Battelle
2019 Bioremediation Symposium | April 15-18 | Baltimore, Maryland

AECOM Imagine it. Delivered.

Bench-Scale Evaluation of PFAS Removal from Landfill Groundwater by Adsorptive Media Containing Biochar

Francisco Barajas, PhD

April, 17, 2019

Presentation Outline

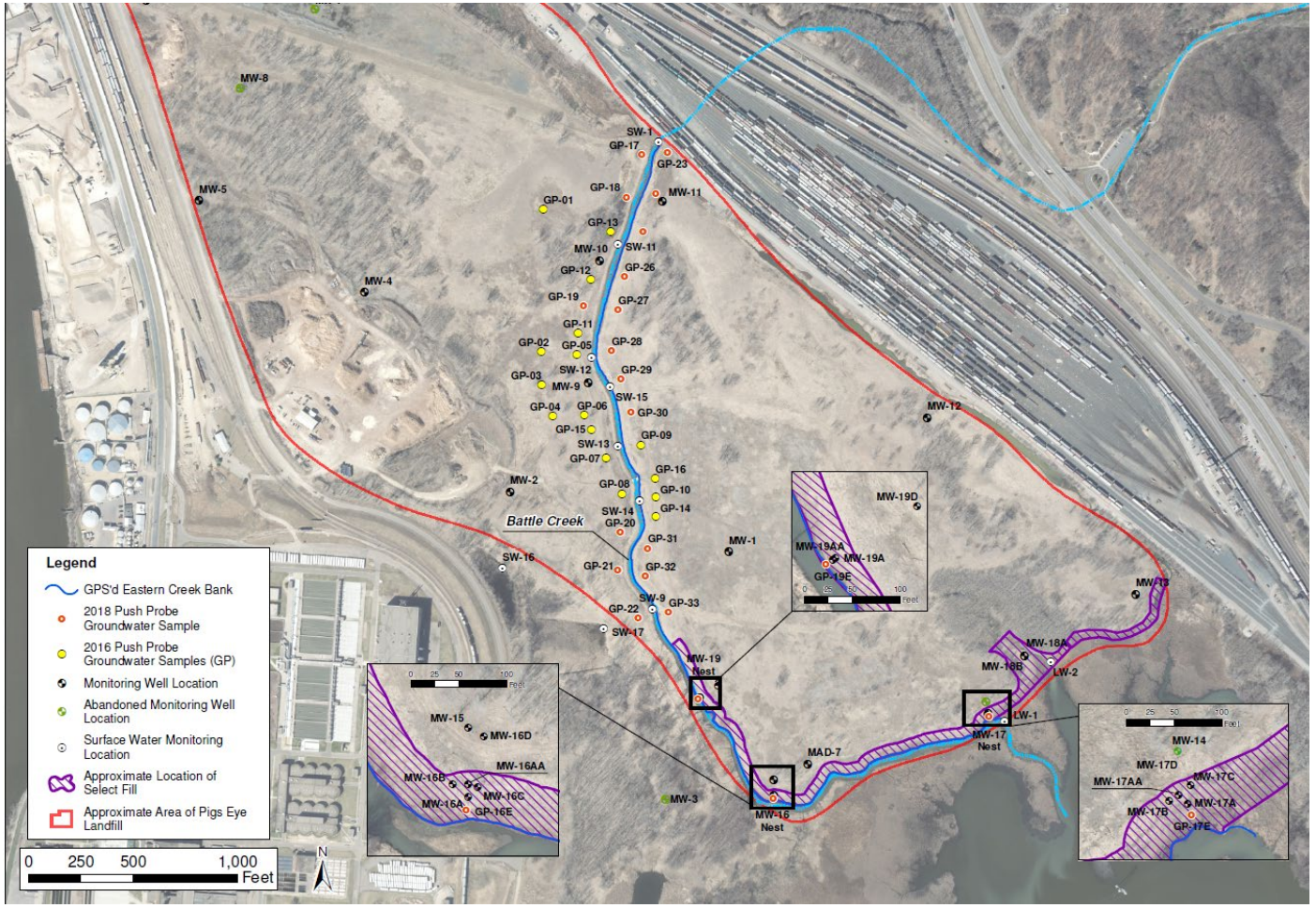
1. Background
2. Experimental Approach
3. Batch Tests
4. Column Test
5. Conclusions and Ongoing Work

01

Background

Background

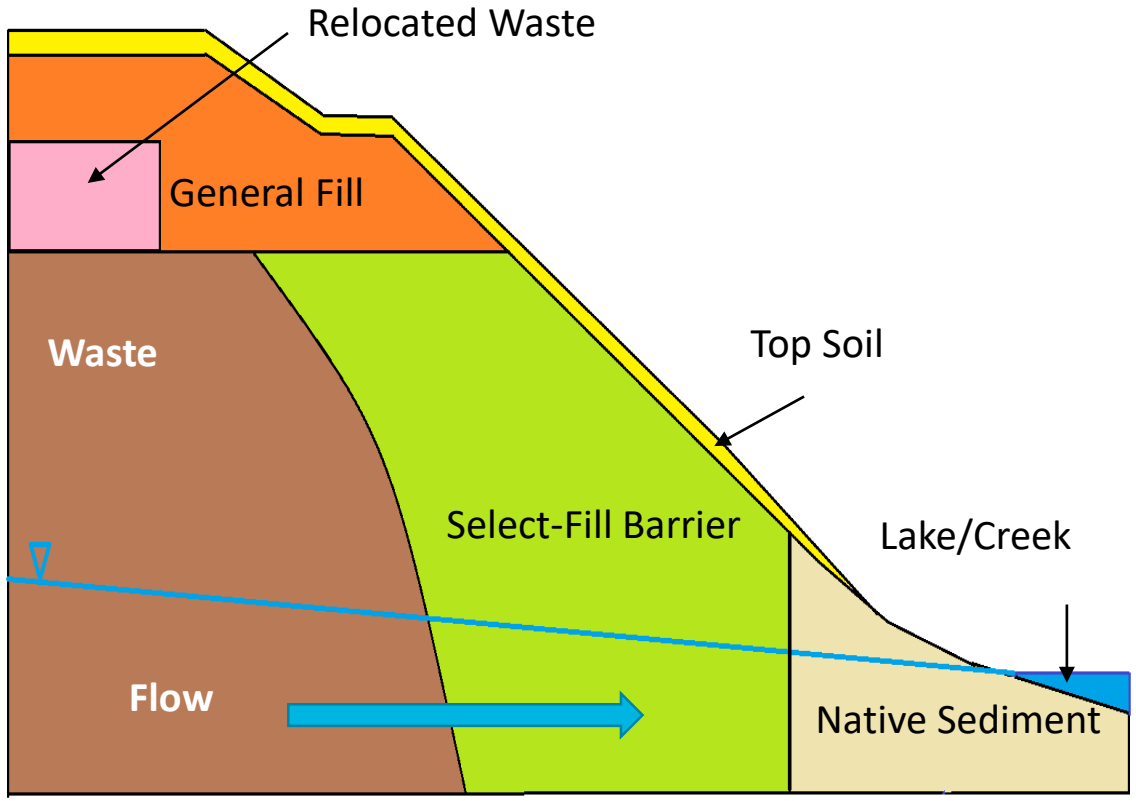
- Site history
  - Landfill used for disposal of waste starting in the mid-1950s
  - Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) above surface water criteria
- Site conditions
  - PFAS-impacted groundwater at the landfill
  - Permeable barrier implemented in a limited section to prevent contaminants migration
  - Creek flows through the central portion and discharges to a nearby lake



