# The In Situ Treatment of TCE and PFAS-Impacted Groundwater Using Anaerobic Bioremediation, Polylactate Ester and Colloidal Activated Carbon

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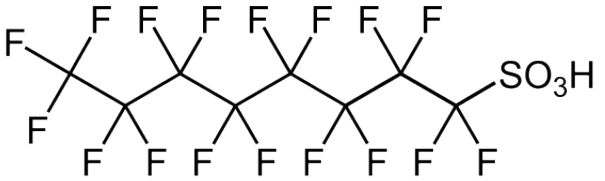
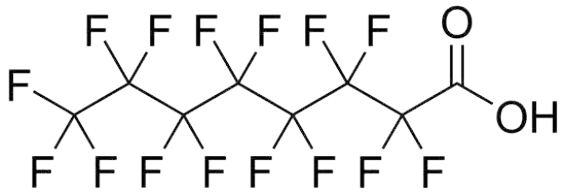
InSitu Remediation Services

Battelle 2023

# Background

- Per & Polyfluoroalkyl Substances (PFAS)
- Emerging Compounds of Concern
  - Perfluorooctane Sulfonate (PFOS)
  - Perfluorooctanic acid (PFOA)
- Thousands of compounds
- Carbon-fluoride bond strong
- Shown to bioaccumulate
- Analytical challenges
- Health Advisory Levels 10s of ng/L (ppt)
- Fate & transport not well understood

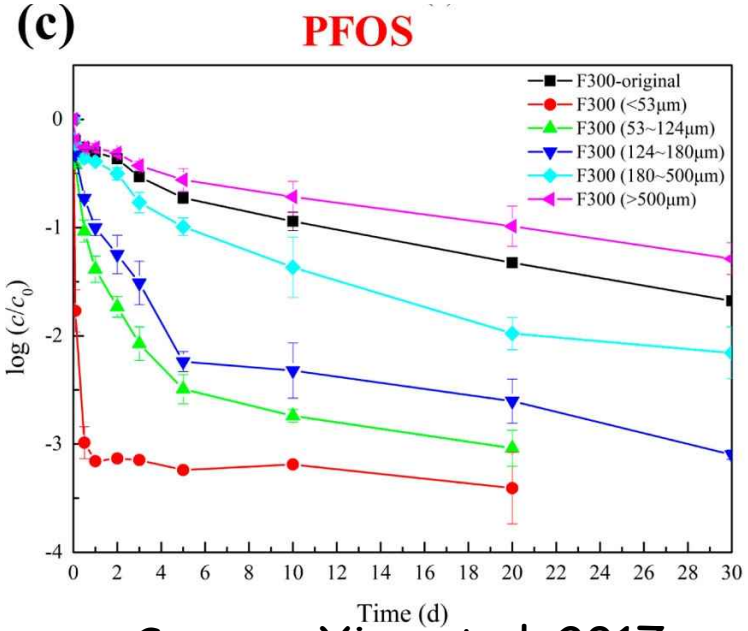


# Background

In Situ Current Approaches

- Proven
  - Colloidal activated carbon
- Development
  - Ion exchange resin
  - Biochar
  - Powdered activated carbon
  - Sonochemical
  - Foam Fractionization
  - Oxidants




Source: Xiao et al.,2017

# Study Site

- Industrial Facility - China
  - Comingled
    - TCE up to 985 ug/L
    - 1,2 cis DCE up to 258 ug/L
    - Vinyl chloride up to 54 ug/L
  - 5 PFAS detected
    - PFBA up to 795 ng/L
    - PFHxA up to 3,240 ng/L
    - PFOA up to 420 ng/L
    - PFPeA up to 12,800 ng/L
    - PFOS up to 2,140 ng/L
  - Geology
    - Silty sand
  - Hydrogeology
    - Unconfined aquifer
    - Water table ~3.2 m below surface
    - K: $5 \times 10^{-6}$ to $6.3 \times 10^{-4}$ m/sec
    - Groundwater velocity ~ 9 m/year
  - Geochemistry
    - Iron & sulfate reducing

