Toronto Port Lands: Bench-Scale and Pilot-Scale Testing Overview

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Waterfront Toronto

SMART Remediation
Toronto, ON | January 25, 2018

SMART is Powered by: VERTEX Environmental Inc.
www.vertexenvironmental.ca
Toronto Port Lands Bench Scale and Pilot Testing Overview
January 25, 2018

SMART Remediation

Agenda

Overview

In-situ Remediation

In-situ Stabilization

Ex-situ Remediation

Next steps
Building a river

Unique and Unprecedented:
- River Mouth concept as flood protection
- No established regulatory approval process for creating a river in brownfield

After Flood Protection:
- New Don River mouth
- Don Greenway (north of the Ship Channel)
- Improved Keating Channel
- Additional Infrastructure to drive development

Port Lands — Historical
Challenges

- Environmental: widespread environmental contamination, free phase, metals in some areas (lead >120 μg/g)
- Geotechnical: compressible peat, flowing sand, low strength soil

Contaminant Distribution
Bench and Pilot Scale to Determine Treatment Options

• Quest for innovative but proven technologies to address the environmental and geotechnical challenges
  • In-situ remediation and/or stabilization of Non-aqueous Phase Liquid (NAPL)
  • In-situ Soil Stabilization to Improve Geotechnical Conditions
  • Ex-situ soil remediation, amendment and dewatering technologies

• 51 original proposals
• Selected 10 bench-scale tests using soil samples from the Port Lands
• Selected 6 field-scale pilot tests

<table>
<thead>
<tr>
<th>Bench Scale Studies</th>
<th>Bench and Pilot Scale Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segregation and Soil Washing</td>
<td>In-situ and ex-situ smoldering (STAR, STARx)</td>
</tr>
<tr>
<td>Ex-situ Physical, Chemical, Biological Treatment</td>
<td>Ex-situ Enhanced Bioremediation</td>
</tr>
<tr>
<td>Electrical-Thermal Dynamic Stripping (ET-DSP) (in-situ)</td>
<td>In-situ Treatment/Immobilization (Block &amp; Adsorb)</td>
</tr>
<tr>
<td>In-situ Cement-based Stabilization Solidification</td>
<td>In-situ Surfactant Flushing and Chemical Oxidation (SEPR-S-ISCO)</td>
</tr>
<tr>
<td>In-situ Geotechnical Improvement (Nitrate Based Stabilization)</td>
<td>In-situ Geotechnical Improvement (Urea Based Stabilization)</td>
</tr>
</tbody>
</table>
In-situ Remediation

- Smoldering
- Surfactant Enhanced Removal and Chemical Oxidation

STAR/STARx (In-situ Self-sustaining Treatment for Active Remediation)

- A smoldering combustion treatment technology where the contaminants are the source of fuel. The process is sustained by the addition of air through a well. Once ignited, the energy of the reacting contaminants is used to pre-heat and initiate combustion of contaminants in adjacent areas (e.g. charcoal briquette)
- Application: In-situ within the future river footprint prior to excavation or outside the river footprint
- Application: Ex-situ - Contaminated soils intended for reuse within the project area
STAR and STARx – Bench Scale Performance

Before and after treatment of shallow soils (0.6–1.2 mbgs)

Table 1: Concentrations of PHCs in Shallow Soils, Before and After Treatment

<table>
<thead>
<tr>
<th>Compound</th>
<th>Table 9 SCS</th>
<th>'Before' STAR Treatment Concentration in Soil</th>
<th>'After' STAR Treatment Concentration in Soil</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum hydrocarbons (µg/g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 (C6-C10)</td>
<td>25</td>
<td>19</td>
<td>-5.0</td>
<td>-78%</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>18.5</td>
<td>-5.0</td>
<td>-78%</td>
</tr>
<tr>
<td>F2 (C10-C15)</td>
<td>10</td>
<td>229</td>
<td>&lt;10</td>
<td>-99%</td>
</tr>
<tr>
<td>F3 (C15-C34)</td>
<td>250</td>
<td>693</td>
<td>&lt;10</td>
<td>-99%</td>
</tr>
<tr>
<td>F4 (C34-C50)</td>
<td>120</td>
<td>957</td>
<td>&lt;10</td>
<td>-99%</td>
</tr>
<tr>
<td>Total PHCs (C6-C50)</td>
<td>No Value</td>
<td>1,600</td>
<td>&lt;72</td>
<td>-86%</td>
</tr>
</tbody>
</table>

Table 2: Concentrations of PHCs in Intermediate Soils, Before and After Treatment

