

# Tools for Monitoring Contaminant Biodegradation When Combined with Colloidal Activated Carbon

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# Overview

- FAQs: PlumeStop Liquid Activated Carbon
  1. Are adsorbed contaminants bioavailable?
  2. How can we know biodegradation is occurring?
- Proof of concept biodegradation demonstrations
  - Column study
  - Microcosm
  - Dual porosity tank study
- Field examples



# PlumeStop<sup>®</sup> Liquid Activated Carbon<sup>™</sup>

## Colloidal remediation agent

- Non-toxic, black “ink”
- 1-2 micron activated carbon
- polymer/sorbent/additives
- Patented formulations and methods



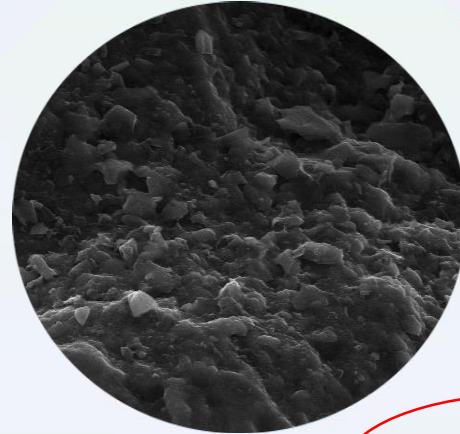
# PlumeStop® Liquid Activated Carbon™

## Goals:

- Decrease the remediation footprint
- Increase the residence time of contaminants in the reactive zone

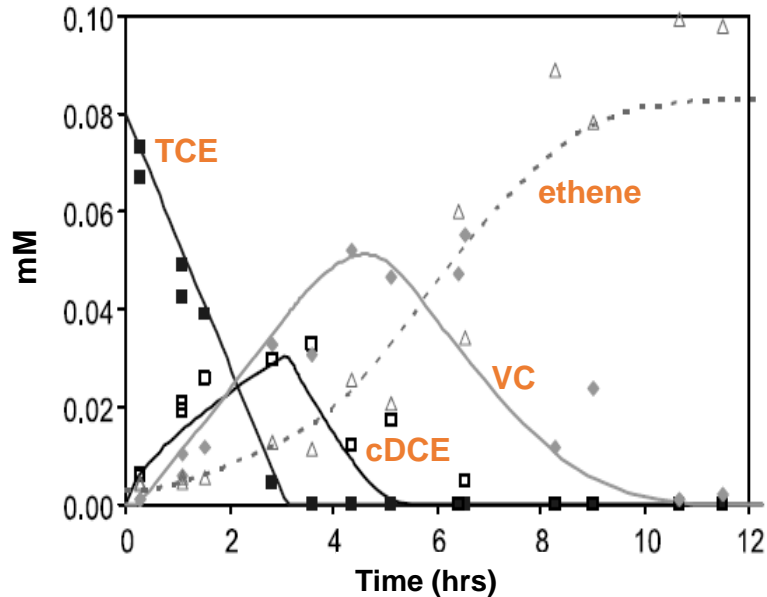
## Key questions:

- Are adsorbed contaminants bioavailable?
- What tools can we use to monitor biodegradation?

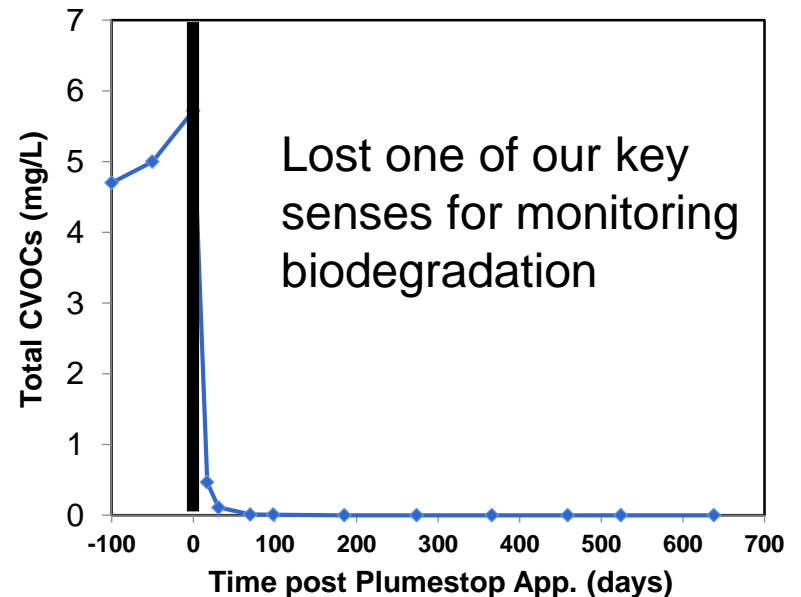


# Monitoring Biodegradation: VOC Concentrations

## ERD Treatment:



## PlumeStop + ERD:



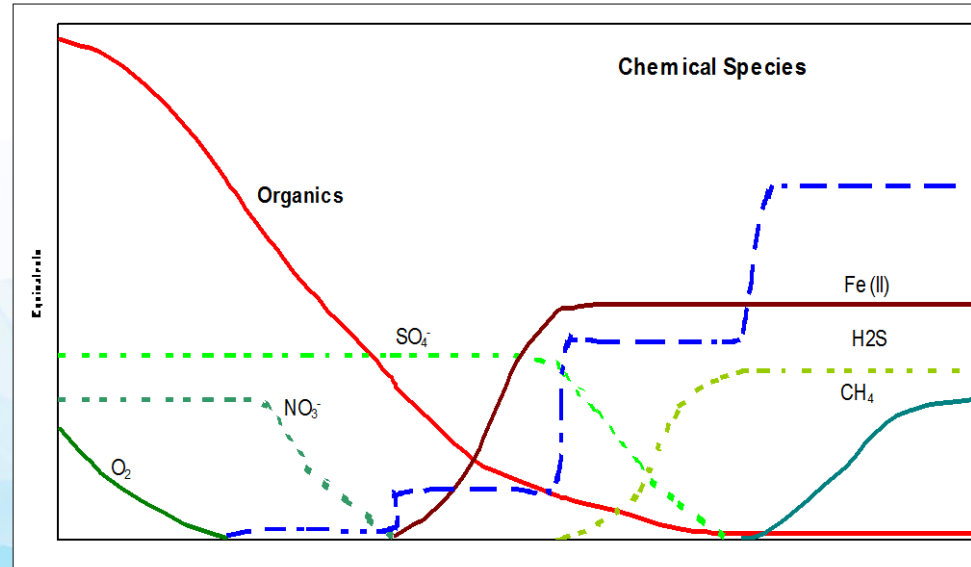
Schaefer et al. Chemosphere, 75, 2009, 141-148.

# Monitoring Biodegradation: Multiple Lines Of Evidence

➤ Need to heighten our awareness to other indicators

- Are the conditions right?
  - Geochemical parameters: TEAs, ORP, DO, etc.
- Biodegradation products
  - Ethene, trace intermediates?
- Microbial Indicators
  - Are the right bacteria present?
  - At useful concentrations?

Important to monitor these parameters over time -> trends



# Proof of Concept: Laboratory Studies

➤ Are sorbed contaminants bioavailable?

