PeroxyChem

Environmental Solutions

Lecithin and Ferrous Iron as Electron Donors for Enhanced Reduction Dechlorination (ERD) and In Situ Chemical Reduction (ISCR) Treatment of Chlorinated Solvents in Groundwater

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Outline

- Enhanced Reductive Dechlorination
  - Overview
  - Common contaminants
  - Electron donors
  - Biotic versus abiotic pathways
- Case Study: California, USA
- Conclusions

Enhanced Reductive Dechlorination and In Situ Chemical Reduction

Reductive Processes

- Donation of electrons to contaminants of concerns transforming contaminants into different compounds
- Electrons tend to be preferentially transferred based upon thermodynamic properties—half reactions
- Typically used to treat oxidized contaminants

Compound	Standard Reduction Potential (V)	Reference
Ozone	2.07	Siegrist et al.
Hydrogen Peroxide	1.78	Siegrist et al.
Chlorine (HOCl)	1.48	CRC (76th Ed)
Oxygen	1.23	CRC (76th Ed)
Oxygen	0.82	Eweis (1998)
Fe (III) reduction	0.77	CRC (76th Ed)
Nitrate reduction	0.36	Eweis (1998)
Sulfate reduction	-0.22	Eweis (1998)
Target		
ZVI	-0.45	CRC (76th Ed)

ERD vs ISCR

Enhanced Reductive Dechlorination

- Biotic process
- Typically involves the addition of organic electron donors
- Microbes mediate the transfer of electrons from the organic donor to the contaminant, which is the electron acceptor
  - Specific microbes often needed

In Situ Chemical Reduction

- Predominately abiotic process
  - Minor biotic pathways
- Reduced metals or minerals donate electrons and can react directly or indirectly with the contaminant (or electron acceptor)
- Can include organic substrates and biotic processes

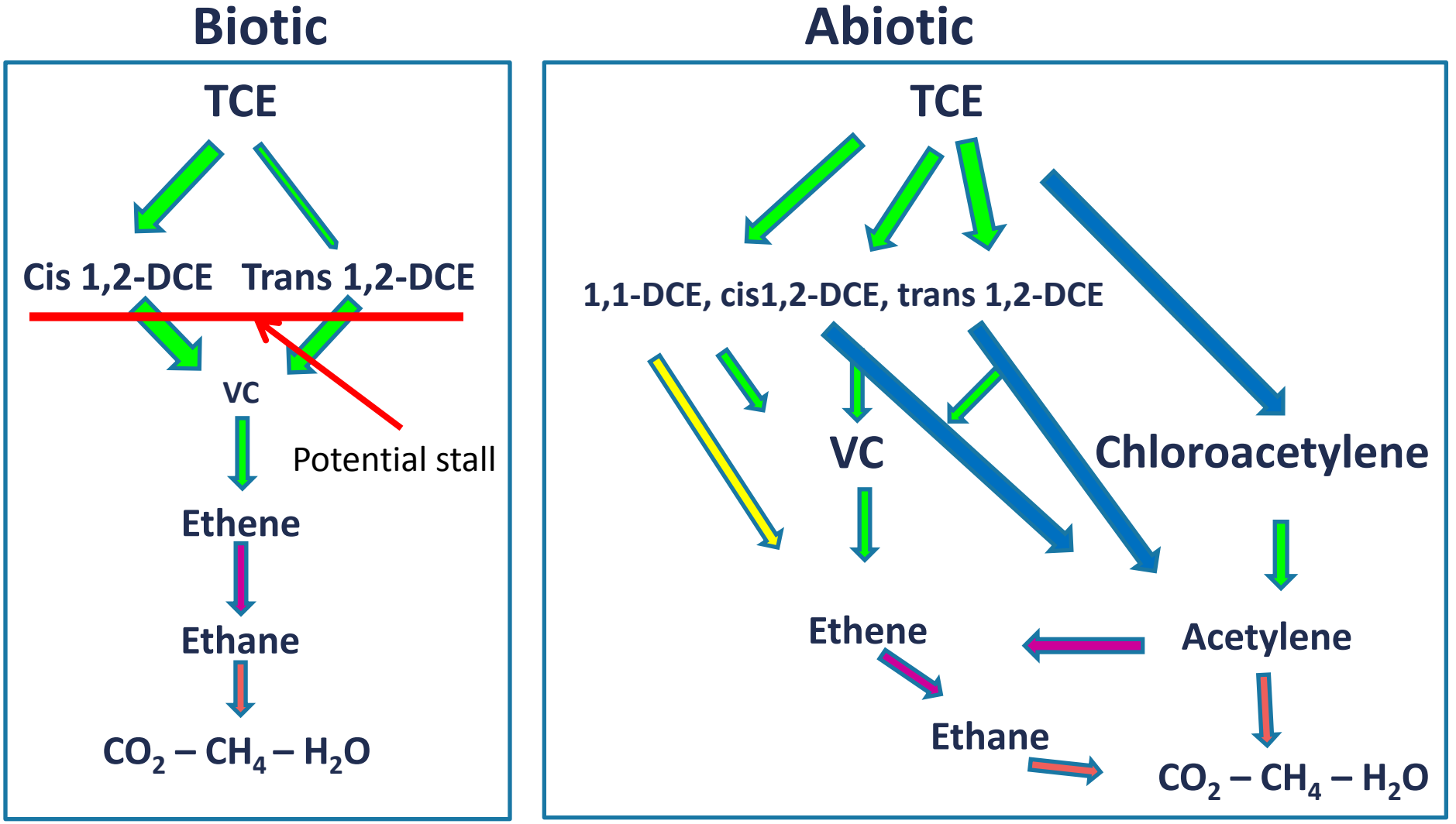
Common Electron Donors

- Biotic (organic)
  - Lactate
  - Whey
  - Emulsified Soybean Oil
  - Molasses
  - **Lecithin**
- Key Characteristics: Distribution
  - Solubility
  - Subsurface distribution
  - Persistence
  - DHC/microbes (Biotic)
- Abiotic (inorganic)
  - Zero Valent Iron (ZVI)
  - Ferrous iron [Fe (II)]
  - Reduced minerals
  - Metallic sulfides (biogeochemical)
- Key Characteristics: Treatment Efficacy
  - H_2 equivalence
  - Degradation pathway
    - End products
    - Potential stall for stalls

