Atmospheric Mercury Monitoring and Modeling Programs of the NOAA Air Resources Laboratory


NOAA Air Resources Laboratory
http://www.arl.noaa.gov/mercury.php

National Water Quality Monitoring Council Meeting
12201 Sunrise Valley Drive, Reston, Virginia
Mercury Fish Consumption Advisories are Ubiquitous

Mercury Fish Advisories
- States with at least one mercury advisory
- Statewide mercury advisory
- Statewide coastal mercury advisory

Source: USEPA, 2008

Fish consumption advisories seem to be working, but mercury still a problem in the general population… (and probably more so in specific sub-populations)
Mercury (Hg) is an element... there is the same amount of mercury on Earth today as there always has been

“natural” Hg cycle – Hg is transported throughout the environment, and chemical transformations interconvert different mercury species

This has always been going on, and there has always been Hg in fish

But, we make some Hg unexpectedly “bioavailable”

Most anthropogenic Hg is “released” as atmospheric emissions:

- Hg in coal is released to the air when coal is burned
- Hg in other fuels is released to the air when they are processed and burned
- Hg in ores is released to the air during metallurgical processes
- Hg in products is released to the air when burned or landfilled after being discarded (e.g., batteries, switches)

Average, current atmospheric Hg deposition is ~3x pre-industrial levels

Evidence suggests that newly deposited Hg is more bioavailable
Different “forms” of mercury in the atmosphere

**Elemental Mercury -- Hg(0)**
- most of total Hg in atmosphere
- *not* very water soluble
- doesn’t easily dry or wet deposit
- upward evasion vs. deposition
- atmos. lifetime approx ~ 0.5-1 yr
- globally distributed

**Reactive Gaseous Mercury -- RGM**
- a few percent of total atmos Hg
- oxidized Hg (HgCl₂, others)
- operationally defined
- *very* water soluble and “sticky”
- atmos. lifetime <= 1 week
- local and regional effects
- bioavailable

**Particulate Mercury -- Hg(p)**
- a few percent of total atmos Hg
- not pure particles of mercury
- Hg compounds in/on atmos particles
- species largely unknown (HgO?)
- atmos. lifetime approx 1~ 2 weeks
- local and regional effects
- bioavailability?

Atmospheric methyl-mercury?
emissions of Hg(0), Hg(II), Hg(p) from other sources: local, regional & more distant

wet and dry deposition to the watershed

Enhanced oxidation of Hg(0) to RGM

Enhanced deposition

Reactive halogens in marine boundary layer

Source Attribution for Deposition?
Why are emissions speciation data - and potential plume transformations -- critical?

![Graph showing deposition flux (ug/m²-yr) for hypothetical 1 kg/day source]

**NOTE**: distance results averaged over all directions – Some directions will have higher fluxes, some will have lower
Model-predicted hourly mercury deposition (wet + dry) in the vicinity of one example Hg source for a 3-day period in July 2007.

* hourly deposition converted to annual equivalent
Model-predicted hourly mercury deposition (wet + dry) in the vicinity of one example Hg source for a 3-day period in July 2007.

* hourly deposition converted to annual equivalent
**Large, time-varying spatial gradients in deposition & source-receptor relationships**

Model-predicted hourly mercury deposition (wet + dry) in the vicinity of one example Hg source for a 3-day period in July 2007.

*hourly deposition converted to annual equivalent*
There are a lot of sources…

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada; 1999 Mexican data from inventory prepared by Acosta y Asociados for the Commission for Environmental Cooperation
Atmospheric mercury measurements can estimate deposition at a given location

- **Wet deposition** – Mercury Deposition Network
Atmospheric mercury measurements can estimate deposition at a given location

- **Wet deposition** – Mercury Deposition Network

- **Dry deposition** – no routine direct method – but can be estimated by combining measured atmospheric concentrations of different Hg forms \([\text{Hg(0), RGM, Hg(p)}]\) with widely used deposition velocity estimation procedures.

\[
\text{Dry Dep} = (\text{Conc}) \times (\text{Deposition Velocity})
\]
These sites are part of an emerging national atmospheric mercury monitoring network, being coordinated by NADP.