## **Expt 1:** Column study

- Evidence for sorption + biodegradation

## **Expt 2:** PCE Microcosm study

- Confirmed contaminant destruction

## **Expt 3:** Dual porosity tank study

- Back diffusion solution

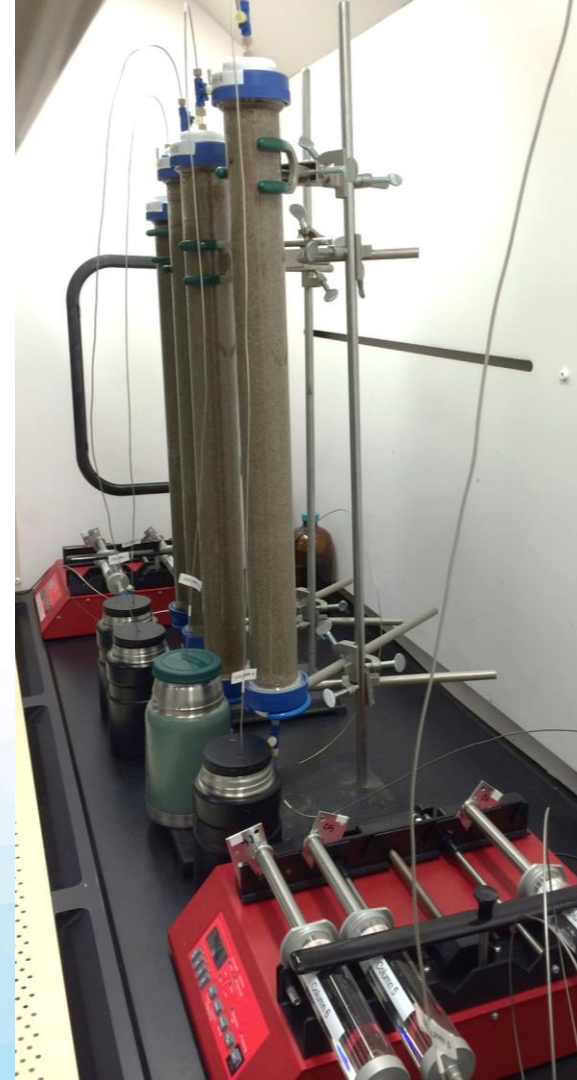


# Expt 1: Column Study Set-Up

## Column Conditions:

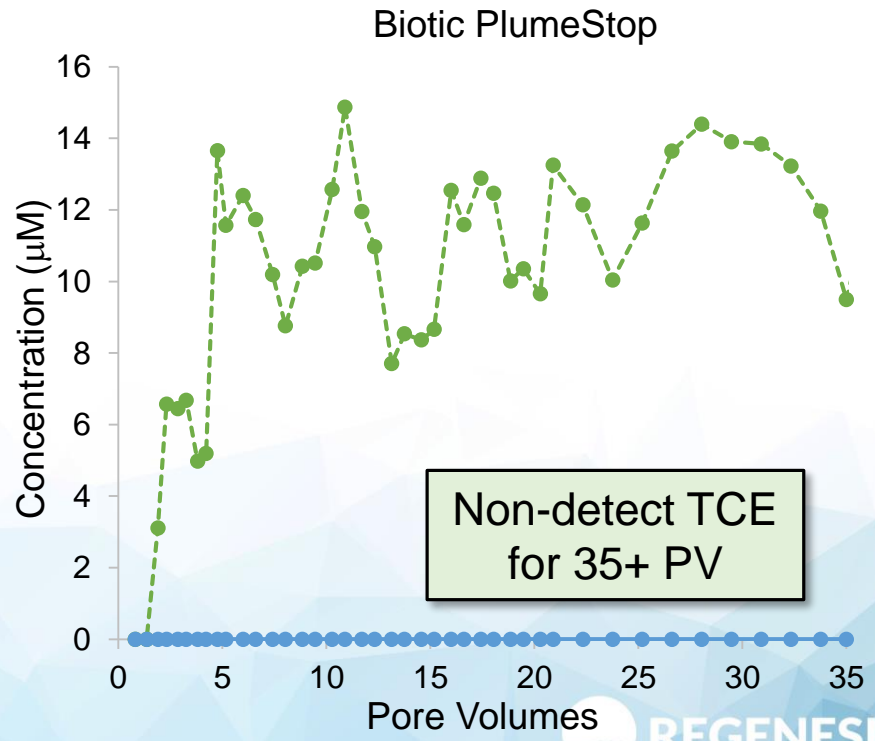
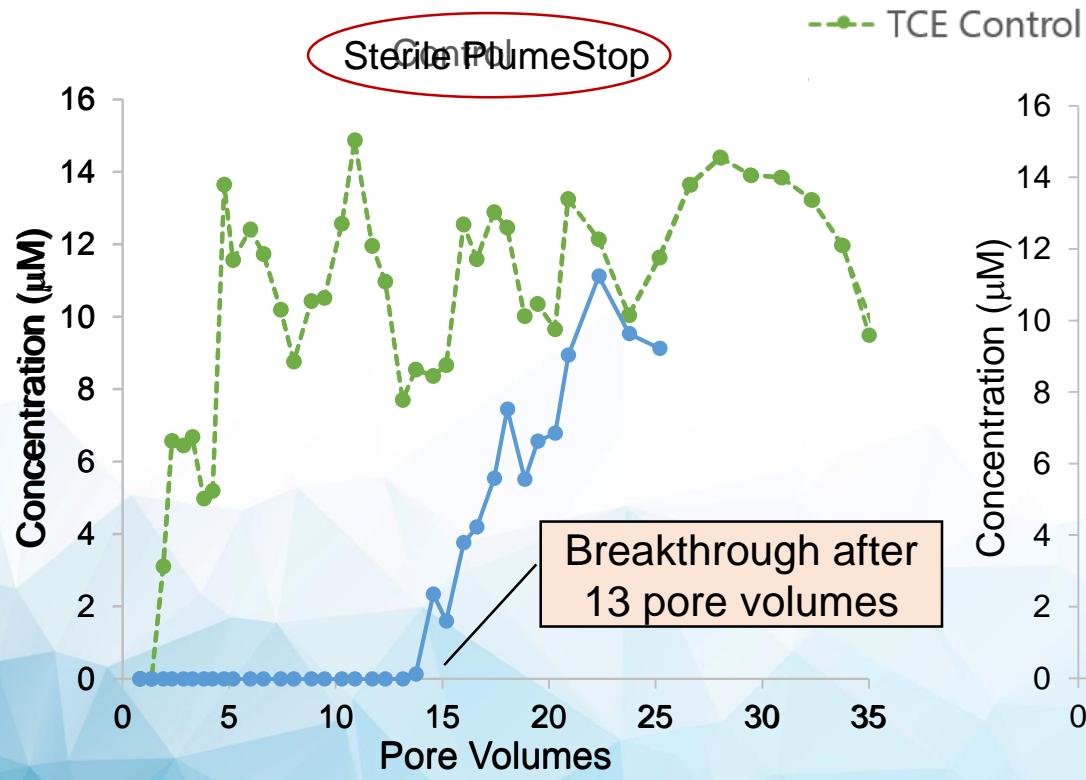
1. Sterile Control: No treatment
2. Sterile PlumeStop: Initial PlumeStop treatment
3. Biotic PlumeStop: Initial PlumeStop treatment & bioaugmentation with *Dehalococcoides*, on-going lactate