Examples of Contaminants Treated

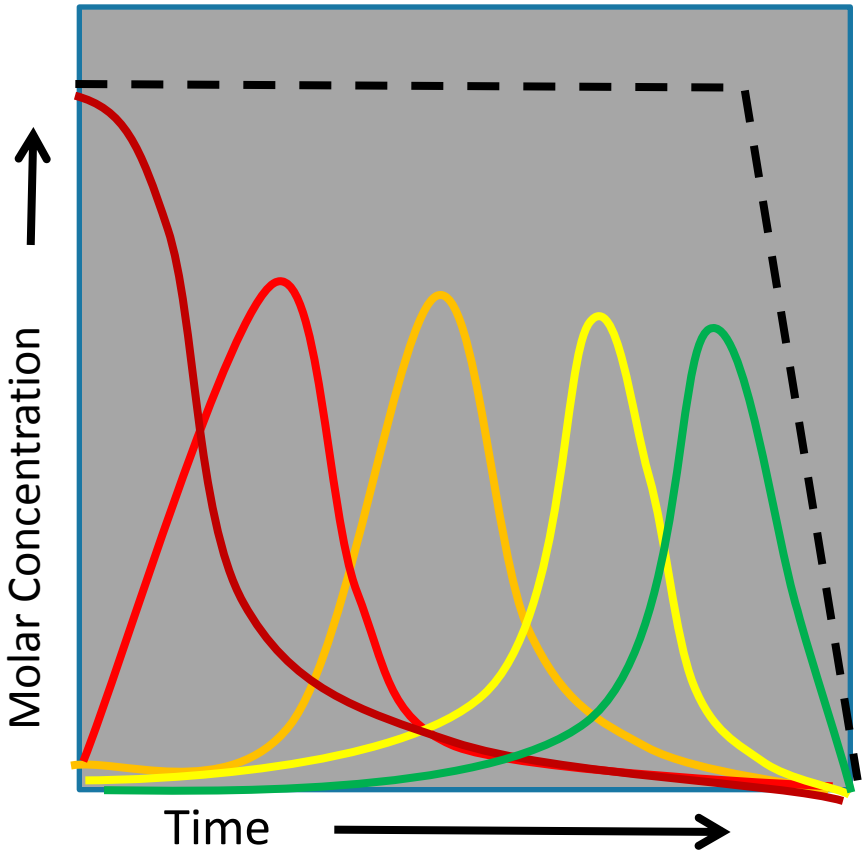
- Chlorinated Solvents
  - PCE, TCE, cis-DCE, 1,1-DCE, VC
  - 1,1,2,2-TeCA, 1,1,1-TCA
  - Carbon Tetrachloride, Chloroform
- Pesticides
  - Toxaphene, Chlordane, Kepone, Dieldrin, Pentachlorophenol
- Energetics
  - TNT, DNT, RDX, HMX, Perchlorate

Reaction Pathways

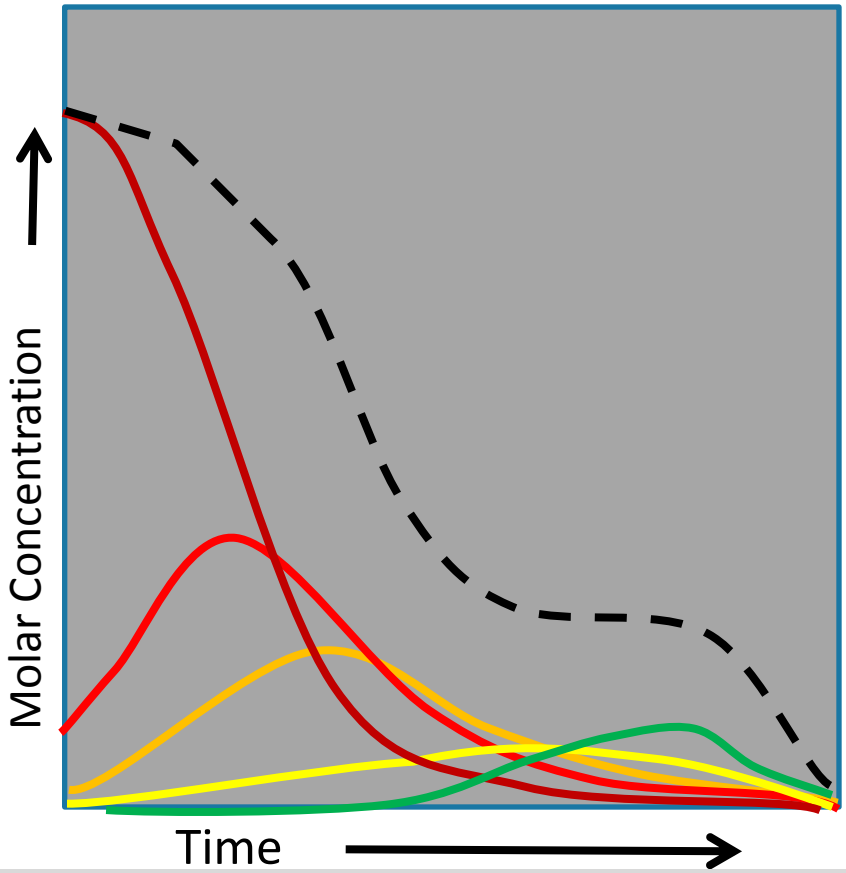


Anticipated Change in CE Molar Concentration

Biological Degradation
(Reductive Dechlorination)