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada; 1999 Mexican data from inventory prepared by Acosta y Asociados for the Commission for Environmental Cooperation.
Atmospheric Mercury Measurement Site at Beltsville, MD

ARL’s Winston Luke working with RGM and Hg(p) collectors

Precipitation measurements (left to right): Mercury Deposition Network, Major Ions (e.g. "acid rain"), Precipitation Amount

mercury and trace gas monitoring tower (10 meters)

Top of tower (close-up) with two sets of RGM and Hg(p) collectors

After RGM and Hg(p) is collected, it is desorbed and analyzed inside the trailer, along with Hg(0)
Sometimes, we see evidence of local and regional “plume” impacts

Beltsville Episode January 7, 2007
Sometimes, we see evidence of local and regional “plume” impacts.
Atmospheric Mercury Measurement Site at the Grand Bay NERR, MS

view from top of the tower

mercury and trace gas monitoring tower (10 meters)
Recent Reactive Gaseous Mercury (RGM) concentrations measured at the Grand Bay NERR

Then down for ~2 months due to hurricanes
Can we learn what is needed about atmospheric mercury deposition by making atmospheric measurements alone?

NO...
### What Do We Need to Know Regarding Atmospheric Mercury?

<table>
<thead>
<tr>
<th>Type of Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric deposition</td>
</tr>
<tr>
<td>Source-attribution for deposition</td>
</tr>
<tr>
<td>Deposition for historical periods</td>
</tr>
<tr>
<td>Deposition for alternative future scenarios</td>
</tr>
</tbody>
</table>
Dry and wet deposition of the pollutants in the puff are estimated at each time step. The puff’s mass, size, and location are continuously tracked.

Initial puff location is at source, with mass depending on emissions rate.

Centerline of puff motion determined by wind direction and velocity.

Phase partitioning and chemical transformations of pollutants within the puff are estimated at each time step.

Dry and wet deposition of the pollutants in the puff are estimated at each time step.

deposition 1

deposition 2

deposition to receptor

Lagrangian Puff Atmospheric Fate and Transport Model

NOAA HYSPLIT MODEL
Over the entire modeling period (e.g., one year), puffs are released at periodic intervals (e.g., once every 7 hours).

Each released puff is advected and dispersed, and the pollutant within the puff is transformed and deposited.
Largest atmospheric deposition contributors to Lake Michigan based on 1999-2000 emissions

Fraction of total modeled deposition contributed by a particular source

- □ 0.1 - 0.3 %
- ▲ 0.3 - 1 %
- ● 1 - 3 %
- ○ 3 - 10 %
- □ 10 - 30 %

Type of Emission Source

- ➥ coal-fired electricity generation
- ➧ waste incineration
- ▼ manufacturing
- ★ metallurgical
- ♦ other fuel combustion
Largest modeled contributors to Lake Michigan (close-up).
Top 25 modeled sources of atmospheric mercury to Lake Michigan
(based on 1999 anthropogenic emissions in the U.S. and Canada)
Models are not perfect

“...Everyone believes monitoring results except for the person making the measurements... and nobody believes modeling results except for the person doing the modeling...”

How not perfect are they?

Results are encouraging, but difficult to evaluate models due to lack of contemporaneous monitoring and emissions inventory data

Models are a test of our knowledge...

If they don’t work, fundamental things about our understanding of atmospheric mercury that are wrong or incomplete...

More certain info at a few locations (monitoring) vs. less certain info region-wide (modeling)
Hey, you got monitoring in my modeling!

Hey, you got modeling in my monitoring!
To get the answers we need, we need to use both monitoring and modeling -- together.

Monitoring needed to provide deposition estimates at a given location and for model development and evaluation.

Modeling needed to help interpret and extend measurements and to estimate source-receptor relationships.

To get the answers we need, we need to use both monitoring and modeling -- together.
Acknowledgements

- Gary Matlock, Russell Callender, Jawed Hameedi (*NOAA NOS Nat’l Centers for Coastal Ocean Science*)
- David Schmeltz, Tim Sharac, Rick Haeuber, Sam Napolitano (*US EPA Clean Air Markets Division*)
- Jake Walker, Mark Woodrey, Glen Ruple (*Grand Bay National Estuarine Research Reserve*)
- Durwin Carter (*U.S. Fish and Wildlife Service -- Grand Bay National Wildlife Refuge*)
- Glenn Rolph, Barbara Stunder, Steve Fine (*NOAA Air Resources Laboratory*)
- Prof's Yerramilli Anjaneyulu, Jerzy Lesczczynski, Shelton Swanier & colleagues (*Jackson State Univ.*)