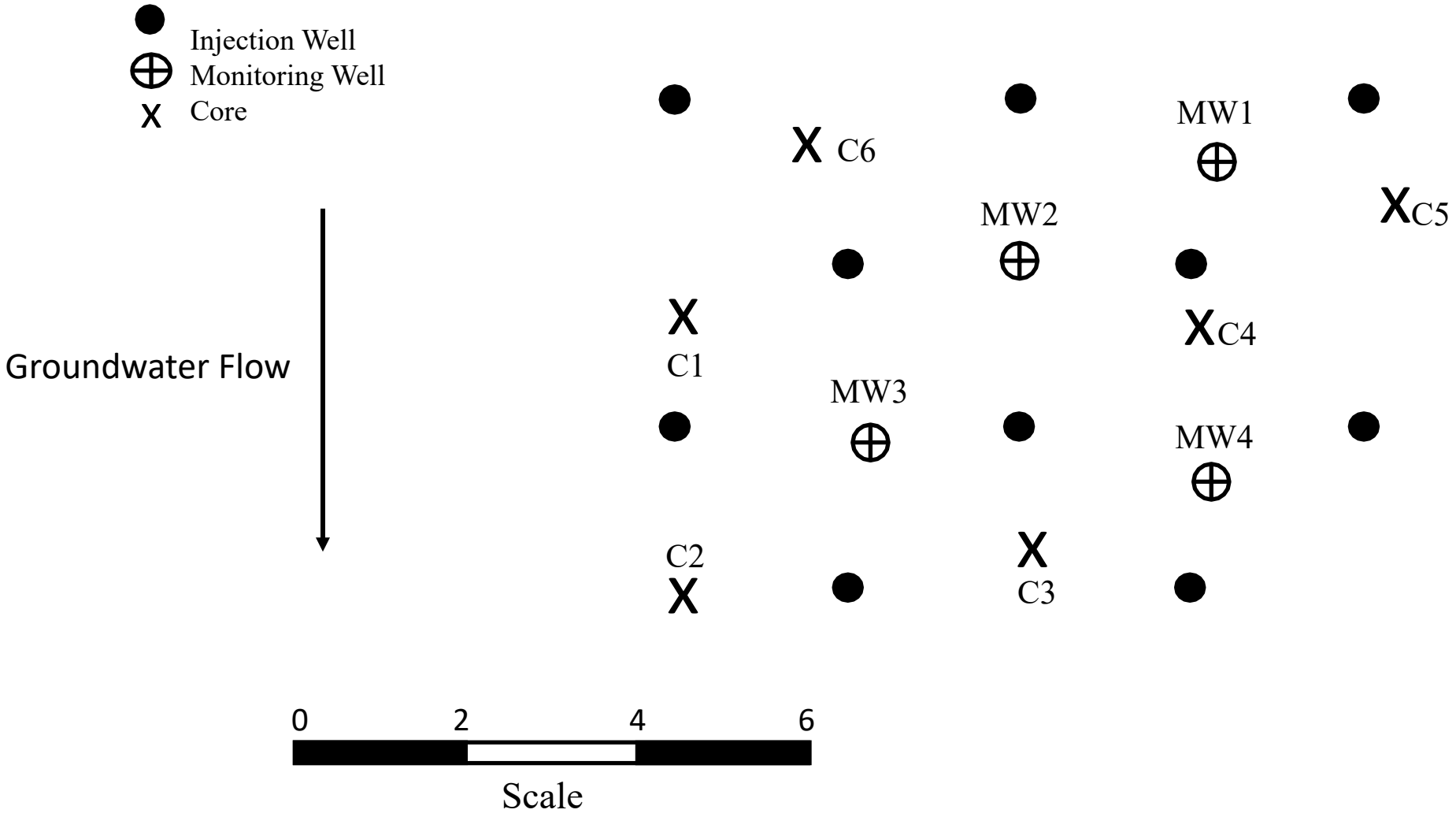
# Study Site - Monitoring

- Groundwater Monitoring
  - Combination of 2" wells (3)
  - cVOCs, cVOCs, inorganics, general chemistry and PFAS
  - Microbiological analyses
  - Groundwater
    - Pre-injection (2 events), Days 122, 248, 362, 547, & 724
- Aquifer Solids
  - Continuous cores for TOC, pre- & post injection
  - Distribution and "radius" of detection
- Aquifer Testing
  - Cores for flexible wall permeameter tests

