Phytoremediation of petroleum and salt-impacted soils: Successfully meeting generic Tier 1 standards and making green technologies work

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Advantages of Phytoremediation

1. Improves the quality of soil
2. It is cost effective, technically feasible and proven
3. Plants provide sufficient microbial biomass for rapid remediation; promotes high rhizosphere activity
4. Reasonable time frames – 2 to 4 years
5. Effective for remediation of petroleum hydrocarbons (PHC) and salt – Relevant to the energy industry
6. Decrease the amount of soil destined for landfills
Physical soil treatment: Seed bed preparation

Phytoremediation: Growth of plants with PGPR

Monitoring and remediation assessment: Environmental chemistry to follow PEPS from start to finish

- **PGPR**: Plant growth promoting rhizobacteria.
- PGPR are applied to the grass seeds prior to sowing → NOT Bioaugmentation
Interaction of a PGPR Containing ACC Deaminase with a Plant Seed or Root

Naturally occurring, non-pathogenic microbes (usually *Pseudomonads*)

Chosen initially based on ACC Deaminase activity and auxin (IAA) production

We have isolated PGPR from ON, AB, SK and the NWT (native to North America)

Can be isolated from soils anywhere

Adapted from Glick *et al.*, 2004
Effect of PEPS on Soil Microbial Community

No statistical difference between plots with and without PGPR

Increase in bacterial count seen with plants
History of the Development of PEPS

Over 13 years of research with full-scale field remediations at each stage of development and application

1. **PHC**: sites in AB, BC, QC, MB, NWT and ON (2004-13)
2. **Salt**: sites in SK, MB, AB and NWT (2007-13)

Performing full scale remediations for over 8 years

PEPS currently operating at over 30 sites

Over 10 sites completed

Grasses (annual and perennial), oats and fall rye

Remediation observed to depth of 18 – 36 inches
PGPR Seed Treatment

PGPR-treated seeds assayed for plant growth enhancement to assure successful PGPR application
North BC – Before PEPS Treatment (May 2009)

Soil Impact – PHC (9,000 ppm)
North BC – With PEPS Treatment (September 2011)

Soil Impact – PHC (9,000 ppm)
Alberta PEPS Treatment

Before PEPS

After PEPS

![Graph showing PHC levels before and after PEPS treatment.](image-url)

PHC (ppm)

- Jun '07: 2000 ppm
- Jun '08: 1500 ppm
- Oct '08: 1000 ppm

*Note: Graph shows a significant decrease in PHC levels post-PEPS treatment.*
Alberta PEPS Treatment

After PEPS

Before PEPS

![Graph showing PHC levels before and after PEPS treatment]

- PHC (mg/kg)
- Jun '07 Oct '07 Oct '08

PHC levels decreased after the PEPS treatment.
### Track Record of PEPS Deployment at PHC Sites

#### Completed Sites

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**Sites in Progress**

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Revegetation of Salt Impacted Soils in Western Canada - Saskatchewan

* - Due to flooding on-site in 2011, samples were not collected

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* Above-Ground Biomass (g/m²)

* - Due to flooding on-site in 2011, samples were not collected
Sample Analyses to Track Phytoremediation

- PHC – Canadian Council of Ministers of the Environment (CCME) GC method

- Salt – $EC_e$, SAR, various ion concentrations

- Plant Tissue: Analysis of ions in plant samples to assess plant uptake of salt
Petroleum Hydrocarbon Analysis: F2 (C10-C16 carbon chains)
Petroleum Hydrocarbon Analysis: F3 (C16-C34 carbon chains)
GC-FID analysis with Enhanced BOC method

No clean up  In-situ Si gel clean-up  Double Si gel column clean-up
Data Validation

- Analytical laboratory PHC analysis by GC-FID can have up to 30% error in one sample
- “Traditional” remediation methods look for Yes or No
- Small changes during phytoremediation can be disguised
- Data should be validated by independent analysis
Summary

- PGPR improve plant growth under stressful soil conditions
- PHC phytoremediation can be achieved to Tier 1 standards in an acceptable timeframe
- Salt impacted soil can be remediated and revegetated to meet criteria
- Analytical data should be validated