Metal toxicity in Magela Creek, northern Australia

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Ranger uranium mine

- Surrounded by World Heritage- and Ramsar-listed Kakadu National Park
- Commenced mining in 1981
- Due to be rehabilitated by 2026
- Subject of much research and intensive annual monitoring (water chemistry, in situ toxicity, biological monitoring) to ensure environmental protection
Ranger uranium mine
Ranger uranium mine

Contaminants of potential concern (CoPCs)

- **Uranium** – in ore, waste rock
- **Manganese** – processing chemical
- **Magnesium** – in ore, in waste rock
- **Ammonia** – processing chemical
Magela Creek

Water quality

Summary
Magela Creek

Water quality

Wet season

![Graph of Electrical Conductivity (S/cm) from 01 Dec 17 to 01 May 18 showing data for Magela Creek Upstream EC and Magela Creek Downstream EC. The investigation trigger is 42 S/cm for >6 hours. Data covers the period 2017-2018.](image-url)
Uranium toxicity

- All species (in prep Aust/NZ default guideline value)
- Local species in Magela Creek water
Uranium toxicity

Site-specific criterion

DOC correction

DOC modified U GV = GV_2 / (1 + 2 \times 0.09) \times (1 + DOC_{c_k} \times 0.09)

<table>
<thead>
<tr>
<th>DOC in creek water (mg/L)</th>
<th>DOC modified U guideline value (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>4</td>
<td>3.2</td>
</tr>
<tr>
<td>5</td>
<td>3.4</td>
</tr>
<tr>
<td>6</td>
<td>3.7</td>
</tr>
<tr>
<td>7</td>
<td>3.9</td>
</tr>
<tr>
<td>8</td>
<td>4.1</td>
</tr>
<tr>
<td>9</td>
<td>4.3</td>
</tr>
<tr>
<td>10</td>
<td>4.5</td>
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<tr>
<td>15</td>
<td>5.6</td>
</tr>
<tr>
<td>20</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Manganese toxicity

- All species (in prep Aust/NZ default guideline value)
- Local species in Magela Creek water

Harford et al. (2015)
Magnesium toxicity

- Can’t compare chronic toxicity with other species, as no data for other species (generally been considered as being of no toxicological concern)
- BUT, results speak for themselves

van Dam et al. (2010)
Magnesium toxicity

- Mg in mine waters also accompanied by some Ca
  - What effect on Mg toxicity?

Effect of Ca on Mg toxicity

- Ca reduces toxicity of Mg, but extent of this is species-specific

van Dam et al. (2010)
Magnesium toxicity

- Re-assessed Mg toxicity, this time at a constant Mg:Ca ratio of 9:1

Mg chronic toxicity in Magela Creek water

@ Mg:Ca (mass) ratio 9:1

- 99% species protection criterion when Mg:Ca ratio <9:1 = 3 mg Mg/L (or ~42 µS/cm)
  - cf. 0.8 mg Mg/L at background [Ca]

van Dam et al. (2010)
## Magnesium toxicity

- Additional lines of evidence using data from:
  - **Mesocosms** – phytoplankton, zooplankton, macroinvertebrates
  - **Field study** – macroinvertebrates

<table>
<thead>
<tr>
<th>Threshold response and calculation</th>
<th>EC₁ or threshold for Mg (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Billabong macroinvertebrates</strong></td>
<td></td>
</tr>
<tr>
<td>GTB similarity</td>
<td>5.6</td>
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<tr>
<td>GTB taxa number</td>
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</tr>
<tr>
<td>SSD: All sites</td>
<td>4.7</td>
</tr>
<tr>
<td>SSD: GTB</td>
<td>5.0</td>
</tr>
<tr>
<td>TITAN: All sites</td>
<td>2.4</td>
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<tr>
<td><strong>Mesocosms</strong></td>
<td></td>
</tr>
<tr>
<td>Zooplankton: 4 weeks: Similarity</td>
<td>2.4</td>
</tr>
<tr>
<td>Zooplankton: 4 weeks: Taxa number</td>
<td>2.3</td>
</tr>
<tr>
<td>Chlorophyll a concentration: 4 weeks</td>
<td>1.5</td>
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<tr>
<td>Chlorophyll a concentration: 8 weeks</td>
<td>2.7</td>
</tr>
</tbody>
</table>

- At the community level, high sensitivity to Mg, and this is relatively independent of Ca concentration
- Supports lab-derived GV

McCullough (2002); Humphrey & Chandler (2018); Mooney et al (in prep)
Magnesium toxicity

- **BUT**, mine discharges occur in pulses

- Derived GVs for different pulse exposure durations, and developed an exposure duration v GV model

Wrap up

Environmental protection of a World Heritage and Ramsar site from mining

Several characteristics of local water quality favouring higher metal bioavailability / toxicity

= Inadequacy of national generic GVs and need to develop site-specific criteria for our ion poor waters

- We have attempted to focus on highest priority CoPCs and most influential modifiers of their toxicity
- Ion poor waters more prevalent than previously thought – numerous issues to consider
- Currently seeking to validate use of multiple single toxicant derived criteria (mixture modelling)
Acknowledgments

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