The use of biosurfactants as soil amendments to enhance phytoremediation of weathered petroleum hydrocarbon (PHC) contaminated soils

RemTech 2012

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Jola Gurska, Ph.D.*, Robin Angell, M.Sc.*, Bruce Greenberg, Ph.D.#, Tereza Dan, Ph.D.* and Gladys Stephenson, Ph.D.*

*** Stantec Consulting Ltd, Guelph, ON**
#University of Waterloo, Waterloo, ON and WEBi, Hamilton, ON

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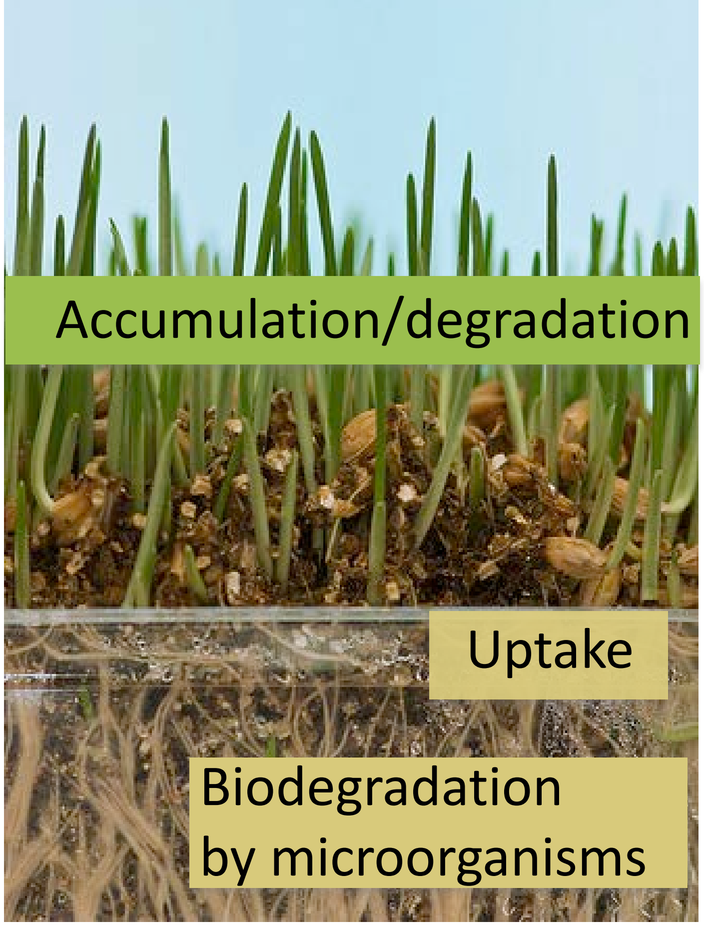
Presentation Overview

- Current process and phytoremediation methodologies
- Case Studies of Phytoremediation at Stantec
- Suncor Landfarm Phytoremediation in Oakville, ON
    - Phytoremediation with grasses for PHC in soil and hydraulic control with willows for groundwater impacts
        - Greenhouse testing prior to implementation
        - Field implementation
- Enhancing phytoremediation technology
    - R&D: Rhamnolipid biosurfactants to enhance bioavailability and degradation of weathered PHC

Phytoremediation - modes of action



- Plants **take up, store and biochemically degrade or transform** organic compounds ("green liver model" - secretion)
- **Microbial degradation** occurs in the plant root zone, *the rhizosphere*.
- Revegetation to **prevent erosion and sorbed pollutant transport**.
- Volatile compounds are **taken up, modified and transpired**.

Successfully remediated contaminants

- Petroleum products eg. gasoline, benzene, toluene, polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons (PHC)
- Trichloroethylene (TCE)
- Explosives eg. trinitrotoluene (TNT)
- Herbicides eg. atrazine
- Metals
- Fertilizers
- Salts

Selection of vegetation used

Must consider:

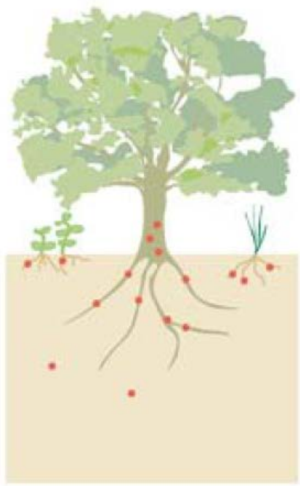
- Contaminant
- Climate/Local Site conditions
- Soil
- Root system of the plants
- Plants’ ability to tolerate the contaminants

Selection of vegetation used

Must consider:

- Contaminant
- Climate/Local Site conditions
- Soil
- Root system of the plants
- Plants' ability to tolerate the contaminants
- Project goal
  - Rhizodegradation in shallow soil (e.g. legumes)
  - Alteration of groundwater migration and evapotranspiration (e.g. hybrid poplars)