Abiotic Degradation



PCE TCE DCE VC Ethene

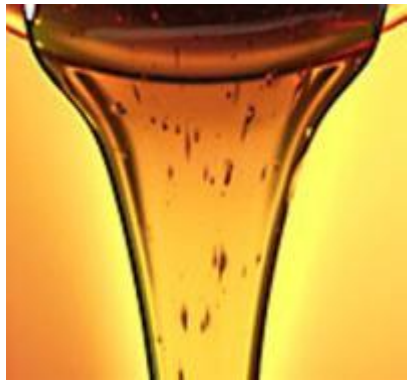
Total Molar Concentration

Lecithin

What is ELS™ Emulsified Lecithin Substrate?

Composition:

- **Food-grade lecithin; GMO free**
- **Natural occurring substance**
- **Mixture of choline, fatty acids, glycerol, glycolipids, triglycerides, & phospholipids. Can also contain sugars.**
- **Polysaccharides and sugars to support rapid creation of reducing conditions**
- **Phospholipids for long-term release of organic carbohydrate**
- **Easy to use: Stable emulsion**

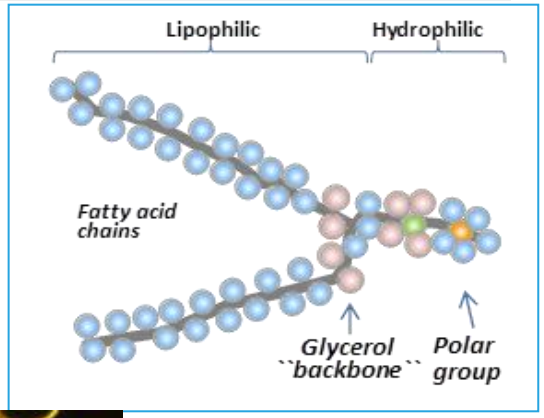


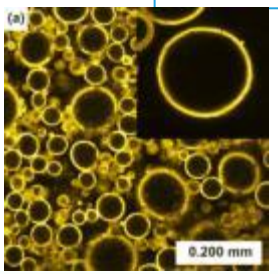
Environmental Solutions

Why Select ELS?

PeroxyChem

- **Slow release nutrients:**
  - **Provides both organic nitrogen and phosphorus**
- **Long lasting:**
  - **Extended release profile of 1 to 3 years**
- **Good distribution:**
  - **Hydrophilic for enhanced distribution**
  - **Small droplet size (60% <1µm and 85% <2µm)**
- **Efficient source of hydrogen:**
  - **High yield of H_2 produced/gram substrate**





Product	Product Concentration (%)	Theoretical Hydrogen yield * (g H_2/g substrate, estimate, as delivered)
ELS™ Concentrate	100	0.324
Emulsified Vegetable Oil	100	0.359
HRC®	100	0.141
Sodium Lactate Solution	100	0.075

Iron Amendments

- Fe (II)
  - Soluble
  - Will flow with groundwater, unless precipitated (i.e. ferrous sulfide)
- Zero Valent Iron (ZVI)
  - Helps offset acid formation
  - Solid
    - Transport characteristics
    - Injection techniques

Case Study

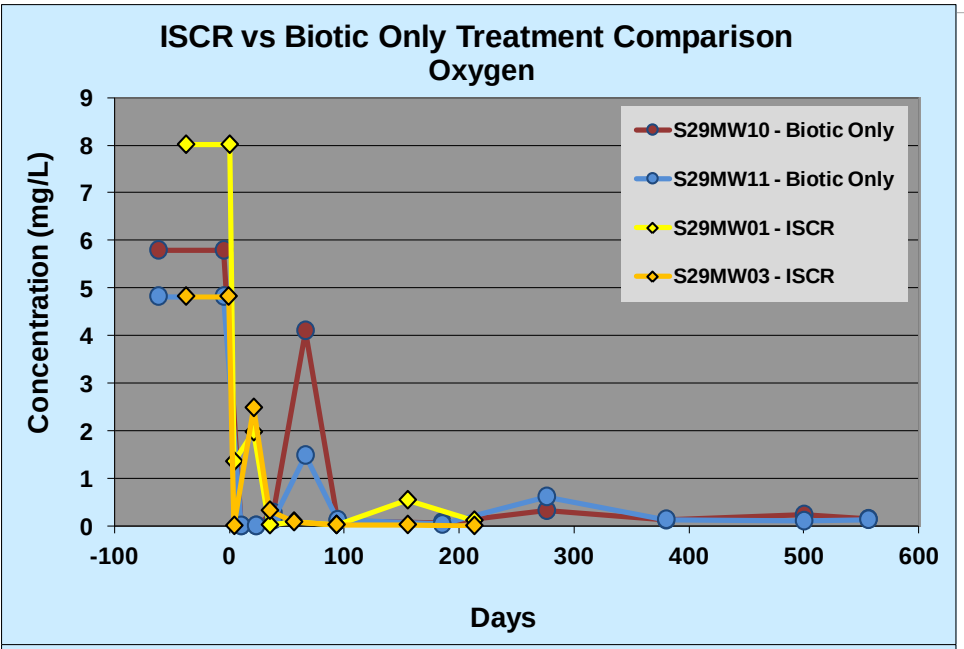
Concord Naval Weapons Facility: IR Site 29