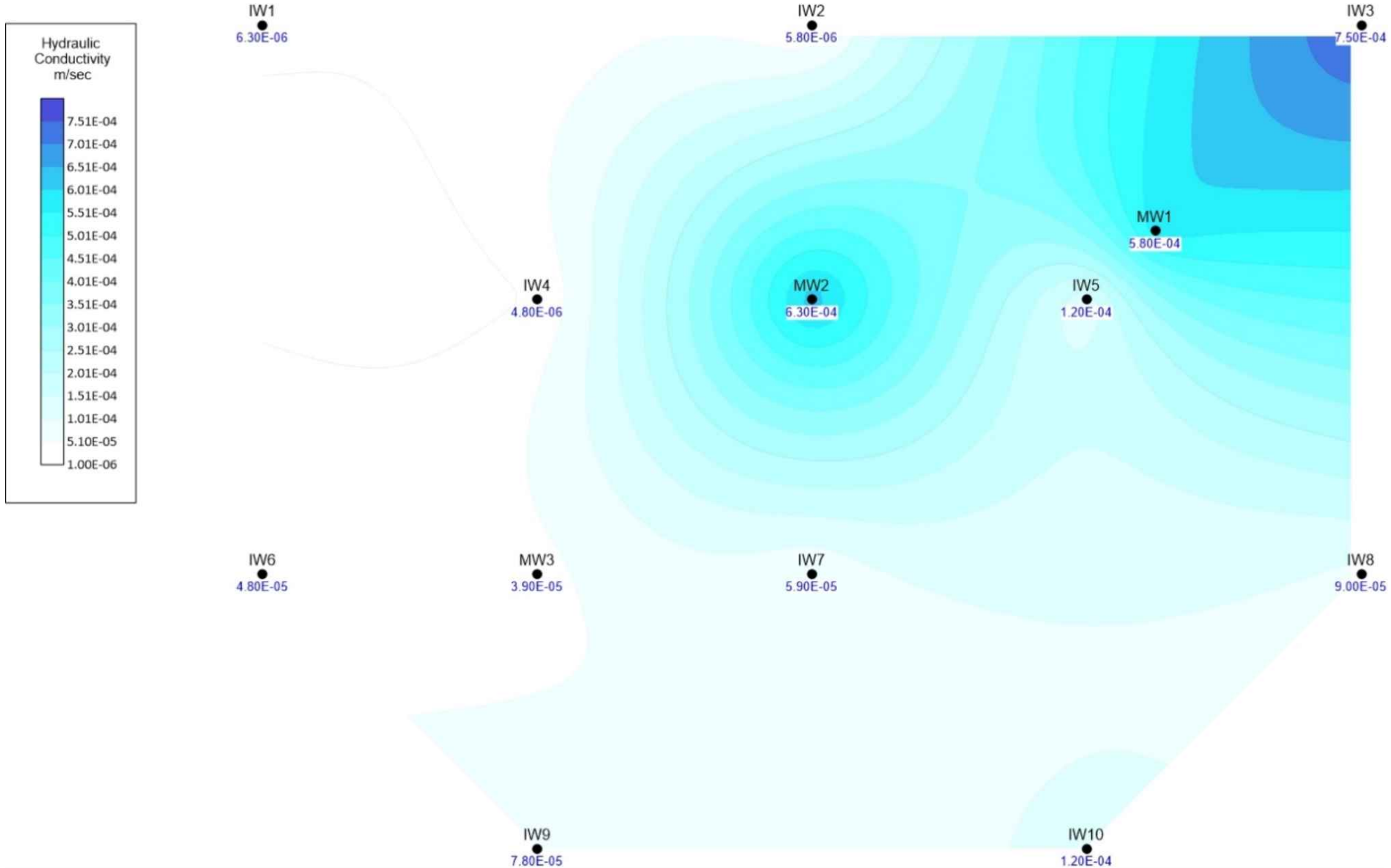
# Study Site Injection Plan

- Test Area:
  - 100 $m^2$ area
  - Targeting shallow plume
- Reagents
  - Colloidal activated carbon (PlumeStop™)
  - Micro SZVI ™
  - Hydrogen Releasing Compound ™
- Injection
  - Grid – 10 ft spacing
  - 10 injection wells (2" PVC)
  - 30 slot opening
  - 10 ft screens

