Assessment of Contaminated Soil in the Canadian Boreal Forest using Standardized Toxicity tests

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Outline

1. Methods
   • Plants
   • Invertebrates
   • Soil collection and handling
2. Performance tests
3. Case study of hydrocarbon impacted site

http://www.borealforest.org/world/world_overview.htm
Project Objectives

- Develop standardized biological test methods to measure effects of contaminants (e.g., brine, PHC) in Canadian boreal and northern (taiga) soils and wetlands
  - Use ecologically-relevant terrestrial and wetland species (single-species and microbial)
  - Test a variety of soils of the boreal and taiga eco-zones

- Develop technical guidance on the collection, handling, and preparation of contaminated soils for biological testing in support of site-specific risk assessments

- Develop tools useful for contaminated land risk assessment and management
Method development process

- Create list of potential species that are ecologically relevant to the boreal
- Acquire or collect seeds or invertebrates, bring to germination or into culture in the lab
- Perform tests of growth, survival or reproduction in a wide variety of soils – “performance testing”
- Test impacted soils diluted in a matching reference soil
- Environment Canada validates the method, publishes
Contaminated Soil Sampling Guidance

Environment Canada EPS 1/RM/53

- Supportive of site-specific risk assessments and soil remediation
  - Single-species and microbial assessments
  - Universal procedures and statistically derived sampling procedures
  - Specific procedures for problematic contamination (e.g., unstable compounds, volatiles)
  - Broad-range of Canada’s eco-zones (e.g., forests, cryosols, stoney soils, wetlands)
# Boreal Test Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plants</strong></td>
<td></td>
</tr>
<tr>
<td>Black spruce</td>
<td>(Picea mariana)</td>
</tr>
<tr>
<td>White spruce</td>
<td>(Picea glauca)</td>
</tr>
<tr>
<td>Paper birch</td>
<td>(Betula papyrifera)</td>
</tr>
<tr>
<td>Jack pine</td>
<td>(Pinus banksiana)</td>
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<tr>
<td>Trembling aspen</td>
<td>(Populus tremuloides)</td>
</tr>
<tr>
<td>Bluejoint reedgrass</td>
<td>(Calamagrostis canadensis)</td>
</tr>
<tr>
<td>Canada goldenrod</td>
<td>(Solidago canadensis)</td>
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<tr>
<td></td>
<td>Commercial seed suppliers or</td>
</tr>
<tr>
<td></td>
<td>locally collected</td>
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<tr>
<td><strong>Earthworm</strong></td>
<td></td>
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<tr>
<td>Dendrodrilus rubidis</td>
<td></td>
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<tr>
<td>Dendrobaena octaedra</td>
<td></td>
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<tr>
<td><strong>Springtail</strong></td>
<td>Proisotoma minuta</td>
</tr>
<tr>
<td><strong>Mite</strong></td>
<td>Oppia nitens</td>
</tr>
<tr>
<td></td>
<td>Alberta</td>
</tr>
<tr>
<td></td>
<td>Sask.</td>
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<tr>
<td></td>
<td>Ontario</td>
</tr>
</tbody>
</table>
## Wetland Plant Test Species

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Species</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsh</td>
<td>Bebb’s willow (Salix bebbiana)</td>
<td>Commercial seed suppliers or locally collected</td>
</tr>
<tr>
<td></td>
<td>Cattail (Typha latifolia)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bluejoint reedgrass (Calamagrostis canadensis)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bebb’s willow (Salix bebbiana)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aquatic sedge (Carex aquatilis)</td>
<td></td>
</tr>
<tr>
<td>Fen</td>
<td>Aquatic sedge (Carex aquatilis)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tamarack (Larix laricina)</td>
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</tr>
<tr>
<td></td>
<td>Sweet gale (Myrica gale)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black spruce (Picea mariana)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bluejoint reedgrass (Calamagrostis canadensis)</td>
<td></td>
</tr>
<tr>
<td>Bog</td>
<td>Bog cranberry (Vaccinium vitis-idaea)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black spruce (Picea mariana)</td>
<td></td>
</tr>
</tbody>
</table>
Establish Invertebrate Species