Continuous TCE flow through all columns: 1-2 mg/L

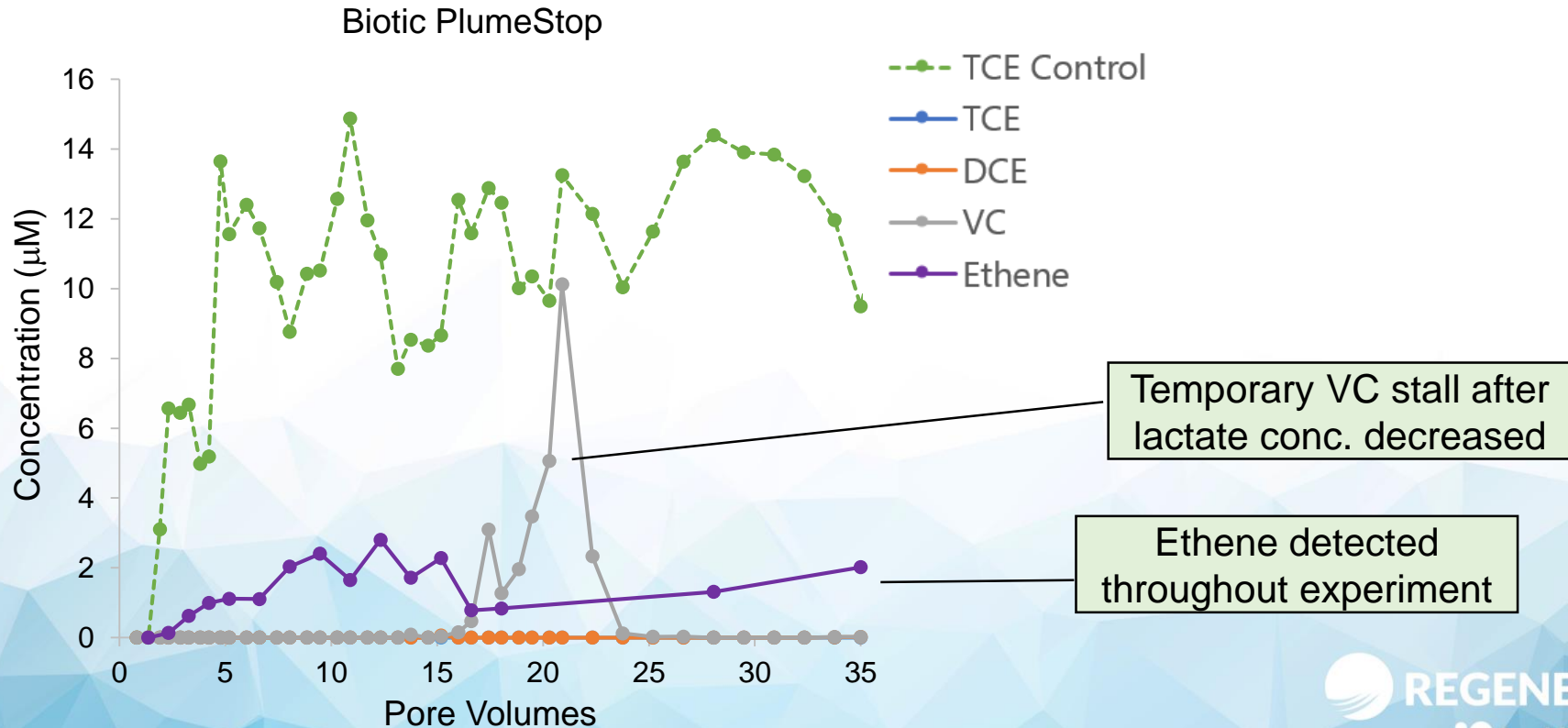




# Expt 1: Column Study Results

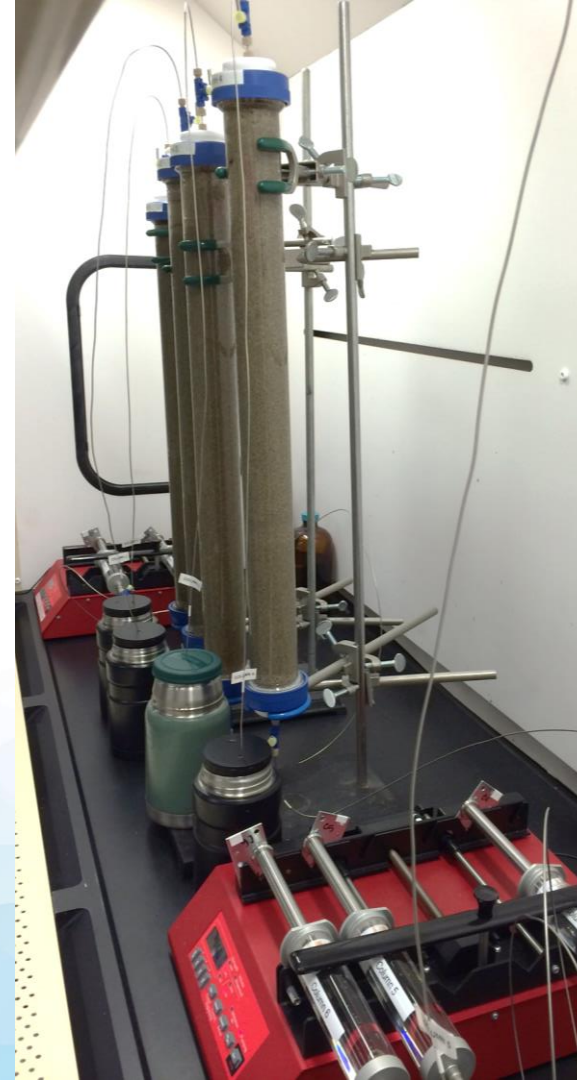


# Expt 1: Column Study Results



# Expt 1: Conclusions

- TCE @ ND throughout experiment
  - Ethene throughout experiment
- Confirmed no inhibition on biodegradation from presence of colloidal activated carbon



# Proof of Concept: Laboratory Studies

## Expt 1: Column study

- Evidence for sorption + biodegradation

## Expt 2: PCE Microcosm study

- Confirmed contaminant destruction

## Expt 3: Dual porosity tank study

- Back diffusion solution



# Expt 2: PCE Microcosm Set-Up

## Conditions:

1. Sterile Control: no treatment
2. Sterile PlumeStop: 50 mg/L PS
3. Biotic PlumeStop: 50 mg/L PS, DHC, lactate

## Contaminant Loading:

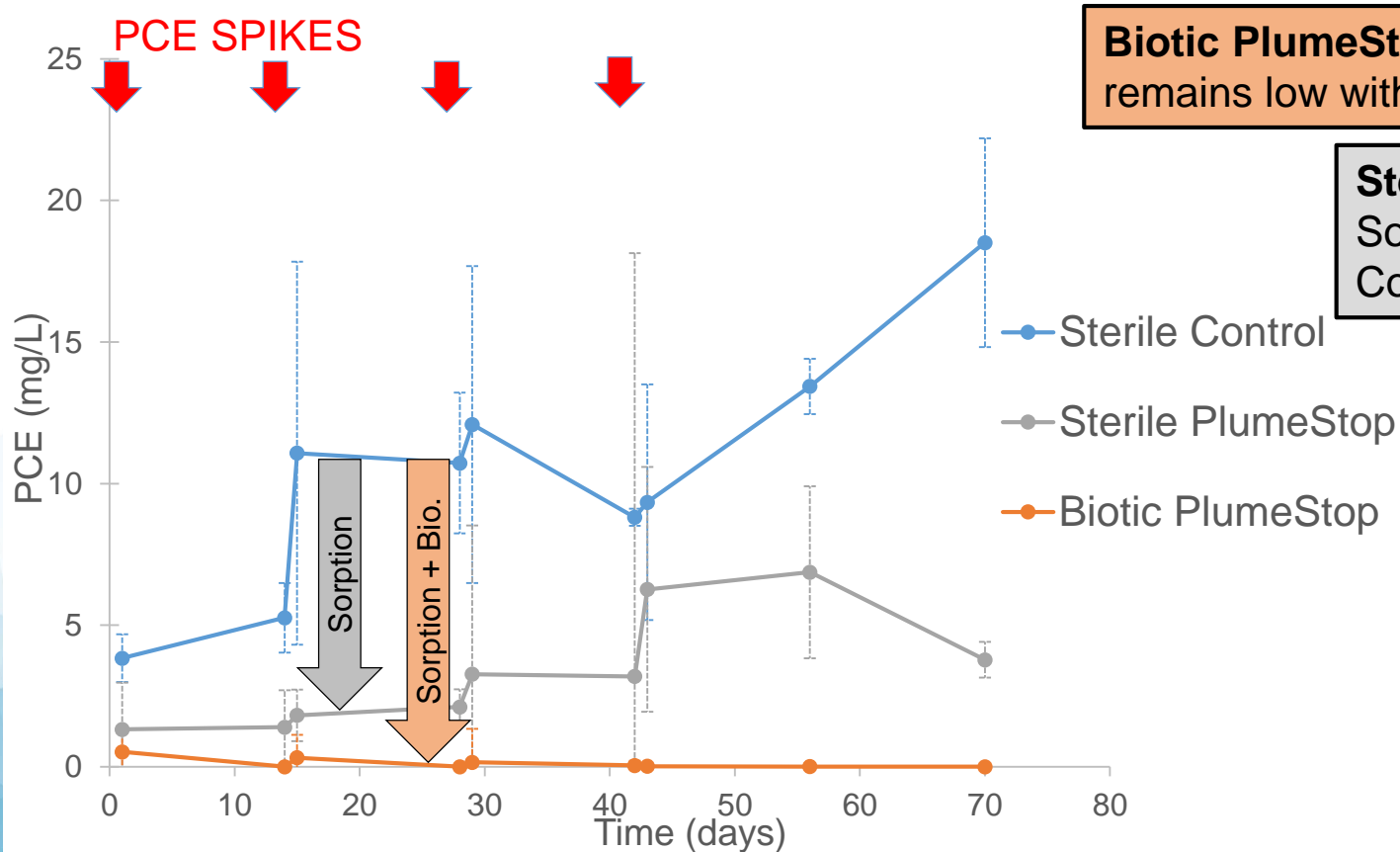
- 10 mg/L PCE spiked every two weeks

## Measurements:

- Dissolved phase PCE
- Total mass PCE across all phases (extraction)



# Expt 2: Results - Dissolved phase PCE



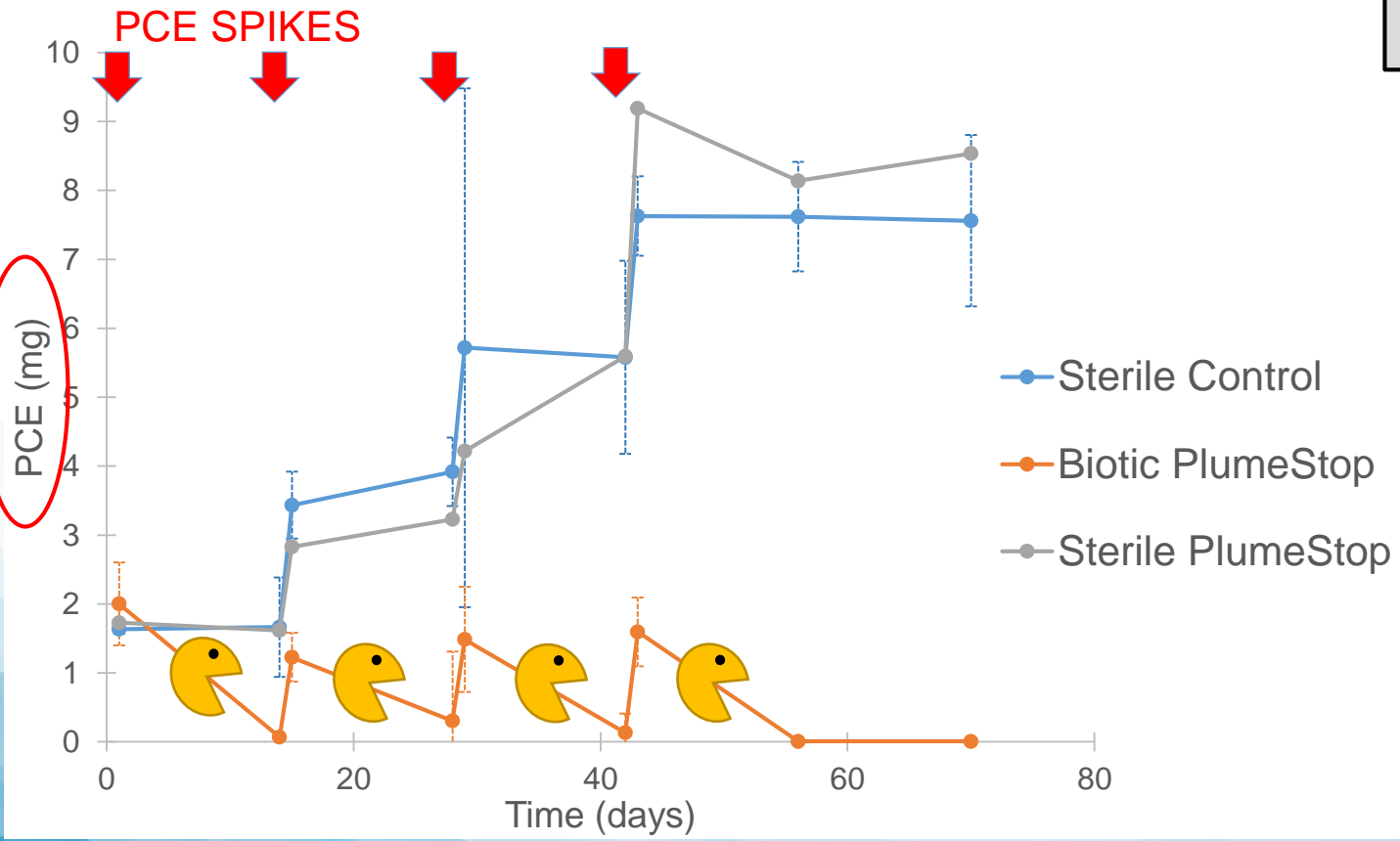
**Biotic PlumeStop** PCE concentration remains low with additional PCE spikes