AECOM

Background

- Bench-scale testing needed to:
  - Demonstrate PFAS removal using similar permeable barrier media (select-fill)
  - Optimize select-fill composition
  - Determine the removal capacity of the select-fill under flow-through conditions

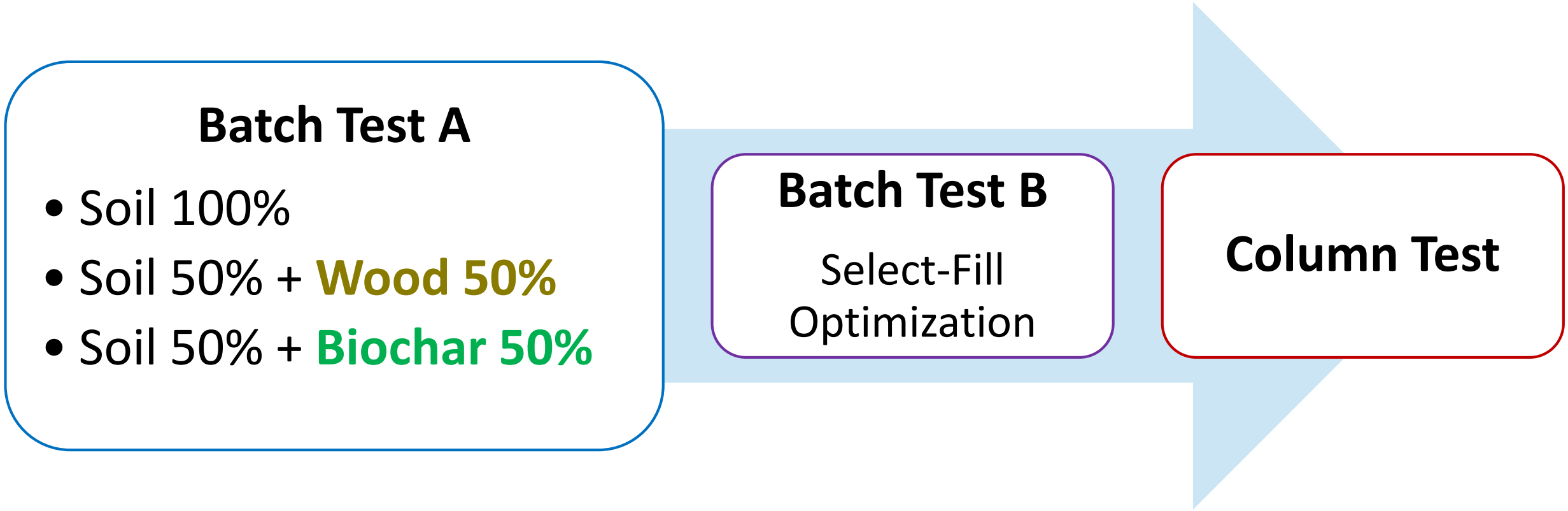


02

Experimental Approach

Experimental Approach

Batch and column tests in sequence



AECOM

Experimental Approach

- Main focus was on PFOA and PFOS, but analysis for other PFAS was also performed
- Analytical work conducted by a fix-based laboratory

Groundwater Analytes

Acronym	Analyte
PFOS	**Perfluorooctane sulfonic acid**
PFOA	**Perfluorooctanoic acid**
PFPeA	Perfluoropentanoic acid
PFHxS	Perfluorohexane sulfonic acid
PFHxA	Perfluorohexanoic acid
PFBA	Perfluorobutyrate
TOC	Total organic carbon

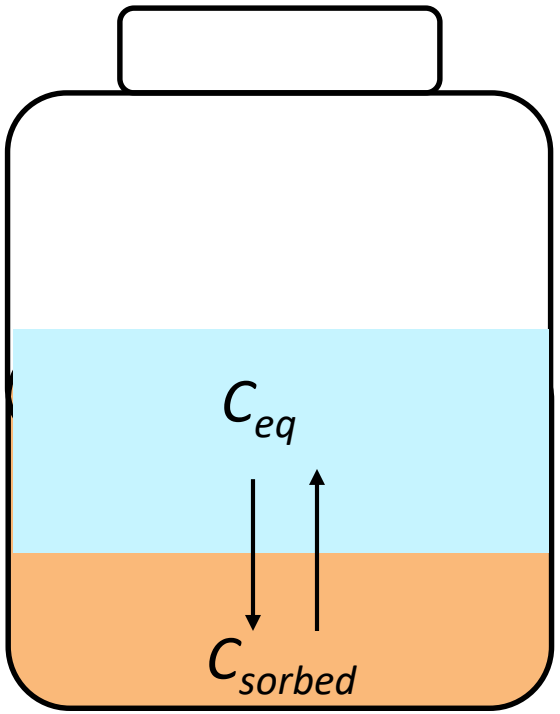
03

Batch Tests

Batch Tests: Methodology

- Adsorptive properties of:
  - Original select-fill
  - Select-fill with biochar
- HDPE containers with:
  - Site groundwater spiked with PFOA and PFOS
  - Select fill
- Measured PFAS and TOC in aqueous phase
  - Equilibrium concentration (C_{EQ})
  - Losses due to diffusion and degradation assumed negligible

$$M_{Initial} = C_{eq}V_{liquid} + C_{sorbed}M_{solids}$$



AECOM

Batch Test A: Experimental Design

- Contact time: 11 days
- Aimed at determining:
  - Adsorption removals
  - Freundlich isotherm
- Biochar A: 3 mm particle size
- Biochar B: 6 mm particle size