- Derived from heat extractions of reference soil
- Ongoing culture in the lab on artificial substrate
Terrestrial Ecozones of Canada

- Chernozem
- Gleysol
- Luvisol, Brunisol & Wetlands
- Podzol
- Podzol
- Podzol

Bulk soil collection sites:
- Gleysol
- Chernozem
- Luvisol, Brunisol & Wetlands
- Podzol

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Collection of bulk soils
- aim to retain soil horizons

Field horizons

Plant test setup

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Effects of salt-contaminated soil

- Roots penetrate both horizons
- Both shoot and root demonstrate effects of salt
Invertebrate Tests Systems

Testing of Individual Horizons

- mite
- Collembolan
- Earthworm
Performance of plants (root length)

The bar chart shows the mean root length (mm) for different soil names: AS, SK-01, SK-02, SH07, PR07, ON07, and NB07. The bars are colored to represent different plant species: Trembling aspen (blue), Bluejoint reedgrass (red), Canada goldenrod (green), and Paper birch (purple). The error bars indicate the variability or standard deviation of the root length measurements.
Performance of *Dd. rubidus* in 14 boreal soils

- Juvenile production varies with soil type but adult survival not affected
- Reduced reproduction in acidic soil (pH < 4.5)
Performance of *Oppia nitens* in 14 boreal soils

- Evaluate survival and reproduction in boreal soils
- Develop performance data to help establish validity criteria

![Graph showing performance of *Oppia nitens* in 14 boreal soils.](image)

**OM an influential factor**
Performance of *P. minuta* in 14 boreal soils
Site of crude oil spill in 1989

Swan Hills bog in Northern Alberta
• water table of 5-15 cm
• pH 4.6
• 20-30 cm peat layer over 10-20 cm Ahg horizon
• trees removed and straw spread to remediate
• 35% of surface not vegetated
• hydrocarbons high in F3: >C16-C34: 190,000 mg/kg
• Test species present: black spruce, bluejoint, paper birch, trembling aspen

2006

Collected two horizons Of/Oh and Ahg at reference and contaminated locations
Plant shoot and root endpoints (IC25)

**Shoot Length (IC25)**

- black spruce
- white spruce
- jack pine
- aspen
- bluejoint
- goldenrod

**Shoot Dry Weight (IC25)**

- black spruce
- white spruce
- jack pine
- aspen
- bluejoint
- goldenrod

**Root Length (IC25)**

- black spruce
- white spruce
- jack pine
- aspen
- bluejoint
- goldenrod

**Root Dry Weight (IC25)**

- black spruce
- white spruce
- jack pine
- aspen
- bluejoint
- goldenrod
Boreal invertebrate survival and juvenile production (IC25)

**Adult Lethality (LC50)**

- D. rubidis: 120%
- F. nivalis: 40%
- P. minuta: 100%
- O. nitens: 80%

**Juvenile Production (IC25)**

- D. rubidis: none
- F. nivalis: 2
- P. minuta: 4
- O. nitens: 8
Species sensitivity distribution

- **Standard Species**
- **Boreal Species**

- F3: 45,500 mg/kg
- F3: 10,600 mg/kg
Research Goal – Soil Test Method Development (ecological-relevance & applicability)

- Collected reference and contaminated soils representative of Canadian boreal, northern and wetland regions
- Established cultures of candidate soil invertebrate species and seed sources
  - Taxonomic verification – traditional and genetic sequencing methods
  - Initiated soil toxicity test method development using reference soils
  - Discovered that some species performance is limited in some soil types; we need to define limits of non-contaminant factors so that appropriate test batteries can be developed for soil-species scenarios
- Ongoing development of test method using established wetland plant species
- Completed guidance document on collection of contaminated soils for site-specific risk assessments using biological tests
Future Goals:

Complete development of ecologically-relevant tools for site assessments and evaluation of remedial techniques

- Boreal and taiga terrestrial plant species (published 2013); wetland plant species (2014)
- Soil invertebrate species in 2013 (collembolan) and in 2014 (earthworm and mite)
- Soil microbial tests (2014)
  - Evaluation of effects on biomass, activity, diversity and community structure in natural consortium
Questions?

SRC
SASKATCHEWAN RESEARCH COUNCIL

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