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# Lysimeters to Evaluate PFAS Leaching at AFFF-Impacted Sites


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# Objectives

**Objective:** Improved insight into PFAS leaching from unsaturated soil

- **Evaluate methods for measuring PFAS porewater concentrations**
- **Assess impacts of site conditions (e.g., moisture; soil texture) on PFAS leaching**
- **Evaluate role of PFAS sorption at air-water interface**

# Approach

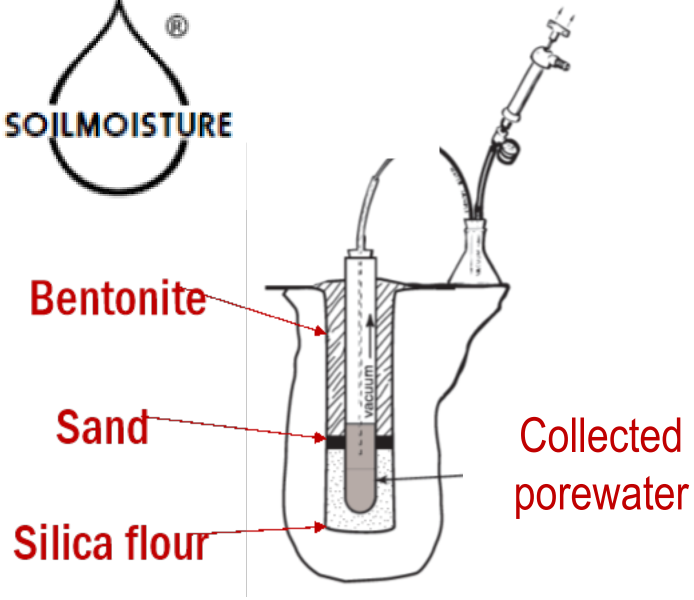
- **PFAS soil and porewater data at six AFFF-impacted sites**
  - 5 soil cores (3 ft x 3 ft)
    - *high-resolution soil sampling*
    - *cores for bench-scale testing*
  - 3 installed lysimeters (3 rounds of porewater sampling)
  - Target and suspect PFAS analyses

- **Parallel bench-scale testing**
  - Batch desorption testing (soil slurry with 3:1 Liquid:Solid ratio)
  - Porewater sampling using collected soil cores

