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A division of Ethical Solutions LLC

Surfactant Enhanced Remediation Technologies and Case Studies

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Green Chemical Solutions for Environmental Remediation

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Optimized plant-based surfactants for enhanced in situ remediation technologies

Surfactant Enhanced Product Recovery (SEPR)	Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO)
Bulk free phase removal – creosote, DNAPL, LNAPL	Oxidation of heavy hydrocarbon contamination on soil

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SEPR Technology

Surfactant Enhanced Product Recovery (SEPR)

- Proprietary plant based surfactant blend with low doses of hydrogen peroxide
- Bubbles generated from peroxide decomposition provide physical agitation to loosen NAPL
- Enables efficient recovery of Non-Aqueous Phase Liquid (NAPL) contamination, including creosote

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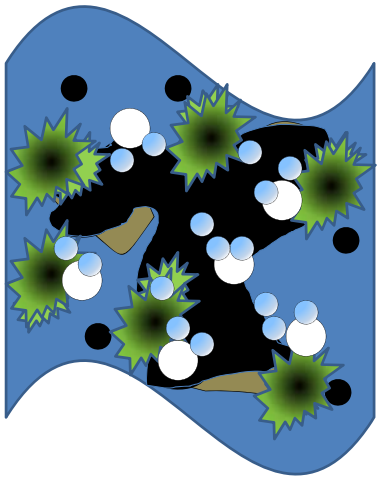
SEPR Performance



- Bulk, free phase NAPL present in subsurface
- SEPR fluid injected
- Surfactants desorb and emulsify NAPL
- Gas bubbles generated from peroxide
- Help facilitate movement to recovery wells
- Residual contamination may remain

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S-ISCO Technology

Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO)

- Combined proprietary surfactant blend & oxidant injection
- Use of the oxidant best suited for site (Klozur, peroxide, etc)
- Addresses contamination sorbed on soil
- Provides clean soil and groundwater
- Avoids contaminant rebound

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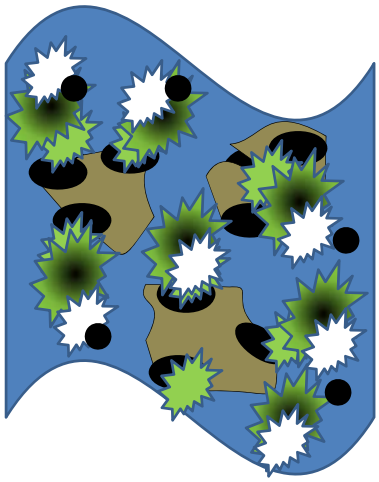
S-ISCO Performance



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

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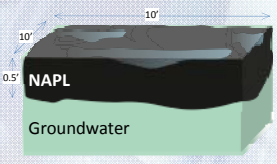
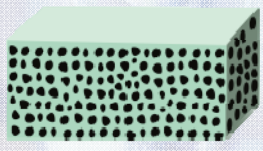
Emulsification and Surface Area

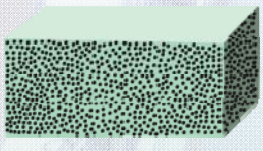
Emulsions increase interface area between oxidant and contaminant by several orders of magnitude



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

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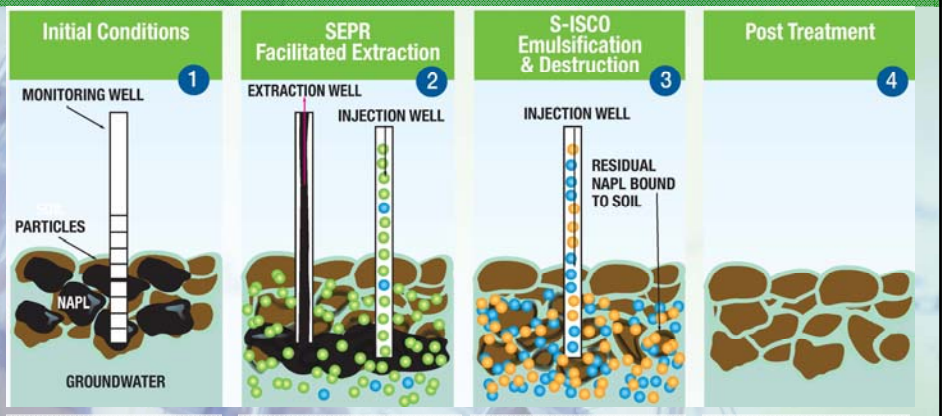
Combined SEPR/S-ISCO Technology



- NAPL contamination

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

- VeruSOL® and oxidant are injected simultaneously
- VeruSOL® emulsifies residual NAPL into fine particles, increasing surface area exposed for oxidation

- Clean soil and groundwater

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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
Full-scale soil remediation