Test	Name	Soil (g)	Wood (g)	Biochar (g)	Water (mL)	PFOS/PFOA (ppb)
1	**100% Soil**	50	0	0	250	10, 100, 250, 500
2	**50% Wood**	25	25	0	250	10, 100, 250, 500
3	**50% Biochar A**	25	0	25	250	10, 100, 250, 500
4	**50% Biochar B**	25	0	25	250	10, 100, 250, 500

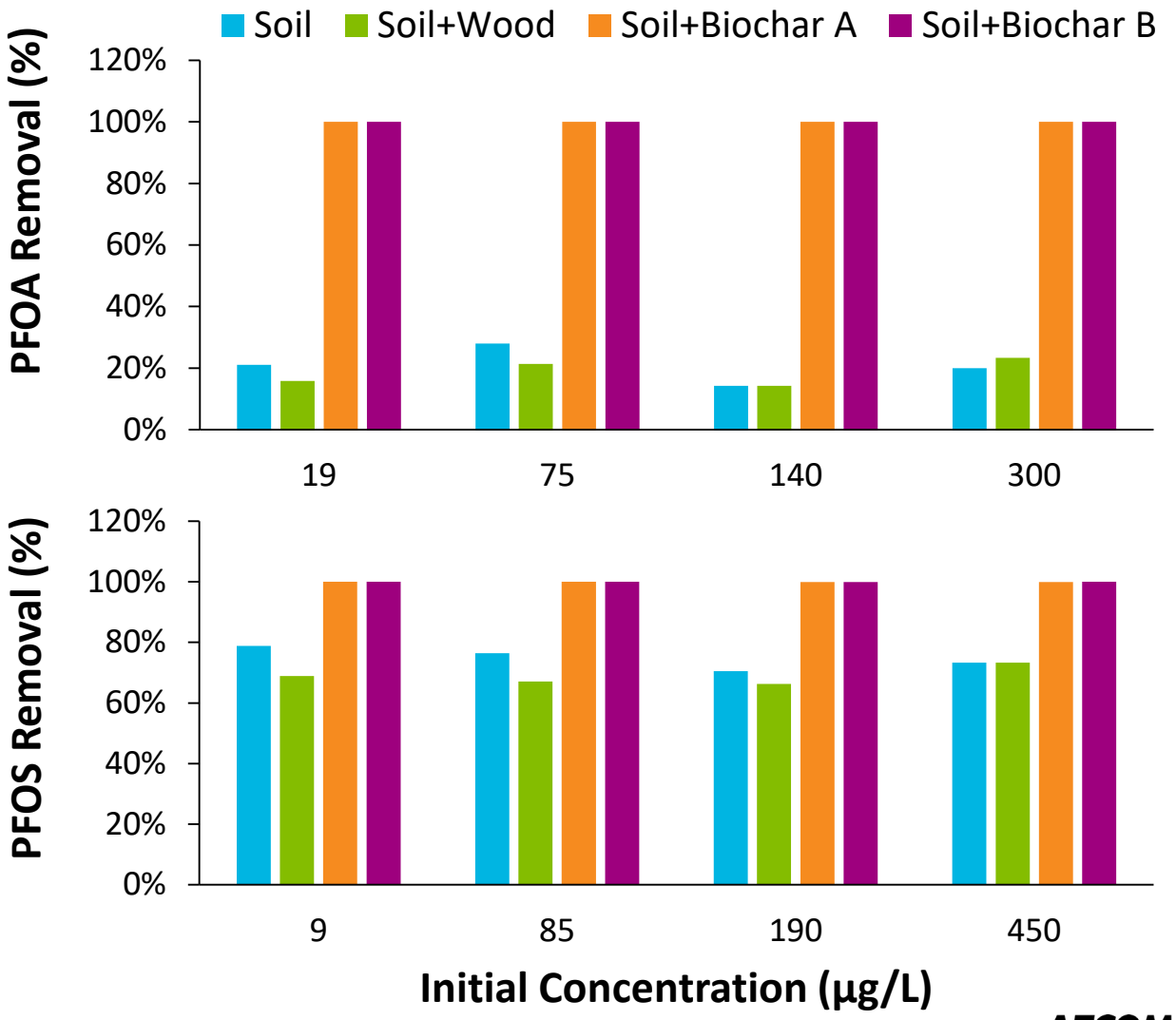
Batch Test B: Experimental Design

- Two organic content (OC) loadings:
  - Low = 5%
  - High = 20%
- Wood/Biochar ratio varied
- Biochar A selected since it is more cost-effective

Test	Description
1	Low OC = 3.75% Wood + 1.25% Biochar
2	Low OC = 4.25% Wood + 0.75% Biochar
3	Low OC = 4.75% Wood + 0.25% Biochar
4	High OC = 15% Wood + 5% Biochar
5	High OC = 17% Wood + 3% Biochar
6	High OC = 18% Wood + 2% Biochar