# Methods

## Field

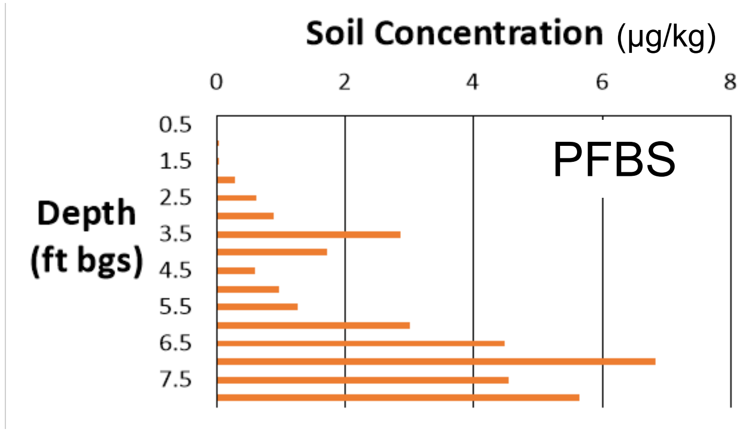
SOILMOISTURE

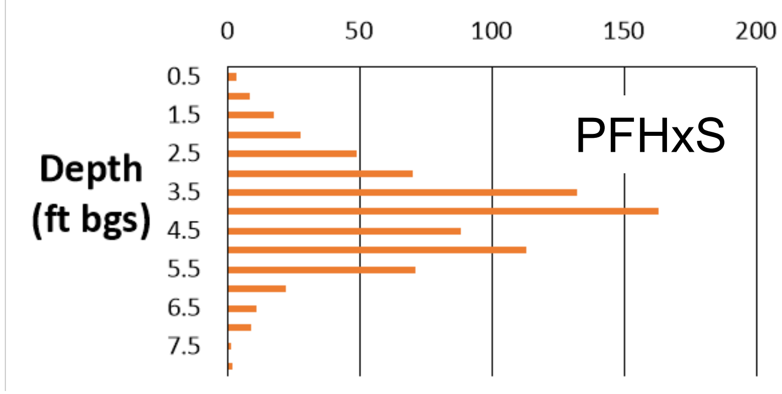


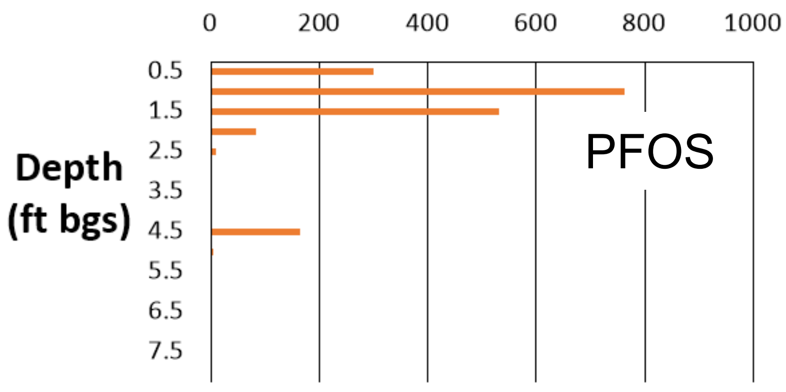

## Bench-Scale Soil Core

# PFAS Soil Concentration Profiles (Semi-Arid)

**AFA**

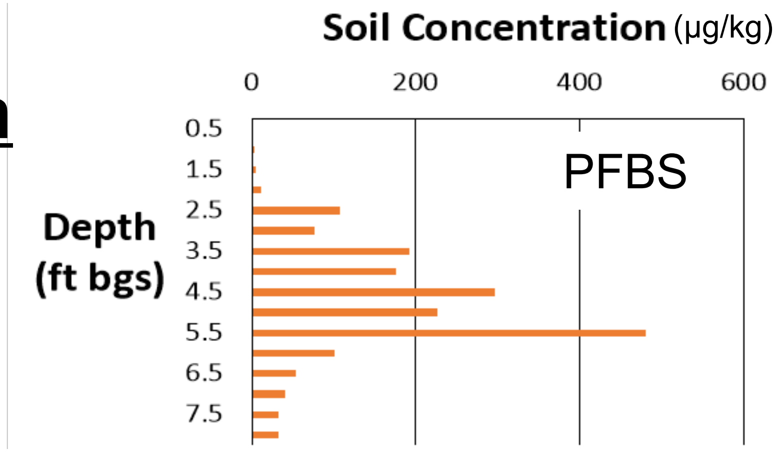


