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A division of Ethical Solutions LLC

Surfactant Enhanced Product Recovery for Creosote Remediation

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Green Chemical Solution for Remediation and Oil Industries

ETHICALCHEM BACKGROUND

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

Remediation Technologies	Oilfield Technologies
• SEPR™ (*Surfactant Enhanced Product Recovery*) • S-ISCO® (*Surfactant-enhanced In Situ Chemical Oxidation)*	• Viscosity reduction • Demulsification • Drilling muds removal • Wellbore cleaning • Oily wastewater separation

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Field Proven Technologies

- ✓ **50+ remediation sites completed**
- ✓ **20+ oil fields**
- ✓ **10 patents**

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Green Chemical Solution for Environmental Remediation

CREOSOTE REMEDIATION WITH SEPR

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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)
  - Desorbsion and gas generation improves recovery of Non-Aqueous Phase Liquid (NAPL) contamination
  - Implemented first to maximize S-ISCO performance

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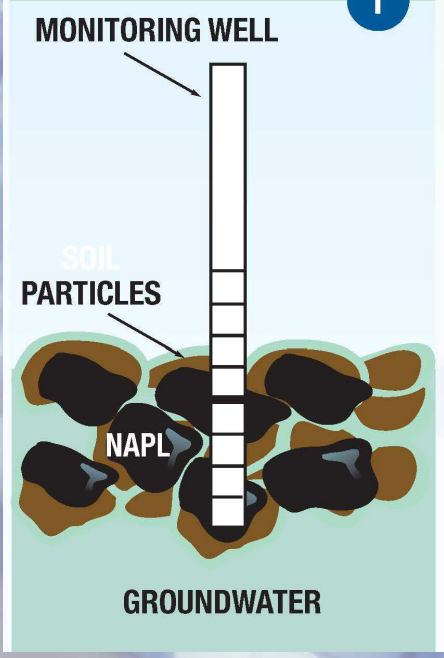
SEPR Technology

Initial Conditions

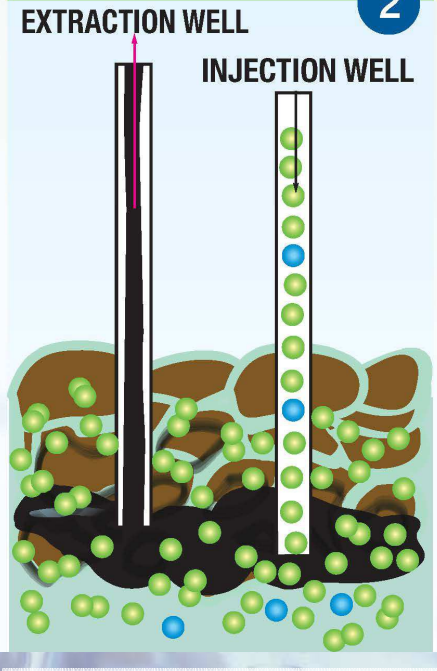
1



- NAPL contamination

SEPR Facilitated Extraction

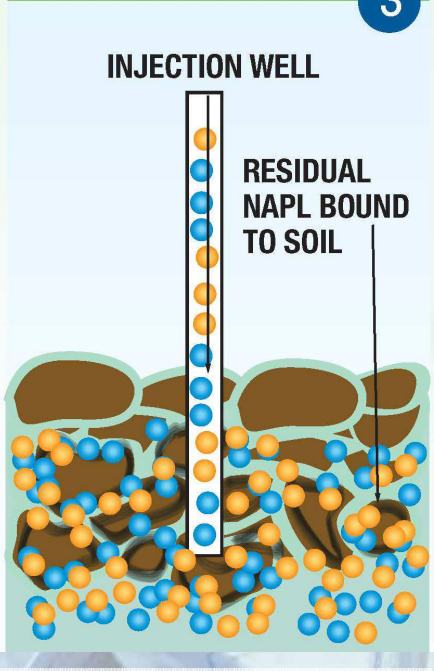
2



- Proprietary surfactant blend and low doses of peroxide are injected
- Surfactant desorbs and lowers viscosity of NAPL
- Gas generated from peroxide loosens NAPL for extraction

S-ISCO Emulsification & Destruction

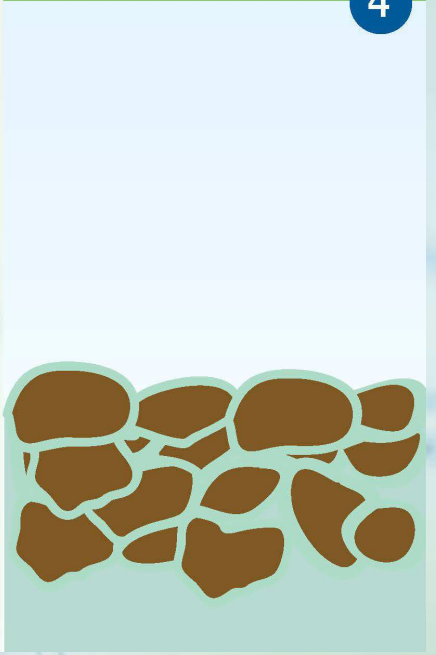
3



- VeruSOL® and oxidant are injected simultaneously
- VeruSOL® emulsifies residual NAPL into micro-sized droplets, facilitating oxidative destruction