Batch Test A Results

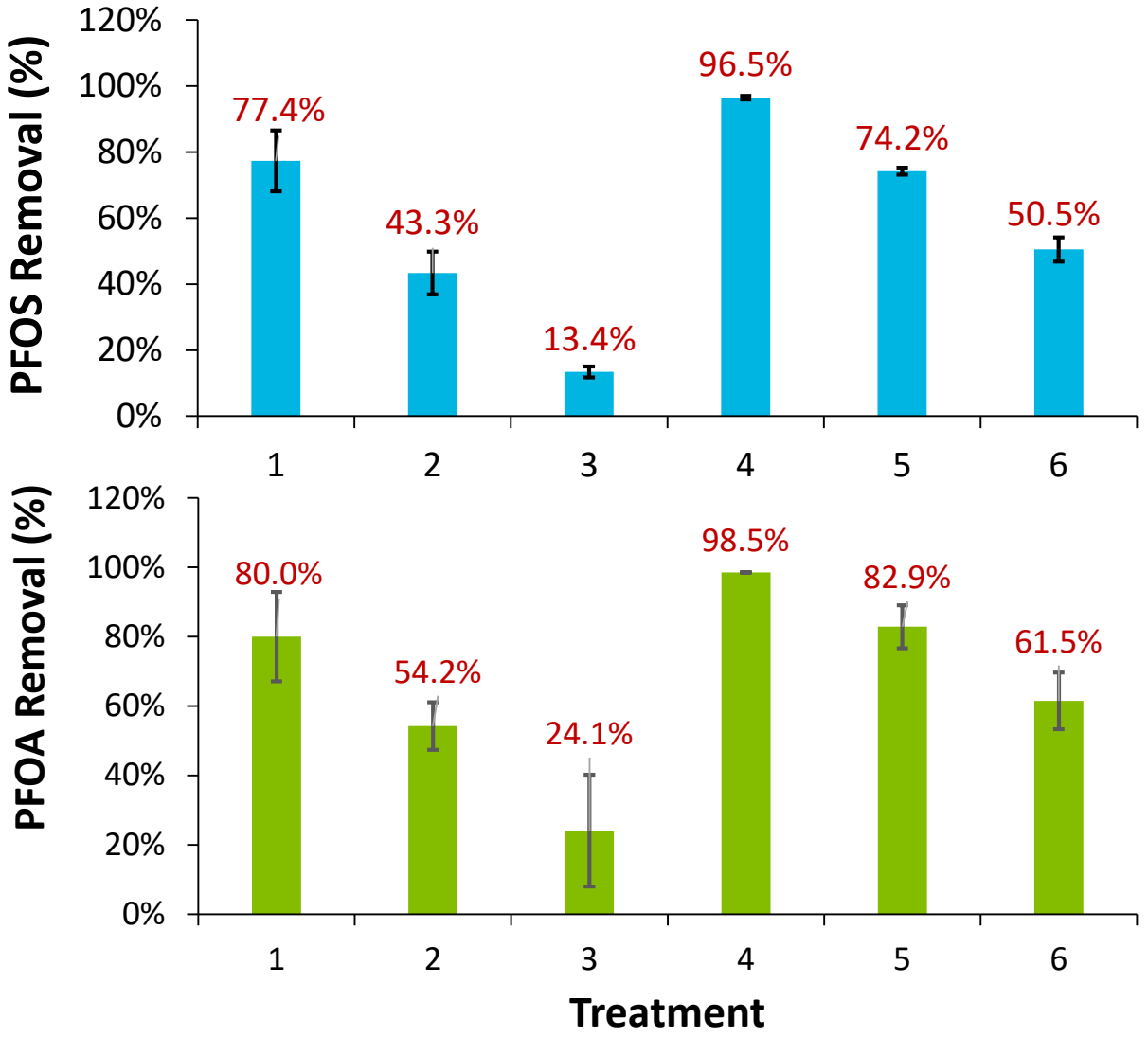
- Biochar treatments
  - Equilibrium concentration (Ceq) = 0 µg/L in some cases
  - Improved adsorption capacity dramatically
  - ~100% PFAS removal
  - No isotherm model fit
- Wood shavings did not have a significant impact



AECOM

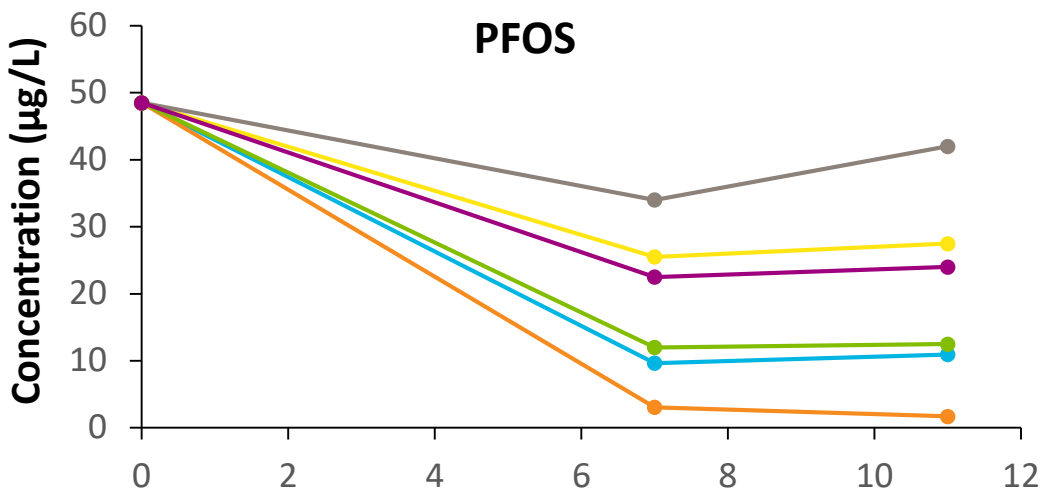
Batch Test B Results

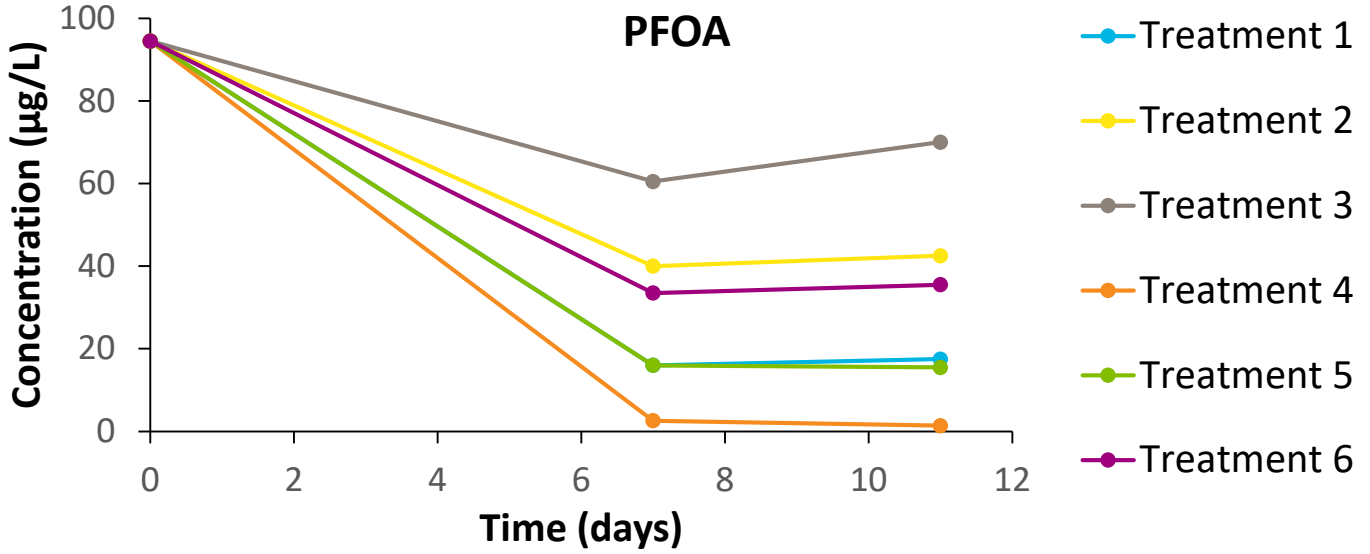
- Removals
  - Up to **96.5% PFOS** removal
  - Up to **98.5% PFOA** removal
- Higher biochar = higher PFAS removal
- Best recipe:
  - Test 4: **5% biochar** + 10% wood