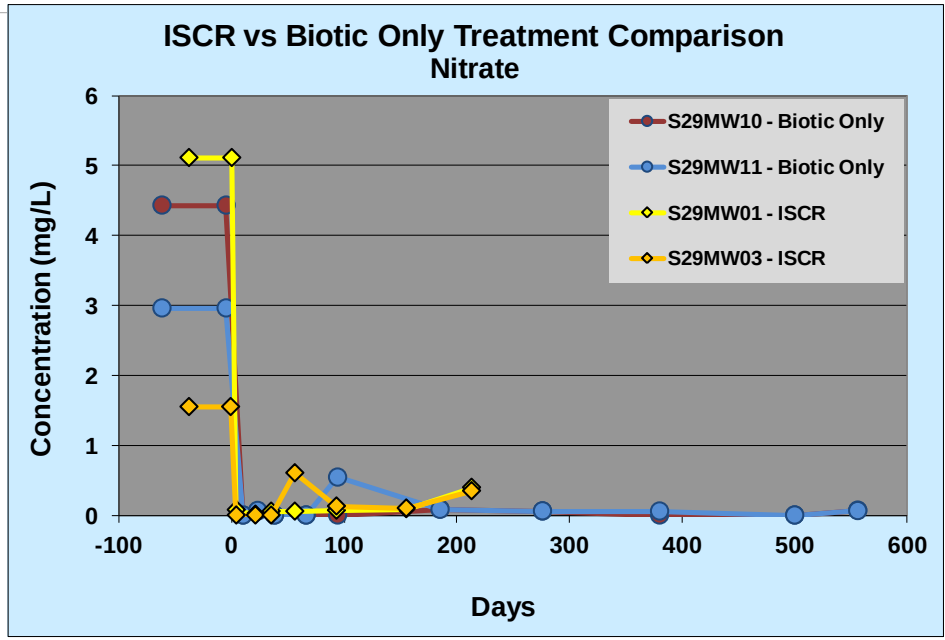
- TCE plume
  - 213 m long
  - Up to 30 m bgs
- Aquifer consists of interbedded silts, sands and clay
- TCE (up to 6 mg/L) with some DCE but no VC
- Aquifer is aerobic (4 to 7 mg/L)
- DHC was not detected

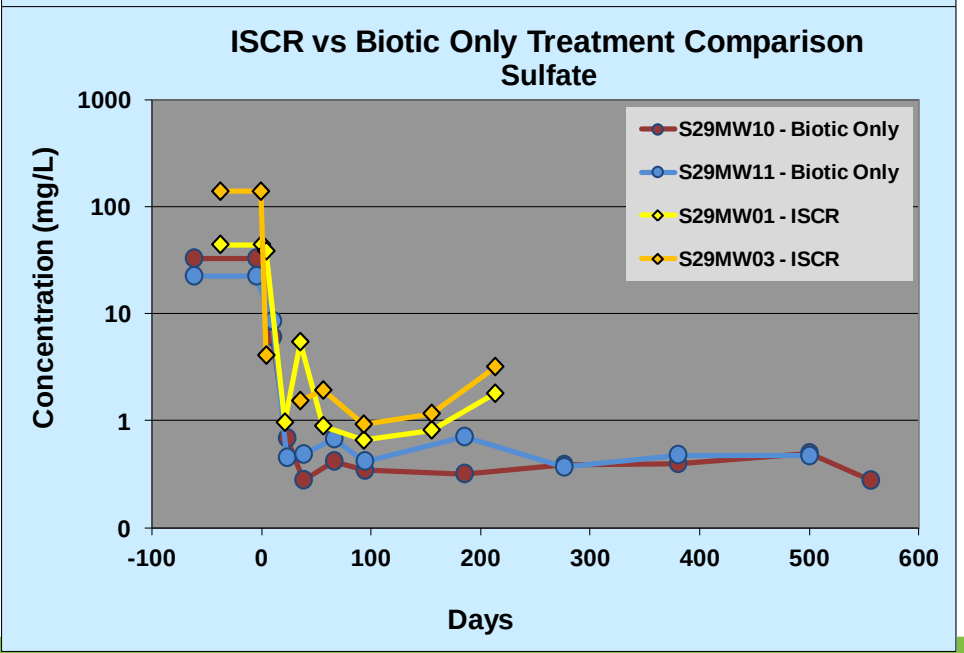
- U.S. Navy issued a "pay for performance" contract
  - Set up to pay for specific remedial goals achieved within a set amount of time

