

IDENTIFICATION OF POSSIBLE MERCURY SOURCES AND ESTIMATION OF MERCURY WET DEPOSITION FLUX IN LAKE ONTARIO FROM LAKE ONTARIO ATMOSPHERIC DEPOSITION STUDY (LOADS)

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Abstract : Total gas phase mercury (TGM) concentrations and event wet-only precipitation for Hg were collected for nine months (from April, 2002 to Dec., 2002) at Sterling, NY on the shoreline of Lake Ontario. TGM concentrations measured in this study ($3.02 \pm 2.14 \text{ ng/m}^3$) were in somewhat high range compared to other background sites. Using simplified quantitative transport bias analysis (SQTBA) possible sources affecting high Hg concentration in Sterling was identified, and they are coal-fired power plants located in southern NY and Pennsylvania. Wet deposition measured at Mercury Deposition Network (MDN) sites including Pt. Petre and Egbert, ON were compared with data obtained at the Sterling to estimate the total mercury wet deposition flux to Lake Ontario. The wet deposition flux was calculated to be the highest at the Sterling site ($7.94 \text{ } \mu\text{g/m}^2$ from April, 2002 to Dec. 2002) and the lowest at the Egbert ($3.92 \text{ } \mu\text{g/m}^2$), due to the both the difference in precipitation depth and Hg concentration in the precipitation. The deposition measured at the Sterling site is similar to Lake Michigan deposition of $6\text{-}14 \text{ } \mu\text{g/m}^2$ (converted for ninth months) measured for Lake Michigan Mass Balance Study (LMMBS).

Key Words : Mercury, TGM, RGM, SQTBA, Source, Wet deposition, Lake Ontario

INTRODUCTION

Mercury is a toxic pollutant of concern in lake ecosystem because of its high ability of bioaccumulation in food chain, so that it threatens human health from consuming contaminated fish. Most of anthropogenic mercury is emitted from atmospheric sources including coal power plants and waste incinerator with other heavy metals, but it differs from other heavy metals because it goes through the emission and deposition cycle continuously after its release.

Also, the dominant species in the environment is vapor phase mercury, while other heavy metals are associated with the particulate phase. Mercury compounds undergo various physical and chemical transformations to other oxidation states. Mercury is capable of existing in three oxidation states: 0, +1, and +2. However the state of +1 is very rare if it exists at all. Elemental mercury (oxidation state 0) is predominant species in ambient air, and its residence time is 1/2~2 yrs due to the low solubility and inertness.^{1,2)} The contribution of elemental mercury is typically more than 95% of total mercury concentrations, but atmospheric particulate forms (Hg(p)) and divalent species of mercury

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(Hg(II)) are considered to wet and dry deposit more rapidly than elemental mercury due to high deposition velocity. However, the mechanisms of dry and wet deposition of mercury are uncertain and there have been few attempts to quantify both dry and wet deposition by direct measurement.

From Lake Michigan Mass Balance Study, atmospheric deposition was determined to be the primary pathway for mercury input to Lake Michigan, contributing approximately 84% of the estimated total annual input. In addition, it indicated that wet and dry deposition contributed almost equally to the annual atmospheric deposition. This work was undertaken in order to identify the major atmospheric mercury sources and to quantify the wet deposition amount of mercury for Lake Ontario, as a part of Lake Ontario Atmospheric Deposition Study (LOADS) that monitors deposition and ambient concentrations of PBTs (Persistent Bioaccumulative Toxics; Hg, PCBs, DDE, Mirex, HCB and Dioxin/Furans) in the Lake Ontario region.

Lake Michigan Mass Balance Study (LMMBS)

The LMMBS was one of the most comprehensive atmospheric Hg monitoring projects completed to date in the Great Lake Region. Hence, a review of LMMBS and comparison between LMMBS and LOADS are useful to gauge the accuracy of the wet deposition flux of Hg estimate for Lake Ontario. From LMMBS, it was reported that the atmospheric wet deposition is the largest contributor to mercury input to Lake Michigan (approximately 44%) compared than other sources including tributaries and direct point sources (U.S. and Canadian). However, from the recent research³⁾ the atmospheric wet loadings were estimated to contribute about 26% of total Hg input to Lake Ontario in 1995 based on RateCon model (Rate Constant model). This result provides that the contribution of wet deposition may be smaller in Lake Ontario than in Lake Michigan.

During the LMMBS, event precipitation was collected at five locations including Kenosha

(KEN), WI, Chicago, IL, Sleeping Bear Dunes (SBD), MI, South Haven (SHN), MI, and Bondville (BON), IL from July 1, 1994 through October 31, 1995. Volume-weighted average concentrations of mercury in precipitation varied from 10.8 to 16.1 ng/L at five sites.⁴⁾ Mercury concentration in precipitation was significantly high at the IIT site in Chicago. The SBD site showed significantly lower concentration, indicating that local and regional sources are contributing significantly to wet deposition quantities of mercury in the southern portion of the Lake Michigan Basin.⁵⁾

Precipitation depth and monthly volume-weighted Hg in precipitation concentrations were interpolated over Lake Michigan on a monthly basis. After interpolating, atmospheric wet deposition was calculated as the product of the Hg concentration and precipitation depth. Although the mercury concentration in precipitation was measured at only five sites, interpolation of these data to the whole lake is not unreliable because the monitoring sites were selected to cover the area of highest anthropogenic source density (IIT) to an area of lowest source density (SBD), representing a conservative upper and lower bounds for the estimated deposition. Atmospheric wet deposition flux of mercury was estimated to be 10.6 mg/m²-yr and total wet deposition amount into Lake Michigan 614 kg.⁵⁾