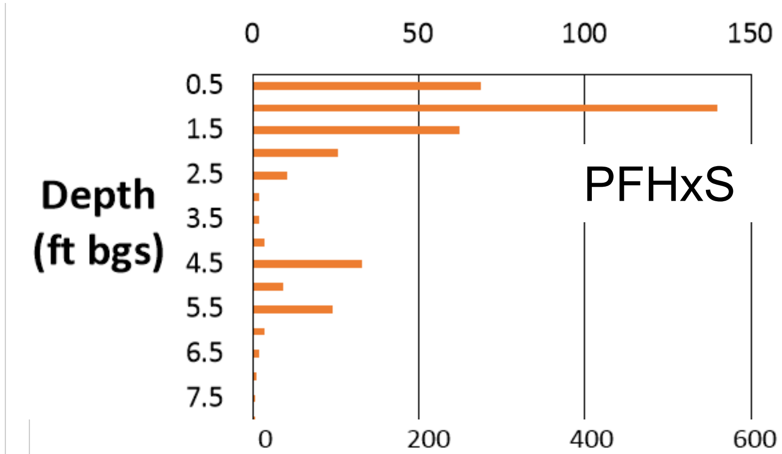



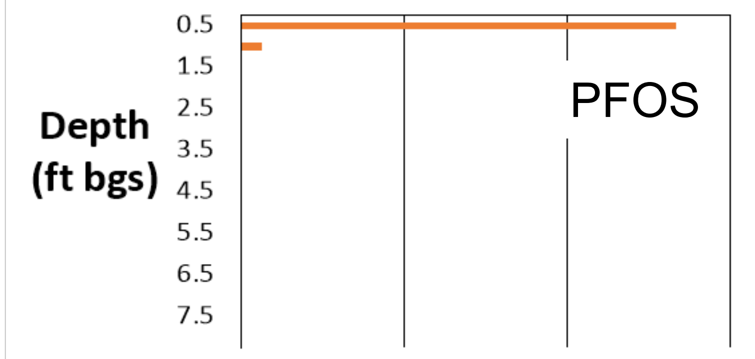




$K_d$ = 10 L/kg

**Peterson**

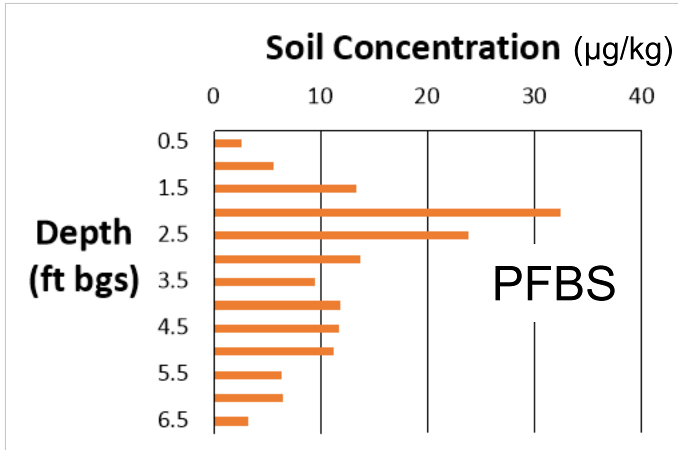


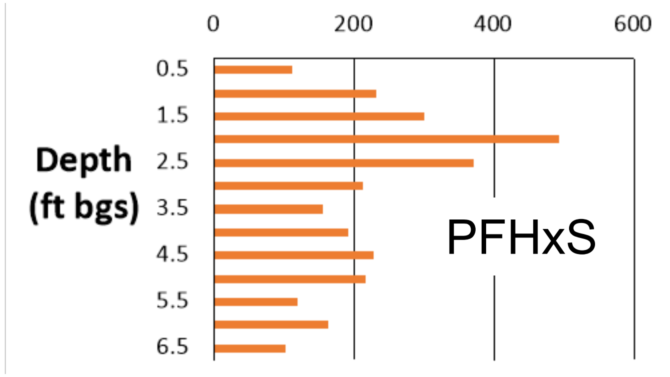



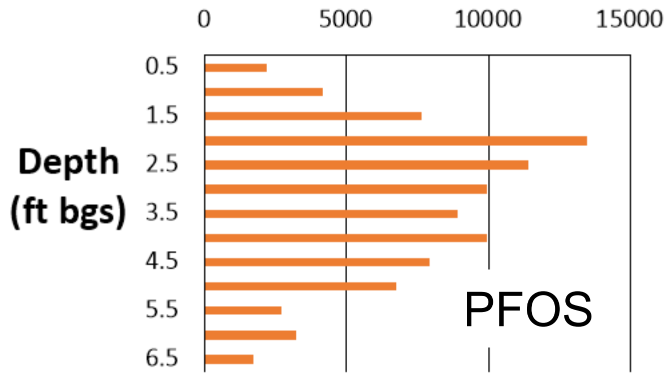




$K_d$ = 1.3 L/kg

# PFAS Soil Concentration Profiles (Non-Arid)



