Concerns over Mercury Pollution in Asia

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Minamata Disease and Hg Pollution

Minamata disease, a neurological disease caused by severe Hg poisoning due to consumption of contaminated fish, was first discovered in Minamata, Japan in 1956.

Hg-containing industrial wastewater discharge was the major Hg source to the fish in Minamata Bay.
Why Is Mercury Still A Concern?
Global Hg Pollution

KEY FINDINGS

- 1044 women of child-bearing age from 25 countries participated in the study. 42% of them had mercury levels greater than 1 ppm – the level that approximately corresponds to the US EPA reference dose. 55% of the women had mercury levels greater than 0.58 ppm mercury, a more recent, science-based threshold based on data indicating harmful effects at lower levels of exposure. Mercury is a health threat to women and the developing fetus.

- Women of the Pacific Islands have elevated mercury levels, likely due to a fish-rich diet. Distant air emissions of mercury from coal-fired power plants, cement kilns and other industries contaminate ocean fish that serve as a primary protein source for Pacific Islanders.

- Artisanal small-scale gold mining results in high mercury body burdens in women from Indonesia, Kenya, and Myanmar. Two likely mercury exposure sources are burning mercury amalgam and eating contaminated fish.

- Industrial mercury emissions contaminate local fish and elevate mercury levels in Thai women living nearby.

- Indigenous women in Alaska have mercury levels of concern due to their subsistence diet of sea mammals and fish. Consumption of seals may be a key source of mercury exposure.

- Women from locations in Albania, Chile, Nepal, Nigeria, Kazakhstan, and Ukraine have mercury levels of concern due to localised pollution of waterways and suspected fish contamination.

- Women using mercury to gold plate statues in Nepal have elevated mercury levels.

*This is the daily exposure that US EPA considers “likely to be without an appreciable risk of deleterious effects during a lifetime.”*
A State-of-the-Science Review of Mercury Biomarkers in Human Populations Worldwide between 2000 and 2018

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BACKGROUND: The Minamata Convention on Mercury provided a mandate for action against global mercury pollution. However, our knowledge of mercury exposures is limited because there are many regions and subpopulations with little or no data.

OBJECTIVE: We aimed to increase worldwide understanding of human exposures to mercury by collecting, collating, and analyzing mercury concentrations in biomarker samples reported in the published scientific literature.

METHOD: A systematic search of the peer-reviewed scientific literature was performed using three databases. A priori search strategy, eligibility criteria, and data extraction steps were used to identify relevant studies.

RESULTS: We collected 424,858 mercury biomarker measurements from 335,991 individuals represented in 312 articles from 75 countries. General background populations with insignificant exposures have blood, hair, and urine mercury levels that generally fall under 5 μg/L, 2 μg/g, and 3 μg/L, respectively. We identified four populations of concern: a) Arctic populations who consume fish and marine mammals; b) tropical riverine communities (especially Amazonian) who consume fish and in some cases may be exposed to mining; c) coastal and/or small-island communities who substantially depend on seafood; and d) individuals who either work or reside among artisanal and small-scale gold mining sites.

CONCLUSIONS: This review suggests that all populations worldwide are exposed to some amount of mercury and that there is great variability in exposures within and across countries and regions. There remain many geographic regions and subpopulations with limited data, thus hindering evidence-based decision making. This type of information is critical in helping understand exposures, particularly in light of certain stipulations in the Minamata Convention on Mercury. https://doi.org/10.1289/EHP3904
Blood Hg Concentrations

1. National Biomonitoring
2. WHO Regions
3. Population Groups

Cross-Sectional Studies

Basu et al., 2018
Blood Hg Concentration by Countries

Maternal blood
- Korea (2006-2010)
- Canadian Health Measures Survey (2007 to 2008)
- Taiwan (TBPS study)

Cord blood
- USA NHANES (2003 to 2008)
- German Environmental Survey (1998 and 2003 to 2006)
- Japan (Sakamoto et al. 2007)

1 – 5 year

6 – 11 year

12 – 19 year

20 – 59 year

60+ year

Courtesy of Dr. Eunhee Ha
Global Hg Pollution

➢ Fish consumption is the major exposure route of Hg to many people worldwide.

➢ Hg concentrations in fish are elevated globally.

(Evers et al., 2012)
Global Hg Pollution

- Atmospheric deposition is the major source of Hg to many aquatic ecosystems.
- Once deposits from atmosphere, inorganic Hg can get methylated by bacteria to form MeHg then bioaccumulates through food chain, resulting in higher concentrations in large long-lived predatory fish.

