EthicalChem

A division of Ethical Solutions LLC

# Successfully Integrating Surfactants Into Chemox Technologies

*Dan Socci, CEO, EthicalChem*

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Green Chemical Solutions for Environmental Remediation

# ETHICALCHEM BACKGROUND

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# EthicalChem Background

- Developer of high performance chemicals for remediation and oil industries
- Specialize in plant-based surfactant chemistry
- 11 issued patents
- 100+ sites, 13 countries

- Flexible business model
  - Chemicals alone
  - Treatment design
  - On site support
  - Full implementation
- Ongoing R&D and acquired IP

# EthicalChem Background

EthicalChem proprietary, patented processes and chemicals enable chemical oxidation treatments of heavily contaminated sites, including those with NAPL

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

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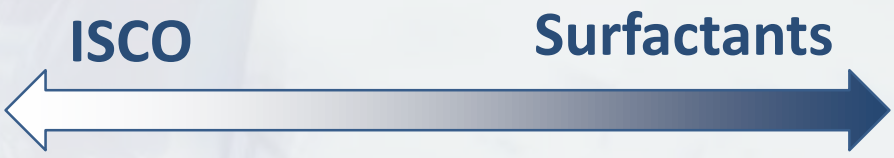
## Benefits of Surfactant Enhanced ChemOx

- Technologies of three ***"S's"***
  - Optimally designed plant based ***surfactants***
  - Benefits of ***simultaneous*** injection of surfactants and oxidants
  - Importance of surfactant ***selection***
- Highly differentiated from surfactants alone or conventional chemical oxidation

## When to Use Surfactants




- **Groundwater contamination**
- **Less hydrophobic compounds (e.g. chlorinated)**

**Heavily contaminated soil**
**Very hydrophobic compounds (e.g. PAH)**
**Free phase**

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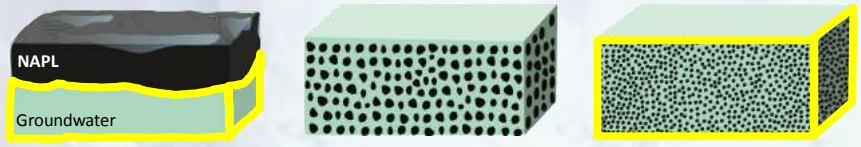
# Enhancing Contact Through Emulsification

**Surfactants create emulsions which increase interface area between oxidant and contaminant by several orders of magnitude**




**Increased surface area due to emulsification**

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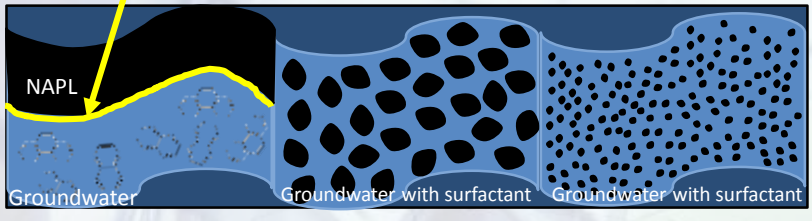
# Enhancing Contact Through Emulsification

- Minimal contact at NAPL-water interface
- Surfactants deliver the contaminant to the oxidant




- Enhanced contact through emulsification

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# APPLYING SURFACTANTS

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## Importance of Surfactant Selection

- Not all surfactant perform equally!
  - Not "one-size-fits-all"
- Surfactant performance varies with different **contaminants**
- Not all surfactants work well with **oxidants**

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# Surfactant Selection for NAPL

Different surfactants can deliver different results.

- Desorption
- Emulsification – stable/unstable
- Change viscosity/mobility

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# Surfactant Selection for NAPL



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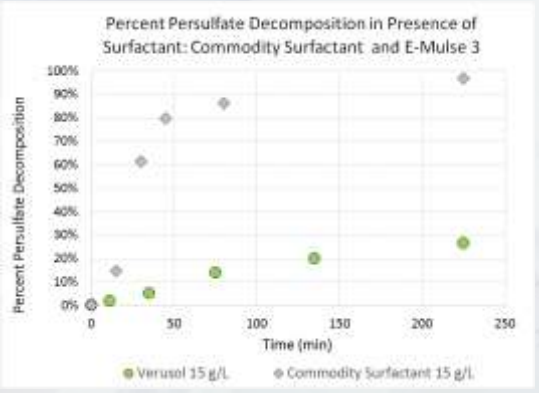
# Surfactant Selection for Oxidant Compatibility

