Results from Six Insitu Pilot Studies for the Treatment of PFAS-Impacted Groundwater

R. McGregor

InSitu Remediation Services

rickm@irsl.ca

September 2020

PFAS Remediation

Current Approaches

- Ex Situ based
- Pump & Treat (current)
  - Granular activated carbon
  - Ion exchange resin
  - Concentrated waste generated
  - Point of Use vs Plume Management
- Pump & Treat (developing)
  - Thermal
  - Plasma

Pilot Scale Site

- Various laboratory and limited field studies
  - Laboratory tests by others suggested possible application of various reagents
    - Sorptives: activated carbon, biochar, ion exchange resin
    - Oxidants: persulfate (activated and unactivated), hydrogen peroxide
    - Reductants: ZVI, bimetals
    - Thermal: STAR
  - Evaluate various parameters
    - Treatment over time
    - Distribution of reagents
    - Effect of heterogeneity on reagents
    - “Lifespans” of reagents
    - Effect of pre-existing sand packs

Pilot Scale Site

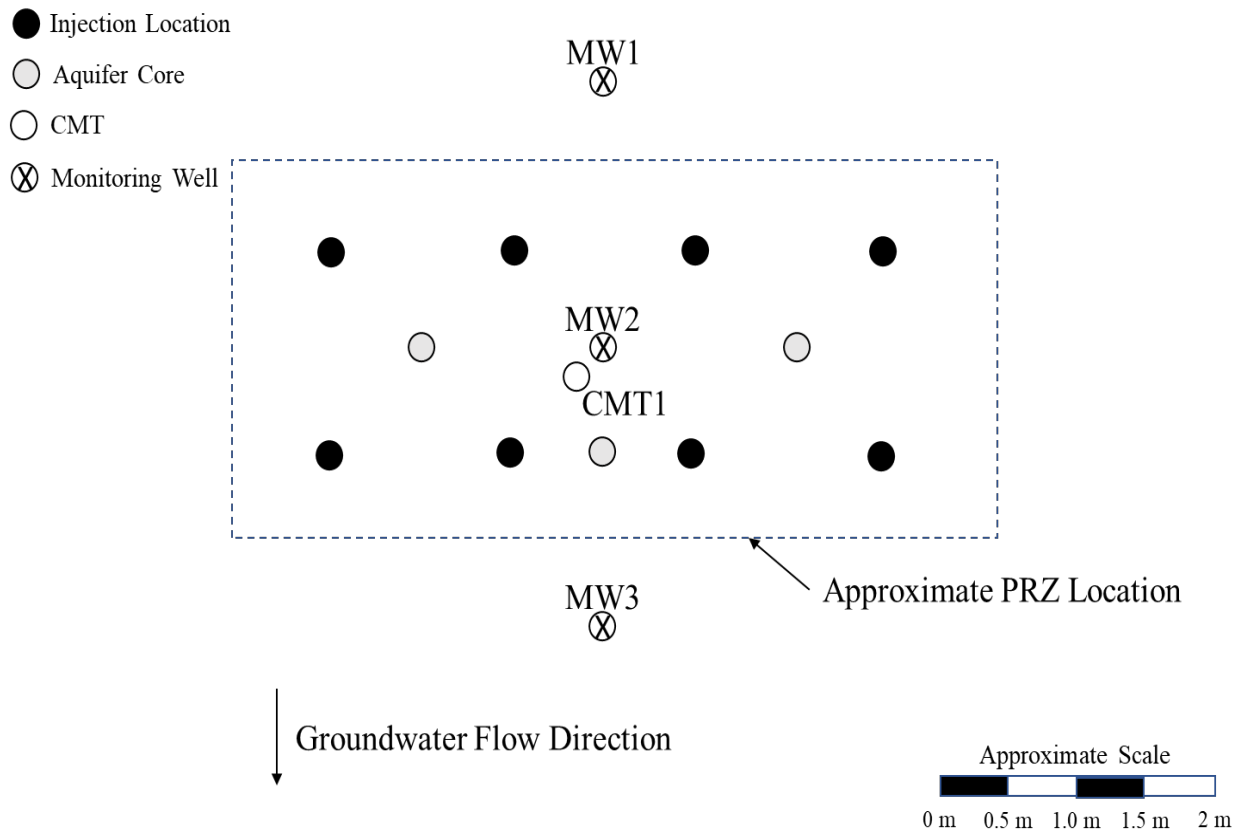
- Large Petroleum Hydrocarbon Facility
  - Large BTEX plume with PFAS present
    - BTEX ~ 680 ug/L
    - GRO ~ 3,500 ug/L
  - 22 PFAS analyzed, 6 detected
    - PFBA up to 6,200 ng/L
    - PFHxA up to 16,100 ng/L
    - PFHpA up to 6,080 ng/L
    - PFNA up to 140 ng/L
    - PFOA up to 450 ng/L
    - PFPeA up to 24,000 ng/L

Pilot Scale Site

- Geology
  - Fine-grained sand
  - Zone of medium grained sand (~1 inch thick)
- Hydrogeology
  - Unconfined aquifer
  - Water table ~17 ft below surface
  - Mean K 5 x 10^{-5} m/sec
  - Groundwater velocity ~ 200 ft/year
- Geochemistry
  - Iron & sulfate reducing

Pilot Scale Site

- Six permeable reactive barriers/zones created using:
  - Colloidal activated carbon
  - Powdered activated carbon
  - Biochar
  - Ion exchange resin
  - Sodium persulfate- unactivated
  - Hydrogen peroxide
- Injection
  - Grid – 5 foot spacing
  - Direct push technology
  - Multiple vertical intervals