(GMOS, 2012)
Atmospheric Mercury Cycling
Sources of Atmospheric Hg

- **Natural emissions**: mercury released from natural weathering of Hg-containing rocks or by geothermal activity. 500 Mg yr\(^{-1}\)
- **Anthropogenic emissions**: mercury released as a result of current human activities. 2500 Mg yr\(^{-1}\)
- **Re-emissions**: mercury released to the atmosphere that are derived from past natural and anthropogenic releases. 5000 Mg yr\(^{-1}\)

(Outridge et al., 2018)
Anthropogenic Hg Emissions in 2015

- Anthropogenic Hg emission is an important contributor to the Hg in the atmosphere. Major sources include:
  - ASGM
  - Coal combustion
  - Cement production
  - Non-ferrous metal production

<table>
<thead>
<tr>
<th>Sector</th>
<th>Mercury emission (range), tonnes</th>
<th>Sector % of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artisanal and small-scale gold mining (ASGM)</td>
<td>838 (675-1000)</td>
<td>37.7</td>
</tr>
<tr>
<td>Biomass burning (domestic, industrial and power plant) *</td>
<td>51.9 (44.3-62.1)</td>
<td>2.33</td>
</tr>
<tr>
<td>Cement production (raw materials and fuel, excluding coal)</td>
<td>233 (117-782)</td>
<td>10.5</td>
</tr>
<tr>
<td>Cremation emissions</td>
<td>3.77 (3.51-4.02)</td>
<td>0.17</td>
</tr>
<tr>
<td>Chlor-alkali production (mercury process)</td>
<td>15.1 (12.2-18.3)</td>
<td>0.68</td>
</tr>
<tr>
<td>Non-ferrous metal production (primary Al, Cu, Pb, Zn)</td>
<td>228 (154-338)</td>
<td>10.3</td>
</tr>
<tr>
<td>Large-scale gold production</td>
<td>84.5 (72.3-97.4)</td>
<td>3.8</td>
</tr>
<tr>
<td>Mercury production</td>
<td>13.8 (7.9-19.7)</td>
<td>0.62</td>
</tr>
<tr>
<td>Oil refining</td>
<td>14.4 (11.5-17.2)</td>
<td>0.65</td>
</tr>
<tr>
<td>Pig iron and steel production (primary)</td>
<td>29.8 (19.1-76.0)</td>
<td>1.34</td>
</tr>
<tr>
<td>Stationary combustion of coal (domestic/residential, transportation)</td>
<td>55.8 (36.7-69.4)</td>
<td>2.51</td>
</tr>
<tr>
<td>Stationary combustion of gas (domestic/residential, transportation)</td>
<td>0.165 (0.13-0.22)</td>
<td>0.01</td>
</tr>
<tr>
<td>Stationary combustion of oil (domestic/residential, transportation)</td>
<td>2.70 (2.33-3.21)</td>
<td>0.12</td>
</tr>
<tr>
<td>Stationary combustion of coal (industrial)</td>
<td>126 (106-146)</td>
<td>5.67</td>
</tr>
<tr>
<td>Stationary combustion of gas (industrial)</td>
<td>0.123 (0.10-0.15)</td>
<td>0.01</td>
</tr>
<tr>
<td>Stationary combustion of oil (industrial)</td>
<td>1.40 (1.18-1.69)</td>
<td>0.06</td>
</tr>
<tr>
<td>Stationary combustion of coal (power plants)</td>
<td>292 (255-346)</td>
<td>13.1</td>
</tr>
<tr>
<td>Stationary combustion of gas (power plants)</td>
<td>0.349 (0.285-0.435)</td>
<td>0.02</td>
</tr>
<tr>
<td>Stationary combustion of oil (power plants)</td>
<td>2.45 (2.17-2.84)</td>
<td>0.11</td>
</tr>
<tr>
<td>Secondary steel production *</td>
<td>10.1 (7.65-18.1)</td>
<td>0.46</td>
</tr>
<tr>
<td>Vinyl-chloride monomer (mercury catalyst) *</td>
<td>58.2 (28.0-88.8)</td>
<td>2.6</td>
</tr>
<tr>
<td>Waste (other waste)</td>
<td>147 (120-223)</td>
<td>6.6</td>
</tr>
<tr>
<td>Waste incineration (controlled burning)</td>
<td>15.0 (8.9-32.3)</td>
<td>0.67</td>
</tr>
<tr>
<td>Total</td>
<td>2220 (2000-2820)</td>
<td>100</td>
</tr>
</tbody>
</table>

