

Performance of Injected Powdered and Colloidal Activated Carbon at a Petroleum Hydrocarbon Site

R. McGregor

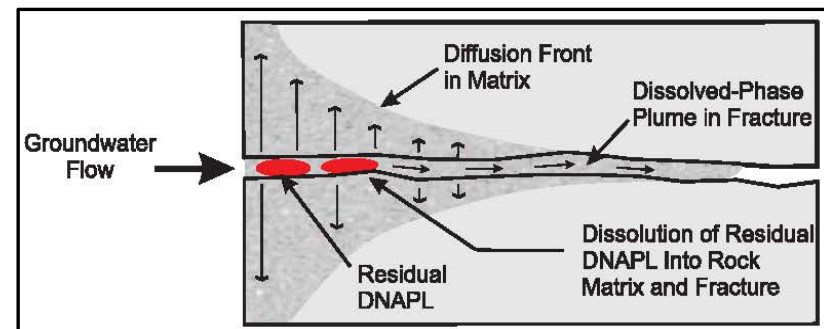
InSitu Remediation Services

Battelle

April 2018

Background

- Insitu challenges
 - Rebound
 - Back diffusion in heterogenetic materials
 - Reaction efficiency at low concentrations
 - Physical property issues
 - Viscosity
 - Density
 - Distribution



Modified after Kueper and Davies, 2009



Background

- Activated Carbon
 - Widely used in waste and groundwater treatment
 - Pump & Treat
 - Dual Phase Extraction
 - Multi Phase Extraction
 - Skimmers
- Cost competitive
- 3 basic forms
 - Granular ($> 177 \mu\text{m}$)
 - Powdered ($10 - 100 \mu\text{m}$)
 - Colloidal ($< 2 \mu\text{m}$)



Background

Limitations for insitu treatment

- Relatively large particle size
 - Carrier fluid required
 - High injection pressure and velocities required
 - Pore throats
 - $> 2 \mu\text{m}$ sand
 - 0.005 to $0.1 \mu\text{m}$ clay
- Lifespan limitations
 - Limited adsorption sites
- Competition for sites
- Inorganic chemistry influences



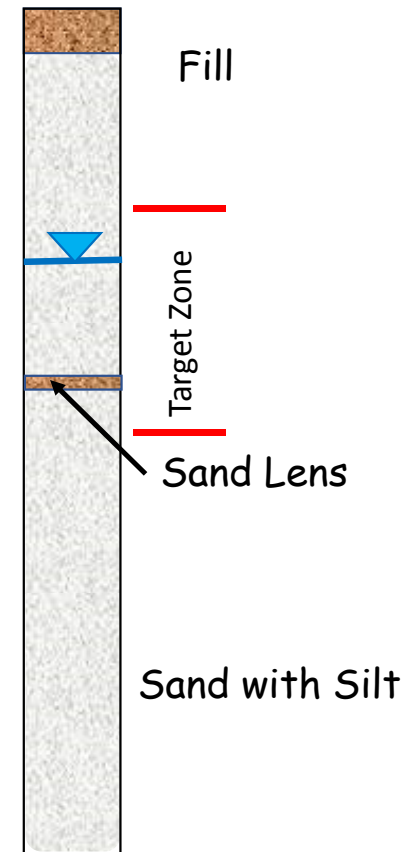
Study Site

- Petroleum Hydrocarbon Spill
 - Source excavated
 - Residue PHCs in groundwater
 - BTEX up to 295 ug/L
 - F1 up to 2,040 ug/L
 - F2 up to 3,500 ug/L
 - Plume geometry
 - ~60 m length
 - ~0.9 m thick
 - Geochemistry
 - Anaerobic
 - Iron-sulphate reducing



Study Site

- **Geology**
 - Sand with silt
 - Sand lens (less than 2 cm thick)
- **Hydrogeology**
 - Shallow water table (~1.5 mbgs)
 - Sand with silt unit
 - $K \sim 5 \times 10^{-5} \text{ cm/sec}$
 - Sand lens
 - $K \sim 4 \times 10^{-4} \text{ cm/sec}$
 - $i \sim 0.01$
 - $V \sim 16 \text{ m/year}$
 - Effective porosity ~ 0.2