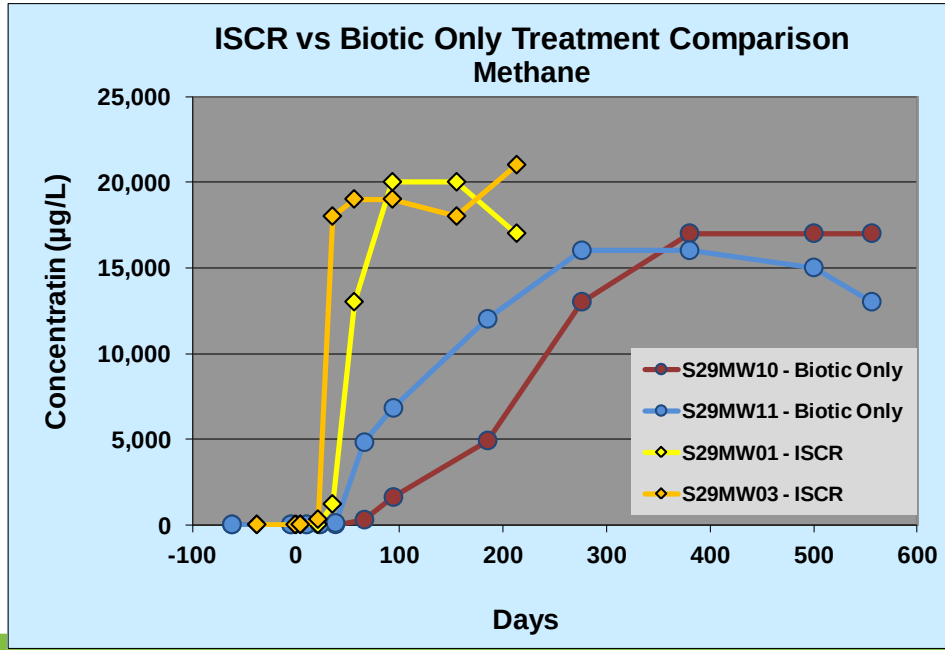
Navy and CB&I pilot tested classic reductive dechlorination versus "ISCR" with lecithin and ZVI

Analytical Results









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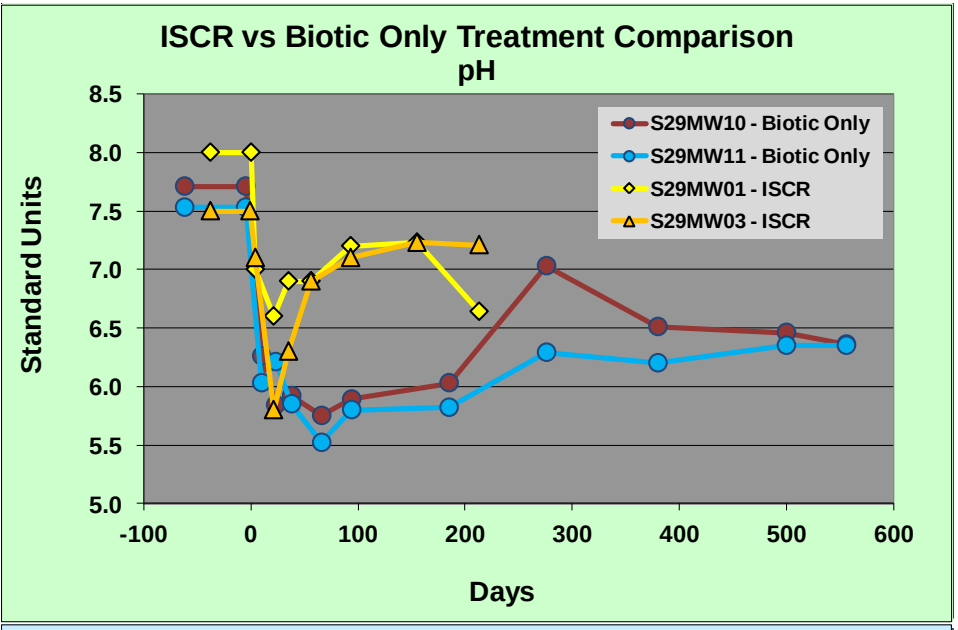