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
- Lagoon was excavated in 1986 but the vertical extent of NAPL was greater than originally reported

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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 Treatment Area:**
  - 4,000+ gal of creosote DNAPL
  - 200 ft X 60 ft X 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:

- **SEPR – 8 weeks**
  - Hydrogen Peroxide (up to 4%)
  - Surfactant (5 – 30 g/L)
  - Extraction of *8,000 gal* of DNAPL and fluid
- **S-ISCO – 8 weeks**
  - VeruSOL (5 – 10 g/L)
  - Hydrogen Peroxide (4 – 8%)
  - Klozur 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 / Pre-S-ISCO Treatment

End of S-ISCO Treatment

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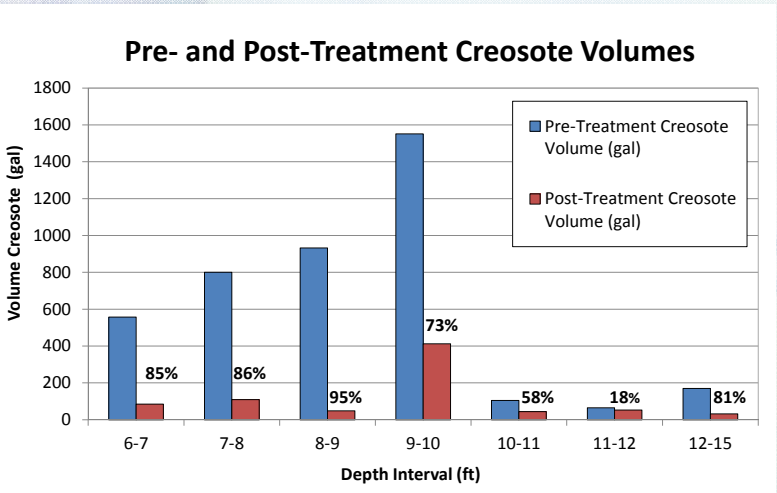
SEPR & S-ISCO Treatment of Creosote



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SEPR & S-ISCO Treatment of Creosote

Result Summary

- **81% of DNAPL was removed from treatment area**
- **Site objective achieved and closure expected**
- **Cost of remediation <$100/cubic yard**
  - **Less than 1/3 the cost of CA identified alternative - thermal desorption followed by bioremediation.**

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S-ISCO Remediation of Coal Tar
NYC Brownfield Site

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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

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MGP Coal Tar Remediation in NYC

- **Site Conditions**:
  - Former roofing manufacture site
  - ~41,000 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

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MGP Coal Tar Remediation in NYC

Treatment Details:

- **S-ISCO Implementation**
  - VeruSOL
  - Klozur Sodium Persulfate
  - Sodium Hydroxide
  - Total injected volume = 1,201,900 gal
  - 100 days of injections
- **RemMetrik^{SM}** process to quantify & target contamination
- Wavefront Technology's **Primawave** Pressure-Pulsing Sidewinder

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MGP Coal Tar Remediation in NYC

Implementation Monitoring:

Weekly Monitoring Results:

- No NAPL mobilization
- No vapor pressure increases
- Reduced soil gas concentrations
- No nuisance complaints

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MGP Coal Tar Remediation in NYC

Results

- ***Soil:*** *EXCEEDED CLEANUP OBJECTIVE*
  - Destroyed **> 90%** Contaminant Mass (PAHs + BTEX)
- ***Groundwater:*** *EXCEEDED CLEANUP OBJECTIVE*
  - Reduced GW Concentrations;
    - *91% BTEX*
- ***Soil Gas:*** *FULLY REDUCED SOIL GAS CONTAMINANTS*
  - *100% of benzene, ethylbenzene, naphthalene*

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MGP Coal Tar Remediation in NYC

- *Certificate of Completion*, New York State DEC,
  - Construction of a 22,000 square foot community library has begun at the site and is anticipated to be completed in 2017

Photo Courtesy – stevenholl.com

Photo Courtesy –qns.com

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FREQUENTLY ASKED QUESTIONS

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FAQs: Mobilization

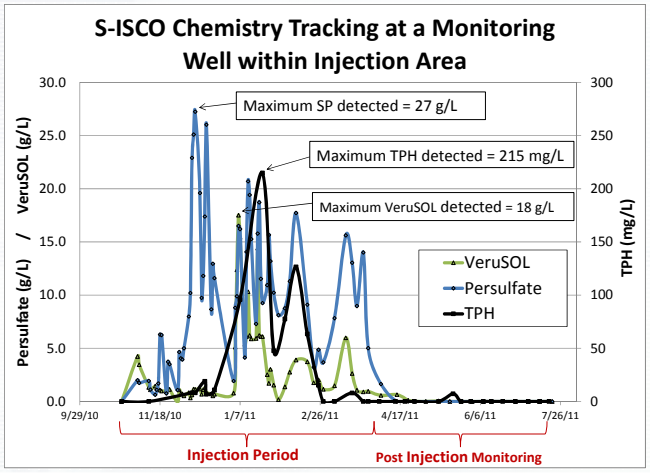
Question: How is contaminant mobilization managed during S-ISCO treatments?

