Mercury Exposure Among Fishermen at Grand Lake

October 22, 2013

OU Health Sciences Center
Bob Lynch

LEAD Agency
Rebecca Jim, Earl Hatley, Kindel Maymi, Gina Manders

Harvard School of Public Health
Laurel Schaider, Ann Backus, Zhao Dong, Jim Shine, Jack Spengler
Why did we study mercury in Grand Lake?

- Popular fishing destination
- Subsistence fishing
- Concerns about local emissions sources

6 coal fired power plants nearby
Which populations are most sensitive to mercury exposure?

- Guidelines developed to protect most vulnerable
  - Young children
  - Pregnant and nursing mothers
  - Women who may become pregnant
Health guidelines for mercury

Health studies
How much mercury can have harmful health effects?
Health guidelines

Health studies
How much mercury can have harmful health effects?

“Reference dose”
Intake rate of mercury that is not associated with harmful health effects
0.1 micrograms methylmercury per kilogram body weight per day

Safety factors
Health guidelines: Biomarkers

**Health studies**
How much mercury can have harmful health effects?

**Blood mercury level**
Guideline indicates exposure at the reference dose
5.8 micrograms per liter

**Safety factors**

**“Reference dose”**
Intake rate of mercury that is not associated with harmful health effects
0.1 micrograms methylmercury per kilogram body weight per day
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Health studies
How much mercury can have harmful health effects?

“Reference dose”
Intake rate of mercury that is not associated with harmful health effects
0.1 micrograms methylmercury per kilogram body weight per day

Blood mercury level
Guideline indicates exposure at the reference dose
5.8 micrograms per liter

Hair mercury level
1 part per million in hair

These are all developed to protect most sensitive population: Women of childbearing age and children
Health guidelines: Fish

Health studies
How much mercury can have harmful health effects?

Concentration of mercury in fish
Assume rate of fish consumption (e.g., 2-3 times a month).
Then calculate concentration of mercury in fish that would get you to reference dose.

US EPA 300 parts per billion (women 15-45, children)

ODEQ 500 parts per billion (women 15-45, children)
1000 parts per billion (for general population)

“Reference dose”
Intake rate of mercury that is not associated with harmful health effects
0.1 micrograms methylmercury per kilogram body weight per day

Rate of fish consumption

Safety factors
2 factors determine mercury intake

- Level of mercury in fish
- How much fish is eaten

Eating a lot of low mercury fish

OR

Eating a little high mercury fish

Reference dose

www.grandlakemercurystudy.org
Our research questions

• What are the levels of mercury in fish in the Grand Lake watershed?
• How much and what types of local fish are eaten by residents of the watershed?
• Are people who eat fish from the watershed exposed to high levels of mercury in their diet?
Fish collection

2010 – 2013
Over 1,400 samples

Types of fish:
- Commonly-eaten (30 species)
- Prey fish (6 species)

Caught by:
- Volunteers
- Dept. of Wildlife Conservation
- Study team
Food Frequency Questionnaire

- 5 times over one year (every 3 months)
- Questions about previous 3 months
- Fish eating:
  - types
  - frequency
  - preparation
- Personal:
  - height
  - weight
  - education
  - ethnicity

<table>
<thead>
<tr>
<th></th>
<th>Largemouth bass</th>
<th>Smallmouth bass</th>
<th>White bass</th>
<th>Spotted bass</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a). How often did you eat this type of fish over the past 3 months?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once a day or more</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4 to 6 times/week</td>
<td></td>
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<tr>
<td>2 or 3 times/week</td>
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<tr>
<td>Once a month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once in last 3 mo.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never in last 3 mo.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b). Where did this fish come from? (check all that apply)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Lake – Upper (UL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Lake – Mid (ML)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Lake – Lower (LL)</td>
<td></td>
<td></td>
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</table>
Hair as biomarker of exposure

- Small hair sample tested for mercury
  - 1 centimeter = 1 month
- 5 times over one year (every 3 months)

![Graph showing hair mercury level associated with increased risk of heart attacks in middle-aged men in some studies.](image)

