaromatic hydrocarbons (PAHs), asbestos and numerous other hazardous air pollutants (HAPs).

[1] ® Responsible Care is a registered trademark of the Canadian Chemical Producers Association

The National Emission Reduction Master Plan (NERM) is a component of the Responsible Care® initiative. Companies involved establish emission targets, and report on their progress.

The 1994 CCPA report estimates that emissions of heavy metals to water were 37 percent lower than in 1993, for a total reduction of 52 percent since 1992 (CCPA 1997).

Table 14 indicates the emissions of mercury to water from the CCPA.

Table 14: Emissions to Water from CCPA Member Operations

Compound	1992 (tonnes)	1993 (tonnes)	1994 (tonnes)	1995 (tonnes)	1996 (tonnes)
Mercury*	0.02	0.008	0.27	0.013	0.006

* As environmental media for emissions of less than one tonne are not specified, it is not certain whether releases of mercury to water actually increased. Elemental, inorganic mercury was included in 1994–1996, none had been reported in 1992–1993.

Sources: The Canadian Chemical Producer's Association (1997); Reducing Emissions Report; Water Quality Section, 1996; Stephanie Butler, 1998

Municipal Mercury Program Survey

In December 1998, Environment Canada contracted the Association of Municipal Recycling Coordinators (AMRC) to carry out a series of workshops to raise awareness of the potential environmental and health hazards posed by mercury-containing consumer products in the home. Further discussion on the project suggested that there was a need to research and document the extent of municipal mercury collection and disposal programs in Ontario, and track the amount and range of mercury-containing products currently being collected.

Based on a response rate of 83 percent, twenty-three municipalities indicated that they do not accept mercury and mercury products. Twenty-five municipalities indicated that they do collect mercury-containing products/wastes, including thermostats, thermometers, button cell batteries, switches and fluorescent lamps (Association of Municipal Recycling Coordinators 1999).

A Certificate of Approval issued by the Minister of the Environment for Ontario, is required to collect mercury and mercury-containing items. The Ministry of Environment is currently reviewing existing waste management regulations with a view toward streamlining and updating them. Included in this review are a series of proposed changes that facilitate the collection and consolidation of mercury-containing items.

The proposed Manufacturer Controlled Network (MCN) would make it easier for the original product manufacturer to set up a collection system with a minimum of paperwork.

The Selected Waste Depot (SWD) sets out a relatively simple procedure to take back residuals including mercury-containing thermometers and thermostats.

The public review period for these proposed initiatives ended in September of 1998, and it is understood that revisions are ongoing.

2.5.2 Product-specific Initiatives

The Canadian Vehicle Manufacturers Agreement

Environment Canada, MOE, Ford, Chrysler and General Motors signed an agreement in May 1992 to cut down and eliminate hazardous releases to the environment and increase efficiency of operations. The Canadian Vehicle Manufacturers Agreement was initially intended to last for a two-year period, but it was extended for another year and a half, and will be renewed again presently.

The Agreement aimed to better the management of facilities and the environmental and technological improvements of materials that go into manufacturing the vehicles, rather than the vehicles themselves. To date, the association has been successful in eliminating the use of, or toxic releases from, thirty to forty products. This includes reduction of air emissions of Volatile Organic Compounds (VOCs), and making changes in regard to heavy metals in paint and the technology that is used in paint-spray operations (Durrant 1997). This agreement may provide the path for negotiating a program to capture mercury in new and used vehicles.

Household Batteries

Canada has Environmental Choice Guidelines concerning mercury in batteries, with elimination of mercury in batteries to be achieved between 1994 and 1996. The elimination of mercury in batteries in the 1994–1996 time frame was an industry voluntary commitment inspired by USA regulatory controls. The following levels of mercury in batteries have been set:

- Zinc-air batteries for hearing aids: a maximum of 40 mg/Ah* rating on mercury content;
- Cylindrical batteries: maximum 0.02 percent mercury by weight by 1 July 1993; and
- Alkaline manganese button or coin batteries: 25 mg per cell.

(CEC Phase I Report)

*milligrams per Amperehour

Paint

The Canadian Paint and Coatings Association, which represents over 90 percent of Canadian consumer paint sales, developed a voluntary initiative that has been in operation since 1991. Member organizations have agreed not to produce interior paints containing mercury. The Association also has a voluntary recycling program for waste household paint and containers with limited mercury content.