<table>
<thead>
<tr>
<th>Compound</th>
<th>Table 9 SCS</th>
<th>'Before' STAR Treatment Concentration in Soil</th>
<th>'After' STAR Treatment Concentration in Soil</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum hydrocarbons (µg/g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 (C6-C10)</td>
<td>25</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td></td>
</tr>
<tr>
<td>F2 (C10-C15)</td>
<td>10</td>
<td>1,200</td>
<td>&lt;10</td>
<td>-99%</td>
</tr>
<tr>
<td>F3 (C15-C34)</td>
<td>240</td>
<td>7,450</td>
<td>&lt;10</td>
<td>-99%</td>
</tr>
<tr>
<td>F4 (C34-C50)</td>
<td>120</td>
<td>2,000</td>
<td>&lt;10</td>
<td>-99%</td>
</tr>
<tr>
<td>Total PHCs (C6-C50)</td>
<td>No Value</td>
<td>11,000</td>
<td>&lt;72</td>
<td>-86%</td>
</tr>
</tbody>
</table>

Waterfront Toronto Pilots

- In situ treatment at two locations (5 – 7 m bgs)
- Ex situ treatment from two locations (< 3 m bgs, pre-treatment PHC up to 73,000 µg/g)
STAR Results – in progress

Monitoring location ~1 m from Ignition Point

Pre-treatment (5-6 mbgs):
10 – 150 ppm PID reading

Post-treatment (5-6 mbgs):
<2 ppm PID reading

SEPR (Surfactant Enhanced Product Recovery) and S-ISCO (Surfactant- enhanced In-Situ Chemical Oxidation)

• In-situ remediation
• SEPR involves the injection of surfactants and low concentrations of hydrogen peroxide to remove free-product and residual NAPL
• S-ISCO treatment addresses residual contamination post bulk NAPL removal
• Application: In-situ within the future river footprint or outside the river footprint

Source: http://www.ethicalchem.com/remediation-technologies
SEPR and S-ISCO – Bench Scale Performance

Before SEPR and S-ISCO treatment

After SEPR and S-ISCO treatment

Concentrations of PAHs, VOCs, and PHCs before and after treatment

<table>
<thead>
<tr>
<th>Compound</th>
<th>Before SEPR and S-ISCO Treatment</th>
<th>After SEPR Treatment</th>
<th>After SEPR and S-ISCO Treatment</th>
<th>Percent Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PAHs</td>
<td>1,299,700</td>
<td>529,100</td>
<td>4,287</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>(ug/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total VOCs</td>
<td>99,400</td>
<td>58,400</td>
<td>1,917</td>
<td>98%</td>
</tr>
<tr>
<td>(ug/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total PHCs</td>
<td>17,581</td>
<td>4,600</td>
<td>186</td>
<td>99%</td>
</tr>
<tr>
<td>(mg/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SEPR and S-ISCO – Pilot Scale Setup

Injection, extraction and observation wells
In-situ Stabilization

• Block & Adsorb
• Cement Stabilization (bench scale only)
Block and Adsorb

• A combination of physical stabilization (using PC) and carbon adsorption (using GAC). GAC will adsorb the free-phased LNAPL present in soils and the PC will bind the soil matrix together to lower the hydraulic conductivity, thereby further physically immobilizing the LNAPL.

• Application:
  o Soil mixing — shallow soils where LNAPL is present
  o Injection — deeper soils where PHC concentrations have migration potential

Block and Adsorb

• 10 batch tests
• % cement ranging from 0.5 to 3.5%
• % GAC ranging from 2 to 20%
• Assessed hydraulic conductivity, strength, NAPL indicators (sheen, film, Sudan IV indicators)
• Selected 0.5 to 1% PC and 2 to 5% GAC for pilot test
• Two approaches: mixing and injection
Block and Adsorb - pilot

Area prior to block and adsorb; showing oily product on well probe and in excavation

Block and Adsorb - pilot

Showing mixed zone after adding of block (cement) and adsorb (carbon)
Soil Stabilization / Solidification

- In-situ Soil Stabilization / Solidification using Portland cement
- This technology involves the mixing of amendments, such as Portland cement, into the soil to physically solidify the soil mass and stabilize NAPL. The solidification process simultaneously improves the structural strength of the soil and creates a stronger, more stable base for construction
- Application:
  - In-situ along the future river channel alignment — can act as dual-purpose barriers

Soil Stabilization / Solidification — Bench Scale Performance

- Tested variations of cement and slag and tested for hydraulic conductivity and strength
- Best performance with:
  - 12% Portland-Limestone cement (per dry weight of soil)
  - 8% Portland cement
  - 2% Portland cement and 4% blast furnace slag
- Application using unique Cutter Soil Mixing Process
Ex-situ Remediation