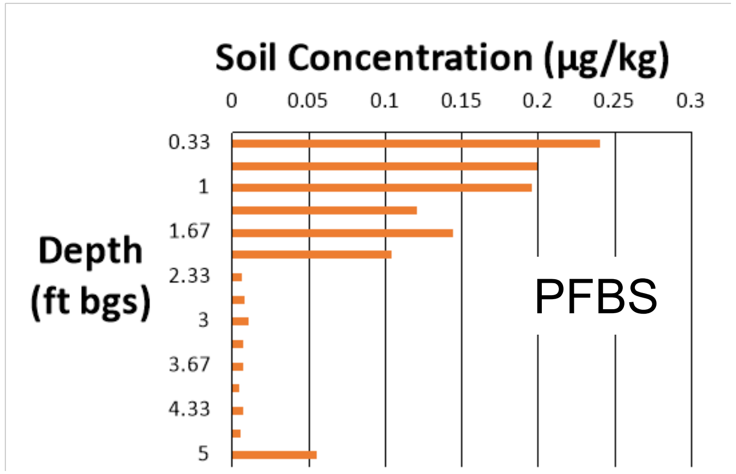



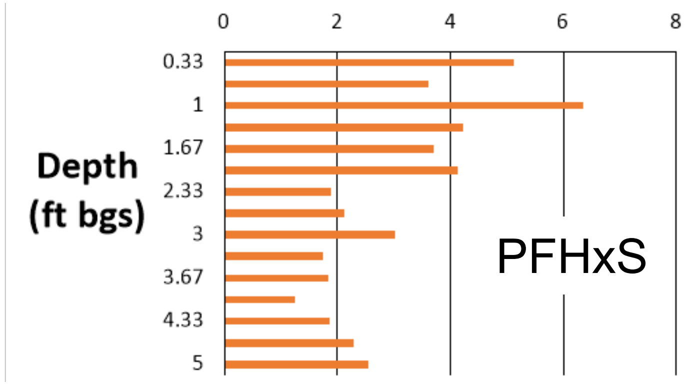

**Randolph**

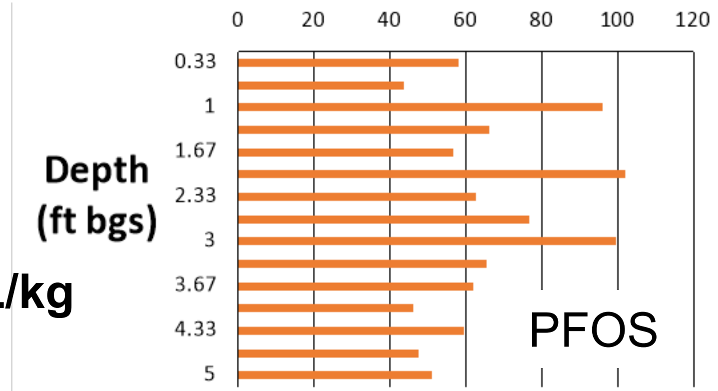
**East Coast1**

**$K_d$ = 6.6 L/kg**

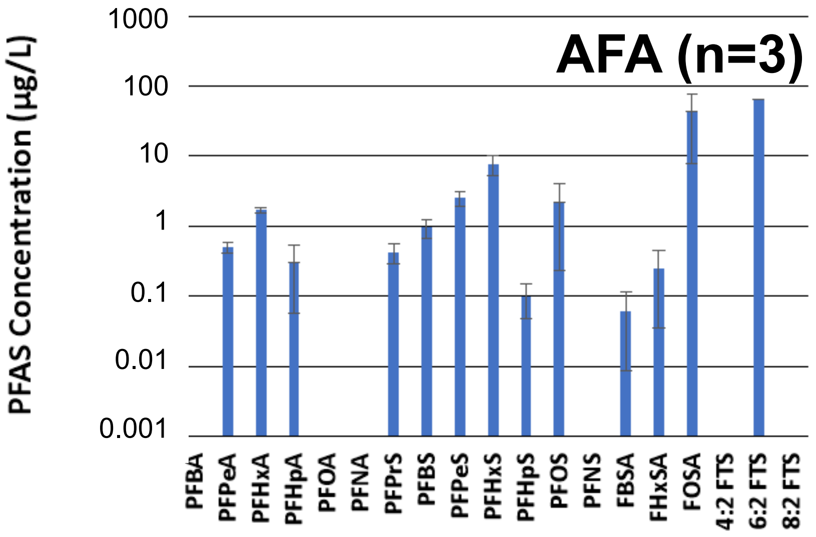
**$K_d$ = 3.3 L/kg**

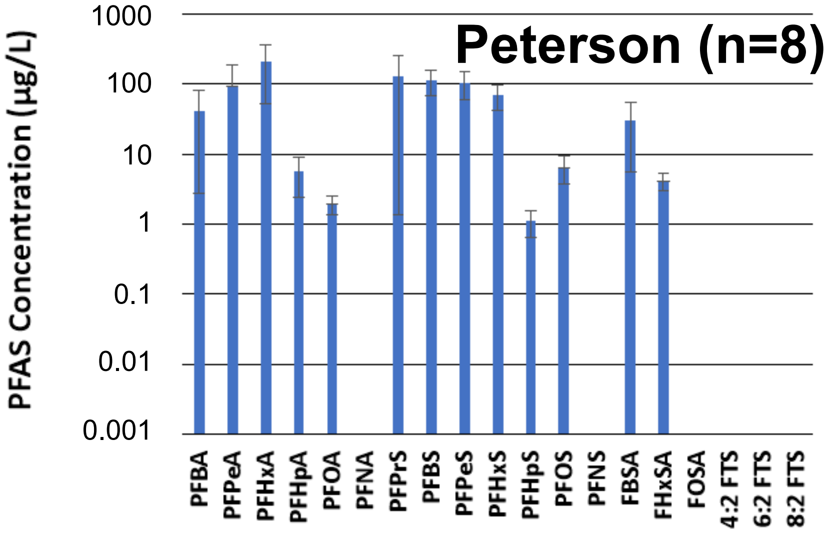