Post Treatment

4



- Soil and groundwater are clean

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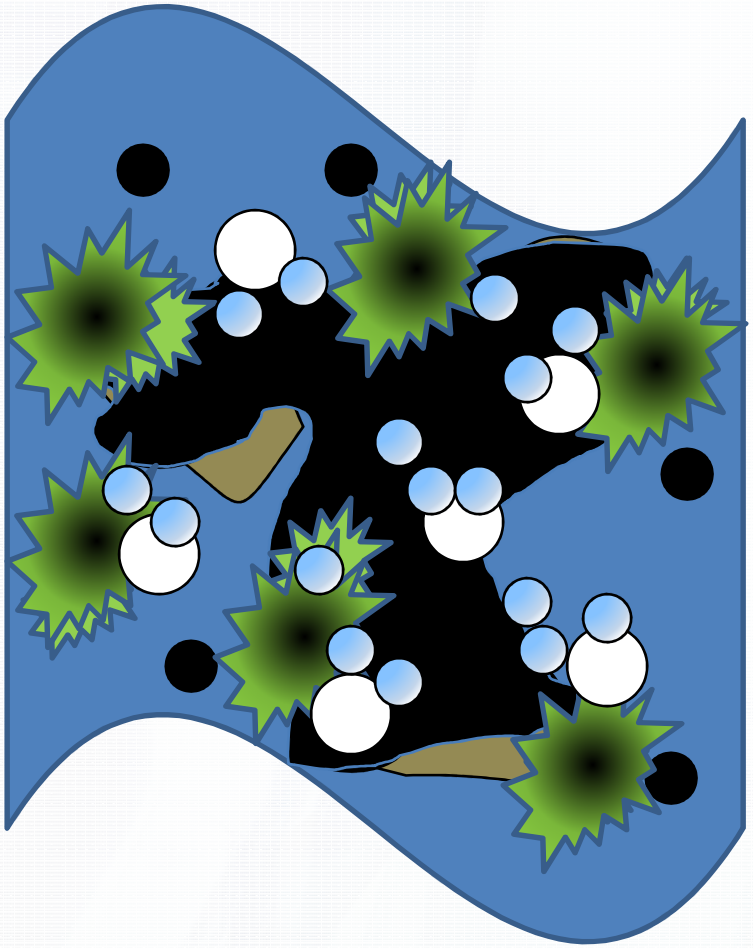
SEPR Performance



- Bulk, free phase NAPL present in subsurface
- SEPR fluid injected
- Surfactants desorb and emulsify NAPL
- Gas bubbles generated from peroxide
- Movement to recovery wells
- Residual contamination remains

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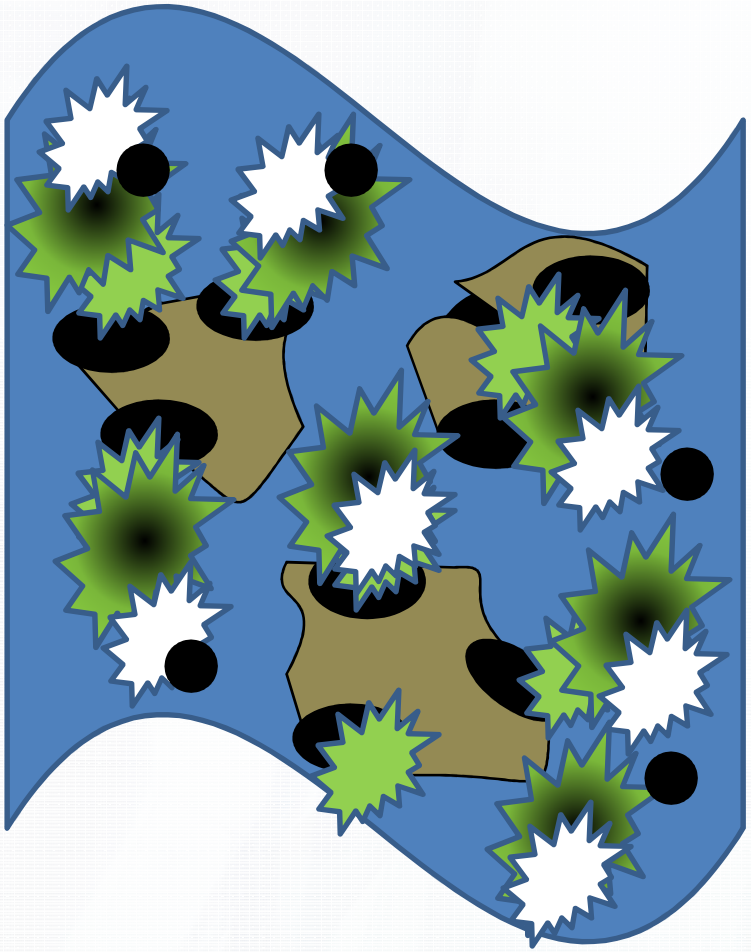
S-ISCO Performance



