

A Field Comparison of Biogeochemically Enhanced, Biological and Chemical Reduction for Treatment of Chlorinated Organics

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B1. Combined Remedies

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Biogeochemical Transformation

Processes where contaminants are degraded by abiotic reactions with naturally occurring and biogenically-formed minerals in the subsurface.

Reactive minerals include iron sulfides (e.g. pyrite, mackinawite, greigite) and oxides (e.g. magnetite)

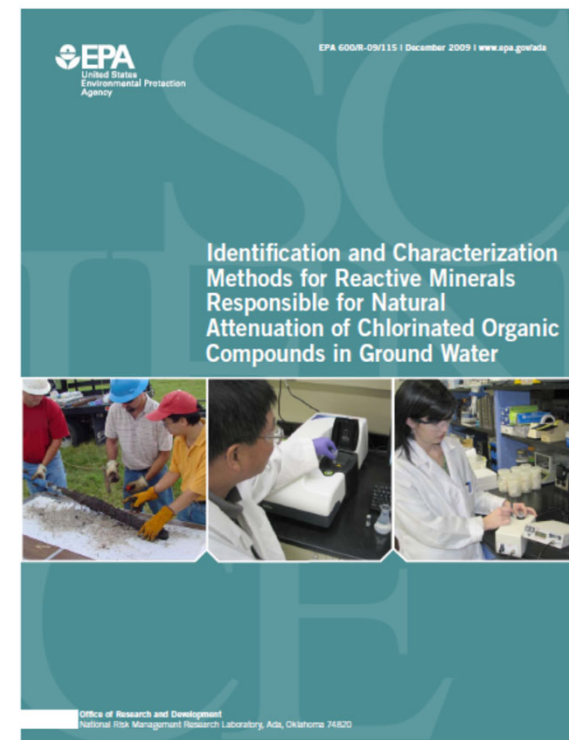


Pyrite (FeS_2)



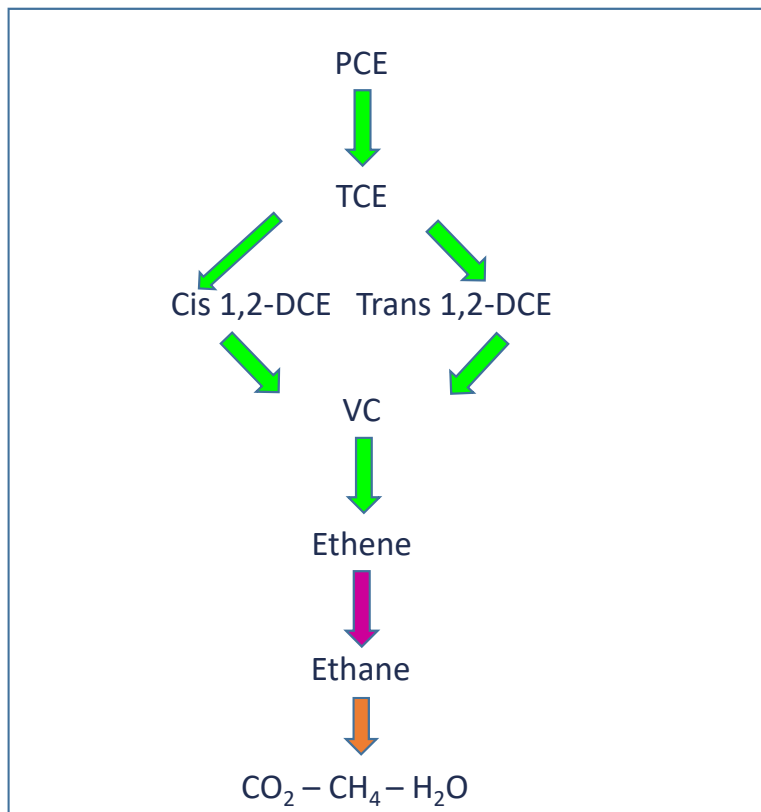
Mackinawite ($\text{Fe}_{(1+x)}\text{S}$)

