Effects of Metal Contaminated Forest Soils from the Canadian Shield on Terrestrial Organisms
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Purpose

Determine the toxicity of metal-contaminated forest soils from three sites on two established transects, to terrestrial organisms.
Study Sites

- Permanent transects established to reflect a concentration gradient from high metal contamination to low, downwind of two smelting operations in;
- Sudbury, Ontario
- Rouyn-Noranda, Quebec
Rouyn-Noranda, Quebec

RN 1

RN 2

RN 3
Soil Collection

» Collected in June and October, 2001
» Soil sampled from ~ 1m² subplots at each site
» 5-10 cm depth
Soil Collection

- Soil sieved on or off site
- Air-dried
- Stored at 20 ± 2°C
Test Organisms

- Northern wheatgrass
  \((Agropyron dasystachyum)\)

- Compost worm
  \((Eisenia andrei)\)

- Springtail
  \((Onychiurus folsomi)\)
Study Design: Phases 1 and 2

Phase 1: Undiluted Soil
- Sudbury (June, October)
- Rouyn-Noranda (June)
- Treatments include:
  - SUD1, SUD2, SUD3
  - RN1, RN2, RN3
  - Expt’l control soils

Phase 2: Diluted Soil
- Sudbury only (June, October)
- SUD1 diluted with SUD3
- Treatments include:
  - 0, 10, 20, 40, 50, 60, 80, 100% of SUD1
Experimental Design - Plant

Acute tests
- 14 days in duration
- Emergence, growth

Definitive tests
- 21 days in duration
- Emergence, growth
Experimental Design - Earthworm

Acute tests
- 14 day duration, 7-d check
- Mortality

Reproduction tests
- 56-63 day duration
- Juveniles, cocoons
Experimental Design - Springtail

Acute tests
- 7 day duration
- Mortality

Reproduction tests
- 35 day duration
- Juveniles, adult survival
Functional Assay

- Bait lamina test
- Carbon mineralization
- Endpoint is number and distribution of perforated holes
- 20 day duration
## Results: Soils

<table>
<thead>
<tr>
<th></th>
<th>SUD1 June</th>
<th>SUD2 June</th>
<th>SUD3 June</th>
<th>SUD1 Oct</th>
<th>SUD2 Oct</th>
<th>SUD3 Oct</th>
<th>RN1 June</th>
<th>RN2 June</th>
<th>RN3 June</th>
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</thead>
<tbody>
<tr>
<td>Cd</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>6</td>
<td>1</td>
<td>0.6</td>
<td>16</td>
<td>13</td>
<td>5.3</td>
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<tr>
<td>Cu</td>
<td>640</td>
<td>200</td>
<td>38</td>
<td>615</td>
<td>294</td>
<td>39</td>
<td>750</td>
<td>280</td>
<td>98</td>
</tr>
<tr>
<td>Ni</td>
<td>340</td>
<td>180</td>
<td>65</td>
<td>435</td>
<td>325</td>
<td>45</td>
<td>18</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Pb</td>
<td>120</td>
<td>53</td>
<td>34</td>
<td>126</td>
<td>85</td>
<td>45</td>
<td>750</td>
<td>440</td>
<td>170</td>
</tr>
<tr>
<td>Zn</td>
<td>29</td>
<td>35</td>
<td>34</td>
<td>28</td>
<td>32</td>
<td>57</td>
<td>300</td>
<td>360</td>
<td>120</td>
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<tr>
<td>As</td>
<td>110</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>101</td>
<td>9.9</td>
<td>3</td>
<td>27</td>
<td>&lt;20</td>
<td>&lt;20</td>
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</tbody>
</table>
Results: Undiluted RN – Plant

- Emergence not affected
- 14- and 21-day results similar
- Growth significantly decreased in RN1 and RN3, compared to RN2
- Toxic response did not correlate with soil metal concentrations
Results: Undiluted RN–Earthworm

