



ATMOSPHERIC MERCURY CONTAMINATION OF REMOTE AQUATIC ECOSYSTEMS IN CANADA

R. J. Allan

*Aquatic Ecosystem Restoration Branch, National Water Research Institute,
Canada Centre for Inland Waters, 867 Lakeshore Road, P.O. Box 5050, Burlington,
Ontario, L7R 4A6 Canada*

ABSTRACT

The long-range atmospheric transport and deposition of metals, particularly mercury (Hg), into lakes has become a subject of increasing interest. In Canada, the sources of anthropogenic, atmospheric Hg are primarily considered to be power stations in the United States and Europe. Increases in deposition of Hg have been recorded in lake sediment cores from many parts of Canada. Where Hg input to lakes from local sources in Canada has been reduced, concentrations in lake sediments and lake biota have declined. However, in many remote lakes, fish consumption advisories are still in effect for Hg. Debate continues over the sources of this mercury, whether long-range anthropogenic, atmospheric or natural. Where studied, the same applies to remote lakes in other parts of the world. © 1999 Published by Elsevier Science Ltd on behalf of the IAWQ. All rights reserved

KEYWORDS

Diffuse pollution; long-range atmospheric; mercury.

INTRODUCTION

Recently, there has been increasing interest in long range atmospheric transport and deposition of metals in Europe and North America, particularly mercury (Hg) (Allan, 1996). Some of the main anthropogenic, atmospheric sources for certain metals are related to mining, as with emissions from smelters, burning coal to produce electric power, or waste incineration. For metals emitted primarily in particulate form, transport is primarily limited to tens of kilometres around a point source. For metals emitted as very fine particulates or in gaseous form, for example Hg, atmospheric transport distances are considered to be far greater. The south-east and the Arctic, are two regions impacted by air masses moving into Canada and possibly causing long-range transboundary atmospheric transport and deposition of metals (Figure 1). Some of the metal sources to the former region are from emissions in the eastern United States (Figure 2) (Schroeder and Markes, 1994) and to the latter region from similar sources in central and eastern Europe (Sturges and Barrie, 1989).

TRENDS

The vertical distribution of metals, especially Hg, in Canadian lake sediment cores (Figure 3) has been interpreted as evidence of increasing, long range, anthropogenic input from the atmosphere (Lockhart *et al.*,

1995). The ratio of recent to geological Hg flux to lake sediments has been calculated for 51 lake sediment cores from lakes in five of the eight circumpolar countries (Landers *et al.*, 1996) (Figure 4). The highest ratios greater than 3.5 are in south central and central Arctic Canada and in southern Scandinavia. Lower values are in the western Canadian Arctic, Quebec and northern Scandinavia. Lowest values are in Alaska and northern Russia.

SOURCES

The proportion of annual emissions of natural and anthropogenic Hg to the atmosphere is a crucial question. New clean techniques for sample collection and analyses of metals in water and ice were implemented in the late eighties. Estimates since 1990 give the ratio of global annual natural/anthropogenic emissions as roughly 50/50 (OECD, 1994) (Figure 5).

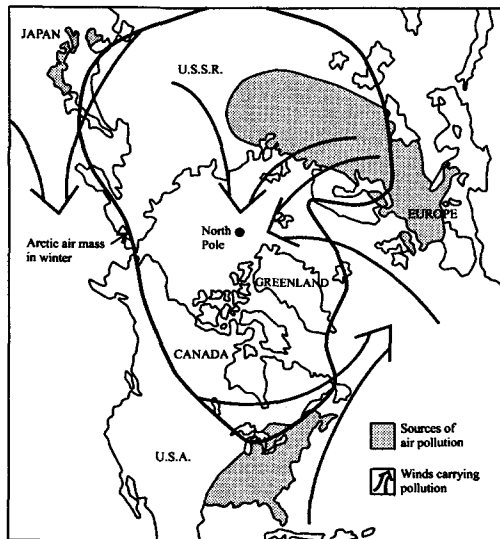


Figure 1. Trajectories of air pollution into Canada.

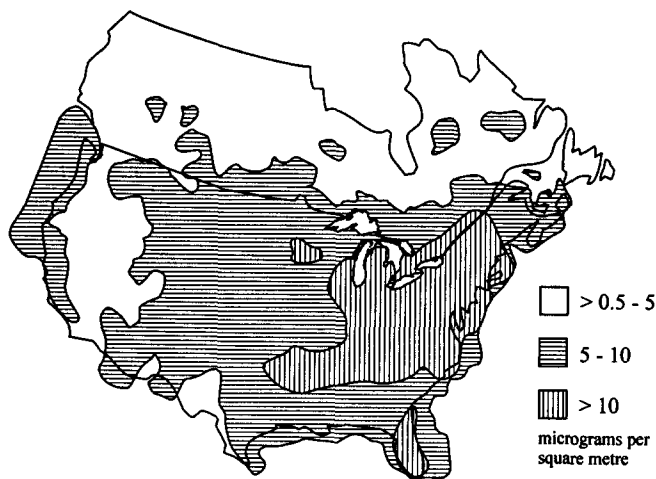


Figure 2. Modelled total wet deposition of Hg based on 1989 emissions in the U.S.A. (Adapted from U.S. EPA, 1996)