β -Elimination does not generate stable toxic daughter products

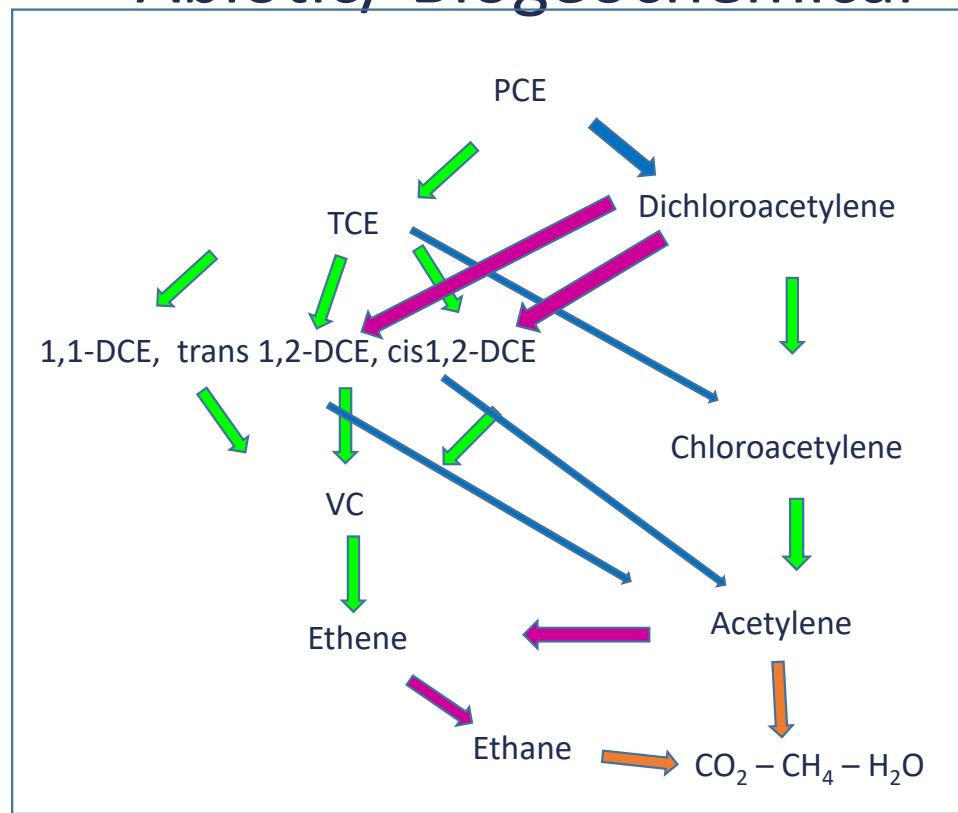


Biotic and Abiotic PCE Degradation Pathways

Biotic



Abiotic/ Biogeochemical



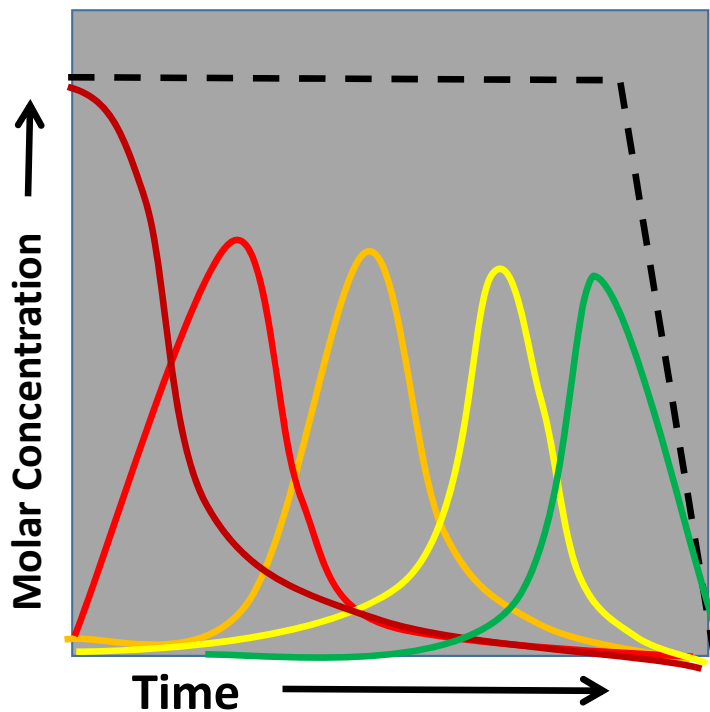
→ β-elimination

→ Hydrogenolysis

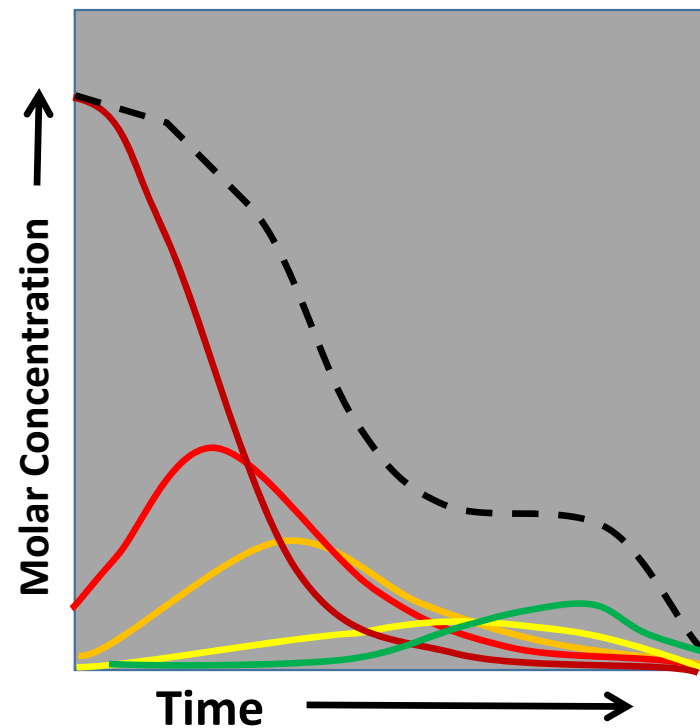
→ Hydrogenation

Anticipated Change in CE Molar Concentration

Biological Degradation (Chlororespiration)



Abiotic Degradation (β elimination)



Confidential Site Location

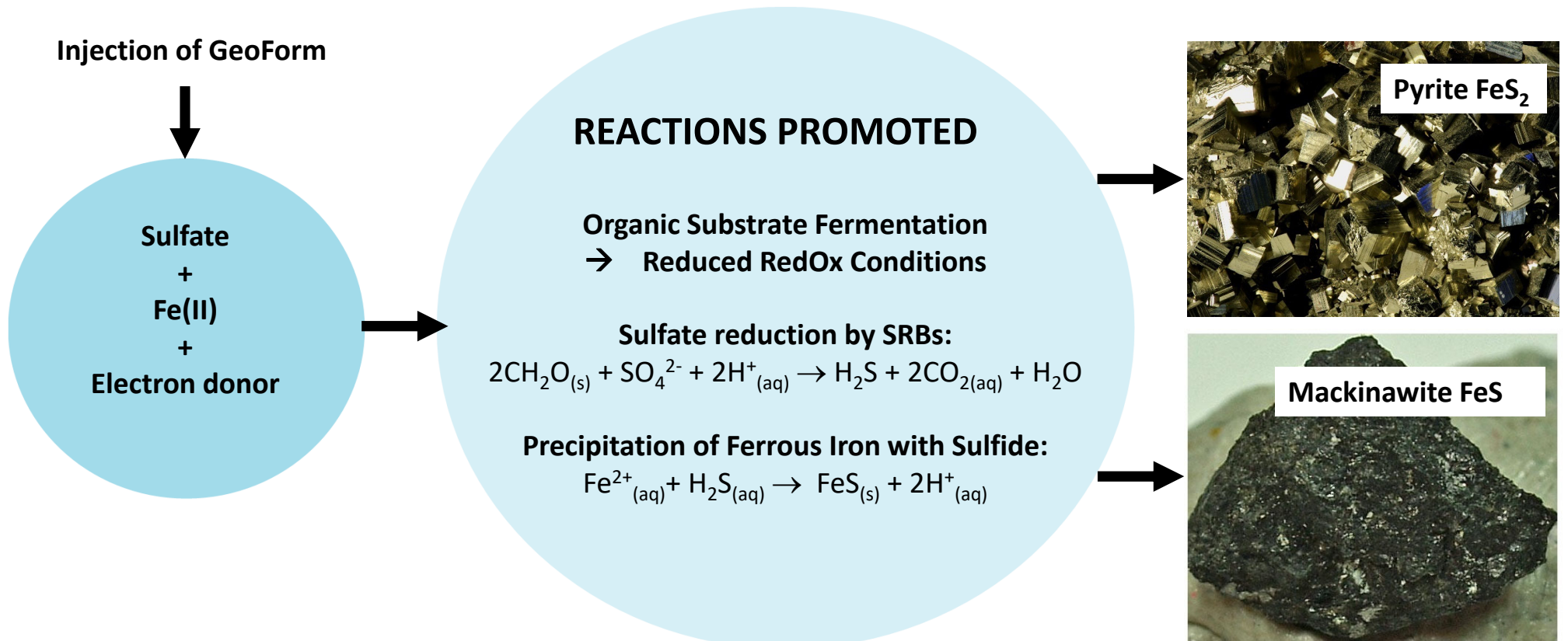
- San Francisco Bay area
- Very high concentration chlorinated VOCs (10s mg/L)
- High sulfate groundwater (~ 500 mg/L)
- Low DO, slightly reducing
- GW flow rate ~ 50 feet per year