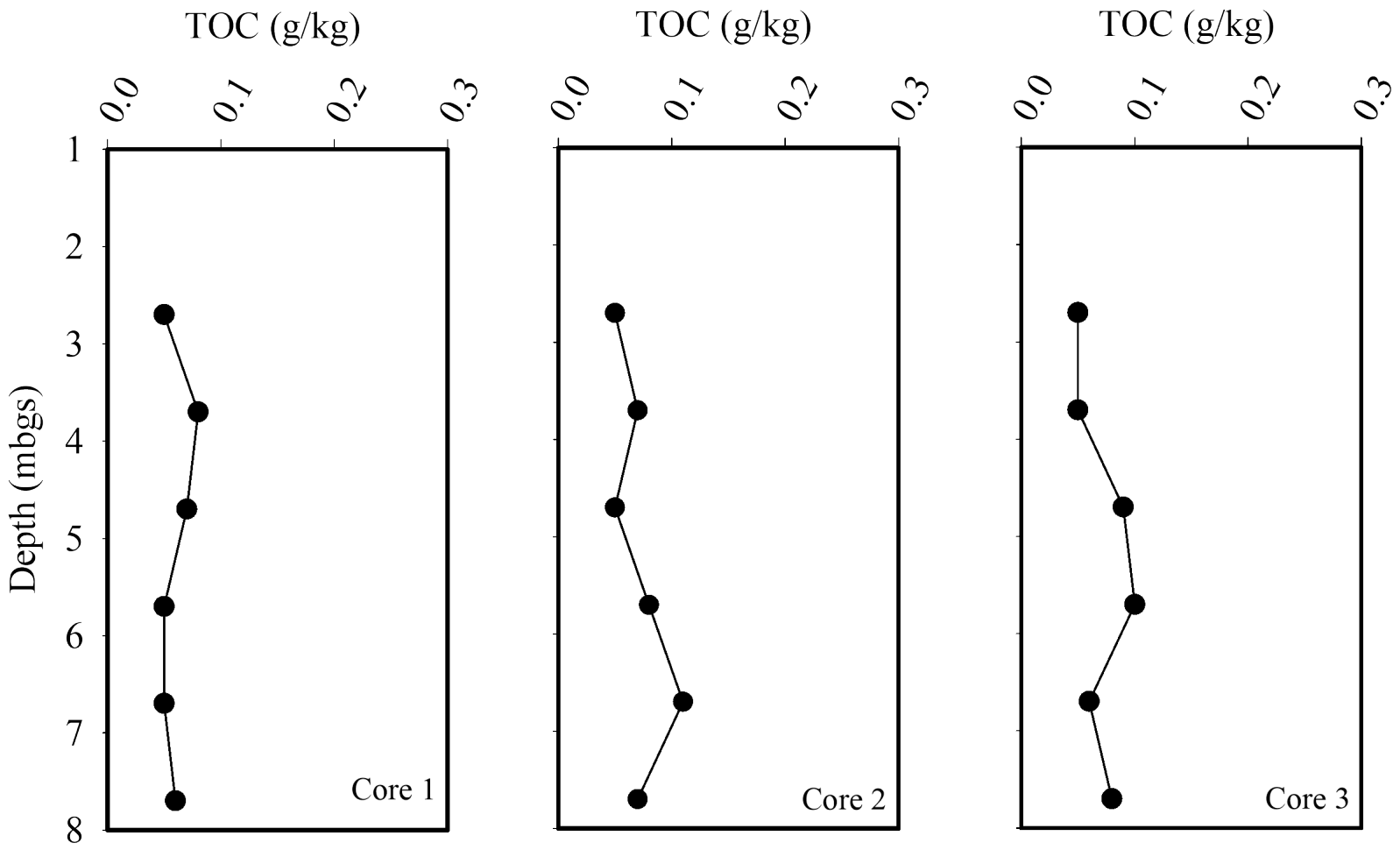
# Study Site Layout



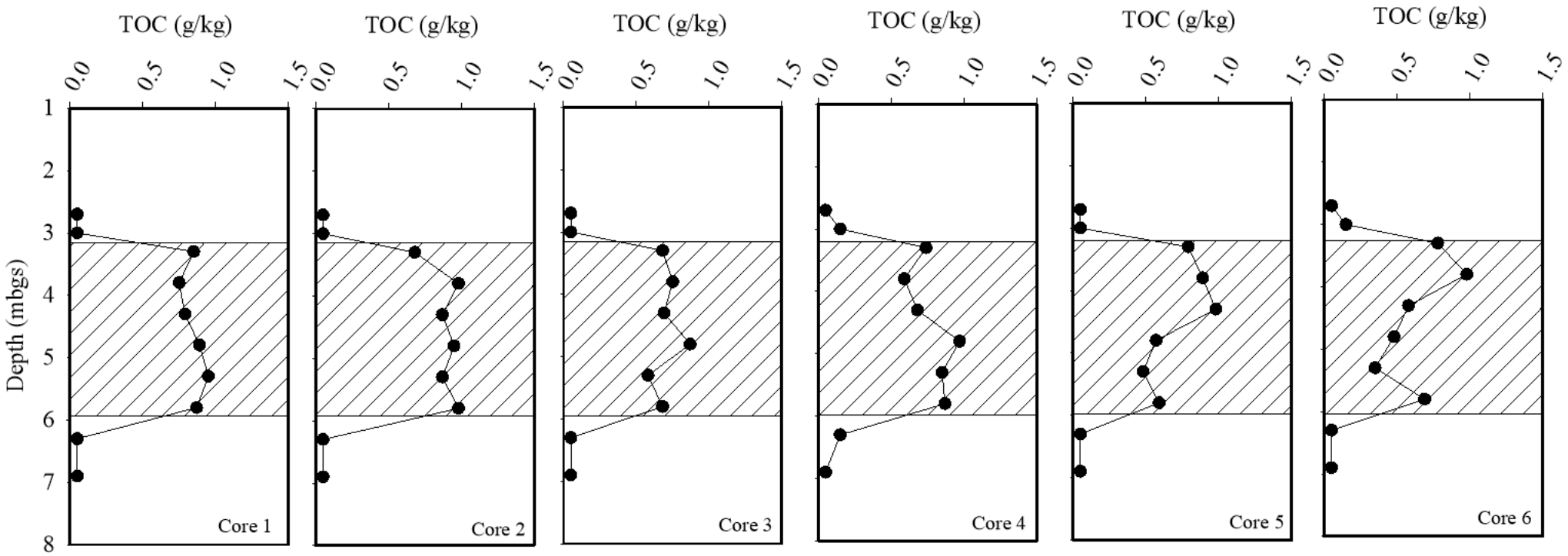
# Study Site Horizontal K



# Study Site Pre-Injection TOC