- Sorbed contaminants on soil and in soil pores
- Surfactant and oxidant introduced into groundwater
- Sorbed contaminants are emulsified into aqueous phase
- Removal of source contamination – no rebound

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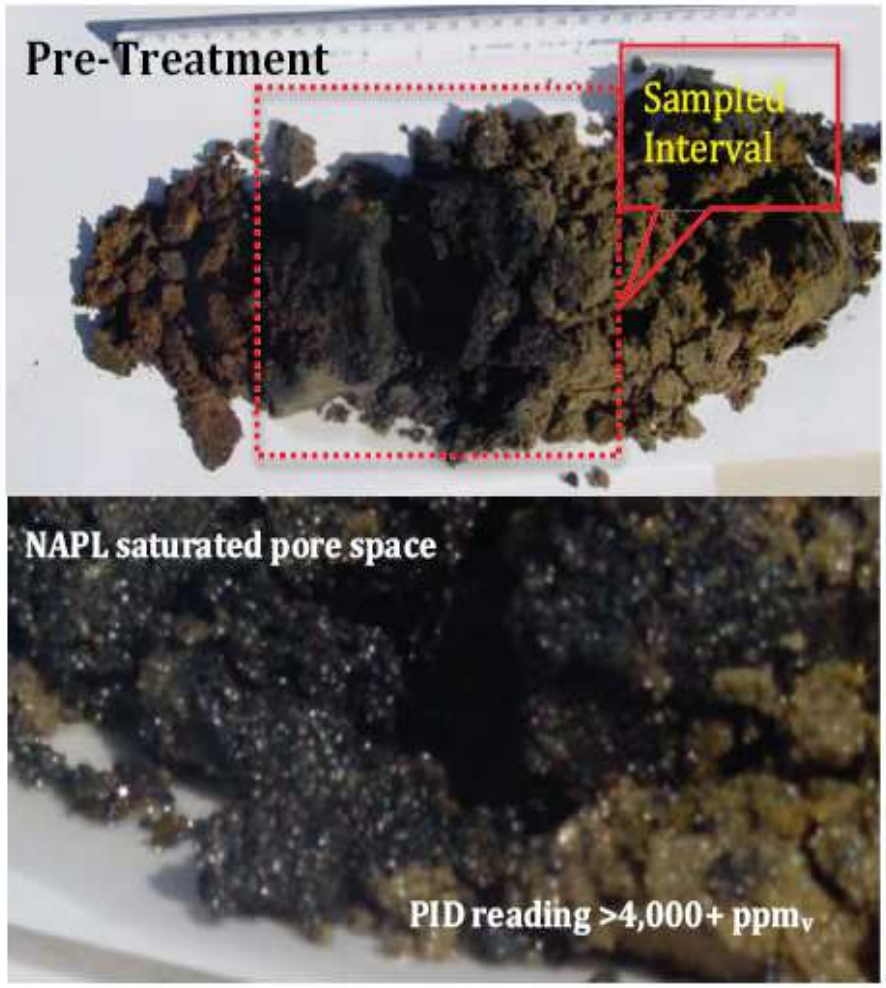
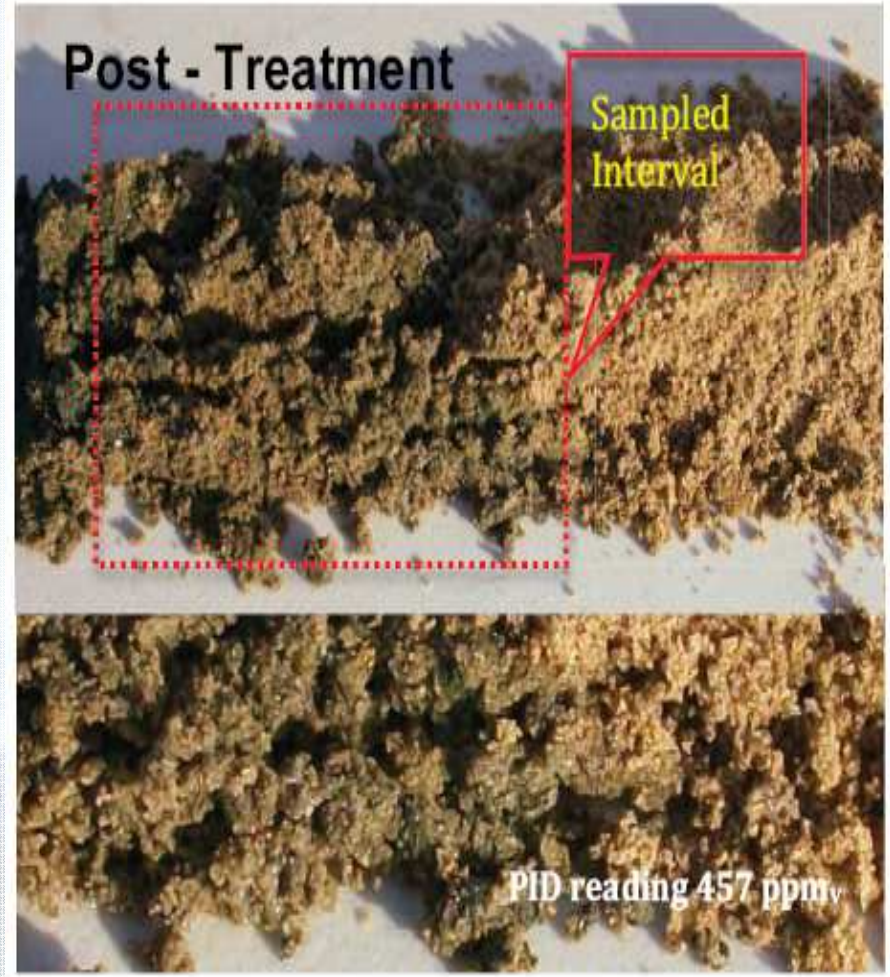
Pre and Post S-ISCO Implementation