Client Wanted Very Aggressive Approach

Evaluated Combined Biotic, Abiotic and Biogeochemical Treatment

Simultaneous Laboratory Batch, Column Tests and Field Pilot Test

Subsequent Full-Scale Field Application



GeoForm Formulations



GeoForm Soluble

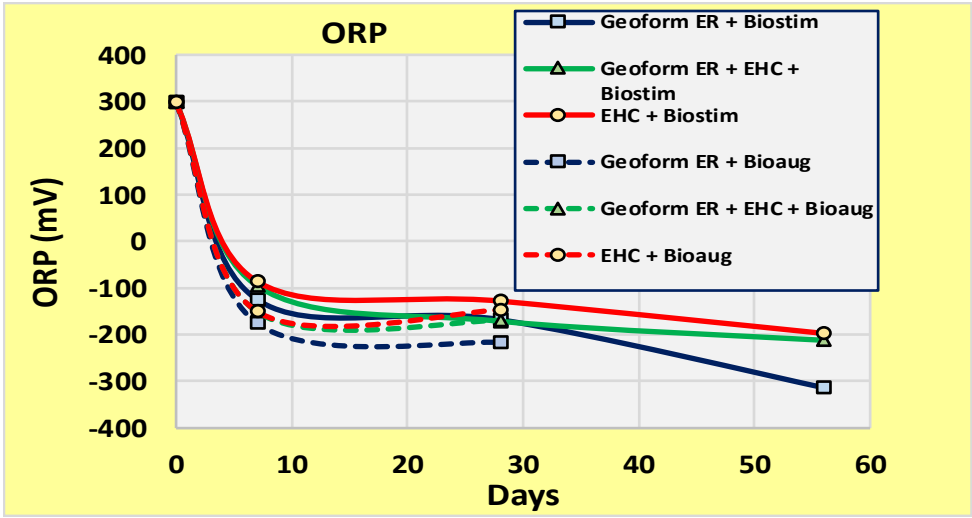
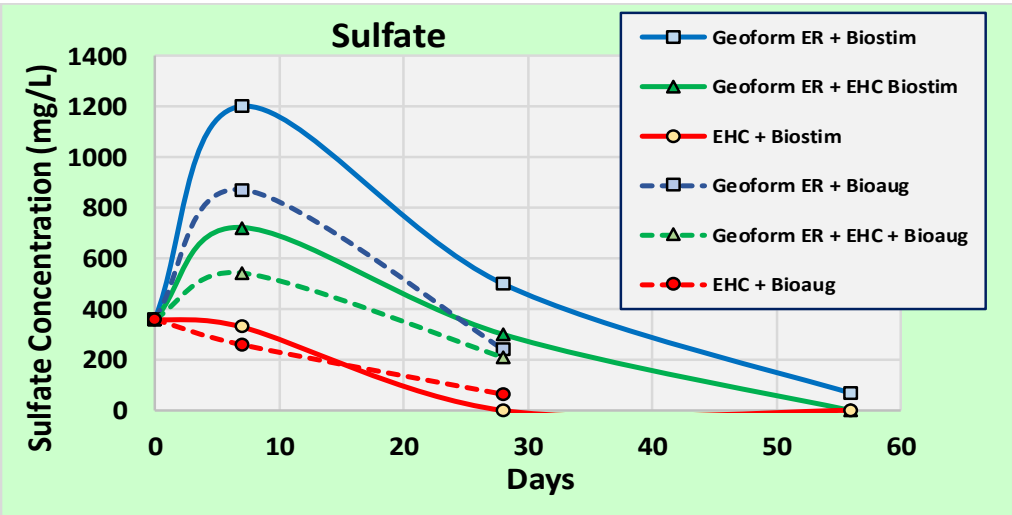
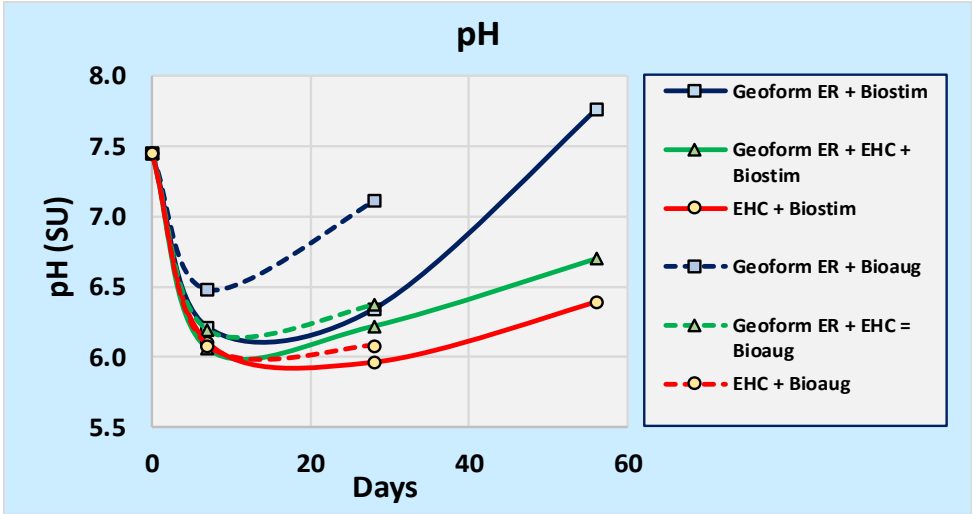
- Injects as a solution forming long lasting solids.
- Proprietary blend of Soluble Organic Carbon, Sulfate, Ferrous Iron, pH buffer and nutrients.
- Delivered in 2 parts allowing for custom designs
- Longevity of 2-3 years or more