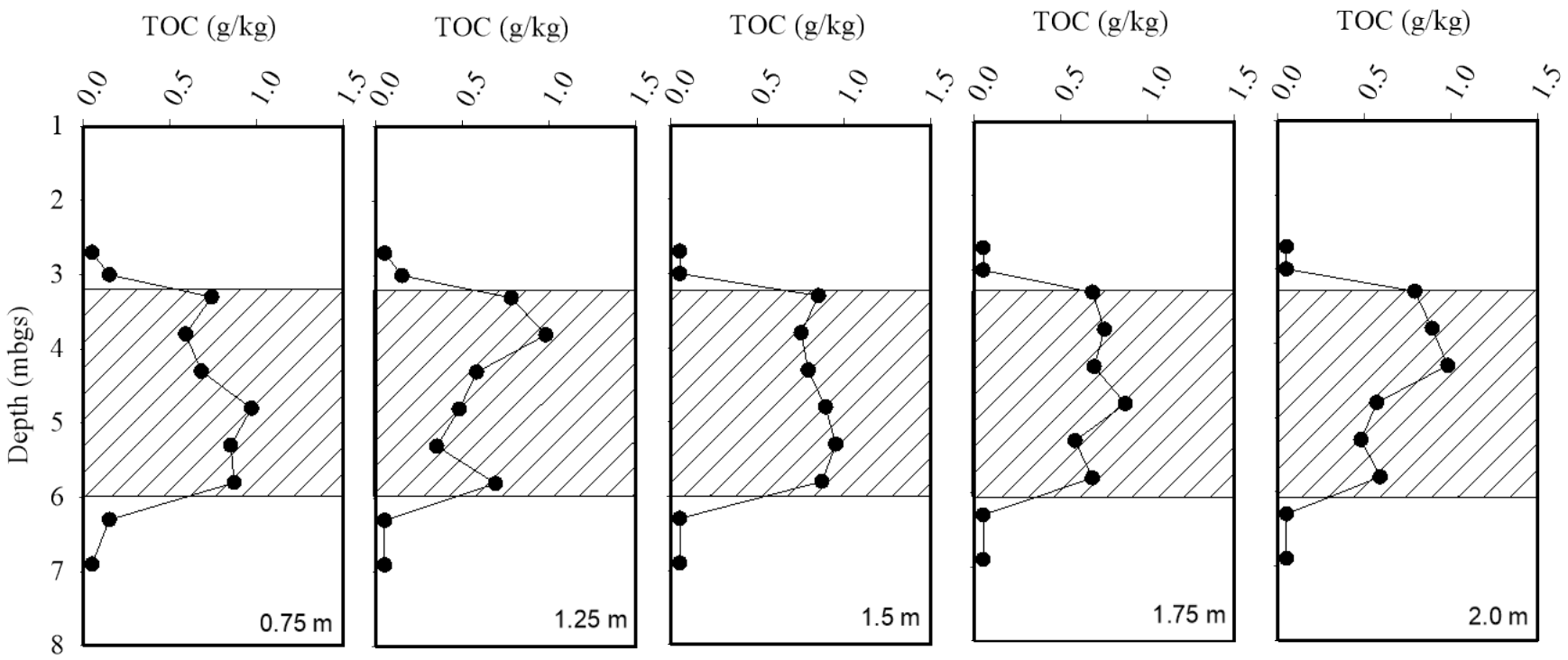


# Study Site Post Injection TOC




Target Injection Zone

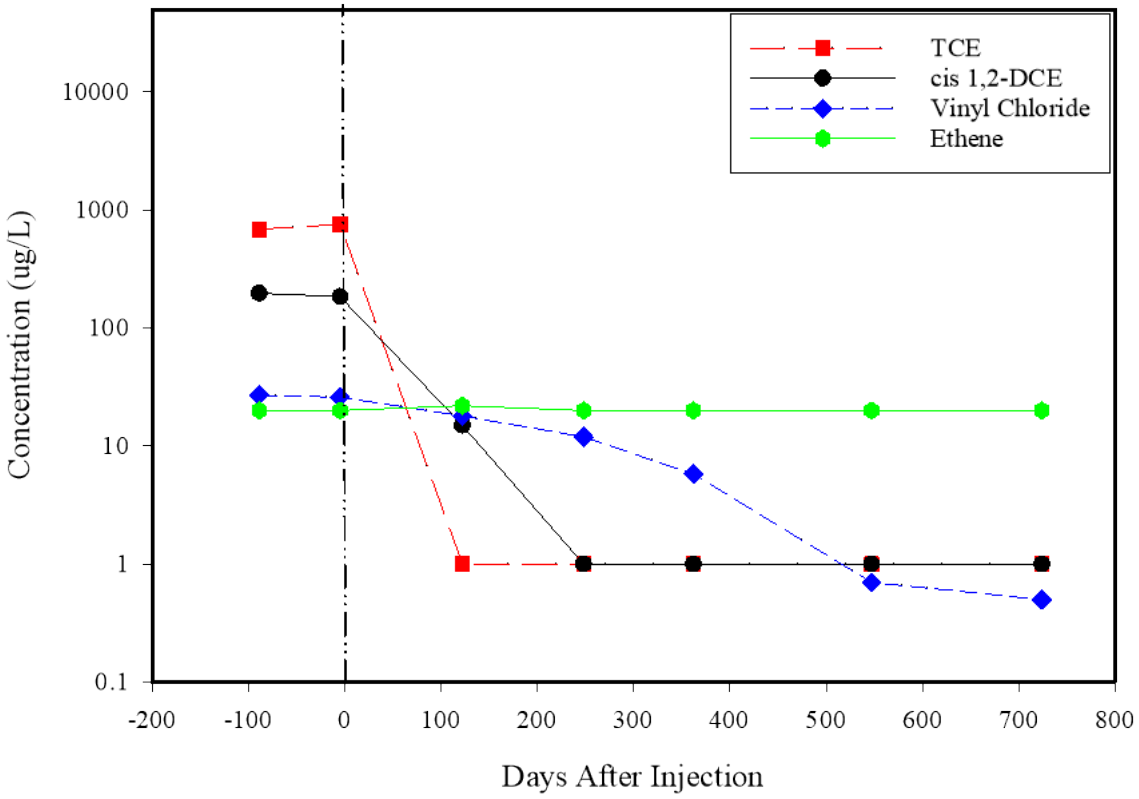
# Study Site Post Injection TOC With Distance