Median hair mercury level in women in nationwide U.S. study (NHANES)

EPA and FDA guideline for pregnant women and women of childbearing age

Hair mercury level associated with increased risk of heart attacks in middle-aged men in some studies

- Your hair mercury concentration

Mercury concentration (parts per million)

- 0.3
- 0
- 0.5
- 1
- 1.5
- 2
- 2.5
- 3

Report-back letter for participants

2. Methods and Approach
Grand Lake watershed fish

<table>
<thead>
<tr>
<th>Species*</th>
<th>Number of samples</th>
<th>Average mercury (parts per billion)</th>
<th>Range (parts per billion)</th>
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<tr>
<td>Flathead Catfish</td>
<td>38</td>
<td>220</td>
<td>46 – 700</td>
<td>24%</td>
<td>33”</td>
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<tr>
<td>Largemouth Bass</td>
<td>99</td>
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<td>11 – 340</td>
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<tr>
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<td>0</td>
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<tr>
<td>Drum</td>
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<td>40”</td>
</tr>
<tr>
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<td>39</td>
<td>15</td>
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*Includes species with at least 10 samples
## Grand Lake watershed fish

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Overall, only 3% of our fish samples exceed EPA’s guideline of 300 parts per billion

*Includes species with at least 10 samples

3. Mercury in Fish
Largemouth bass

Mercury (parts per billion, wet weight)

EPA guideline: 300 ppb

ODEQ guideline: 500 ppb

Length (inches)

Location
- Upper Grand
- Neosho River
- Spring River
- Lost Creek
- Twin Bridges
- Elk River
- Wolf Creek
- Mid Grand
- Sailboat Bridge
- Horse Creek
- Honey Creek
- Airport
- Duck Creek
- Ketchum
- Cabin Creek
- Dam
- Mid Hudson
- Lower Hudson
- Other
- Pond

3. Mercury in Fish

www.grandlakemercurystudy.org
Largemouth bass

Mercury (parts per billion, wet weight)

ODEQ guideline: 500 ppb

EPA guideline: 300 ppb

Length (inches)

3. Mercury in Fish
Flathead catfish

Mercury in Fish

EPA guideline: 300 ppb

ODEQ guideline: 500 ppb

Length (inches)

Mercury (parts per billion, wet weight)

Location
- Upper Grand
- Neosho River
- Elk River
- Mid Grand
- Horse Creek
- Duck Creek
- Other

www.grandlakemercurystudy.org
White bass

3. Mercury in Fish

www.grandlakemercurystudy.org
Stable carbon and nitrogen isotopes

- $\delta^{15}N$ (“del N 15”): Food web position
  - Increases up a food chain
- $\delta^{13}C$ (“del C 13”): Source of carbon in diet
  - Lower = more open water (pelagic)
  - Higher = closer to shore (littoral)
What can stable isotopes tell us?

**Mercury in Fish**

- **EPA guideline:** 300 ppb
- **ODEQ guideline:** 500 ppb

**Graph:**
- Y-axis: Mercury (parts per billion, wet weight)
- X-axis: Length (inches)
- Data points for different lengths and mercury levels are plotted for Flathead catfish.

**Legend:**
- Upper Grand
- Neosho River
- Elk River
- Mid Grand
- Horse Creek
- Duck Creek
- Other

**Questions:**
- What is the significance of point A?
- What is the significance of point B?
Higher del15N $\rightarrow$ higher mercury
del13C: carbon sources
del13C and mercury

3. Mercury in Fish

w w w . g r a n d l a k e m e r c u r y s t u d y . o r g
Our participants

- 152 regular participants started
- Goal for each participant over 1 year:
  - 5 food frequency questionnaires
  - 5 hair samples for mercury testing
- Fish logs between visits

Number of completed FFQs and hair samples:

- 1st: 152
- 2nd: 123
- 3rd: 104
- 4th: 123
- 5th: 109
Overall fish consumption frequency

Around three-quarters of participants ate fish: 2-3 times a month or once a week
4. Fish consumption

