Mercury in the North

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ACAT – CHE, June 15 2016
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Connect the dots

Source ............ Path ............ Receptor

SRB bacteria
Sources

- Wildfires, volcanoes, erosion of soil & natural rock
- Industry
  - Coal plants
  - Incinerators
  - Gold mines – no gold mines currently in Alaska release mercury
Prediction of episodic outflow of Asian mercury on April 25, 2004 measured at Mt. Bachelor observatory, Oregon, USA
Elemental Hg$^0$

- Stable and happy
- Gas
- “gaseous elemental mercury” GEM

Stays in this form for years (half life of a year)
If it stays up there ....

... how does it get into fish and into us?
**Ionic Hg\(^{2+}\)**
- Wants a hand to hold
- Gas
- “reactive gas mercury”

**Before it becomes stable**
- Water
- Dissolved HgX
- Rock
- Solid
- HgX

Hg “species”
Ligands – just a hand to hold

- Toddler Hg

Hg$^{2+}$
Ligands – just a hand to hold

- Toddler Hg
- Aunties
Ligands – just a hand to hold

- Toddler Hg
- Aunties
- Momma S
Ligands — just a hand to hold

- Toddler Hg
- Aunties
- Momma S
- Methyl Hg (MeHg)

Only bacteria can put a methyl group on!
Happy places for methylating bacteria

- Gaseous, stable $\text{Hg}^0$ floats around until it becomes gaseous, reactive $\text{Hg}^{2+}$, which wants to partner up ($\text{HgX}$) and precipitate to ground.
- If it lands in a wet area without oxygen, this is the home of bacteria that can make methyl mercury ($\text{MeHg}$)

- Estuaries
- Wetlands

NOT
- Running streams
- Mountaintops
- Dry tundra
Pathways are not complete unless bacteria methylate the mercury.

Once methylated, mercury can cross into cells.

What can be methylated can also be DE-methylated.
Mercury Levels in Northern Pike in Relation to Wetlands

KEY
- Pike Sampling Locations
- Total Mercury in Pike (PPM)
  - 0.00000 - 0.21000
  - 0.21001 - 0.39000
  - 0.39001 - 0.65000
  - 0.65001 - 0.85900
  - 0.85901 - 1.35670
- Mineral occurrences, prospects
- or mines containing Hg, chalcophile, or associated elements
- Wetlands
- Major Rivers
- Lakes

Department of the Interior
United States Geological Survey
Physical Science Technician: Derick Froehliger
Map Datum: GCS North American Datum 1983
Map Projection: Alaska Albers Equal Conic
Volcanic activity caused several metals to form together—gold, arsenic, mercury all bind to sulfides to become solid rock.

Hg = S
Source Donlin’s ore processing

Ore is heated to extract the gold, heating causes mercury to vaporize

(Hg=S become gaseous mercury and sulfuric acid)
Ore is heated to extract the gold, heating causes mercury to vaporize (Hg=S become gaseous mercury and sulfuric acid)

Some will remain as solids in tailings (Hg=S)
Tailings water will have high concentrations of dissolved mercury – Leakage?

100 lbs per year is expected to be emitted to the atmosphere (GEM)

About 17 tons will be captured, condensed, and held in flasks or drums (stable liquid Hg)
Receptors  Toxicity

- **Wildlife (animals eating contaminated food)**
  - Physical deformities
  - Slow growth
  - Lower reproductive success
  - Lower survival

- **Humans (eating contaminated food)**
  - Unborn children, infants at most risk
  - Nerve damage – speech, vision, walking
  - Immune system damage

- **Humans (inhalation)**
  - Industrial plant workers most at risk
  - Nerve damage – walking, fatigue, dizziness
  - Can be fatal
Toxicity

at the cellular level

- Toxicity occurs when MeHg becomes reactive Hg^{2+} and then attaches to \(-S\) ligands (“Momma S”) on proteins or other cellular molecules, particularly fast-dividing ones like nerve cells.
Toxicity at the cellular level

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1. Momma S
   Ligand available

2. Momma S in action, binding molecules

3. Momma S Blocked
Vegetation (lichens, berries, spruce, willow, alder) in the Donlin “mercury belt” area had about the same mercury as has been found in other areas of Alaska.

- **Donlin area**
  - highest in lichen (9-36 ng/g)
  - lowest in cranberry, blueberry (<8 ng/g)

- **Lichen throughout Alaska (EPA, UAF studies)**
  - Alaska parks 20-30 ng/g mercury
  - Reindeer ranges 37-47 ng/g mercury

- Lichen don’t get mercury from the soil and don’t pass mercury on to reindeer.
  - Lichen < 40 ng/g
  - Hair 15-83 ng/g
  (Fish is safe at 300-1,000 ng/g)
Why are reindeer low in Hg?

- Lichen and water, even near old mercury mines
  - Low mercury
  - Low methylmercury
  - Mercury from air isn’t methylated
- Vegetation to Reindeer
  - One-step food chain
Path - Receptors

Water - Kuskokwim Fish

- Water near old mercury mines
  - Less than 50 ng/L (safe)
  - 500-2500 ng/L with sediment
  - Very little methylmercury

- Fish near old mercury mines
  - 620 ng/g mercury (potentially unsafe)
  - nearly all is methylmercury
  - 300-1000 ng/g considered safe

Why are some fish higher in mercury?

- Pike can have high mercury
- Hg in water more likely to methylate
- Hg concentrates up the food chain
- Aquatic food chains are longer than on land
Are we doomed?

No

- Not all fishy areas are places where mercury will methylate
  
  Methylmercury is not related to the amount of Hg that enters the environment, but whether the environment supports bacteria that can add methyl groups

- What can be methylated can be DE-methylated
  
  Even where bacteria are tacking methyl groups on, UV light is busy taking them off. It’s a balance.