Health Canada has developed a regulatory amendment relating to this initiative (Armstrong 1997). The amendments are currently included in Part One of the *Canada Gazette* under the Hazardous Products Act, as part of the Liquid Coating Materials Regulations. They stipulate that liquid coatings for use on furniture, household products, children's products, or any interior surface of a building may not contain more than 10 ppm mercury. If products contain more than 10 ppm mercury, the container must display a warning that the coating contains mercury and is for exterior use only (*Canada Gazette,* Part I, 1997).

Fluorescent Lamps

The mercury content of fluorescent lamps has been steadily decreasing since 1985. The average mercury content in fluorescent lamps has fallen from 48.2 mg in 1985 to 22.5 mg in 1995. The target is an additional reduction of mercury content to 15.0 mg, a 69 percent reduction from the 1985 content (CEC Phase I Report). Current technology will make it difficult to reduce mercury content in fluorescent lamps further. In 1992, 2400 kg of mercury from lamps was disposed of in Canadian municipal waste systems; however, fluorescent lamps require much less energy than incandescent light bulbs, so eliminating their use would only increase mercury emissions from electricity generators. This makes the continued use of fluorescent lamps a feasible alternative if they are safely disposed of at the end of their life. There is a recovery process that is in use to recover mercury from used fluorescent and high intensity discharge (HID) lamps. Lamps are first imploded to collect the mercury vapor in the lamps. The lamp components then undergo separation to recover remaining mercury. This process involves air separation, mechanical separation and a special patented sieving process (RLF). Under the CCME Canada-wide Standards process, fluorescent lamps are targeted for control action guidelines to be approved in summer 2000.

3. Remediation Activities

3.1 Retirement Management of Stocks

Environment Canada has conducted an initial study into the subject of Retirement Management of stocks. A report recommends several options needed to be considered on an industry specific basis. These include sequestration in stable matrices, conversion to cinnabar, storage in steel flacks, and stabilization of incinerator ash residues.

3.2 Contaminated Sites

3.2.1 Major Sites of Mercury Contamination

There are two major anthropogenic activities in Canada that have resulted in contaminated sites:

1. From the mid-1850s to the mid-1970s, about 500 gold mines practiced mercury amalgamation. The tailings from amalgamating gold mills contain unknown and variable quantities of mercury and were most often discharged directly to the environment. Significant mercury contamination of environments near abandoned gold mines has resulted. Present day gold mines in Canada no longer practice mercury amalgamation, however, many former sites warrant further investigation.

2. In the early 1970s, 15 chlor-alkali plants using mercury cells were in operation in Canada. One plant continues today, operating within the federal Chlor-alkali Mercury Release Regulations described in CEPA and the liquid effluent regulations under the Fisheries Act (see sections 1.2.2.2 and 2.3.2.3) (CEPA, online, Chlor-alkali Mercury Release Regulations, 1999). The extent of mercury contamination of the soils at the 14 decommissioned sites varies with the disposal methods that were used for brine sludges during plant operation. For example, at the Dow Chemical Canada plant in Thunder Bay, sludges were treated using a Chemfix process and then impounded in a disposal cell on-site, so no significant mercury concentrations were found in the soil. The Canadian-Oxy plant in Squamish, BC, had high levels of contamination. Sludge was put into an old lagoon or into landfill cells, some of which were lined with clay and polyethylene. All of the decommissioned sites in Canada continue to be monitored for mercury contamination.

3.2.2 National Contaminated Sites Remediation Program (NCSRP)

In 1989, the CCME initiated a five-year, $250 million, National Contaminated Sites Remediation Program (NCSRP). The program addressed sites polluted with hazardous materials as the result of former industrial or commercial activities, concentrating on assessment and remediation of “orphan” sites for which the owner was unknown, unwilling or unable to finance remediation. The program’s objective was assessment and remediation of orphaned contaminated sites that posed an imminent threat to human health or the environment (CCME 1994/1995).
The NCSRP also supported the development and testing of innovative new technologies for the clean-up of contaminated sites, and the bringing of these methods to commercial viability. Projects funded under the Development and Demonstration of Site Remediation Technology Program (DESRT) included: demonstration of stabilization techniques using foamed bitumen on soil contaminated with petroleum and heavy metals; use of in-situ electrokinetics to treat soil contaminated by heavy metals; and the use of the Tallon^{TM} process to treat soils contaminated by heavy metals.

