Physicochemical factors affecting the spatial variance of monomethylmercury in artificial reservoirs in Korea

Seunghee Han
Gwangju Institute of Science and Technology
Gwangju, Republic of Korea

2015 International Conferences on Mercury Pollution Prevention and Control
Effectiveness of Minamata Convention Implementation

Fate and behavior study
- Atm deposition-water interactions
- Atm deposition-fish interactions
- Natural lakes in high reaches (10)
  - Artificial reservoirs (6)

Temporal trend study
- Long-term trends of Hg conc in rainwater, lake water, and fish
- Major rivers (4)
  - Artificial reservoirs (10)

Parameters and sites
- Analytical methods
- Quality control and assurance methods

Establishment of a long-term mercury monitoring plan
Indirect atmospheric deposition, such as runoff from upland catchments, is widely recognized as a primary pathway for Hg input.
Water chemistry, such as sulfate, pH and DOC, largely influences on MMHg concentration in reservoir water and organisms.

Sources of MMHg in artificial reservoirs

- Overland runoff: DOC, POC, TP
- Stream discharge: DOC, POC, TP
- Sediment flux: Residence time, hypoxic conditions
- In situ production
  Sulfate, pH, DOC
- Fish MMHg concentrations in artificial reservoirs are higher in eutrophic water than oligotrophic water.

- Eutrophic water may provide higher sulfate and DOC that can enhance the in situ Hg(II) methylation rate than oligotrophic water.
Study Area

- 16 lakes were visited in 2013-2015
- Temperature, conductivity, pH, SPM, chl-a, sulfate, nitrate, DOC in water
- THg (filtered/unfiltered)
- MMHg (filtered/unfiltered) in water
- THg and MMHg in sediment
- THg in fish
Experimental methods

**Water**
- THg
  - BrCl oxidation
  - SnCl₂ reduction
- MMHg
  - Distillation
  - Ethylation

**Sediment**
- Lyophilization
- Acid digestion
- AAS (DMA-80)

**Fish**
- Lyophilization
- Acid digestion
- AAS (DMA-80)
- Extraction
  - CH₂Cl₂
- KOH/MeOH

**CVAFS**

Acid digestion or
Extraction KOH/MeOH
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest: 66%</td>
<td>Forest: 80%</td>
<td>Forest: 79%</td>
<td>Forest: 64%</td>
<td>Forest: 80%</td>
<td>Forest: 42%</td>
<td>Forest: 89%</td>
<td>Forest: 67%</td>
</tr>
<tr>
<td>Agricul: 15%</td>
<td>Agricul: 4.1%</td>
<td>Agricul: 8.0%</td>
<td>Agricul: 13%</td>
<td>Agricul: 11%</td>
<td>Agricul: 39%</td>
<td>Agricul: 2.8%</td>
<td>Agricul: 19%</td>
</tr>
<tr>
<td>Urban: 17%</td>
<td>Urban: 14%</td>
<td>Urban: 9.9%</td>
<td>Urban: 23%</td>
<td>Urban: 6.6%</td>
<td>Urban: 15%</td>
<td>Urban: 6.8%</td>
<td>Urban: 8.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest: 87%</td>
<td>Forest: 18%</td>
<td>Forest: 8.2%</td>
<td>Forest: 25%</td>
<td>Forest: 10%</td>
<td>Forest: 18%</td>
<td>Forest: 7.5%</td>
<td>Forest: 12%</td>
</tr>
<tr>
<td>Agricul: 8.0%</td>
<td>Agricul: 43%</td>
<td>Agricul: 86%</td>
<td>Agricul: 60%</td>
<td>Agricul: 81%</td>
<td>Agricul: 57%</td>
<td>Agricul: 53%</td>
<td>Agricul: 80%</td>
</tr>
<tr>
<td>Urban: 3.2%</td>
<td>Urban: 39%</td>
<td>Urban: 5.3%</td>
<td>Urban: 15%</td>
<td>Urban: 9.0%</td>
<td>Urban: 25%</td>
<td>Urban: 39%</td>
<td>Urban: 8.0%</td>
</tr>
</tbody>
</table>
Reservoir characteristics

Data sources:
Water resources management information system (WRMIS), Korea meteorological administration (KMA), K-water
Hg in surface waters

Results & Discussion

US EPA WQC for wildlife
- Unfiltered Hg  1.3 ng L$^{-1}$
- Dissolved Hg  0.6 ng L$^{-1}$
- Unfiltered MMHg  50 pg L$^{-1}$
Self organizing map (SOM)

Results & Discussion

Data sources:
Water resources management information system (WRMIS),
Korea meteorological administration (KMA), K-water
Water chemistry were measured from 16 lakes (Jun-Oct)
Self organizing map (SOM)

Data sources:
Water resources management information system (WRMIS), Korea meteorological administration (KMA), K-water
Water chemistry were measured from 16 lakes (Jun-Oct)
Principal component analysis (PCA)