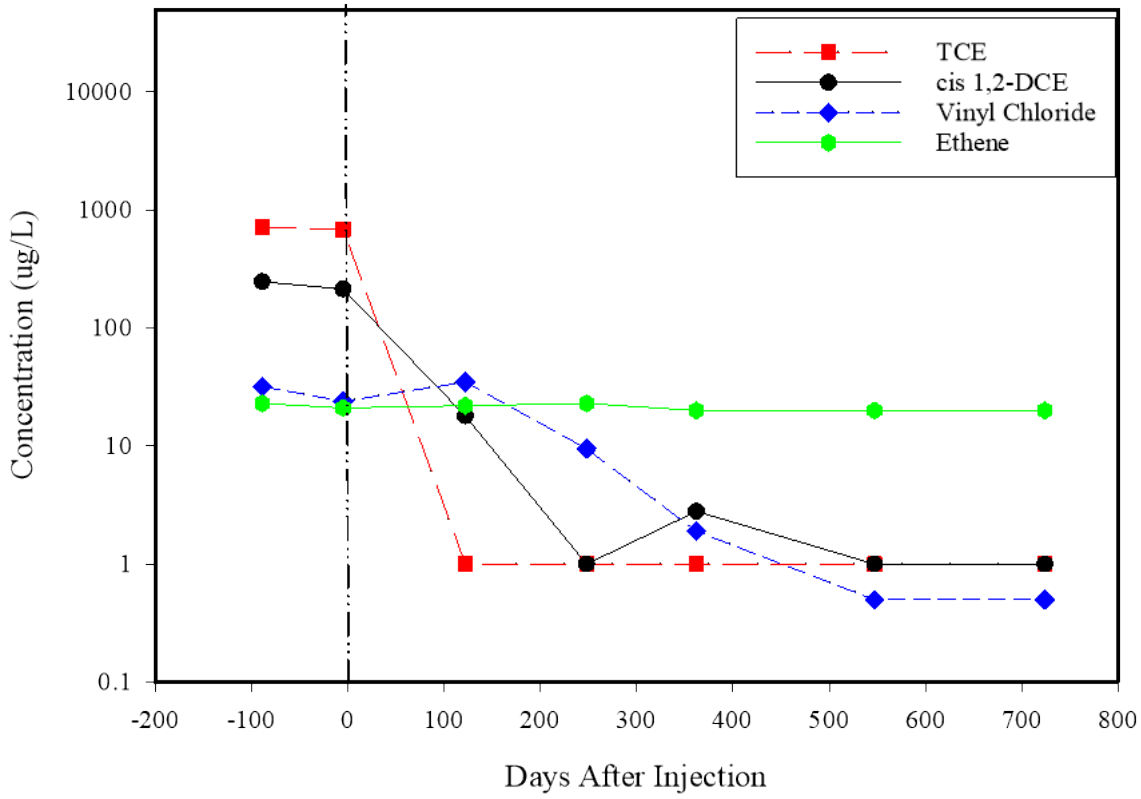

Target Injection Zone

# Study Site Ethene Treatment with Time

MW2

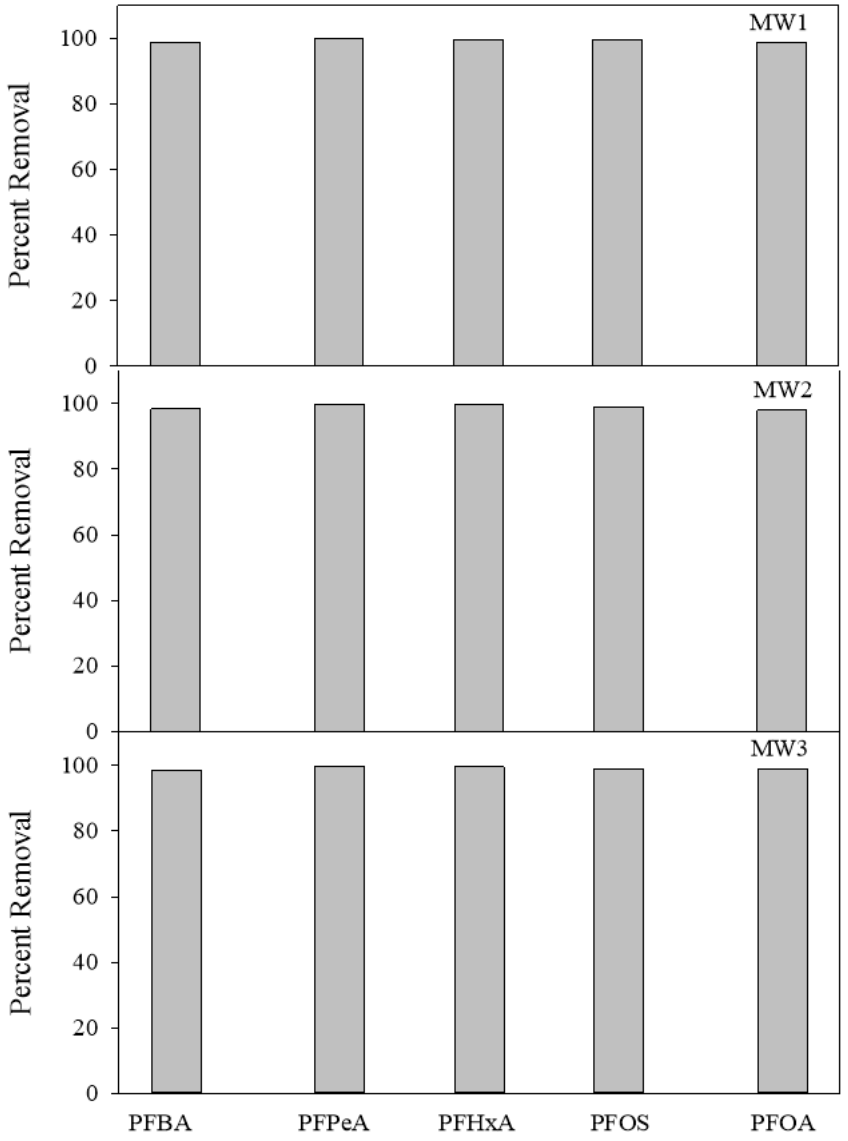



MW3



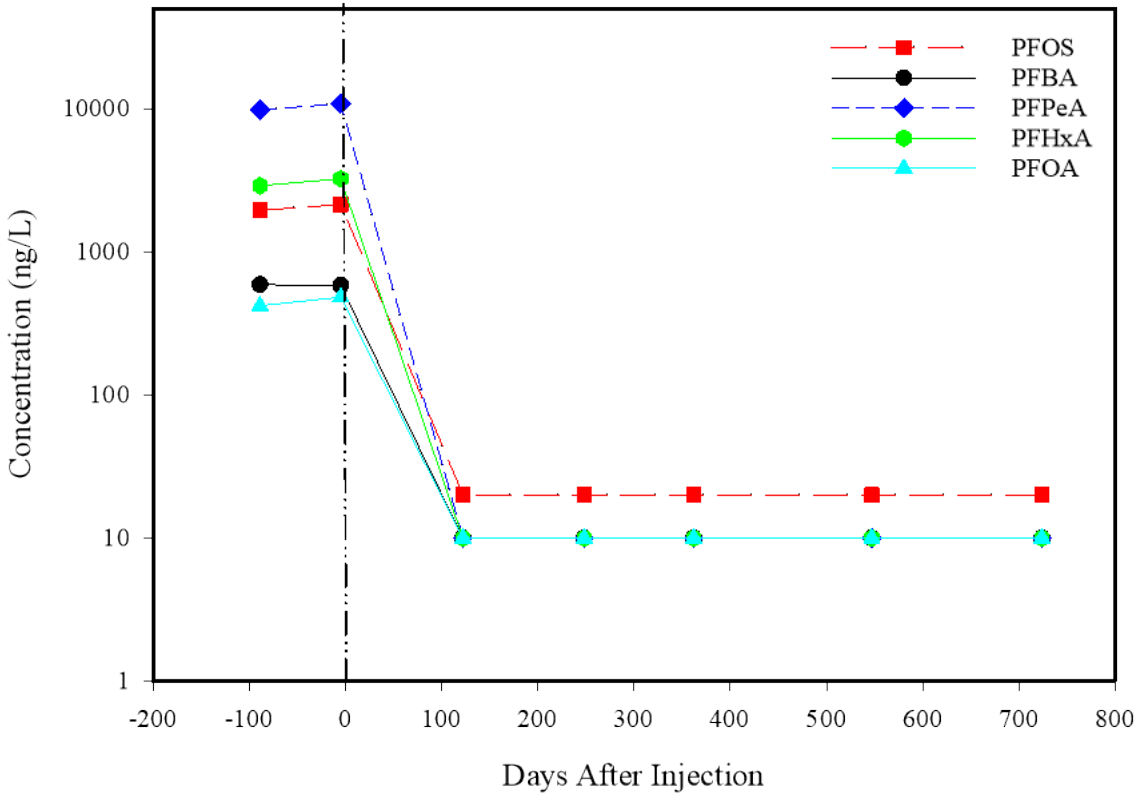
# Study Site Ethene Removal Percent

- Greater than 99% removal of all PFAS analyzed within 3 months of injection
- Removal percentage remained greater than 99% for the 2-year monitoring period
- Low C chained PFAS showed "lowest" removal