**Sterile PlumeStop**  
Sorption only:  
Concentration will increase

# Expt 2: Results – Total PCE mass

**Sterile PlumeStop:**  
No destruction,  
mass retained

**Biotic PlumeStop:**  
PCE is destroyed



# Expt 2: Conclusions

## Demonstrated:

- Regeneration cycle
  - 4 rounds of sorption and biodegradation
- Sustained treatment of PCE mass “flux”
  - Low GW levels throughout expt
- Definitive contaminant destruction
  - Confirms contaminant bioavailability



# Proof of Concept: Laboratory Studies

## **Expt 1:** Column study

- Evidence for sorption + biodegradation

## **Expt 2:** PCE Microcosm study

- Confirmed contaminant destruction

## **Expt 3:** Dual porosity tank study

- Back diffusion solution



# Expt 3: Dual Porosity Tank Study



Collaboration with:

- Kevin Saller, CDM Smith
- Tom Sale, Colorado State University



Investigators in a SERDP funded project:  
“Treatment of Contaminants in Low Permeability Zones”

- Used this tank set-up to simulate back diffusion and evaluate different remediation treatments (SERDP Project ER-1740)

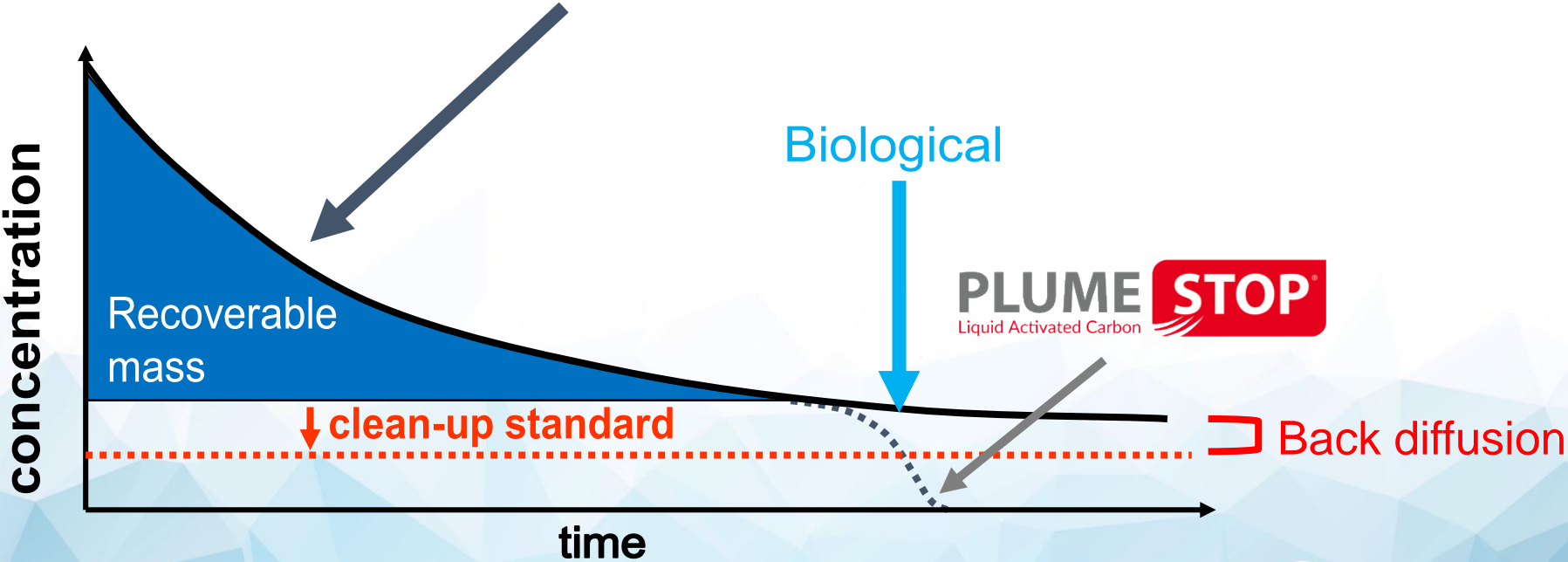
Our study goal:

- Compare the performance of a PlumeStop treatment under similar test conditions to ERD



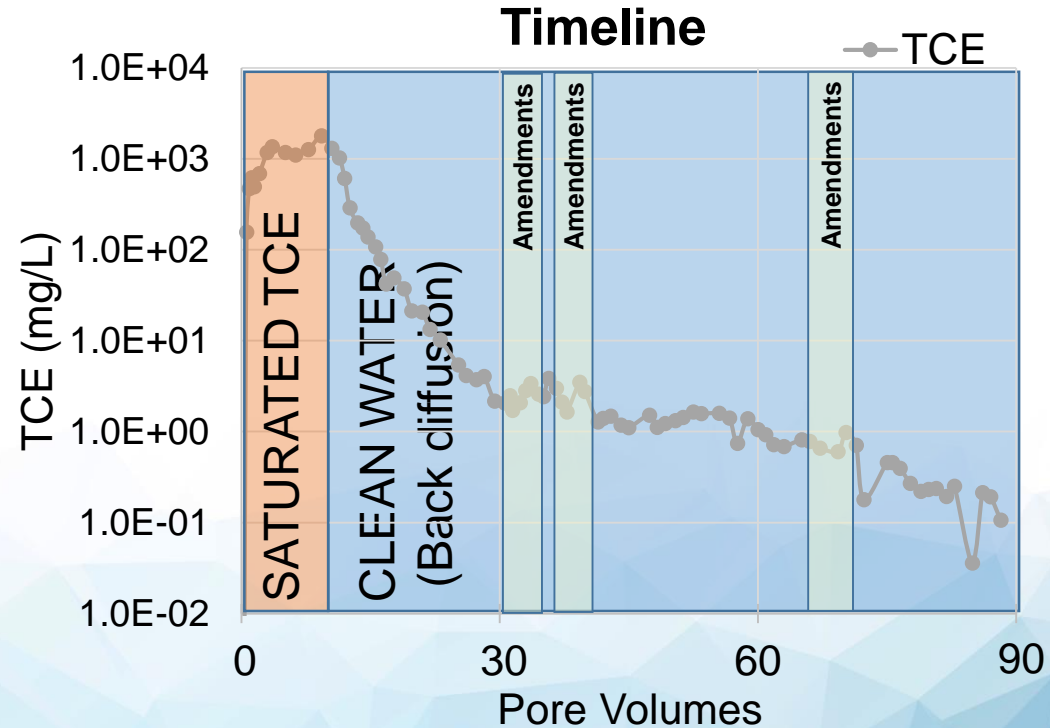
# Back Diffusion

Physical Removal or Chemical Oxidation



# Expt 3: Dual Porosity Tank Study Procedure

1. "TCE Spill"
  - a. TCE saturated water flowed through tanks (~12 PV)
2. Back diffusion:
  - a. Influent switched to clean water until effluent TCE <5 mg/L
3. Inject remediation treatments



# Expt 3: Conditions Tested

- Tank 1**      Control, no treatment
- Tank 2**      PlumeStop only
- Tank 3**      ERD Treatment
  - Lactate + DHC
- Tank 4**      Biotic PlumeStop
  - PlumeStop, lactate, DHC



# Expt 3: Analyses



Control Tank

Effluent



Influent

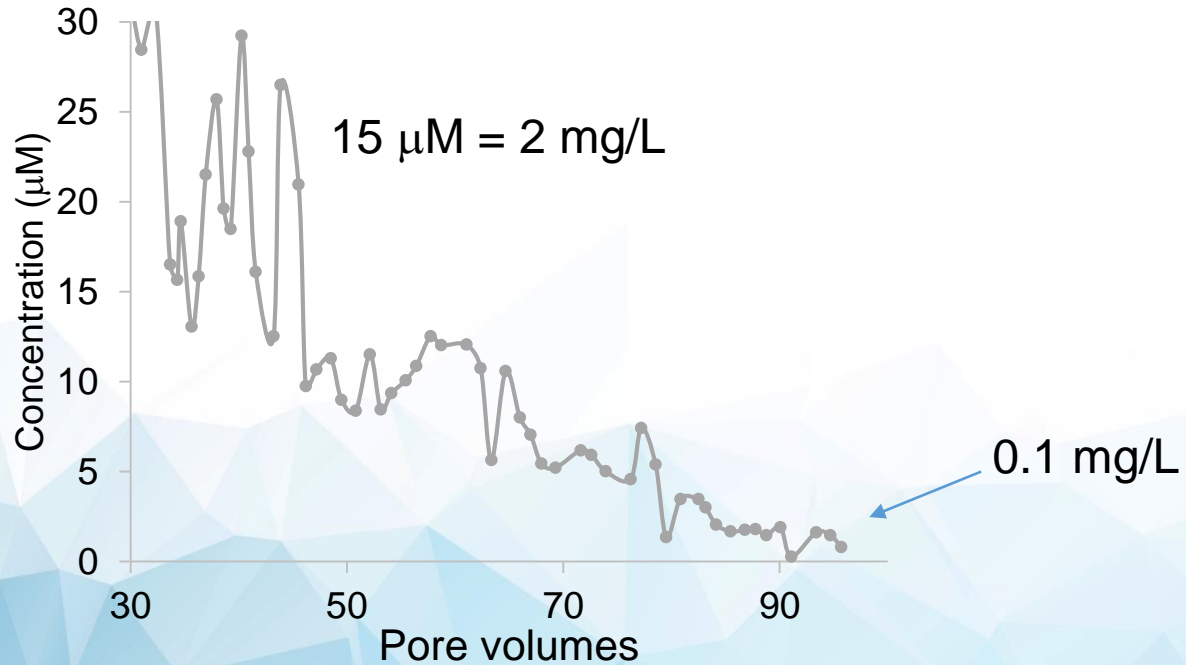


PlumeStop Tank

- Effluent samples collected throughout experiment for VOCs
- qPCR analysis of water and soil upon completion of experiment

