Estimation of Mercury Loading to Lake Ontario Due to Atmospheric Deposition

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Despite efforts to significantly reduce mercury from waste streams in the United States and other developed countries, mercury continues to be a problem for many water bodies. The chemistry of mercury dictates that it is relatively harmless in the atmosphere and present at low concentrations. Yet when it enters water, some is converted to methyl-mercury which bioaccumulates in the fatty tissue of organisms and is highly toxic. Fish consumption advisories in many states are a result of this process, and the Great Lakes are no exception.

For these reasons, estimating the amount for mercury entering bodies of water like the Great Lakes is important. This is particularly true of mercury entering through the atmosphere. One study of Lake Michigan attributed 80% of all mercury loadings to the lake to atmospheric deposition (Mason and Sullivan 1997). Atmospheric deposition is why some pristine lakes far from mercury sources also have problems with mercury.

Currently, researchers are gathering atmospheric mercury data in and around Lake Ontario. Using these data, it is possible to estimate how much mercury is entering Lake Ontario annually through the atmosphere. However, as reliable methods for measuring mercury have only emerged in the last ten years, there is not an abundance of data. It is therefore the focus of this paper to estimate a highest and lowest deposition scenario while the actual mercury loading to Lake Ontario is probably somewhere in between.

There are three processes and two mercury forms important in the cycling of mercury through the atmosphere. The three processes are wet deposition, dry deposition and air-water exchange, and the two forms of mercury are reactive gaseous mercury (RGM) and elemental mercury (Hg\(^0\)). Wet deposition involves primarily Hg\(^0\) that is oxidized into divalent mercury (Hg\(^{2+}\)) in rain water. Dry deposition is primarily Hg\(^0\) that has been sorbed onto particles (Hg(p)). Air-water exchange involves two components, dissolved gaseous mercury (DGM), or Hg\(^0\) in water, and total gaseous mercury (TGM), or Hg\(^0\) present in air. The two interact at the surface of water to create a gradient, moving mercury into and out of the water. Historically, many bodies of water are often super-saturated with mercury relative to the air.

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and so the net mercury flux is out of the water. Reactive gaseous mercury is the Hg\(^{2+}\) present in the atmosphere. As indicated by the name, it is highly reactive and exists primarily as HgCl\(_2\).

Measurements of all these components except dry deposition were made in the field from April 2002 to February 2003. However, the majority of the data are only from one or two land locations, quite few considering the lake’s surface area of 7340 mi\(^2\) (18960 km\(^2\)). Still, these data, data gathered from a ten-day research cruise during the year-long sampling period, and data from the Lake Michigan study (Landis and Keeler 2002, Vette et al. 2002) are adequate for an initial estimate of mercury loadings to Lake Ontario.

Estimating mercury loading to a lake so large with so few data points was accomplished by subdividing Lake Ontario into three sections based on available data. One station was located in Sterling, NY and the other at Pt. Petre, ON (Figure 1). As both these locations are rural in nature, a third section, referred to as “Urban,” was included although it did not have a sampling station to represent it. However, urban influences on mercury loadings are very significant so data from the Lake Michigan study was used to estimate the levels there (Landis and Keeler 2002). Mercury concentrations and fluxes were assumed to be constant over each section. Multiplying the flux by the area resulted in the total loading to that area of the lake. These were summed to estimate the total mercury loadings to Lake Ontario for one year.

By trying to estimate mercury loading to Lake Ontario with so little data, different scenarios were developed. These were to produce a range of estimates with the actual loading probably in between. These scenarios included (1) using concentrations of total gaseous mercury (TGM) and RGM at Pt. Petre and its corresponding area equal to or 60% of the concentrations measured at the Sterling site, (2) assuming the dry deposition flux for the whole lake was the same as what was measured in the Lake Michigan study or it was estimated based on a wet/dry deposition ratio observed in the Lake Michigan study, and (3) assuming there is an urban influence affecting roughly 18% of the lake or there is no urban influence.
The lowest deposition scenario is that 17.4 kg of mercury is entering the lake per year. This would be the case if there is no urban influence, if the wet/dry ratio observed for Lake Michigan is the same for Lake Ontario, and if TGM and RGM concentrations over the Pt. Petre area are only 60% of the concentrations measured at Sterling. The highest deposition scenario is that 308 kg of mercury is entering the lake per year. This would be the case if urban areas influenced 18% of Lake Ontario, if the dry deposition flux observed for Lake Michigan is the same for Lake Ontario, and if TGM and RGM concentrations over the Pt. Petre area are the same as those measured at Sterling. Urban influences had the greatest effect of all the scenarios by doubling dry deposition, dictating whether the net mercury flux was moving into or out of the lake through air-water exchange, and increasing RGM contributions 55%. While urban influences may not have had as great an effect as was estimated in this study, there is certainly some influence due to cites located near on Lake Ontario such as Toronto, ON, Hamilton, ON, and Rochester, NY.