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SEPR Technology

When to Implement SEPR

Hydrophobic Compounds

BTEX, diesel, gasoline, naphthalene, chlorinated solvents

Free phase NAPL present
> 1" (2.5 cm)
or
Soil Concentrations
>10,000 mg/kg

Very Hydrophobic Compounds

Creosote, MGP/Gas Works, PAHs, # 6 fuel oil,

Any presence of NAPL phase materials, blebs and residual free phase in soil

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SEPR Implementation for Creosote Remediation

CASE STUDY EXAMPLES

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SEPR & S-ISCO Treatment of Creosote

Site
Former Wood Treatment Facility, Bridgeville, DE

Contaminants of Concern
Creosote DNAPL

Objectives
Demonstrate efficacy of SEPR & S-ISCO technologies for remediation of creosote DNAPL

Remedial Implementation
SEPR & S-ISCO

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SEPR & S-ISCO Treatment of Creosote

Site Background

- Lumber Treating Facility (1963 – 1986)
- DNREC-Hazardous Substances Cleanup Act (HSCA) Program
- Creosote waste oil & condensate water was gravity-fed into unlined waste lagoon (1000 ft^2)
- Lagoon was excavated in 1986 but the vertical extent of NAPL was greater than originally reported
- Subsequent investigations uncovered NAPL free product in monitoring wells & present in the test pits

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SEPR & S-ISCO Treatment of Creosote

Remedial Design

• Observations of free product and/or residual DNAPL in soil borings were used to define the area of the DNAPL plume in each 1-ft interval from 6 to 15 ft below ground surface (bgs).

• **Target:**

- 4,180 gal of creosote DNAPL
- 510 yd^3 of soil, 6 –15 ft bgs.

• **Treatment*:***

- SEPR to remove DNAPL
- S-ISCO to remove residual contamination

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SEPR & S-ISCO Treatment of Creosote

Implementation: Area I

- **SEPR – 18 days**
  - Injection of *5,000 gal*
  - Hydrogen Peroxide (0.5 – 4%)
  - Surfactant (10 – 30 g/L)
  - Extraction of *4,400 gal* of DNAPL and fluid
- **S-ISCO – 6 weeks**
  - Injection of *27,000 L*
  - VeruSOL (5 – 10 g/L)
  - Hydrogen Peroxide (4 – 8%)
  - Sodium Persulfate (50 – 100 g/L)

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SEPR & S-ISCO Treatment of Creosote

Implementation: Area II

- **SEPR – 6 weeks**
  - Injection of *8,900 gal*
  - Hydrogen Peroxide (up to 4%)
  - Surfactant (5 – 10 g/L)
  - Extraction of *3,200 gal* of DNAPL and fluid
- **S-ISCO – 2 weeks**
  - Injection of 3,800 gallons
  - VeruSOL (5 – 10 g/L)
  - Hydrogen Peroxide (4 – 8%)
  - Sodium Persulfate (50 – 100 g/L)