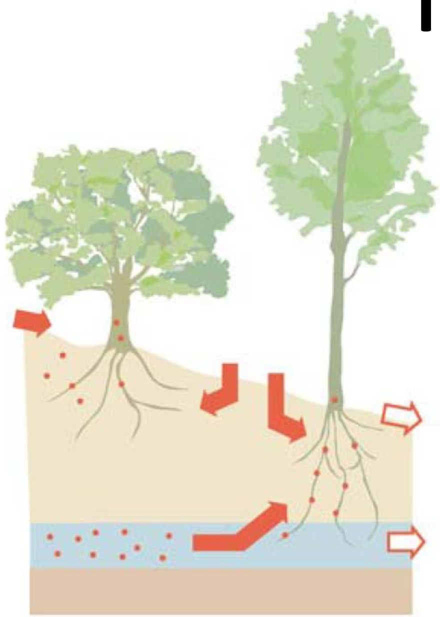
Phytoremediation approaches: Vegetative cap



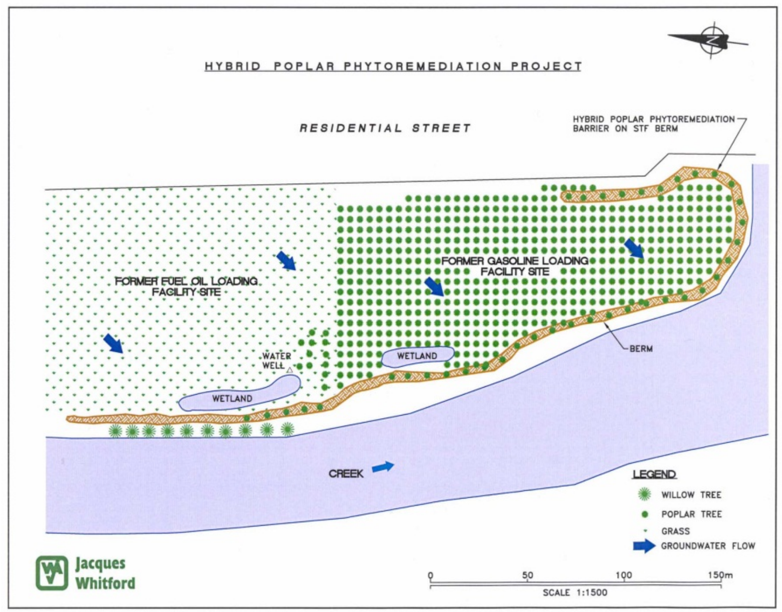
Farming polluted soil or vegetative cap

- Prussian Blue impacted creek
- Sediment was excavated, placed on property
- Cyanide tolerant and accumulator species:
  - poplars, willows, mulberry and post remediation species

Phytoremediation approaches: Hydraulic control



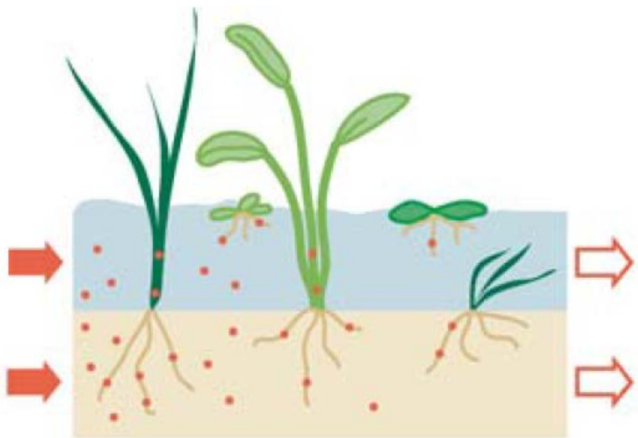
Hydraulic control



- PHC in soil and groundwater
- 4ha planted with 2000 hybrid poplars and willows
- Xylene concentrations reduced below applicable site condition standards

Phytoremediation approaches: Constructed wetlands

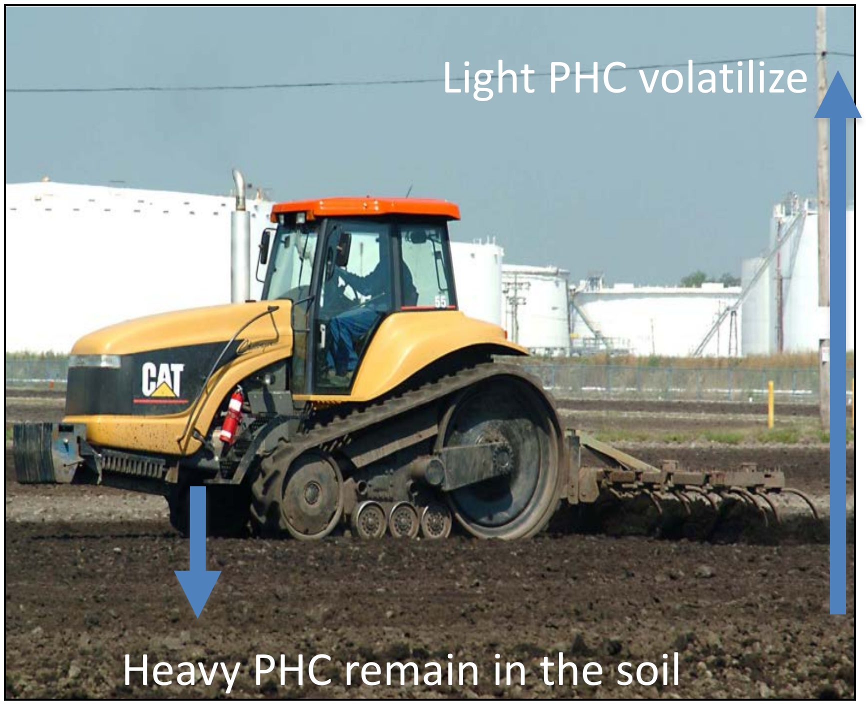
- Engineered Wetlands to treat run-off from de-icing agents at Buffalo International Airport