GeoForm Extended Release

- Provides a longer lasting source of electron donors for continued rejuvenation of reactive minerals.
- Extended Release Organic Carbon, Micro-Scale ZVI, Sulfate, Ferrous Iron, pH buffers and nutrients
- Longevity of 5-10 years

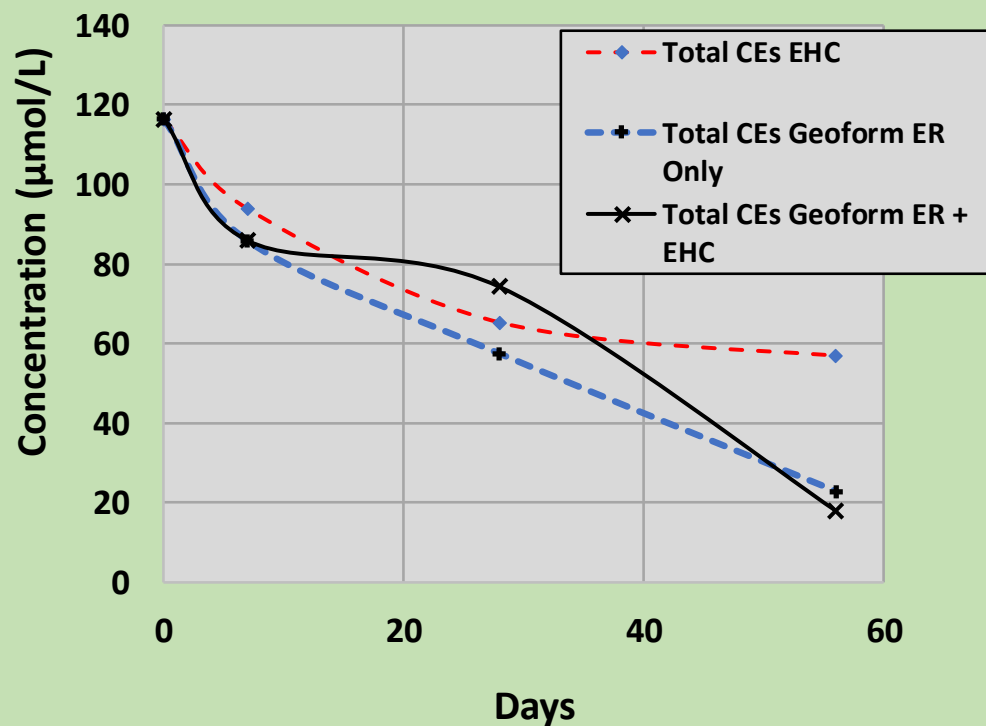
GeoForm™ Formulation	Treatment Mechanisms		
	Biotic Reduction	Abiotic Reduction	
		Reductive Minerals	ZVI
GeoForm™ Soluble	•	•	
GeoForm™ Extended Release	•	•	•