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SEPR & S-ISCO Treatment of Creosote

Pre SEPR
No Product Recovery; Clear Samples

Day 1
Product + Emulsion Recovered

Day 2
Increased Product Recovery

Day 3
Product Flow

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SEPR & S-ISCO Treatment of Creosote

Late Stage of SEPR Treatment

End of S-ISCO Treatment

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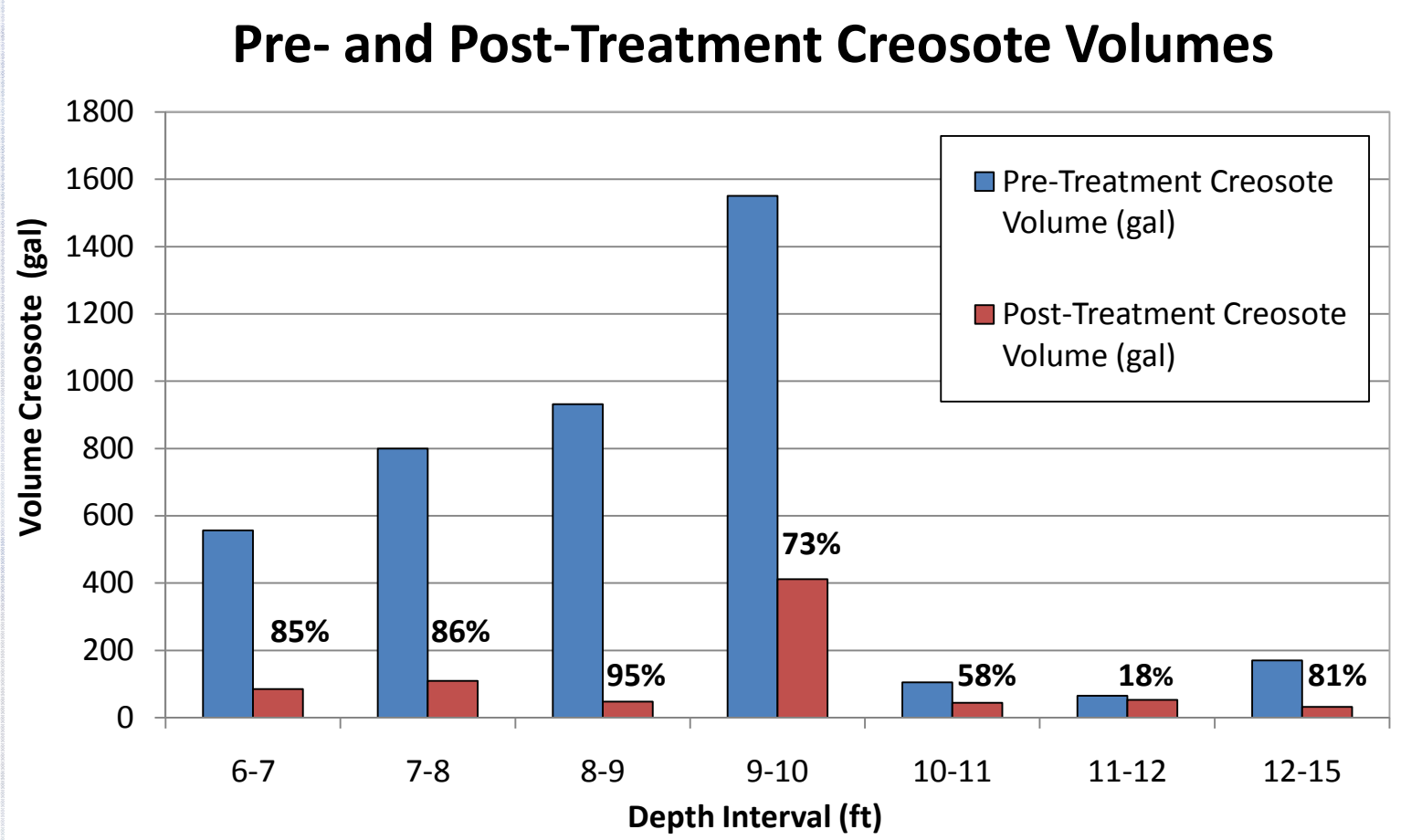
SEPR & S-ISCO Treatment of Creosote



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SEPR & S-ISCO Treatment of Creosote

Result Summary

Area I:

- **87% of contaminant mass was removed from 6 to 10 ft interval, where majority of creosote was located**
- **Led to immediate expansion of treatment for Area II**

Area II

- **81% of DNAPL was removed from treatment area**

Cost of remediation <$100/cubic yard

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Creosote Remediation with SEPR Technology

U.S. Gulf State

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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

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Superfund Creosote Site in U.S. Gulf State

Treatment Details:

