TOXIC ENVIRONMENTS & TOXIC BODIES

Mercury in the South African Environment

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Introduction

- Mercury in South African Environment
- Mercury human health risk
- Summary
- Way Forward
Toxic Environments - Mercury

- Mercury, also known as quick silver, is ubiquitous in the environment

- Uses
  - Medical: medicines, thermometers, dental amalgam, etc.
  - Manufacturing industry: batteries, gold mining, chlorine production, cement production, etc.
  - Personal care products: make up, e.g. mascara, skin lighteners, anti-aging products, etc.
Toxic Environments - Mercury

Sources

- Natural degassing of the earth
- Fossil fuel combustion process – e.g. coal based electricity generation
- Biomass burning
- Industrial discharges and wastes, e.g. medical waste streams
- Incineration & crematories

Hg is found in all environmental compartments
- air
- water
- soil/sediment
- biota

Inorganic and organic mercury

- Elemental Hg
- Divalent Hg
- Methylmercury

\[
\begin{align*}
\text{Hg}^0 & \rightarrow \text{Hg}^{2+} & \rightarrow \text{CH}_3\text{Hg}^+ \\
\end{align*}
\]
Mercury in the South African Environment

- **Emissions**
  - Coal combustion
    - 82.6 tonnes Hg p.a. → Stationery sources (2000)
      - 50.4 tonnes Hg p.a. → Coal fired power plants
        - Per capita emissions → 1.24 g Hg per person\(^{-1}\) y\(^{-1}\) R\(^{-1}\)
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  - Gold mining
    - Gold extraction & refining processes → 706 tonnes p.a. → 193 Hg kg yr\(^{-1}\)
    - Decline gold production → 204.9 tonnes p.a. (2009) → lower emissions
    - No estimates for artisanal gold mining

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Dabrowski et al., 2008; Pacyna et al., 2006; Schroeder et al., 1982; Chamber of Mines 2009
(http://www.bullion.org.za/)
Mercury in the South African Environment

- Air concentrations

  - Cape Point Global Atmospheric Watch Station

  - Total gaseous mercury (TGM)
    - 1.2 - 1.4 ng/m$^3$ (1995-1999)

  - Gaseous elemental mercury (GEM)
    - below detection limit (0.05 ng/m$^3$) – 5.88 ng/m$^3$ (2007-2008)

  - TGM: 1.5 ng/m$^3$ - biomass burning episode in the Cape Peninsula

- Coal fired power plants
  - Hg$^0$ → 0.25 ng/m$^3$; Hg$^{2+}$ → 0.19 ng/m$^3$; Hg$^0$ → 0.04 ng/m$^3$

Baker et al., 2002; Carter, W. 2009; Brunke et al., 2010
Mercury in the South African Environment

- **Surface Water**
  - Rivers: Eerste/Kuils, Silvermine, Liesbeeck, Black (Western Cape) and Steenkoolspruit (Mpumalanga)
  - MeHg $\rightarrow$ 0.1 – 0.9 ng/L

- Water Management Areas: Inkomati, Olifants and Upper Vaal
  - T-Hg > global average (5 ng/L) in 38% of samples
  - MeHg $\rightarrow$ below detection limit (0.02 ng/L) to 2.73 ng/L

- Concentrations below SA target value 1 μg/L

Learner et al., 2009; Williams et al., 2010
## Mercury in the South African Environment

<table>
<thead>
<tr>
<th>Freshwater Fish</th>
<th>Marine Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WMA</strong></td>
<td><strong>Site</strong></td>
</tr>
<tr>
<td>Inkomati</td>
<td>Durban Harbour</td>
</tr>
<tr>
<td>Upper Vaal</td>
<td>False Bay</td>
</tr>
<tr>
<td>uMvoti/ uMzimkhulu</td>
<td>West Coast</td>
</tr>
</tbody>
</table>
## Human Health Risks – Hg poisoning

<table>
<thead>
<tr>
<th>Place</th>
<th>Year</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minamata</td>
<td>1953-60</td>
<td>1 000</td>
</tr>
<tr>
<td>Nigata</td>
<td>1964-65</td>
<td>646</td>
</tr>
<tr>
<td>Guatemala</td>
<td>1963-65</td>
<td>45</td>
</tr>
<tr>
<td>Ghana</td>
<td>1967</td>
<td>144</td>
</tr>
<tr>
<td>Pakistan</td>
<td>1969</td>
<td>100</td>
</tr>
<tr>
<td>Iraq</td>
<td>1956</td>
<td>100</td>
</tr>
<tr>
<td>Iraq</td>
<td>1960</td>
<td>1 002</td>
</tr>
<tr>
<td>Iraq</td>
<td>1971</td>
<td>40 000</td>
</tr>
</tbody>
</table>
Mercury – Health Effects

