

Appendix D

Research Status Report

Mercury Deposition and Effects in the Lake Champlain Basin

RESEARCH STATUS REPORT

Mercury Deposition and Effects in the Lake Champlain Basin

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Background:

Since 1992, EPA, NOAA and other agencies have supported research and monitoring of atmospheric pollutant deposition to the Lake Champlain basin, a designated Great Water. Our work has focused on the deposition, ecosystem cycling, and fate of atmospheric mercury (Hg), as well as the wet and dry deposition of sulfur, nitrogen, other major ions and trace metals, and meso-scale modeling of pollutant deposition in the basin. Recent efforts have emphasized understanding Hg movement in forested watersheds, providing information on seasonal patterns of concentration and deposition, soil water transport mechanisms, winter accumulation in the snowpack, and input/output relations.

These studies are important to our efforts to understand Hg patterns, impacts and control in the Lake Champlain basin and the region. Our deposition monitoring is one of the longest running consistent Hg data base (5 years) in air and precipitation in the world, and is the only long-term year-around toxics deposition monitoring project in New England. These long-term data allow us to observe if changes in Hg emissions and controls on sources such as medical and municipal waste incinerators have impacts on Hg deposition in Vermont. Our site is also one of the few locations in North America where watershed deposition and ecosystem processing of Hg is being investigated. It is a critical site in the NESCAUM Hg monitoring program (EPA REMAP) started this past June. It is a critical location for comparisons and cooperation with the Canadian Networks. And finally, it allows us to connect the Lake Champlain and New England projects into the Great Lakes and Great Waters Hg research programs.

What we know:

Total Hg deposition (Figure 1) averages around 130 mg/ha per year (wet plus dry), and varies seasonally with 68% of annual deposition occurring during May-Sept. Dry deposition comprises approximately 38% of the total Hg deposition. About 85% of the total Hg deposition is retained in the terrestrial ecosystem (although some of this may return to the atmosphere by volatilization). Of the 15% exported in streamflow (Figure 2), about 1/3 is dissolved and 2/3 is associated with organic particulate matter. Our data suggest that a large proportion of total Hg flux in streamflow may occur during a very few large runoff events (spring snowmelt, floods). In the Lamoille River system, Hg concentrations are generally 3-10 ng/L, and tend to follow the pattern of the upland catchment, with elevated concentrations during higher flows (Figure 3). In the forest ecosystem, we know that Hg accumulates in foliage during the growing season, and the flux of Hg to the forest floor in autumn litterfall is large and comparable to the annual total wet plus dry atmospheric deposition. Concentrations of Hg in soil water (unpublished data) are much greater in the organic horizons (15-20 ng/L) than in the mineral horizons (1-2 ng/L), reflecting the similar behavior of dissolved organic carbon (DOC). At this time, we have begun analysis of the relationship between Hg in soil and stream water, with special attention to the role of DOC, and have also begun examination of the concentrations and pools of Hg in aquatic food web components (plankton, minnows, fish).

What we need to know:

We need to know atmospheric concentrations (gaseous Hg⁰ and Hg²⁺) and particulate phase Hg in its various forms) and deposition rates to (a) determine trends, and (b) understand atmospheric chemistry, transport and loading. Knowing the levels of atmospheric Hg, when determined with other trace elements (e.g., manganese, nickel, vanadium) and major ions (e.g. sulfate, nitrate, chloride) allows us to investigate the source(s) of the Hg in the environment. This requires continued monitoring of Hg in precipitation, vapor and aerosol phases.

We also need to refine our knowledge of the mechanisms controlling Hg transport within the forested watershed in order to identify risk factors and possible control points. Several lines of evidence indicate that soils - particularly highly organic forest soils - are very large sinks for Hg and can under certain conditions be significant sources for Hg. We need to continue work studying Hg transport and cycling in the forest, particularly the roles of particulate and dissolved organic carbon compounds in Hg transport. Lastly, the rates of

production of methyl-Hg in forested wetlands need to be investigated as this may control methyl-Hg levels in the ecosystem and in Lake Champlain.

We need to examine the pathways and mechanisms of Hg bioaccumulation in aquatic primary producers and consumers in order to complete our understanding of the movement of Hg from the atmosphere into the food web. This will require measurement of total and methyl-Hg in the water column, plankton and minnows.

To more accurately quantify total Hg deposition and loadings in the Lake Champlain basin, we need to refine models predicting spatial deposition patterns and dry deposition rates in the basin. This will require coordination among our group in Vermont (including the Vermont Air Pollution Control Division), the University of Michigan Air Quality Laboratory and the atmospheric modeling community (e.g., NOAA, EPA) to further develop and use these deposition models.