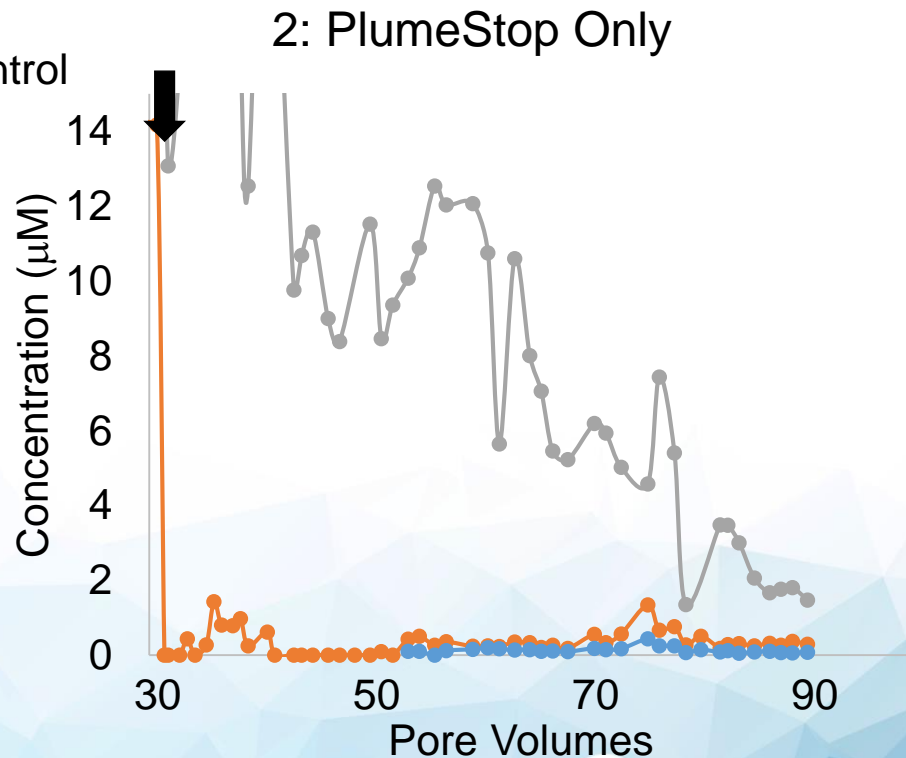
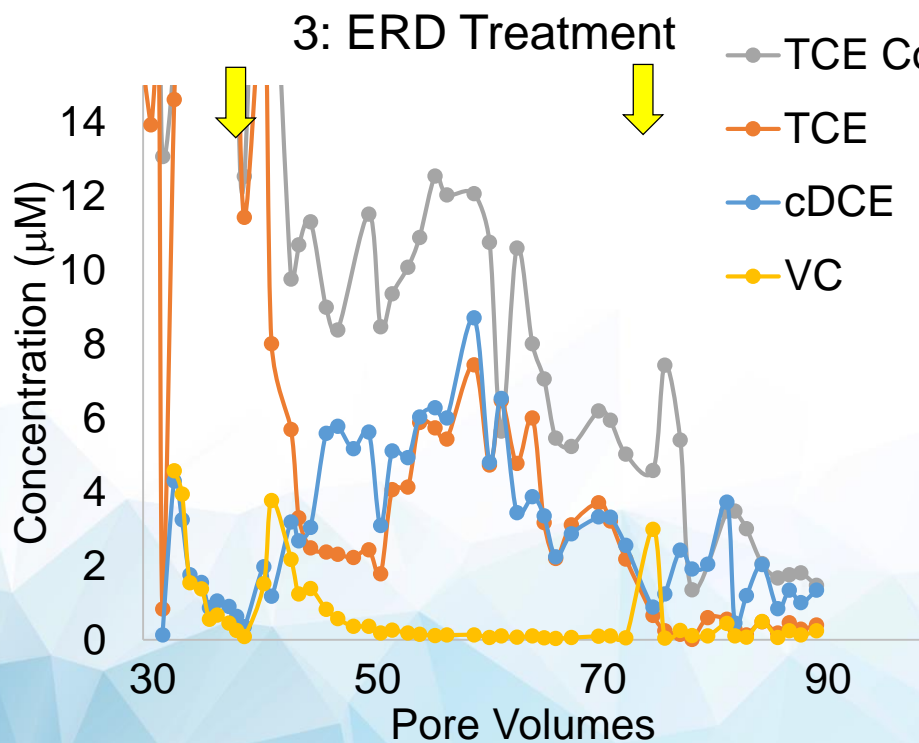
# Expt 3: Tank Effluent Results