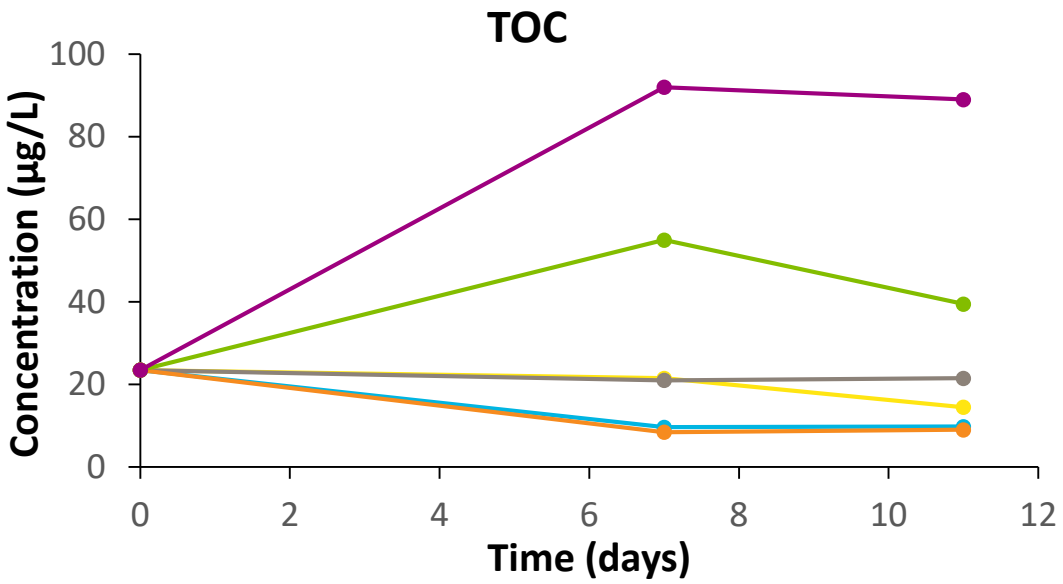


AECOM

Batch Test B Results







Test	Description
1	Low OC = 3.75% Wood + 1.25% Biochar
2	Low OC = 4.25% Wood + 0.75% Biochar
3	Low OC = 4.75% Wood + 0.25% Biochar
4	High OC = 15% Wood + 5% Biochar
5	High OC = 17% Wood + 3% Biochar
6	High OC = 18% Wood + 2% Biochar