The NCSRP helped to crystallize the “Polluter Pays” principle across Canada. All provinces and territories in Canada have enacted legislation to ensure that former site owners are liable for clean-up costs when their past use of hazardous materials endangers health or the environment. As a result of this type of legislation, site remediation activities are now largely led by the private sector, and data on various site remediation activities is collected using the REMTEC™ database (http://www.oceta.on.ca/sedtec/products/remtec.html).

3.2.3 Management of Environment Canada’s Contaminated Sites

Environment Canada is currently developing and maintaining a list of sites that are, or are suspected to be, contaminated with various pollutants. This national contaminated sites database currently lists over 3,000 locations. In the process of determining the likelihood and type of contamination of these sites, a representative

sample of 34 sites was investigated, while more sites await assessment on a draft priority list. A pilot assessment of potential mercury contamination sites at is already taking place within the Ontario Region. The site assessment is a response to the new Environment Canada operational Environmental Policy, which is implemented as part of the Department's Environmental Management System.

The Contaminated Sites Management Working Group (CSMWG) is an interdepartmental committee that was established in the summer of 1995. It was developed primarily to devise a consistent federal approach for the management of contaminated sites and provide expert advice to the contaminated sites sub-committee of the Environmental Accountability Partnership Steering Committee. CSMWG publishes an annual report that documents their progress and serves as a repository of information for new members. The group also publishes other useful materials, such as the reference manual on site remediation technologies.

3.3 Technologies Development

Earth Treatment Technologies

A company named Earth Treatment Technologies developed a commercialized acidic extraction process to remove contaminated mercury from soils. The process involves physical separation of the mercury from the earth, followed by chemical extraction (mixing the solution in acid in special tanks), and finally rinsing the soil with a neutralizing base (DuGuay et al. 1993).

PPG Canada Inc.

The Beauharnois, Québec chlor-alkali plant of PPG Canada Inc. utilized a mercury cell chlor-alkali process to produce chlorine from 1948 to 1990. A result of this process was significant mercury contamination of the soil on the site. PPG and Biogénie SRDC Inc. designed their own project using gravimetric and flotation technologies to remove the contaminants. The project objectives were to recover an average 95 percent of the visible mercury in the soil, recycle process water, keep

residual mercury contamination below 1,000 mg/kg in the treated soil, design a mobile technology and assess treatment costs. This program consisted of three primary steps: soil preparation, soil treatment, and soil dewatering. The mercury free solids were deposited in a landfill on the PPG site (Environment Canada 1997, St. Lawrence Technologies).

Environmental Technologies Advancement Division, Environment Canada

The Environmental Technologies Advancement Division (ETAD) is currently involved in the assessment of a number of innovative biology based techniques for the reduction, removal, and recovery of metals from contaminated matrices. Metal contamination is a persistent problem at many contaminated sites across North America. ETAD, in cooperation with NRCan-Canmet, is currently pursuing the establishment of a strategic alliance to explore the potential of several indigenous plant species to remove/reduce metals at select sites across Canada. The intent of this alliance is to establish demonstration projects to evaluate efficacy of plant species for heavy metal removal as well as develop techniques for metal recovery/biomass disposal, in cooperation with industry, academia, site owners and managers, and the environmental technology community. A number of demonstration projects were conducted in 1998–99 (Terry MacIntyre 1999).

4. Research and Policy Development Activities

Environmental Protection Service

Environment Canada's Environmental Protection Service (EPS) has a mandate to assess and manage risk associated with both national and international environmental issues, focusing on strategy and policy development. More specifically, priorities of this arm of Environment Canada include toxic substance management, national and international air issues, Canadian water quality and pollution prevention.