## 1: Control



Note: Graph starts at time when amendments were applied

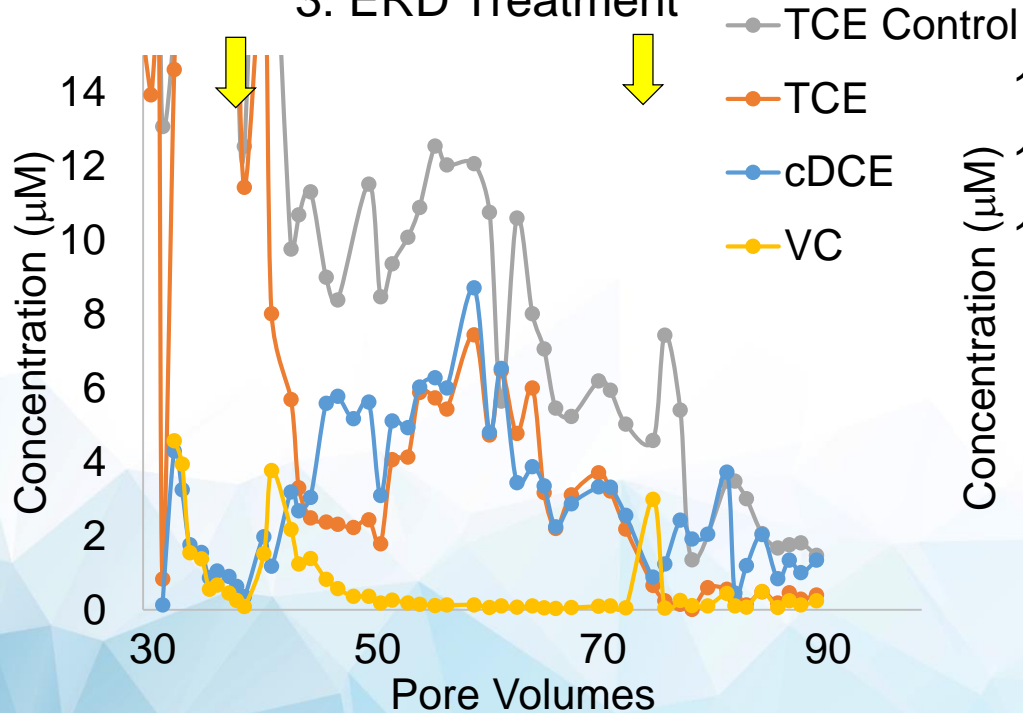
# Expt 3: Tank Effluent Results



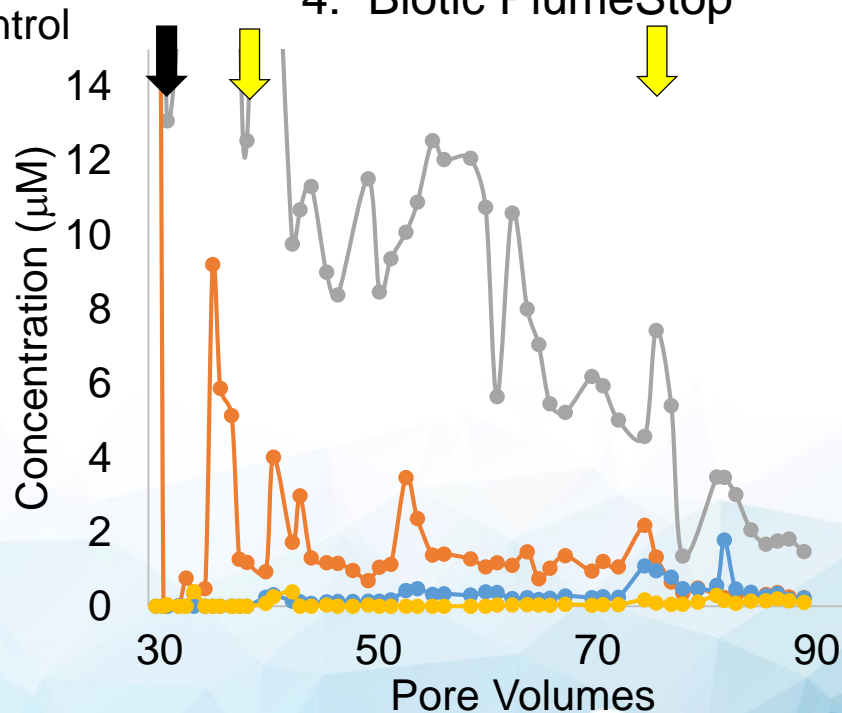


# Expt 3: Tank Effluent Results

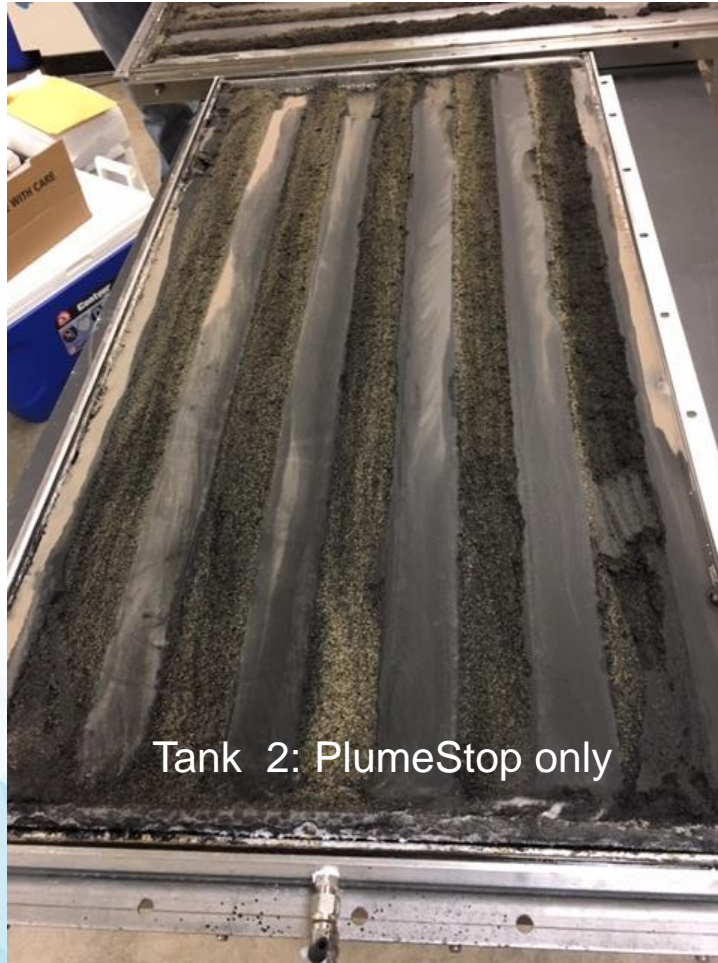
## 3: ERD Treatment



## 4: Biotic Plume Stop



# PlumeStop Transport



Tank 2: PlumeStop only

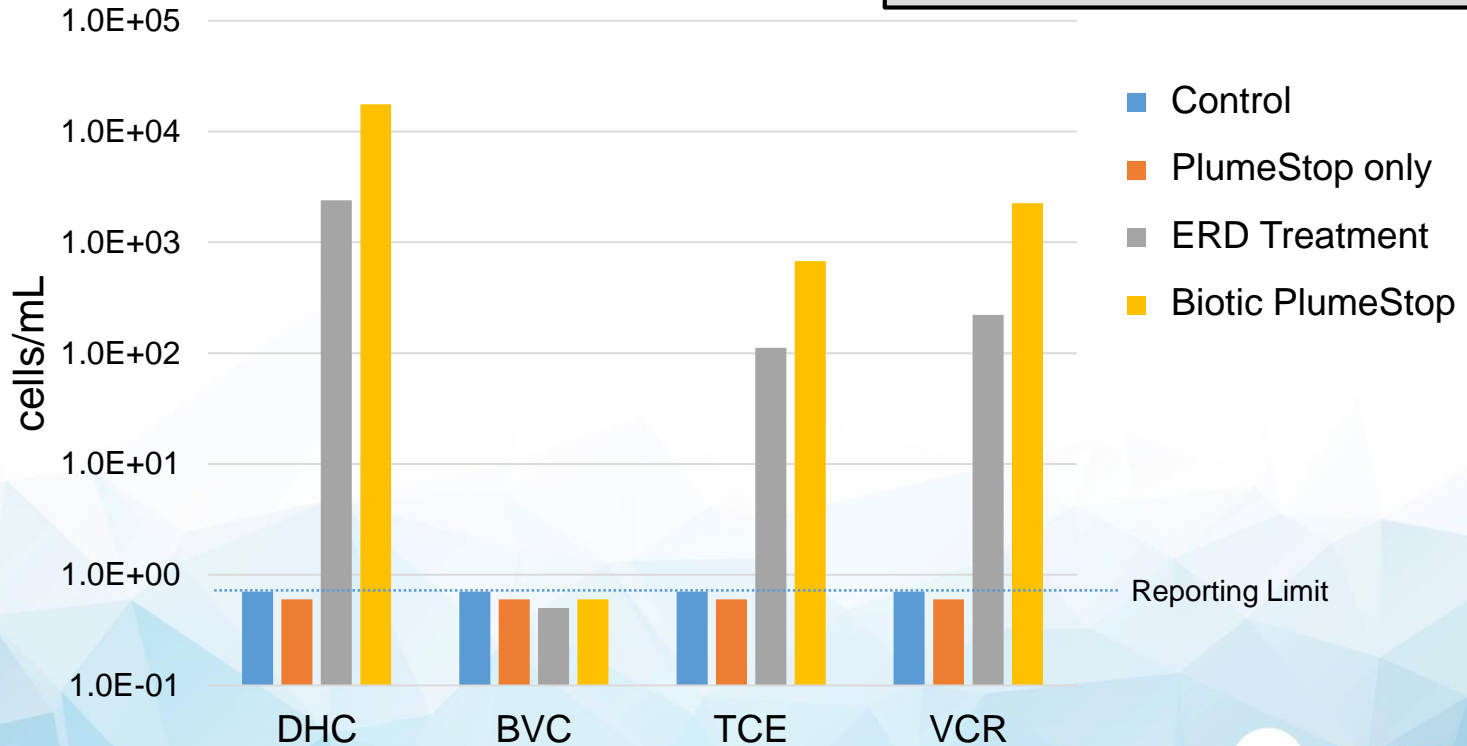


Tank 4: PlumeStop + bio

Noticeable  
penetration into  
low k zones

# Expt 3: qPCR Data - Water

Enhanced DHC + functional gene populations measured in PlumeStop + ERD tank.

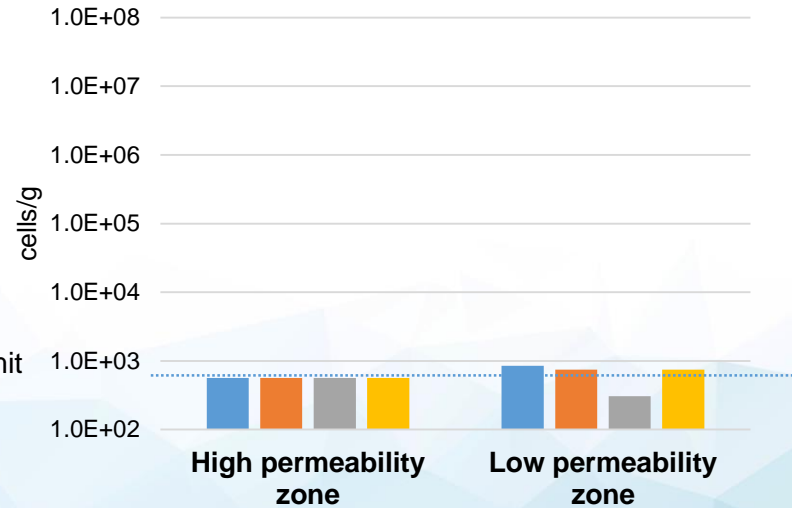
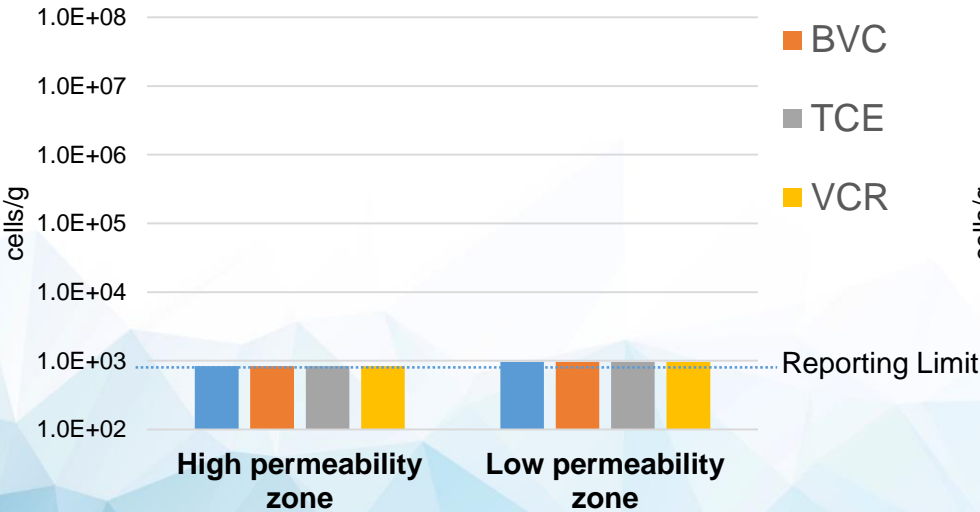