Most commonly eaten local fish

<table>
<thead>
<tr>
<th>Fish</th>
<th>Once a month or less</th>
<th>2-4 times a month</th>
<th>More than once a week</th>
</tr>
</thead>
<tbody>
<tr>
<td>crappie</td>
<td>18%</td>
<td>38%</td>
<td>5%</td>
</tr>
<tr>
<td>blue catfish</td>
<td>19%</td>
<td>28%</td>
<td>7%</td>
</tr>
<tr>
<td>channel catfish</td>
<td>11%</td>
<td>18%</td>
<td>4%</td>
</tr>
<tr>
<td>flathead catfish</td>
<td>14%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>white bass</td>
<td>18%</td>
<td>10%</td>
<td>3%</td>
</tr>
<tr>
<td>largemouth bass</td>
<td>12%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>spoonbill</td>
<td>9%</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>perch</td>
<td>9%</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>frogs</td>
<td>11%</td>
<td>3%</td>
<td>2%</td>
</tr>
</tbody>
</table>
Most commonly eaten non-local fish

- **Percent of Participants**
  - Shrimp: 36% (9% once a month or less, 9% 2-4 times a month, 18% more than once a week)
  - Light Tuna: 30% (9% once a month or less, 9% 2-4 times a month, 12% more than once a week)
  - Salmon: 19% (9% once a month or less, 9% 2-4 times a month, 1% more than once a week)
  - Tilapia: 13% (5% once a month or less, 11% 2-4 times a month, 1% more than once a week)
  - Fish Sticks or Nuggets: 4% (8% once a month or less, 2% 2-4 times a month, 1% more than once a week)
  - Albacore Tuna: 3% (3% once a month or less, 3% 2-4 times a month, 1% more than once a week)
  - Sardines: 3% (2% once a month or less, 3% 2-4 times a month, 1% more than once a week)
  - Sushi: 3% (2% once a month or less, 3% 2-4 times a month, 1% more than once a week)

4. Fish consumption
Compare to general population

**Our population**
Average: 51 grams per day (1.8 oz per day)  
Median: 24 grams per day (0.8 oz per day)

**General U.S. population (includes non fish eaters)***
Average: 20 grams per day (0.7 oz per day)

**U.S. fish consumers (includes only people who eat fish)***
Average: 129 grams per day (4.5 oz per day)

*Source: U.S. EPA *Exposure Factors Handbook*
Fish consumption rate

SALTWATER AND OTHER NON-LOCAL SOURCES OF FISH 31%

Tuna: 11%

Local Fish Species 69%

Catfish: 43%

Blue Catfish 22%
Channel Catfish 12%
Flathead Catfish 9%
Bass: 5%

Based on grams per day of fish consumption
Sources of dietary mercury

5. Mercury exposure

SALTWATER AND OTHER NON-LOCAL SOURCES OF FISH 38%

LOCAL FISH SPECIES 62%

Catfish: 44%
Bass: 4%
Hair mercury levels

1 part per million (ppm) is EPA guideline for children and women of child-bearing age.
5% of participants are above the EPA’s guideline value.
## How do our results compare?

<table>
<thead>
<tr>
<th></th>
<th>Median hair mercury level</th>
<th>% above reference dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>This study</td>
<td>0.15 μg/g</td>
<td>4.7%</td>
</tr>
<tr>
<td>NHANES (women 16-49)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General U.S.</td>
<td>0.19 μg/g&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7%&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>South (includes Oklahoma)</td>
<td>--</td>
<td>4.6%&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Non-coastal U.S.</td>
<td>--</td>
<td>2.1%&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>


- Reference dose: cautious guideline for mercury exposure in children and women of child-bearing age
- Median hair mercury level and fraction of participants above reference dose similar to general U.S. population
Good News

- Good news: mercury levels generally low
- Possible reasons:
  - Low emissions?
  - Selenium?
  - Mercury cycling within watershed?
- Tributaries and ponds might be higher in mercury than associated lakes
Bad News

• In spite of the low levels of mercury in Grand Lake...
  – 5% of project participants had elevated mercury in their hair.

