Atmospheric Mercury Monitoring in Canada

Dr. Alexandra (Sandy) Steffen
Air Quality Research Division
Science and Technology Branch
Mercury is an important issue in Canada

- Certain Canadian populations are at higher risk of exposure
- MeHg levels can be high enough (>0.3 µg g⁻¹) to pose a risk to the reproductive health of fish and fish-eating wildlife
- ~90% of annual provincial/territorial fish consumption advisories are from high Hg levels
- Hg levels exceed the Canadian limit for commercial sale of fish at many sites across Canada
- 95% of anthropogenic Hg deposited in Canada comes from external source regions
- Canada is a net recipient of mercury
Canadian Mercury Science Assessment

Synthesis of mercury research results collected within Canada

• Understand the status of mercury in the Canadian environment and the impact on ecosystems and the Canadian population

• Quantify current and past levels of Hg in the environment
• Determine knowledge gaps of transport routes from points of emission to exposure to ecosystems
• Identify key indicators of stress and exposure
• Develop the capacity to predict changes in indicators

• Develop a baseline status for mercury levels in Canada
Mercury remains a risk to Canadian ecosystems and human health

In humans, the average exposure of Canadians to mercury is low

Levels of Hg in the air in Canada are mostly decreasing

Trends in the levels of Hg in biota vary

Significant global-scale reductions in mercury emissions are predicted to be required to reduce mercury levels in fish below those currently observed across Canada.
Policy questions

In light of our current understanding of mercury in the Canadian environment, where, and to what extent, do we need to continue atmospheric and effects monitoring?

Where, and on what, should we focus future research efforts for mercury?
✓ Atmospheric deposition is the main pathway for the introduction of mercury to watersheds, and thus air levels need to be understood to follow the pathways through the environmental compartments

✓ Wet deposition of mercury is a good indicator of changes in the mercury load from the atmosphere to the environment

✓ More monitoring and research is required to entirely understand atmospheric transformation and deposition of mercury

✓ Atmospheric monitoring is undertaken to address several different goals including: (1) to measure the input levels of mercury to ecosystems; (2) to measure ambient levels resulting from domestic and regional emission sources; and (3) to assess transboundary transport of mercury into Canada.
Air Monitoring Networks in Canada over time

Initiated cohesive monitoring in 1997

- Canadian Atmospheric Mercury Measurement Network (CAMNet)
- Canadian Air and Precipitation Monitoring Network (CAPMoN)
- Northern Contaminants Program (NCP)
- Environment Canada – Clean Air Regulatory Agenda (CARA)
- Environment and Climate Change Canada (CCAP)

✓ Atmospheric total gaseous Hg (TGM) / gaseous elemental Hg (GEM)
✓ Wet deposition (total and methyl Hg)
✓ Atmospheric speciation
  – Gaseous elemental Hg (GEM)
  – Reactive Gaseous Hg (RGM)
  – Particulate Hg (PHg)
✓ Passive sampling research to initiate monitoring
Air Monitoring in Canada over time

Air monitoring
1. **CAMNet** (1996-2007) 9-13 sites
2. **CAPMoN** (2007-present) 4 sites
3. **Wet deposition** (1996-now) 5-6 sites CAMNet/CAPMoN
4. **NCP** (1995-now)
7. **CCAP** (2015 - …)
Air Monitoring today in Canada

TGM - total gaseous Hg; Speciation – air gas and particles; Precipitation - total and methyl Hg
Canadian research products

- Monitoring
  - Assess spatial and temporal air concentration levels (Cole et al., 2014)
  - Determine trends with time (Cole et al., 2014)
  - Provide data for modeling

- Processes
  - Select specific environments of concern
  - Investigate transport, transformation and deposition
  - Provide information to research community (esp. modelers)

- Modelling
  - Assess concentration levels across all of Canada
  - Produce deposition maps across all of Canada
  - Assess source regions of Hg coming into Canada
TGM concentration in Canada (over all years)

- Total gaseous mercury
- 23 sites
- Different time periods
- Inset Flin Flon*

*metals smelter
## Temporal trends for TGM

<table>
<thead>
<tr>
<th>Site</th>
<th>Time period</th>
<th>TGM trend, pg m⁻³ yr⁻¹</th>
<th>TGM trend, % yr⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reifel Island</td>
<td>1999-2004</td>
<td>-55 (-70 to -40)</td>
<td>-3.3 (-4.2 to -2.4)</td>
</tr>
<tr>
<td>Genesee</td>
<td>2004-2010</td>
<td>-6 (-21 to +1) ns</td>
<td>-0.4 (-1.4 to +0.1) ns</td>
</tr>
<tr>
<td>Bratt’s Lake</td>
<td>2001-2010</td>
<td>-37 (-48 to -23)</td>
<td>-2.5 (-3.4 to -1.6)</td>
</tr>
<tr>
<td>Burnt Island</td>
<td>1998-2007</td>
<td>-15 (-22 to -7)</td>
<td>-1.0 (-1.4 to -0.4)</td>
</tr>
<tr>
<td>Egbert</td>
<td>1996-2010</td>
<td>-20 (-27 to -16)</td>
<td>-1.3 (-1.7 to -1.0)</td>
</tr>
<tr>
<td>Kuujjuarapik</td>
<td>1999-2009</td>
<td>-40 (-55 to -23)</td>
<td>-2.4 (-3.4 to -1.4)</td>
</tr>
<tr>
<td>Point Petre</td>
<td>1996-2007</td>
<td>-29 (-38 to -20)</td>
<td>-1.7 (-2.2 to -1.2)</td>
</tr>
<tr>
<td>St. Anicet</td>
<td>1995-2009</td>
<td>-24 (-29 to -19)</td>
<td>-1.5 (-1.8 to -1.2)</td>
</tr>
<tr>
<td>St. Andrews</td>
<td>1996-2007</td>
<td>-30 (-42 to -20)</td>
<td>-2.2 (-3.1 to -1.5)</td>
</tr>
<tr>
<td>Kejimkujik</td>
<td>1996-2010</td>
<td>-14 (-20 to -6)</td>
<td>-1.0 (-1.4 to -0.5)</td>
</tr>
<tr>
<td>Alert</td>
<td>1995-2009</td>
<td>-11 (-15 to -6)</td>
<td>-0.7 (-1.0 to -0.4)</td>
</tr>
</tbody>
</table>