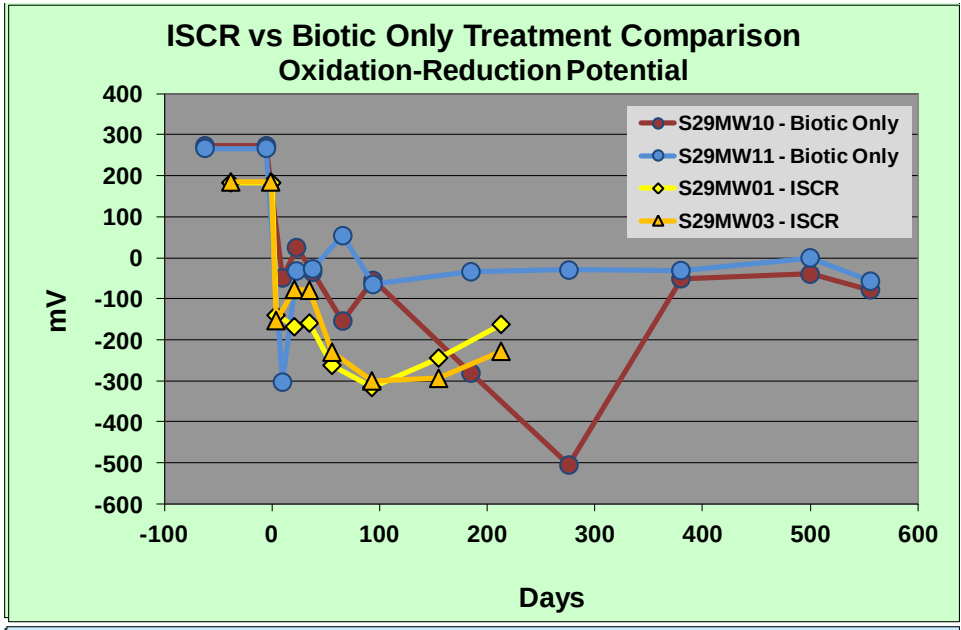

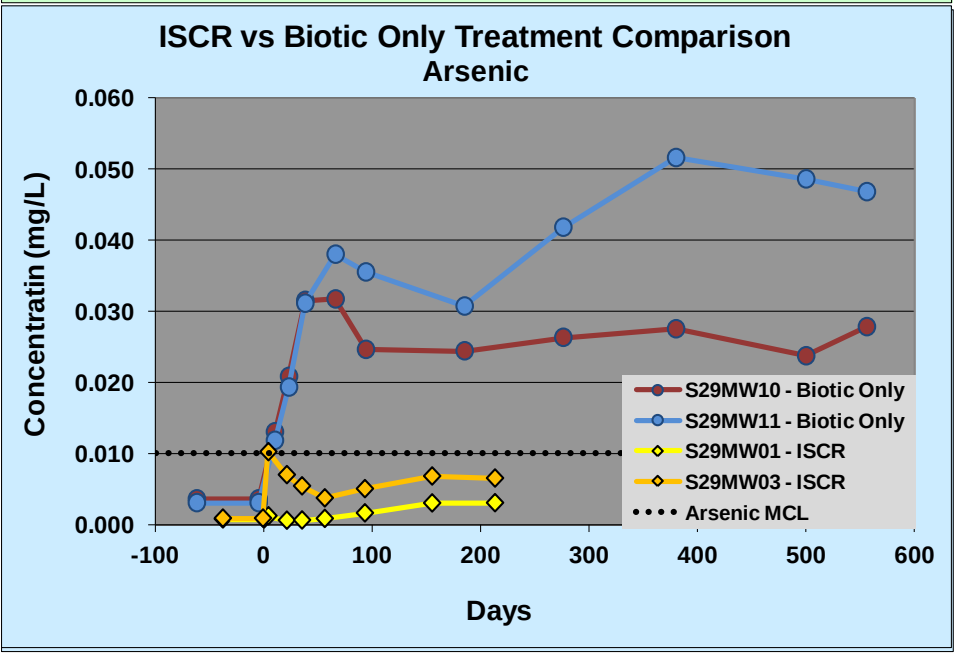

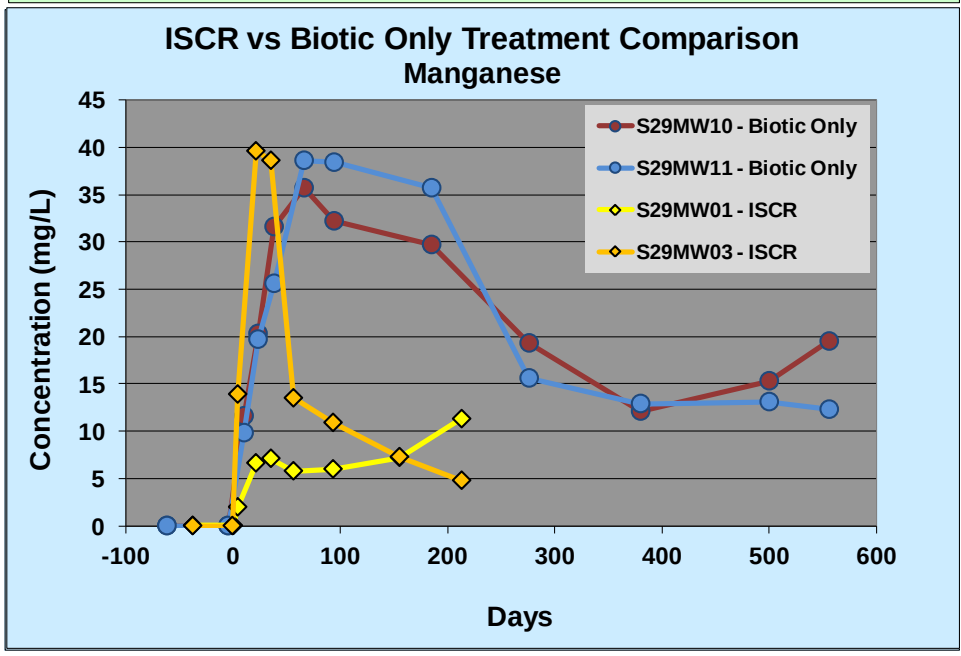

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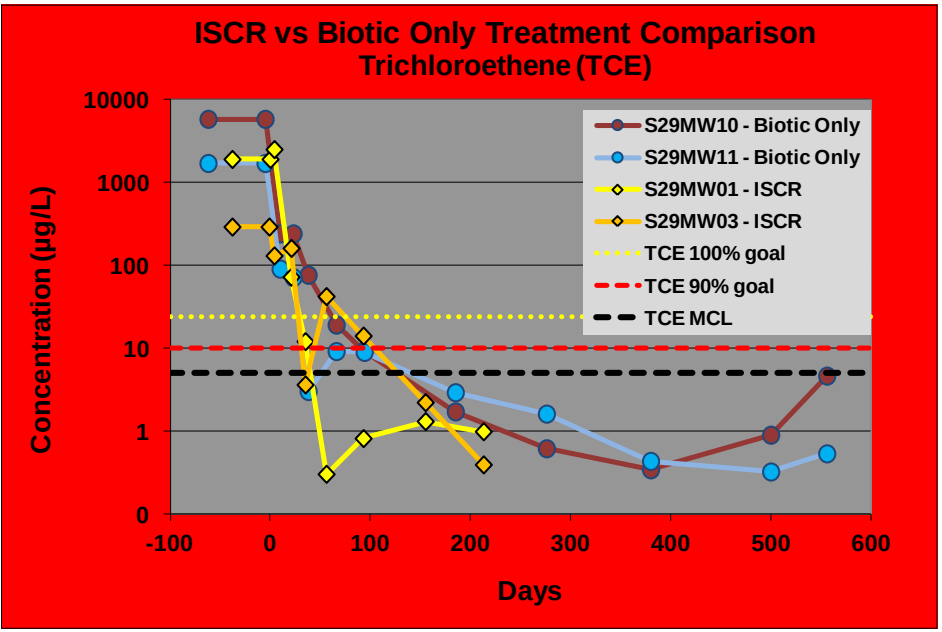
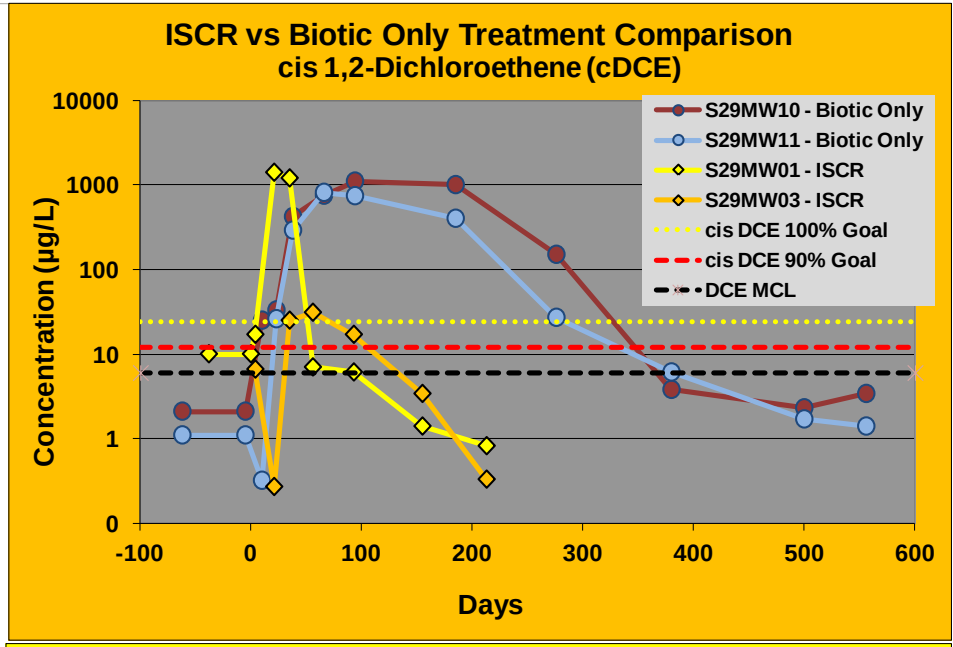
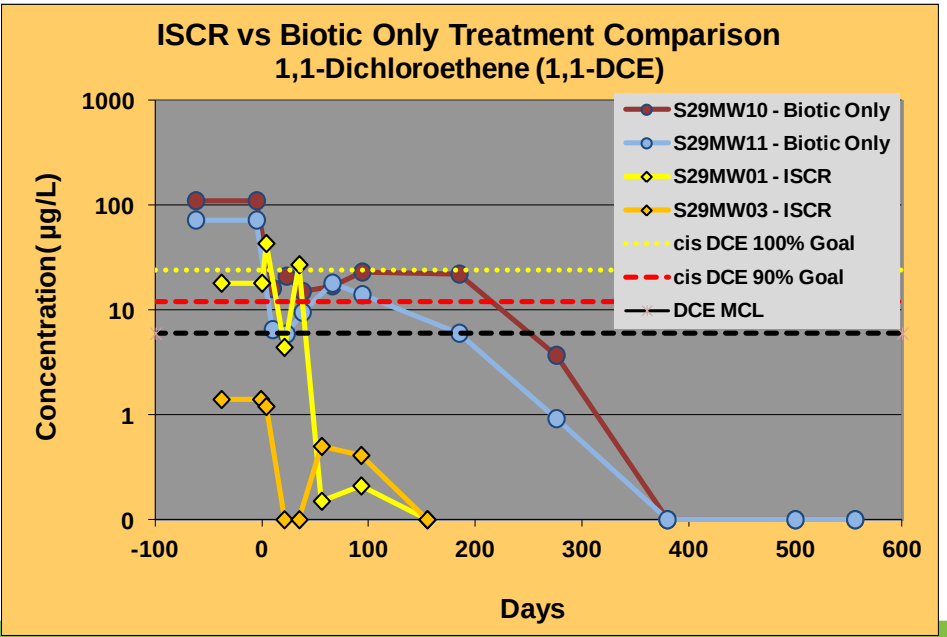
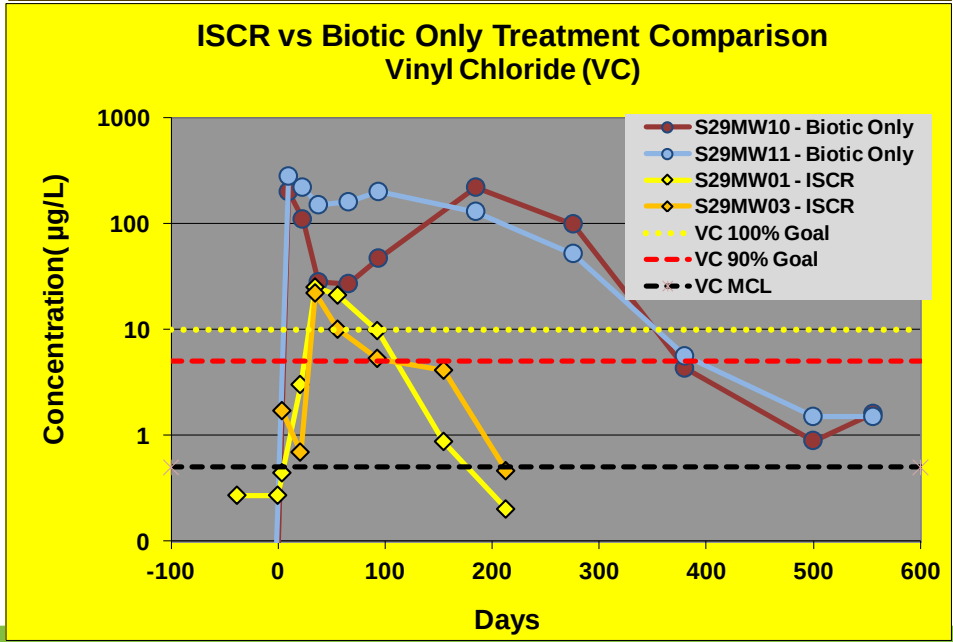
