The Great Lakes Atmospheric Mercury Monitoring Network: Design and Implementation

Martin R. Risch, U.S. Geological Survey
Donna M. Kenski, Lake Michigan Air Directors Consortium
David A. Gay, Illinois State Water Survey, Univ. of Illinois
Overview

- Mercury (Hg) is an ecosystem problem
- Atmospheric mercury monitoring in the Great Lakes Region
- Evaluation and design for the Great Lakes Atmospheric Mercury Monitoring Network in the NADP
- First year of data for this new network
Mercury is an ecosystem problem

- Human activities add Hg to the environment
- Hg in the air returns in the precipitation
- Dry deposition – cities and forests are ‘sinks’, places of Hg accumulation
- Some Hg becomes methylmercury – a persistent and bioaccumulative toxin
Methylmercury in Ecosystems

- Freshwater and marine and terrestrial ecosystems have methylmercury
- Health risks for young and adult humans from subsistence and sport fishing
- Adverse affects on fish, along with the mammals and birds that eat them
The Need for Atmospheric Hg Monitoring
The Atmospheric Mercury Signal

- Concentrations of mercury in the atmosphere originating from major anthropogenic sources can be expected to decrease in USA and Canada.
- State rules require Hg emissions reduction in Illinois, Minnesota, Michigan, Wisconsin, and New York passed from 2006-2012; Ontario’s rule was in 2010.
- USEPA Mercury and Air Toxics Standards planned for 2015—preemptive Hg emissions reductions.
- 11 percent of coal-based energy in the Great Lakes Region will be gone by 2019, most by 2014 – 89 energy units in 39 cities retired or converted to gas.
Hg wet-deposition monitoring in the Great Lakes Region, 1996-2012 (51 sites)

NADP Mercury Deposition Network (42 sites, 1996-2012)

Michigan Mercury Monitoring Network (7 sites, 2002-2008)

Integrated Atmospheric Deposition Network (2 sites, 2001-2007)

Great Lakes Region = 8 USA States and Ontario
Over time, the number of Hg-monitoring sites ever operated in the Great Lakes Region was reduced by 39% for the 15-year period 1996-2012, so that only 31 of 51 sites were active.

As of January 2013, approximately half of the Region in IL, IN, OH, and MI Lower Peninsula were represented by a single site in central IL.

Will we miss the change in the atmospheric Hg signal?
The Great Lakes Atmospheric Mercury Network

- Evaluation of active and historic Hg wet deposition monitoring sites with >75% complete annual records for at least 6 of 9 years 2002-2012 = 36 sites
- Rating system of 21 factors for location and Hg data
- Scoring of factors for each site by quartile or points
- Compilation of spatial data and GIS analysis
- Quantitative, statistical, and spatial analysis
- Optimized design for Hg monitoring to fill data gaps, reduce data overlaps, maintain long-term records, and increase efficiency of network operation

From Risch, Kenski, & Gay (2014) *Atmos. Env.* v. 85
<table>
<thead>
<tr>
<th>Factor Group</th>
<th>Factor for rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Location</td>
<td>- Geographic area represented</td>
</tr>
<tr>
<td></td>
<td>- Population represented</td>
</tr>
<tr>
<td></td>
<td>- Population density</td>
</tr>
<tr>
<td></td>
<td>- Protected natural area location</td>
</tr>
<tr>
<td></td>
<td>- Urban area location</td>
</tr>
<tr>
<td></td>
<td>- Co-located acid rain monitoring site</td>
</tr>
<tr>
<td></td>
<td>- Great Lakes watershed location</td>
</tr>
<tr>
<td>2. Hg sources</td>
<td>- Number of nearby Hg emissions point sources</td>
</tr>
<tr>
<td></td>
<td>- Annual Hg emissions from nearby point sources</td>
</tr>
</tbody>
</table>

**Evaluation:**
- special location
- quantification within the area represented by site

**Quantitative Analysis**

![Map of Hg sources and monitoring sites](image-url)
Quantitative Analysis

Hg Sources and Annual Emissions

Where are the Hg sources?
Factor Group

4. Hg trends and changes

Factor for rating

- Significant trend in weekly Hg concentration or weekly Hg deposition, 2002–2010, 90-95% confidence
- 9-year percent change in Hg concentrations or Hg deposition, increasing or decreasing

Statistical Analysis

Where are the changes?

