Phytoremediation of Impacted Soil

Field Research Trials with New Applications, Species, and Challenges.

Elizabeth Murray, Bruce Greenberg, Ben Poltorak, Kent Cryer, Perry Gerwing.

- Developed through collaboration with Dr. Bruce Greenberg of the University of Waterloo and Earthmaster Environmental.
- Earthmaster has assumed control of the PEPS technology and continues to collaborate with Dr. Greenberg.
- Earthmaster now manages all PGPR testing, selection and seed treating in Calgary.
- Earthmaster is conducting new research into how PGPR can be used in other applications such as enhanced reclamation.
Phytoremediation – How it Works

- **Improved rhizosphere**
  - Soil
  - Organic matter
  - Bacteria
  - Water
  - Roots
  - Contaminants

- **Phytostimulation**
  - Petroleum Hydrocarbons

- **Phytoextraction**
  - Salts
  - Metals

**Challenge** – getting the plants to grow.
PGPR – Facilitating Plant Growth in Challenging Conditions

Active rhizosphere: PGPR co-localize with developing roots

Stress ethylene
Plant vigor
Root development
Rhizobacteria
Leaves
Salt and metals uptake
Degradation of PHC
Bacteria (*Pseudomonas sp.*) are isolated from area soil:

- Naturally occurring soil/water bacteria.
- Ubiquitous, geographically relevant, and frequently associated with plants.
- Not genetically modified.
- In general, they are classified as biosafety level 1 – no threat to humans, wildlife, or the environment.

PGPR are cultured in the lab:

- Tested and selected for ACC deaminase and auxin (IAA) levels.
- Cultured and tested in greenhouse trials as individual species.

Grasses are selected based on surrounding area:

- Suitable for the area – not prohibited.
- Must produce high biomass.
Development and Full Scale Application of PEPS

Joint activities by the University of Waterloo and Earthmaster Environmental:

- PEPS is based on peer reviewed research published in scientific journals by many groups world wide.

- 15+ years of research (Dr. Greenberg) and 10+ years of full-scale commercial field remediation at >30 sites across Canada.

- Successful remediation of both PHC and salt impacted sites in 7 Canadian provinces and territories since 2004.
Baytex Red Earth Creek oilfield emulsion spills

- 9,200 m³ of PHC and salt impacted soil
- Soil from historical spill sites - numerous treatment methods had been attempted previously
- Earthmaster constructed 3 soil treatment facilities:
  - Engineered clay pad minimum 0.60 m thick
  - Perimeter clay berm to contain material
  - Surface water run off collection system
    - Channels
    - Collection sumps with poly liners
  - AER compliant
- Impacted soil was spread across the clay liners
  - ~0.45 m thick
Starting Material

Impacted soil guideline value exceedances (surface soil comparison):

• F1: 310 to 1,100 mg/kg
• F2: 170 to 3,000 mg/kg
• F3: 1,500 to 7,500 mg/kg
• F4: complied
• Benzene: 0.062 to 0.880 mg/kg
• Ethylbenzene: 0.190 to 1.200 mg/kg
• Toluene: 0.63 mg/kg
• Xylenes: complied
• Salts: complied with AER agreed to levels
Site / Phytoremediation Details

- Topsoil stockpiles
- Bermed clay treatment pads
- Collection channels and sumps
- Active lease sites
- Permanent assessment points
- End point – meet remediation guideline values for natural land use fine textured soil
- Seed – ARG, PRG, TF
- PGPR – UW3, UW4
- First seeding – fall 2011
Stockpiled Impacted Soil

June 2011
Clay Pad Construction

July 2011
First Year Growth

October 2012
Phytoremediation Mid-Point – F1
Phytoremediation Mid-Point – F2
Phytoremediation Mid-Point – F3

![Graph showing F3 levels across different time points and areas](image-url)
Soil Stripping

July 2015
Soil stockpiles arising from 2015 stripping:

- If they complied with surface and/or subsoil remediation guideline values, they were designated for the corresponding use.
- If they did not comply they were re-spread for additional phytoremediation.

Remaining treatment areas:

- As of August 2016, 23 of 26 assessment points complied with surface soil F2 criteria (3 pts between 160-230 mg/kg).
- Impacted soil has met all remediation goals.
- Site will be completed in the spring of 2017.
- Soil piles will remain onsite for future use.
Enhanced Reclamation – Research Goals

New research – using PGPR to improve efficacy of re-vegetation of marginal and disturbed soils:

• Previous studies have shown that PGPR can increase the tolerance of plants to stressed conditions:
  ▪ Hydrocarbons and salts
  ▪ Poor soil conditions
  ▪ Used in combination with fertilizer and specific seeding densities

• Can PGPR be used in a more traditional way to assist in reclamation or revegetation of “clean” soil:
  ▪ Use lower density seeding rates with native grass mixes
  ▪ Increase plant emergence, growth, and survival of plants on marginal soils

• IRAP funded project
Enhanced Reclamation – Central Alberta Site

Former gas plant located east of Drumheller (traditional phytoremediation site):

- 8,000 m³ of excavated PHC impacted soil.
- Earthmaster constructed a soil treatment facility:
  - AER compliant
- Impacted soil was spread across the clay liner.
- Clean topsoil was placed in the NW corner – used for **test plot #1** (not an ideal location).
- Several lifts of soil have been treated.
- Treated soil was placed back in the excavation – used for **test plot #2**.