Answer:

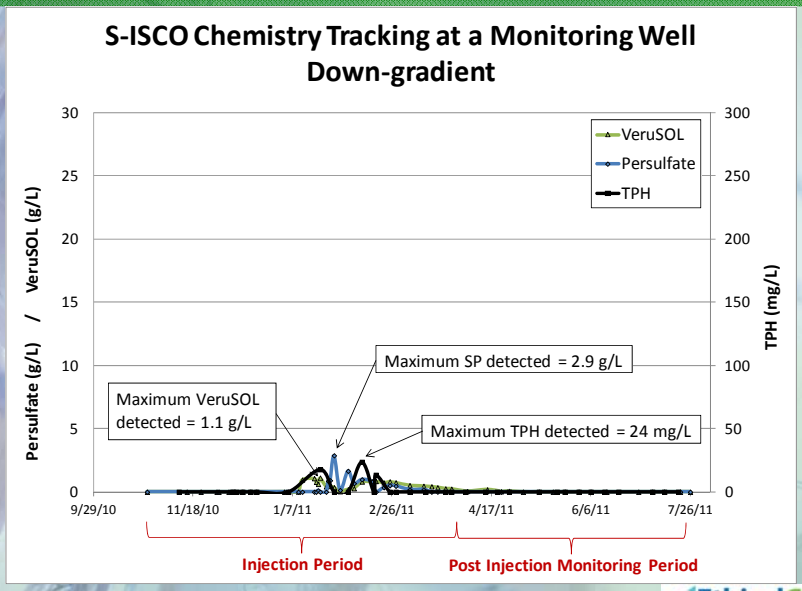
- During S-ISCO the surfactant and oxidant are injected together as a homogeneous solution
  - Injected chemistry travels together through subsurface
  - Emulsification and oxidation take place simultaneously
  - Average groundwater speeds do not carry emulsion offsite prior to destruction
- Monitoring plans & contingency measures provide added protection for sensitive receptors

FAQs: Mobilization

- S-ISCO chemistry travels together
- Data from an on site monitoring well during and after injections



Monitoring Well Data



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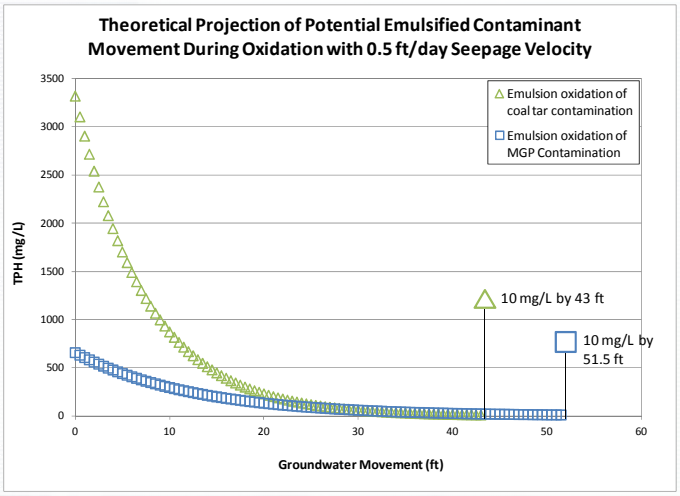
FAQs: Mobilization

Projection of two emulsions, traveling vs. destruction

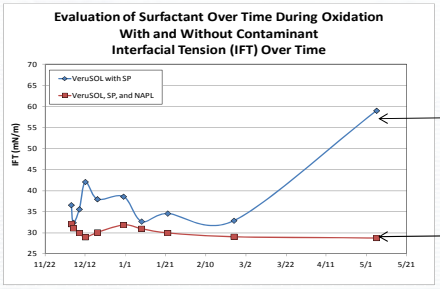


FAQs: Surfactant/Oxidant Interaction

Question: Do the surfactants compete with contaminants to consume oxidants?

Answer:

- Contaminants oxidized first
- Surfactant oxidation is minimal while contaminant is present



Increase in IFT indicates destruction of surfactant

Stable, low IFT indicates stable presence of surfactant

S-ISCO/SEPR Summary

- Optimized Surfactant/Oxidant Treatments Provide:
  - Clean soil & groundwater
  - Avoid rebound
  - Are effective for a broad range of organic contaminants

Thank you.

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USA

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