- **3 stage treatment approach**
  - Vadose zone NAPL removal
  - Well rehabilitation (in saturated zone)
  - Improved saturated zone NAPL removal
- **SEPR Chemistry**
  - Up to 8% hydrogen peroxide
  - 1-5% VeruSOL Creosote formula

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Superfund Creosote Site in U.S. Gulf State

Total fluid recovered: 32,000 gallons
Pilot Test duration: 9 weeks

Treatment Stage	Vadose Zone	Saturated Zone
SEPR Chemistry	8,600 gallons total	24,000 gallons total
Treatment Area	275 sq. ft	1.5 acres
Treatment Depth	9ft – 19ft	16ft -29ft

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Superfund Creosote Site in U.S. Gulf State

Saturated Recovery Well Performance			
Well	**Pre SEPR Average Yield (gpm)**	**Post SEPR Average Yield (gpm)**	**% Increase**
R5	0.82	2.40	193%
R9	0.16	1.11	594%
R10	0.11	0.23	109%
R12	0.24	1.27	429%
R15	0.31	0.67	116%
R17	0.04	0.54	1250%
R18	0.15	0.45	200%

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Superfund Creosote Site in U.S. Gulf State

Frac Tank Containing Extracted Fluid

Samples of Extracted Fluid

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Superfund Creosote Site in U.S. Gulf State

Results:

- Enhanced recovery rates by up to 1200% in saturated zone
- Achieved 84% TPH mass reduction in the vadose zone
- Enhanced removal of free phase creosote NAPL from the vadose and the saturated zone

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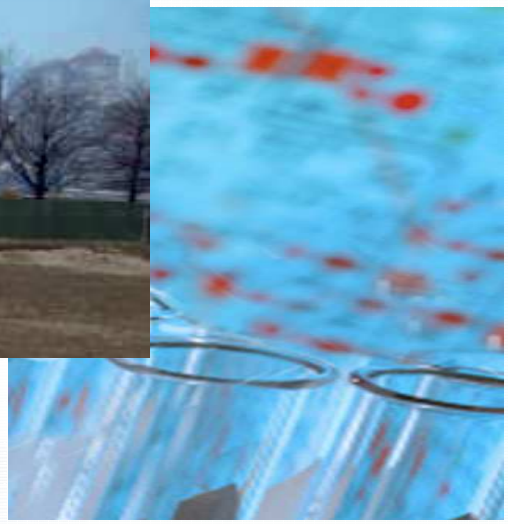
Thank you.



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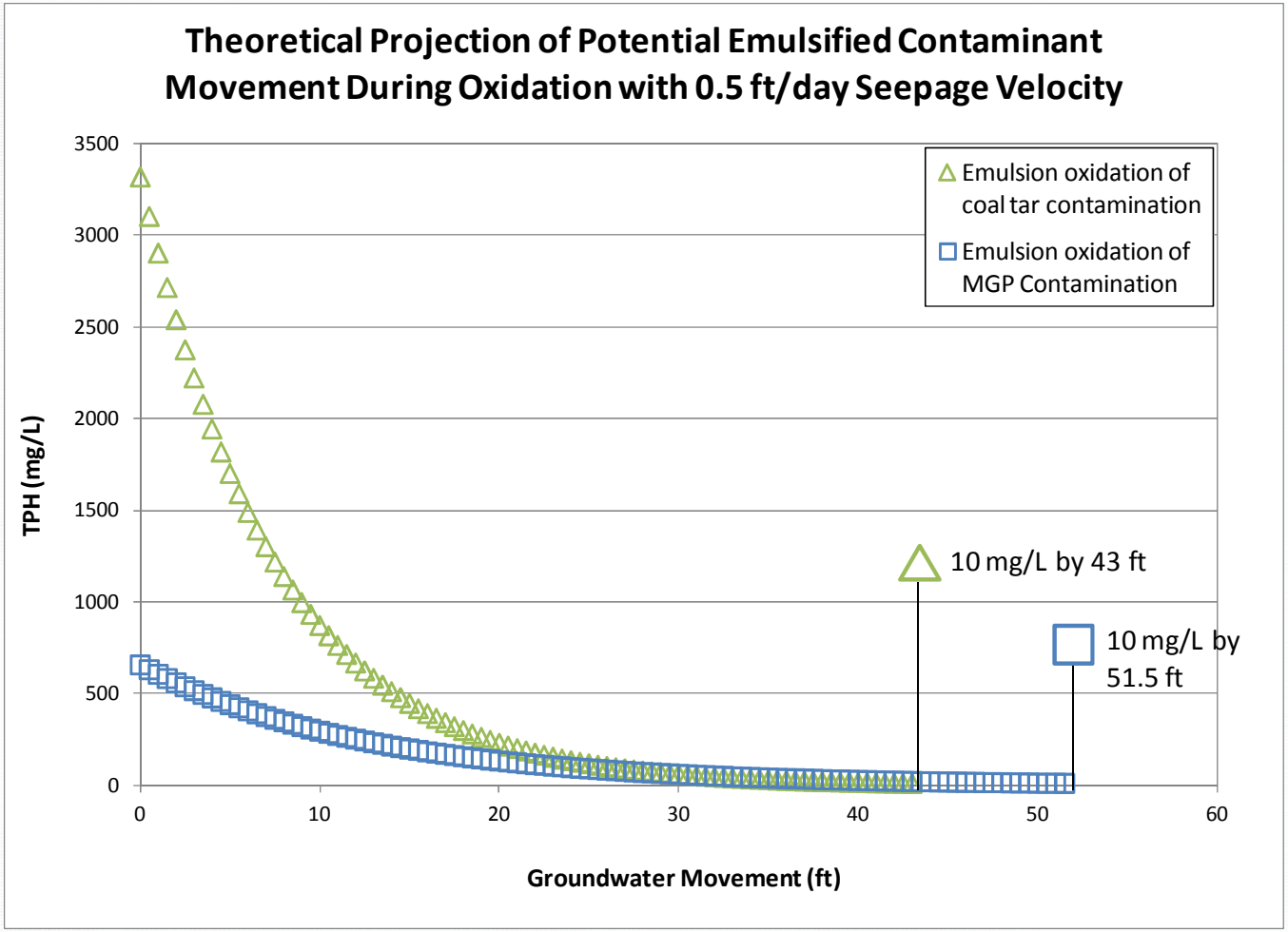
FAQs: Mobilization