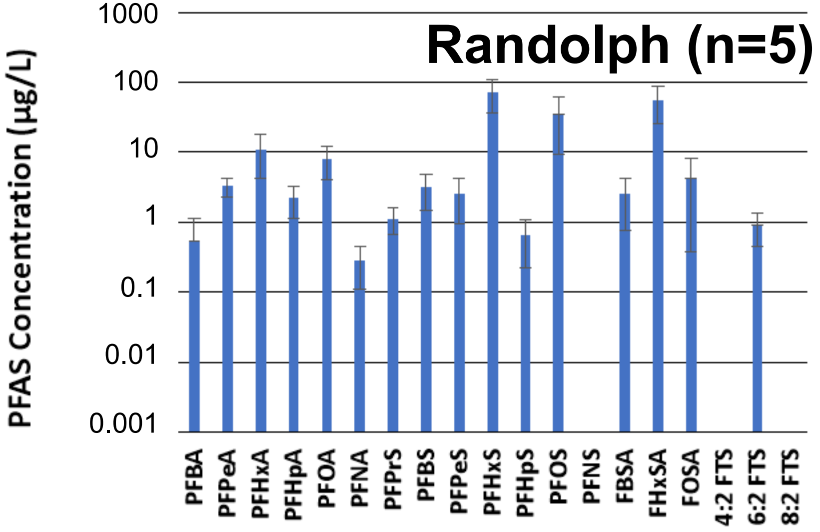



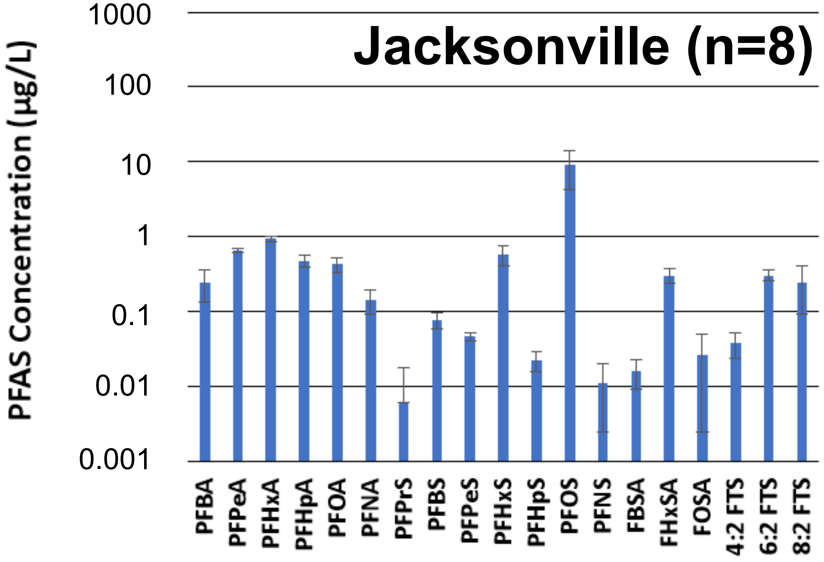



# Field Lysimeters: PFAS Concentrations

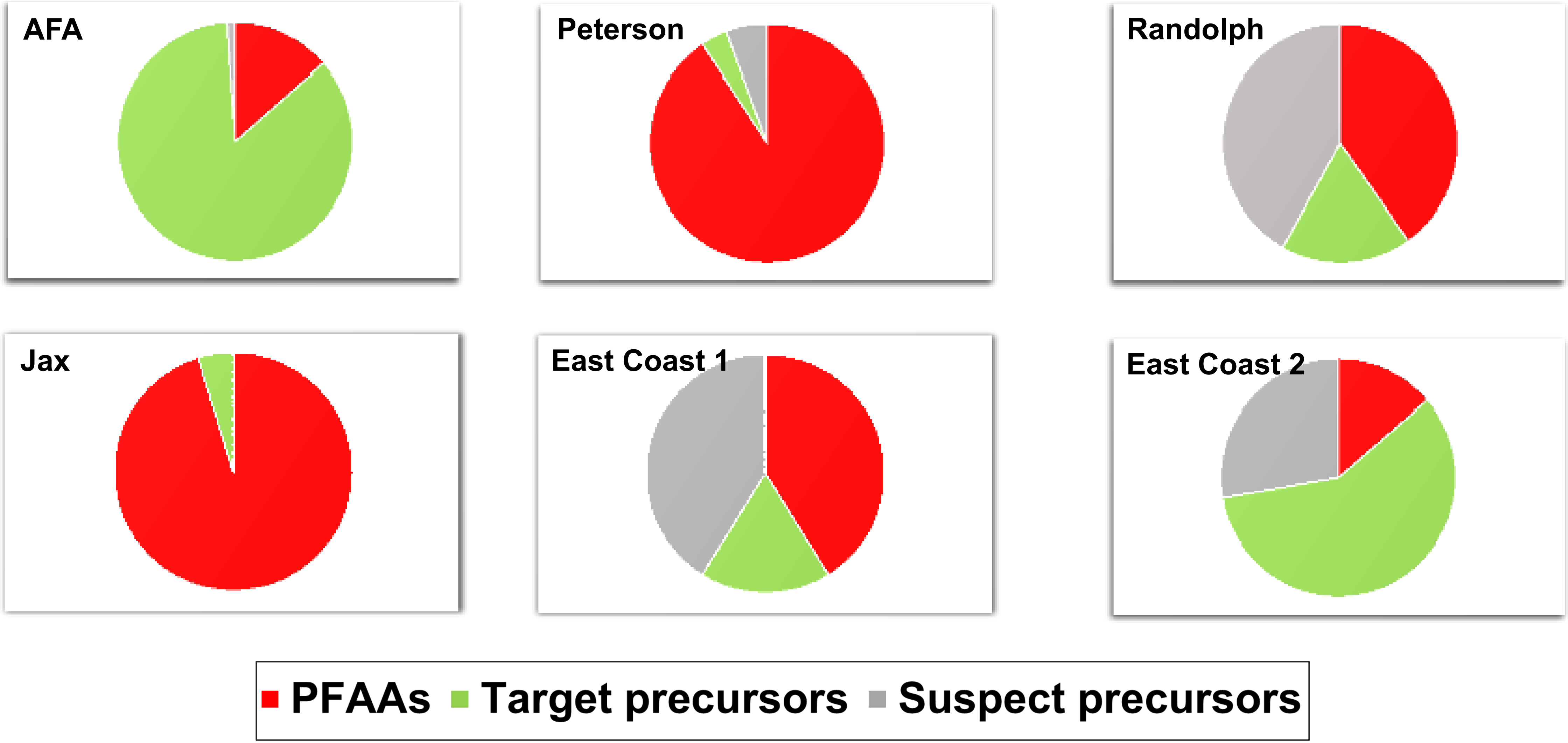


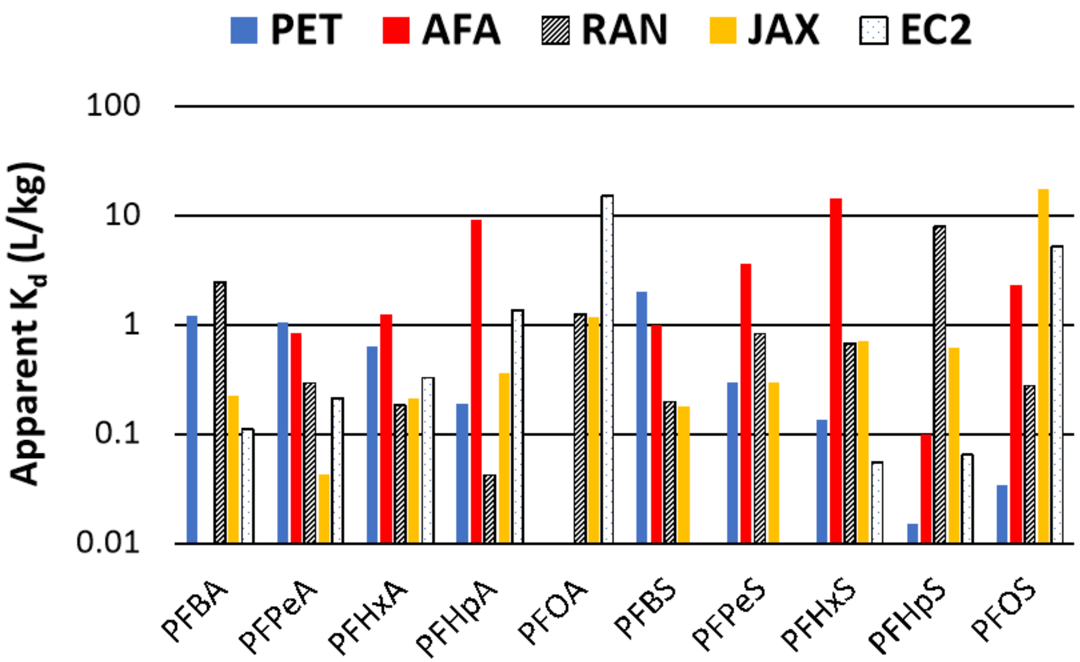



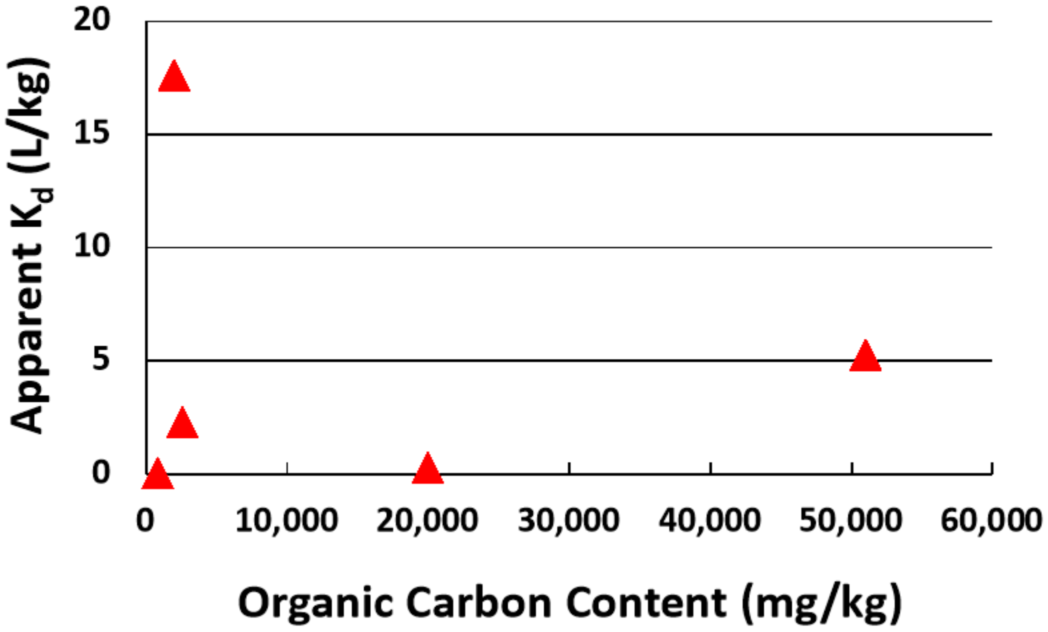
# PFAS Porewater Fluorine Distribution (% Fluorine Basis)