This is a preliminary study.
Site / Enhanced Reclamation Test Plot Details

- Clean disturbed soil
- Seed – commercial native grass mix
- PGPR – CMH3
- No fertilizer
- Lower density seeding rate

Topsoil test plot: 2 x 3.5 m

- +PGPR
- -PGPR

Subsoil test plot: 2 x 2 m

- +PGPR
- -PGPR
Subsoil Test Plot

July 11, 2016 – 3 weeks
Topsoil Test Plot
## Topsoil Plot Results

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<tr>
<th>Block #</th>
<th>Seed Status</th>
<th>16Aug2016</th>
<th>15Sep2016</th>
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<td>Height (cm)</td>
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<td>% cover</td>
<td>Height (cm)</td>
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Results

What we learned:

- Plots were too small so edge effects were very pronounced.
- They cannot be compared to the treatment area as they were different plant species.
- Slight advantage to PGPR treated seed.
- Further studies are required using different seed types and different PGPR on larger plots so edge effects can be eliminated and efficacy of PGPR fairly evaluated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment Area</th>
<th>Test Plots</th>
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<tbody>
<tr>
<td>seed type</td>
<td>ARG, PRG, TF</td>
<td>native grass mix</td>
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<tr>
<td>PGPR</td>
<td>UW3, UW4</td>
<td>CMH3 or none</td>
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<td>fertilizer</td>
<td>yes</td>
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<td>lower rate</td>
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<td>seeder</td>
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<tr>
<td>edge effects</td>
<td>yes</td>
<td>yes</td>
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Historical Salt Impacts in Southern Saskatchewan

Produced water disposed in a flare pit
ECe ~10-20 dS/m
Plant Growth Three Months After Seeding

Seed: ARG, PRG, TWG, Oats
PGPR: CMH3
Plant Growth Year 3
New research - using PGPR with commercial seed treatments to improve efficacy/speed of salt remediation:

- Previous field projects have identified a seed/PGPR combination capable of remediating salt impacts in soil.
- Remediation currently takes ~4-10 years depending on the soil, groundwater, weather conditions, and salt levels.
- Can the speed of this process be increased using a commercial seed treatment in combination with PGPR?
  - Decrease time to meet remediation goals (<5 years)
  - Increase plant biomass, rooting depth, and salt uptake rates
- Worked with commercial suppliers to find a suitable treatment compatible with PGPR.
- IRAP funded project.
Salt Spill – Southern Saskatchewan Wetland

Produced water release in southeastern SK:

• 500 m³ of produced water was released from a pipeline:
  ▪ Flowed north into a non-agricultural wet-meadow
  ▪ Impacted area ~30,000 m² in size
  ▪ Area is prone to flooding for periods of time
  ▪ Surrounding land use is cultivated farmland

• Impacted soil will be treated in situ:
  ▪ ECe: 8 to 18 dS/m
  ▪ SAR: 13 to 40

• Remediation goal:
  ▪ Revegetate the affected area
  ▪ Remove salt from the surface soil to allow for sustainable plant growth
Salt Spill – Southern Saskatchewan

July 2015
Lowland Seed Selection

Seed mix requirements:

- Suitable for both flooded and dry conditions.
- Must be common to southern SK.
- Must not be on the SK invasive plant list.
- Must be able to take up and accumulate salt.
- Must be somewhat tolerant to saline conditions.
- Should be able to sow the seeds with a seed drill or broadcast spreader.
- Should rapidly accumulate biomass.
- Must be able to be harvested from the site to remove accumulated salt.
- Prefer perennials to avoid replanting.
- Prefer quick regrowth following harvest.
Seed Mixes

Uplands mix – based on previous field work:
  • Annual ryegrass
  • Perennial ryegrass
  • Tall fescue

Lowlands mix – based on criteria, availability, and price:
  • Western wheatgrass
  • American sloughgrass
  • Perennial ryegrass
  • Soft rush
  • Faults alkali grass
  • Fowl bluegrass
  • Cattails
Test Plot Set-up on Commercial Phytoremediation Site

Lowland test plot

<table>
<thead>
<tr>
<th>Block 5</th>
<th>Block 6</th>
<th>Block 7</th>
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</table>

Sections are 4 x 16 m

Section 5: PGPR
Section 6: no treatment
Section 7: PT
Section 8: PGPR + PT

Upland test plot

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
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Section 1: PGPR
Section 2: no treatment
Section 3: PT
Section 4: PGPR + PT
Early Results – 1 Month

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
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<tbody>
<tr>
<td>+PGPR</td>
<td>Field with green grass and ample growth.</td>
</tr>
<tr>
<td>No Treatment</td>
<td>Field with sparse, dry grass.</td>
</tr>
<tr>
<td>+PGPR +PT</td>
<td>Field with green grass and noticeable growth, indicating treatment efficacy.</td>
</tr>
<tr>
<td>+PT</td>
<td>Field with green grass and improved growth, suggesting enhanced treatment effects.</td>
</tr>
</tbody>
</table>
Early Results – 1 Month
Hydroseeding – Proposed Research Project

Proposed PGPR/hydroseeding applications:
• Re-vegetation along roadways/highways
• Would involve disturbed soils
• Other challenges would be expected including:
  ▪ High salt concentrations
  ▪ Steep inclines

Unknowns to be tested:
• Will PGPR survive the hydroseeding process?
• Will the slurry mixture cause the PGPR to come off of the seed?
• What is the best seed/PGPR combination?
Acknowledgements

Anthony Traverse – Baytex Energy Ltd.

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Additional clients who have allowed Earthmaster to conduct field trials to advance the technology.
Thank You

Questions?