Thanks!
EXTRA SLIDES
Spatially Distributed Inventories of Global Anthropogenic Emissions of Mercury to the Atmosphere, 2000

Total Hg, point sources + distributed sources, 0.5° grid

Unprojected (geographic)

Citation:

S. Wilson (AMAP), F. Steenhuisen (Arctic Centre, RuG), J. Pacyna (NILU)
Wet and dry deposition of different Hg forms to Gulf of Mexico & watershed

Source attribution information for deposition
Atmospheric Mercury Modeling for the Gulf of Mexico region
examples of recent, current, and planned work

<table>
<thead>
<tr>
<th>Model</th>
<th>Group(s)</th>
<th>PI’s</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEAM-CTM</td>
<td>AER (Atmos. &amp; Environ. Research, Inc.); EPRI</td>
<td>Christian Seigneur, Leonard Levin</td>
<td>ongoing, global, nested grid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CAMR, regional + boundary</td>
</tr>
<tr>
<td>CMAQ-Hg</td>
<td>EPA</td>
<td>Russ Bullock</td>
<td>meteorological and Hg modeling effort starting</td>
</tr>
<tr>
<td></td>
<td>Jackson State University</td>
<td>Yerramilli Anjaneyulu</td>
<td>modeling to be carried out for Florida TMDL</td>
</tr>
<tr>
<td></td>
<td>Florida DEP; Univ of Mich, others</td>
<td>Jerry Keeler</td>
<td></td>
</tr>
<tr>
<td>REMSAD</td>
<td>EPA Office of Wetlands, Oceans &amp; Watersheds; ICF</td>
<td>Dwight Atkinson, Ruth Chemerys</td>
<td>recent report; regional + boundary</td>
</tr>
<tr>
<td>Geos-Chem</td>
<td>Harvard University</td>
<td>Daniel Jacob</td>
<td>ongoing, global, coarse grid</td>
</tr>
<tr>
<td>HYSPLIT-Hg</td>
<td>NOAA Air Resources Laboratory</td>
<td>Mark Cohen, Roland Draxler</td>
<td>ongoing, regional; soon global</td>
</tr>
</tbody>
</table>

- Others?
- Collaboration? (e.g., emissions inventories, model intercomparisons)
Mercury emissions from municipal and medical waste incineration in the United States dropped significantly during the 1990’s.

**REASONS:**
- closure of some municipal waste incinerators and many medical waste incinerators
- MACT-related pollution control requirements
- reduction in mercury content of waste (e.g., battery legislation)
Direct, Anthropogenic Mercury Emissions in the United States
(data from USEPA)

* Data for Lime Manufacturing are not available for 1990.
** Data for Electric Arc Furnaces are not available for 1999. The 2002 estimate (10.5 tons) is shown here.
1965

1970

1975

1980

1985

1990

1995

2000

2005

2010

Some events in the U.S. regulation and prevention of mercury emissions

1970’s - 1990’s: many mercury-cell chlor-alkali plants converted to alternate processes or closed due to regulatory and other pressures

Clean Air Act Amendments of 1990 – calls for Maximum Achievable Control Technology (MACT) to regulate hazardous air pollutants; *intent is to prohibit emissions trading for these air toxics*

1990’s – Hg emissions from municipal and medical waste incinerators fall dramatically due to:
- closure of *some* municipal waste incinerators and *many* medical waste incinerators
- MACT-related pollution control requirements
- reduction in mercury content of waste (e.g., battery legislation)

2002 – Clear Skies Initiative for power plants introduced (*ultimately withdrawn*)

2005 – CAIR (Clean Air Interstate Rule) for power plants (Hg reduced as co-benefit of SO₂ & NOₓ controls)

2005 – EPA meets court-ordered deadline and promulgates CAMR (Clean Air Mercury Rule) for power plants – *based on Hg emissions trading*

“Hot Spot” Controversy -- Many States sue EPA & propose / promulgate more strict regulations
The Conference Report accompanying the consolidated Appropriations Act, 2005 (H. Rpt. 108-792) requested that NOAA, in consultation with the EPA, report to Congress on mercury contamination in the Great Lakes, with trend and source analysis.

Reviewed by NOAA, EPA, DOC, White House Office of Science and Technology Policy, and Office of Management and Budget (OMB).