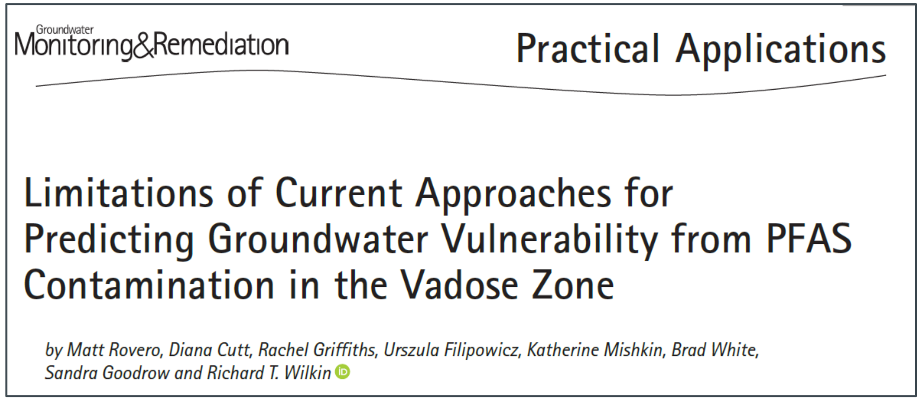


# Apparent $K_d$ Values




$K_d$ based on in situ porewater and soil data at lysimeter depth



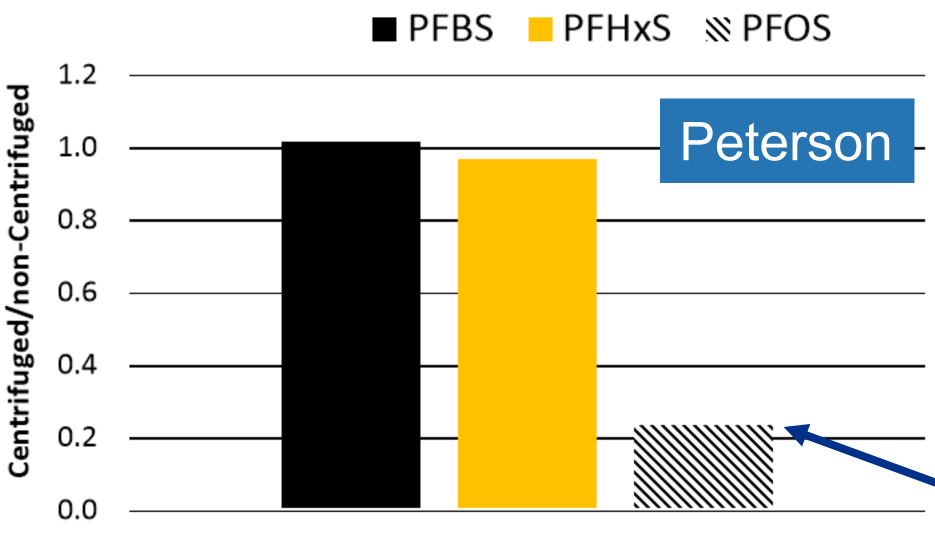


Groundwater Monitoring&Remediation

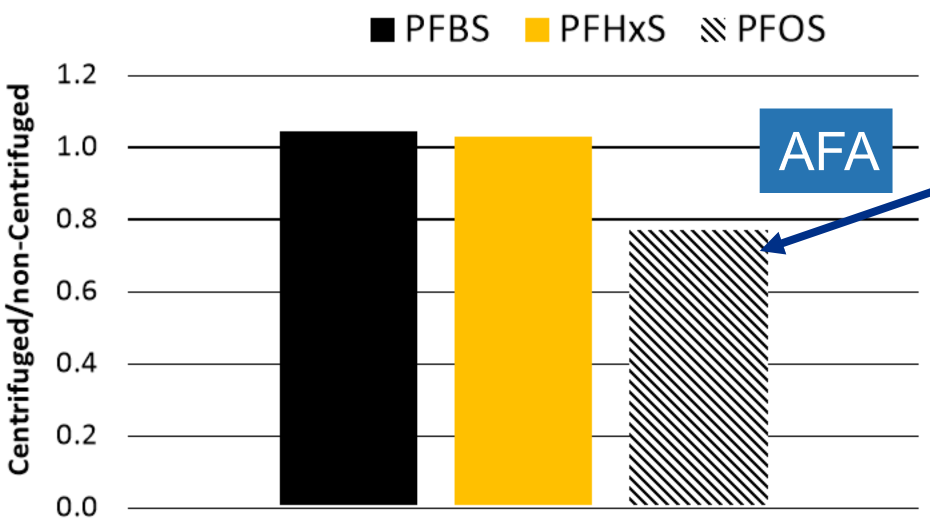
Practical Applications

Limitations of Current Approaches for Predicting Groundwater Vulnerability from PFAS Contamination in the Vadose Zone

*by Matt Rovero, Diana Cutt, Rachel Griffiths, Urszula Filipowicz, Katherine Mishkin, Brad White, Sandra Goodrow and Richard T. Wilkin*