Simplified Quantitative Transport Bias Analysis (SQTBA)

Quantitative Transport Bias Analysis^{6,7)} contains more sophisticated features than other common back-trajectory based models (e.g. Potential Source Contribution Function, Residence Time-Weighted Concentration); this is possible due to the fact that it incorporates deposition and reaction along the back trajectory. In addition, the concept of the flow path of a single particle is no longer used in this approach. Instead, the normal distribution by atmospheric dispersion is approximated along the trajectory centerline with a standard deviation that increases linearly with time in the upwind direction.^{6,8)} The probability

of a reactive depositing tracer arriving at a point x at time t is given by Lamb and Seinfeld⁹⁾ and Cass¹⁰⁾ as

$$A(x,t) = \int_{-t}^t \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} T(x,t | x',t') dx' dt' \quad (1)$$

where $T(x,t|x',t')$ is the potential mass transfer function, given by

$$T(x,t|x',t') = \frac{Q(x,t|x',t') R(t|t')}{D(x',t') W(x',t')} \quad (2)$$

in which $Q(x,t|x',t')$ is the probability of an air parcel located at x' at time t' arriving at the receptor site x at time t , $R(t|t')$ is the probability of the tracer not being removed by reaction in the interval between t' and t , $D(x',t')$ is the probability that the material is not lost by dry deposition at (z',t') , and $W(x',t')$ is the corresponding probability for not being lost through wet deposition. Because the amount lost during transport due to the deposition is poorly known, Keeler⁷⁾ assumed that deposition is linearly proportional to the concentration of the species with the rate constants for dry (k_d) and wet (k_w) deposition of;

$$k_d = \frac{v_d}{h} \quad (3)$$

$$k_w = \frac{T(z)}{h} \quad (4)$$

where h is mixing height, T is the washout ratio for species z (mm/hr) and v_d is the deposition velocity.

The transition probability function $Q(x,t|x',t')$ is expressed as Equation 5.

$$Q(x,t|x',t') = \frac{1}{2\pi s_x(t')s_y(t')} \exp \left[-\frac{1}{2} \left\{ \left(\frac{X-x'(t')}{s_x(t')} \right)^2 + \left(\frac{Y-y'(t')}{s_y(t')} \right)^2 \right\} \right] \quad (5)$$

where (X,Y) is the coordinate of the grid

center and $x'(t')$ and $y'(t')$ are the coordinates of the centerline of the trajectory and s is the standard deviation of trajectories assumed to grow with time.

$$s_x(t') = s_y(t') = at' \quad (6)$$

where a is a dispersion speed, 5.4 km/hr.⁶⁾

The integrated potential mass transfer for a given trajectory, j , arriving at time t is calculated as

$$\bar{T}_j(x|x') = \frac{\int_{t-t}^t T(x,t|x',t') dt'}{\int_{t-t}^t dt'} \quad (7)$$

This natural probability field predicts the possibility of the contribution from any upwind area to a specific receptor site without regards to the actual location of the emission sources. These probabilities are then incorporated into a Transport Bias Analysis by examining the ensemble average of potential mass transfer functions calculated for each trajectory over the same sampling period to obtain the mean potential mass transfer for that period. The spatial distribution of this field provides an estimate of the potential for the contribution to the atmospheric concentrations of a constituent if the sources of that species were spatially homogeneous in the horizontal plane.

The measured concentrations of the species can then be used to calculate the transport bias. Using the potential mass transfer fields calculated for each trajectory, k , weighted by the corresponding concentration measured during that sampling interval results in a concentration-weighted mass transfer potential field as defined by

$$\tilde{T}(x|x') = \sum_{k=1}^K \bar{T}_k(x|x') z_k(z) \quad (8)$$

where \bar{T} is the integrated potential mass

transfer calculated in Equation 7, and $z_k(z)$ is the concentration of the species of interest measured at x when trajectory k arrived. The difference between the weighted and the unweighted field represents the degree of bias associated with the transport of the species of interest to the receptor site.

One final manipulation is then made to convert the Transport Bias Analysis to Quantitative Transport Bias Analysis (QTBA). The concentration-weighted mass transfer potential of Equation 9 is divided by the unweighted mass transfer potential resulting in a concentration unit.

$$QTBA(x|x') = \frac{\tilde{T}(x|x')}{\sum_{k=1}^K \bar{T}_k(x|x')} \quad (9)$$

EXPERIMENTAL METHOD

The Sterling Nature Center is a 5.7 km² nature preserve located along the southeast corner of Lake Ontario with approximately 3.2 m of undeveloped shoreline (Figure 7). One such drumlin is topped by a 0.05 km² field extending to a near vertical bluff located 27 m above the lake. This site has an opportunity to sample air affected by in-State sources as well as out-of-State sources. TGM concentrations were measured in every six days using two consecutive gold sand traps at a flow rate of 300 mL/min. Event precipitation of Hg was collected using a modified MIC-B (MIC, Thornhill, ON) automatic precipitation collector at the Sterling site from April 2002 to December 2002 on a six-day basis.

