Determining the Aquatic Toxicity of Deicing Materials

- Laboratory-based study to evaluate the aquatic toxicity of liquid deicing chemicals
- Acute and “chronic” tests
- Test species
  - *Ceriodaphnia dubia*
    - Water flea, zooplankton
  - *Pimephales promelas*
    - Fish, fathead minnow
  - *Selenastrum capricornutum*
    - Algae
The Laboratory
Study Design

• Acute and chronic toxic effects
• Acute
  – 48 to 96 hour test
  – Measure survival
• Chronic
  – 7 day test (C. dubia, fathead)
  – 4 day test (algae)
  – Measure growth, reproduction, and survival
• Measureable outcome-endpoints
Study Design endpoints

- **LC50**
  - Concentration at which there is a 50% reduction in survival...

- **IC25**
  - Concentration at which there is a 25% reduction in young production, growth...

- **IC50**
  - Concentration at which there is a 50% reduction in young production, growth...

- **NOEC**
  - Highest concentration at which there is no toxicity...

...compared to the controls
Study Design

• Dose-response
  – Add a range of volumes of deicing chemical to water
  – Get a range of responses from the test organisms
  – Result is a curve showing how the organism responds
Products Evaluated

1. Watershed Cl inhibitor with sodium chloride salt brine
2. Beet 55 inhibitor with sodium chloride salt brine
3. FreezGard Cl Plus inhibitor-magnesium chloride
4. Meltdown Apex inhibitor-magnesium chloride
5. Road Guard Plus inhibitor-calcium chloride
6. Boost inhibitor-calcium chloride
7. CF-7 inhibitor-potassium acetate
8. Apogee-glycerol
Toxicity Test Dose-Response Example: Watershed CI

Fathead Minnows: Growth

product concentration (grams product per liter of MH laboratory water)

FH Minnow Weight (mg) - Day 7 of Test

control

chronic

resourceful. naturally.
Toxicity Test Dose-Response Example: Watershed CI

*Ceriodaphnia dubia*: Reproduction

C. *dubia* Mean Young Production-Day 7 of Test

Product Concentration (grams product per liter of MH laboratory water)

control

chronic
Toxicity Test Dose-Response Example: Watershed CI

**Selenastrum capricornutum:** Growth

Mean Cell Production in Millions-Day 4 of Test

Product Concentration (grams product per liter of MH laboratory water)
Toxicity Test Dose-Response Example: Watershed CI

Acute and Chronic

Fathead Minnows: Survival

- 96 Hour: Acute
- 7-Day: Chronic

Product Concentration (grams product per liter of MH laboratory water)
Toxicity Test Dose-Response Example: Watershed CI

Ceriodaphnia dubia: Survival

Acute and Chronic

Product Concentration (grams product per liter of MH laboratory water)
Endpoints example
RoadGard Plus

Fathead Minnows: Growth

IC25 = 2.46

25% reduction

Product Concentration (grams product per liter of MH laboratory water)

FH Minnow Weight (mg) - Day 7 of Test

resourceful. naturally.
Endpoints example

RoadGard Plus

Fathead Minnows: Growth

IC50 = 3.30

50% reduction

Product Concentration (grams product per liter of MH laboratory water) vs. FH Minnow Weight (mg)-Day 7 of Test

Slide 13
### Endpoint Tables

**mass based**

**Ceriodaphnia dubia**

<table>
<thead>
<tr>
<th>Product</th>
<th>Acute NOEC (survival)</th>
<th>Acute LC50 (survival)</th>
<th>Chronic NOEC (survival)</th>
<th>Chronic LC50 (survival)</th>
<th>Chronic NOEC (young production)</th>
<th>Chronic IC25 (young production)</th>
<th>Chronic IC50 (young production)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed Cl: Inhibitor + Salt (NaCl)</td>
<td>12.0</td>
<td>17.0</td>
<td>3.00</td>
<td>4.81</td>
<td>1.00</td>
<td>0.990</td>
<td>3.43</td>
</tr>
</tbody>
</table>

**Mass of Product/Volume of Diluent** = Mass of liquid product diluted in runoff and the receiving water body
Endpoint Tables

**Volume based**

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**Ceriodaphnia dubia**

<table>
<thead>
<tr>
<th>Product</th>
<th>Toxicological Endpoint as Product (milliliters of product/liter of diluent)(^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acute NOEC (survival)</td>
</tr>
<tr>
<td>Watershed Cl : Inhibitor + Salt (NaCl)</td>
<td>9.4</td>
</tr>
</tbody>
</table>

**Volume of Product/Volume of Diluent** = volume of liquid product diluted in runoff and the receiving water body

For the practitioner!
Endpoint Tables
salt content based

*Ceriodaphnia dubia*

<table>
<thead>
<tr>
<th>Product</th>
<th>Chemical Used for Endpoint Calculation</th>
<th>Stock Concentration (grams salt / liter of product)²</th>
<th>Toxicological Endpoint as Primary Salt (milligrams salt/liter of diluent)¹</th>
</tr>
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<tbody>
<tr>
<td>Watershed Cl : Inhibitor + Salt (NaCl)</td>
<td>Na + Cl</td>
<td>288</td>
<td>Acute NOEC (survival)</td>
</tr>
<tr>
<td>Beet 55: Inhibitor + Salt (NaCl)</td>
<td>Na + Cl</td>
<td>224</td>
<td>Acute NOEC (survival)</td>
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</table>