Results & Discussion

<table>
<thead>
<tr>
<th>Variable</th>
<th>PC1</th>
<th>PC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>-.110</td>
<td>.839</td>
</tr>
<tr>
<td>Residence time</td>
<td>-.161</td>
<td>.567</td>
</tr>
<tr>
<td>Basin area</td>
<td>.085</td>
<td>-.270</td>
</tr>
<tr>
<td>Lake area</td>
<td>-.166</td>
<td>-.671</td>
</tr>
<tr>
<td>Lake depth</td>
<td>-.404</td>
<td>-.736</td>
</tr>
<tr>
<td>% farm</td>
<td>.241</td>
<td>.550</td>
</tr>
<tr>
<td>% forest</td>
<td>-.433</td>
<td>-.554</td>
</tr>
<tr>
<td>% urban</td>
<td>.462</td>
<td>.364</td>
</tr>
<tr>
<td>Temperature</td>
<td>.264</td>
<td>.514</td>
</tr>
<tr>
<td>Conductivity</td>
<td>.906</td>
<td>-.093</td>
</tr>
<tr>
<td>pH</td>
<td>.660</td>
<td>-.107</td>
</tr>
<tr>
<td>SPM</td>
<td>.832</td>
<td>.150</td>
</tr>
<tr>
<td>Chla</td>
<td>.807</td>
<td>.040</td>
</tr>
<tr>
<td>SO₄</td>
<td>.912</td>
<td>.004</td>
</tr>
<tr>
<td>NO₃</td>
<td>-.286</td>
<td>-.682</td>
</tr>
<tr>
<td>DOC</td>
<td>.831</td>
<td>.314</td>
</tr>
<tr>
<td>THg</td>
<td>.005</td>
<td>.397</td>
</tr>
<tr>
<td>DHg</td>
<td>-.323</td>
<td>.575</td>
</tr>
<tr>
<td>MMHg</td>
<td>.501</td>
<td>.202</td>
</tr>
<tr>
<td>DMMHg</td>
<td>.011</td>
<td>.568</td>
</tr>
<tr>
<td>%MMHg</td>
<td>.298</td>
<td>-.103</td>
</tr>
<tr>
<td>%DMMHg</td>
<td>.206</td>
<td>.028</td>
</tr>
</tbody>
</table>

Kaiser-Meyer-Olkin (0.51), Bartlett <0.001
### Hg bioaccumulation & geochemical factors

**Results & Discussion**

<table>
<thead>
<tr>
<th></th>
<th>rainfall</th>
<th>area</th>
<th>depth</th>
<th>cond</th>
<th>SPM</th>
<th>TOC</th>
<th>Chl-a</th>
<th>TN</th>
<th>TP</th>
<th>Sed THg</th>
<th>Sed MMHg</th>
<th>%sed MMHg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bluegill</strong></td>
<td>.31</td>
<td>.52</td>
<td>.18</td>
<td>-.45</td>
<td>-.31</td>
<td>-.19</td>
<td>-.26</td>
<td>-.13</td>
<td>-.24</td>
<td>-.28</td>
<td>.76*</td>
<td>.80*</td>
</tr>
<tr>
<td><strong>Bass</strong></td>
<td>.50</td>
<td>.29</td>
<td>.34</td>
<td>-.67</td>
<td>-.89*</td>
<td>-.61</td>
<td>-.69</td>
<td>-.35</td>
<td>-.55</td>
<td>.38</td>
<td>.86*</td>
<td>.74</td>
</tr>
<tr>
<td><strong>Steed</strong></td>
<td>.40</td>
<td>.10</td>
<td>.23</td>
<td>-.32</td>
<td>-.22</td>
<td>.10</td>
<td>.07</td>
<td>.22</td>
<td>.10</td>
<td>-.34</td>
<td>.79*</td>
<td>.82*</td>
</tr>
<tr>
<td><strong>Mandarin</strong></td>
<td>.30</td>
<td>-.81*</td>
<td>-.79*</td>
<td>-.50</td>
<td>-.25</td>
<td>.70</td>
<td>-.03</td>
<td>-.82*</td>
<td>-.83*</td>
<td>.03</td>
<td>.31</td>
<td>.22</td>
</tr>
</tbody>
</table>

Adjusted Hg for standard length (bluegill: 11cm, bass 20cm, steed 22cm, mandarin 19cm)
Water chemistry from WRMIS (3yr average)
Sediment Hg from this study (surface 2 cm)
Hg bioaccumulation & geochemical factors

Results & Discussion

Log[Bluegill] = 5.6 × Log[sed MMHg] + 0.91, r² > 0.58, p < 0.05
Log[Bass] = 4.0 × Log[sed MMHg] + 1.5, r² > 0.73, p < 0.05
Log[Barbel steed] = 6.7 × Log[sed MMHg] + 1.3, r² > 0.63, p < 0.05
Results & Discussion

Hg bioaccumulation & geochemical factors

Adjusted Hg for standard length of fish Chl-a from WRMIS (3yr average)
Conclusion

- Preliminary study performed in 2013-2015 demonstrated that a greater MMHg production in the algal-enriched reservoirs did not guarantee greater MMHg bioaccumulation. When chl-a > 4 ug L⁻¹, algal biomass diluted MMHg in fish.

- The relationship between fish MMHg concentration and trophic state of reservoir water was non-linear.

- Korea will launch a long-term Hg monitoring program in 2016 to evaluate effectiveness of the Minamata Convention implementation.
Acknowledgment

- Seam Noh and EGL students
- Korea Ministry of Environment (MOE)
- National Institute of Environmental Research (NIER)