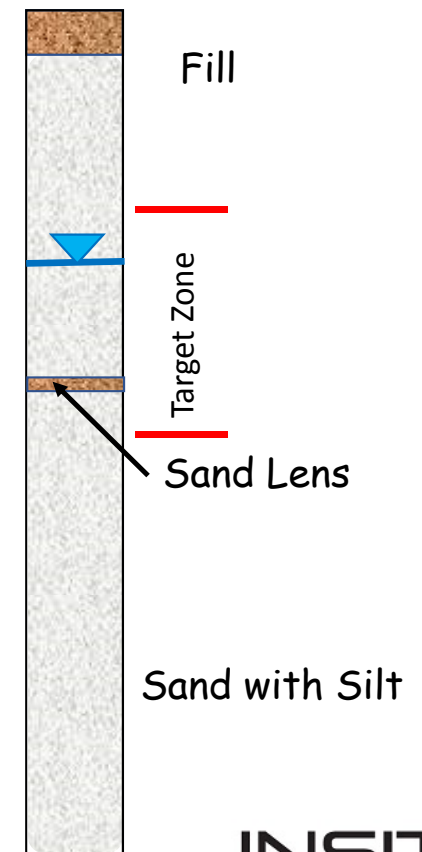
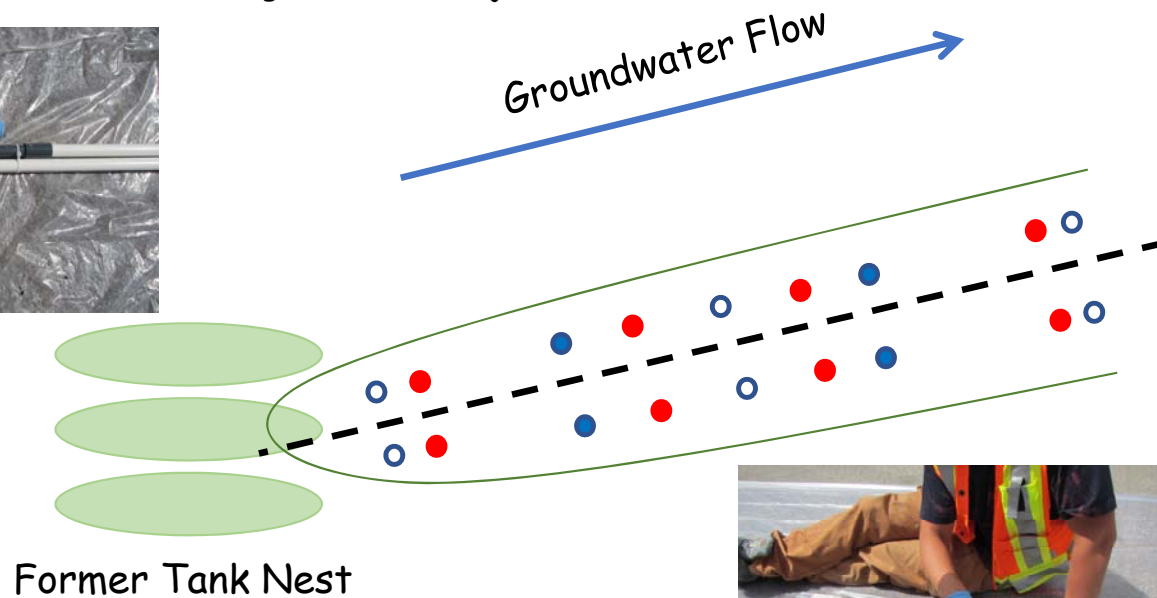
Study Site

- Remedial Options Considered
 - Pump & Treat
 - Air Sparging & SVE
 - Chemical oxidation
 - Enhanced aerobic bio
 - Sulphate reduction
 - Thermal
 - Adsorption
 - Combination



Study Site

- 2" Monitoring Well
- 3 Channel CMT - Post Injection
- 2" Monitoring Well - Post Injection

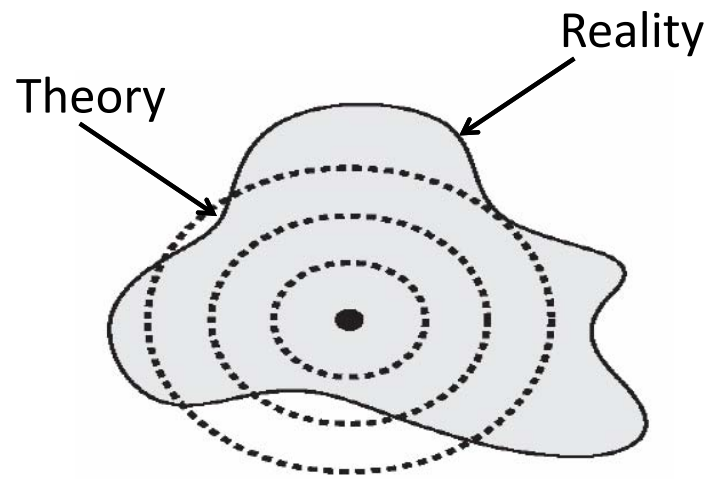


Study Methodology

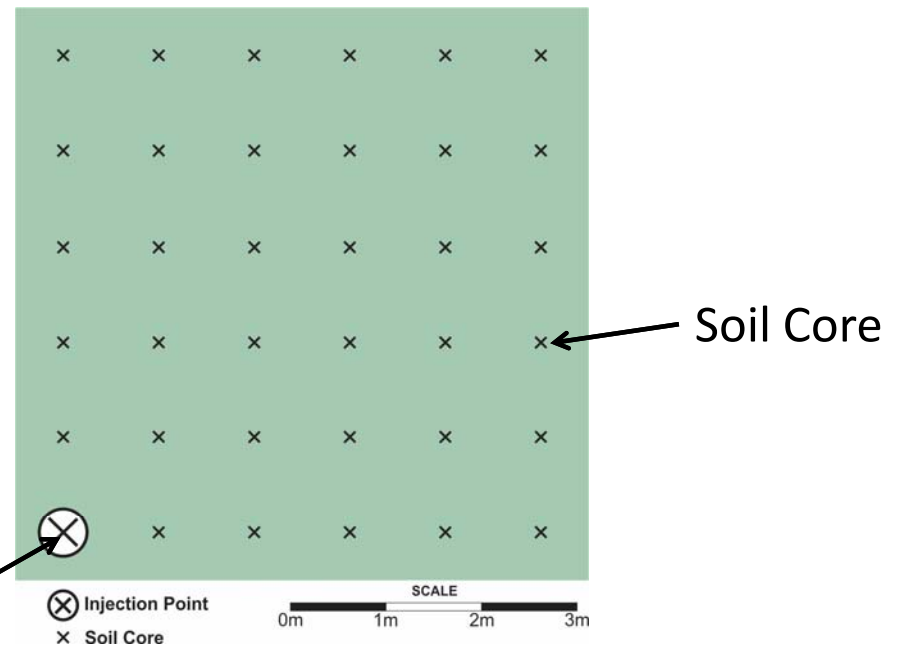
- Comparison field study
 - Reagents
 - Colloidal Activated Carbon (CAC)
 - Enhanced with oxygen releasing material
 - Powdered Activated Carbon (PAC)
 - Enhanced with gypsum
 - Granular Activated Carbon (GAC)
 - No bioaugmentation
 - Evaluate
 - Distribution of activated carbon
 - Vertical and lateral
 - Effects on biological community
 - PHC and BTEX treatment
 - Up to 3 years