Mercury-related research and policies through the EPS includes:

- Transboundary Air Issues Branch—UN ECE Heavy Metals Protocol and CEC NARAP on Mercury
- Mining, Minerals and Metals Division—policy development concerning metals in relation to the Strategic Options Process
- The National Air Toxics Sampling Network—collecting and analyzing particulate samples at various sites across Canada for mercury
- The Commercial Chemicals Evaluation Branch—developing criteria for classification of metals in terms of toxicity, persistence and bioaccumulation in the environment as well as method development for ecological risk assessment.

Meteorological Services Canada (formerly Atmospheric Environment Service)

Meteorological Services Canada (MSC) is responsible for the delivery of the Atmospheric Environment Program. MSC is also the responsibility center for understanding the atmospheric transport and transformation of atmospheric pollutants. MSC concentrates its metals research program in support of the Great Lakes Water Quality Agreement. Research through the MSC involving mercury includes:

- Monitoring and modelling atmospheric deposition of mercury.
- Developing atmospheric transport models for mercury that could ultimately be used to analyze the impacts of emission control scenarios.
- Monitoring atmospheric metal particle levels in British Columbia, Ontario and New Brunswick (conducted by the Air Quality Research Branch) to determine their contribution to visibility degradation.
- Analyzing weekly air measurements to determine sources, occurrence, trends and fate of lead in the Canadian Arctic.

Environmental Conservation Service

Environment Canada's Environmental Conservation Service (ECS) has a mandate to ensure future Canadians have an undamaged environment. The objectives of ECS include: maintenance of the abundance and diversity of native plants and animals, conservation of the health and integrity of Canada's ecosystems and promotion of ecologically sustainable use of our resources.

Mercury-related research through ECS includes:

- Creation of a database which includes government documents, articles and consultation reports on the effects of mining in Canada.
- The development of the Canadian Environmental Quality Guidelines for Metals. The guidelines include information on forms and fate of metals in the environment, sources and pathways of metals as well as environmental and toxicological effects.
- Development of wildlife tissue residue guidelines used to assess actions for the protection of wildlife from mercury consumption.

Canadian Wildlife Service

Research in this division of ECS includes:

- Monitoring and surveying of mercury in wildlife throughout Canada. Of particular emphasis is the examination of mercury levels in seabirds, shorebirds, waterfowl, fish-eating birds and mammals from the Arctic region.
- Method development for exposure and assessment estimation of impacts of metals on wildlife. This is part of the Wildlife Contaminant Exposure Model (WCEM), which presently contains information on a limited number of bird, mammal, amphibian and reptile species.

- Quantifying methylmercury levels in fish-eating birds, with work on identification of contamination sources. Mercury levels in fish are being investigated as a result of chemical variables in lakes.

National Water Research Institute

The National Water Research Institute (NWRI) of Environment Canada is Canada's largest freshwater research establishment. Its program includes research in the aquatic sciences carried out in cooperation with the scientific community both nationally and internationally. Its mission is to increase knowledge and understanding of aquatic ecosystems to assist in the resolution of environmental problems of particular significance to Canada. The NWRI has several ongoing research activities, including:

- The National Water Research Institute (NWRI) of Environment Canada is currently involved in determining mercury's post-depositional redistribution patterns and the variation of mercury levels through time. Both of these studies entail the analysis of lake sediment cores taken from various locations throughout northern Ontario.
- The Aquatic Ecosystems Protection Branch of NWRI has ongoing programs for monitoring the concentrations of mercury in sediments and biota in the St. Lawrence and Ottawa Rivers. Focusing primarily on species of freshwater mussels, the programs have produced a wealth of information on the bioavailability and bioaccumulation of metals in these river systems.
- There is also a project involving sustainable mining, whereby the effects of metal mining on aquatic ecosystems are examined in both field and laboratory studies.
- The Aquatic Ecosystem Conservation branch of the NWRI has a project involving the wet deposition of trace metals at stations of the Integrated Atmospheric Deposition Network (IADN) in the Great Lakes Basin and across Canada.

- The same branch is also testing precipitation and surface waters to determine trace heavy metal concentration.
- Research is being conducted on the improvement and development of methods for remediating groundwater environments that are contaminated by metals at high concentrations from mining waste.
- Mercury levels in Hamilton harbor are being examined to determine responses to reductions in atmospheric loading.
- Fate and transport studies are being conducted of metal contaminants found in aquatic systems, focusing on highway and urban runoff.
- A project associated with the Great Lakes is examining past and current trends in metal inputs and pathways into the lakes.
- There are also projects through NWRI that look at ecosystem effects of metal contaminants originating from mining.