AECOM

02

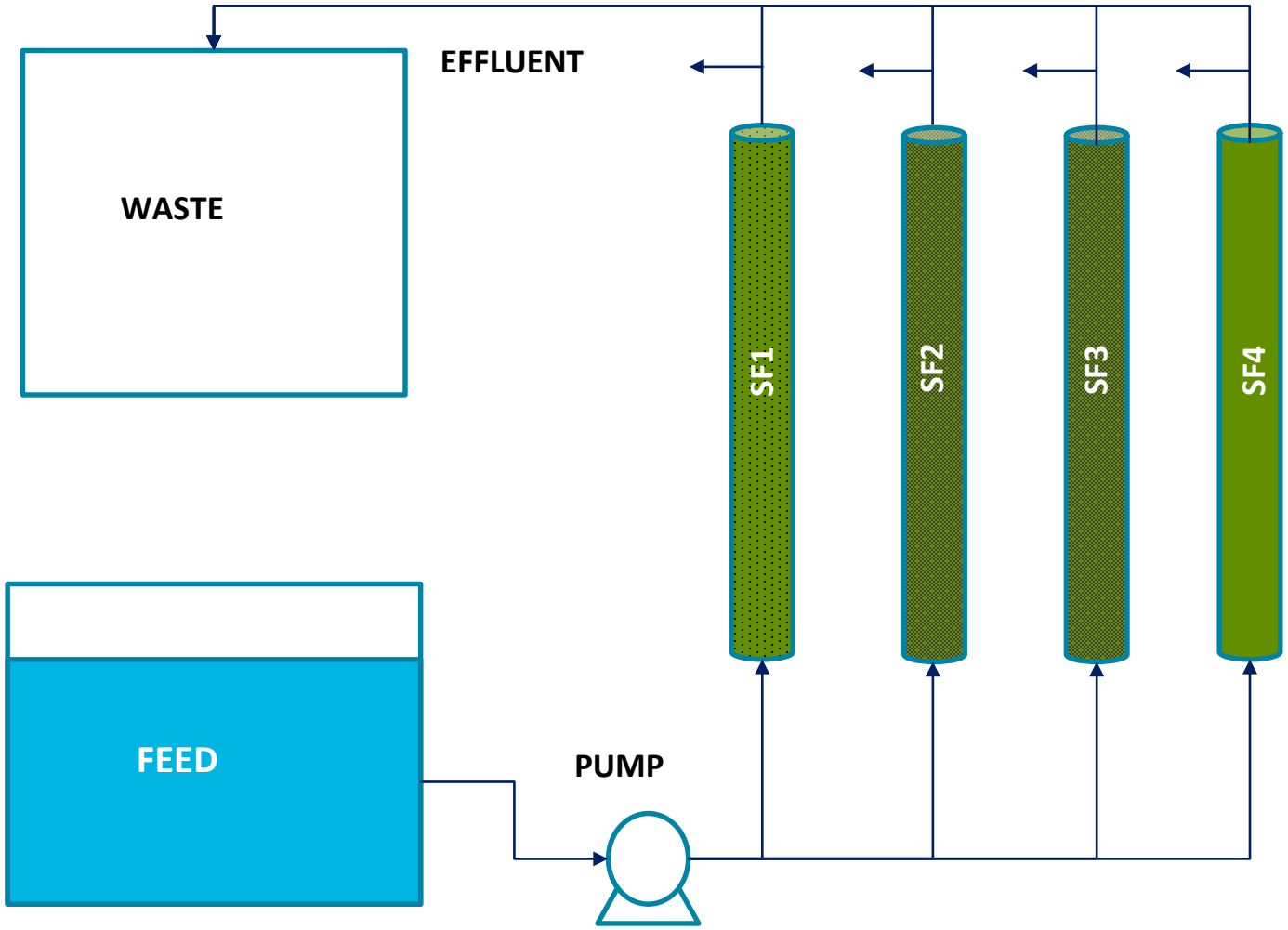
Column Test

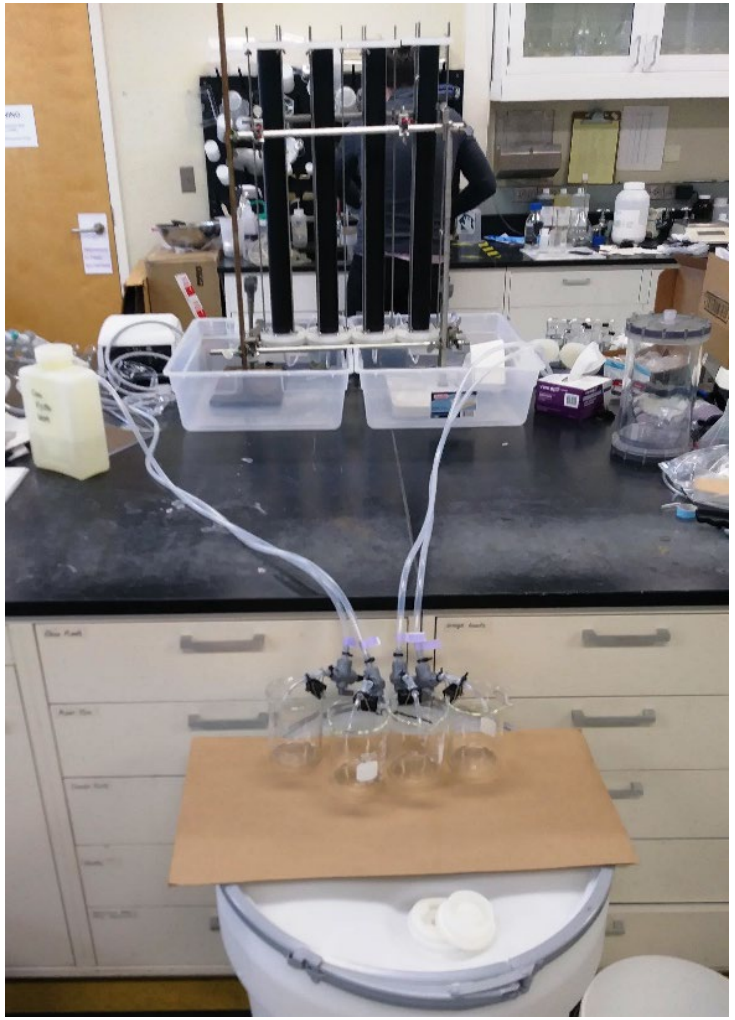
Column Test: Methodology

- PFAS removal under flow-through conditions
- Tested three select-fill media recipes and soil only
- Site groundwater
  - 300 ppb PFOA
  - 30 ppb PFOS
  - 100 ppb PFBA
- Set up:
  1. Pack columns
  2. Saturate with lab water
  3. Monitor flowrate
  4. Run site groundwater
  5. Take effluent samples
  6. Obtain breakthrough curves

Treatment	Soil Mix	Wood	Biochar
SF 1	85%	14%	1%
SF 2	85%	10%	5%
SF 3	95%	0%	5%
SF 4	100%	0%	0%