- *E. andrei* survival not affected following 7- and 14-day exposures to the three Rouyn-Noranda soils
- Reproduction greatest in RN2 > RN1 = RN3
- Reproduction adversely affected in all three soils compared to experimental control soils
Results: Undiluted RN – Springtail

- Adult *O. folsomi* survival not affected following 7- and 35-day exposures to the three RN soils
- Juvenile production greatest in RN2 compared to RN1 and RN3
- Adult fecundity greatest in RN2 and lowest in RN3
Rouyn-Noranda Undiluted Soils

Northern wheatgrass

Eisenia andrei

Onychiurus folsomi
Results: Undiluted SUD – Plant

- Emergence not affected
- 14- and 21-day results similar
- Growth significantly decreased in SUD1 and SUD2, excellent in SUD3
- Toxic response is the same in June- and October-collected soils
- Toxic response correlates with soil metal concentrations
Results: Undiluted SUD – Earthworm

- *E. andrei* survival not affected following 7-, 14- and 35-day exposures to the SUD soils
- Reproduction significantly decreased in SUD1 and SUD2, but not affected in SUD3
- Toxic response is the same in June- and October-collected soils
- Toxic response correlates with soil metal concentrations
Results: Undiluted SUD – Springtail

June Samples
- Adult *O. folsomi* survival not affected following 7- and 35-day exposure
- Reproduction in SUD1 lower than in SUD3

October Samples
- SUD3 acutely and chronically toxic
- Survival and reproduction greater in SUD1 than in SUD3
Sudbury Undiluted Soils

Northern wheatgrass

Eisenia andrei

Onychiurus folsomi

Root Length

Juvenile Wet Mass

Number of Juveniles
Sudbury Diluted Soils: Northern Wheatgrass

<table>
<thead>
<tr>
<th></th>
<th>ICp* (%)</th>
<th>June Soils</th>
<th>October Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-day</td>
<td>IC20</td>
<td>3 – 73</td>
<td>3 - 93</td>
</tr>
<tr>
<td></td>
<td>IC50</td>
<td>12 – 94</td>
<td>84 - &gt;100</td>
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<tr>
<td>21-day</td>
<td>IC20</td>
<td>16 - 56</td>
<td>57 – 80</td>
</tr>
<tr>
<td></td>
<td>IC50</td>
<td>39 - 91</td>
<td>93 - 96</td>
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</table>

* ICp values are a range of six endpoints
### Sudbury Diluted Soils: *Eisenia andrei* Reproduction

<table>
<thead>
<tr>
<th>Estimate (% SUD1)</th>
<th>June Soils</th>
<th>October Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC20</td>
<td>4 - 8</td>
<td>2 - 36</td>
</tr>
<tr>
<td>EC50</td>
<td>10 - 22</td>
<td>14 - 50</td>
</tr>
<tr>
<td>NOEC</td>
<td>10 - 40</td>
<td>0 - 80</td>
</tr>
<tr>
<td>LOEC</td>
<td>20 - 50</td>
<td>10 - 100</td>
</tr>
</tbody>
</table>

Values are a range of five endpoints.
Sudbury Diluted Soils: 
*Onychiurus folsomi* Reproduction

![June Soils](chart)

![October Soils](chart)
Functional Assay

- Exposed to June and October Sudbury soils only
- No evidence of carbon mineralization following 20 days of exposure
- No effect of soil type or metal concentration on carbon mineralization
- Functional assays will continue to be evaluated in the future with longer test durations
Summary

- Short-term and longer-term toxicity of metal-contaminated forest soils were determined for a plant, earthworm and springtail species.
- The toxic response in the RN soils did not correlate with soil metal concentrations.
- The toxic response in the Sudbury soils did correlate with soil metal concentrations.
Summary

- Earthworms most sensitive of the three species tested, and springtail the least
- Seasonally-related toxicity:
  - October SUD1 less toxic to plant and earthworm
  - October SUD3 toxic to springtail
Broader View

Effects data provide an important link between metal levels and the potential risk to terrestrial organisms.

Data compliment other MITE studies.

These types of studies are germane to ecological risk assessments of metals in soils.
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