Constructed wetland

The Site

Phytoremediation at a former Suncor landfarm, Oakville ON



- Former landfarm (1972-2006)
- Decommissioned and functioning as a terminal
- 4 parcels with varying PHC concentrations
- Soil - metal, PHC exceedances
- Groundwater: F1, F3, benzene, Na

Tilled during summers, >30 years

Two-pronged Phytoremediation Approach at the Oakville Terminal

1. PGPR Enhanced Phytoremediation System (PEPS) on all four Parts
   a) Benchscale treatability test for soil remediation with PEPS
2. Parts with ground water exceedances – *deep planting* of hybrid willows for hydraulic control

- Phytoremediation system was chosen as a cost effective remediation strategy with limited impact on facility operations

Greenhouse Treatability Test

Greenhouse Phytoremediation Treatability Study (2012)

- Representative soils collected from each of the four parcels
- Phytoremediation with a mixture of grasses using PEPS
  - 60 day test

7 0.8% PHC DW soil

2.4 % PHC DW soil 20

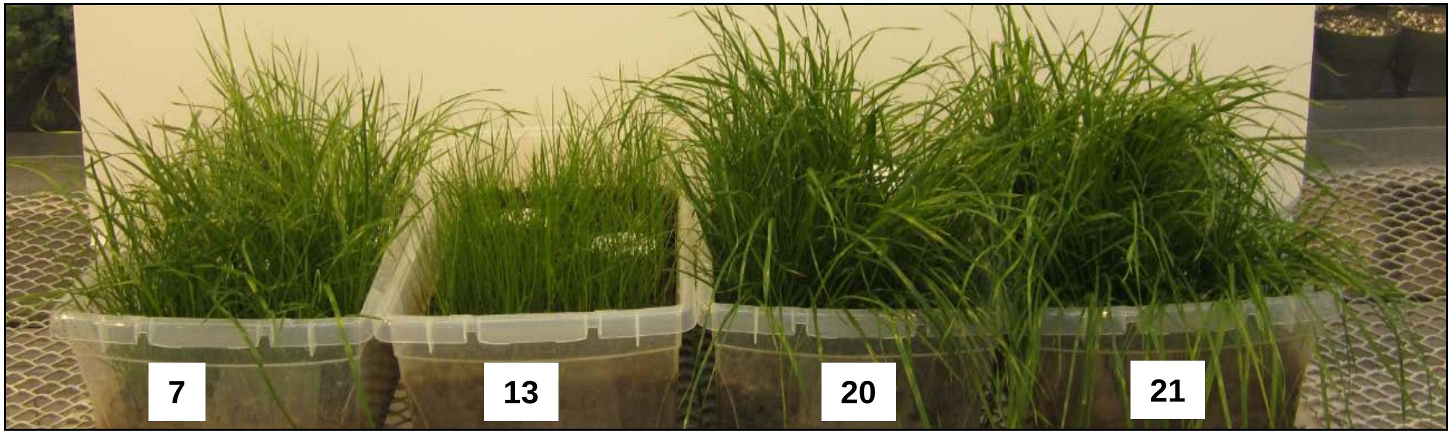
13 2.1% PHC DW soil

0.4 % PHC DW soil 21

Excellent plant growth and remediation on site soils

	Parcel 7	Parcel 13	Parcel 20	Parcel 21
PHC % DW Soil	0.8 %	2.1 %	2.4 %	0.4 %

Day 30

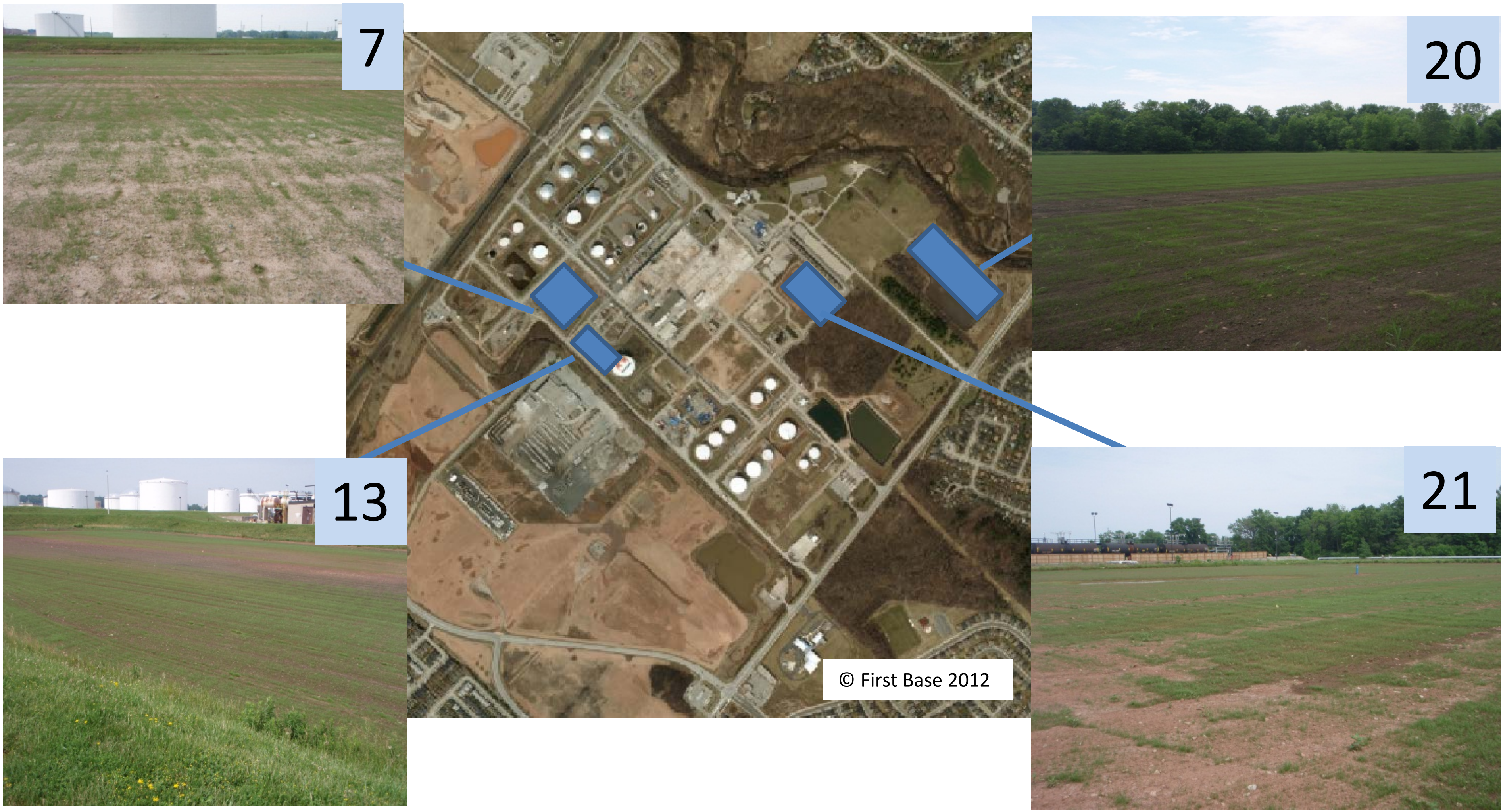


Day 38

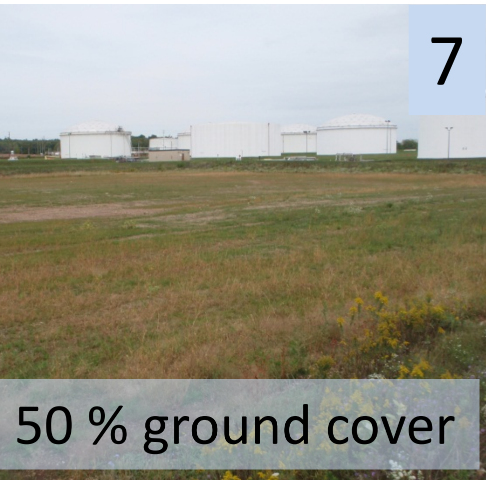
Soil Phytoremediation

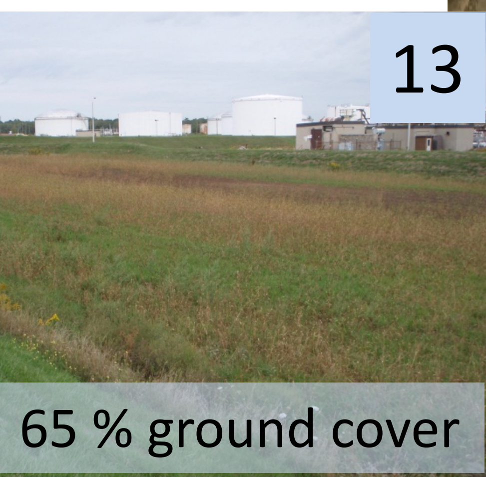
- Sites planted with selected grass mixture treated with PEPS
  - Seeding with perennial and annual grass mix
  - Planting took place mid May 2012

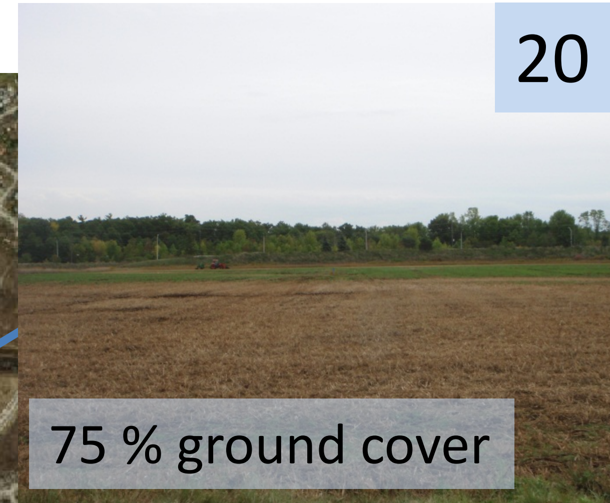
Phytoremediation Performance After Seeding