Batch Test Results

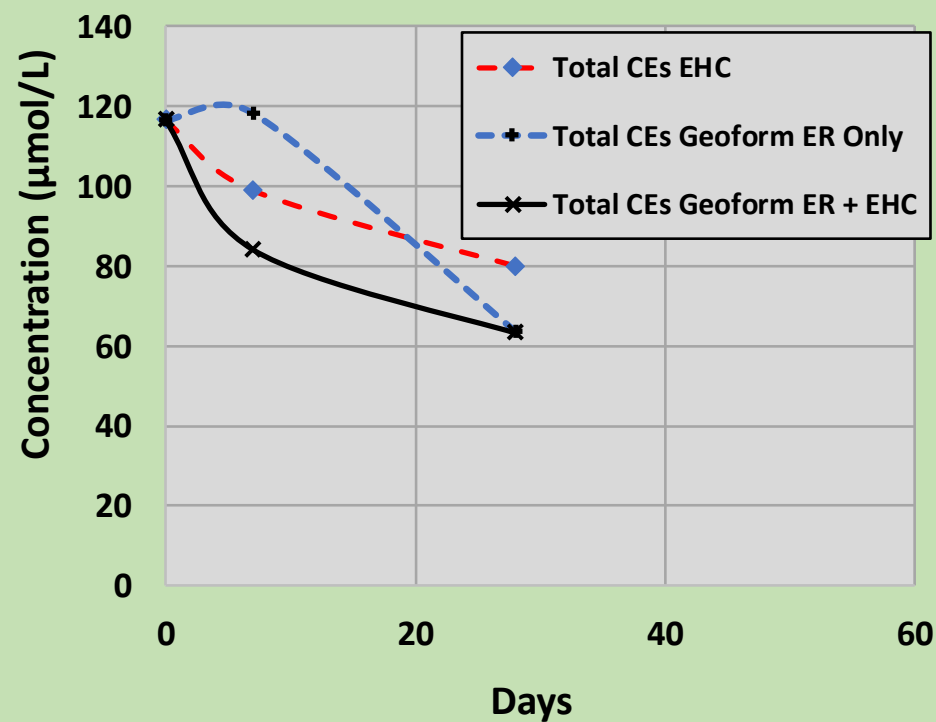


Laboratory Batch Tests

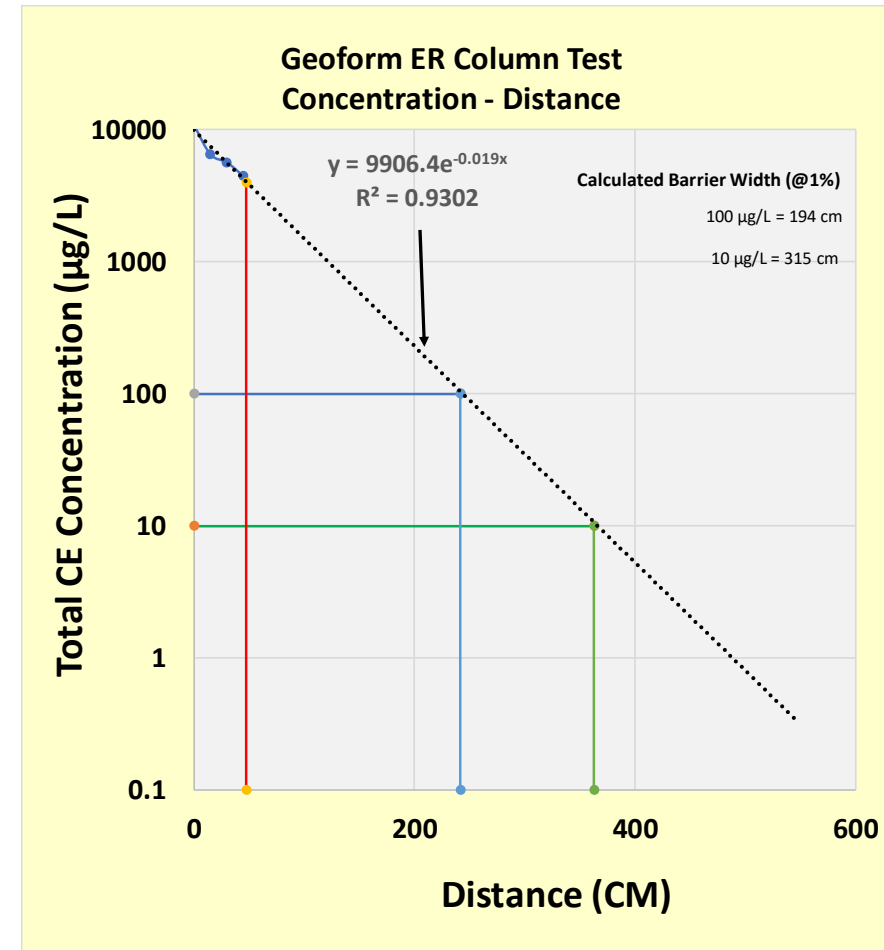
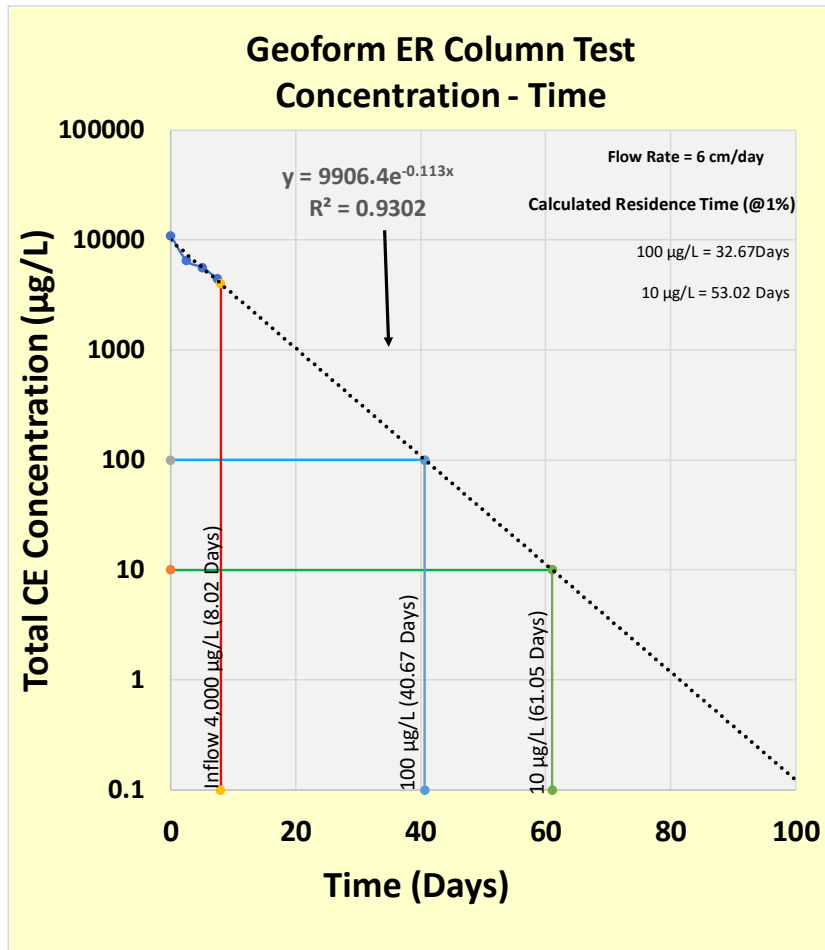
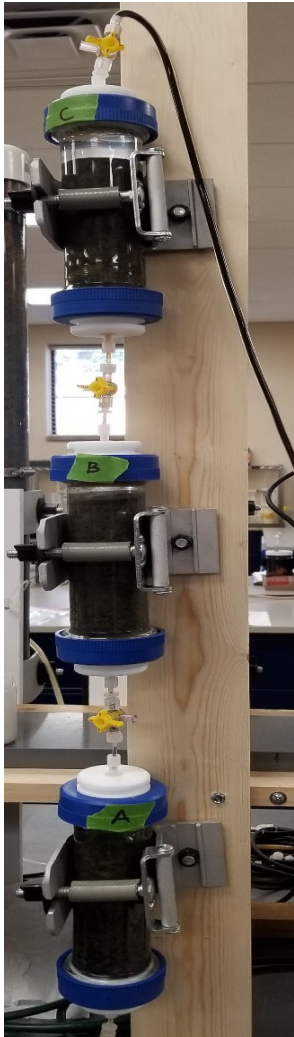
EHC, Geoform ER , Geoform ER + EHC Biostimulation