- Fish, mink, us, and other animals get rid of mercury
  
  For MeHg to pose a risk, it must come in faster than it goes out. MeHg has a half life of about 90 days in humans and fish (Young, 2001; ICPS 1990; Kramer and Neidhart 1975)
So everything’s fine, no worries?

Monitor!

- **Industrial facilities should measure mercury releases**
  
  Monitor levels in stacks, air, dust/soil, water
  
  Monitor processing areas – inhaling gaseous Hg is extremely toxic to adults as well as children

- **Fish tissue, human hair should be tested**

  Can request fish tissue monitoring as part of mine activity environmental monitoring

  Human hair testing is free through the state of Alaska
So everything’s fine, no worries?

- Packaging for storage and transport
- Spills of Hg into rivers and estuaries are a risk

About 17 tons of mercury will be transported out of Donlin

Several layers of protection have been added inside the drums: (1) The drums are lined with an epoxy-phenolic coating; (2) a cushioning material is located in the bottom of each drum; (3) the flasks are separated by a cardboard divider for additional cushioning; (4) the contents are sealed in a thick plastic bag; and (5) each drum lid is equipped with a half-inch rubber gasket and a steel-locking ring that is bolted to seal the drum. The drums are very secure and both airtight and liquid-tight.
Summary

Source....

Path......

Receptor...

Monitor

Or direct inhalation

Quyana  Tsin’aen  Chin’un  Thank you
Mercury in Northern Pike from the Yukon Delta National Wildlife Refuge  
U.S. Fish and Wildlife Service and Alaska Dept. of Health and Social Services – Division

**Should I worry about eating fish?**

Overall, mercury levels in Alaska fish are low, so the only people who need to think about limiting the amount of fish they eat are women who are or can become pregnant, nursing mothers, and children age 12 years and under. Women and children can still get the benefits of eating fish by choosing to eat fish that are low in mercury, like salmon.

Men, elders, and teenage boys may eat unlimited amounts of most Alaska fish, including pike.

The State of Alaska has developed guidelines for women and children on how much of each fish they can safely eat, based on the amount of mercury in a variety of fish species. These guidelines:
- Reflect guidelines developed by other states and national agencies.
- Incorporate studies of dietary mercury effects on children.
- Include a large safety factor, so do not have to be viewed as strict dietary limits.

**Why study mercury in pike?**

There is more of the toxic form of mercury – methylmercury – in fish that eat other fish and in older fish, like large pike. In this study, we measured mercury in pike muscle, from pike caught at traditional and well-used subsistence fishing sites. We are sharing this information with you because you live in an area where people eat a lot of pike. With the help of subsistence fishermen, we collected 163 pike from 11 sites in the Yukon Delta National Wildlife Refuge in 2005 (on the Kuskokwim River) and 2006 (on the Lower Yukon River).

**MeHg in fish (mg/kg)  Meals per month**

<table>
<thead>
<tr>
<th>MeHg in fish (mg/kg)</th>
<th>Meals per month</th>
<th>Fresh pike</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 0.15</td>
<td>Unlimited</td>
<td>Kuskokwim &lt; 2 ft</td>
</tr>
<tr>
<td>&gt;0.15 - 0.32</td>
<td>up to 16</td>
<td>Kuskokwim &lt; 2 ft</td>
</tr>
<tr>
<td>&gt;0.32 - 0.40</td>
<td>up to 12</td>
<td>Kuskokwim &lt; 2 ft</td>
</tr>
<tr>
<td>&gt;0.40 - 0.64</td>
<td>up to 8</td>
<td>Kuskokwim &lt; 2 ft</td>
</tr>
<tr>
<td>&gt;0.64 – 1.2</td>
<td>up to 4</td>
<td>Kuskokwim &lt; 2 ft</td>
</tr>
<tr>
<td>&gt;1.2 - 1.4</td>
<td>up to 3</td>
<td>Kuskokwim &gt; 2 ft</td>
</tr>
<tr>
<td>&gt;1.4 - 2.0</td>
<td>up to 2</td>
<td>Kuskokwim &gt; 2 ft</td>
</tr>
<tr>
<td>&gt;2.0 - 3.4</td>
<td>up to 1</td>
<td>Kuskokwim &gt; 2 ft</td>
</tr>
</tbody>
</table>

Notes: Small pike (< 2 feet long) often have less mercury than large pike (> 2 feet long). Also, dried pike has a higher mercury concentration than fresh pike (the mercury is “diluted” with the water in the fresh pike), so the guidance allows fewer meals of dried pike than fresh pike.

**Measuring Mercury**

A simple hair test can tell you how much mercury you may have in your body. For more information on hair mercury monitoring, or to arrange for testing, contact the Environmental Public Health Program at the Alaska Division of Public Health, 3601 C Street, Suite 540, Anchorage, AK 99503, 907-269-8000, http://www.epi.hss.state.ak.us/eh/default.cfm

**Deciding**

Fish are nutritious, with vitamins A, E, and C, iron, zinc, protein, and very important omega-3 fatty acids. These nutrients help keep your nervous system, your immune system, and your heart healthy, and are important for a healthy pregnancy.


For more information on mercury in pike contact Angela Matz, angela.matz@fws.gov, 907-456-0442, U.S. Fish and Wildlife Service, 101-12th Ave., Room 110, Fairbanks, AK 99701.
What’s wrong with this picture?

It doesn’t show the methylation pathway.

Although most methylation occurs in wetlands and estuaries, new research indicates it may also happen at some depths in the ocean.


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And various photos from wikipedia sites


And