Collected gold sand traps were brought to the Clean Room and thermally desorbed with mercury-free argon stream at about 500°C, so that vapor Hg was analyzed using a cold-vapor atomic fluorescence (CVAFS) analyzer (Brooks and Model III). Hg in precipitation was analyzed in a Class 100 clean room at the University of Michigan Air Quality Laboratory, with a method

identical to LMMBS.⁴⁾ Samples were oxidized with concentrated BrCl to a 1 % solution (v/v) and stored at 4°C in the dark overnight CVAFS analysis. The sampling and analytical methods for Hg in air and precipitation utilized in this study have been detailed elsewhere.¹¹⁻¹³⁾

Quality assurance/quality control was performed as required by the EPA standard methodology. The overall precision was assessed using relative percent difference between collocated samples, and they were 7.6±5.4% ($R^2=0.97$, $n=13$) and 1.6±1.5% ($R^2=0.99$, $n=11$) for TGM and precipitation samples, respectively. A minimum of one field blank was taken for every 6 samples collected (average field blank values were 0.23 ng/m³ for atmospheric TGM and 0.85 ng/L for precipitation sample), and the method detection limits (MDLs) were calculated by 3 times of standard deviation of field blank. MDLs were within 15% of sample values (0.06 ng/m³ and 0.85 ng/L for atmospheric concentration of TGM and Hg concentration in precipitation, respectively). All apparatus were cleaned using an 11 day acid cleaning procedure described in U.S. EPA Lake Michigan Mass Balance Methods Compendium.¹⁴⁾ After acid-cleaned, they were triple bagged in polyethylene bags before being used.

RESULT AND DISCUSSION

Atmospheric Mercury Sources

TGM concentrations at the Sterling site ranged from 0.43 to 13.79 ng/m³ (3.02±2.14). Ambient TGM sources for Sterling were identified using Simplified QTBA (SQTBA) in this study. As described earlier, common back-trajectory based models such as PSCF may have large uncertainty since it assumes that the location of air parcel is well predicted by a single particle trajectory. A sufficient number of samples (sufficient number of endpoints) can provide reasonable source areas if the errors are random and not systematic. QTBA has advantages over other back-trajectory based models because it incorporates the concept of atmos-

pheric dispersion by applying a normal distribution along the trajectories; it may thus reduce the error associated with small sample number (60 samples in this study) and a single trajectory. In this study, five-day backward trajectories were calculated using the NOAA (National Oceanic and Atmospheric Administration) HYSPLIT (Hybrid Single Particle Integrated Trajectory, version 4) applied to EDAS (Eta Data Assimilation System) meteorological data and vertical mixing model. EDAS has a horizontal resolution of 80 km, twenty three vertical levels up to 2250 hPa, and a temporal resolution of 3 h.¹⁵⁾ Trajectories were calculated every 6 hr for all 24 hr-averaged samples, therefore four trajectories were combined to represent one sample. SQTBA used the grid-cell size of 1° by 1° and arrival heights of 500 m. A trajectory height range of 0 to 5,000 m was used.

In this study, SQTBA which omits the reactions and deposition was performed. SQTBA is reasonable to be applied for TGM since elemental mercury, which makes up the majority of TGM, is inert and has low deposition rates. The natural probability field for the contributions from any upwind area to a specific receptor site without regards to the actual location of the emission sources (represented as equation 7) is shown in Figure 1. The standard deviation was assumed to be 5.4 times the traveled time,⁷⁾ which may be too simplistic to fully describe atmospheric dispersion. In this work, a weight function was applied when a grid cell had a natural probability less than three times the average value in order to reduce the uncertainty in a grid cell with low natural probability^{11,16,17)} (equation 10).

$$W(n_{ij}) = \begin{cases} 1.00 & 1.77 \times 10^{-5} < n_{ij} \\ 0.70 & 5 \times 10^{-6} < n_{ij} \leq 1.77 \times 10^{-5} \\ 0.42 & 1 \times 10^{-6} < n_{ij} \leq 5 \times 10^{-6} \\ 0.17 & n_{ij} \leq 1 \times 10^{-6} \end{cases} \quad (10)$$