Pilot Scale Site

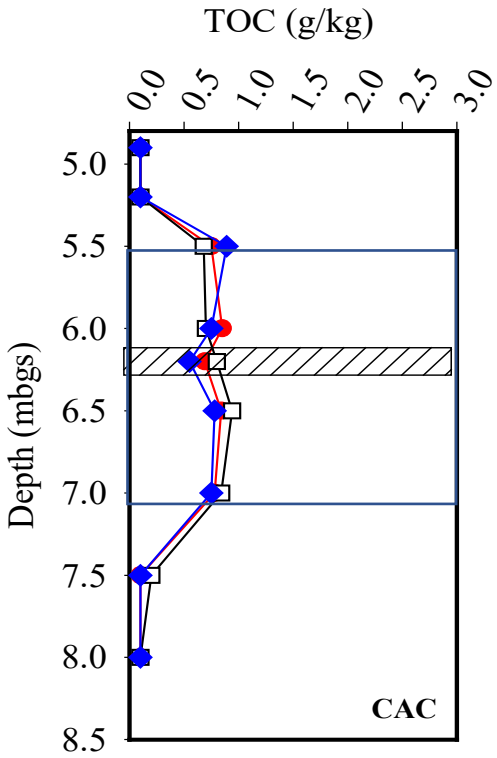
- Groundwater Monitoring
  - Combination of 2” and CMT wells
  - BTEX, GRO, inorganics, general chemistry and PFAS
  - Pre-injection (2 events), Days 92, 184, 278, 366 & 549
- Aquifer Solids
  - Continuous cores for TOC, persulfate and hydrogen peroxide
  - Direct push technology
- Aquifer Testing
  - Pre- and post-injection
  - Cores for flexible wall permeameter tests

Pilot Scale Site

- Injection Program
  - Each cell 40 square meters
  - Eight injection points
  - Direct push technology
  - Multi vertical intervals (~ 2 ft)
  - All reagents injected at 10 weight percent
  - Pressures ranged from 20 to 250 psi
    - PAC, Biochar, IER greater than 185 psi
    - CAC, S_2O_8, H_2O_2 less than 35 psi

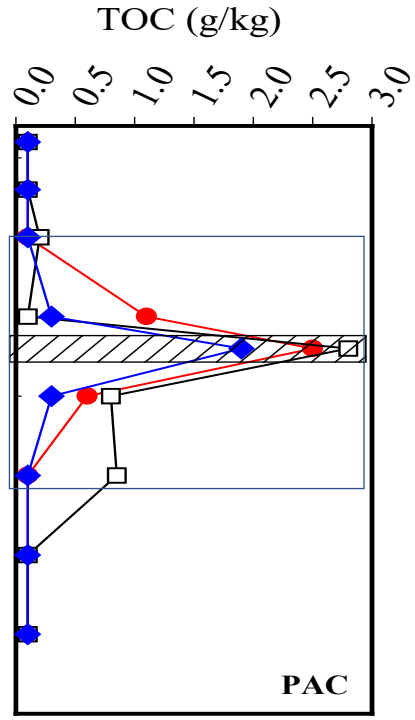
Pilot Scale Site

- Distribution of reagents
  - CAC
    - Inside Target Zone - 0.77 g/kg
    - Outside Target Zone - 0.11 g/kg
    - Pre–Injection - 0.006 g/kg
    - 100 % of samples within Target Zone had detectable TOC
    - 33 % of samples outside of Target Zone had detectable TOC



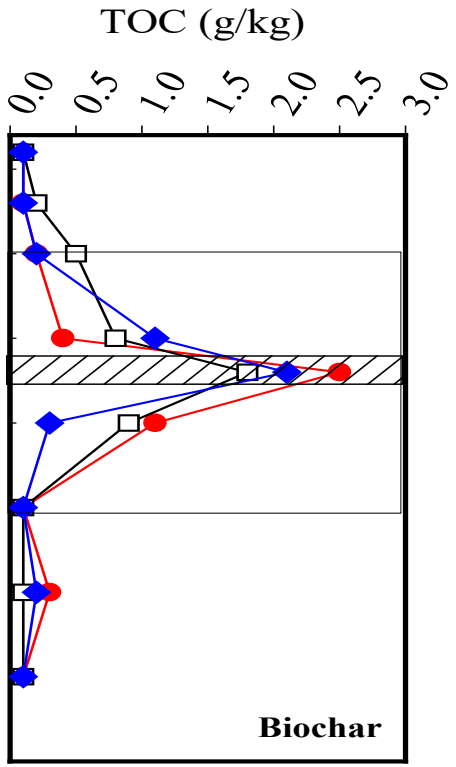
Pilot Scale Site

- Distribution of reagents
  - PAC
    - Inside Target Zone - 0.79 g/kg
    - Sand seam – 2.40 g/kg
    - Outside Target Zone - 0.10 g/kg
    - Pre–Injection - 0.006 g/kg
    - 67 % of samples within Target Zone had detectable TOC
    - 17 % of samples outside of Target Zone had detectable TOC