EHC, Geoform ER , Geoform ER + EHC Bioaugmentation



Column Studies



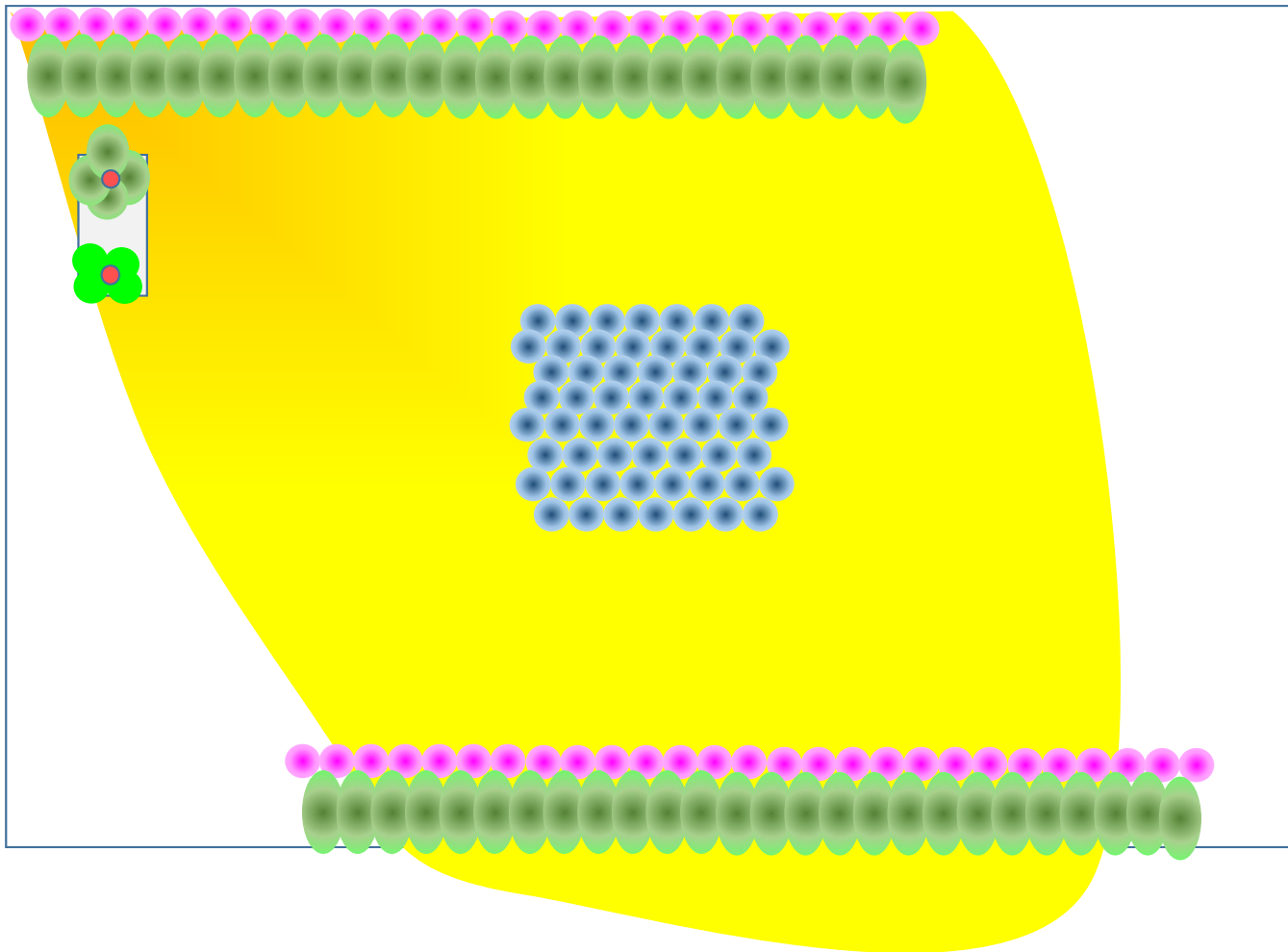
Mixing Geoform Soluble



GeoForm Extended Release (ER)



Full Scale Application



Pilot Test Area



Geoform Soluble



Geoform Extended Release (ER)

Permeable Reactive Barriers



EHC



Geoform ER



Hot Spot - EHC-L

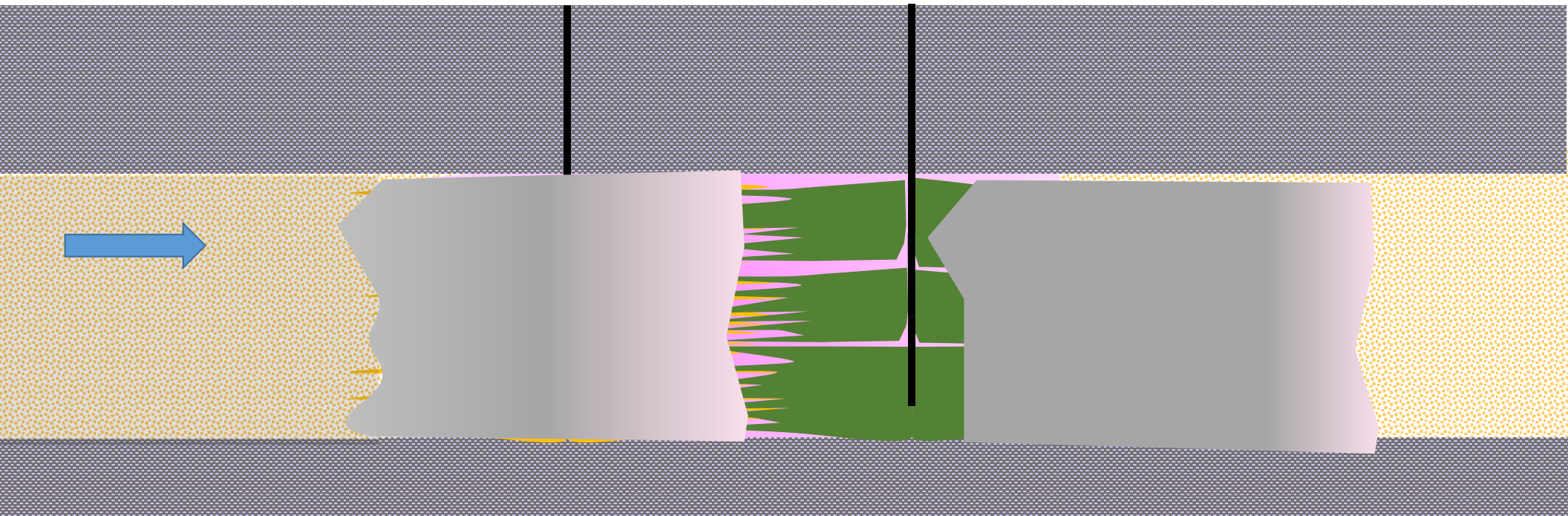
PRB Construction

EHC

ZVI +
Organic Carbon +
SDC-9

Geoform ER

ZVI + Organic Carbon +
Ferrous Iron + Sulfate +
SDC-9



Nearby Site Geoform ER Application



- **San Francisco Bay**
- **High Sulfate (~700 mg/L)**
- **1 Recalcitrant Well**
- **High TCE, 1,2-DCA, CF**

