Arsenic in the Environment: Health Effects and Risk Assessment

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Characteristics
Sources
Uses
Arsenic Characteristics

• Most natural waters contain inorganic species
  – As (III) or arsenite predominant in ground waters \( \text{H}_3\text{AsO}_3 \)
  – As (V) or arsenate in surface waters \( \text{H}_2\text{AsO}_4 \) & \( \text{HAsO}_4^{-2} \)
### Natural Arsenic Levels

<table>
<thead>
<tr>
<th>Environment</th>
<th>Levels Range</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystalline Rock</td>
<td>Avg. 2 ppm</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>1-40 ppm</td>
<td></td>
</tr>
<tr>
<td>Ground Water</td>
<td>0.01 – 800 ppb</td>
<td>As high as 40,000 in hot springs</td>
</tr>
<tr>
<td>Surface Water</td>
<td>2.38 – 65 ppb</td>
<td>As high as 22,000 in river water</td>
</tr>
</tbody>
</table>
Some Arsenic Uses/Anthropogenic Sources

- Smelting of metals
- Pharmaceutical industry (medicines)
- Pesticide manufacture (very limited)
- Wood preservative – CCA [in phase out]
- Cattle and sheep dips
- Feed additives
- Dye stuffs
- Petroleum, coal, and wood burning
- Semiconductor manufacture
- Waste incineration
Toxicokinetics
Toxicokinetics

• Absorption
  – Soluble forms
    • Humans – 40% to complete absorption
    • Animals – 50% to complete absorption
  – Insoluble forms
    • Limited absorption
Toxicokinetics cont.

• Distribution
  – Found in all humans – Blood conc. (1-5 ppb)
    • Smokers (2 – 10 ppb)
    • Occupational exposure (~10 ppb)
    • Taiwan (20 – 60 ppb)
    • Poisonings (1,000 – 2,000 ppb)
Distribution

• Highest levels (ppb)
  – Nails (0.89)
  – Hair (0.18)
  – Bone (0.07 – 0.12)
  – Heart, kidney, liver, lung (0.03 – 0.05)
Metabolism of Inorganic Arsenic

- Reduction
- Methylation

\[ \text{iAs}^5 \rightarrow \text{iAs}^3 \]
\[ \text{SAM} \rightarrow \text{SAH} \]
\[ \text{MA}^5 \rightarrow \text{MA}^3 \]
\[ \text{SAM} \rightarrow \text{SAH} \]
\[ \text{DMA}^5 \rightarrow \text{DMA}^3 \]
\[ \text{SAM} \rightarrow \text{SAH} \]
\[ \text{TMA}^5 \rightarrow \text{TMA}^3 \]
Excretion

- Primarily via urine
  - 60% - 95% in 5 days
- Fecal excretion low
Adverse Health Effects

Non-Cancer
# Acute Toxicity

<table>
<thead>
<tr>
<th>Animal</th>
<th>LD$_{50}$ (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rats</td>
<td>15 - 293</td>
</tr>
<tr>
<td>Mice</td>
<td>26 - 43</td>
</tr>
<tr>
<td>Guinea pigs</td>
<td>9</td>
</tr>
<tr>
<td>Humans</td>
<td>1 - 4 (approx)</td>
</tr>
</tbody>
</table>
Acute Effects – Humans
(est. LD$_{50}$ ~ 1-4 mg/kg)

- Peripheral neuropathy
- Anemia
- Renal and liver dysfunction
- Skin pigmentation
- EKG abnormalities
- Severe GI effects
Chronic Toxicity: Humans
Vascular

• Taiwan
  – Blackfoot disease

• Poland
  – Vintners
  – 6 cases of gangrene

• Chile
  – Raynaud’s disease
Chronic Toxicity: Humans

• Nervous system
  – Peripheral neuropathy – legs and arms

• Cranial nerves
  – Loss of hearing in Japanese infants
Adverse Health Effects

Cancer
Countries Reporting Tumors After Arsenic Exposure

- Taiwan
- Mexico
- Argentina
- Chile
- China
- Mongolia
- Japan
Cancers Associated with Exposure to Arsenic in Drinking Water

- Skin
- Bladder
- Lung
- Kidney
- Liver
- Prostate
Lifetime Risk of Cancer (per 1000)

- ED$_{01}$ = Effective dose (central estimate) at which 1% of population is affected by the contaminant
- LED$_{01}$ = Lower limit of range with 95% certainty of being the effective dose for 1%
- MOE = Ratio of LED$_{01}$ divided by MCL option (300/50) = 6

Point of Departure (PoD)

--- Margin of Exposure ---
(MOE)