(UNEP, 2018)
Concerns in Asia
## Anthropogenic Hg Emissions in 2015

<table>
<thead>
<tr>
<th>Region</th>
<th>Fuel combustion</th>
<th>Industry sectors</th>
<th>Intentional-use (including product waste)</th>
<th>Artisanal and small-scale gold mining</th>
<th>Regional total (range), tonnes</th>
<th>% of global total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia, New Zealand &amp; Oceania</td>
<td>3.57</td>
<td>4.07</td>
<td>1.15</td>
<td>0.0</td>
<td>8.79 (6.93-13.7)</td>
<td>0.4</td>
</tr>
<tr>
<td>Central America and the Caribbean</td>
<td>5.69</td>
<td>19.1</td>
<td>6.71</td>
<td>14.3</td>
<td>45.8 (37.2-61.4)</td>
<td>2.1</td>
</tr>
<tr>
<td>CIS &amp; other European countries</td>
<td>26.4</td>
<td>64.7</td>
<td>20.7</td>
<td>12.7</td>
<td>124 (105-170)</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>East and Southeast Asia</strong></td>
<td><strong>229</strong></td>
<td><strong>307</strong></td>
<td><strong>109</strong></td>
<td><strong>214</strong></td>
<td><strong>859 (685-1430)</strong></td>
<td><strong>38.6</strong></td>
</tr>
<tr>
<td>EU28</td>
<td>46.5</td>
<td>22.0</td>
<td>8.64</td>
<td>0.0</td>
<td>77.2 (67.2-107)</td>
<td>3.5</td>
</tr>
<tr>
<td>Middle Eastern States</td>
<td>11.4</td>
<td>29.0</td>
<td>12.1</td>
<td>0.225</td>
<td>52.8 (40.7-93.8)</td>
<td>2.4</td>
</tr>
<tr>
<td>North Africa</td>
<td>1.36</td>
<td>12.5</td>
<td>6.89</td>
<td>0.0</td>
<td>20.9 (13.5-45.8)</td>
<td>0.9</td>
</tr>
<tr>
<td>North America</td>
<td>27.0</td>
<td>7.63</td>
<td>5.77</td>
<td>0.0</td>
<td>40.4 (33.8-59.6)</td>
<td>1.8</td>
</tr>
<tr>
<td>South America</td>
<td>8.25</td>
<td>47.3</td>
<td>13.5</td>
<td>340</td>
<td>409 (308-522)</td>
<td>18.4</td>
</tr>
<tr>
<td><strong>South Asia</strong></td>
<td><strong>125</strong></td>
<td><strong>59.1</strong></td>
<td><strong>37.2</strong></td>
<td><strong>4.50</strong></td>
<td><strong>225 (190-296)</strong></td>
<td><strong>10.1</strong></td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>48.9</td>
<td>41.9</td>
<td>17.1</td>
<td>252</td>
<td>360 (276-445)</td>
<td>16.2</td>
</tr>
<tr>
<td>Global inventory</td>
<td>533</td>
<td>614</td>
<td>239</td>
<td>838</td>
<td>2220 (2000-2820)</td>
<td>100.0</td>
</tr>
</tbody>
</table>

(UNEP, 2018)
Anthropogenic Hg Emissions in 2015

(Urban Environmental Movement, 2018)
Trends in Anthropogenic Hg Emissions

- Anthropogenic Hg emissions from Europe and North America are declining, whereas emissions from Asia are increasing.

(UNEP, 2013) (UNEP, 2018)
It is likely that Hg emission will increase in the future. The main driving force is the expansion of coal-burning electricity generation, especially in Asia.
Biomass Burning Hg Emissions

SEAS + EQAS = 249 Mg Hg/year = 37% of global biomass burning emission
Distribution of Atmospheric Hg Concentrations and Deposition Fluxes: Modeling Results

Figure 2. Global distribution of ensemble mean annual GEM concentration in ambient air (a) and annual total mercury deposition (b) in 2013.

Corbitt et al., 2011

Costa et al., 2012
Trend in SW Hg Conc. in Surface Oceans

(Driscoll et al., 2013)
Rising Hg Levels in the Pacific Tuna

Mercury levels in Hawaiian bigeye, yellowfin tuna rising

7 March 2017, by Jim Erickson

Most of the work was done while Drevnick was at U-M, and the research was funded in part by the university. The new study updates yellowfin findings that Drevnick reported two years ago and expands the effort to include bigeye tuna.

"This paper confirms our previous work showing that mercury concentrations in yellowfin tuna caught near Hawaii are increasing, and it demonstrates that the same phenomenon is happening in bigeye tuna," Drevnick said.

Both yellowfin and bigeye tuna are marketed as ahi and are widely used in raw fish dishes—especially sashimi—or for grilling. In January, the U.S. Food and Drug Administration and the U.S. Environmental Protection Agency added bigeye tuna to its list of fish to be avoided by pregnant women, women who might become pregnant, breastfeeding women and young children due to mercury concerns.

Mercury is a toxic trace metal that can accumulate to high concentrations in fish, posing a health risk to people who eat large, predatory marine fish such as swordfish and tuna. In the open ocean, the principal source of mercury is atmospheric deposition from human activities, especially emissions from coal-fired power plants and artisanal gold mining.