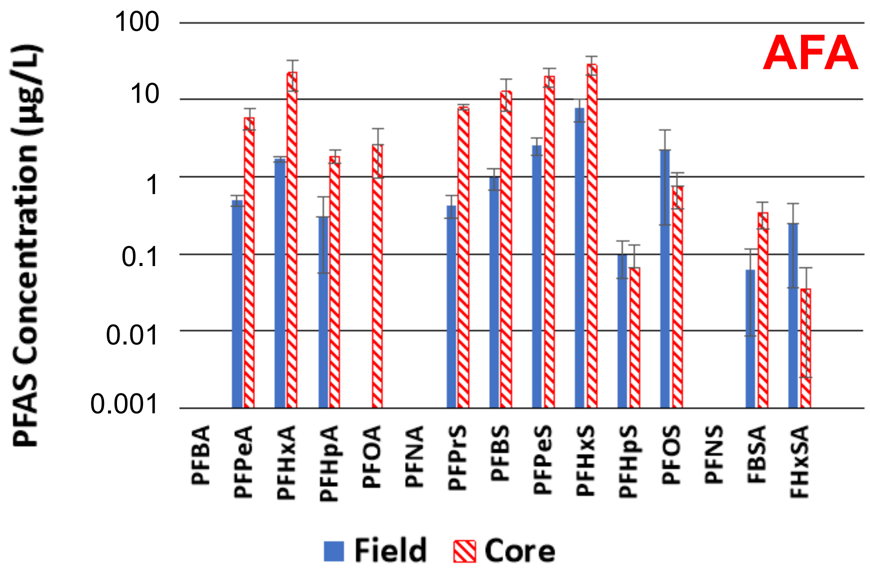
# PFAS Attachment to Natural Colloids

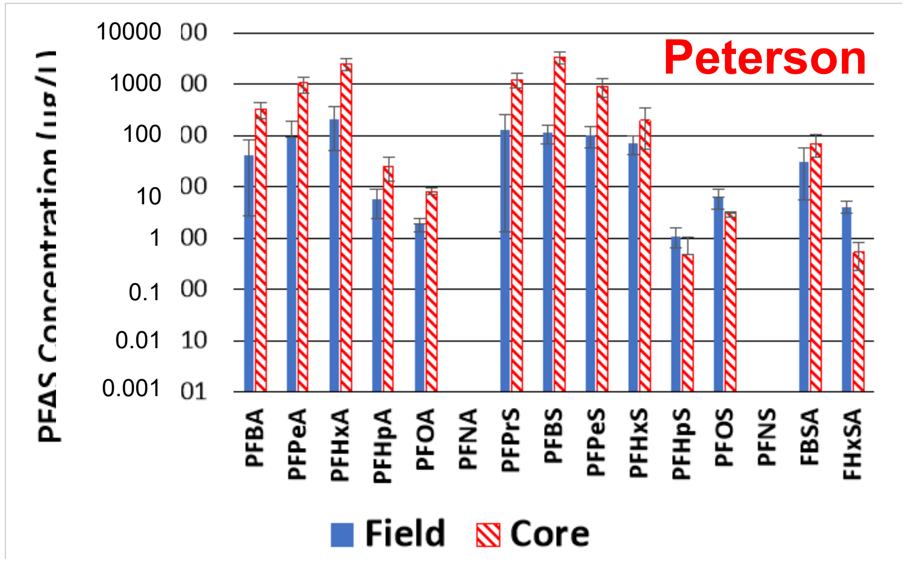



**Apparent colloidal impacts for PFOS in batch slurry systems**

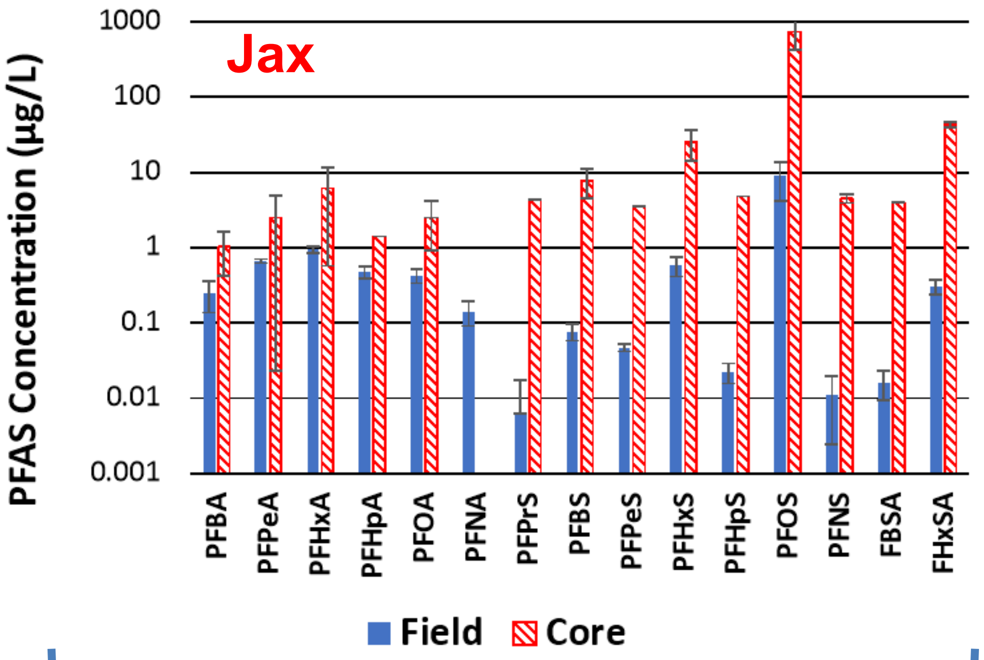
# Porewater: Field Lysimeters vs. Equilibrated Soil Cores

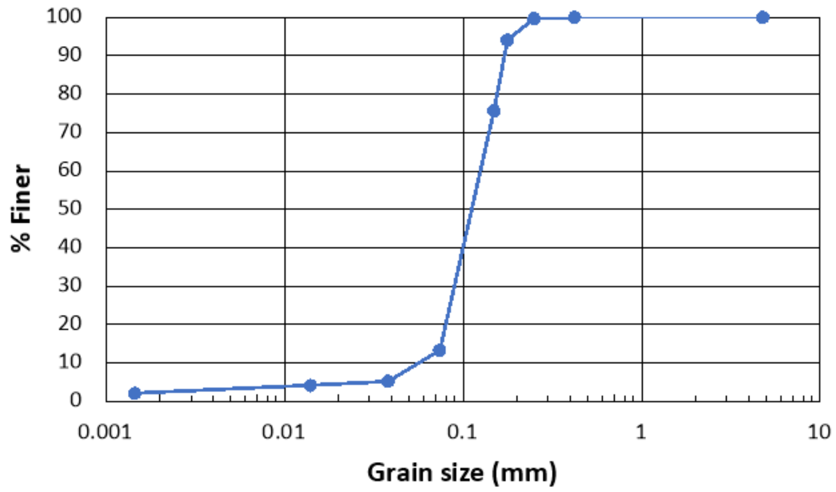


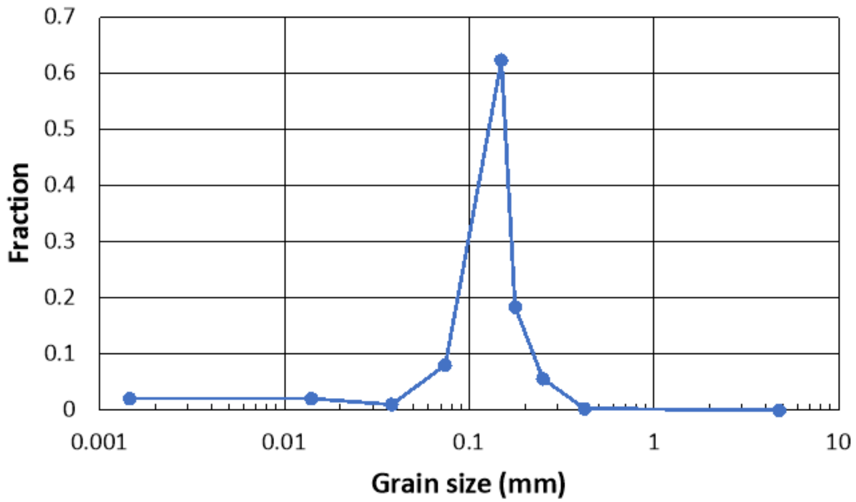




- Agreement between field and core samples suggests local equilibrium
- Short-chained PFAS less in field sample results in:
  - dilution
  - non-equilibrium

# Porewater: Field Lysimeters vs. Equilibrated Soil Cores



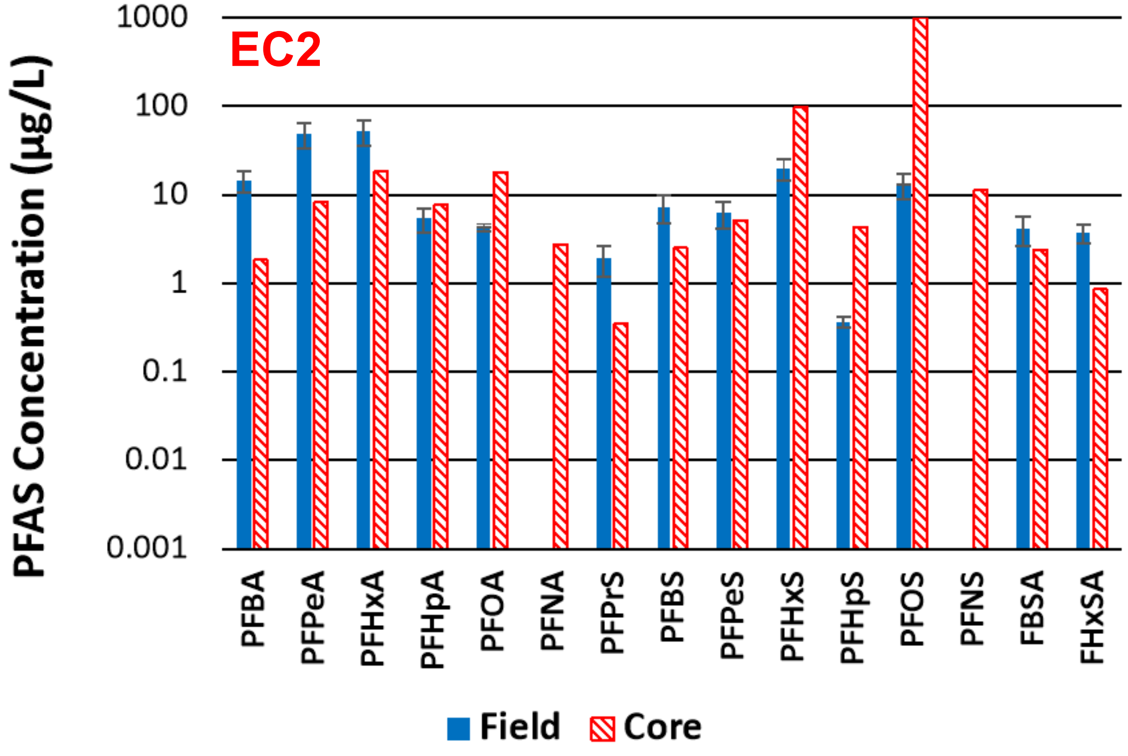




**Discrepancy in PFAS porewater suggests non-equilibrium**

- Heavy rain during sampling
- High pore saturations (~50%)