To calculate Hg loading to Lake Champlain we need information on Hg concentrations in soils and export to streams from important land use types. We currently have good information from one hardwood forested catchment, but need data from agricultural lands and other forest systems and catchments.

Therefore, our priorities for the next three years are to: (1) continue monitoring atmospheric Hg concentration and deposition, including cloud water and dew chemistry, (2) continue research on the role of organic matter in Hg transport in soil/stream systems, (3) expand the runoff and stream transport analysis to other watersheds in the basin (including both agricultural and other land uses), (4) measure Hg and methyl-Hg in aquatic food web components, and (5) assess regional air transport patterns, loadings to the basin and lake, and mass balance with the goal of identifying critical control points. We propose to address these five research areas through continuation of our collaborative research in the Lake Champlain basin utilizing experts in forest eco-physiology (Scherbatskoy), atmospheric chemistry (Keeler), watershed biogeochemistry (Shanley), and toxicology (Watzin). While this description focuses on Hg, most of these samples will also be analyzed by ICP-MS for other trace elements (Cd, As, Pb, Ni, V, Cr, Mn, etc.) as well, which will broaden our understanding of pollutant deposition and movement in the environment.

Relevant Publications:

- Scherbatskoy, T. ,J.B. Shanley and G.J. Keeler, Factors controlling mercury transport in an upland forested catchment. Submitted to Water, Air, and Soil Pollution.
- Rea, A.W., G.J. Keeler 1997. Microwave digestion and analysis of foliage for total mercury by cold vapor atomic fluorescence spectroscopy. In press, Biogeochemistry.
- Rea, A.W., G.J. Keeler and T. Scherbatskoy. 1996. The deposition of mercury in throughfall and litterfall in the Lake Champlain watershed: a short-term study. Atmos. Environ. 30:3257-3263.
- Scherbatskoy, T. , J.M. Burke, A.W. Rea and G.J. Keeler. 1997 Atmospheric mercury deposition and cycling in the Lake Champlain Basin of Vermont. pp 245-258 in: J.E. Baker (ed.) Atmospheric deposition of contaminants to the Great Lakes and coastal waters. SETAC Press, Pensacola, FL
- Burke, J., M. Hoyer, G. Keeler and T. Scherbatskoy. 1995. Wet deposition of mercury and ambient mercury concentration at a site in the Lake Champlain Basin. Water Air Soil Pollut. 80:353-362.

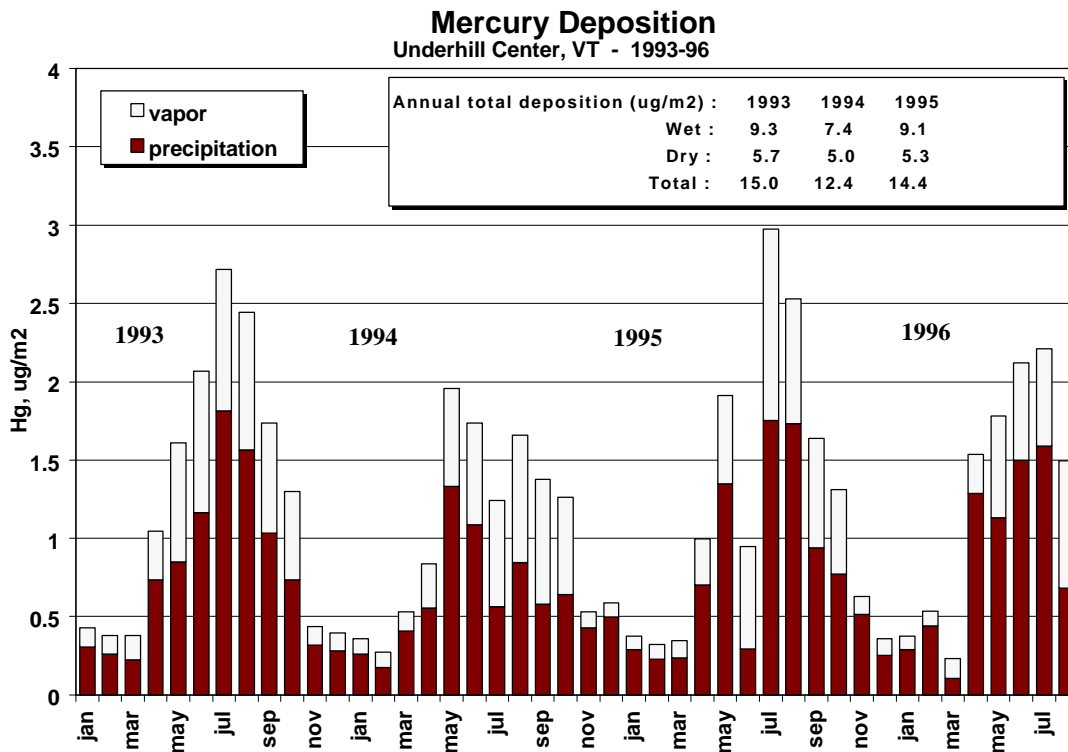


Figure 1. Monthly wet and dry deposition of Hg at the Underhill monitoring site.