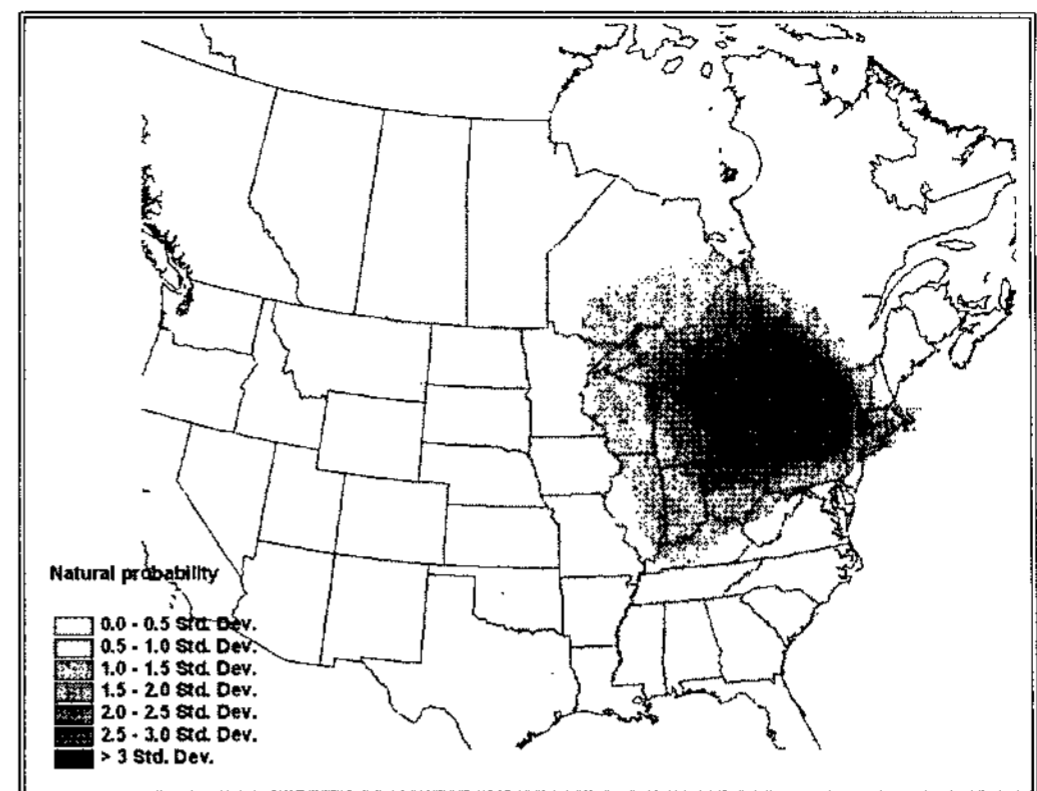


Figure 1. Natural probability for the Sterling site over the sampling period.

SQTBA identified southern New York and Pennsylvania as major mercury source areas for Sterling, NY (Figure 2). According to the National Wildlife Federation,¹⁸⁾ the C.R. Huntley Steam Station near Buffalo is the largest NYS source and emits 124 kg of mercury annually. The Russell electric generation station and medical and sludge waste incinerators located around Rochester are also large sources in New York State. In Pennsylvania, large coal-fired power plants and waste incinerators are gathered in western and eastern state, respectively.^{19,20)} This finding suggests that the regulation of coal utilities in NYS and Pennsylvania may effectively reduce the ambient Hg concentrations in Lake Ontario region.

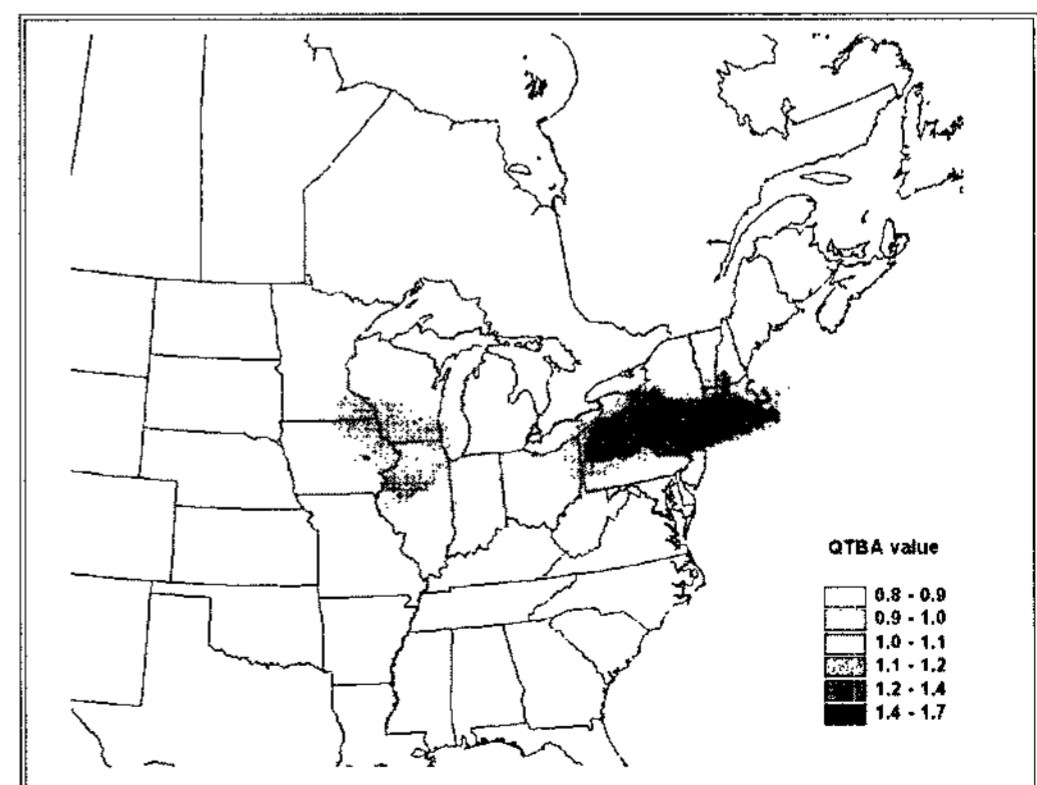


Figure 2. Possible source locations identified by simplified QTBA, affecting mercury concentration in Lake Ontario region.

Calculation of Wet Deposition

Wet deposition flux was computed as the product of the Hg concentration and precipitation depth (Figure 3). The total Hg wet deposition flux was measured to be $7.94 \mu\text{g}/\text{m}^2$ during the complete sampling period. Volume-weighted concentration was the highest in August (20.0 ng/L) and the lowest in October (6.3 ng/L), however a distinct seasonal variation was not observed. Significant negative correlation was found between precipitation depth and Hg concentration using non-parametric statistical spearman correlation (Figure 4; spearman correlation coefficient, $r_s = -0.348$ and $p\text{-value} = 0.011$). The