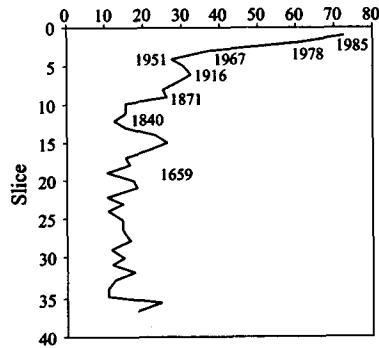


Figure 3. Mercury in a lake sediment core from Amituk Lake, Cornwallis Island, Canadian Arctic Archipelago. Dates earlier than about 1850 are extrapolations based on sedimentation rates established from recent slices.

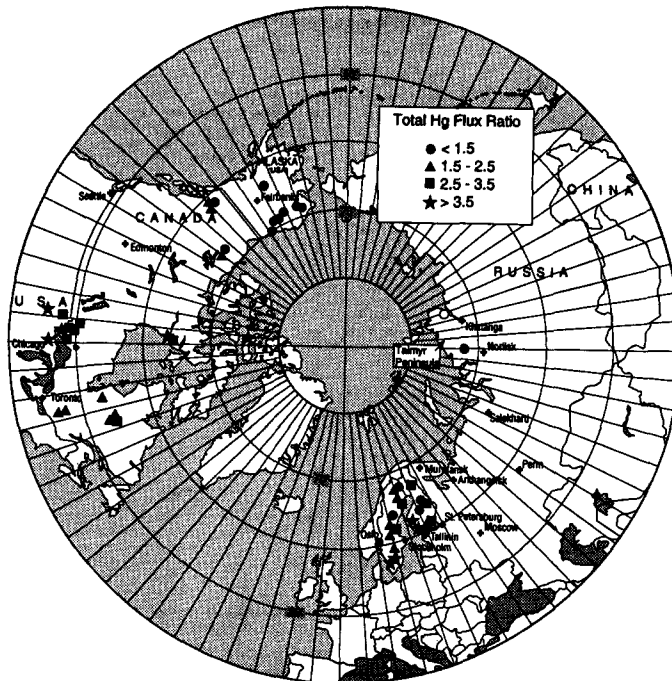


Figure 4. Mercury flux ratios (present/historical-geological) in circumpolar lake sediment cores (Figure courtesy of D. Landers, U.S. EPA)

EFFECTS

Reduction or removal of point source Hg effluents from chloralkali plants has resulted in burial of Hg in downstream lake sediments and reduction of Hg concentrations in downstream biota (Figure 6) in aquatic ecosystems (Allan *et al.*, 1984). However, when contamination of aquatic ecosystems with anthropogenic Hg is less severe, for example from long range atmospheric transport and deposition of Hg from anthropogenic sources, the results of this on Hg concentrations in aquatic biota are not yet clear.

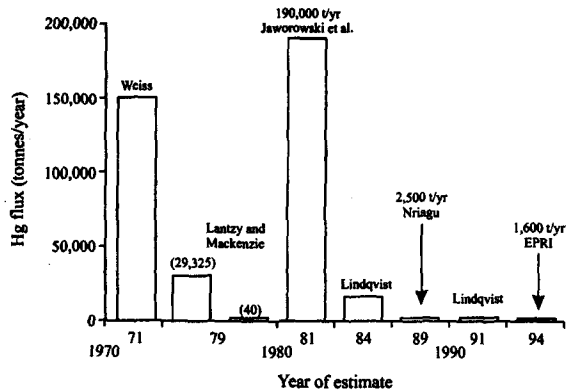


Figure 5. Calculated natural global annual Hg fluxes. Shows early estimates of natural Hg fluxes based on a Greenland ice core (Weiss) and global ice and snow samples (Jaworowski) both of which are much larger than recent estimates.

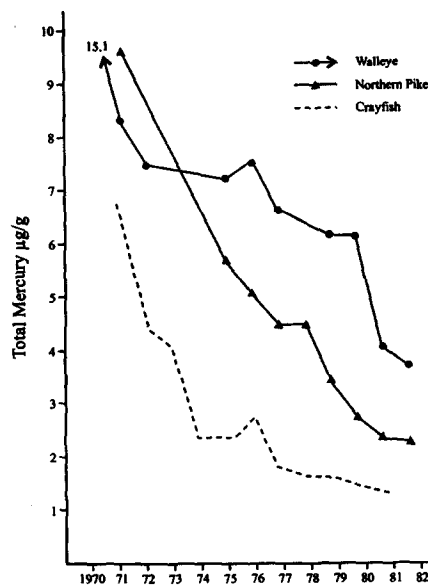


Figure 6. Mercury concentrations 60 cm northern pike, 50 cm walleye and crayfish from Clay Lake, 1970-82.