- Blindness – deafness
- Cerebral Palsy – seizures
- Abnormal reflexes and muscle tone
- Retarded/delayed motor development
- Visual and auditory deficits
- Impaired mental development
Human Health Risks

- Dose-response

- Risk = Hazard * Exposure

- Individual susceptibility

- Scenario development
  - Scenario 1: 1 fish meal every day of the week
  - Scenario 3: 1 fish meal per week
  - Fish meal – 227 g/day
  - Adult: >18 yrs
  - Child: 10 yrs
# Mercury Health Risks – Freshwater Fish

Health risks from air and water were negligible.

<table>
<thead>
<tr>
<th>WMA</th>
<th>Species</th>
<th>Hazard Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Adult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berg</td>
<td>Silverfish, Catfish; Yellowfish</td>
<td>1.44 – 2.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.03 – 0.35)</td>
</tr>
<tr>
<td>Upper Vaal</td>
<td>Yellow fish; Banded Tilapia</td>
<td>0.16 – 0.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.01 – 0.10)</td>
</tr>
<tr>
<td>Inkomati</td>
<td>Largemouth bass</td>
<td>6.68 (0.95)</td>
</tr>
<tr>
<td>uMvoti/Umzimkhulu</td>
<td>Banded tilapia; Yellowfish; Red breast tilapia</td>
<td>1.15 - 4.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.04 – 0.63)</td>
</tr>
</tbody>
</table>

Adult = >18 yrs; Child = 10 yrs; S1 – Scenario 1; S3 = Scenario 3
# Mercury Health Risks – Marine Fish

<table>
<thead>
<tr>
<th>Sites</th>
<th>Species</th>
<th>HQ Adult</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durban</td>
<td>Red roman Mullet</td>
<td>1.21 – 7.59 (0.58 – 1.13)</td>
<td>3.58 – 21.26 (0.50 – 5.04)</td>
</tr>
<tr>
<td>False bay</td>
<td>Red roman Yellowtail</td>
<td>3.50 – 12.12 (1.56 – 5.40)</td>
<td>9.79 – 33.92 (1.45 – 5.04)</td>
</tr>
<tr>
<td>Kalk Bay</td>
<td>Hottentot seabream Blueskin seabream</td>
<td>1.42 – 1.87 (0.63 – 0.83)</td>
<td>3.97 – 5.23 (0.59 – 0.78)</td>
</tr>
<tr>
<td>West Coast</td>
<td>Kob, Red panga; Silversfish, White stumpnose</td>
<td>3.16 – 12.21 (1.41 – 5.44)</td>
<td>3.95 – 15.23 (1.55 – 5.08)</td>
</tr>
</tbody>
</table>

Adult = >18 yrs; Child = 10 yrs; S1 – Scenario 1; S3 = Scenario 3
Mercury Health Risks

- Artisanal gold mining community’s Hg exposure

  - T-Hg below the target value for South Africa (1 μg/L)
  - T-Hg in fish was 0.34 μg/g
  - 20% of respondents used coal for cooking
  - 57.1% of the urine sample levels were at or above the guideline of 5 μg/g creatinine
  - 21% of the blood sample levels were at or above the guideline of 10 μg/L
  - The maximum levels detected in the urine and blood were above the occupational Biological Exposure Index (BEI) for South Africa, which is 35 μg/g creatinine for urine and 15 μg/L for blood.

Oozthuizen et al., 2010
Human Health Risks

- Hg and Selenium (Se)

- Hg exposure and potential to cause adverse effects is mediated by selenium. Therefore, there may be cases where Hg exposure is elevated but the impacts are minimal.

- Suggests that Hg risk assessments need to account for Se antagonistic role in the developing Hg associated adverse effects
Summary

- Hg emissions increasing globally
  - South Africa is a significant contributor to total global Hg emissions
  - Source contributions from other sources not clearly known

- Ambient air and surface water concentrations very low. Exposure from these media unlikely to pose a health risk to the exposed.

- Fish tissue concentration indicate bioaccumulation and biomagnification – predatory fish – exposure potentially high for sensitive consumers – adverse effects more likely.

- South Africa has vulnerability issues which enhance people’s susceptibility to environmental exposures.
Way Forward

- A better understanding of other source emissions, e.g. biomass burning, cement production, etc.

- Improved monitoring systems for sensitive ecosystems, e.g. wetlands, to establish trends

- A better understanding of concentrations in fish species and other food types.

- A better understanding of South African fish consumption patterns

- Characterisation of adverse health impacts particularly for people with high fish consumption levels
Thank you