STUDY ON MERCURY AND RISK ASSESSMENT FROM CONSUMPTION OF FISH IN WEST PENINSULAR MALAYSIA

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OVERVIEW

- Introduction
  - What is mercury (Hg?)
  - Different forms of Hg
  - Application of Hg
  - Sources of Hg
  - Importance of Hg
  - Routes of exposure
  - Health effects of mercury
  - Examples of mercury poisoning
    - Minamata Disease

- Study objectives
- Methodology
- Results & Discussions
- Conclusions
INTRODUCTION

- What is mercury (Hg)?
  - Known in ancient time as ‘hydragyros’
  - Hydra (water); Agyros (Silver)
  - Also known as ‘quicksilver’
  - Exists as liquid
INTRODUCTION

- Hg exists in 3 different forms:
  - Elemental Hg (Hg$^0$)
  - Inorganic Hg (Hg$^{2+}$, Hg$^+$)
  - Organic Hg (CH$_3$Hg$^+$)

<table>
<thead>
<tr>
<th>Elemental Hg</th>
<th>Inorganic Hg</th>
<th>Organic Hg</th>
</tr>
</thead>
</table>
| - Silver in colour  
- Liquid at room temperature  
- Fat soluble & bioaccumulates  
- Vaporises easily and can be absorbed dermally | - Water soluble salts (e.g Mercury chloride)  
- Inorganic Hg is converted to MeHg by bacteria | - MeHg is fat soluble (and therefore insoluble in water) but found in waterways and bioaccumulates |
INTRODUCTION

- Wide use of applications:
  - Art (pigment)
  - Science (thermometer)
  - Medicine (treatment of syphilis, dental amalgam, vaccines)
  - Agriculture (pesticides)
  - Industries (cathode in electrolytic production of caustic soda)
SOURCES OF MERCURY

Regional mercury emissions in 2010

Source: UNEP (2013)
ROUTES OF EXPOSURE

- **Inhalation**
  - Primary route for elemental mercury
  - 75 percent to 80 percent is absorbed by lungs

- **Skin or Eye Contact**
  - Absorbed slowly through skin
  - Causes irritation to skin and eyes and possibly contact dermatitis

- **Ingestion**
  - Methyl mercury completely absorbed and not readily eliminated
HEALTH EFFECTS OF MERCURY

- A potent neurotoxin that inhibits the production of neurotransmitters and creates serious imbalances in the development of the brain.

- Mercury can cross the blood, brain and placental barriers, posing an increased risk to children.

- Children can be exposed to Hg through their mother’s blood while infants can be exposed through breast milk.

- High risk groups: developing fetus, infants, children, pregnant mothers.
Why is Hg important?

BIOACCUMULATION / BIOMAGNIFICATION

1. Pollutants get into the sediment or water from man-made or natural processes

2. Plants and small organisms absorb/ingest the pollutants, including juvenile fish.

3. Large fish eat smaller fish.

4. Top predators (man, eagles, raccoons) eat the big fish
Why is Hg important?

- Fish consumption is the major pathway to Hg exposure in humans (Clarkson 2002)
Fish is good food

• Cheap supply of protein & minerals
• Contain omega-3 fatty acids (EPA & DHA)
• May reduce cholesterol levels & incidence of heart disease
• Reduce risk of Alzheimer's disease
• Per capita consumption is at 58 kg per person (Nurnadia et al. 2011)
CLASSIC EXAMPLES OF MERCURY POISONING

- Minamata Disease
  - A form of methyl mercury poisoning caused by eating large quantities of fish and shellfish polluted by methyl mercury
  - It is not a contagious disease nor inherited
  - Number affected: > 12 000 people
  - Symptoms:
    - numbness and unsteadiness in the legs and hands
    - tiredness
    - ringing in the ears
    - narrowing of the field of vision
    - loss of hearing
    - slurred speech
    - awkward movements
OBJECTIVES OF STUDY

- To determine the concentrations of mercury (Hg) and methyl mercury (MeHg) in commonly consumed fish and other seafood (molluscs, crustaceans) in West Peninsular Malaysia.

- To estimate the risk of Hg contamination through seafood consumption by Malaysians.

- To assess risk of consumption of fish and other seafood by comparing Hg and MeHg concentrations to Malaysian Food Regulation guidelines and Provisional Tolerable Weekly Intake (PTWI).
METHODOLOGY

STUDY LOCATION

- M1 - Wholesale market
- M2 - Wholesale market
- L1 – Landing site

SAMPLE

- N= 110 samples
- freeze-dried
- 50 ml centrifuge tubes

Map of sampling locations in West Peninsular Malaysia

NEHAP CONFERENCE 2015
“Exposure assessment of selected contaminants from consumption of seafood in Peninsular Malaysia”