Hg Trends

- 22 sites
- 10 sites
- 8 sites

EXPLANATION

- Hg-monitoring site and identification number
- Statistically significant trend in weekly Hg concentration at site
- Statistically significant trend in weekly precipitation at site
- Statistically significant trend in weekly Hg wet deposition at site

Symbol indicates increase
Symbol indicates decrease
No symbol means no trend
Which sites are unique?

Cluster diagram of weekly Hg deposition per site

Statistical Analysis

EXPLANATION
- Red: $R^2 > 0.9$
- Green: $R^2 > 0.8$
- Blue: $R^2 > 0.7$
- Gray: $R^2 < 0.5$

Site Pair / Cluster

MN27

Linear Coefficient of Variation ($R^2$) for Weekly Mercury Deposition
<table>
<thead>
<tr>
<th>Factor Group</th>
<th>Factor for rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Hg data average</td>
<td>Average weekly Hg deposition, 2002–2010</td>
</tr>
<tr>
<td></td>
<td>Average weekly Hg concentrations, 2002–2010</td>
</tr>
</tbody>
</table>

**Spatial Analysis**

Where is Hg highest?

Avg Wkly Hg Deposition

[Map showing average weekly Hg deposition, 2002-2010, in nanograms per square meter.]

- 106 - 130
- 131 - 160
- 161 - 190
- 191 - 210
- 211 - 240
- 241 - 270
- 271 - 300

USGS
Spatial Analysis

Hg Emissions Density

Where are the highest emissions?
Efficiency -- Where are the NADP monitoring sites?

Strong correlation of Hg and sulfate deposition $r = 0.6 - 0.9$, $n > 300$
Minimum of 21 sites: continue 12 sites, restart 3 sites, add Hg to 5 NTN sites, 1 new site
Implementation of the Great Lakes Mercury Monitoring Network in NADP

- USEPA Region 5 Air Program funds for GLAMM
- New and restarted NADP MDN sites – administered by LADCO
- Existing state supported MDN sites continued
- New and restarted sites active January 2014
- Framework for additional Hg monitoring—AMNet and litterfall Hg
- Structure for maintaining long-term sites
Hg Data from the GLAMM in 2014

-- 52 weeks of monitoring at 19 of 21 sites in GLAMM, plus one site with 43 weeks;
-- 42 to 52 weeks with Hg deposition
For 20 GLAMM sites:
Precipitation-weighted annual Hg concentrations
-- median 8.3 ng/L
-- 6 sites > 10 ng/L
IN21 10.4
IL11 11.7
IL63 10.8
WI99 11.2
PA37 12.9
MN27 11.5

Provisional – subject to revision
NADP Hg annual concentration gradients, 2013-2014

Provisional – subject to revision
From Risch and others (2012) *Env. Poll*. v. 161

Hg concentrations for 2002 - 2008
NADP Hg annual wet deposition in 2014 at GLAMM sites

2014 median for 20 GLAMM sites 9.0 μg/m²
NADP Hg annual deposition gradient, 2012-2013

Map showing the distribution of mercury deposition across the United States for the years 2012 and 2013. The map highlights regions with higher deposition rates, with concentrations indicated by color gradients from green (low) to red (high). The map is produced by the USGS.
From Risch and others (2012) *Env. Poll. v. 161*

**EXPLANATION**

Great Lakes watersheds
- Precipitation-monitoring sites

Ranges of mean annual mercury wet deposition, 2002-2008, in micrograms per square meter:
- 4.3 to 6.0
- 6.1 to 8.0
- 8.1 to 10.0
- 10.1 to 12.0
- 12.1 to 14.0
- 14.1 to 15.9

**Hg wet deposition for 2002 - 2008**

From Risch and others (2012) *Env. Poll. v. 161*
Summary and Conclusions

- Mercury is an ecosystem problem.
- Long-term monitoring in an optimized network is needed to detect changes in the atmospheric Hg signal.
- The Great Lakes Atmospheric Mercury Monitoring network of the NADP fills data gaps and corrects data overlaps from previous years, while maintaining many long-term data sites.
- Potential evidence for changes in annual Hg concentrations and Hg wet deposition in some parts of the Great Lakes region in 2014.
- Stability in network operation is needed to verify trends.