**Independent research completed at University of Madrid***



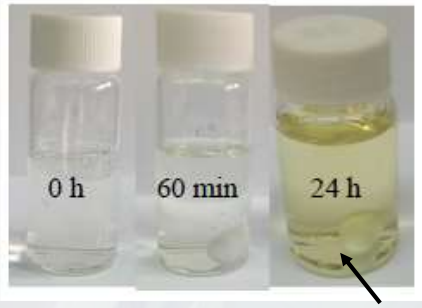

- Not all surfactants are suitable to work with oxidants
- **Commodity surfactant** resulted in 97% persulfate decomposition in about 4 hours (without contaminant)
- **EthicalChem E-Mulse 3** resulted in <26% persulfate decomposition in about 4 hours (without contaminant)

*Research completed independently by Researching Group INPROQUIMA (Universidad Complutense de Madrid): Miguel A. Lominchar, David Lorenzo, Arturo Romero, and Aurora Santos

# Surfactant Selection for Oxidant Compatibility

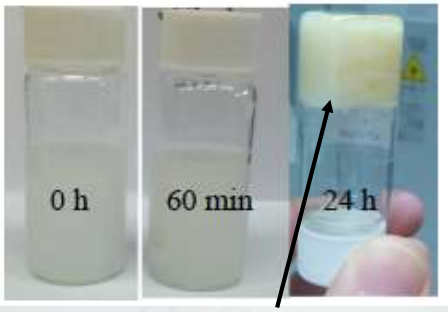
**Independent research completed at University of Madrid***

**EthicalChem E-Mulse Surfactant**
With NaOH and Persulfate




At 24 hours E-Mulse retains thin consistency as aqueous solution.

**Commodity Surfactant**
With NaOH and Persulfate




Commodity surfactant gels to thick, immobile material.

*Research completed independently by Researching Group INPROQUIMA (Universidad Complutense de Madrid): Miguel A. Lominchar, David Lorenzo, Arturo Romero, and Aurora Santos

# SURFACTANT/OXIDANT TECHNOLOGIES FROM ETHICALCHEM

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## S-ISCO Technology

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

- ***Simultaneous injection*** of EthicalChem proprietary surfactant blend & oxidant (patented process)
  - Oxidant compatible surfactant
  - Site specific/contaminant surfactant selection
  - Use of the oxidant best suited for site conditions
- Enables chemical oxidation of heavily contaminated sites
  - Addresses contamination sorbed on soil
  - Cleans soil and groundwater
  - Avoids contaminant rebound

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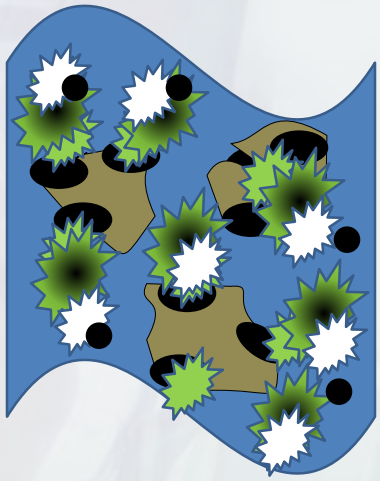
# S-ISCO Performance



- 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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# SEPR Technology

## Surfactant Enhanced Product Recovery (SEPR)

- Efficient recovery of Non-Aqueous Phase Liquid (NAPL) contamination, including creosote
  - Proprietary plant based surfactant blend
  - Low doses of hydrogen peroxide
  - Bubbles generated from peroxide decomposition provide physical agitation to loosen NAPL
- Can be implemented as primary treatment or prior to S-ISCO

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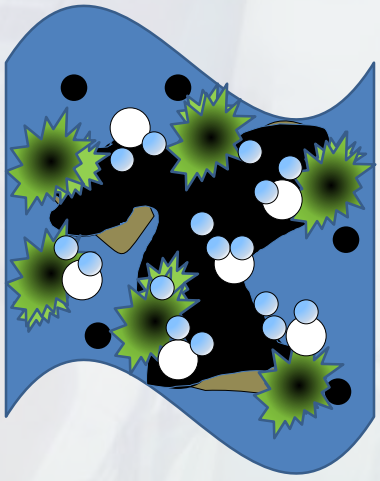
# SEPR Performance



- Bulk, free phase NAPL present in subsurface
- SEPR fluid injected
- Surfactants desorb and emulsify NAPL
- Gas bubbles generated from peroxide
- Facilitates movement to recovery wells
- Residual contamination may be addressed with S-ISCO if required

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# CASE STUDY EXAMPLES

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# Case Study 1

- EthicalChem S-ISCO Treatment
- Consultant: Fleming, Lee-Shue
- Coal Tar Site
- Queens, NY