Column Test: Methodology



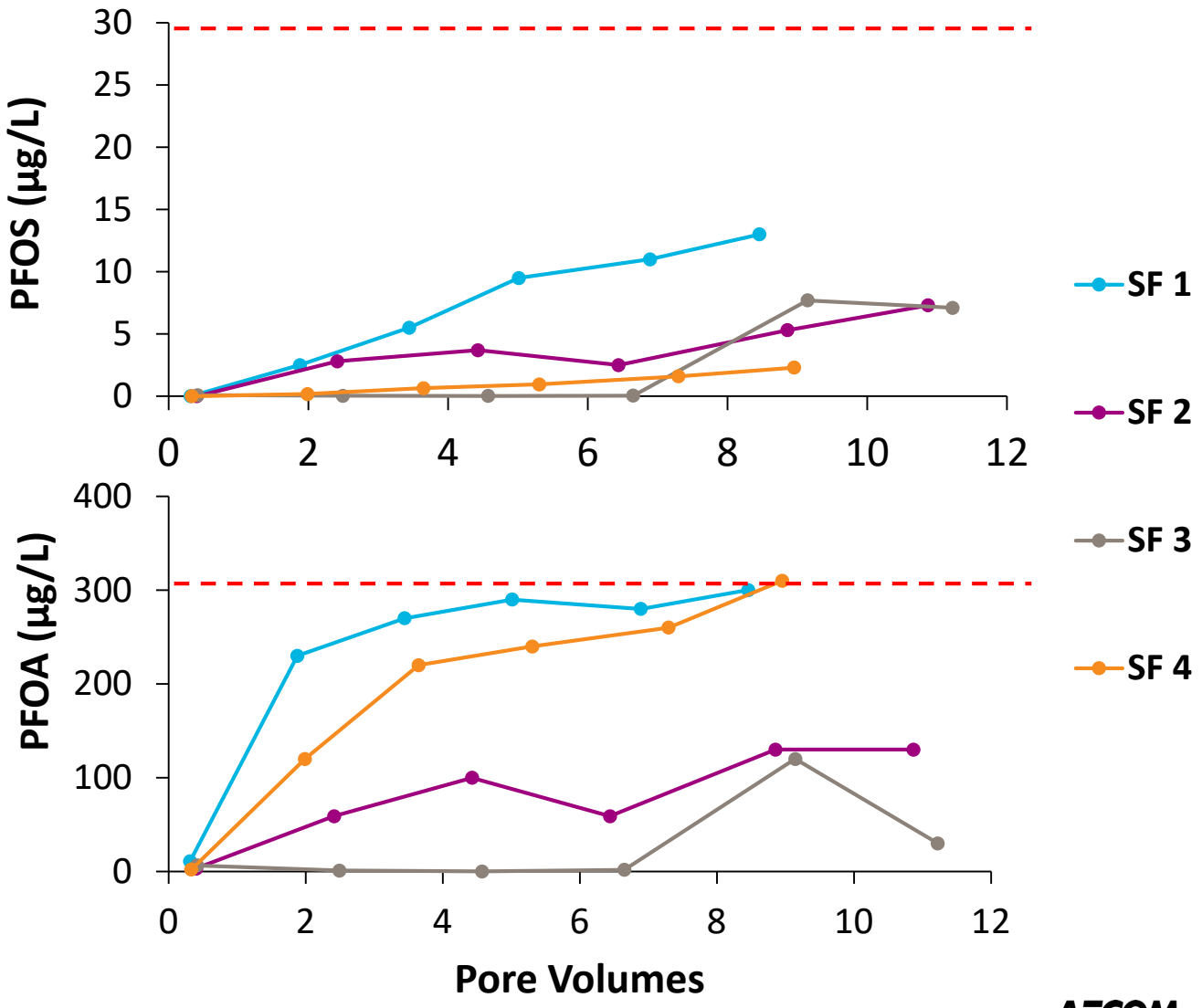


AECOM

Column Test: Results

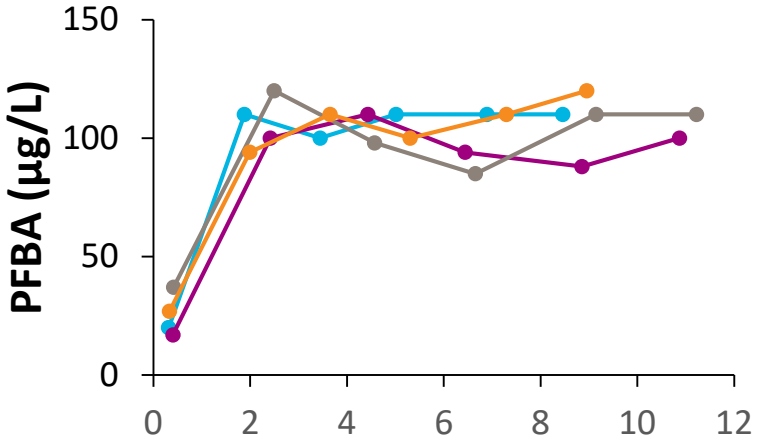
- SF3 had the longest PFAS retention overall
- PFOS better retained than PFOA
- Wood increased bulkiness and permeability

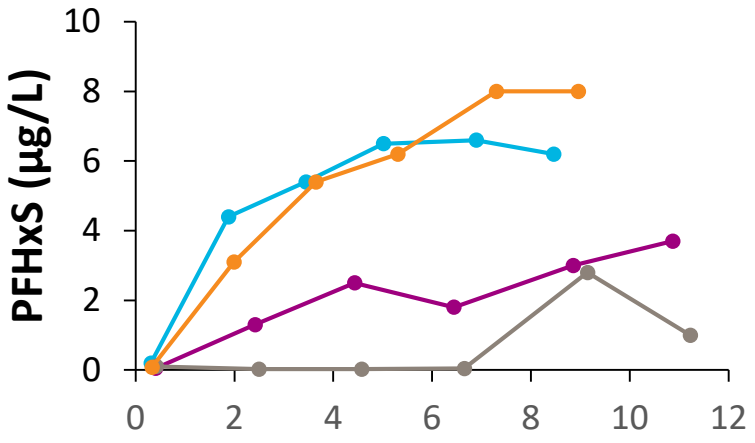
Treatment	Soil	Wood	Biochar
SF 1	85%	14%	1%
SF 2	85%	10%	5%
SF 3	95%	0%	5%
SF 4	100%	0%	0%