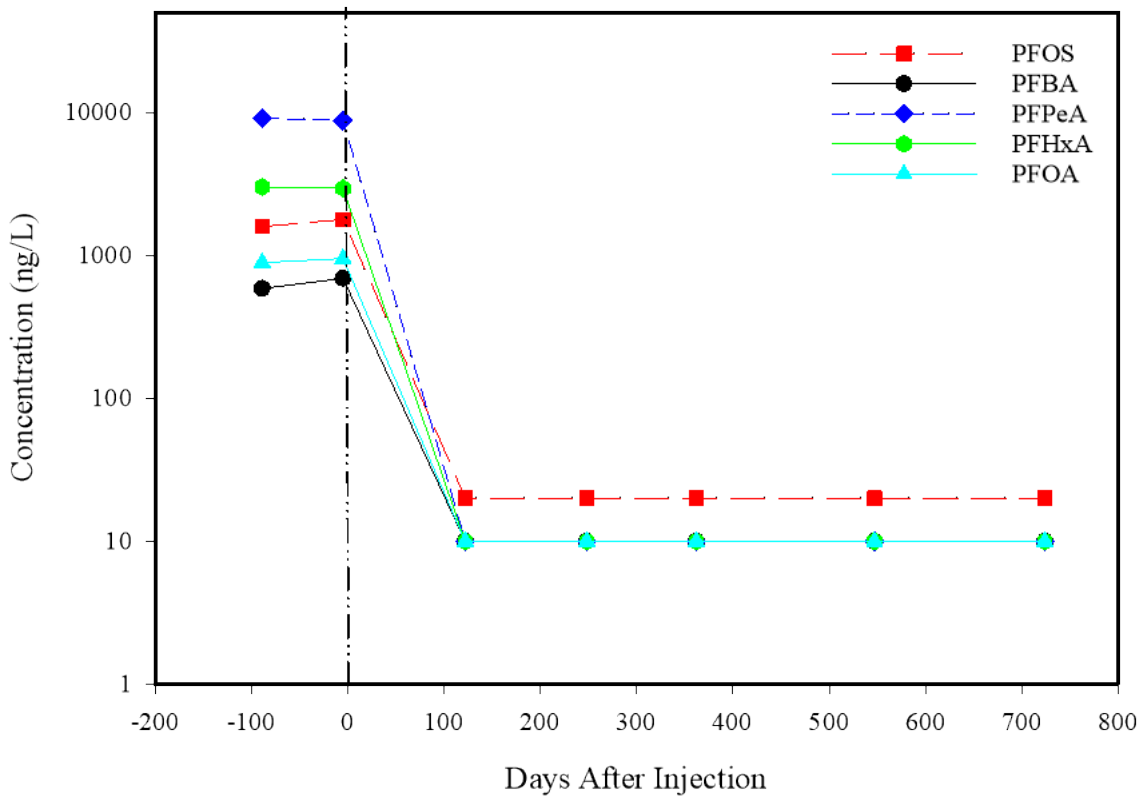


# Study Site PFAS Treatment with Time

MW2



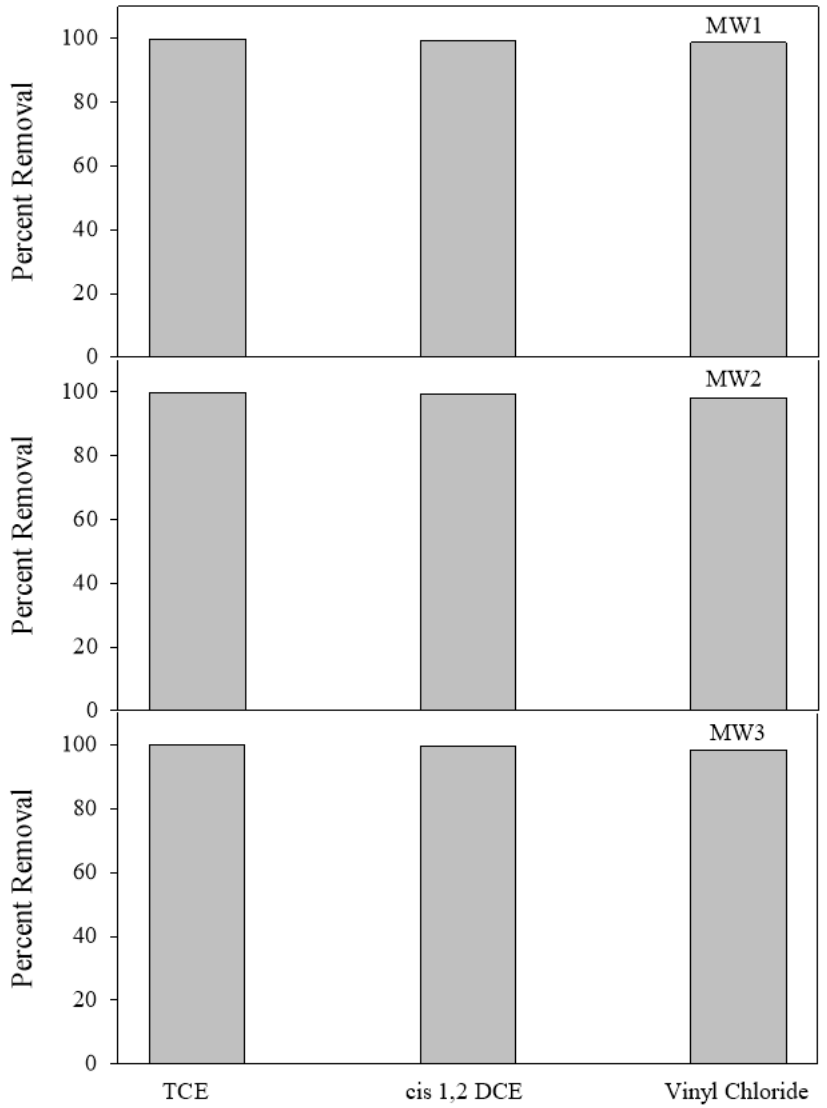

MW3



# Study Site PFAS Removal Percent

- Greater than 99% removal of TCE and cis 1,2 DCE within 3 months of injection and maintained for the 2-year monitoring period.

- Vinyl chloride concentrations remained below 2 µg/L for monitoring period.



# Study Site Summary

- Treatment with 3 months of application
  - Comingled with TCE, 1,2 DCE and vinyl chloride
  - Strong reduction conditions, dichlorination of TCE noted, treatment for greater than 2 years
  - Removal of PFAS to below 10 ng/L for greater than 2 years
  - Greater than 99% of samples within target injection zone had CAC present

RESEARCH ARTICLE

WILEY

The in situ treatment of TCE and PFAS in groundwater within a silty sand aquifer

Rick McGregor | Ye Zhao

Abstract

Chlorinated ethenes such as trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride along with per- and polyfluoroalkyl substances (PFAS) have been identified as chemicals of concern in groundwater, with many of the compounds being confirmed as being carcinogens or suspected carcinogens. While there are a variety of demonstrated in situ technologies for the treatment of chlorinated ethenes, there are limited technologies available to treat PFAS in groundwater. At a former industrial site shallow groundwater was impacted with TCE, cis-1,2-DCE, and vinyl chloride at concentrations up to 985, 258, and 54 µg/L, respectively. The groundwater also contained maximum concentrations of the following PFAS: 12,800 ng/L of perfluoropentanoic acid, 3210 ng/L of perfluorohexanoic acid, 795 ng/L of perfluorobutanoic acid, 950 ng/L of perfluorooctanoic acid, and 2140 ng/L of perfluorooctanesulfonic acid. Using a combination of adsorption, biotic, and abiotic degradation in situ remedial approaches, the chemicals of concern were targeted for removal from the groundwater with adsorption being utilized for PFAS whereas adsorption, chemical reduction, and anaerobic biodegradation were used for the chlorinated ethenes. Sampling of the groundwater over a 24-month period indicated that the detected PFAS were treated to either their detection, or below the analytical detection limit over the monitoring period. Postinjection results for TCE, cis-1,2-DCE, and vinyl chloride indicated that the concentrations of the three compounds decreased by an order of magnitude within 4 months of injection, with TCE decreasing to below the analytical detection limit over the 24-month monitoring period. Cis-1,2-DCE, and vinyl chloride concentrations decreased by over 99% within 8 months of injections, remaining at or below these concentrations during the 24-month monitoring period. Analyses of Dehalococcoides, ethene, and acetylene over time suggest that microbiological and reductive dechlorination were occurring in conjunction with adsorption to attenuate the chlorinated ethenes and PFAS within the aquifer. Analysis of soil cores collected pre- and post-injection, indicated that the distribution of the colloidal activated carbon was influenced by small scale heterogeneities within the aquifer. However, all aquifer samples collected within the targeted injection zone contained total organic carbon at concentrations at least one order of magnitude greater than the preinjection total organic carbon concentrations.

KEYWORDS

colloidal activated carbon, in situ, PFAS, synthetic dye, trichloroethene

# Thank You

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