Review process took ~2 years.

Transmitted to Congress on May 14, 2007

NOAA Report to Congress on Mercury Contamination in the Great Lakes

http://www.arl.noaa.gov/data/web/reports/cohen/NOAA_GL_Hg.pdf
<table>
<thead>
<tr>
<th>Reaction</th>
<th>Rate</th>
<th>Units</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GAS PHASE REACTIONS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{O}_3 \rightarrow \text{Hg}(p) )</td>
<td>3.0E-20</td>
<td>cm(^3)/molec-sec</td>
<td>Hall (1995)</td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{HCl} \rightarrow \text{HgCl}_2 )</td>
<td>1.0E-19</td>
<td>cm(^3)/molec-sec</td>
<td>Hall and Bloom (1993)</td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{H}_2\text{O}_2 \rightarrow \text{Hg}(p) )</td>
<td>8.5E-19</td>
<td>cm(^3)/molec-sec</td>
<td>Tokos et al. (1998) (upper limit based on experiments)</td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{Cl}_2 \rightarrow \text{HgCl}_2 )</td>
<td>4.0E-18</td>
<td>cm(^3)/molec-sec</td>
<td>Calhoun and Prestbo (2001)</td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{OH} \rightarrow \text{Hg}(p) )</td>
<td>8.7E-14</td>
<td>cm(^3)/molec-sec</td>
<td>Sommar et al. (2001)</td>
</tr>
<tr>
<td><strong>AQUEOUS PHASE REACTIONS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{O}_3 \rightarrow \text{Hg}^{+2} )</td>
<td>4.7E+7</td>
<td>(molar-sec(^{-1}))</td>
<td>Munthe (1992)</td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{OH} \rightarrow \text{Hg}^{+2} )</td>
<td>2.0E+9</td>
<td>(molar-sec(^{-1}))</td>
<td>Lin and Pehkonen (1997)</td>
</tr>
<tr>
<td>( \text{HgSO}_3 \rightarrow \text{Hg}^0 )</td>
<td>( T^*e^{((31.971\times T)-12595.0)/T} ) sec(^{-1})</td>
<td>[( T = \text{temperature (K)} )]</td>
<td>Van Loon et al. (2002)</td>
</tr>
<tr>
<td>( \text{Hg}^{(II)} + \text{HO}_2 \rightarrow \text{Hg}^0 )</td>
<td>( \approx 0 )</td>
<td>(molar-sec(^{-1}))</td>
<td>Gardfeldt &amp; Jonnson (2003)</td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{HOCl} \rightarrow \text{Hg}^{+2} )</td>
<td>2.1E+6</td>
<td>(molar-sec(^{-1}))</td>
<td>Lin and Pehkonen (1998)</td>
</tr>
<tr>
<td>( \text{Hg}^0 + \text{OCl}^{-1} \rightarrow \text{Hg}^{+2} )</td>
<td>2.0E+6</td>
<td>(molar-sec(^{-1}))</td>
<td>Lin and Pehkonen (1998)</td>
</tr>
<tr>
<td>( \text{Hg}^{(II)} \leftrightarrow \text{Hg}^{(II)}_{\text{soot}} )</td>
<td>9.0E+2</td>
<td>liters/gram; ( t = 1/\text{hour} )</td>
<td>eqlbrm: Seigneur et al. (1998); rate: Bullock &amp; Brehme (2002).</td>
</tr>
<tr>
<td>( \text{Hg}^{+2} + \text{h}^{\phi} \rightarrow \text{Hg}^0 )</td>
<td>6.0E-7</td>
<td>(sec(^{-1})) (maximum)</td>
<td>Xiao et al. (1994); Bullock and Brehme (2002)</td>
</tr>
</tbody>
</table>
Total mercury deposition in the Gulf of Mexico region for 2001 estimated by the USEPA-NOAA CMAQ-Hg model (micrograms per square meter, 36 km grid)

Image and modeling results courtesy of Russ Bullock, USEPA, based on modeling analysis done for the Clean Air Mercury Rule
Total mercury deposition in the Gulf of Mexico region (ca. mid to late 1990’s) estimated by the EPRI TEAM-Hg model, coupled with a global chemical transport model (micrograms per square meter, 100 km grid)