Study Methodology

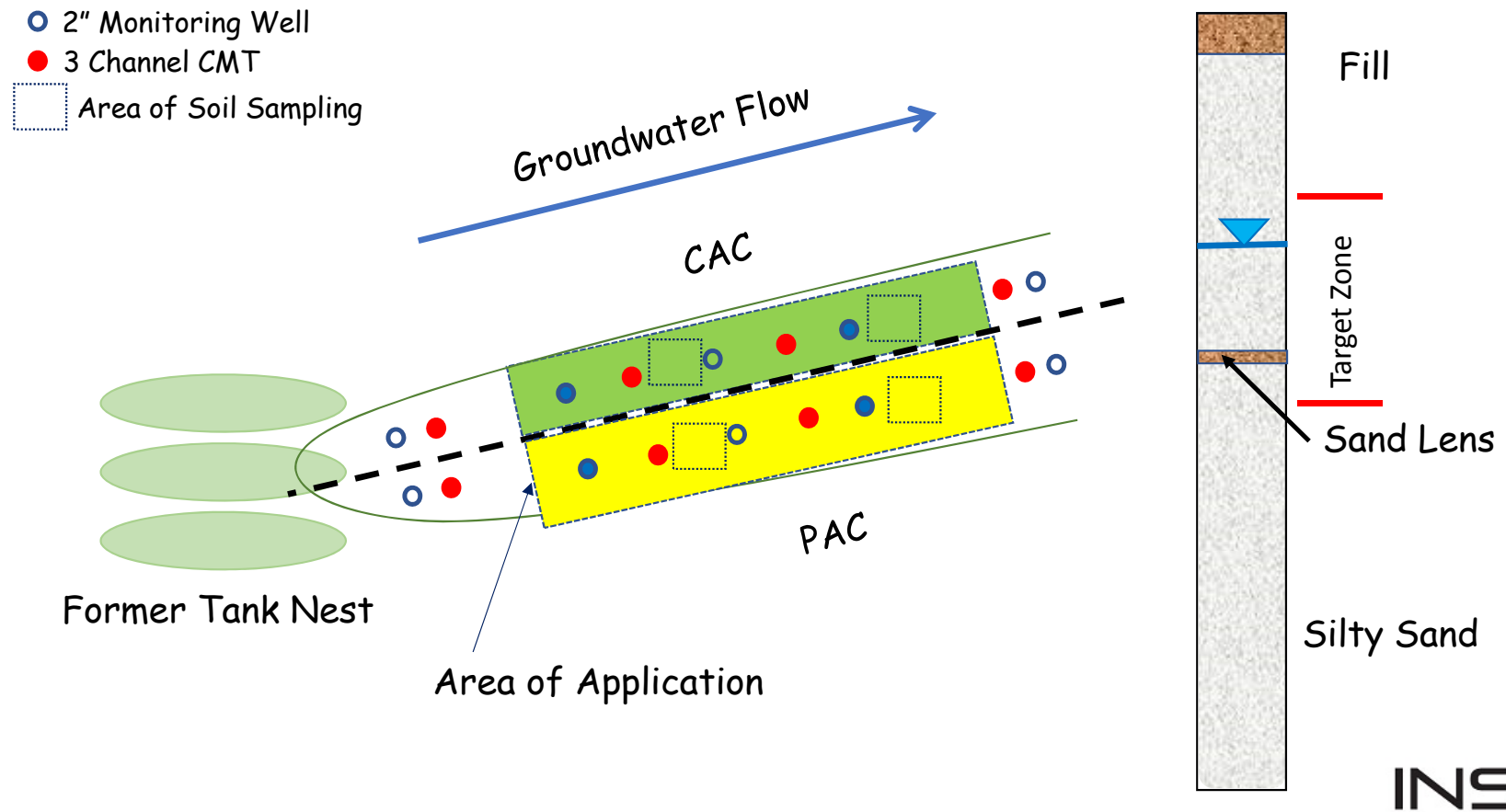


Injection Point



Groundwater Flow →

Study Methodology



Injection Methodology

- Based on Pore Volume
 - > 0.2 PV
 - One event
- Direct Push
- Geology Specific Tools
- Multiple Locations
- Multiple Intervals
- Lowest Practical Pressure
 - < 25 psi
- Low Volume
 - ~100 to 200 litres/location



Injection Methodology

- Powdered Activated Carbon
 - 0.3 m long side injection tool
 - 317 kg of PAC
 - Sulfate enhanced
 - ~20 wt. %
 - 1,260 litres of water
 - Up to 25 psi
 - 8 locations using DPT
 - 1 day injection