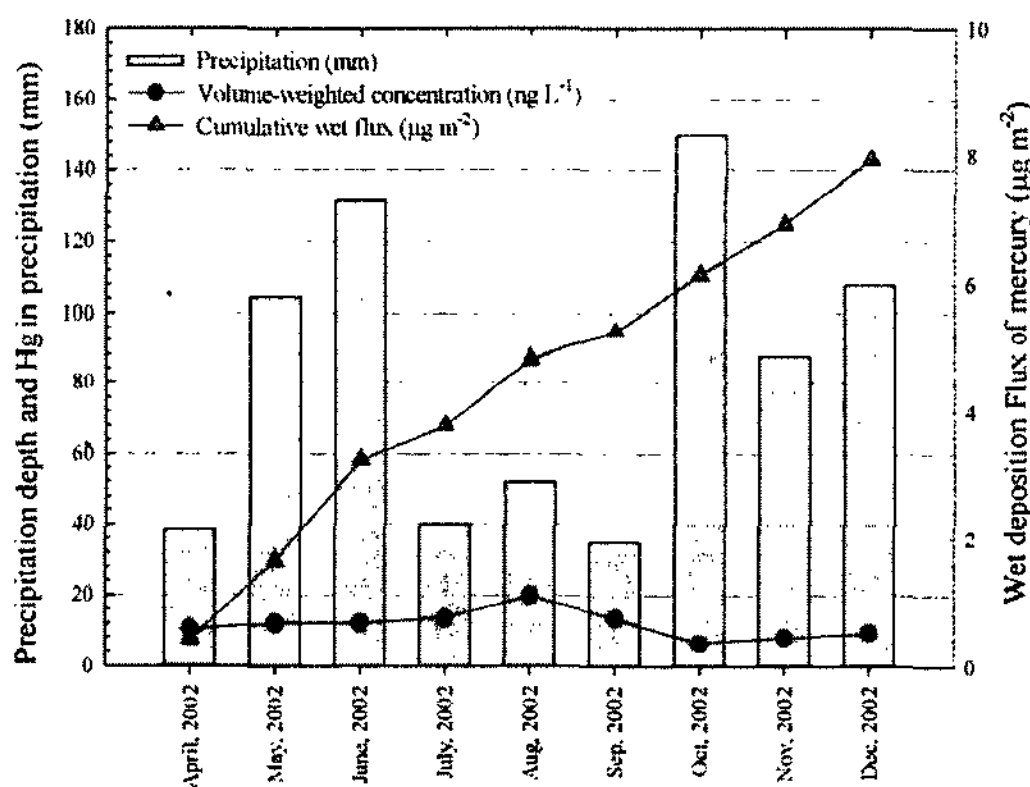


Figure 3. Wet deposition flux calculated by precipitation depth and Hg concentration in precipitation measured at the Sterling site from April 16 to December 31, 2002.

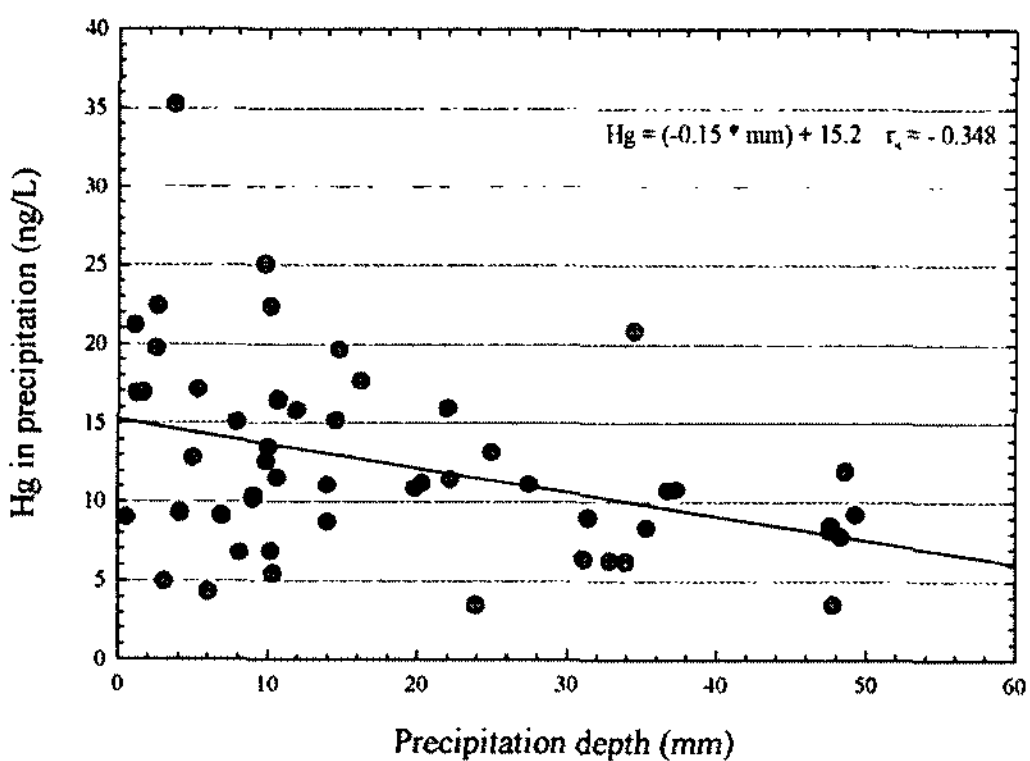


Figure 4. Relationship between precipitation depth and Hg concentration in precipitation measured at the Sterling site during the complete sampling period.

importance of precipitation depth to the observed Hg concentration consistently appeared in other studies.^{21,22,4)}