3 Applications

- 1. ELS, ZVI, SDC-9**
- 2. ELS, ZVI, SDC-9, MDB-1**
- 3. Geoform ER SDC-9, MDB-1**

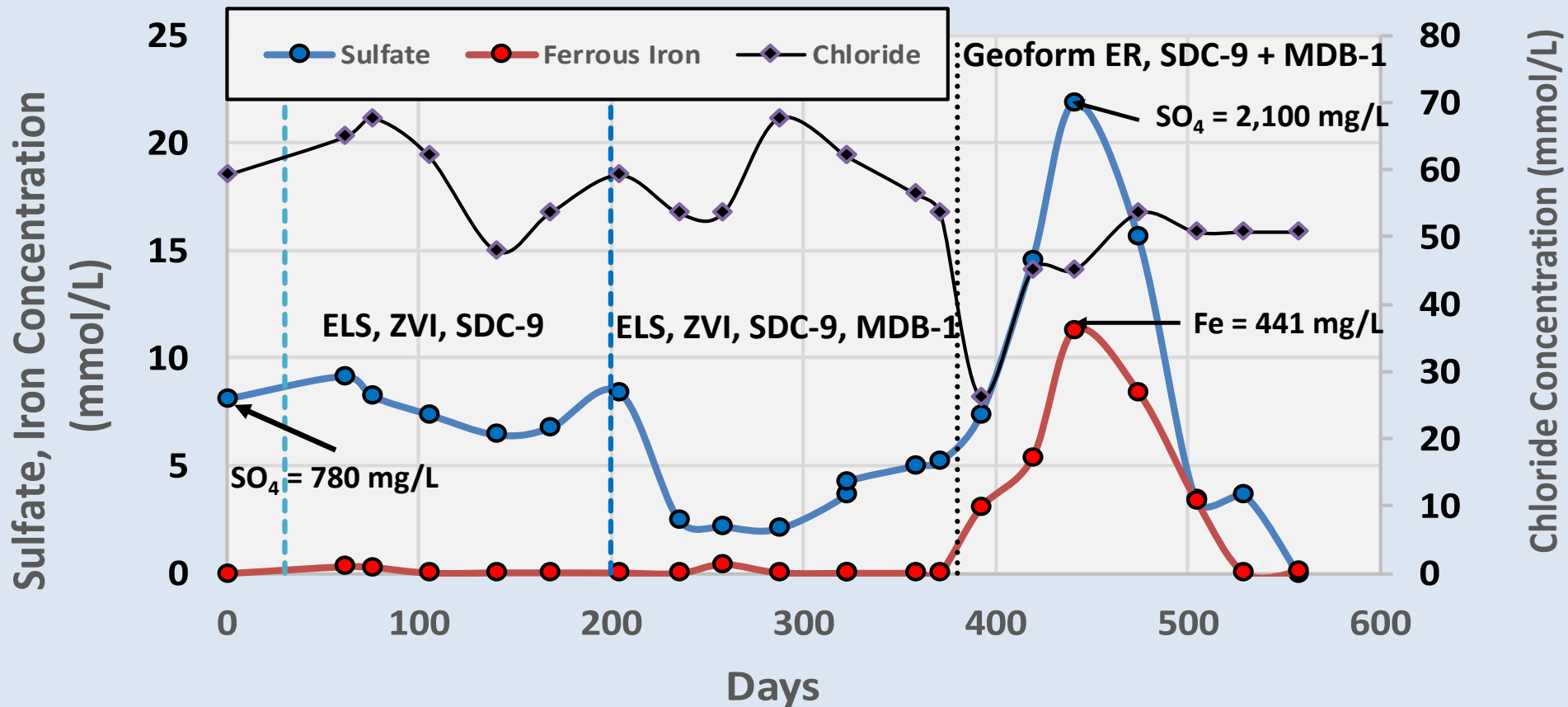
Session C2 Holiday 5, Tuesday 11:20

Impacts of Mixed Contaminants on Biodegradation

Combining Biotic and Abiotic Treatment Processes to Overcome Challenges of a Mixed Chlorine Solvent Plume. Isaac Pelz for Darrell Smolko (Environmental Resources Management/USA) A. Chemburkar, A. Breckenridge, and D. Leigh

