Surfactant Enhanced Remediation Technologies

Dan Socci, CEO
2014
Green Chemical Solution for Remediation and Oil Industries

ETHICALCHEM BACKGROUND
EthicalChem Background

- Recently acquired the intellectual property assets of VeruTEK Technologies Inc.
- Provides plant-based, green chemical solutions for remediation and oilfield applications

<table>
<thead>
<tr>
<th>Remediation Technologies</th>
<th>Oilfield Technologies</th>
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<tbody>
<tr>
<td>• SEPR <em>(Surfactant Enhanced Product Recovery)</em></td>
<td>• Viscosity reduction</td>
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<tr>
<td>• S-ISCO <em>(Surfactant-enhanced In Situ Chemical Oxidation)</em></td>
<td>• Demulsification</td>
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<td></td>
<td>• Drilling muds removal</td>
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<td></td>
<td>• Wellbore cleaning</td>
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<td>• Oily wastewater separation</td>
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Field Proven Technologies

- 50+ remediation sites completed
- 20+ oil fields
- 10 patents
Green Chemical Solution for Environmental Remediation

REMEDIATION TECHNOLOGIES
• Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO)
  – Desorbs and destroys residual contamination in place
  – Simultaneous injection of surfactant and oxidant

• Surfactant Enhanced Product Recovery (SEPR)
  – Desorption and gas generation improves recovery of Non-Aqueous Phase Liquid (NAPL) contamination
  – Implemented first to maximize S-ISCO performance
Emulsions increase interface area between oxidant and contaminant by several orders of magnitude.

Volume: 50 cubic feet
Surface area: 220 square feet

Volume: 50 cubic feet
Emulsion Diameter: 1 millimeter
Surface area: 91,440 square feet
Approximately 2.5 orders of magnitude higher

Volume: 50 cubic feet
Emulsion Diameter: 1 micrometer
Surface area: 91,493,000 square feet
Approximately 5 orders of magnitude higher
ISCO Performance

- Sorbed contaminants on soil and in soil pores
- Oxidants introduced into groundwater
- Dissolved contaminants oxidized
- Contaminants leach back into groundwater – Rebound
- Repeat treatments
S-ISCO Performance

- Sorbed contaminants on soil and in soil pores
- Surfactant and oxidant introduced into groundwater
- Sorbed contaminants are emulsified into aqueous phase
- Complete removal of contamination – no rebound
SEPR Performance

- Bulk, free phase NAPL present in subsurface
- SEPR fluid injected
- Surfactants desorb and emulsify NAPL
- Gas bubbles generated from peroxide
- Help facilitate movement to recovery wells
- Residual contamination remains
Pre and Post S-ISCO Implementation

Pre-Treatment
- NAPL saturated pore space
  - PID reading > 4,000 ppm

Post-Treatment
- PID reading 457 ppm
S-ISCO and SEPR Implementation

CASE STUDY EXAMPLES
1. S-ISCO treatment of VOCs in NY State
2. SEPR Creosote Recovery in a U.S. Gulf State
3. SEPR & S-ISCO MGP remediation in Sydney, AU
4. S-ISCO treatment of New York City Brownfield site
S-ISCO Treatment of VOCs at NY Site

**Site**
Textile Manufacturing Company

**Contaminants of Concern**
TCA, Volatile Organic Compounds

**Objectives**
Achieve NYSEC Commercial Use Soil Cleanup Criteria

**Remedial Implementation**
S-ISCO

**Consultant**
Fleming Lee Shue
S-ISCO Treatment of VOCs at NY Site

S-ISCO

- Combined surfactant/oxidant desorb & destroy treatment for hydrophobic contaminants

RemMetrik

- Calculates the mass and 3D location of subsurface contamination
- Targets the contamination for treatment with S-ISCO and subsurface pressure waves
- Assesses the effectiveness of treatment

Wavefront Primawave

- Generates subsurface pressure waves that open soil pore spaces.
Treatment Details:

• 50 ft x 50 ft treatment area
• Saturated treatment of 10 - 15 ft bgs
• Treatment Adjacent to creak flowing into Hudson River
• S-ISCO chemical delivery
  - 3 permanent injection wells
  -5 Geoprobe points
• 6 days of S-ISCO injections
S-ISCO Treatment of VOCs at NY Site

S-ISCO injections

Alkaline activated Klozur (persulfate) and EthicalChem proprietary plant based surfactant VeruSOL.