Wet deposition obtained, on a weekly basis, at two other MDN (Mercury Deposition Network) sites in the Lake Ontario Region including Pt. Petre and Egbert were compared. Precipitation depth was significantly high at the Sterling site, compared to two other sites due to the lake effect that produced in the winter when cold winds move across long expanses of warmer lake water, picking up water vapor which freezes and is deposited on the shores (Figure 5). In order to estimate the wet deposition amount over the whole Lake Ontario, areal average precipitation in Lake was also computed using a thiesen polygon technique by NOAA GLERL (Great Lakes Environmental Research Laboratory) based on precipitation depth measured at ten surface weather stations operated by NOAA and Environment Canada. Comparison of volume-weighted Hg concentration in precipitation measured at the three sites is shown in Table 1. The Wilcoxon signed rank test indicated that the null hypothesis of the same monthly volume-weighted concentrations between the Egbert and Pt. Petre ($p\text{-value} = 0.314$) was not rejected at a significance level of 0.05; however, the concentrations were determined to be statistically different between the Egbert and Sterling sites and

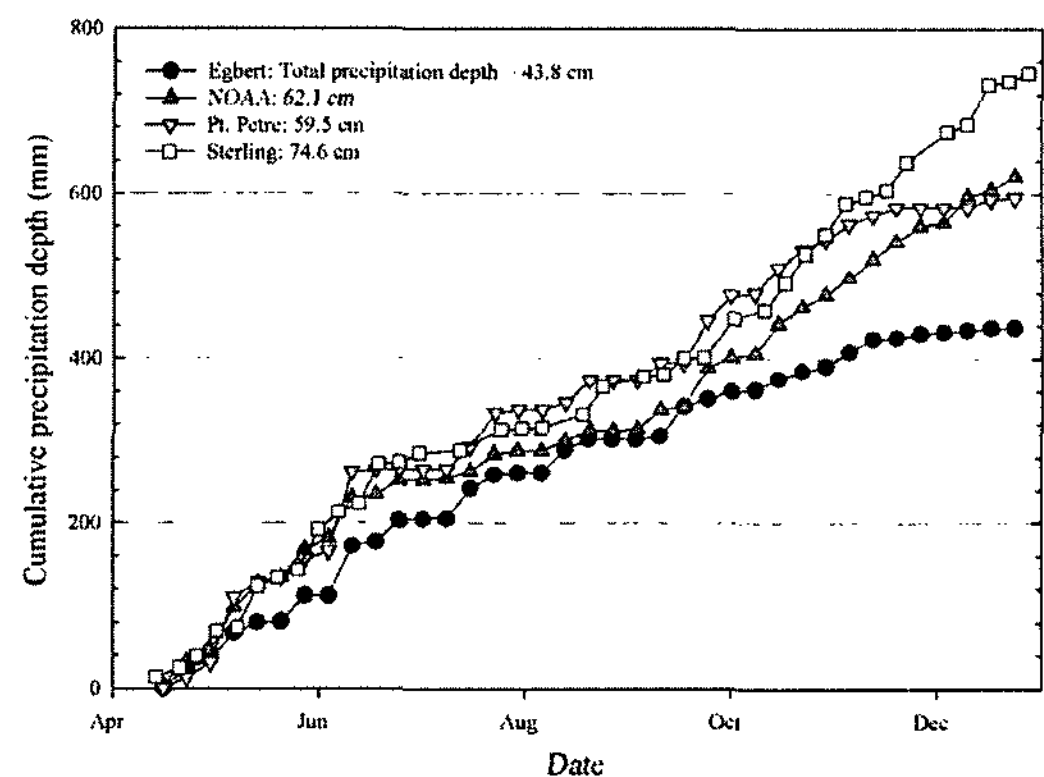


Figure 5. Precipitation depth measured at three sampling sites and areal average precipitation depth in Lake Ontario calculated using thiesen polygon technique by NOAA.

between the Pt. Petre and Sterling sites at a significance level of 0.05 (p -value= 0.008 and 0.011, respectively). The flux computed by a product of precipitation depth and Hg concentration in precipitation was the highest at the Sterling site and the lowest at the Egbert site (Table 1 and Figure 6).

In order to identify the primary factor causing the difference in wet flux between these two sites, the NOAA areal average precipitation depth was multiplied by the volume-weighted Hg concentration obtained at each site. Calculated wet deposition fluxes using NOAA precipitation depth are 6.6, 5.4, and 5.5 $\mu\text{g}/\text{m}^2$ at the Sterling, Pt. Petre, and Egbert sites, respectively. The difference of flux between Pt. Petre and Egbert is negligible while the measured flux using the precipitation depth measured on site are 5.3 and 3.9 $\mu\text{g}/\text{m}^2$ at the Pt. Petre and Egbert, respectively. This finding indicates that the difference in measured wet flux at these two sites is primarily due to the precipitation depth rather than to Hg concentration in precipitation. The flux computed using the NOAA