National Hydrology Research Institute

The NHRI was established to provide knowledge in the various areas of water research. Located at the University of Saskatchewan in Saskatchewan, Alberta, the Institute researches environmental matters relating to the viability and health of Canada's aquatic ecosystems. Research from this area includes:

- A Canadian-Russian project looking at heavy metal impact on wetland ecosystems.
- Investigation of metals in water, sediments and certain fish species from Resolute Bay, Great Slave Lake (Northwest Territories).
- Investigation of metal leaching from acid mine drainage.

Regional Environment Canada Initiatives

Ontario Region

- The Integrated Atmospheric Deposition Network (IADN) analyzes samples using inductively coupled plasma emission spectroscopy to determine metal levels in atmospheric particulate matter.
- In the Ontario Region, a project is underway to investigate mercury in ambient air measured at IADN sites in Ontario.
- For the Mercury Elimination and Reduction Challenge Project, emissions, uses and sources of mercury in Ontario have been determined. Implementation of mercury reduction initiatives is being put forth through workshops and has also focused on mercury elimination and reduction in the health care sector.
- Monitoring of levels and effects of metals in vertebrates is occurring for the Great Lakes Basin-St. Lawrence River.
- Water quality near Wolfe Island on the St. Lawrence River is monitored for mercury.
- In the Great Lakes region, precipitation samples are collected monthly from nine sampling areas and are tested for mercury. The results are used for trend evaluation and for estimation of atmospheric loading. Similar projects are also underway for the mouth of the St. Clair River and the outlet of the Niagara River.

Québec Region

- In the Lower St. Lawrence Region, mercury contamination in fish-eating birds is being investigated.
- At various Québec sites, metal concentrations in wildlife are being monitored in various tissues from a variety of birds, mammals and reptiles.

- Studies are being done to determine metal concentrations in wildlife as a result of mine tailings on wildlife in the mine tailing deposits around Aldermac.
- At the Université du Québec à Montréal, research is being carried out on long-range atmospheric transportation of mercury. Scientists have measured mercury levels in the soils throughout northern and southern Quebec. Results from this study have shown that there is about three to five times as much mercury in soils now as there was 100 years ago. Mercury depositions are thought to be stable and are probably not entering the food chain, as they are found predominantly in the inorganic phase. Studies are also being completed on mercury levels in lakes and watersheds to determine distribution patterns of mercury in water. Studies are also being done on the long-term health effects of mercury.

Atlantic Region

- Flux of atmospheric mercury within ecosystems in Atlantic Canada is being monitored.
- The Canadian Wildlife Service is looking at the effects of mercury exposure on common loons that breed in the Maritime Provinces.
- The assessment of temporal variation in mercury levels in eggs of four seabird species from Atlantic Canada from 1968 to 1996.
- A project in the Atlantic region is examining mercury contamination in lake waters, dissolved organic carbon and sediments.
- Another Atlantic region project assesses sources and impacts of mercury in freshwater ecosystems.

Prairie and Northern Regions

- Through the Canada-Manitoba Water Quality Agreement, 20 sites are monitored for metals on a monthly basis.
- Through the Northwest Territories Water Quality Program, water and sediment samples collected throughout the NWT are analyzed for trace metals and other toxic pollutants.
- In the Prairie and Northern Region, mercury exposure in common loons is being investigated through analysis of dead loons throughout the region.
- Long-term mercury deposition histories are being compiled.
- Through the Prairie Provinces Water Board, ongoing monitoring at 12 sites is being conducted for a large variety of variables in water and fish.
- An atmospheric sampler is being adapted in the Prairie region to determine whether it can be used to measure mercury and other metals being deposited into aquatic ecosystems. Measurements will be initiated by mid 2000.
- Water monitoring is underway at the East Poplar, Souris and Red Rivers for metals and other contaminants.