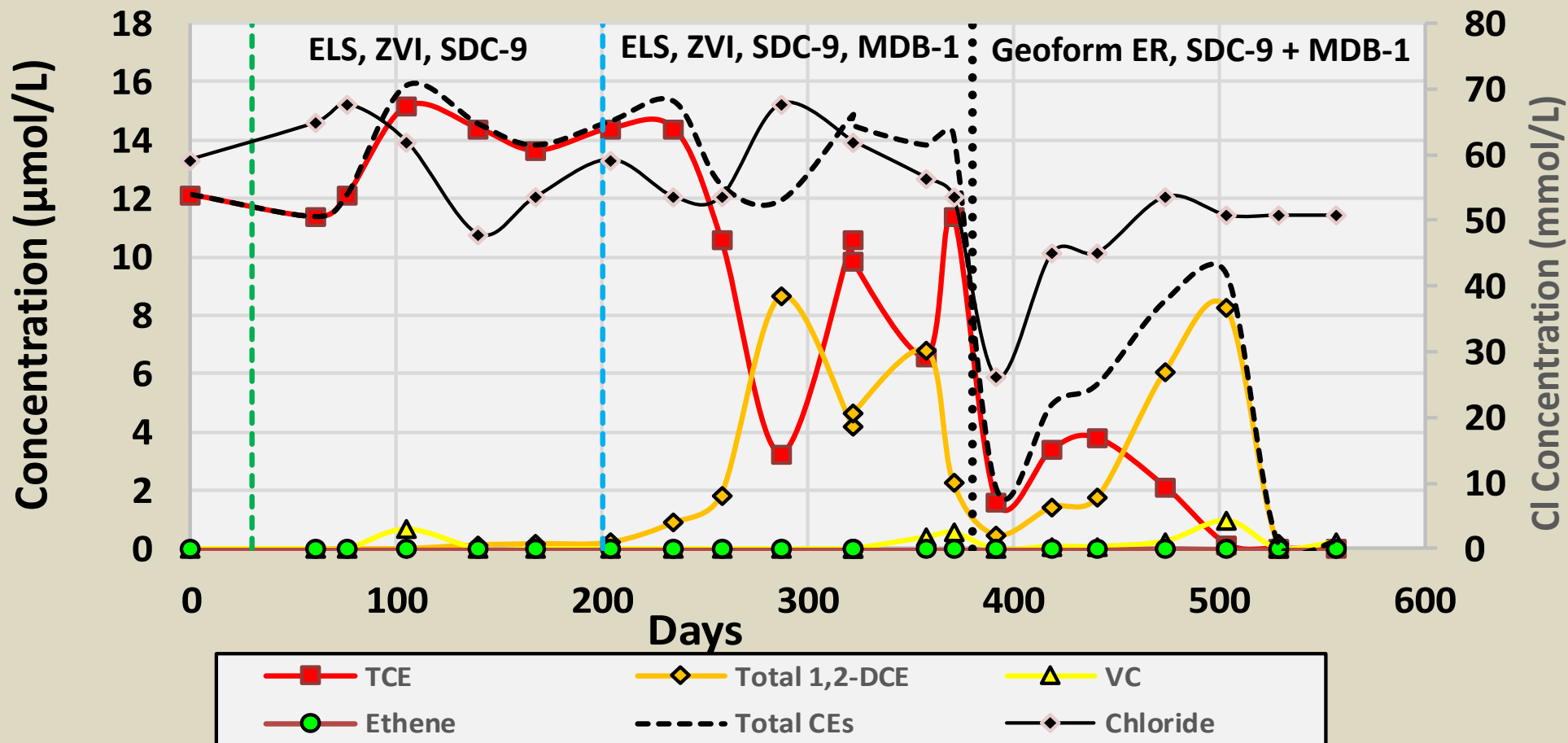
Recalcitrant Well

Sulfate - Iron

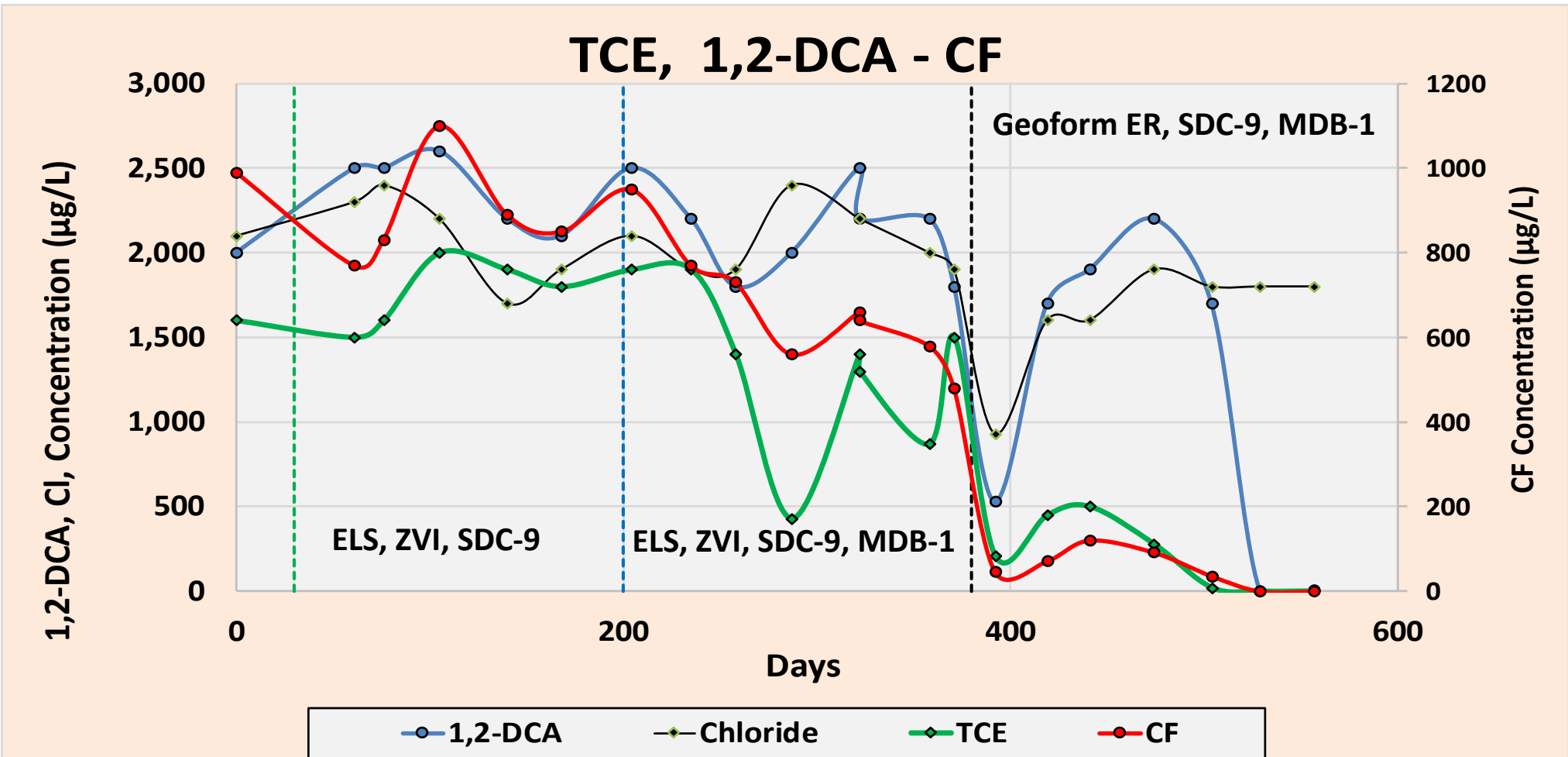


Recalcitrant Well

Chlorinated Ethenes



Recalcitrant Well



Conclusions



Sulfate and ferrous in solution rapidly reduced and precipitated as reactive FeS

Biogeochemical enhancement increases contaminant degradation rate

Biogeochemical enhancement, with MDB-1, very effective for treatment of mixed plume

Geoform easier to inject than EHC alone (anecdotal)

Biogeochemical zone will extend barrier width

Addition of sulfate results in sulfidization of ZVI, increases reactivity of ZVI.



Questions?

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