<table>
<thead>
<tr>
<th>Types of seafood</th>
<th>Frequencies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mackerel</td>
<td>70.9</td>
</tr>
<tr>
<td>Prawn</td>
<td>26.6</td>
</tr>
<tr>
<td>Yellow tail scad</td>
<td>26.2</td>
</tr>
<tr>
<td>Black pomfret</td>
<td>22.6</td>
</tr>
<tr>
<td>Tuna</td>
<td>21.8</td>
</tr>
<tr>
<td>Hair-tail scad</td>
<td>20.9</td>
</tr>
<tr>
<td>Spanish mackerel</td>
<td>20.9</td>
</tr>
<tr>
<td>Squid</td>
<td>21.3</td>
</tr>
<tr>
<td>Red snapper</td>
<td>14.7</td>
</tr>
<tr>
<td>Threadfin bream</td>
<td>11.2</td>
</tr>
<tr>
<td>Stingray</td>
<td>10.6</td>
</tr>
<tr>
<td>Catfish</td>
<td>7.3</td>
</tr>
<tr>
<td>Barramundi</td>
<td>7.2</td>
</tr>
<tr>
<td>Croaker</td>
<td>5.4</td>
</tr>
</tbody>
</table>

The most preferred seafood consumed among Malaysians based on dietary survey in Peninsular Malaysia (Nurul et al. 2015)
TOTAL MERCURY ANALYSIS

0.07 g of freeze-dried fish + 1 ml HNO₃ → Digestion (1 hour)

ICP-MS

Dilute 1:10 (auto dilutor)

9 ml H₂O

Reference: Baldwin et al. (1994)
METHYL MERCURY ANALYSIS

0.2 g of freeze-dried fish

8 ml phosphate buffer + 20 mg protease type XIV in 0.05% cysteine

incubate

37 °C; 120 min; 20 rpm

Add 2 ml phosphate buffer

Centrifuge: 20 min, 3000 rpm

Filter

HPLC-ICP-MS

Reference: Rai et al. (2002)
METHODOLOGY

Calculation of Provisional Tolerable Weekly Intake (PTWI)

PTWI (µg/kg⁻¹)

= Mean Hg in fish (µg/g⁻¹ wet weight) x Weekly fish consumption (g)

_____________________________________________________________________

Body weight (kg)
Provisional Tolerable Weekly Intake (PTWI)

"Is the amount of a substance that can be consumed weekly over an entire lifetime without appreciable risk to health and is an end-point used for food contaminants (such as heavy metals with cumulative properties). Its value represents permissible human weekly exposure, protecting the most susceptible part of the population, to those contaminants unavoidably associated with the consumption of otherwise wholesome and nutritious foods”

-Joint FAO/WHO Expert Committee on Food Additives (JECFA).
Table 1: The recommended levels for mercury and methyl mercury in fish and seafood by various organizations

<table>
<thead>
<tr>
<th>Country/Organization</th>
<th>Fish Type</th>
<th>Maximum allowed/recommended levels*</th>
<th>Type of Measure</th>
<th>Tolerable intake levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>All fish except predatory fish</td>
<td>0.5 mg/kg methyl mercury</td>
<td>Food Act 1983 and Food Regulations 1985</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Predatory fish (e.g. shark, swordfish, tuna, pike and others)</td>
<td>1 mg/kg methyl mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>Fish known to contain high levels of mercury e.g. swordfish, southern bluefin tuna, barramundi, ling, orange roughy, rays, shark</td>
<td>1.0 mg/kg mercury</td>
<td>The Australian Food Standards Code</td>
<td>Tolerable Weekly Intake: 2.8 μg/kg Hg body weight per week for pregnant women</td>
</tr>
<tr>
<td></td>
<td>All other species of fish, crustaceans and mollusks</td>
<td>0.5 mg/kg mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHO/FAO</td>
<td>All fish except predatory fish</td>
<td>0.5 mg/kg methyl mercury</td>
<td>FAO/WHO Codex alimentarius guideline level</td>
<td>JECFA provisional tolerable weekly intake: 3.3 μg/kg methyl mercury body weight per week</td>
</tr>
<tr>
<td>United States of America</td>
<td>Fish, shellfish and other aquatic animals</td>
<td>1 ppm methyl mercury</td>
<td>FDA action level Local trigger level</td>
<td>US EPA reference dose: 0.1 μg/kg methyl mercury body weight per week.</td>
</tr>
<tr>
<td></td>
<td>States, tribes and territories are responsible for issuing fish consumption advise for locally caught fish; Trigger level for many state health departments</td>
<td>0.5 ppm methyl mercury</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

Factors influencing Hg and MeHg concentrations

- Length *(the bigger the fish, the higher the Hg concentrations)*
- Trophic level *(fish on higher trophic level has higher Hg concentrations)*
- Habitat *(benthic fish vs pelagic fish)*
RESULTS

Hg concentrations vs length

slope = 0.006, adjusted $r^2 = 0.064$, $F_{1,104} = 8.144$, $p = 0.005$
RESULTS

MeHg concentrations vs length

slope = 0.06, adjusted $r^2 = 0.051$, $F_{1,28} = 2.549$, $p = 0.122$
RESULTS

Relationship between Hg concentrations and $\delta^{15}N$

slope = 0.015, adjusted $r^2 = -0.022$, $F_{1, 41} = 0.076$, $p = 0.784$
RESULTS

Relationship between MeHg concentrations and $\delta^{15}N$

\[ \text{slope} = -0.015, \text{ adjusted } r^2 = -0.064, F_{1, 14} = 0.159, p = 0.696 \]
RESULTS

