STARx (Ex Situ Smouldering) for the Treatment of Contaminated Soils and Liquid Organic Wastes

Case Studies from Around the Globe

Presented by: Grant Scholes, M.E.Sc., P.Eng.
• Smouldering Combustion Basics
• STARx Case Studies
  • Case Study 1: Canada
  • Case Study 2: China
  • Case Study 3: Taiwan
  • Case Study 4: Southeast Asia (Site 1)
  • Case Study 5: Southeast Asia (Site 2)
• STARx Projects In Progress
  • Upcoming Pilots: Brazil, Africa, United States, Australia
  • Full Scale Design: Middle East
• Summary and Questions
Smouldering Combustion
STAR and STARx are based on the process of smouldering combustion:
Exothermic reaction converting carbon compounds to $\text{CO}_2 + \text{H}_2\text{O}$

Smouldering possible due to large surface area of organic liquids (e.g., NAPL) within the presence of a porous matrix (e.g., aquifer)
- **In situ (below water table)**
  - Applied via wells in portable in-well heaters

- **Ex situ (above ground)**
  - Soil piles placed on “Hottpad” system
Overview of Hottpad Treatment

Video accelerated 50 times
Smouldering Combustion

Typical transformation of soil undergoing STARx process:
Hottpad Field Scales

Rapid Screening
- 1.5-2m³ batches
- Rapid screening tests
- Multiple tests / fast deployment

Pilot Scale
- 6-10m³ batches
- Full scale design parameters

Full Scale – Base System
- 150-200m³ batches
- Multiple Base Systems integrated into larger plants to meet throughput
Case Study 1: Toronto, Canada

STARx

Case Study 1: Waterfront Toronto
Toronto, Canada
Site Background

- The Port Lands Area is an 880 acre brownfield site, 715 acres of that are high-risk flood area.
- In June 2017, WFT announced $1.25 billion in funding to naturalize the mouth of the Don River, provide flood protection and lay the groundwork for new communities.
- Soil quality: widespread impacts across the site, with petroleum hydrocarbons (PHCs) being the predominant contaminant of concern.

Scope of Work

- Treatability Study on Site soils
- STAR single ignition point pilot test
- STARx Hottpad pilot test (2 x 10 m³ tests)
STARx Pilot Test
### Test 1

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Pre Operations</th>
<th>Post Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 cm</td>
<td>60 cm</td>
</tr>
<tr>
<td>F1 (C6-C10)</td>
<td>266</td>
<td>106</td>
</tr>
<tr>
<td>F2 (C10-C16)</td>
<td>2,510</td>
<td>891</td>
</tr>
<tr>
<td>F3 (C16-C34)</td>
<td>25,200</td>
<td>17,900</td>
</tr>
<tr>
<td>F4 (C34-C50)</td>
<td>7,250</td>
<td>4,790</td>
</tr>
<tr>
<td>Total</td>
<td>35,200</td>
<td>23,700</td>
</tr>
</tbody>
</table>

#### Notes:
- Thermocouple bundles A, B, C, and D are offset 60 cm from each corner.
- Thermocouple bundle E is located in the center of the Hotpad™.
- Thermocouple heights (i.e., 0 cm, 10 cm, 25 cm, 50 cm, 100 cm, 140 cm, and 170 cm) reported as distances above the screen at the base of the soil pile.
STARx Results
• Sludge disposal and brick manufacturing facility
• Sludge waste (3 types)
  • Plus oil-soaked bags
• Dual-unit rapid screening system
<table>
<thead>
<tr>
<th>Test No.</th>
<th>Soil Type</th>
<th>Soil:Sludge: Shredded Bag Ratio</th>
<th>Sludge Type</th>
<th>Propagation Rate (m/d)</th>
<th>Total Petroleum Hydrocarbon Concentrations (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pre-STARx</td>
</tr>
<tr>
<td>1</td>
<td>Quartz sand</td>
<td>13:1:0</td>
<td>Pond #1</td>
<td>0.43</td>
<td>3,360*</td>
</tr>
<tr>
<td>2</td>
<td>Site soil</td>
<td>13:1:0</td>
<td>Pond #1</td>
<td>0.37</td>
<td>7,830*</td>
</tr>
<tr>
<td>3</td>
<td>Site soil</td>
<td>6:1:0</td>
<td>Pond #1</td>
<td>0.15</td>
<td>13,000*</td>
</tr>
<tr>
<td>4</td>
<td>Site soil</td>
<td>8:1:0</td>
<td>Pond #2</td>
<td>0.22</td>
<td>5,510*</td>
</tr>
<tr>
<td>5</td>
<td>Site soil</td>
<td>4:1:0</td>
<td>Centrifuge</td>
<td>0.15</td>
<td>16,800*</td>
</tr>
<tr>
<td>6</td>
<td>Site soil</td>
<td>4:3:0</td>
<td>Pond #2</td>
<td>0.13</td>
<td>30,600*</td>
</tr>
<tr>
<td>7</td>
<td>Site soil</td>
<td>2:1:0</td>
<td>Centrifuge</td>
<td>0.17</td>
<td>25,300*</td>
</tr>
<tr>
<td>8</td>
<td>Site soil</td>
<td>1:1:1</td>
<td>Pond #2</td>
<td>0.12</td>
<td>66,300*</td>
</tr>
</tbody>
</table>
Sludge Disposal, Shaanxi, China