Figure 6-3c. Simulated Annual Mercury Deposition (g km-2) for the REMSAD 12-km Modeling Domain (with Average Boundary Conditions): Total (Dry + Wet) Deposition.
Pre-Industrial Global Mercury Cycling

Sunderland and Mason (2007). Global Biogeochemical Cycles 21, 4022
Figure 4. Global budgets for current and preindustrial mercury cycling in oceans. For the present-day ocean, 90% confidence intervals are shown in brackets. Note that for the present-day budget, river fluxes shown refer to the amounts of mercury deposited in each region (estuaries, shelf, open ocean), not the total flux (sum >14 Mmol). (a) From Mason and Sheu [2002]. (b) Calculated by assuming preindustrial atmosphere is at steady state. (c) Estimated from sediment core data showing contemporary atmospheric deposition to terrestrial systems is approximately 3 times greater than preindustrial deposition [Fitzgerald et al., 1998]. (d) Lower end of range is year 2000 global anthropogenic emissions from Pacyna et al. [2006]. Upper limit of anthropogenic emissions were used in GEOS-Chem simulations and include additional sources described by Selin et al. [2007b]. (e) Estimate derived by Selin et al. [2007b].

GLOBAL MERCURY CYCLING


**pre-industrial:**
total mercury in atmosphere ~ $8.0 \times 10^6$ moles

**contemporary:**
total mercury in atmosphere ~ $28.0 \times 10^6$ moles

(note $-10^6$ moles ~ 200 metric tons)
Natural vs. anthropogenic mercury?

Studies show that anthropogenic activities have typically increased bioavailable Hg concentrations in ecosystems by a factor of 2 – 10

source: USGS, Shuster et al., 2002
- total mercury in Gulf of Mexico recreational finfish
- reconnaissance survey to provide info for larger surveys
- cookbook for conducting estuarine and marine fish surveys
Public Health Context
Public Health Context

- Methyl-mercury is a developmental neurotoxin -- risks to fetuses/infants
- Cardiovascular toxicity might be even more significant (CRS, 2005)
- Uncertainties, but mercury toxicity relatively well understood
  - Well-documented tragedies: (a) Minimata (Japan) ~1930 to ~1970; (b) Basra (Iraq), 1971
  - Epidemiological studies, e.g., (a) Seychelles; (b) Faroe Islands; (c) New Zealand
- Critical exposure pathway: methylmercury from fish consumption
Mean Methylmercury Concentrations for "Top 24" Types of Fish Consumed in U.S. Commercial Seafood Market

Source of data: Carrington and Bolger, 2002
Based on slide from: Elsie Sunderland, USEPA
Percent Contribution to per capita Methylmercury Intake by Fish Type for "Top 24" Types of Fish in U.S. Commercial Seafood Market

Source of data: Carrington and Bolger, 2002
Based on slide from: Elsie Sunderland, USEPA
Seafood consumption estimated in this study from NMFS fisheries supply data compared with available data for marine and estuarine fish consumption from CSFII dietary survey data [uncooked weights (U.S. EPA 2002)].

Percentage of total Hg intake (product of seafood supply and Hg concentrations) for the top 15 seafood categories; intake is allocated by the source region for each of the fisheries products [Atlantic, Pacific, imported (foreign sources), and high seas landings].

Methyl-mercury is a developmental neurotoxin -- risks to fetuses/infants

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Critical exposure pathway: methylmercury from fish consumption

Toxicity believed to be occurring at current exposures
Blood Hg (μg/L) - U.S. Women ages 6-49 based on NHANES data (1999-2002)

Mean Organic [Hg] μg/L (95% CI)

- **2.7 (2.4-3.1)** Atlantic Coast
- **1.7 (1.5-1.9)** Pacific Coast
- **1.4 (0.7-2.0)** Northeast
- **1.3 (0.6-2.0)** Gulf Coast
- **1.1 (0.7-1.6)** South
- **1.0 (0.7-1.2)** West
- **0.8 (0.6-1.0)** Mid West

*Source of data: Mahaffey et al., 2005*

*Based on slide from: Elsie Sunderland, USEPA*
Based on the NHANES national survey, approximately 6% of women of child-bearing age in the U.S. have blood mercury levels above the EPA’s Reference Dose for potential adverse fetal/infant health impacts (~3600 women tested nationwide)


There is controversy over the absolute level of the reference dose and how to interpret it.