Approximately 14,200 gallons of total fluids consisting of

• Klozur, 15 – 50 g/L
• Sodium hydroxide, 12 – 50 g/L
• VeruSOL 5– 15 g/L
S-ISCO Treatment of VOCs at NY Site

Soil Treatment Results

- cis-1,2 DCE: 89% Reduction
- 112-TCA: 97% Reduction
- PCE: 70% Reduction

Pre-treatment | Post Treatment
### Groundwater Treatment Results

<table>
<thead>
<tr>
<th>VOC</th>
<th>Pre-treat Max. Conc. (µg/L)</th>
<th>Post-treat Max. Conc. (µg/L)</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total VOCs</td>
<td>86,530</td>
<td>11,706</td>
<td>86%</td>
</tr>
<tr>
<td>TCA</td>
<td>48,300</td>
<td>8,630</td>
<td>82%</td>
</tr>
<tr>
<td>112-TCA</td>
<td>34.5</td>
<td>2.3</td>
<td>93%</td>
</tr>
<tr>
<td>1,1-DCA</td>
<td>36,100</td>
<td>2,540</td>
<td>93%</td>
</tr>
<tr>
<td>Chloroethane</td>
<td>1,280</td>
<td>334</td>
<td>74%</td>
</tr>
</tbody>
</table>

All GW Concentrations below site cleanup criteria
S-ISCO Treatment of VOCs at NY Site

Current Site Status:

Based on the post treatment results consultant has recommended site closure.

The site is currently under review for closure by the NYSDEC.
Creosote Remediation with SEPR Technology

U.S. Gulf State
Superfund Creosote Site in U.S. Gulf State

**Site**
- 34 acre Former Wood Treating Facility,

**Contaminants of Concern**
- Creosote DNAPL

**Objectives**
- Enhance well yield of the existing recovery system in saturated zone
- Reduce soil concentrations of TPH in vadose zone
Superfund Creosote Site in U.S. Gulf State

Treatment Details:

- **3 stage treatment approach**
  - Well rehabilitation
  - Vadose zone NAPL removal
  - Saturated zone NAPL removal

- **SEPR Chemistry**
  - Up to 8% hydrogen peroxide
  - 1-5% VeruSOL Creosote formula
## Saturated Recovery Well Performance

<table>
<thead>
<tr>
<th>Well</th>
<th>Pre SEPR Average Yield (gpm)</th>
<th>Post SEPR Average Yield (gpm)</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5</td>
<td>0.82</td>
<td>2.40</td>
<td>193%</td>
</tr>
<tr>
<td>R9</td>
<td>0.16</td>
<td>1.11</td>
<td>594%</td>
</tr>
<tr>
<td>R10</td>
<td>0.11</td>
<td>0.23</td>
<td>109%</td>
</tr>
<tr>
<td>R12</td>
<td>0.24</td>
<td>1.27</td>
<td>429%</td>
</tr>
<tr>
<td>R15</td>
<td>0.31</td>
<td>0.67</td>
<td>116%</td>
</tr>
<tr>
<td>R17</td>
<td>0.04</td>
<td>0.54</td>
<td>1250%</td>
</tr>
<tr>
<td>R18</td>
<td>0.15</td>
<td>0.45</td>
<td>200%</td>
</tr>
</tbody>
</table>
Superfund Creosote Site in U.S. Gulf State

Frac Tank Containing Extracted Fluid

Samples of Extracted Fluid
Results:

• Enhanced recovery rates by up to 1200% in saturated zone

• Achieved 84% TPH mass reduction in the vadose zone

• Enhanced the removal of free phase creosote NAPL from the vadose and the saturated zone
SEPR & S-ISCO Remediation of MGP Contamination

Sydney, AU
MGP Remediation in Sydney, AU

**Site**
Former Gasworks Plant

**Contaminants of Concern**
BTEX, PAHs, TPH

**Objectives**
Demonstrate effectiveness of SEPR & S-ISCO technology at the site

**Remedial Implementation**
SEPR & S-ISCO
Treatment Details:

• 3 Stage Approach
  
  o SEPR Implementation – 2.5 weeks
    ▪ 20 – 40 g/L VeruSOL with 0.5 – 1.0% peroxide
  
  o S-ISCO Implementation with persulfate – 4.5 weeks
    ▪ 5 – 15 g/L VeruSOL with 100 – 200 g/L persulfate
  
  o S-ISCO Implementation with peroxide – 2.5 weeks
    ▪ 5 – 10 g/L VeruSOL with 0.5 – 4% peroxide
MGP Remediation in Sydney, AU

Results

- 31 soil samples were analyzed post treatment
- Majority of samples reached criteria levels

<table>
<thead>
<tr>
<th>Post Injection Samples Below Criteria</th>
<th>Percent of Samples Below Criteria (out of 31)</th>
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<tbody>
<tr>
<td>C10-C14</td>
<td>31</td>
</tr>
<tr>
<td>C15-C28</td>
<td>30</td>
</tr>
<tr>
<td>C29-C36</td>
<td>30</td>
</tr>
<tr>
<td>cPAHs</td>
<td>20</td>
</tr>
<tr>
<td>Benzene</td>
<td>31</td>
</tr>
<tr>
<td>B(a)Ph</td>
<td>26</td>
</tr>
<tr>
<td>Total PAHs</td>
<td>24</td>
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</table>
MGP Remediation in Sydney, AU