# Expt 3: qPCR Data - Soil

No detectable DHC on soil in tanks that were not bioaugmented

1: Control

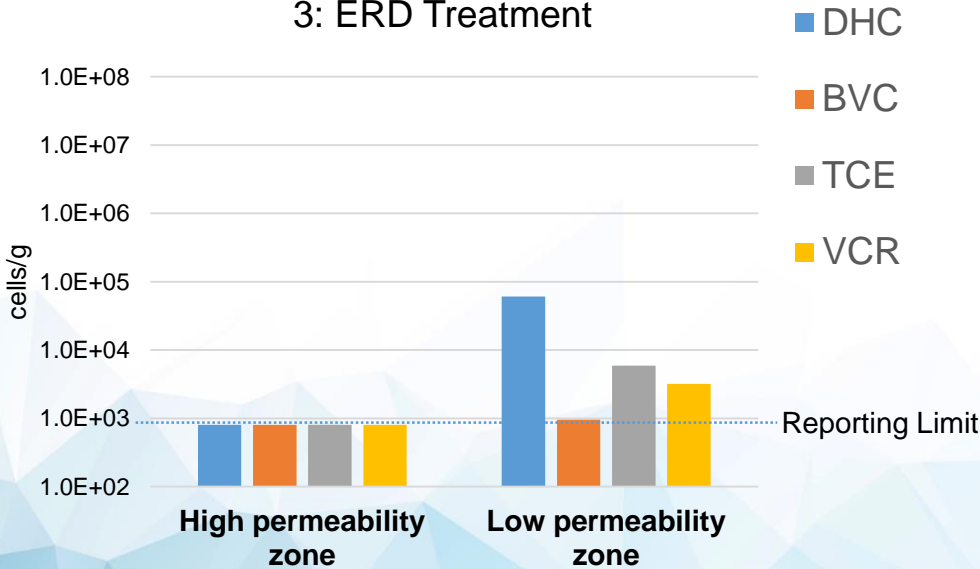
2: PlumeStop only



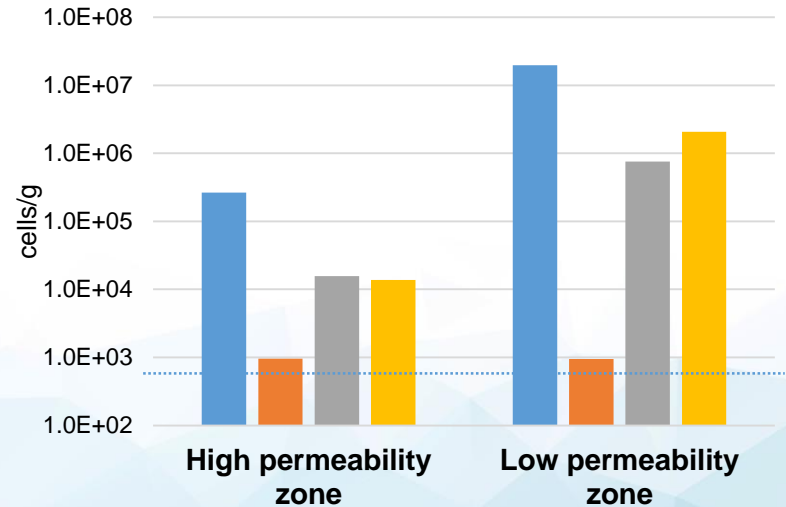
# Expt 3: qPCR Data - Soil

Over 2 orders of magnitude  
DHC population increases  
in presence of PlumeStop

### 3: ERD Treatment



### 4: Biotic PlumeStop



...Even in the high permeability zone!

# Expt 3: Dual Porosity Tank Study

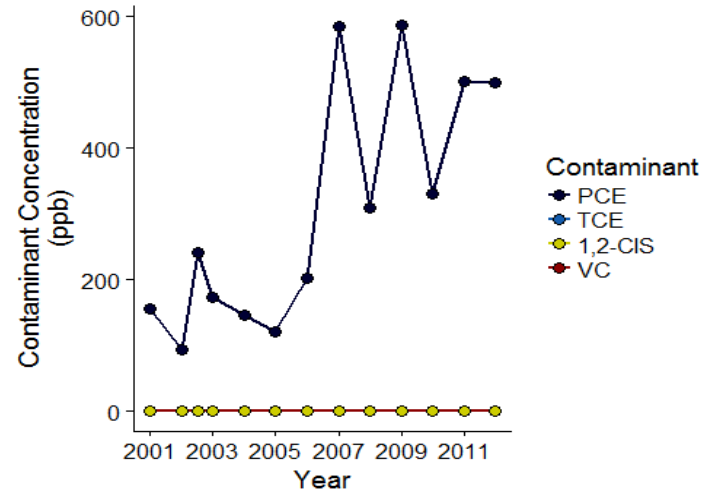
## Conclusions

### Demonstrated:

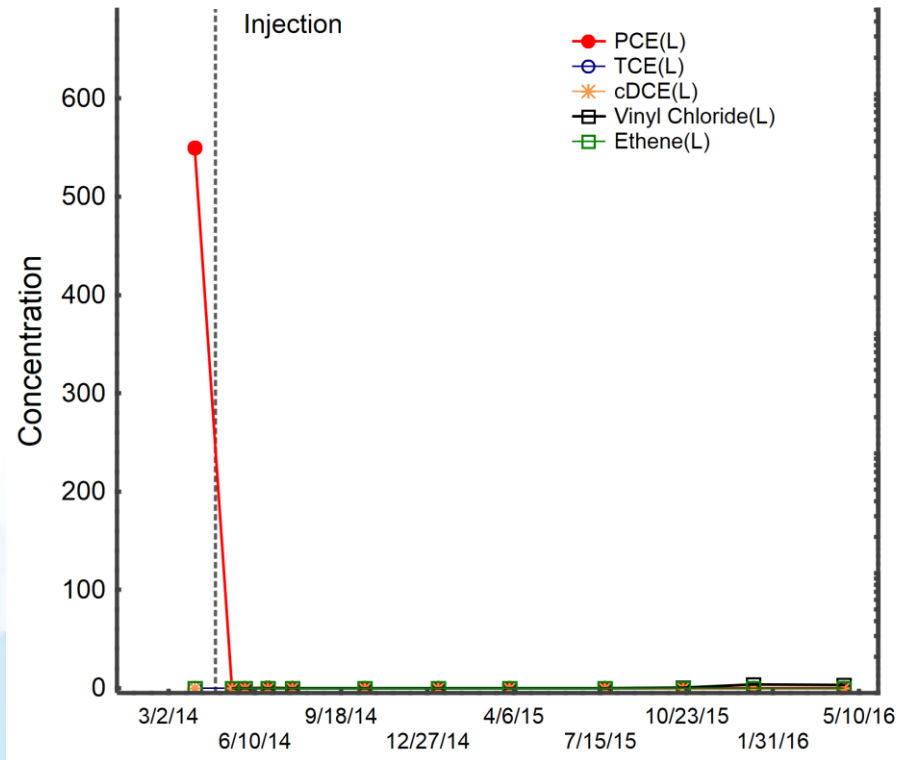
- Improved containment of back diffusing contaminants over ERD treatments alone
- Minimal daughter products
- Orders of magnitude increase in *Dehalococcoides* + functional genes populations with PlumeStop

# Case Study - Introduction

- No Daughter Products (since 2001)
- No Detected Dehalogenating Bacteria
- No Attenuation
- Sandy Aquifer
  - 10 m/yr GW Flow