For decades, scientists have expected to see mercury levels in open-ocean fish increase in response to rising atmospheric concentrations, but evidence for that hypothesis has been hard to find. In fact, some studies have suggested that there has been no change in mercury concentration in ocean fish.

By compiling and re-analyzing three previously published reports on yellowfin tuna caught near Hawaii, U-M's Paul Drevnick and two colleagues found that the concentration of mercury in that species increased at least 3.8 percent per year from 1998 to 2008.

Mercury levels in open ocean fish are responsive to mercury emissions."

Drevnick and his colleagues re-analyzed data from three studies that sampled the same yellowfin tuna population near Hawaii in 1971, 1998 and 2008. In each of the three studies, muscle tissues were tested for total mercury, nearly all of which was the toxic organic form, methylmercury.

In their re-analysis, Drevnick and his colleagues included yellowfin salmon between 48 and 167 pounds and used a computer model that controls for the effect of fish body size. Data from 229 fish were analyzed: 111 from 1971, 104 from 1998 and 14 from 2008.

The researchers found that mercury concentrations in the yellowfin did not change between the 1971 and 1998 datasets. However, concentrations were higher in 2008 than in either 1971 or 1998. Between 1998 and 2008, the mercury concentration in yellowfin increased at a rate greater than or equal to 3.8 percent a year, according to the new study.

"Mercury levels are increasing globally in ocean water, and our study is the first to show a consequent increase in mercury in an open-water fish," Drevnick said. "More stringent policies are needed to reduce releases of mercury into the atmosphere. If current deposition rates are maintained, North Pacific waters will double in mercury by 2050."

Yellowfin tuna, often marketed as ahi, is widely used in raw fish dishes—especially sashimi—or for grilling. The Natural Resources Defense Council's guide to mercury in sushi lists yellowfin tuna as a "high mercury" species.

International Actions
**Article 19**

**Research, development and monitoring**

1. Parties shall endeavour to cooperate to develop and improve, taking into account their respective circumstances and capabilities:
   
   (a) Inventories of use, consumption, and anthropogenic emissions to air and releases to water and land of mercury and mercury compounds;
   
   (b) Modelling and geographically representative monitoring of levels of mercury and mercury compounds in vulnerable populations and in environmental media, including biotic media such as fish, marine mammals, sea turtles and birds, as well as collaboration in the collection and exchange of relevant and appropriate samples;
   
   (c) Assessments of the impact of mercury and mercury compounds on human health and the environment, in addition to social, economic and cultural impacts, particularly in respect of vulnerable populations;
   
   (d) Harmonized methodologies for the activities undertaken under subparagraphs (a), (b) and (c);
   
   (e) Information on the environmental cycle, transport (including long-range transport and deposition), transformation and fate of mercury and mercury compounds in a range of ecosystems, taking appropriate account of the distinction between anthropogenic and natural emissions and releases of mercury and of remobilization of mercury from historic deposition;
   
   (f) Information on commerce and trade in mercury and mercury compounds and mercury-added products; and
   
   (g) Information and research on the technical and economic availability of mercury-free products and processes and on best available techniques and best environmental practices to reduce and monitor emissions and releases of mercury and mercury compounds.

2. Parties should, where appropriate, build on existing monitoring networks and research programmes in undertaking the activities identified in paragraph 1.

**Article 22**

**Effectiveness evaluation**

1. The Conference of the Parties shall evaluate the effectiveness of this Convention, beginning no later than six years after the date of entry into force of the Convention and periodically thereafter at intervals to be decided by it.

2. To facilitate the evaluation, the Conference of the Parties shall, at its first meeting, initiate the establishment of arrangements for providing itself with comparable monitoring data on the presence and movement of mercury and mercury compounds in the environment as well as trends in levels of mercury and mercury compounds observed in biotic media and vulnerable populations.

3. The evaluation shall be conducted on the basis of available scientific, environmental, technical, financial and economic information, including:
   
   (a) Reports and other monitoring information provided to the Conference of the Parties pursuant to paragraph 2;
   
   (b) Reports submitted pursuant to Article 21;
   
   (c) Information and recommendations provided pursuant to Article 15; and
   
   (d) Reports and other relevant information on the operation of the financial assistance, technology transfer and capacity-building arrangements put in place under this Convention.
Currently, long-term or background atmospheric Hg monitoring activities in SE and S Asia are still lacking.
Asia Pacific Mercury Monitoring Network

Systematically monitor wet deposition and atmospheric concentrations of mercury in a network of stations throughout the Asia-Pacific region
APMMN Site Map
THANK YOU!

Contact:
grsheu@atm.ncu.edu.tw