Mercury Inputs & Outputs at Nettle Brook

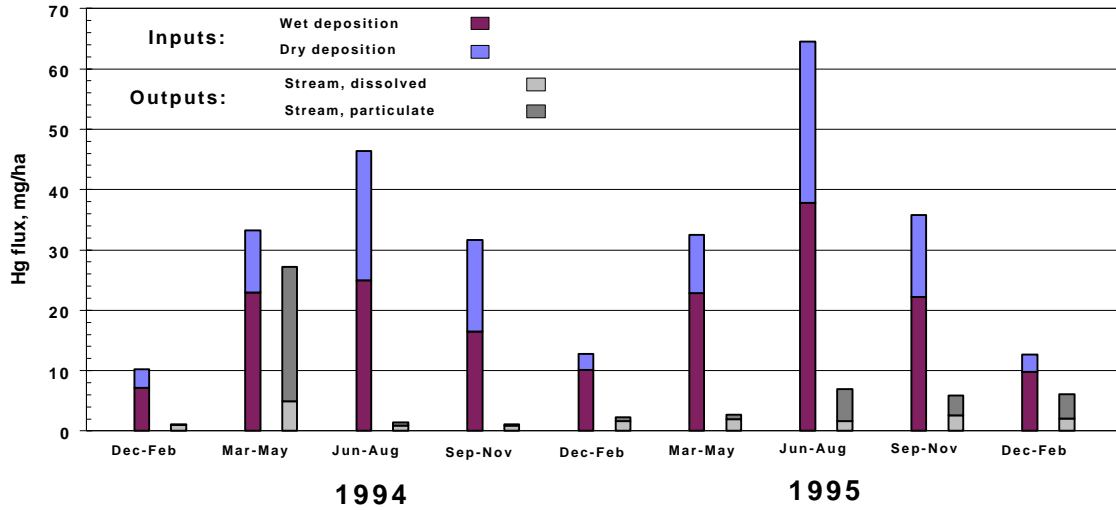


Figure 2. Hg input (wet and dry deposition) and output in streamflow (dissolved and particulate) in Nettle Brook, draining a small (11 ha) upland deciduous forest catchment in Underhill, VT.

Mercury at Lamoille River Sites

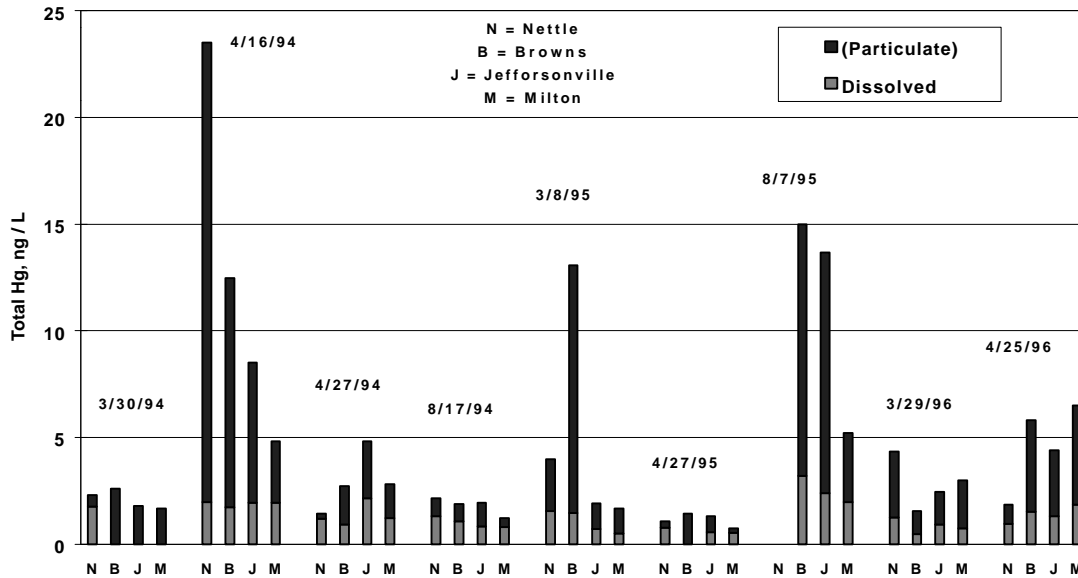


Figure 3. Hg concentration (dissolved and particulate phase) in Nettle Brook, Browns River, and two sites in the Lamoille River (Jeffersonville and Milton) during 1994-1996.