Hg concentrations between habitat

MeHg concentrations between habitat
RESULTS

Table 2: Hg concentrations in molluscs, crustaceans and fish of West Peninsular Malaysia (n=110)

Hg maximum allowed levels = 0.5 mg/kg
RESULTS

Table 3: MeHg concentrations in molluscs, crustaceans and fish of West Peninsular Malaysia (n=32)

![Graph showing MeHg concentrations in various species compared to maximum allowed levels]

Hg maximum allowed levels = 0.5 mg/kg
Table 4: Estimation of allowable seafood intake on weekly and daily basis

<table>
<thead>
<tr>
<th>Common name</th>
<th>n</th>
<th>Mercury (µg/g ww)</th>
<th>Weekly consumption (g)</th>
<th>Daily consumption (g)</th>
<th>Daily portion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catfish</td>
<td>4</td>
<td>0.02</td>
<td>15415</td>
<td>2202</td>
<td>14</td>
</tr>
<tr>
<td>Prawn</td>
<td>5</td>
<td>0.04</td>
<td>8323</td>
<td>1189</td>
<td>7</td>
</tr>
<tr>
<td>Pomfret</td>
<td>5</td>
<td>0.04</td>
<td>7456</td>
<td>1065</td>
<td>7</td>
</tr>
<tr>
<td>Shrimp</td>
<td>10</td>
<td>0.04</td>
<td>7389</td>
<td>1056</td>
<td>7</td>
</tr>
<tr>
<td>Squid</td>
<td>13</td>
<td>0.05</td>
<td>6013</td>
<td>859</td>
<td>5</td>
</tr>
<tr>
<td>Mackerel</td>
<td>20</td>
<td>0.06</td>
<td>5148</td>
<td>735</td>
<td>5</td>
</tr>
<tr>
<td>Scad</td>
<td>9</td>
<td>0.09</td>
<td>3288</td>
<td>470</td>
<td>3</td>
</tr>
<tr>
<td>Croaker</td>
<td>8</td>
<td>0.10</td>
<td>3107</td>
<td>444</td>
<td>3</td>
</tr>
<tr>
<td>Stingray</td>
<td>7</td>
<td>0.11</td>
<td>2800</td>
<td>400</td>
<td>2</td>
</tr>
<tr>
<td>Tuna</td>
<td>5</td>
<td>0.14</td>
<td>2218</td>
<td>317</td>
<td>2</td>
</tr>
<tr>
<td>Snapper</td>
<td>13</td>
<td>0.15</td>
<td>2083</td>
<td>298</td>
<td>2</td>
</tr>
<tr>
<td>Barramundi</td>
<td>4</td>
<td>0.18</td>
<td>1759</td>
<td>251</td>
<td>2</td>
</tr>
<tr>
<td>Bream</td>
<td>7</td>
<td>0.21</td>
<td>1516</td>
<td>217</td>
<td>1</td>
</tr>
</tbody>
</table>

# Weekly consumption is estimated based on PTWI of 5 µg/kg Hg and 64 kg body weight
^ Daily consumption is derived from weekly consumption divided by 7 days
*Daily portion of fish equals to 160 g serving (equivalent to daily fish consumption by average Malaysian)
GUIDELINES ON FISH CONSUMPTION

- **Prawn**: >10 portions/day
- **Shrimp**: Up to 7 portions/day
- **Catfish**: Up to 5 portions/day
- **Pomfret**: Up to 3 portions/day
- **Squid**: Up to 2 portions/day
- **Mackerel**: Up to 1 portion/day
- **Scad**: 1 portion/day
- **Croaker**: 1 portion/day
- **Stingray**: 1 portion/day
- **Tuna**: 1 portion/day
- **Snapper**: 1 portion/day
- **Bream**: 1 portion/day
- **Barramundi**: 1 portion/day
Conclusions

• Hg concentrations were influenced by length, but not tropic levels and habitat

• Hg and MeHg concentrations were within safe limits of 0.5 mg/kg

• None of the fish and seafood exceed the PTWI hence presents no risk for human consumption
Acknowledgements

• EHRC Staff
• Dr Nurul Izzah
• Dr Simon Foster
• Prof William Maher
• Mr Frank Krikowa
• IAE labmates
QUESTIONS??

COUNTERTHINK
"SEAFOOD MERCURY WARNING"

SO WHY ARE WE NOT SUPPOSED TO EAT HUMANS ANYMORE?

BECAUSE THEY CONTAIN TOXIC LEVELS OF MERCURY, THANKS TO ALL THE FILLINGS IN THEIR TEETH.

CONCEPT: MIKE ADAMS  ART: DAN BERGER  WWW.NATURALNEWS.COM

NEHAP CONFERENCE 2015
Happiness is like jam
You can’t spread even a little without getting some on yourself
Anonymous