Before

After
Case Study 3: Kaohsiung, Taiwan

STARx

Case Study 3: PHC-Impacted Soil
Kaohsiung, Taiwan
• Former base oil and lubricant blending plant
• Range of soil types:
  • Silt, sand, and gravelly sand
• Focus on finding lower concentration threshold of SS smouldering
• Rapid screening system
PHC-Impacted Soil, Kaohsiung, Taiwan

• Site silts and gravelly sands successfully treated
  • SS smouldering achieved with initial concentrations as low as ~4,000 mg/kg TPH
  • Lower initial concentrations possible if amended with surrogate fuel
Case Study 4: Southeast Asia (Site 1)

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Case Study 4: Fine Grained Materials and Revegetation of Treated Soils Southeast Asia (Site 1)
• Treat oil-impacted soil (OIS)
  • Confirm treatment via STARx
• Assess operational envelope
  • Oil content, moisture content, clay content
• Develop information to support system design
  • Full-scale systems (fixed and mobile)
• Field study of revegetation potential
Hottpad Rapid Screening System Set up
• High clay and silt content (70 – 80%)
• Moderate to High moisture content (15 – 40%)
• Variable oil content (1 – 4.5%)
  • Non-uniform distribution
Combustion Results

• Completed 12 test runs
  • All runs successfully treated OIS
  • The treatment process is very robust
  • Clay, water, and oil content

• Soil mixing for more uniform oil distribution
  • Does not require homogeneity

• Improved performance at lower injection flow
  • More uniform treatment
  • Less probability of fracturing the pile
Revegetation Study

Clean Soil

Oil-Impacted Soil

Hottpad Treated Soil

Fertilizer

No Amendments
Case Study 5: Full-Scale Treatment of Oil-Water Separator Sludge
Southeast Asia (Site 2)
Site Background

- Active terminal facility in south east Asia
- Designed to treat 3,500 m³ of stockpiled API separator sludge
- Co-treatment with oil-impacted site soils
Hottpad Full-Scale – Field Deployment
Process Monitoring
### Additional Post-Treatment Results

<table>
<thead>
<tr>
<th>Compound</th>
<th>“Before” Concentration</th>
<th>“After” Concentration (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTEX</td>
<td></td>
<td>ND</td>
</tr>
<tr>
<td>TPH C&lt;sub&gt;6&lt;/sub&gt;-C&lt;sub&gt;9&lt;/sub&gt;</td>
<td></td>
<td>ND</td>
</tr>
<tr>
<td>TPH C&lt;sub&gt;10&lt;/sub&gt;-C&lt;sub&gt;22&lt;/sub&gt;</td>
<td></td>
<td>ND</td>
</tr>
<tr>
<td>TPH C&lt;sub&gt;23&lt;/sub&gt;-C&lt;sub&gt;36&lt;/sub&gt;</td>
<td></td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td>35,506</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Grand Prize INDUSTRIAL WASTE PRACTICE 2018**
STARx (Upcoming Projects)
UPCOMING PROJECTS

Brazil

- STARx Pilot on Chloronitrobenzene compounds in soil (Q3 2019)
- Former Chemical manufacturing facility in Brazil
- Multiple 10m³ test runs to optimize full scale operating parameters

Africa

- STARx Pilot to test hydrocarbon paraffin sludges (Q1 2019)
- Active oil terminal facility in Western Africa
Upcoming Pilot Projects

United States
- Active oil field in western United States
- Treat hydrocarbon sludge and impacted soil
- Demonstrate technology with regulatory agencies

Australia
- Commercial waste processing facility in North Western Australia
- Full scale treatment of hydrocarbon sludge
- Trial emerging contaminants
4 Base System Plant

- Designed to treat approximately 300,000m³ of hydrocarbon sludge in 5 years
- Design underway, field deployment set to begin in 2019
Technology Cost Drivers

- **Capital**
  - Hottpad system
  - Emissions treatment system
- **Throughput**
  - Treatment propagation rate
  - Project duration
- **Energy Requirements**
  - Heaters
  - Blowers
  - Emissions treatment

**Example Project**

- 4-Base System Plant in North America to designed to treat ~ 200,000 tonnes of soil in 5 years
- CapEx of 40$/tonne (CDN)
- OpEx of 25$/tonne (CDN)
Summary

• Effective and Robust
  • Rapid on-site treatment
  • Complete destruction of contaminants
• Reduced cost versus other technologies
• Safe and Sustainable
  • Self-sustaining process = less energy use
• Flexible
  • Modular STARx systems fully expandable to meet target throughput
  • Deployable at source areas and remote locations all over the world
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