Project Outcome & Current Status

• SEPR and S-ISCO technology was deemed effective for removal and destruction of site contaminants

• EthicalChem is currently engaged in submitting plans for full scale work

• Full scale is planned for March 2015
S-ISCO Remediation of MGP Coal Tar
NYC Brownfield Site
MGP Coal Tar Remediation in NYC

**Site**
Former Roofing Products Manufacturer

**Contaminants of Concern**
BTEX, PAHs, & naphthalene

**Objectives**
Reduce contaminant mass to enable issuance of Certificate of Completion

**Remedial Implementation**
S-ISCO
MGP Coal Tar Remediation in NYC

- **Site Conditions:**
  - Former roofing manufacture site
  - ~50,000 lb contamination
  - BTEX, PAHs, naphthalene
  - NAPL
  - Heterogeneous subsurface

- **Challenges:**
  - Adjacent to East River
  - Dense urban neighborhood
  - Weather
  - NAPL

Northern edge of site boundary
~ 100 ft from high-rise, luxury residential building
MGP Coal Tar Remediation in NYC

Treatment Details:

• S-ISCO Implementation
  ▪ 5 g/L VeruSOL
  ▪ 25 – 50 g/L Sodium Persulfate
  ▪ 20 g/L Sodium Hydroxide
  ▪ Total injected volume = 1,201,900 gal
  ▪ 100 days of injections

• RemMetrik™ process to quantify & target contamination

• Wavefront Technology’s Primawave Pressure-Pulsing Sidewinder
MGP Coal Tar Remediation in NYC

Implementation Monitoring:

Weekly Monitoring Showed:

- No NAPL mobilization beyond site boundaries
  - Controlled process
- No vapor pressure increases
- Reduced soil gas concentrations
- No nuisance complaints
MGP Coal Tar Remediation in NYC

Results

- **Soil**: ACHIEVED OBJECTIVE
  - Destroyed > 90% Contaminant Mass (PAHs + BTEX)

- **Groundwater**: ACHIEVED OBJECTIVE
  - Reduced GW Concentrations; Achieved Asymptotic Decreases
    - 91% BTEX

- **Soil Gas**: REDUCED SOIL GAS CONTAMINANTS
  - 100% of benzene, ethylbenzene, naphthalene


- Public Library & Park Ranger Station
On-going Quarterly Groundwater Monitoring Confirmed:
- No rebound
- Continuing asymptotic decreases
- Concentrations approaching Ambient Groundwater Quality Standards

➢ **BTEX:** all wells exhibit overall decreasing or asymptotic trend

➢ **Naphthalene:** most wells show decreasing or asymptotic trend

➢ **Toluene:** 3 more wells met TOGS AWQS

“In samples collected 11 months following the end of injections the continuing overall decline instead of rebound suggests that the source contamination has been effectively treated.”

Fleming Lee Shue report
Q: Will surfactant use cause undesirable contaminant mobilization?

- Surfactant and oxidant are injected together as a homogeneous solution
  - Injected chemistry travels together through subsurface
- Emulsification and oxidation take place simultaneously over time
- VeruSOL typically remains in the soil about a month due to biodegradation and oxidation
- Groundwater speeds typically do not carry emulsion offsite prior to destruction
FAQs: Mobilization

Field and lab projection of two emulsions, traveling vs. destruction

Theoretical Projection of Potential Emulsified Contaminant Movement During Oxidation with 0.5 ft/day Seepage Velocity

- Emulsion oxidation of coal tar contamination
- Emulsion oxidation of MGP Contamination

- 10 mg/L by 43 ft
- 10 mg/L by 51.5 ft
FAQs: Mobilization

• S-ISCO chemistry traveling together – data from an on site monitoring well during and after injections

![Graph showing S-ISCO Chemistry Tracking at a Monitoring Well within Treatment Area - NW]

- Maximum SP detected = 27 g/L
- Maximum TPH detected = 215 mg/L
- Maximum VeruSOL detected = 18 mg/L
FAQs: Surfactant Consumption by Oxidant

Q: Will the surfactant be consumed by the oxidant?

Contaminants are more susceptible to oxidation than surfactant.

- Contaminants will be oxidized first.

![Graph of Interfacial Tension (IFT) Over Time](image)

- Increase in IFT indicates destruction of surfactant.
- Stable, low IFT indicates stable presence of surfactant.

**Evaluation of Surfactant Over Time During Oxidation With and Without Contaminant**

Interfacial Tension (IFT) Over Time

11/22 12/12 1/1 1/21 2/10 3/2 3/22 4/11 5/1 5/21

- VeruSOL with SP
- VeruSOL, SP, and NAPL
Thank you.

EthicalChem
USA

www.ethicalchem.com