Injection Methodology



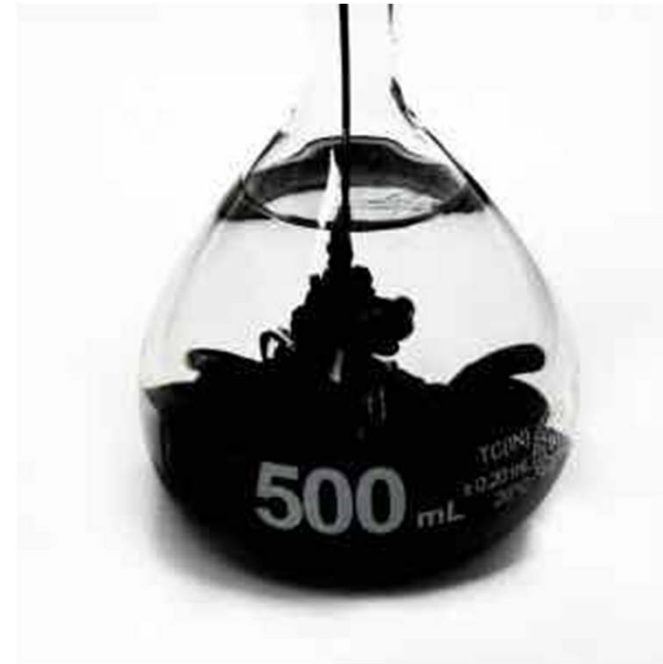
Powdered Activated Carbon



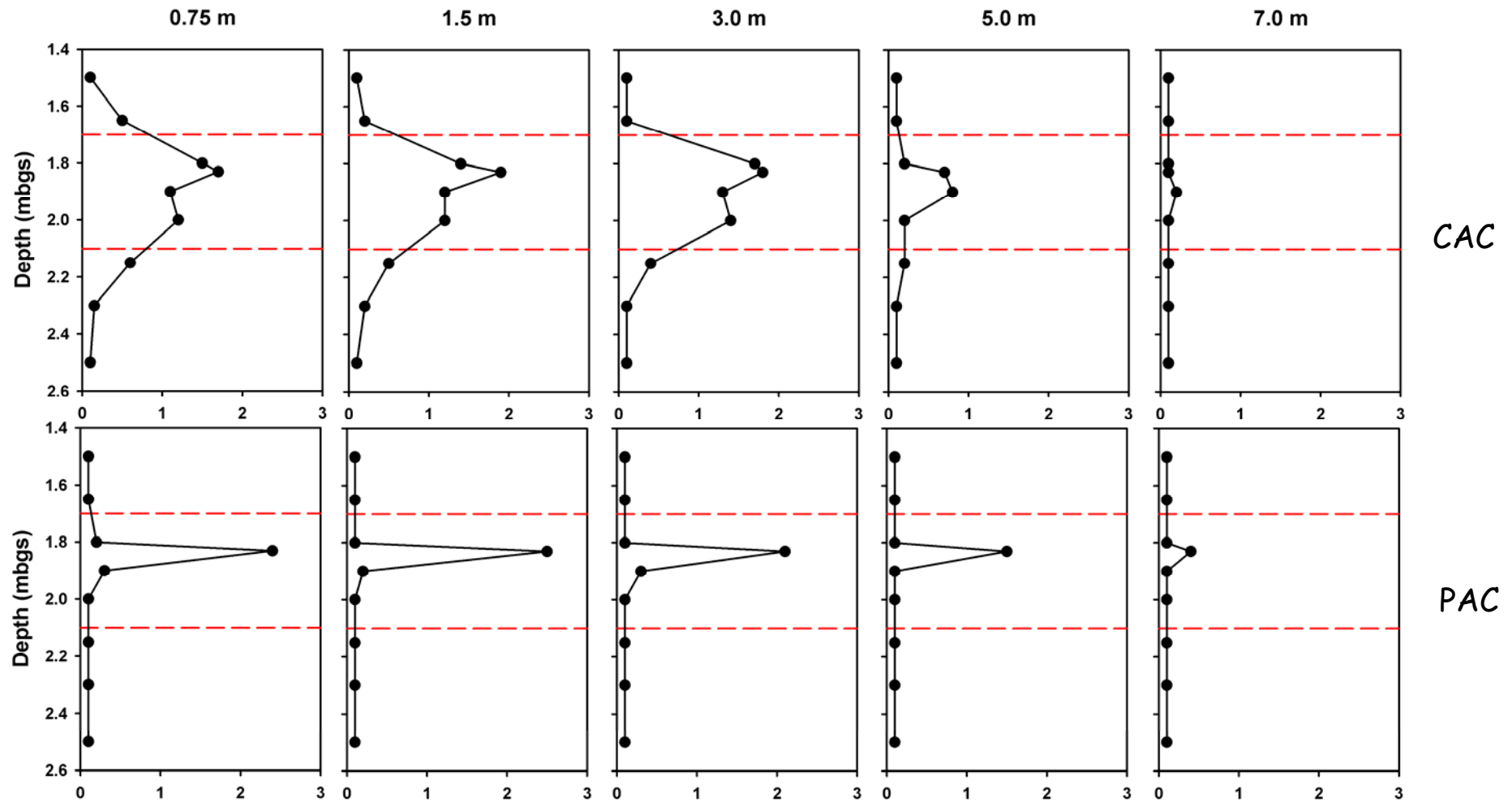
Colloidal Activated Carbon

Injection Methodology

- Colloidal Activated Carbon
 - 0.3 m long side injection tool
 - 362 kg of LAC
 - ~10 wt. %
 - Oxygen-releasing material enhanced
 - 3,260 litres of water
 - Up to 20 psi
 - 8 locations using DPT
 - 1 day injection