• Enhanced Bioremediation
• Soil Washing
• Physical, Chemical, Biological Treatment (bench only)
• Smoldering (STARx) (see previous slides)

Enhanced Bioremediation (Biopiles)

• Involves construction of soil piles dosed with nutrients, bulking agents, surfactants, and/or microbial cultures to enhance biological performance
• Application: Stockpiled soils or any contaminated soils intended for reuse

Source: http://vertexenvironmental.ca/2017/03/wait-dont-throw-beneficial-reuse-soils-just-may-better-way-go/
Enhanced Bioremediation (Biopiles) – Bench Scale Performance

- Bench Scale: Over 10 batch tests with varying microbial augmentation, nutrients, bulking agents; variable treatment: ranged from 45 to 99% contaminant reduction
- Pilot Scale: proceeded with 4 treatment cells

<table>
<thead>
<tr>
<th>Pile Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>The control pile is covered with an impermeable liner. No amendments or other changes are introduced to this pile</td>
</tr>
<tr>
<td>Anaerobic Bio</td>
<td>Soils dosed with BOS-200 (activated carbon adsorbent/microbial growth matrix, anaerobic electron acceptors (sulfate from gypsum), nutrients, and microbial augment) and covered</td>
</tr>
<tr>
<td>Aerobic Bio</td>
<td>Soils dosed with sawdust as a bulking agent + blood meal as a natural nutrient source</td>
</tr>
<tr>
<td>Aerobic Bio</td>
<td>Soils dosed with sawdust as a bulking agent + blood meal as a natural nutrient source + Matsphere (silica microsphere adsorbent/ microbial growth matrix, nutrients and a microbial augment) + Micro-Blaze (surfactant nutrients, and microbial augment) formulations to provide a combination of surfactants, microbial growth substrates, and microbial populations.</td>
</tr>
</tbody>
</table>

Enhanced Bioremediation (Biopiles) – Pilot Scale

Biopile – adding amendment and piping  Biopile – piles covered and system operation
PhysChemBio

• A soil washing and dewatering technology that incorporates various unit modules to treat soil using both physical and chemical extraction techniques that also enhance natural biological treatment functions and subsequently dewater the soil/sediment in the process of treatment, all in one operation
• Application: Stockpiled soils or any contaminated soils intended for reuse
• Produce Treated Sand and Treated Silt/Clay Fractions
• Treatment of PAHs, VOCs, PHCs typically >90%; challenges with PHC F4 treatment

Segregation & Soil Washing

• separation and washing excavated soil constituents by particle size
• Uses on-site mobile system to produce backfill material, using minimal volumes of clean water, and remediates PHCs from the soil
• Application: Stockpiled soils or any contaminated soils intended for reuse
Segregation & Soil Washing – Bench Scale Performance

<table>
<thead>
<tr>
<th></th>
<th>F1 PHCs (ug/g)</th>
<th>F2 PHCs (ug/g)</th>
<th>F3 PHCs (ug/g)</th>
<th>F4 PHCs (ug/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>856</td>
<td>4315</td>
<td>5640</td>
<td>915</td>
</tr>
<tr>
<td>Treatment Goals</td>
<td>210</td>
<td>150</td>
<td>300</td>
<td>2800</td>
</tr>
<tr>
<td>Screen 2 (6.4 mm)</td>
<td>131</td>
<td>853</td>
<td>1730</td>
<td>296</td>
</tr>
<tr>
<td>Screen 3 (2 mm)</td>
<td>164</td>
<td>1940</td>
<td>3620</td>
<td>860</td>
</tr>
<tr>
<td>Fines</td>
<td>90.4</td>
<td>1450</td>
<td>2770</td>
<td>620</td>
</tr>
<tr>
<td>Sediment</td>
<td>117</td>
<td>8100</td>
<td>15400</td>
<td>3400</td>
</tr>
</tbody>
</table>

High Pressure-Low Flow – Soil Mass VS PHC Mass

PHC mass is being concentrated into the sediments, which only comprise a very small fraction of the overall soil mass.

- **20% to 25%** of the soil mass >2 mm in size
- **10-15%** of the soil mass in the form of sediments contain the highest concentrations of the F2, F3 and F4 range PHCs and require additional treatment or off-site disposal
- **60% to 70%** of the soils would be fines (<2 mm) that still have some F2, F3 and F4 PHC impact that require additional treatment prior to re-use at the site
Next Steps

• Contaminants can be managed via remediation and/or RMMs
• Decisions on appropriate technology require consideration of:
  • Treatability (based on bench and pilot test results)
  • Implementability (based on schedule and construction plans)
  • Cost (based on lifecycle analysis)

Questions?