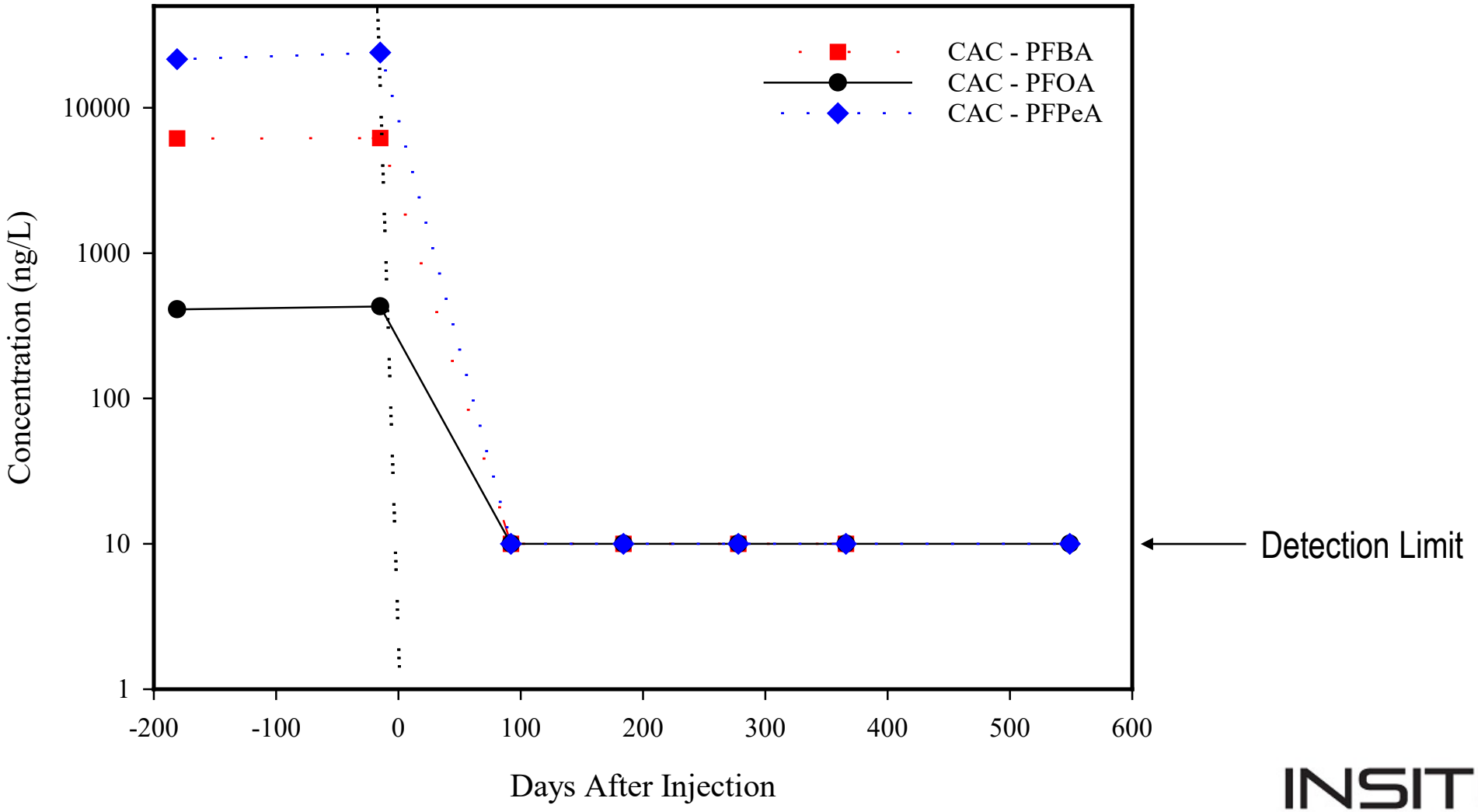
Pilot Scale Site

- Distribution of reagents
  - Biochar
    - Inside Target Zone - 0.81 g/kg
    - Sand seam – 2.13 g/kg
    - Outside Target Zone - 0.13 g/kg
    - Pre–Injection - 0.006 g/kg
    - 75 % of samples within Target Zone had detectable TOC
    - 50 % of samples outside of Target Zone had detectable TOC