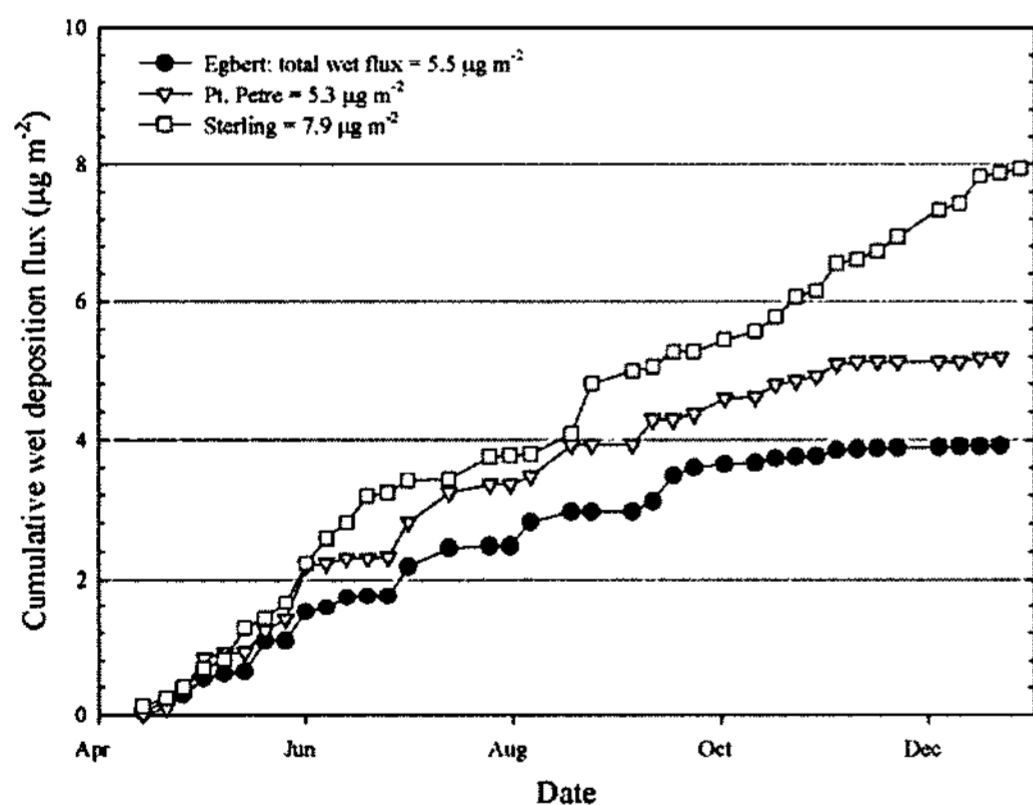


Figure 6. Wet deposition flux obtained at three sampling sites from April to December, 2002.

Table 1. Volume-weighted average concentrations of mercury in precipitation and wet deposition measured (April 16-December 31, 2002)

Site	N	Hg (ng/L)	Range (ng/L)	Hg wet flux ($\mu\text{g}/\text{m}^2$)
Sterling	38	10.6	3.5 - 35.2	7.9
Pt. Petre	29	8.7	1.4 - 150.4	5.3
Egbert	32	8.9	0.1 - 52.6	3.9

average precipitation depth and the volume-weighted concentration at the Sterling site is smaller than the flux calculated using the precipitation depth measured at Sterling. However, this result still shows a significant difference from two other sites, indicating that both precipitation depth and Hg concentration contribute to the large flux obtained at the Sterling site.

Estimation of Total Wet Deposition Flux into Lake Ontario

The monitoring sites utilized for LOADS did not include the area of highest anthropogenic source density (Toronto, ON) in the Lake Ontario region. Therefore, the uncertainty in the final estimation of total wet deposition flux into Lake Ontario may be large. To bracket this uncertainty, the total Hg wet deposition flux was estimated using several different scenarios. Although the Egbert site is the closest one to Toronto, the most urbanized area in Lake Ontario region, its volume-weighted concentration is not statistically higher than those of Pt. Petre or Sterling. Instead, the highest Hg wet deposition flux occurred at the Sterling site because of a combination of the highest Hg concentration in precipitation, probably caused by emissions from large coal power plants located in southern NY, and the highest precipitation depth due to lake effect precipitation. Estimating the wet deposition flux to the lake using only the measurements at the Sterling site ($7.94 \mu\text{g}/\text{m}^2$) results in an input of 134 kg of total wet Hg flux from April 16 to December 31, 2002 (surface area of Lake Ontario= $18,960 \text{ km}^2$).

Since there was no measurement in urban areas during LOADS, several scenarios based on LMMBS results are included in this report

(Table 2). Egbert data was not used for the estimation because it could not represent the urban site due to the low concentration, and not being located on the shoreline of the lake. The lake was split into approximately two sectors, each of which has its own a sampling site: Pt. Petre for the northern half and Sterling for the southern half, and western portion was regarded as an urban contribution (Figure 7). From LMMBS, the volume-weighted concentration spatially ranged from 10 to 22 ng/L from background to urban sites. Therefore, for LOADS, it was assumed that the highest anthropogenic source density is approximately two times higher than the lowest concentration measured at Pt. Petre. Precipitation depth measured at each site was multiplied by the locally measured Hg concentration at the Pt. Petre and Sterling sites; however, the areal average precipitation depth (calculated by NOAA) was used for the calculation of urban contribution to total wet flux. Since the volume-weighted concentration of Hg at the Pt. Petre is 8.72 ng/L, the urban volume-weighted concentration was assumed to be 17.44 ng/L. The average precipitation depth calculated by NOAA is 620.6 mm from 4/16/02 to 12/31/02, resulting in 10.8 $\mu\text{g}/\text{m}^2$ of total wet flux to the urban influenced area. A summary of results of each scenario is shown in Table 3. The wet loadings range from a low estimate of 130 kg to the high estimate of 150 kg from