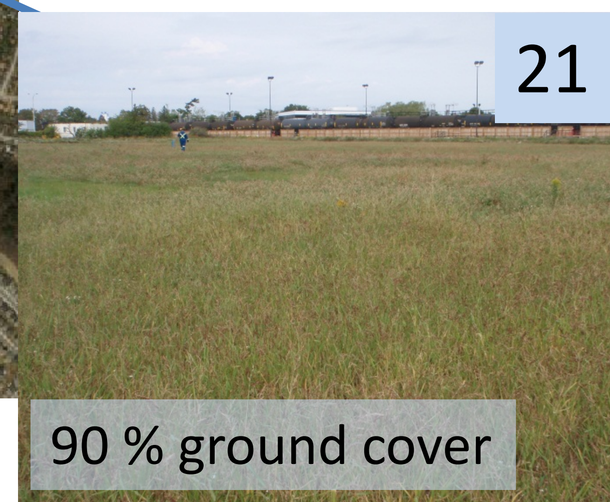


Phytoremediation Performance September 21 2012









Expected Remediation Targets

- 30-50% remediation in year one, surficial soil (0-30 cm)
- 60-70% remediation over three years
- Site closure anticipated in 4-5 years from planting

* Where general site specific targets are not met during this timeline, site-specific risk assessment will be conducted to address any potential environmental risk to human and ecological receptors

Phytoremediation of Ground Water: Hydraulic Control and Evapotranspiration

QUEEN ELIZABETH WAY
SPEERS RD
BRIDGE RD
BRONTE RD
REBECCA ST
MISSISSAGA ST
WYECROFT RD
HARVESTER RD
BURLOAK DR
LAKESHORE RD W
BP-21
BP-39
BP-19N
98.66
BP-36-2
100.05
BP-36-1
BP-19A
BP-19B
BP-19S
98.16
BP-7
BP-6
MW101S/D
99.85
BP-31-2
100.29
BP-31-1
MW102S/D
99.86
BP-1
98.63
BP-2
97.05
BP-30
BP-16
94.17
94.56
BP-15
MW103S/D
93.26
BP-33
91.24
92.78
BP-34
88.80
88.25
89.48
BP-25
BP-28-2
89.35
BP-28-1
BP-40-1
BP-40-2
BP-32-2
88.98
BP-32-1
BP-27
BP-18
90.46
BP-18A
BP-17
BP-17A
90.55
BP-37
100
99
98
97
96
95
94
93
92
91
90
89
88

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Phytoremediation of Ground Water: Hydraulic Control and Evapotranspiration

- Total willows planted = 465
  - Part 20: 266
  - Part 21: 199
- Average depth of deep-planted trees: 60-70cm

Phytoremediation of Ground Water: Hydraulic Control and Evapotranspiration

Part 20

Part 21

Based on similar sites with this approach we expect groundwater results to show decrease in impacts within 1-2 years

Presentation Overview

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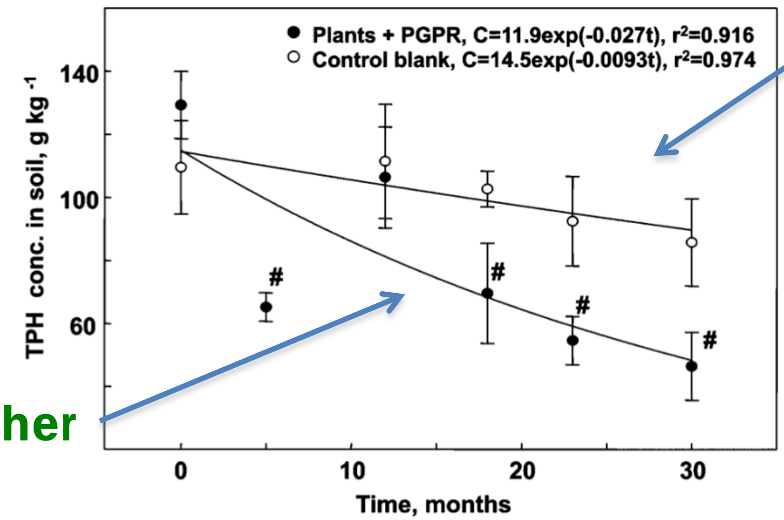
- Current process and phytoremediation methodology
- Suncor Landfarm Phytoremediation in Oakville ON
    - Soil and Groundwater
    - Phytoremediation with grasses for soil contaminants and willow hydraulic control for groundwater remediation and mitigation of contaminant movement

- Enhancing phytoremediation technology
    - R&D: Rhamnolipid biosurfactants to enhance bioavailability and degradation of weathered PHC

Can we make phytoremediation more effective?