Pacific and Yukon Region

- Through the Water Quality Monitoring Network, 42 monitoring stations throughout the region collect water samples and analyze them for mercury to examine long-term water quality trends.
- Through the Fraser River Action Plan, contaminants in the sediment, suspended sediment and fish in the Fraser River Basin are being surveyed, which includes trace metal analysis.
- In the Pacific and Yukon Region, there is an ongoing project investigating the relationship between emission and deposition of mercury.

- In the Lower Fraser Valley of southwestern British Columbia, a series of studies have been carried out quantifying and qualifying atmospheric metal loading.

Natural Resources Canada Initiatives

Geological Survey of Canada

The Geological Survey of Canada (GSC) of Natural Resources Canada is currently expanding the amount of research devoted to mercury. The GSC is developing methods to determine the relative contributions of anthropogenic and natural sources of mercury to the atmosphere. The long-range transport of mercury is being studied by analyzing sediment and ice cores taken from various locations in the Arctic and the Northwest Territories.

5. Future Program Directions

Much research is still required regarding the amounts and effects of mercury in Canada. While the process of the conversion of mercury to its bioavailable form has become better defined, an improved understanding of the effects of organically bound mercury on human health and the environment is required. (CEC Phase I Report). Although there is a large body of scientific information on the levels and effects of mercury in the Canadian environment, there is much that is not known (Davies 1997).

Reference Dose

Reference doses for methylmercury intake in North America ranging between 0.1 and 0.5 µg/kgbw/day (micrograms per kilogram of body weight per day) (Environment Canada 1998). Federally, Health Canada now recommends a reference dose for methylmercury of 0.2 µg/kgbw/day for sensitive groups such as pregnant women. This number was recently adjusted down from the traditional allowable intake 0.47µg/kgbw/day (Environment Canada 1998).

Health advisories on fish are an adequate risk management tool, if advertised properly, and are sufficient for Canada. There should be regional initiatives to promote more public outreach and communication on fish advisories and work with other agencies to determine the necessity of a common methylmercury reference dose for sensitive groups.

Risk Groups

An important uncertainty in mercury science is the difficulty of identifying the effect level at which sensitive neurobehavorial consequences of prenatal exposure to methylmercury occur, and the extent to which the public, especially sensitive populations (e.g., pregnant women, children and high-end consumers of selected species of fish) are at risk from methylmercury through fish consumption. Risk assessment of sensitive groups is needed, especially in regions where children or young adults constitute a large portion of the population (Environment Canada 1998).

To promote the advancement of health and environmental issues within the NAFTA countries, workshops should be instituted which would serve to bring experts together to address this issue (Environment Canada 1998).

Atmospheric Measurements and Models

A trilateral, compatible deposition and gas-phase mercury network would provide needed data and scientific opportunities for collaboration between the NAFTA countries. The value added by the development of such a network would be a compatible analytical capacity, technological transfer of mercury analyzers, data for hemispheric models, and consensus science for NAFTA policy decisions on the environment.

Risks to Wildlife

Based on the levels of methylmercury found in the food of piscivorous birds (loons, osprey, kingfisher and eagles) and mammals (otter and mink), these creatures may be at risk from mercury exposure. Levels above 0.3–0.4 ppm per 20 to 50 grams of fish are suggested to be critical to loon reproduction (Environment Canada 1998). Blood samples taken from adult loon populations in eastern Canada showed mercury concentrations four times higher than Alaskan loons in the remote northwest United States. Support for ecosystem-based studies of chronic effects on the reproduction of piscivorous birds and animals is needed for Canada. An option to consider is bringing together regional wildlife toxicological experts by supporting a wildlife toxicology session as part of a science and health mercury workshop. Such a workshop could be held each year in each of the NAFTA countries on a rotating basis.

Technology Transfer, Emission Reduction Strategies and Inventories

Mercury atmospheric speciation and radioisotope tracing studies are essential scientific techniques for developing future controls on the relevant sources. Transferring best available control technology (BACT), standardizing analytical procedures and methodologies, and developing equivalent mercury measuring capacities between Mexico, Canada and the United States are essential (Environment Canada 1998).

Sector Studies

Long-term, multidisciplinary studies in selected areas, similar to those in the Northern Contaminants Program of the Arctic Environmental Strategy, need to be implemented (Davies 1997). The importance of continued research and monitoring of mercury-related issues must be emphasized because there are many things that are still unknown.

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