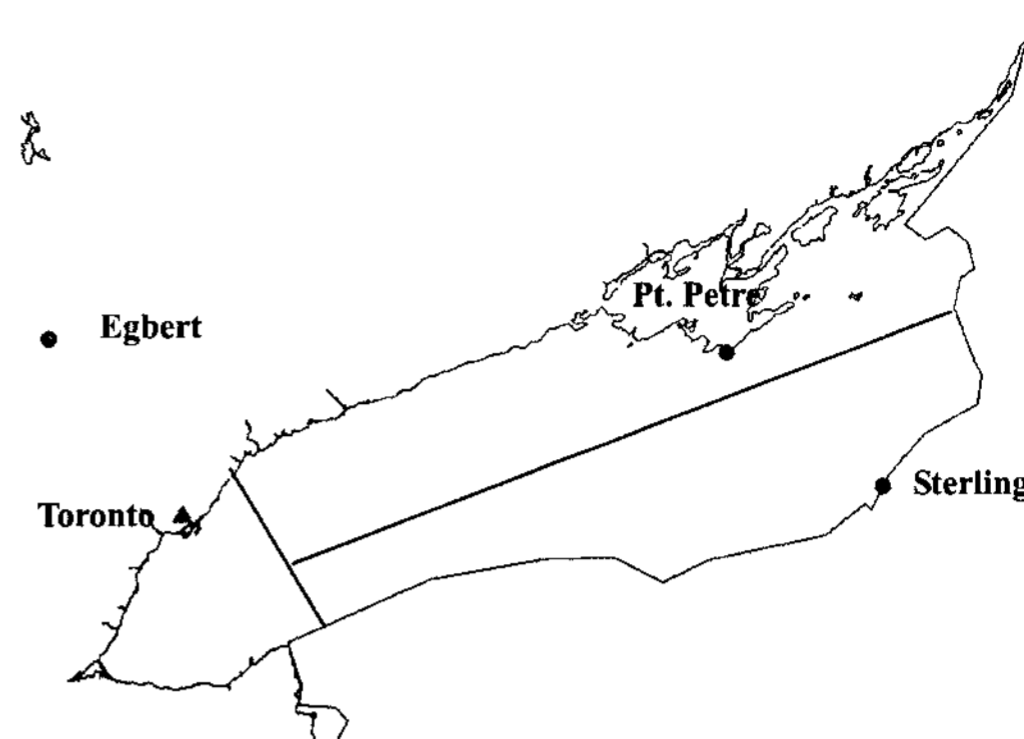


Figure 7. Subdivision of Lake Ontario used to estimate mercury loadings. Fluxes were considered constant over the entire area of each section.

April 16 to December 31, 2002, and % difference between the lowest and the highest estimation is 15%. The estimated flux in this study has limitations, as mentioned earlier, primarily the lack of measurements at the urban site. However, by using several scenarios, it is reasonable to assume that the range of estimated fluxes covers the actual loadings of mercury through wet deposition to Lake Ontario. If the wet loadings estimated for the complete sampling period of nine months is approximated to yearly value, the annual wet deposition amount of Hg into Lake Ontario ranges from 173 to 200 kg. Considering the difference in surface area between Lake Michigan and Lake Ontario (about 3:1), the annual wet deposition amount in

Table 2. Description of each scenario used for estimation of total wet deposition flux of mercury into Lake Ontario in LOADS

	Urban contribution (%)	Pt. Petre contribution (%)	Sterling contribution (%)
Scenario 1	5	47.5	47.5
Scenario 2	10	45	45
Scenario 3	20	40	40
Scenario 4	30	35.5	35.5

Table 3. Total wet deposition flux estimated by using several scenarios from April to December, 2002

	Urban flux (kg)	Pt. Petre flux (kg)	Sterling flux (kg)	Total flux (kg)
Scenario 1	10	48	71	130
Scenario 2	21	46	68	135
Scenario 3	41	40	62	142
Scenario 4	61	36	53	150

Lake Ontario is similar to (or a little less than) the Lake Michigan Deposition (614 kg). The result obtained in this study was also compared with the result of mass balance model, RateCon model,³⁾ applied for Lake Ontario in 1995. Wet loadings were estimated to be 347 kg/yr based on RateCon model, which is fairly larger than the value calculated in this study. This dissimilarity was derived by the fact either that the wet flux at urban was being estimated instead of being measured in this study or that the wet loadings into Lake Ontario was calculated by atmospheric concentrations multiplied by wet deposition velocity by RateCon model instead of being sampled in the paper written by Booty et al.³⁾

CONCLUSIONS

Mercury has become an important research subject in many countries based on recognition that it is harmful to human and environment due to its toxicity and high bioaccumulation rate. Since the Lake Michigan Mass Balance Study (LMMBS), the most comprehensive atmospheric Hg monitoring project for the Great Lakes Region, was finished in late 1990s, the Hg study for other Great Lakes has been significantly become a prominent figure. The significant findings from this study are following.

- 1) Ambient TGM concentration measured at the Sterling site is $3.02 \pm 2.14 \text{ ng/m}^3$ ($n=60$). This value is in somewhat high range compared to other background regions probably because the Sterling site may be affected by the C.R. Huntley Steam Station near Buffalo, the largest coal utilities in New York State.
- 2) Possible major source areas affecting ambient Hg concentrations in Lake Ontario region were identified to be southern New York and Pennsylvania based on SQTBA result. Pennsylvania is an area with one of the largest Hg emissions of coal-fired power plants in the U.S.
- 3) Volume-weighted Hg concentration in precipitation was 10.6 ng/L, and wet deposition flux

was $7.94 \text{ } \mu\text{g/m}^2$ at the Sterling site through the complete sampling period (April to December, 2002). These values are statistically higher than those of the other two sites (Pt. Petre and Egbert) monitored by Mercury Deposition Network due to both the high precipitation depth and/or the high Hg concentration in the precipitation.

- 4) Total wet loadings of Hg to Lake Ontario ranged from a low estimate of 130 kg to the high estimate of 150 kg throughout the complete sampling period, and it is similar to Lake Michigan wet deposition.

For future work, dry and wet deposition for Hg^0 , Hg^{2+} , and Hg(p) will be computed based on measurements and estimated mass transfer coefficients. The results will be compared with LMMBS.

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