Results

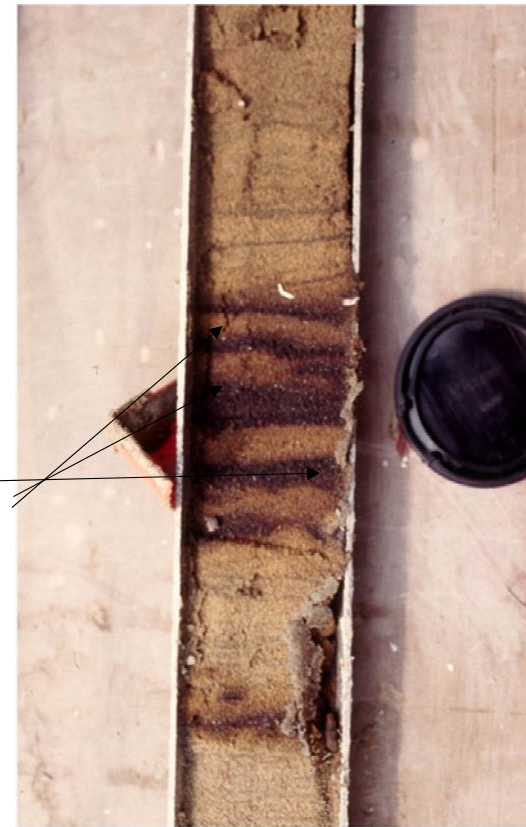


Results



Colloidal Activated Carbon

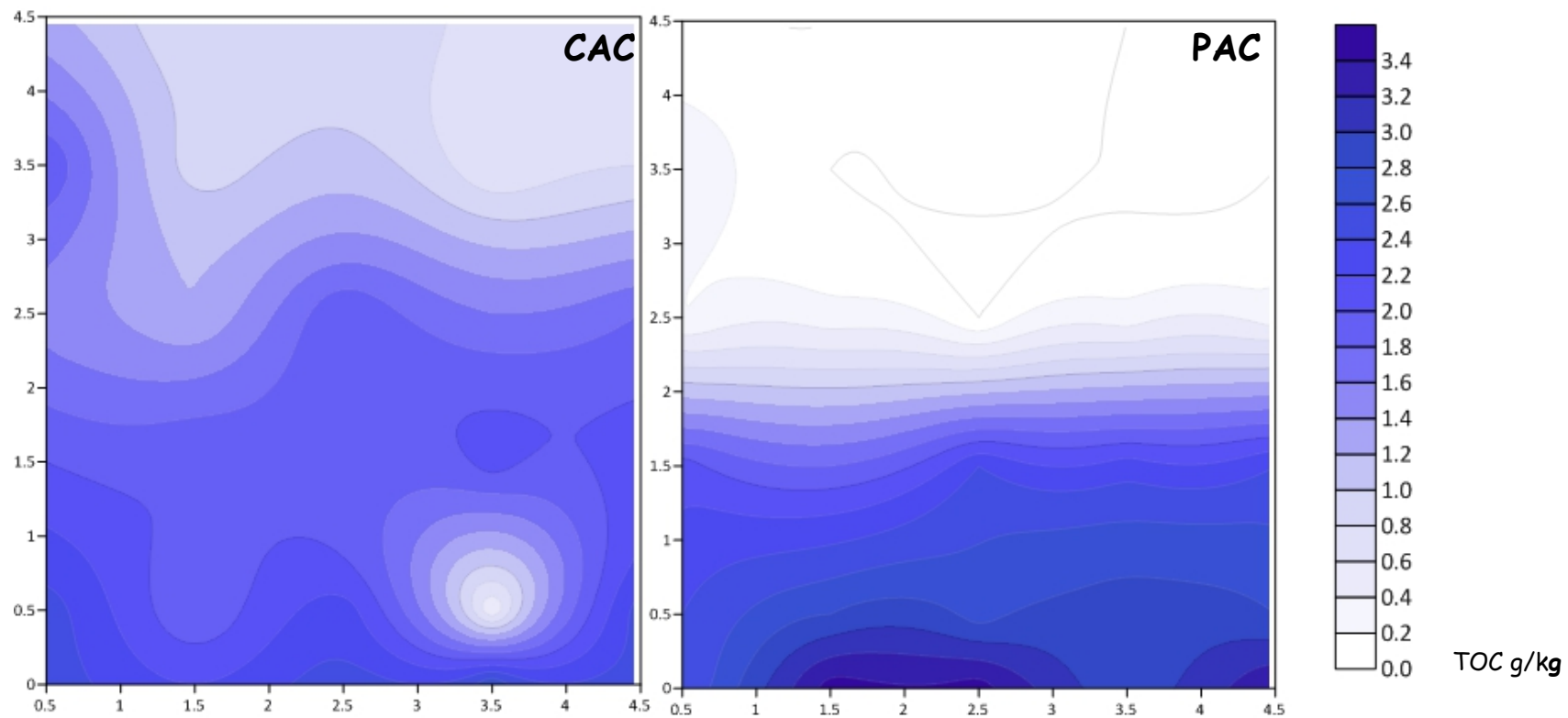
Powdered Activated Carbon



~4 cm

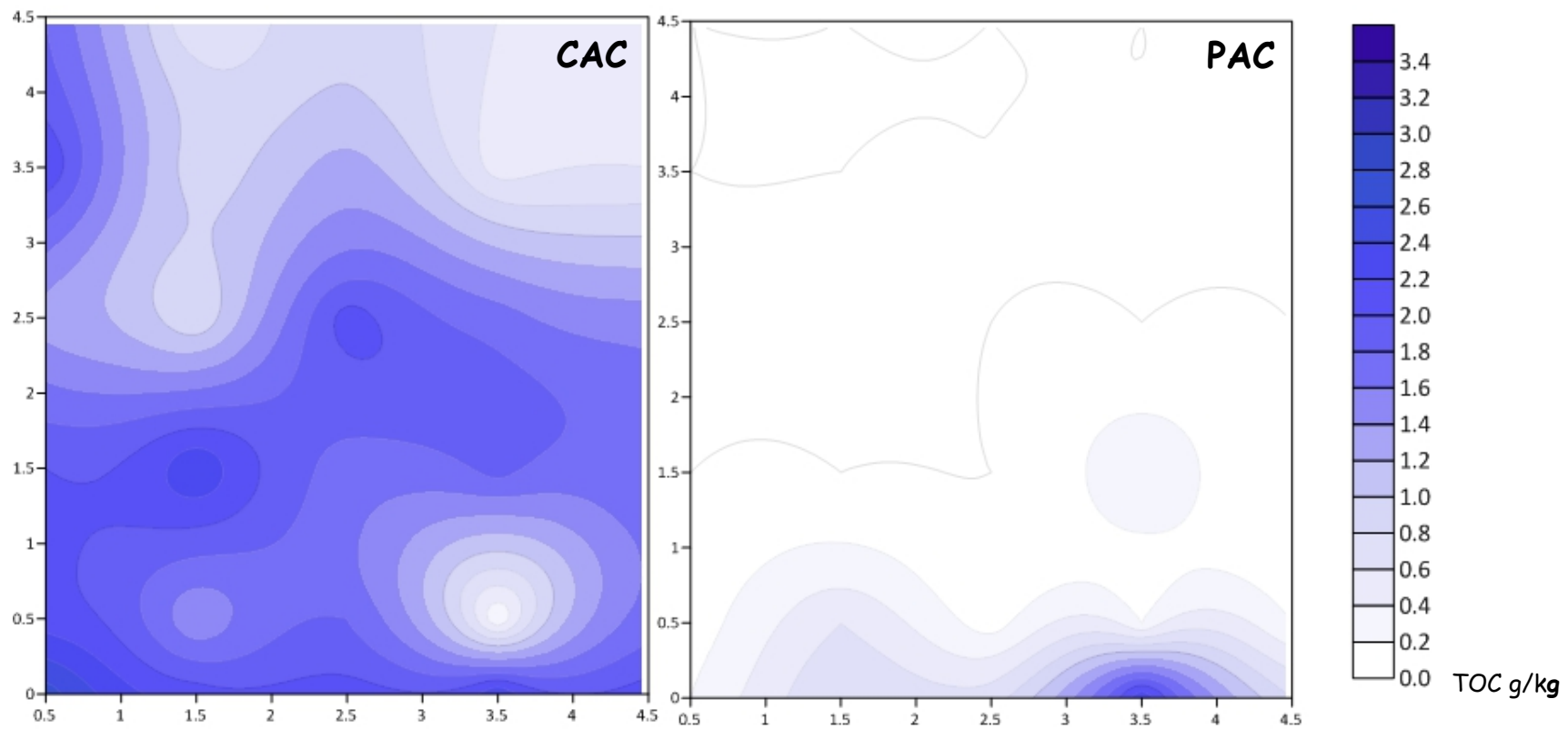
Results

Depth of Injection - 1.9 m



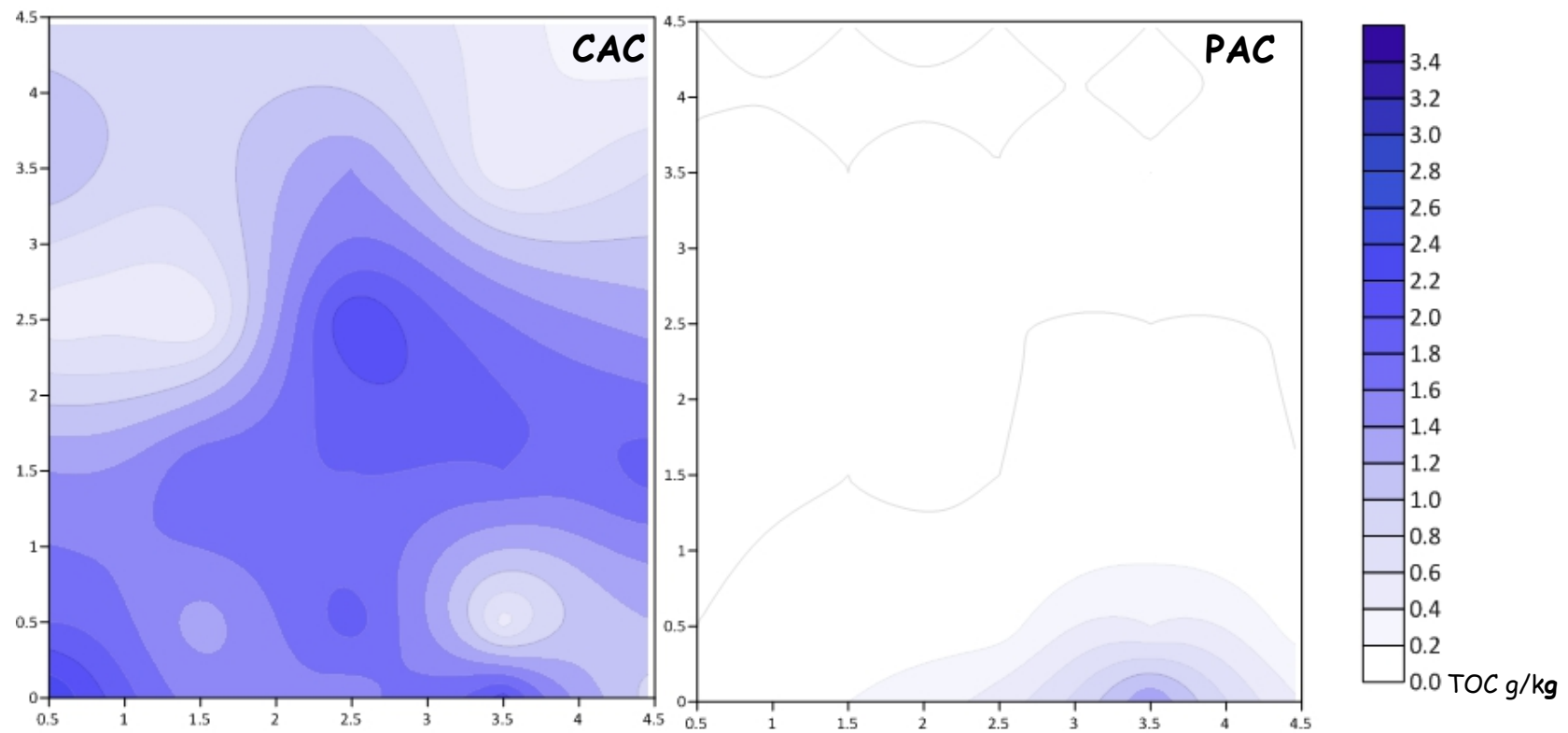
Results

Above Depth of Injection - 1.7 m