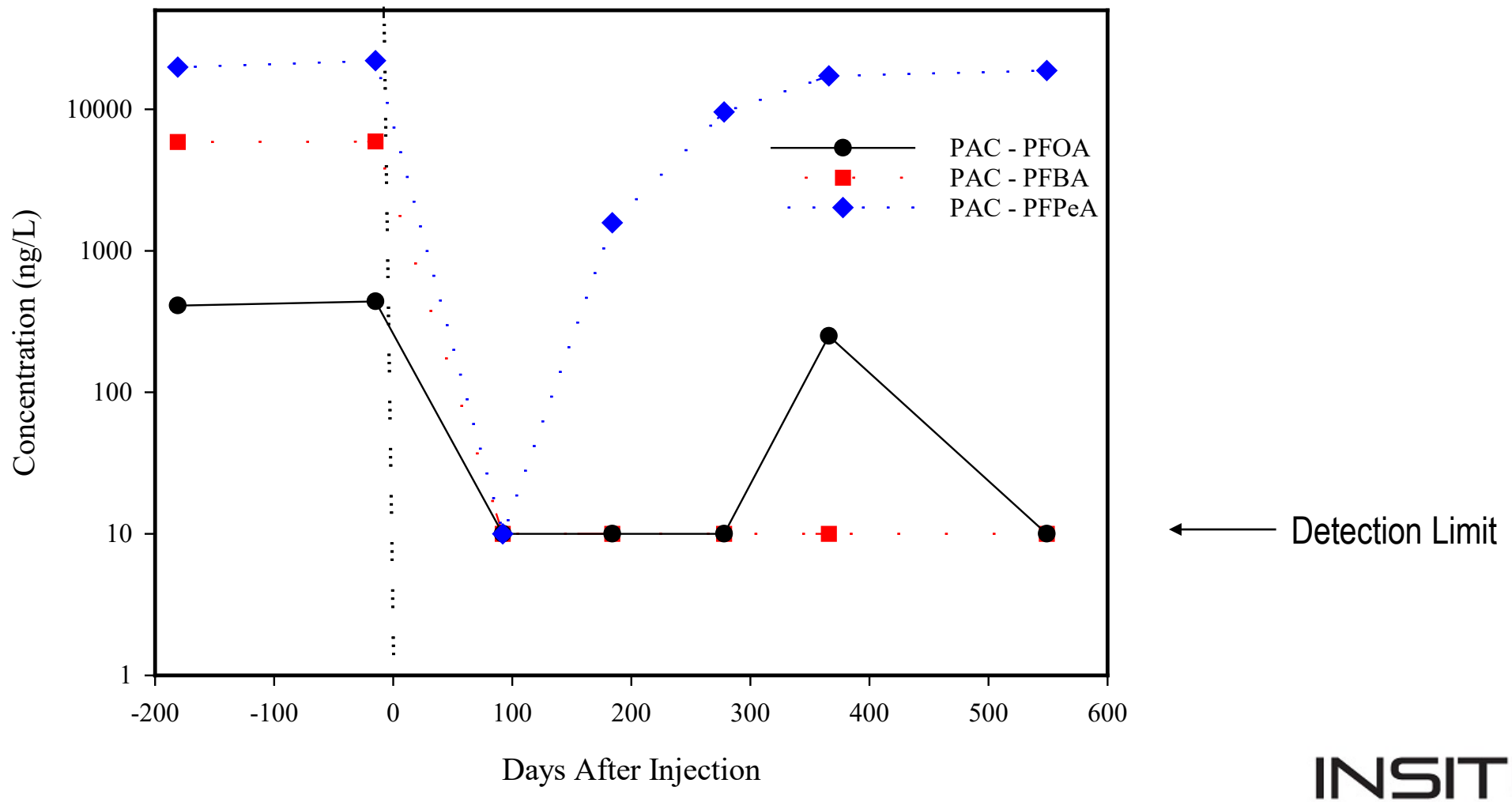
Pilot Scale Site

Colloidal Activated Carbon

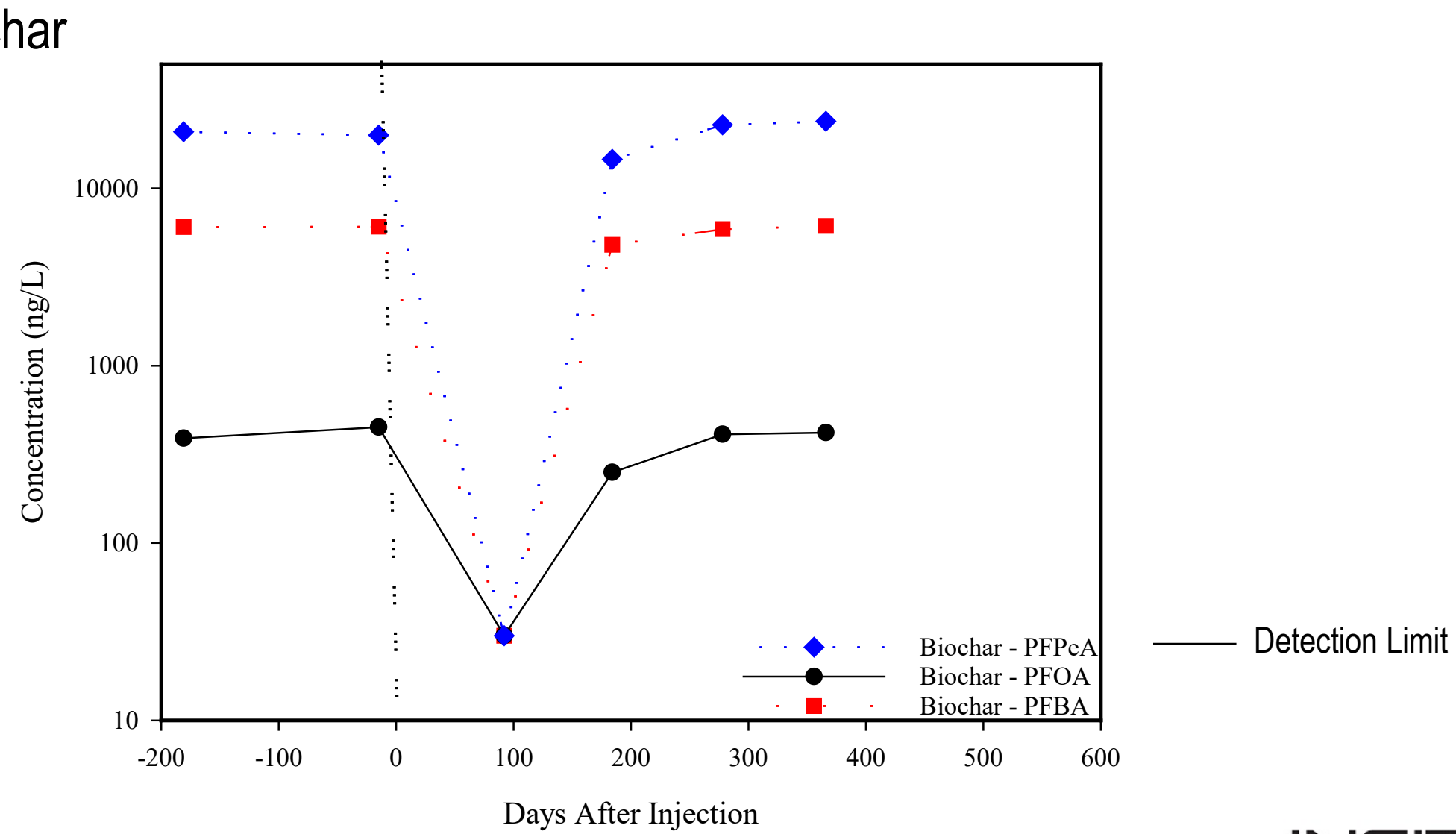


Pilot Scale Site

Powdered Activated Carbon

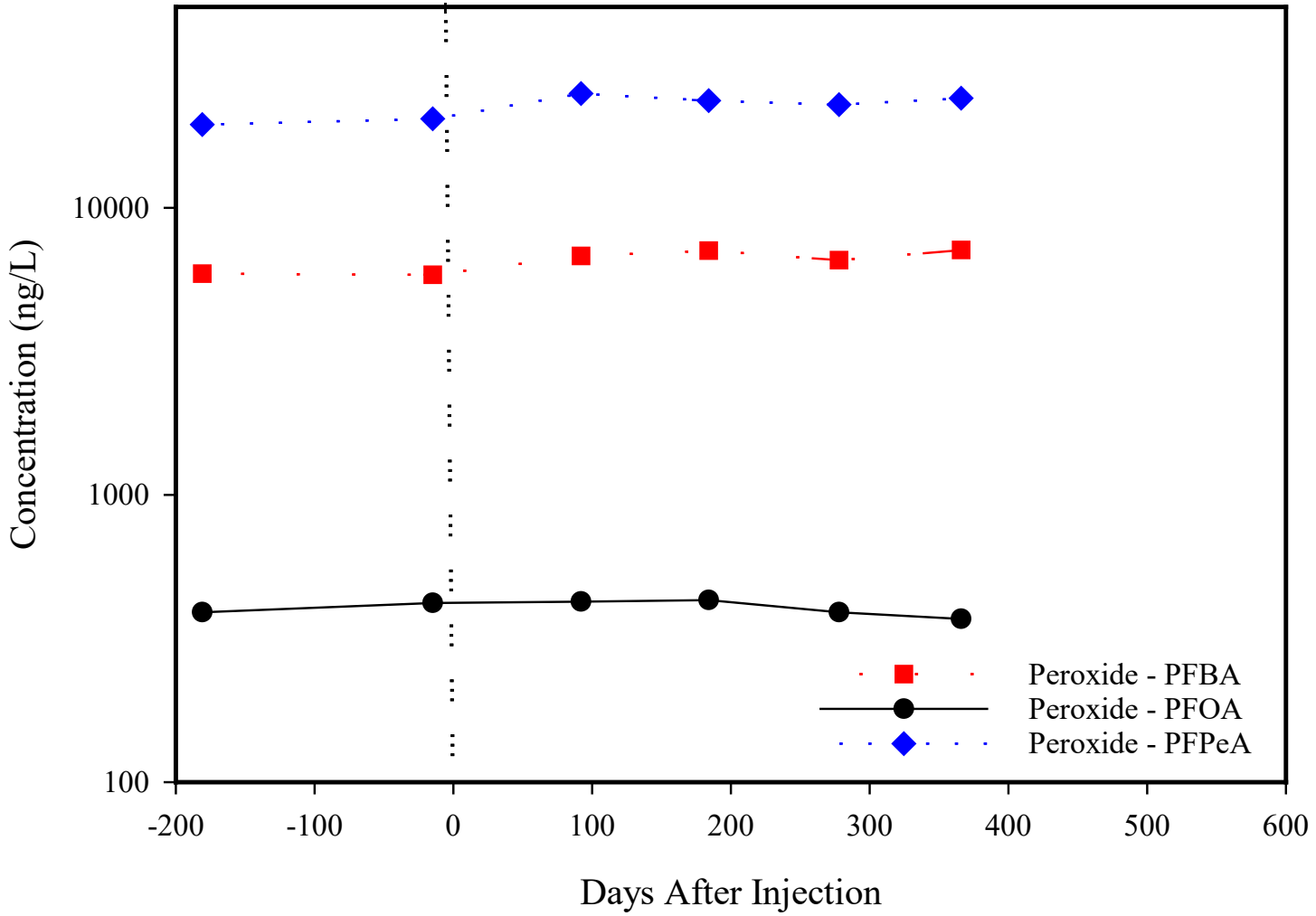