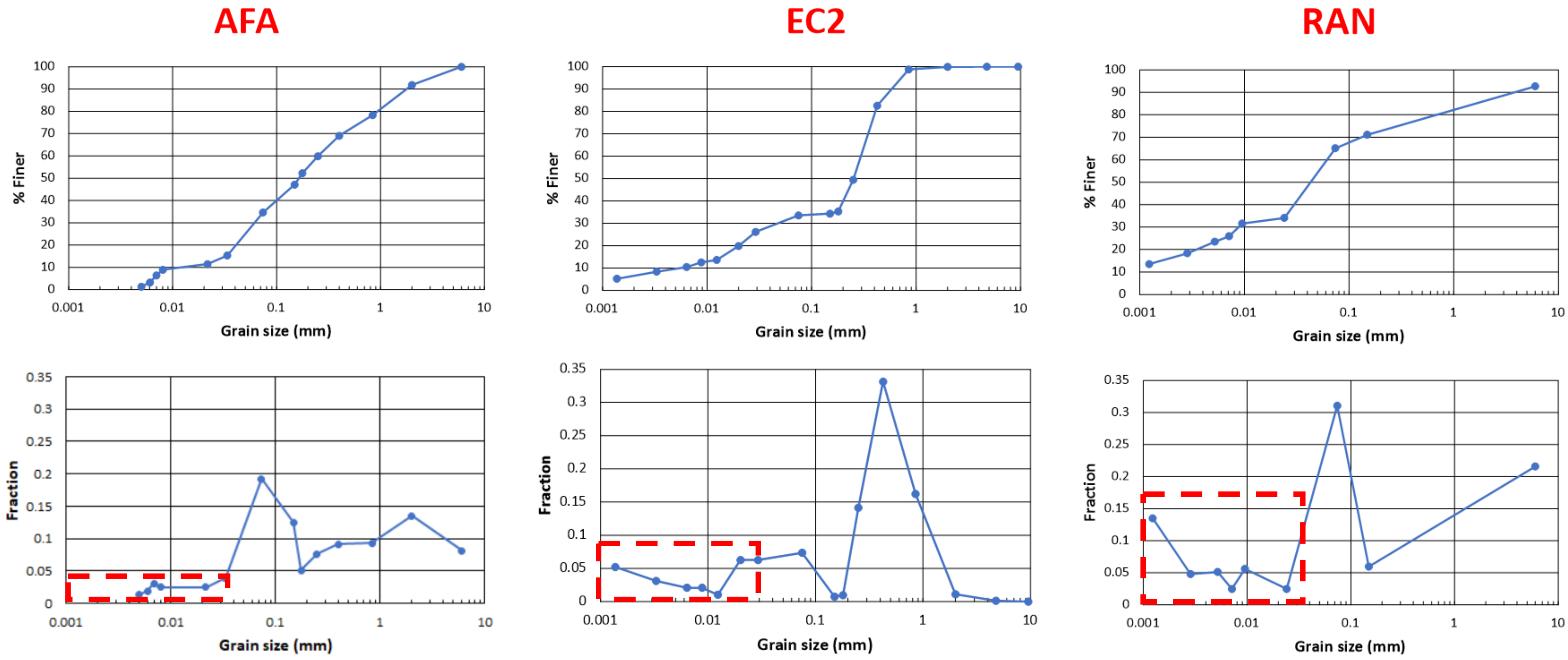
**Plan to re-install and sample lysimeters under low recharge**

# Porewater: Field Lysimeters vs. Equilibrated Soil Cores




Reasonable agreement, but long-chained PFAS are much greater in the core sample

# Small Grain/Pore Sizes Enhance Air-Water Interfacial Area




**Wetting the soil prior to the core porewater extraction in the EC2 soil has a substantial impact on the collapse of air-water interfaces**

# PFOS Phase Behavior

| Site | PFOS porewater concentration (μg/L) | Dissolved PFOS concentration in soil-water slurry (μg/L) |
|---|---|---|
| AFA | 2.2 | 0.084 |
| Peterson | 6.4 | 0.10 |
| Jax | 730* | 13 |
| Randolph | 36 | 1,000 |
| EC2 | 13 | 140 |

* *Using soil core porewater*

- These increases for RAN and EC2 are not observed for short-chained PFAS
- RAN and EC2 have substantial fraction of fine particles

# PFOS Phase Behavior

$$M_T = M_s + M_w + C_w a K_{aw}$$

| Site | $K_{aw}$ based on mass balance (cm) | Approximate $K_{aw}$ based on interfacial tension data (cm) |
|---|---|---|
| **Lakehurst** | 0.18 (confirmed using porewater sorption test) | Langmuir: 0.05 Freundlich: 0.25 |
| **Randolph** | $0.027 \leq K_{aw} \leq 0.95$ | Langmuir: 0.05 Freundlich: 0.15 |
| **EC2** | $0.013 \leq K_{aw} \leq 3.4$ | Langmuir: 0.02 Freundlich: 0.02 |
| **AFA** | $\leq 0.012$ | Langmuir: 0.05 Freundlich: 0.5 X |
| **Peterson** | $\leq 0.0008$ | Langmuir: 0.05 Freundlich: 0.4 X |
| **Jax** | $\leq 0.0025$ | Langmuir: 0.02 Freundlich: 0.02 X |

PFOS sorption at the air-water interface is often less than expected

# Summary

- **Reasonable repeatability among lysimeters**
- **Target and suspect precursors in porewater**
- **Local equilibrium for long-chained PFAS**
  - Exceptions during high percolation?
  - Exceptions for more complex geologies?
- **Impacts of air-water interfacial sorption are unclear**
  - Grain/pore size distribution matters
  - PFAS accumulation at the air-water interface may be inhibited in porewater

# Acknowledgement

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# Thank You

**Charles Schaefer, PhD**
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