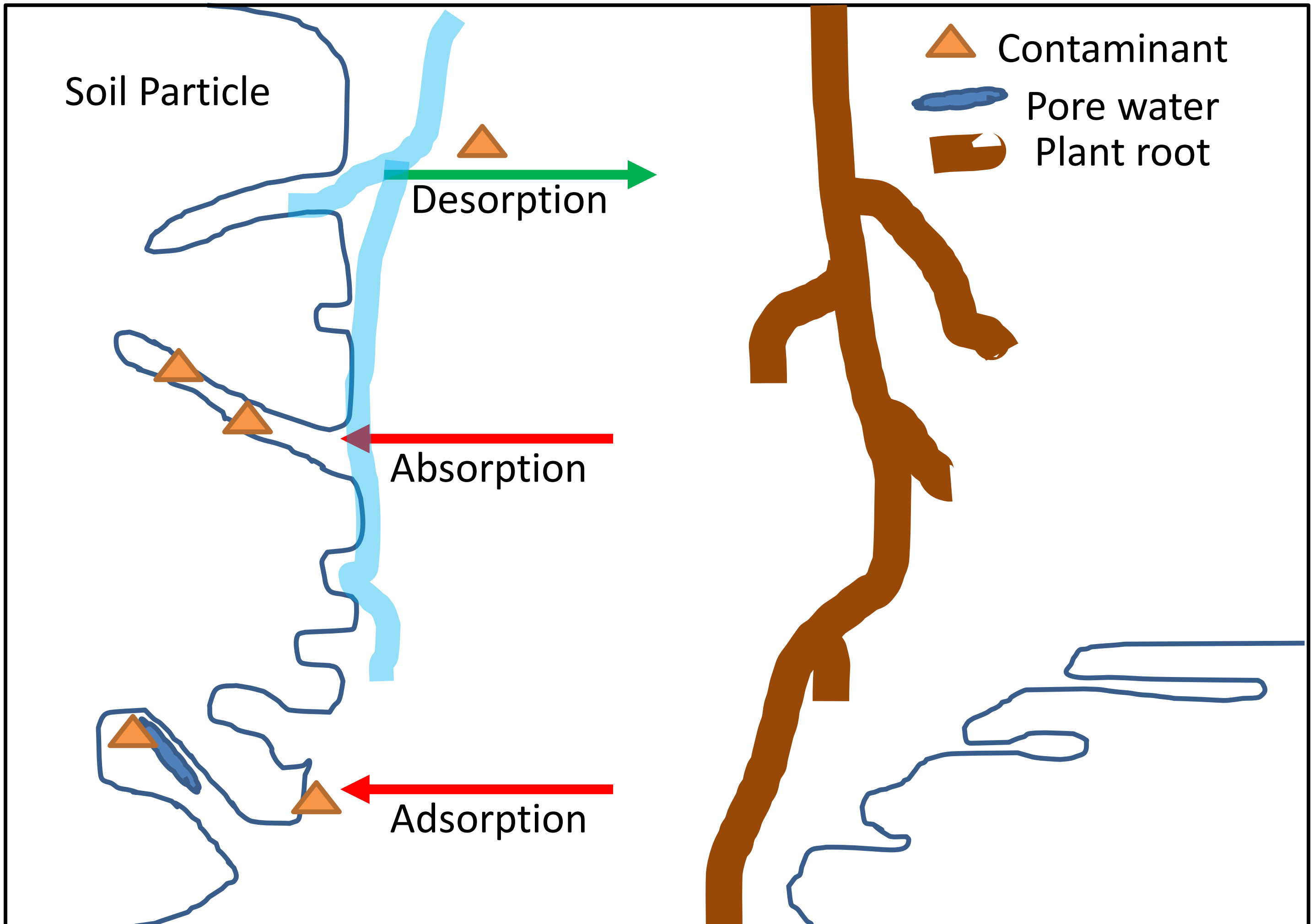
Unplanted Control

PEPS
rate 3-4 times higher

(Gurska et al, 2009)

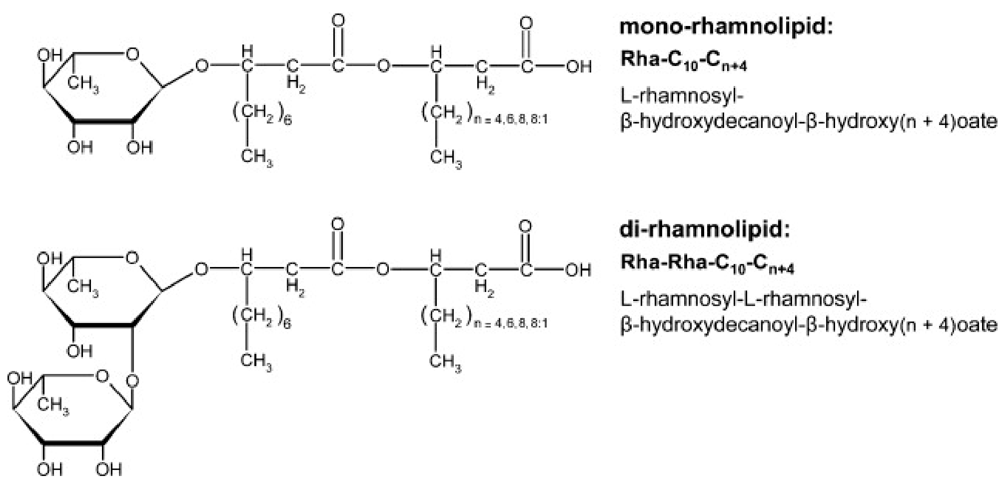
- Rapid decrease in PHC in the first year
- Remediation slows as readily available compounds are degraded first