Pilot Scale Site



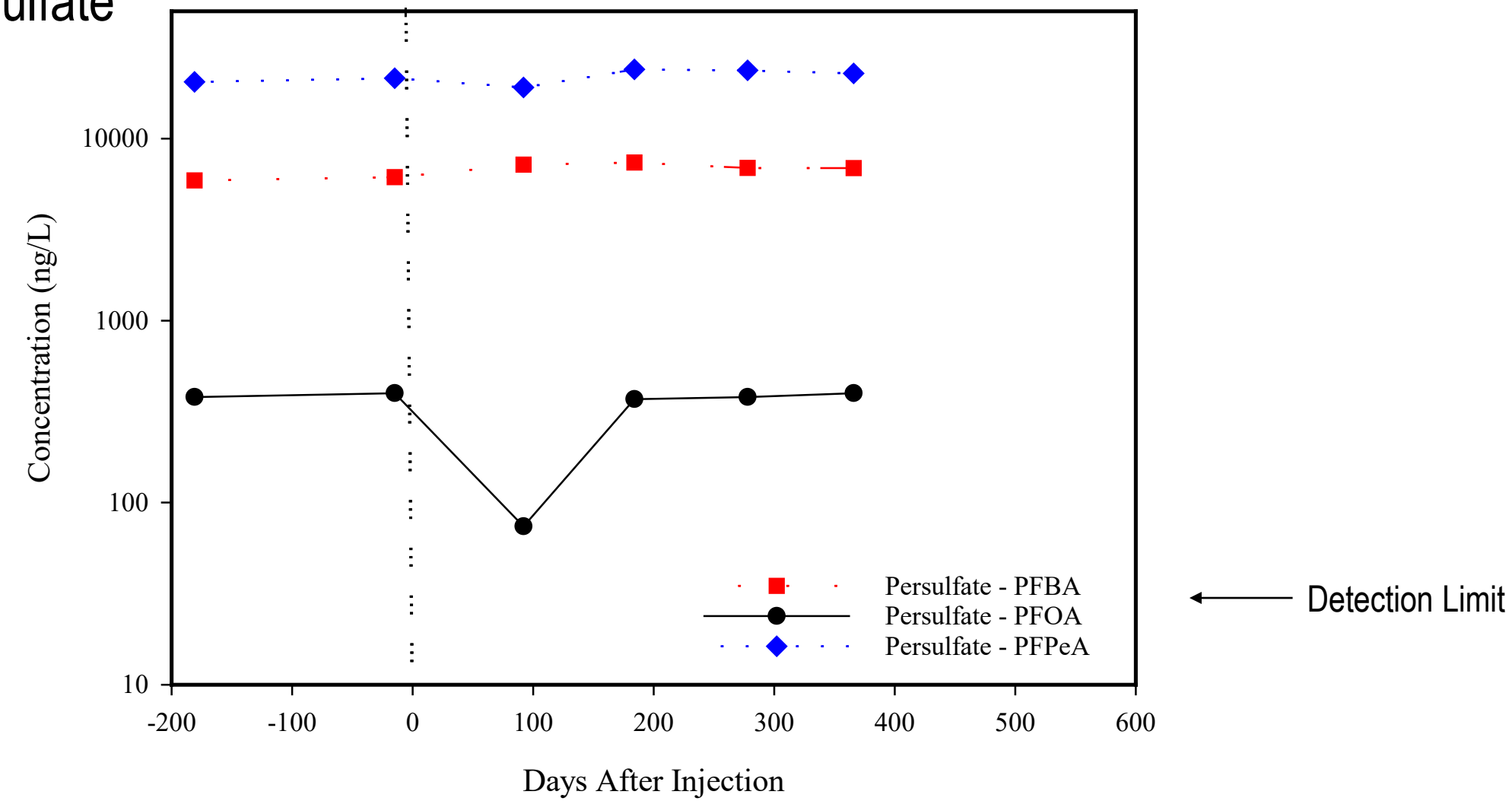
Pilot Scale Site

Hydrogen Peroxide



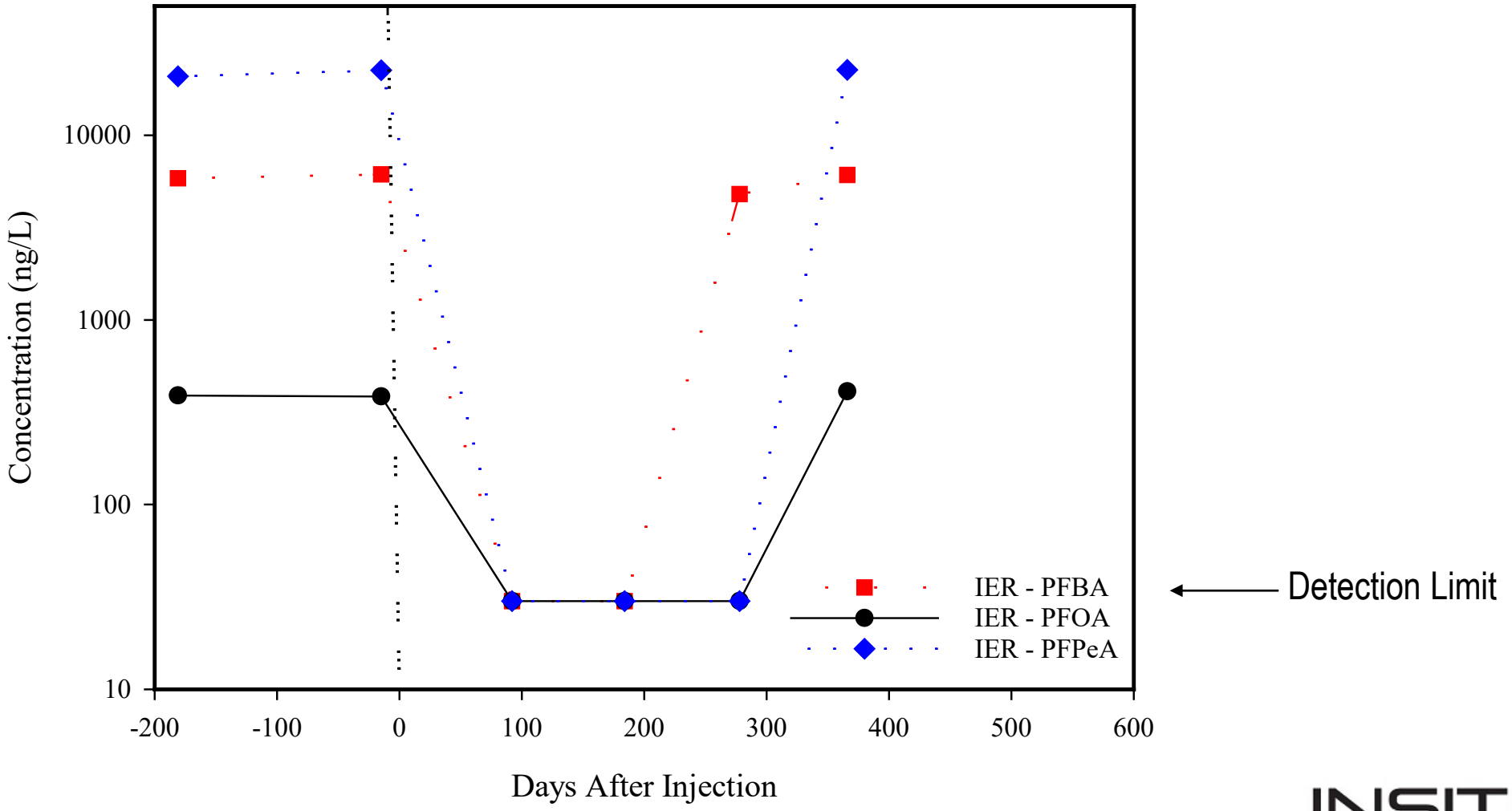
Pilot Scale Site

Sodium Persulfate



Pilot Scale Site