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## S-ISCO Remediation of Coal Tar
## NYC Brownfield Site


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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

## Soil & Groundwater 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*

**Weekly Monitoring Results:**

- No NAPL mobilization
- No vapor pressure increases
- No nuisance complaints

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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 underway
- Completion 2018

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# Case Study 2

- **EthicalChem SEPR & S-ISCO Treatment**
- **Consultant: TetraTech**
- **Creosote**
- **Delaware Site**

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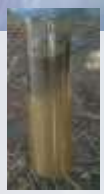
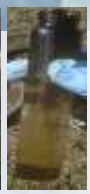
# SEPR & S-ISCO® Creosote Remediation
# Wood Treatment Facility, DE

**Pre SEPR**
*No Product Recovery; Clear Samples*



**Day 1**
*Product + Emulsion Recovered*



**Day 2**
*Increased Product Recovery*

**Day 3**
*Product Flow*

**End of S-ISCO Treatment**

- **Site Objective:**
  - Remove and treat creosote contamination to meet site objectives
- **Treatment:**
  - SEPR with VeruSOL and hydrogen peroxide
  - S-ISCO with VeruSOL and activated sodium persulfate
- **Outcome:**
  - Client objective achieved
  - 81% of DNAPL was removed

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# Case Study 3

- **EthicalChem S-ISCO® Treatment**
- **Consultant: GST**
- **LNAPL – BTEX, TPH**
- **Pipeline Pumping Station**
- **Texas**

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# S-ISCO® Remediation of LNAPL Pipeline Pumping Station, TX


- **Site Objective:**
  - Reduce soil and groundwater TPH and Benzene concentrations to below risk-based closure goals
- **Treatment:**
  - S-ISCO with VeruSOL and activated hydrogen peroxide
- **Outcome:**
  - Soil TPH reduced from 64,000 mg/kg to 432 mg/kg
  - Soil BTEX reduced from 1,271 mg/kg to 0.546 mg/kg
  - No detectible NAPL

# Case Study 4

- EthicalChem S-ISCO® Treatment
- TCA
- Textile Manufacturing Company
- NY

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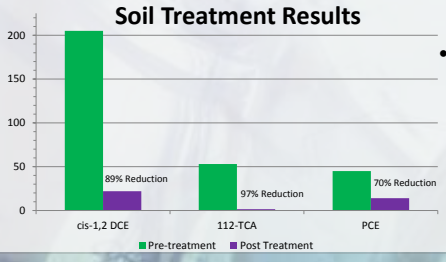
# S-ISCO® TCA Remediation
# Textile Manufacturing Company, NY

**Groundwater Treatment Results**

| VOC | Pre-treat Max. Conc. µg/L | Post-treat Max. Conc. µg/L | Percent Reduction |
|---|---|---|---|
| Total VOCs | 86,530 | 11,706 | 86% |
| TCA | 48,300 | 8,630 | 82% |
| 112-TCA | 34.5 | 2.3 | 93% |
| 1,1-DCA | 36,100 | 2,540 | 93% |
| Chloroethane | 1,280 | 334 | 74% |




- **Site Objective:**
  - Achieve NYSDEC Commercial Use Soil Cleanup Criteria
- **Treatment:**
  - S-ISCO with VeruSOL and activated sodium persulfate
- **Outcome:**
  - All 31 soil samples collected post treatment met NYDEC Commercial Use Cleanup Criteria
  - 90% of the 31 soil samples collected also met more stringent Residential Clean Up Criteria

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# FREQUENTLY ASKED QUESTIONS

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# FAQs: Mobilization

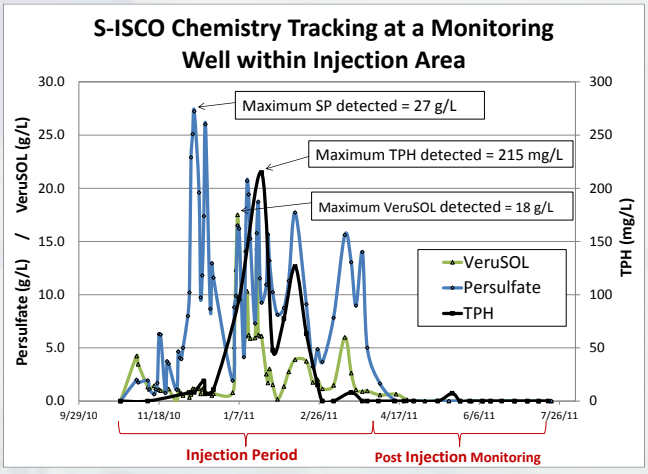
Question: How is contaminant mobilization managed during S-ISCO and SEPR treatments?