Water penetration into the soil pores is limited

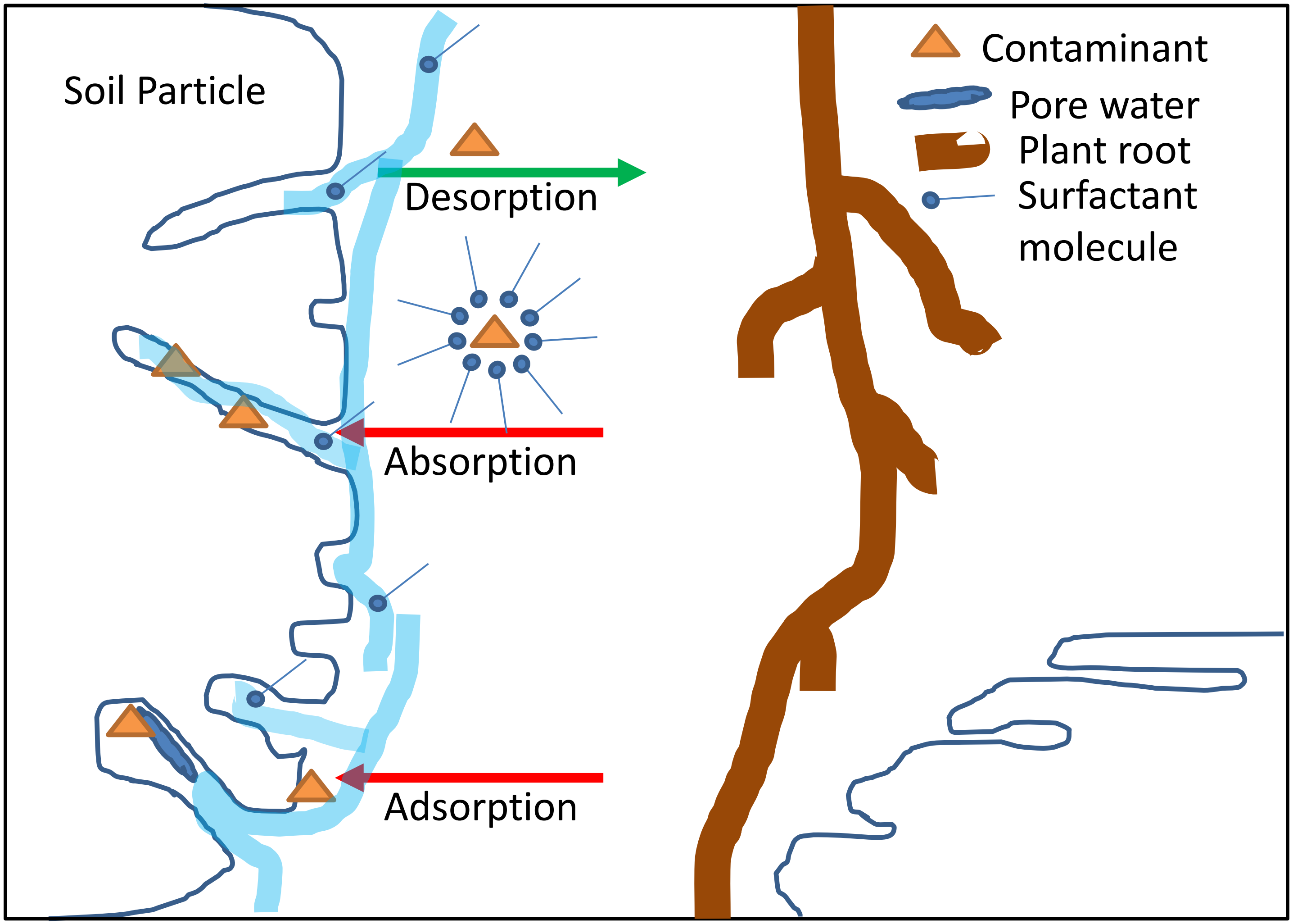


Rhamonolipids

- Biosurfactants
- Naturally produced by *Pseudomonas* bacteria
  - Can be produced in large amounts
- Improves desorption of PHC from soil
- Degraded by soil microorganisms so won’t remain in the soil



With biosurfactant addition, water penetration into soil pores is more effective and surfactants emulsify contaminants