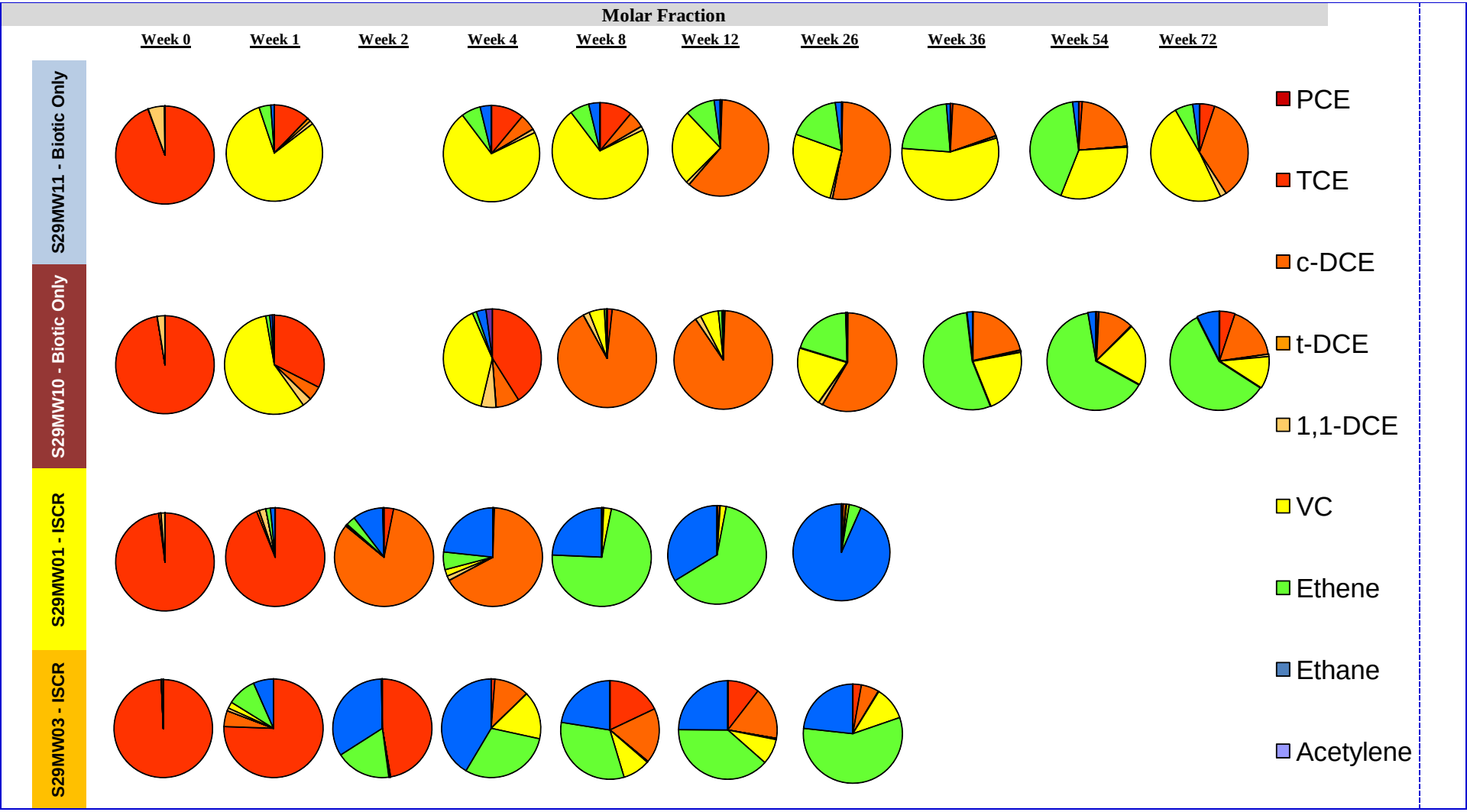








Pilot Test Analytical Results



Conclusions

- Reductive technologies can effectively treat many common contaminants of concern
- ISCR can contain both organic and inorganic substrates, providing multiple treatment pathways
  - More rapid accumulation of ethane and ethene
  - Abiotic pathway can greatly minimize, if not eliminate, the potential for buildup of DCE or VC
- Lecithin combines good characteristics for distribution, persistence, and hydrogen equivalence
- Combined with an inorganic, such as ZVI or Fe (II), ERD/ISCR with lecithin has been proven to be very effective

Questions

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