• Many lakes in Oklahoma have much higher levels of mercury – especially S.E.
  – 32 lakes have advisories about fish consumption (27 have no advisory)
  – Elevated levels of mercury in hair are certainly much higher among fish consumers:
    • Given similar fish consumption rates.
Lakes with Mercury Advisories

- Atoka
- Boomer
- Broken Bow
- Canton
- Carlton
- Cedar
- Clayton
- Coalgate
- Draper
- Dripping Springs
- Elmer Thomas
- Ft. Supply
- Hugo
- Kaw
- Carl Albert
- Carl Blackwell
- Eufaula
- Heyburn
- Nanih Waiya
- Ozzie Cobb
- Talawanda #2
- Wayne Wallace
- Lloyd Church
- McAlester City
- McGee Creek
- Pine Creek
- Quanah Parker
- Rush
- Sardis
- Schooler
- Skiatook
- Wister
Length-normalized mercury
Largemouth bass, 60 Okla. lakes

Source of data: ODEQ
Collected 2008–2012 (mostly 2008)
Concentrations normalized to 14” length for comparison across lakes
Other lakes

- Lake Hudson
- Grand Lake
- Lake Ellsworth
- Lake Eufaula
- Fort Supply Reservoir
- Lake Hugo

Average mercury (ppb, wet weight)

Source of data: ODEQ
Top 25 Coal Plants for Mercury Emissions
## Mercury Emissions from Power Plants (2007)

<table>
<thead>
<tr>
<th>State</th>
<th>Lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oklahoma</td>
<td>1,451</td>
</tr>
<tr>
<td>Texas*</td>
<td>14,509</td>
</tr>
<tr>
<td>Luminant Generation (TX)</td>
<td>1501</td>
</tr>
</tbody>
</table>

* Five of the top ten U.S. coal plant Hg emitters are in Texas
Conclusions

• Grand Lake and Hudson lakes have low levels of Hg.
  – Even in these lakes, larger fish should be avoided.

• Many other lakes (>50%) have some level of advisory concerning mercury.
  – ODEQ advisories are based on 500 ppb.
Conclusions

• It is probable that a significant number of fish consumers in other areas of Oklahoma (especially in the S.E.), have elevated levels of mercury.
  – given fish consumption rates similar to what we found
  – other sources of mercury exposure should be considered when determining total dietary exposure.
Acknowledgements

• National Institute of Environmental Health Sciences, Grant number 1R21ES017941
• Study participants
• Community Advisory Board and Council of Fishing Experts
• Members of focus groups, NATURE meetings, and others who provided feedback
• Brent Gordon, Department of Wildlife Conservation
• Darrell Townsend, Brent Davis, Sam Ziara, GRDA
• ODEQ for data from other lakes
Sources of mercury (Hg)

Mercury emissions from human activities are around 3 times higher than emissions from natural sources

Natural sources
- Volcanoes
- Emissions from soils

Human sources
- Coal-fired power plants
- Incinerators
- Cement kilns
- Mining

25% 75%
Sources of mercury (Hg)

Hg from coal-fired power plants is released in 3 forms:

1. Reactive gaseous mercury (RGM) - 25-80%
   - tens of miles

2. Particulate mercury (Hgₚ) - 2-10%
   - hundreds of miles

3. Mercury vapor (Hg⁰) - 25-70%
   - globally

1. Background
Bacteria in sediments can convert inorganic mercury from the atmosphere and runoff into methylmercury.

Factors that promote methylmercury formation:
- ↓ dissolved oxygen
- ↑ organic matter
- ↑ acidity
- ↑ sulfate
Health effects of mercury

• Unborn and young children most sensitive
  – Effects on brain development
  – Impaired motor skills and learning problems

• Effects in adults less well-understood
  – High levels of exposure associated with impaired movement, speech and vision
  – Conflicting evidence whether lower levels of exposure are associated with heart attacks in middle-aged men