~4,000,000 U.S. live births / yr x ~6% = ~240,000 newborns potentially at risk each year.

NHANES is not designed to capture vulnerable sub-populations with unusually high fish consumption and mercury exposure.

Figure 1. Geometric mean and 95% CI for blood lead, cadmium and mercury concentrations in adults residing in NYC compared with the United States overall, NYC HANES 2004, and NHANES 1999–2002 (CDC 2005a). *

*Blood mercury comparison for women age 16–49 years (NHANES) and 20–49 years (NYC HANES).

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- Critical exposure pathway: methylmercury from fish consumption
- Toxicity believed to be occurring at current exposures
- Widespread fish consumption advisories
Mercury Fish Consumption Advisories are Ubiquitous
1. Do not eat Shark, Swordfish, King Mackerel, or Tilefish because they contain high levels of mercury.

2. Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.

   • Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.

   • Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna.

   • So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

3. Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.

   Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions.
Public Health Context

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- Methylmercury vs. Omega-III Fatty Acids
Net Effect of Mercury and Fish Oils on Neurodevelopment at 6 months of Age (1 Fish Meal/Week)

Public Health Context

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- Methylmercury vs. Omega-III Fatty Acids

- Selenium – protective role?

+ Wildlife Health Issues
  e.g., fish-eating birds
Elemental Mercury -- Hg(0) -- Emissions to the Air

- **Color of symbol denotes type of mercury source**
  - Red: coal-fired power plants
  - Green: other fuel combustion
  - Blue: waste incineration
  - Gray: metallurgical
  - Yellow: manufacturing & other

- **Size/shape of symbol denotes amount of mercury emitted (kg/yr)**
  - ▲: 5 – 10
  - ○: 10 – 50
  - ▲: 50 – 100
  - □: 100 – 300
  - ○: 300 – 500
  - □: 500 – 1000
  - ○: 1000 – 3500

*2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada; 1999 Mexican data from inventory prepared by Acosta y Asociados for the Commission for Environmental Cooperation*
Reactive Gaseous Mercury -- RGM -- Emissions to the Air

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada; 1999 Mexican data from inventory prepared by Acosta y Asociados for the Commission for Environmental Cooperation.
Particulate Mercury – Hg(p) -- Emissions to the Air

2002 U.S. data from USEPA National Emissions Inventory (NEI); 2002 Canadian data from Environment Canada; 1999 Mexican data from inventory prepared by Acosta y Asociados for the Commission for Environmental Cooperation
Emissions and deposition to Lake Michigan arising from different distance ranges
(based on 1999 anthropogenic emissions in the U.S. and Canada)

Only a small fraction of U.S. and Canadian emissions are emitted within 100 km of Lake Michigan…

… but these “local” emissions are responsible for a large fraction of the modeled atmospheric deposition.
Contradicting a key part of the Bush administration's environmental policy, a new federal study estimates most of the mercury falling into Lake Michigan comes from smokestacks close to the shoreline.

Sixteen of the top 25 sources of mercury dropped into the lake are coal-fired power plants, according to the study by the National Oceanic and Atmospheric Administration (NOAA). Some of the toxic metal comes from as far away as Nevada and Texas, the study found, but most blows toward the lake from coal plants and factories in Illinois, Wisconsin, Michigan and Indiana.
Atmospheric Mercury Measurement Site at Beltsville, MD

ARL’s speciated mercury measurements at Beltsville are co-located with sites from several monitoring networks (CASTNET, MDN, NADP-NTN) and are funded by an Interagency Agreement between the USEPA and NOAA.
Mercury transformed by bacteria into methylmercury in sediments, soils & water, then bioaccumulates in fish.

Humans and wildlife affected primarily by eating fish containing mercury.

Best documented impacts are on the developing fetus: impaired motor and cognitive skills.

Adapted from slides prepared by USEPA and NOAA.
Oxidized mercury [Hg(II)] required – provided by atmospheric deposition of Hg(II) or *in-situ* oxidation
- Hg(II) transformed to MeHg (methyl-mercury) by sulfate-reducing bacteria under anoxic conditions
- Most commonly occurs in the top layers of the waterbody’s sediment
- Methylation can also occur in the water column and in the watershed (e.g., wetlands)
- Me-Hg can bioaccumulate, other environmental forms of mercury do not
- Me-Hg is much more toxic than other environmental forms of mercury