Answer:

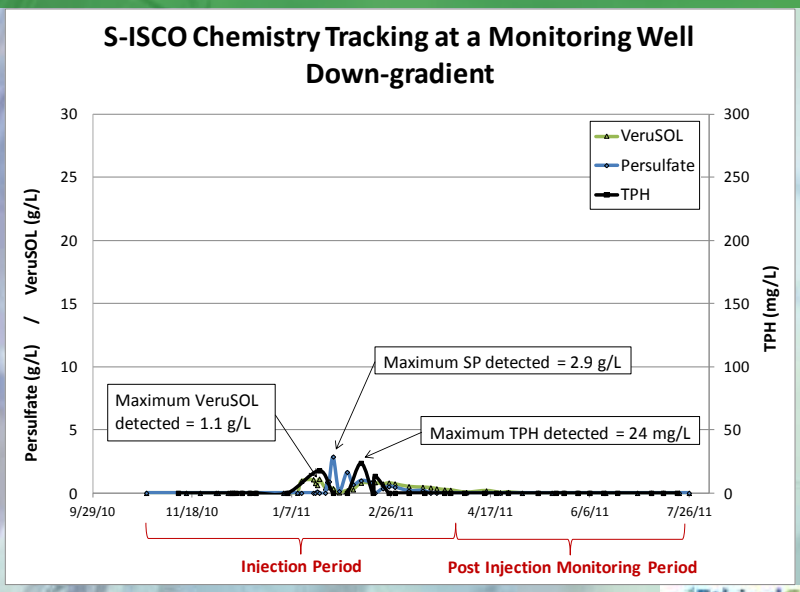
- During S-ISCO the surfactant and oxidant are ***injected simultaneously*** as a homogeneous solution
  - Injected chemistry travels together through subsurface
  - Emulsification and oxidation take place simultaneously
  - Average groundwater speeds do not carry emulsion offsite prior to destruction
  - During SEPR simultaneously injected hydrogen peroxide-
    - generates oxygen gas which loosens NAPL
    - provides buoyancy to transport NAPL upward
- 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



# FAQs: Mobilization



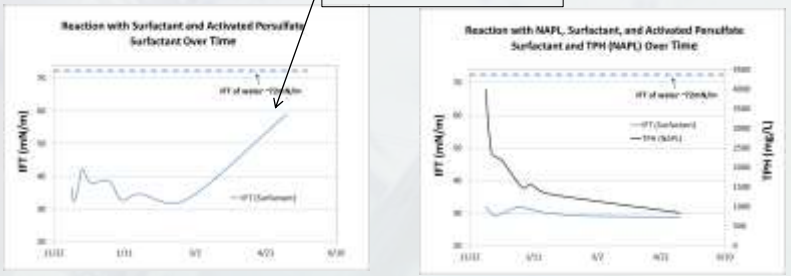

# FAQs: Surfactant/Oxidant Interaction

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

Answer:

- Oxidation by activated persulfate is minimal while contaminant is present
- Contaminants oxidized first

Increase in IFT indicates destruction of surfactant



## S-ISCO/SEPR Summary

- Optimized Surfactant/Oxidant Treatments

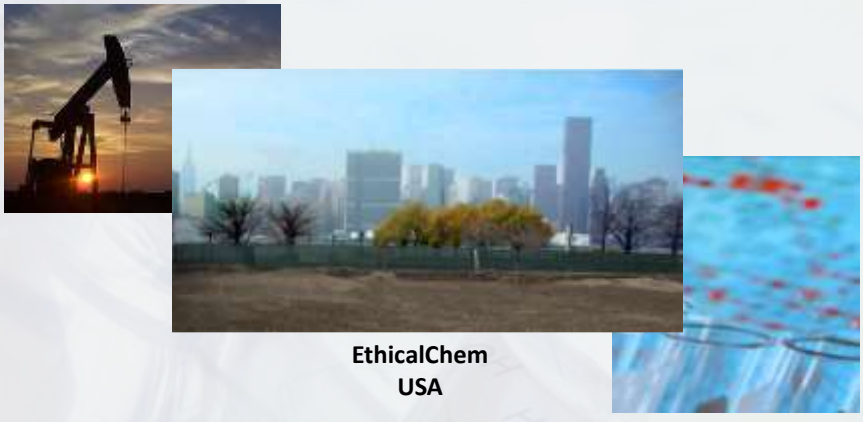
Provide:

- Permanently clean soil & groundwater
- Avoids rebound
- Effective for a broad range of organic contaminants

Require:

- Use of site optimal surfactant
- Compatibility of surfactant and oxidant

## Thank you.



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