- Overall levels declined 10-26% (-0.9% to -3.3% yr⁻¹ - over varying years)
- Greater decreases closer to emission sources
- Arctic shows different patterns
- Canadian Emissions decreased 85% since 1990
Arctic TGM trends differ from temperate regions

High eastern Arctic (Alert) overall annual trend (1995-2013) - 0.987% per year

Western Arctic (Little Fox Lake) overall annual trend (2007-2014) + 1.40 % per year

Above zero – increasing trend
Below zero – decreasing trend
Speciation Concentration in Canada Particulate (TPM), Reactive Gaseous Hg (RGM)

- Hg$^0$ converts to Hg$^{2+}$
- Reactive gaseous mercury (RGM)
- Total particulate mercury (TPM)
- 11 sites
- Inset includes Churchill*
- * over a very short time during spring
Trends of Hg speciation

- Overall trends not reported
- Very small trends

- Monthly trends
  - RGM Alert May +6.8 % increase
  - Other no trend for RGM
  - TPM ELA and St A, some months -3 to +12%
  - TPM Alert April +7%

- GEM decreasing

- Speciation starting to increase at some locations
Mercury concentration and deposition in precipitation

- Total Hg concentrations
- Total Hg deposition
- Part of US MDN
- 22 sites
- Flin Flon (smelter)
  - Conc: 158 ng L\(^{-1}\)
  - Dep: 6.05 ug m\(^2\)
- Higher levels close to local emission sources
### Hg concentration trends in precipitation

<table>
<thead>
<tr>
<th>Site</th>
<th>Time period</th>
<th>[Hg] trend, a ng L⁻¹ yr⁻¹</th>
<th>[Hg] trend, % yr⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egbert</td>
<td>2000–2010</td>
<td>-0.18 (-0.31 to -0.05)</td>
<td>-2.1 (-3.7 to -0.6)</td>
</tr>
<tr>
<td>St.Anicet</td>
<td>1998–2007</td>
<td>-0.22 (-0.41 to -0.05)</td>
<td>-2.8 (-5.2 to -0.6)</td>
</tr>
<tr>
<td>St.Andrews</td>
<td>1996–2003</td>
<td>-0.25 (-0.43 to -0.02)</td>
<td>-3.7 (-6.5 to -0.3)</td>
</tr>
<tr>
<td>Kejimkujik</td>
<td>1996–2010</td>
<td>-0.12 (-0.17 to -0.06)</td>
<td>-2.2 (-3.3 to -1.2)</td>
</tr>
<tr>
<td>Mingan</td>
<td>1998–2007</td>
<td>-0.13 (-0.23 to +0.01) (NS)</td>
<td>-2.5 (-4.6 to +0.2) (NS)</td>
</tr>
<tr>
<td>Cormak</td>
<td>2000–2010</td>
<td>-0.07 (-0.15 to +0.01) (NS)</td>
<td>-1.7 (-3.5 to +0.3) (NS)</td>
</tr>
</tbody>
</table>

**Volume weighted monthly means**

95% confidence limits in parentheses

Data for sites > 5 years

NS not statistically significant from zero

Trends also differ over time periods
Model results
Global/Regional Atmospheric Heavy Metals Model

Modelled annual means of GEM and TGM measurements at Canadian sites active throughout 2006
Wet deposition concentrations as modelled and measured (dots) in 2006

January

April

July

October
Hg deposition regional contribution
Global/Regional Atmospheric Heavy Metals Model for 2005

Relative contributions from individual source regions to net mercury deposition

Over 95% of anthropogenic Hg deposited in Canada comes from sources outside of Canada

Information courtesy of Ashu Dastoor, Environment Canada from the Canadian Mercury Science Assessment - Chapter 4
Where should we monitor Hg in Canada?

Atmospheric monitoring is undertaken to address several different goals:

1. Input levels of mercury to ecosystems

2. Ambient levels resulting from domestic and regional emission sources

3. Transboundary transport of mercury into Canada
Ecosystem impacts: Fish eating fish

- Impaired behaviour
- Health impairment
- Impaired reproduction
- Below all benchmarks
Mercury is a risk to Iconic Canadian bird
The Common Loon

Risks
Failed Productivity
Impaired Productivity
Impaired Behaviour
Below all benchmarks
Canadian Anthropogenic Emissions

- Canadian emitters from the four most important industrial sectors
- Contribute > half of Canada’s emissions.

Sectors
- Iron and steel production
- Coal-fired power plants
- Non-ferrous metals processing
- Cement production and processing
Transport into Canada

Data courtesy of D. Durnford
INCATPA Project
Ref. Durnford et al., ACP 2010
Air Monitoring today in Canada

1. Ecosystems
2. Regional emissions
3. Long range transport
Acknowledgements and those who do the work

- Amanda Cole, Geoff Stupple
- Ashu Dastoor, Dorothy Durnford
- Martin Pilote, Rob Tordon, Chris Eckley, Jennifer Graydon, Vince St Louis, Matt Parsons
- Neil Burgess, David Depew
- Julie Narayan
- Greg Skelton
Thank you!