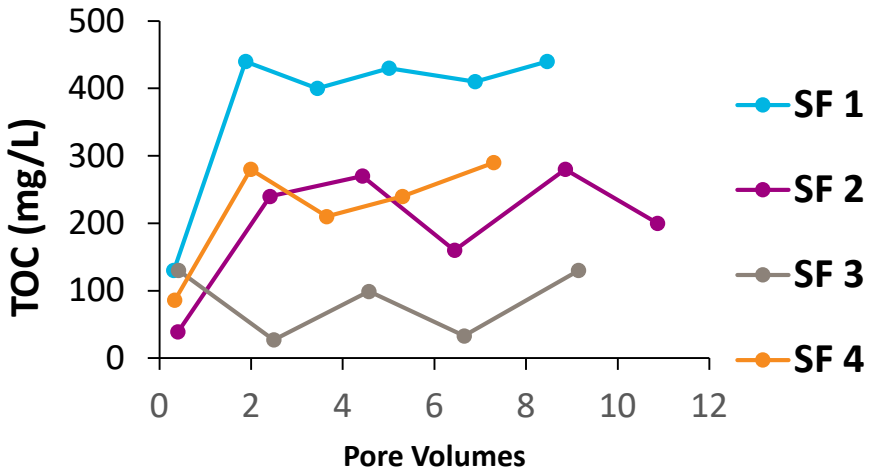


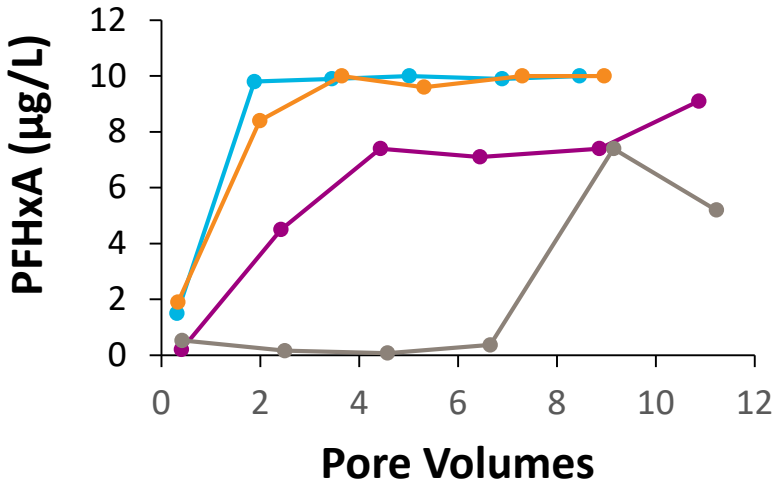
AECOM

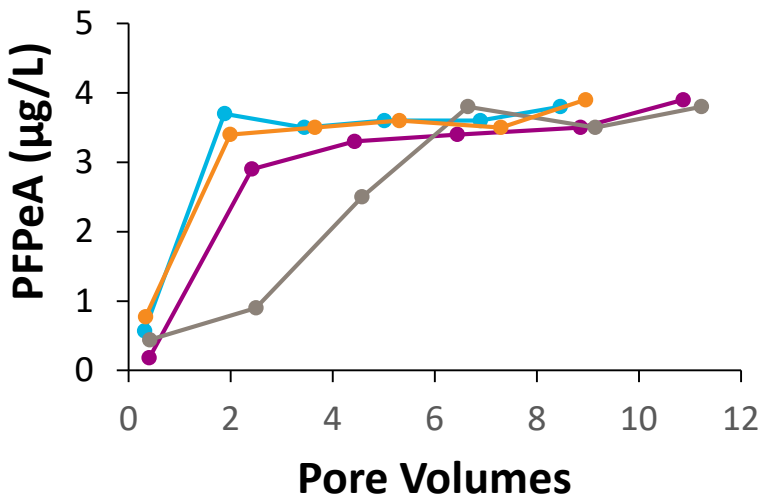
Column Test: Results









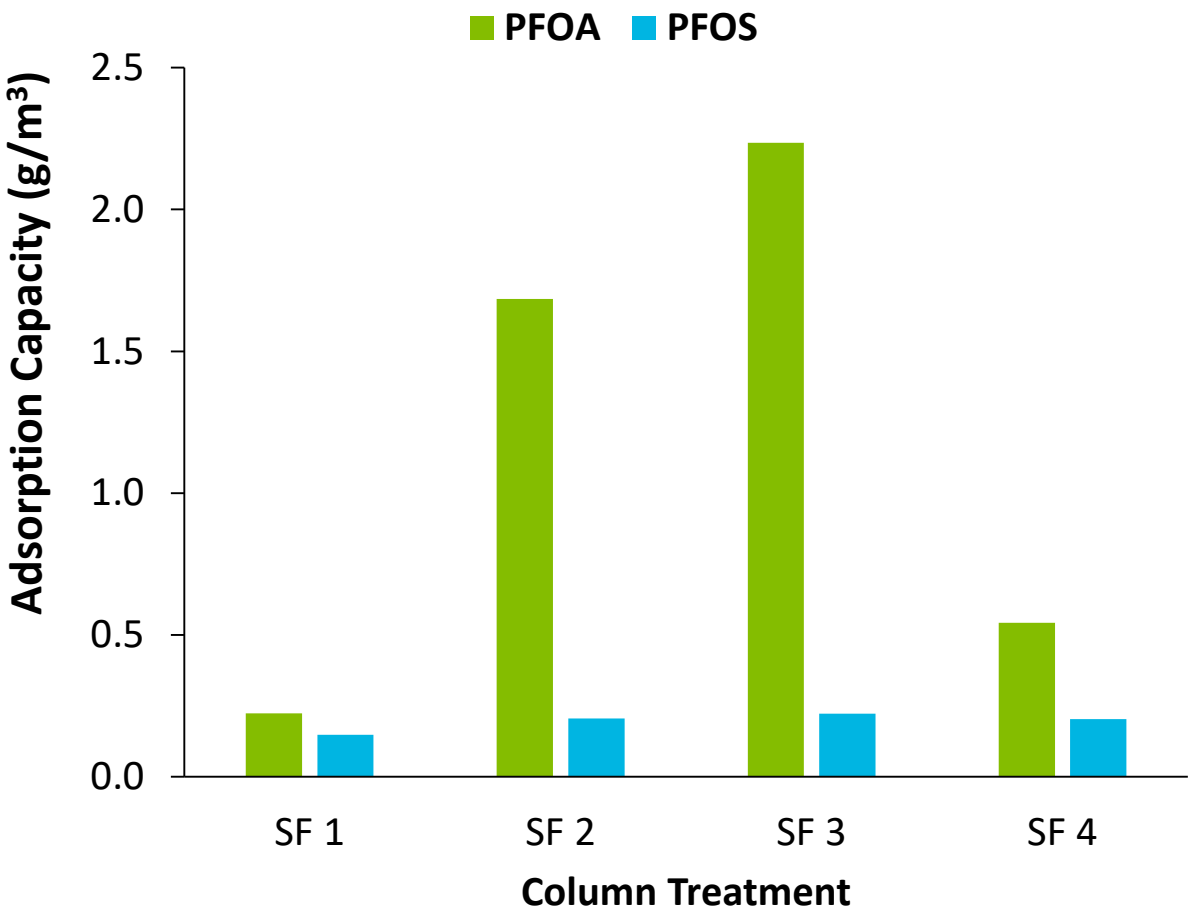


Treatment	Soil	Wood	Biochar
SF 1	85%	14%	1%
SF 2	85%	10%	5%
SF 3	95%	0%	5%
SF 4	100%	0%	0%

AECOM

- The best media composition was **SF3** with 5% biochar and 95% soil on a volumetric basis
- **SF1** and **SF2** media were bulkier and had higher porosities

Treatment	Soil	Wood	Biochar
SF 1	85%	14%	1%
SF 2	85%	10%	5%
SF 3	95%	0%	5%
SF 4	100%	0%	0%



AECOM

02

Conclusions and Ongoing Work

Conclusions

- Batch Test A, PFAS removal:
  - Soil + Wood = limited removal
  - Soil + Biochar = high removal ~96% to 98%
- Batch Test B:
  - Best media recipe: 15% wood and **5% biochar**
- Biochar is key for improved adsorption
- Wood is less relevant and affects bulkiness
- Column test:
  - Best media recipe **5% biochar** and 95% soil
  - Small changes in biochar content (1 to 5 %) affect adsorption greatly
  - PFBA and PFPeA had the poorest retention

Ongoing Work

- Tests including amendments at 10% and 20% doses:
  - Biochar
  - Granular Activated Carbon
  - Peat Moss
  - Modified Bentonite
- Columns will be run at longer pore volumes (60 to 90 PVs)
  - Obtain full saturation of adsorption sites
- Estimate longevity of select-fill media
- Cost-effectiveness analysis

Thank You!

T 512-419-5447
E francisco.barajas@aecom.com