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

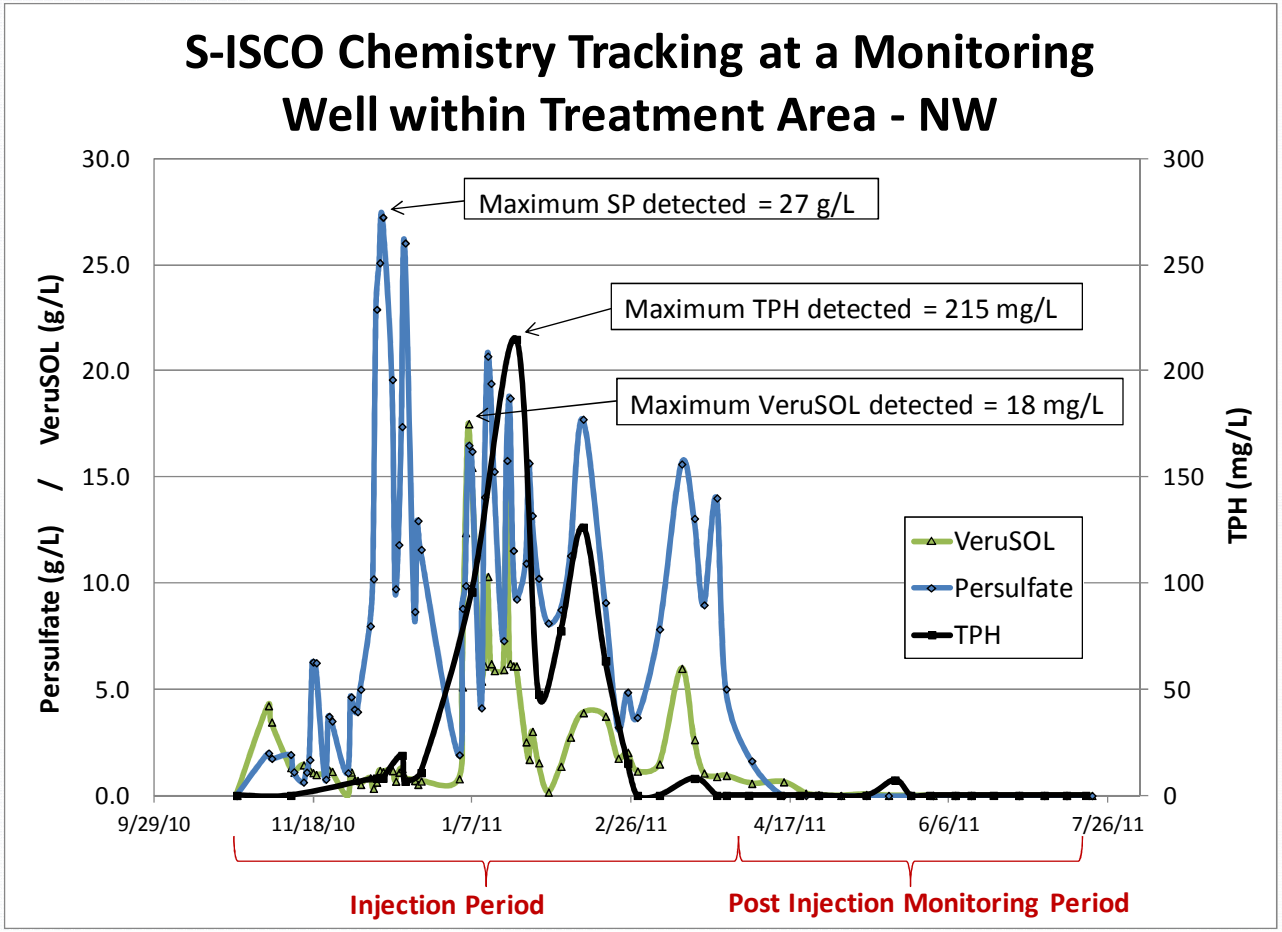
FAQs: Mobilization

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



FAQs: Mobilization

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

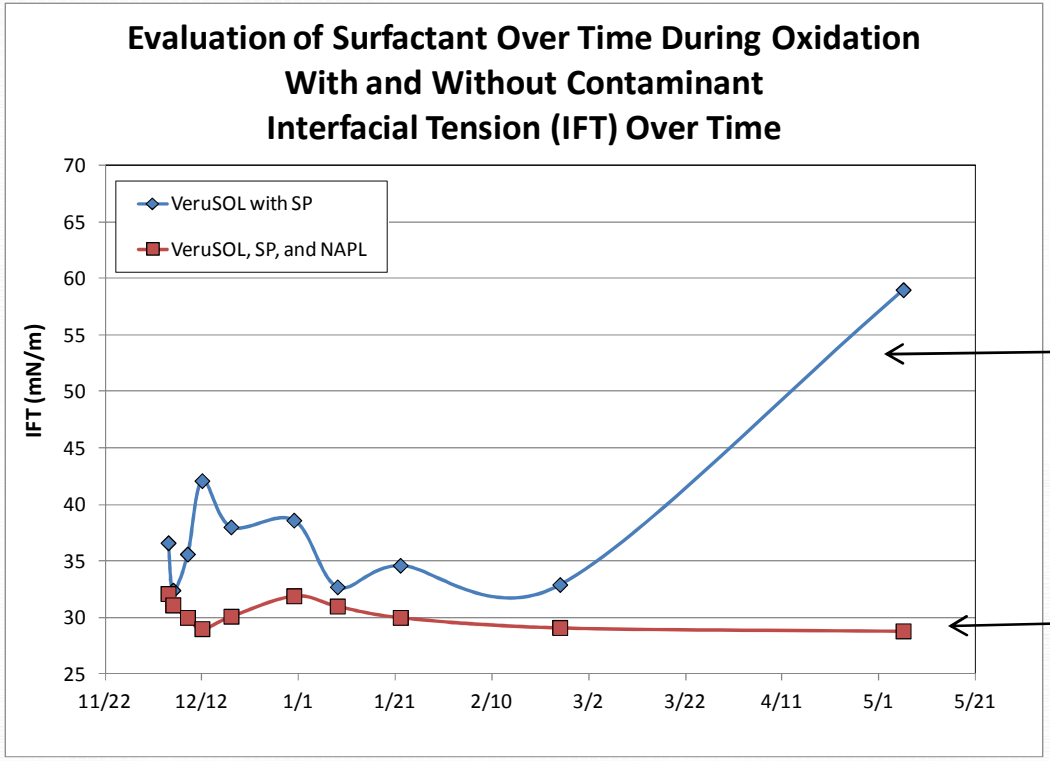


FAQs: Surfactant Consumption by Oxidant

Q: Will the surfactant be consumed by the oxidant

Contaminants are more susceptible to oxidation than surfactant

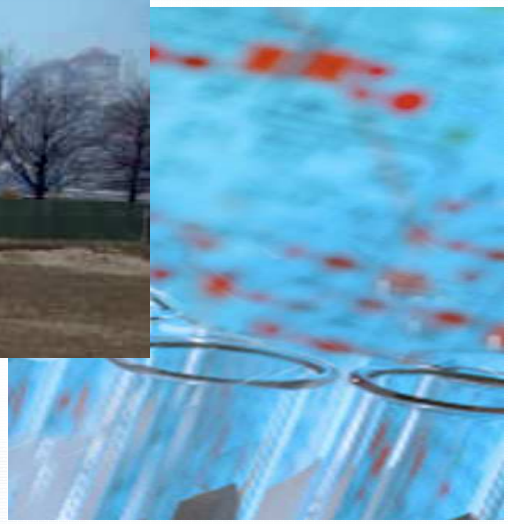
- Contaminants will be oxidized first



Increase in IFT indicates destruction of surfactant

Stable, low IFT indicates stable presence of surfactant

Thank you.



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