In many remote areas of Canada, concentrations of Hg can exceed consumption guidelines in specific native food items, such as freshwater fish and attain levels of concern in fish eating birds such as loons (Evers *et al.*, 1998) (Figure 7). Mercury concentrations in the blood of many aboriginal Canadians, especially the Inuit (Table 1), sometimes exceed 20 ppb, the lower limit for increasing risk (less than 20 ppb is the normal acceptable range) (Wheatley and Paradis, 1995). An unquantified component of this Hg may come from long range, anthropogenic atmospheric emissions.

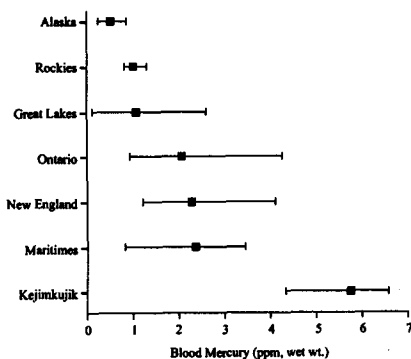


Figure 7. Mercury in North American adult loons (Mean and range) (Figure courtesy of N. Burgess, Canadian Wildlife Service)

CONCLUSIONS

1. In the recent past, mercury concentrations in sediment cores and in other media have gone up or stayed constant but rarely seem to have gone down except where local pollution sources have been reduced.
2. Measured atmospheric deposition rates for mercury are similar to the deposition rates calculated from lake sediment cores and from mass balances in calibrated watersheds.
3. In the western Canadian Arctic, the natural mercury component in aquatic sediment cores is higher than in the eastern Arctic, as is the accumulation of mercury in seals and whales.
4. The dates of increases in mercury concentrations in various media is similar and seems to match industrialization and not any sudden natural geological change.
5. Watersheds are complex and lakes of different types in different geological and hydrological settings react to mercury load increases and decreases in complex ways.

REFERENCES

- Allan, R.J. (1996). *Long Range Atmospheric Transport of Heavy Metals, Particularly Mercury, in Canada: Sources, Fate and Effects*. Environment Canada, National Water Research Institute, Burlington, Ontario, Canada, Contribution No. 96-80, 81 pp.
- Allan, R.J., Brydges, T., Dodge, D., Hamilton, R.D., Jeffs, D.G. and Shikaze, K. (1984). *Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures*. Final Report of the Steering Committee, Minister of Supply and Services Canada, Cat. No. Em 37-67/1984E, Vol. 1: 18 pp.; Vol. 2: 538 pp.
- Evers, D.C., Kaplan, J.D., Meyer, M.W., Reaman, P.S., Braselton, W., Emmett, Major, A., Burgess, N. and Scheuhammer, A.M. (1998). Geographic trend in mercury measured in common loon feathers and blood. *Environmental Toxicology and Chemistry* 17(2), 173-183.
- Landers, D.H., Gubala, C., Verta, M., Lucotte, M., Johansson, K., Vlasova, T. and Lockhart, W.L. (1998). Using lake sediment mercury flux ratios to evaluate the regional and continental dimensions of mercury deposition in arctic and boreal ecosystems. *Atmospheric Environment* 32, 919-928.
- Lockhart, W.L., Wilkinson, P., Billeck, B.N., Hunt, R.V., Wagemann, R. and Brunskill, G.J. (1995). Current and historical inputs of mercury to high-latitude lakes in Canada and to Hudson Bay. *Water, Air, Soil Pollution* 80, 603-610.
- OECD (Organisation for Economic Cooperation and Development) (1994). *Mercury Risk Reduction*. OECD, Monograph No. 4, pp. 37 and 38.
- Schroeder, W.H. and Markes, J. (1994). Measurements of atmospheric mercury concentrations in the Canadian environment near Lake Ontario. *Journal of Great Lakes Research* 20(1), 240-259.
- Sturges, W.T. and Barrie, L.A. (1989). Stable lead isotope ratios in Arctic aerosols: evidence for the origin of Arctic air pollution. *Atmospheric Environment* 23, 2513-2519.
- U.S. EPA (1996). *Mercury Studies Report to Congress*. Office of Air Quality Planning & Standards and Office of Research and Development, EPA-452/R-96-001.
- Wheatley, B. and Paradis, S. (1995). Exposure of Canadian aboriginal peoples to methylmercury. *Water, Air, Soil Pollution* 80, 3-11.