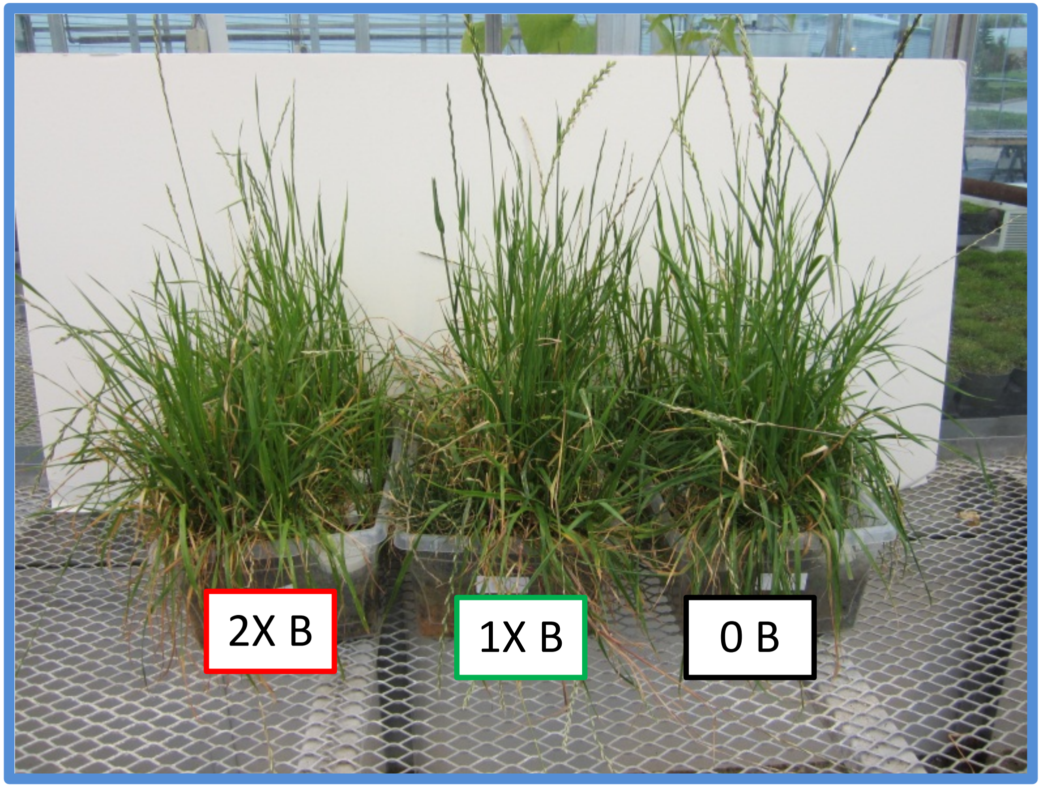


Goals

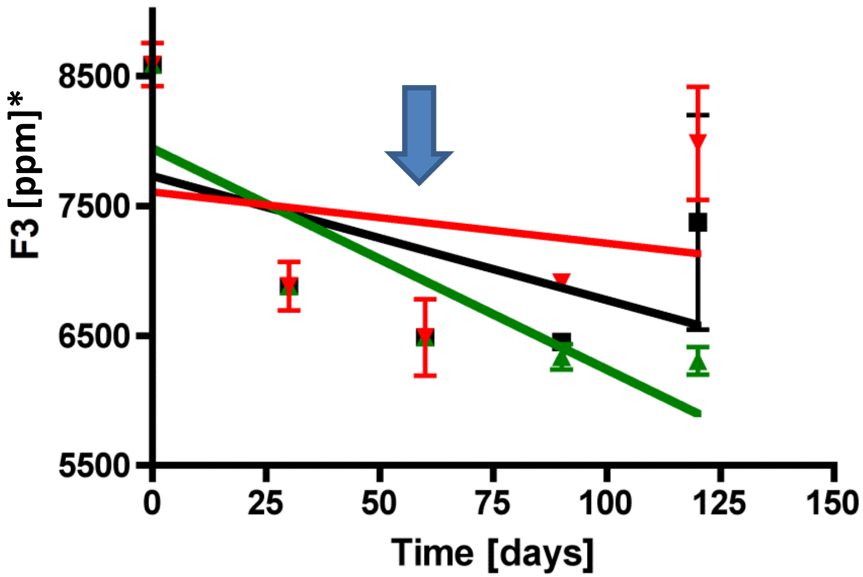
- Test if application of biosurfactants enhances phytoremediation
  - Identify biosurfactants (rhamnolipids) to mobilize PHC in the soil and enhance phytoremediation
  - Conduct bench-scale treatability tests
    - Range finding study
  - Pilot scale field studies

Benchscale testing with rhamnolipids: 40 days with weekly rhamnolipid addition (100 days from planting)

	Parcel 7	Parcel 13	Parcel 20	Parcel 21
PHC % DW Soil	0.8 %	2.1 %	2.4 %	0.4 %



Addition of rhamnolipids increased degradation of PHC



- Low rhamnolipid [1X] increased degradation
- High rhamnolipid [2X] decreased degradation
  - Co-extraction with PHC?
  - Inhibitory effect?

* Data normalized to % surrogate recovery

Conclusions and Future Directions

- Rhamnolipids increase degradation of PHC
  - More is not necessarily better
  - We will be narrowing down concentrations of rhamnolipid further to optimal range
- Optimal rhamnolipid concentrations will be used for future pilot studies
  - Site with high exceedances

General Conclusions

- PHC degradation observed in the greenhouse, expect to see similar results in the field as significant plant growth was achieved
- Based on success with other sites, we're expecting 30-50% remediation of soil and decrease in groundwater PHC/Na concentration

Acknowledgements

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Questions?

Jola.Gurska@Stantec.com