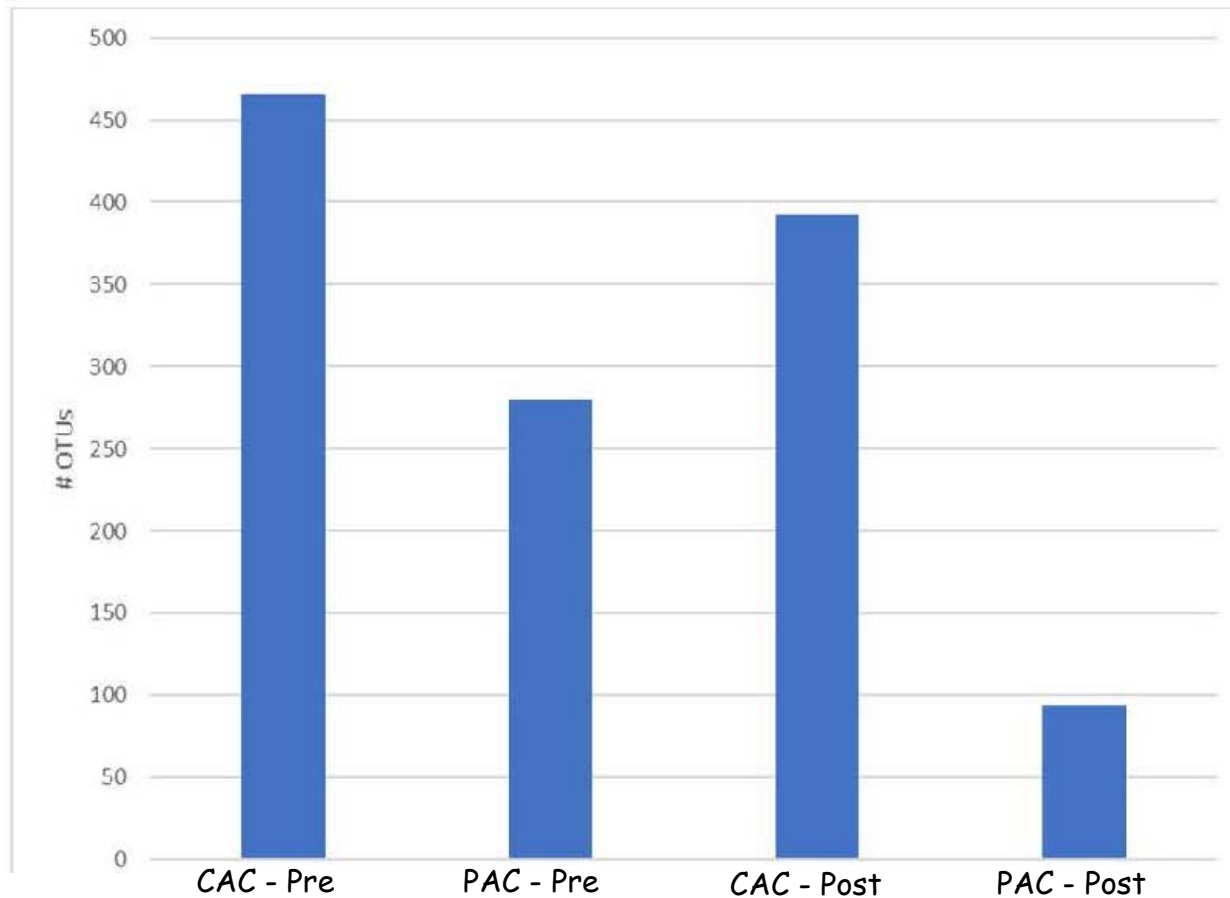


Results

Below Depth of Injection - 2.1 m



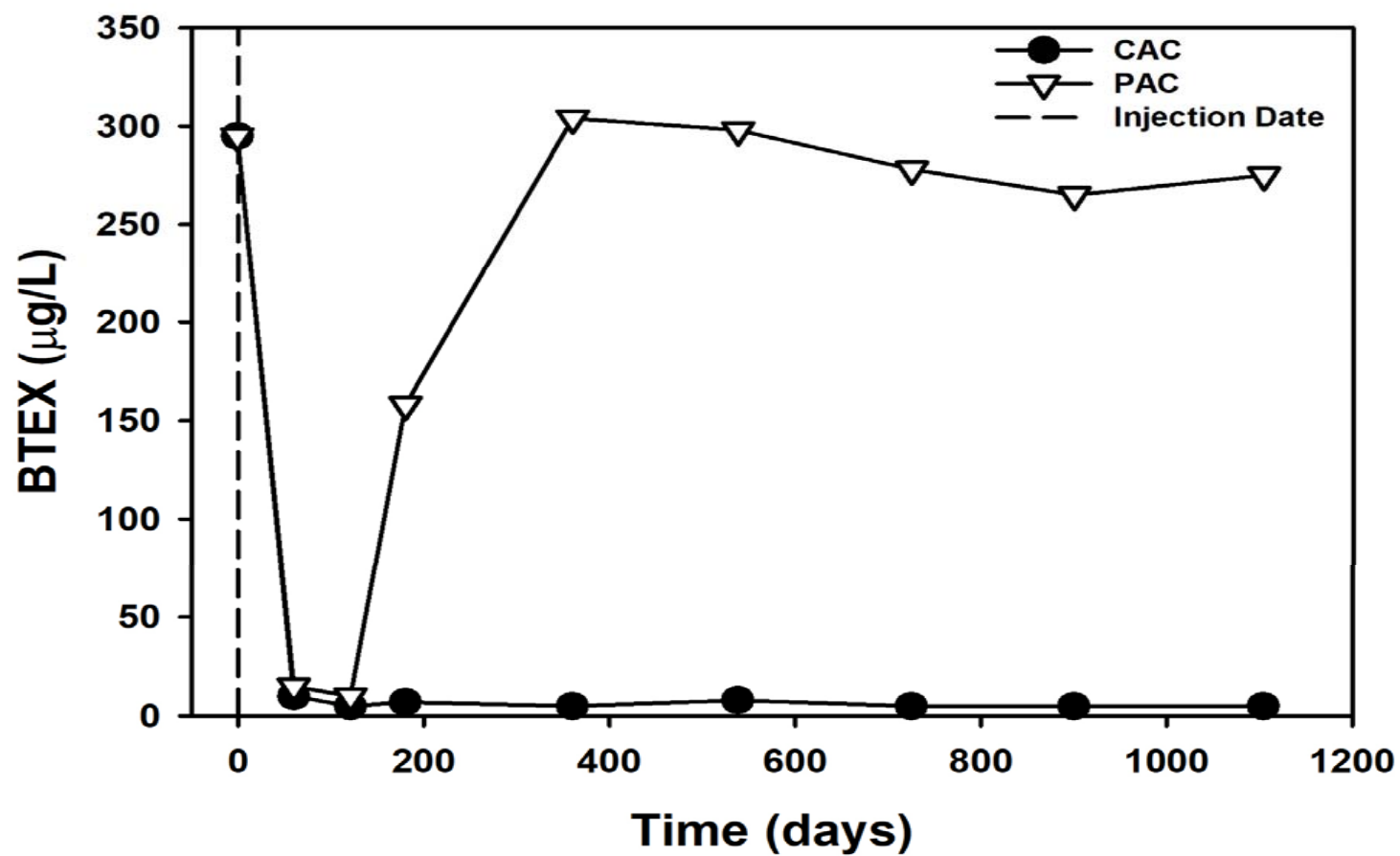
Results



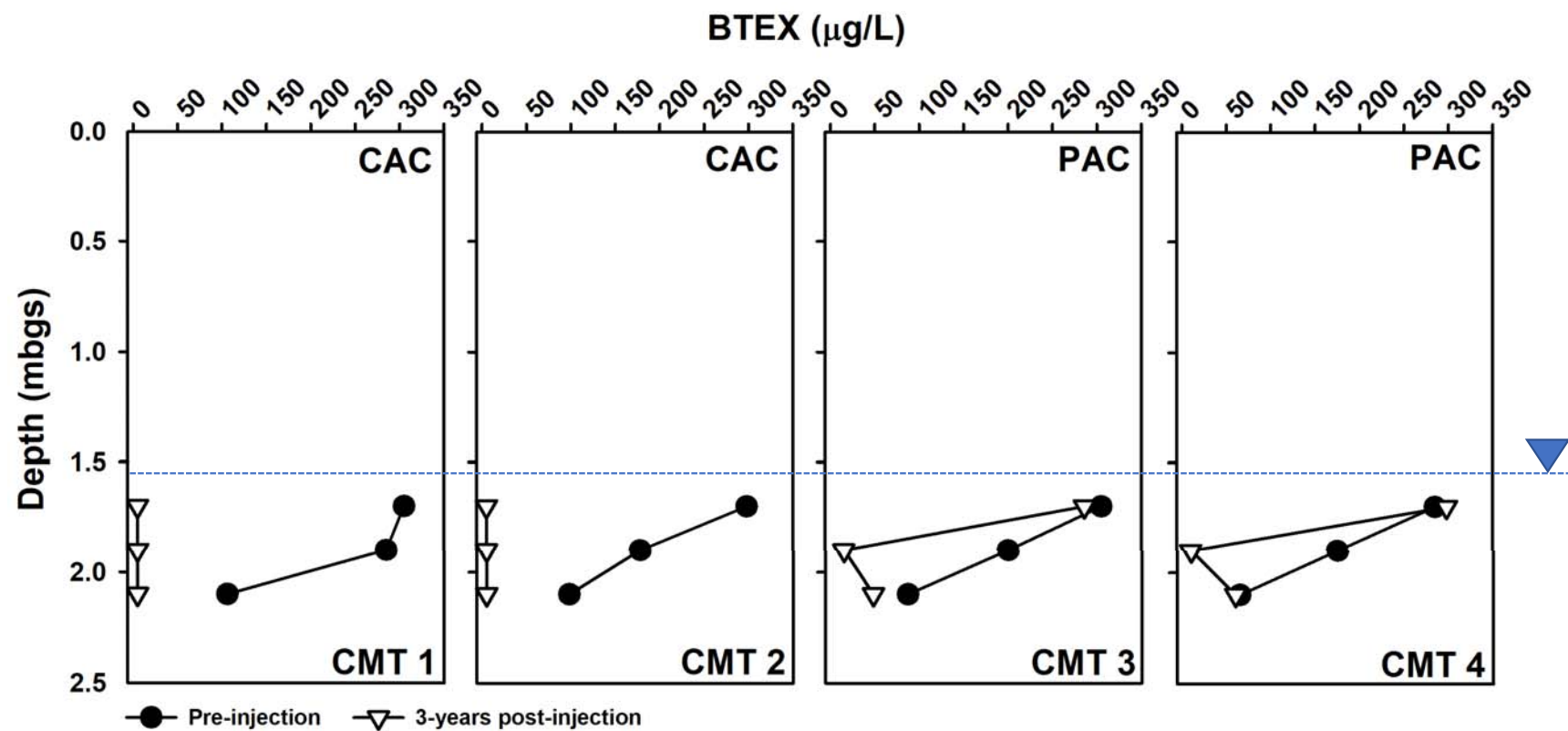
Operational Taxonomic Units (OTUs)

- Pre-Injection
 - ~500 OTUs
 - Some variability
- Post Injection
 - ~80% decrease in PAC area
 - ~40% decrease in LAC area
 - "enhancement" of aerobic bacteria in LAC area
 - No observable enhancement of SRBs in PAC area

Results



Results



Conclusions

- Activated carbon is a well proven technology for a wide range of organic and some inorganic compounds
- Both CAC and PAC can be injected into a wide range of unconsolidated geologies
- At this site, CAC showed a more uniform distribution compared to PAC with CAC being detected throughout the target zone compared to PAC which was detected in less than 10% of the target zone
- Enhancement with ORM influence bacterial populations positively at this site