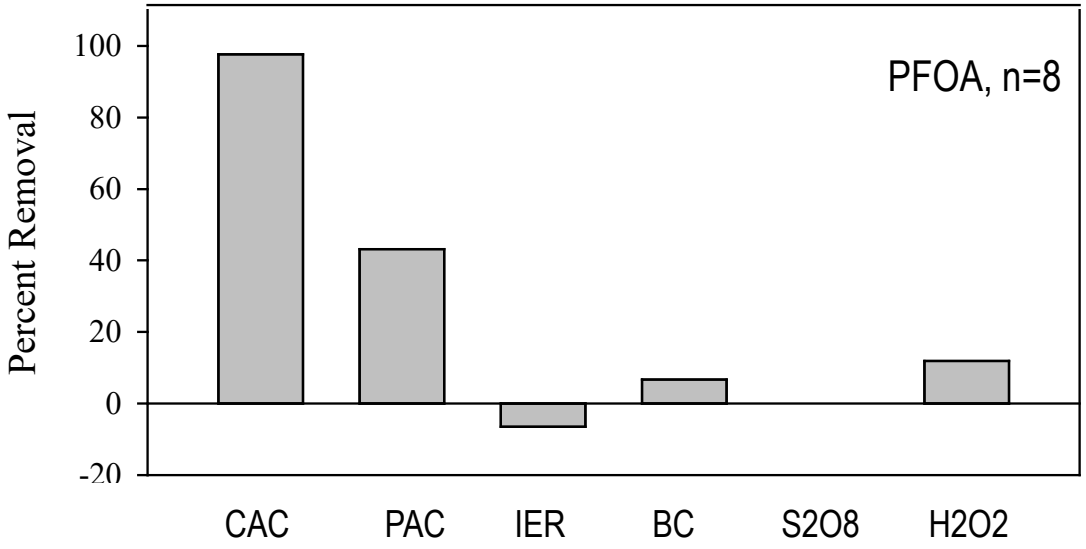
Ion Exchange Resin

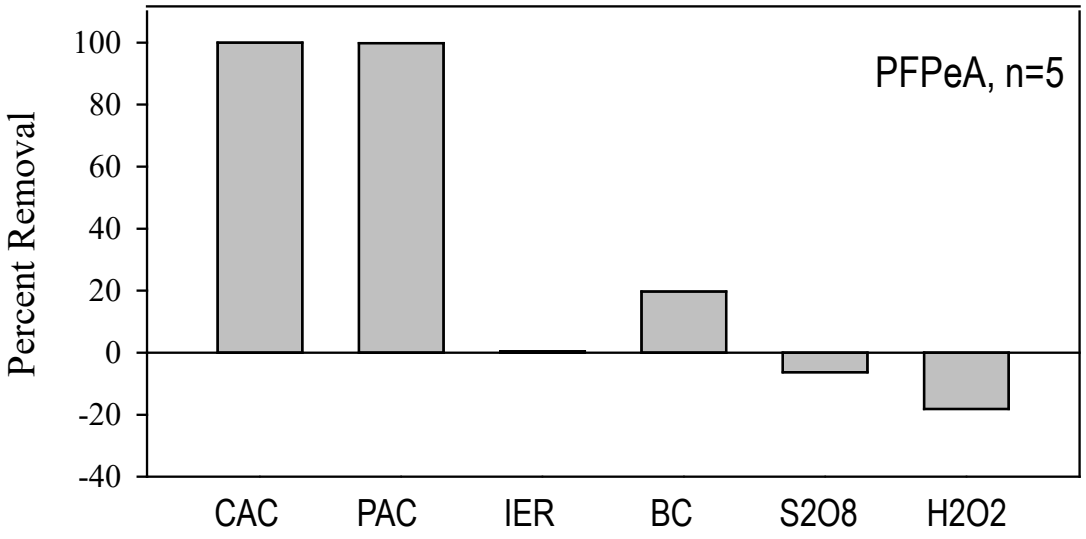


Pilot Scale Site

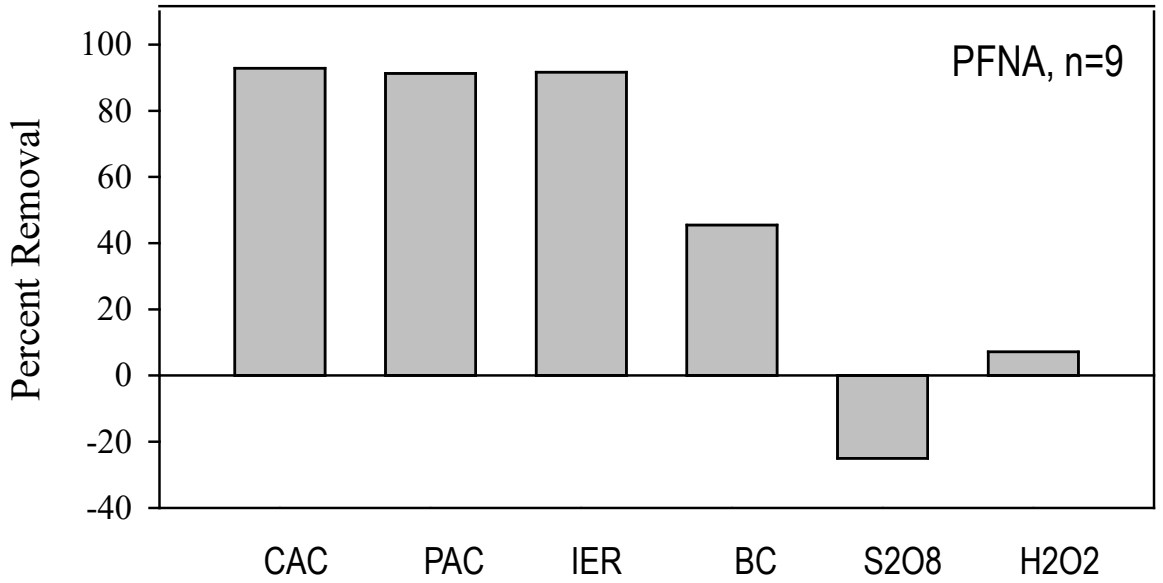
- Treatment with time
  - Breakthrough observed throughout target zone
    - Except for CAC
    - Hydrogen peroxide & persulfate breakthrough in 90 days
    - Low C PFAS > High C PFAS
    - Hydrogen peroxide = persulfate > Biochar > IER > PAC > CAC