Mass of salt per volume of product/volume of diluent = mass of salt diluted in runoff and the receiving water body

To normalize products based upon salt mass per unit volume and to promote comparison

Which inhibitor is more chronically toxic?
### Ranking by Total Product Mass

<table>
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<tr>
<th>Product</th>
<th>Relative Toxicological Rank</th>
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<tbody>
<tr>
<td>Watershed Cl: Inhibitor + Salt (NaCl)</td>
<td>1</td>
</tr>
<tr>
<td>Boost (CaCl2)</td>
<td>2</td>
</tr>
<tr>
<td>Road Guard Plus (CaCl2)</td>
<td>3</td>
</tr>
<tr>
<td>Beet 55: Inhibitor + Salt (NaCl)</td>
<td>4</td>
</tr>
<tr>
<td>FreezGard Cl Plus (MgCl2)</td>
<td>5</td>
</tr>
<tr>
<td>Apogee (Glycerol)</td>
<td>6</td>
</tr>
<tr>
<td>Meltdown Apex (MgCl2)</td>
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<td>CF-7 (K-Acetate)</td>
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### Ranking by Salt Mass

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Ranking by Salt Type

For this current study (from most to least toxic):

K-Acetate > MgCl₂ > CaCl₂ > NaCl

Salt only toxicity from the literature:

K-Acetate > MgCl₂ > CaCl₂ = NaCl
### Dissolved Oxygen Measured During The Test

<table>
<thead>
<tr>
<th>Product</th>
<th>C. dubia At Acute LC50</th>
<th>C. dubia At Chronic IC50</th>
<th>Fathead Minnow At Acute LC50</th>
<th>Fathead Minnow At Chronic IC50</th>
<th>Selenastrum Capricornutum At IC50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed Cl : Inhibitor + Salt (NaCl)</td>
<td>7.91</td>
<td>8.09</td>
<td>5.1</td>
<td>6.54</td>
<td>9.49</td>
</tr>
<tr>
<td>Beet 55: Inhibitor + Salt (NaCl)</td>
<td>4.26</td>
<td>7.69</td>
<td>1.70</td>
<td>6.24</td>
<td>9.64</td>
</tr>
<tr>
<td>FreezGard Cl Plus (MgCl₂)</td>
<td>7.96</td>
<td>8.04</td>
<td>4.70</td>
<td>7.09</td>
<td>9.53</td>
</tr>
<tr>
<td>Meltdown Apex (MgCl₂)</td>
<td>8.07</td>
<td>8.19</td>
<td>7.20</td>
<td>7.38</td>
<td>8.14</td>
</tr>
<tr>
<td>Road Guard Plus (CaCl₂)</td>
<td>7.24</td>
<td>7.74</td>
<td>4.24</td>
<td>4.60</td>
<td>8.16</td>
</tr>
<tr>
<td>Boost (CaCl₂)</td>
<td>5.54</td>
<td>7.33</td>
<td>3.28</td>
<td>3.97</td>
<td>9.01</td>
</tr>
<tr>
<td>CF-7 (K-Acetate)</td>
<td>7.29</td>
<td>7.98</td>
<td>4.64</td>
<td>6.50</td>
<td>9.05</td>
</tr>
<tr>
<td>Apogee (Glycerol)</td>
<td>7.16</td>
<td>7.70</td>
<td>4.54</td>
<td>5.58</td>
<td>9.78</td>
</tr>
</tbody>
</table>

**Reminder: Daily Renewals**

Dissolved oxygen effects still possible in the receiving water body
Other Observations
species sensitivity to products

**Acute Toxicity:**
more sensitive........less sensitive
fathead minnow > *Ceriodaphnia dubia*

(96 hour test) (48 hour test)

**Chronic Toxicity:**
more sensitive.......................less sensitive
*Ceriodaphnia dubia* >>> *Selenastrum* > *fathead minnow*

(7 day test) (4 day test) (7 day test)
Conclusions

• Testing provided high-quality data set for a selected number of liquid deicing products
• Testing results can be used to make estimates of potential toxicological impact on receiving waters, recognizing that:
  – Receiving water may have different chemistry than the laboratory water used in this study
  – Some of the product may be retained in soils and this will need to be considered in any impact assessment.
• Acute or chronic data use
  – Depends upon typical storm length for given region of country
  – Depends upon the receiving water body, e.g.
    • Large river = acute
    • Lake = chronic
Conclusions:

potential future work

• Temperature
  – Need to determine if these products are more or less toxic at low temperatures

• Longer term dissolved oxygen loss and effects on toxicity

• Product retention and decay

• Study effects with exposure periods representative of storm events