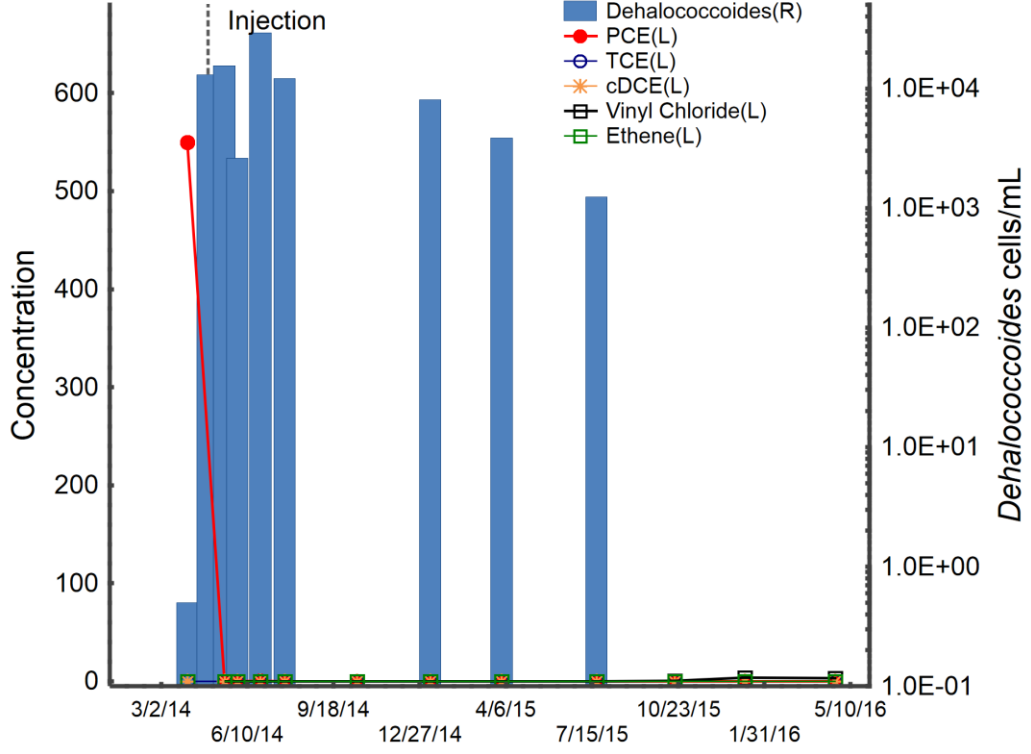


# Contaminant Concentrations

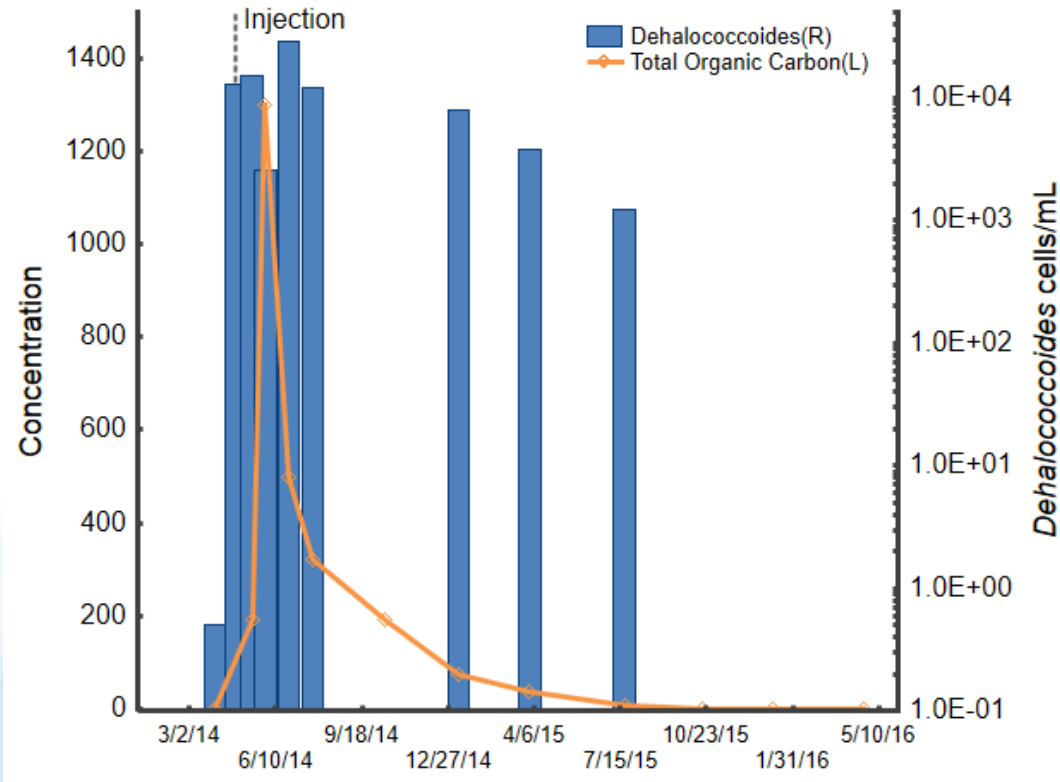




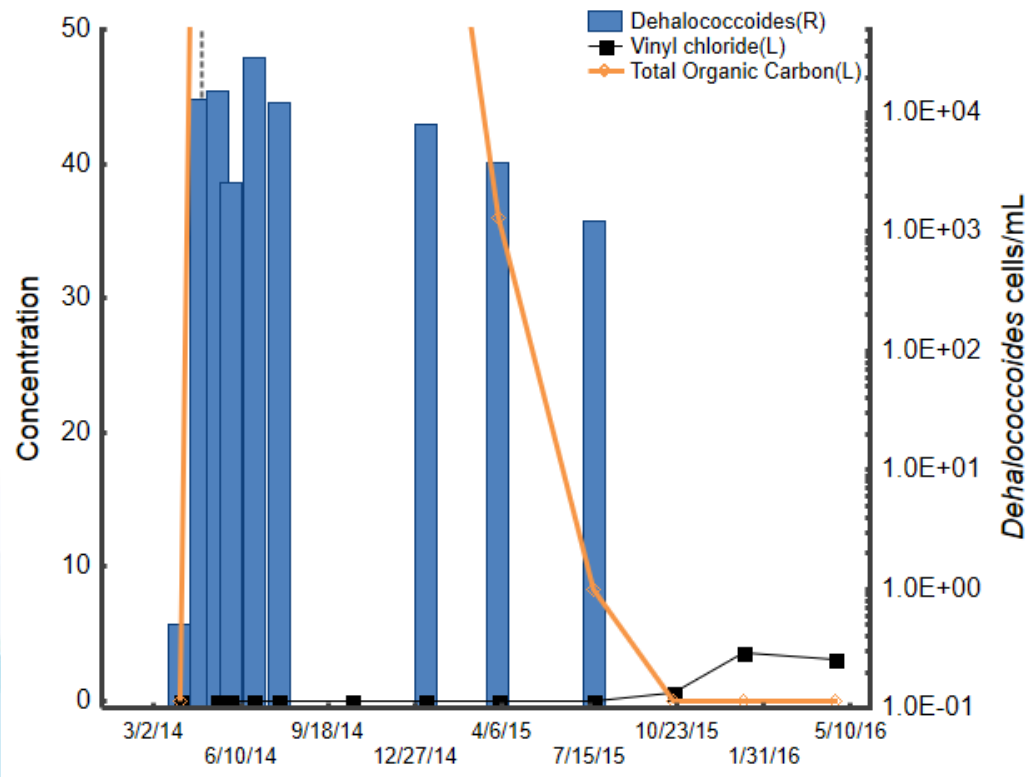
# Dehalococcoides



# Electron Donor Concentration



# Daughter Products

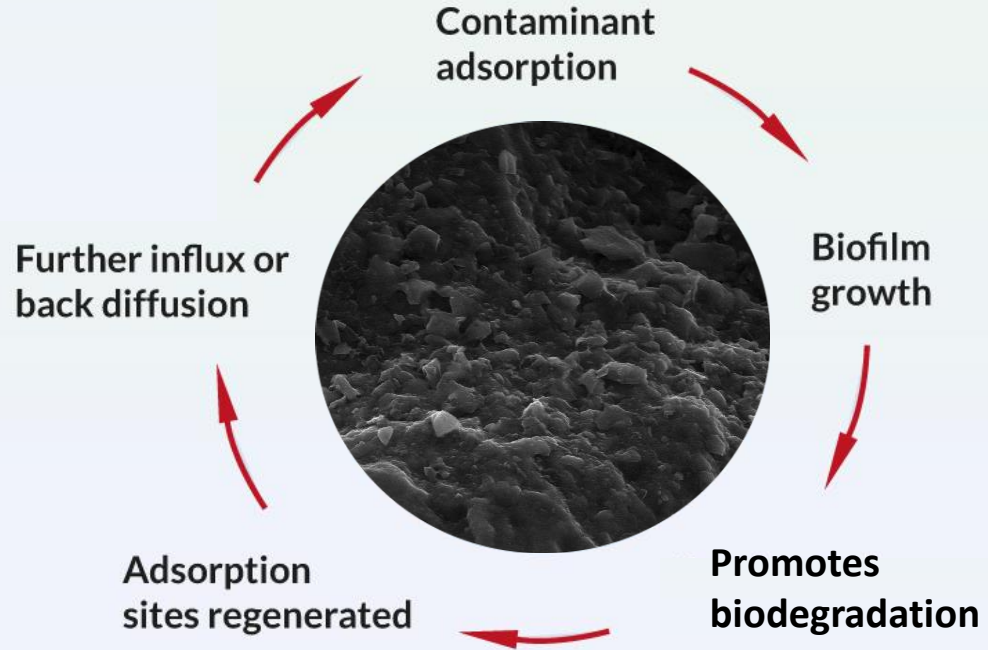


# Case Study - Conclusions

- Effective Adsorption and Biodegradation
  - *Dehalococcoides* is an Obligate Halorespiring Microbe
  - *Dehalococcoides* Decreased when e<sup>-</sup> Donor was Consumed
  - Daughter Products Detected after Low Concentration of *Dehalococcoides*
- Microbial Monitoring Critical after PlumeStop®
  - Daughter Products Not Detected during Biodegradation
  - Daughters Only Detected after Biodegradation Slowed

# Summary

- Monitoring biodegradation with a PlumeStop application requires the use of multiple indicators
- Laboratory experiments confirm the bioavailability of adsorbed contaminants



# Ongoing Research

- Sorption + biodegradation is a continued focus of REGENESIS R&D
- Improved predictions & designs
- Goal: Success at your site
- Collaborations
- Internal research efforts



# Thank you!

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