Pilot Scale Site



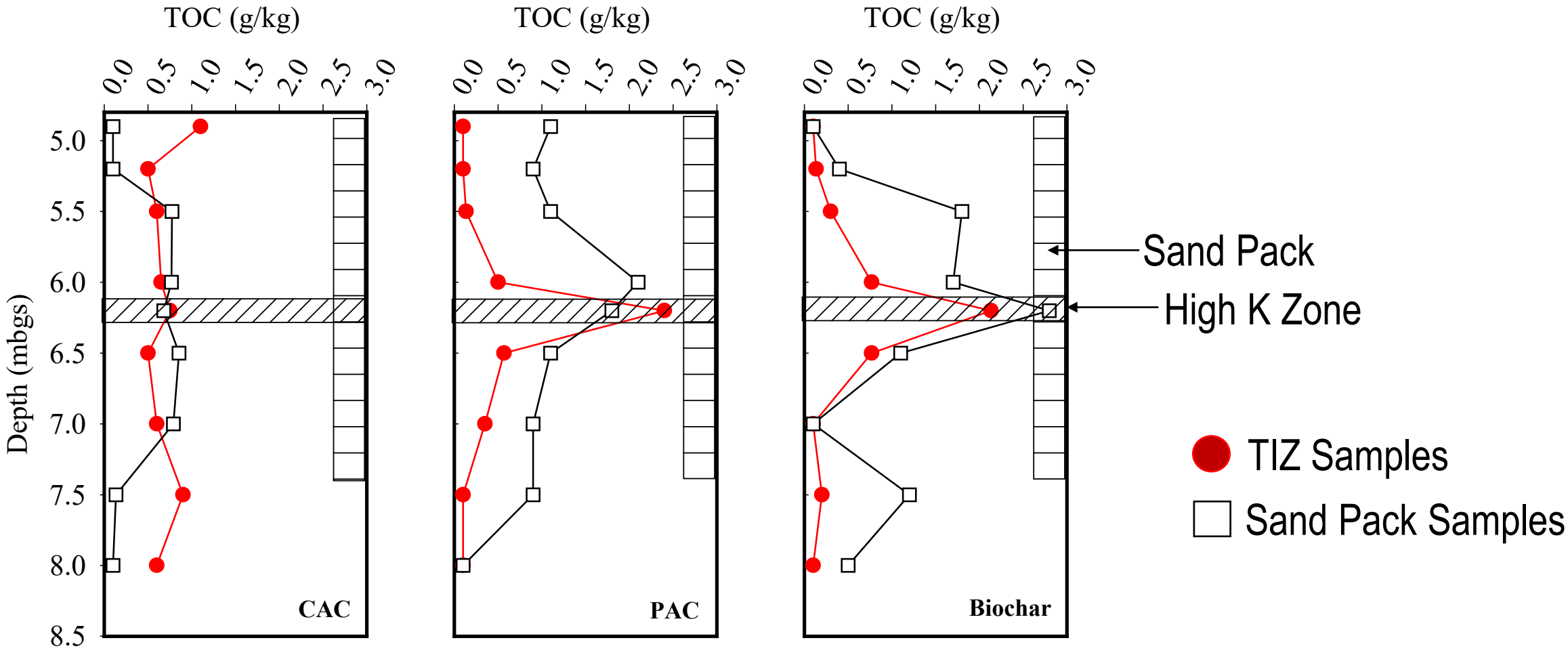


Treatment at 366 days



Pilot Scale Site

Effect of Sand Packs



Pilot Scale Site

- Effect of Well Screen
  - CAC
    - Sand Pack - 0.61 g/kg
    - Surrounding Target Zone – 0.77 g/kg
  - PAC
    - Sand Pack – 1.11 g/kg
    - Surrounding Target Zone – 0.79 g/kg
  - Biochar
    - Sand Pack – 1.08 g/kg
    - Surrounding Target Zone – 0.81 g/kg

Pilot Scale Site

DOI: 10.1002/rem.21653

RESEARCH ARTICLE

WILEY

Six pilot-scale studies evaluating the in situ treatment of PFAS in groundwater

Rick McGregor

InSitu Remediation Services Ltd., St. George, Canada

Correspondence
Rick McGregor, InSitu Remediation Services Ltd., PO Box 324, St. George, ON N0E 1N0, Canada.
Email: rickm@irsl.ca

Abstract

Per- and polyfluoroalkyl substances (PFAS) have been identified by many regulatory agencies as emerging contaminants of concern in a variety of media including groundwater. Currently, there are limited technologies available to treat PFAS in groundwater with the most frequently applied approach being extraction (i.e., pump and treat). While this approach can be effective in containing PFAS plumes, previous studies of pump and treat programs have met with limited remedial success. In situ treatment studies of PFAS have been limited to laboratory and a few field studies. Six pilot-scale field studies were conducted in an unconfined sand aquifer coimpacted by petroleum hydrocarbon along with PFAS to determine if a variety of reagents could be used to attenuate dissolved phase PFAS in the presence of petroleum hydrocarbons. The six reagents consisted of two chemical oxidants, hydrogen peroxide (H_2O_2) and sodium persulfate ($Na_2S_2O_8$), and four adsorbents, powdered activated carbon (PAC), colloidal activated carbon (CAC), ion-exchange resin (IER), and biochar. The reagents were injected using direct push technology in six permeable reactive zone (PRZ) configurations. Groundwater concentrations of various PFAS entering the PRZs ranged up to 24,000 ng/L perfluoropentanoic acid, up to 6,200 ng/L **perfluorobutanoic** acid, up to 16,100 ng/L perfluorohexanoic acid, up to 6,080 ng/L perfluoroheptanoic acid, up to 450 ng/L perfluorooctanoic acid, and up to 140 ng/L perfluorononanoic acid. Performance groundwater sampling within and downgradient of the PRZs occurred for up to 18 months using single and multilevel monitoring wells. Results of groundwater sampling indicated that the PFAS were not treated by either the persulfate nor the peroxide and, in some cases, the PFAS increased in concentration immediately following the injection of peroxide and persulfate. Concentrations of PFAS in groundwater sampled within the PAC, CAC, IER, and biochar PRZs immediately after the injection were determined to be less than the method detection limits. Analyses of groundwater samples over the 18-month monitoring period, indicated that all the PRZs exhibited partial or complete breakthrough of the PFAS over the 18-month monitoring period, except for the CAC PRZ which showed no PFAS breakthrough. Analysis of cores for the CAC, PAC, and biochar PRZs suggested that the CAC was uniformly distributed within the target injection zone, whereas the PAC and biochar showed preferential injection into a thin coarse-sand seam. Similarly, analysis of the sand packs of monitoring wells installed before the injection of the

INSITU

Thank You

Academic Partners

Industrial Partners

Porewater Solutions
Expertise • Experience • Innovation