BATTELLE 2023 SEDIMENTS CONFERENCE

Quantifying Aqueous Concentrations in Direct Contact with NAPL-Containing Sediment Using Porous Ceramic Samplers

Learning Lab: Tuesday and Wednesday, 2:40 to 3:05 p.m.

Presented by: Michael Gefell, PG; Dimitri Vlassopoulos, PhD; and Deirdre Reidy, Anchor QEA

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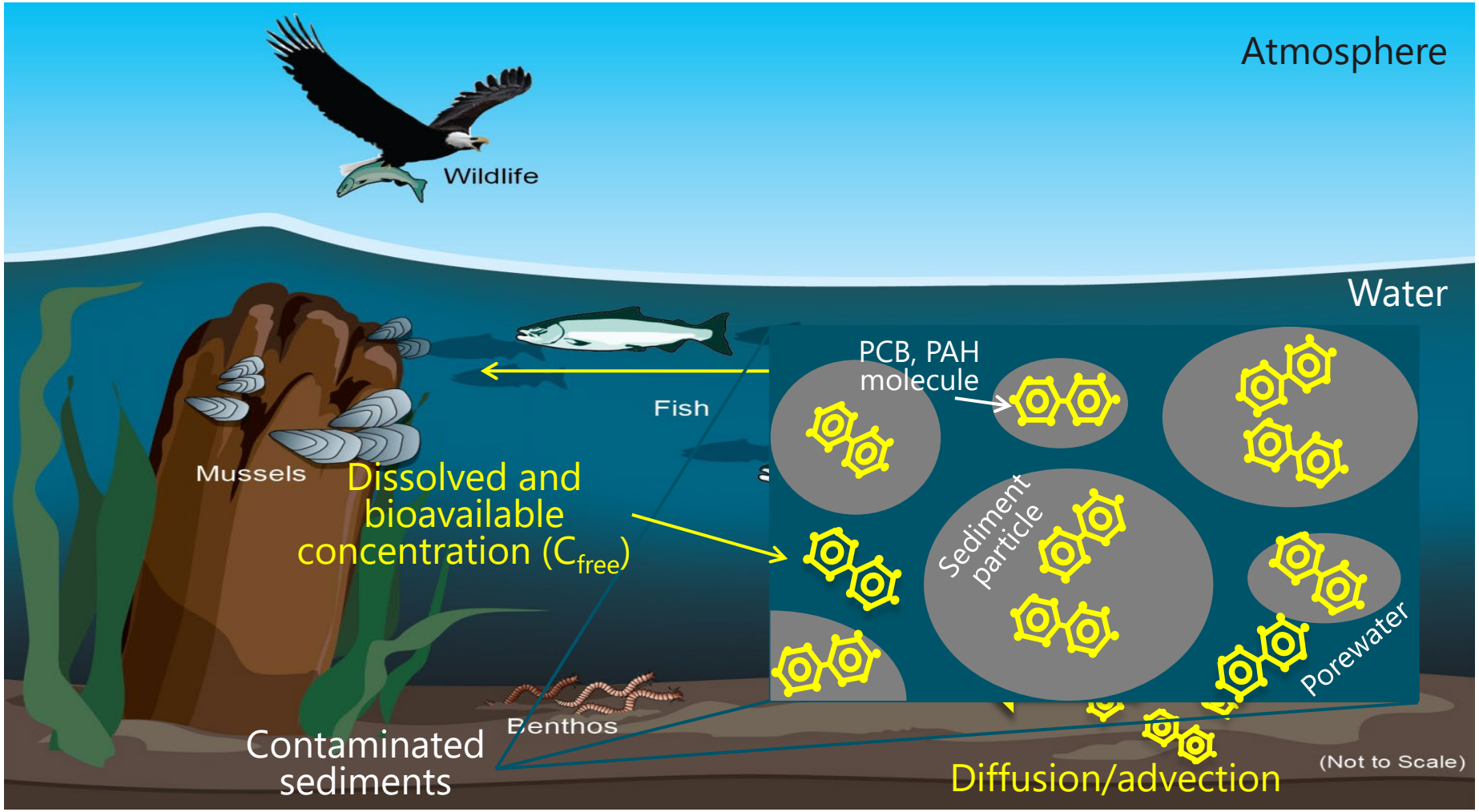
Importance of Accurate Porewater Samples



Source: Burgess 2013

Nonaqueous phase liquids (NAPLs) can exaggerate “aqueous” concentrations

NAPLs can enter push-point samplers and wells and coat/foul hydrophobic passive samplers

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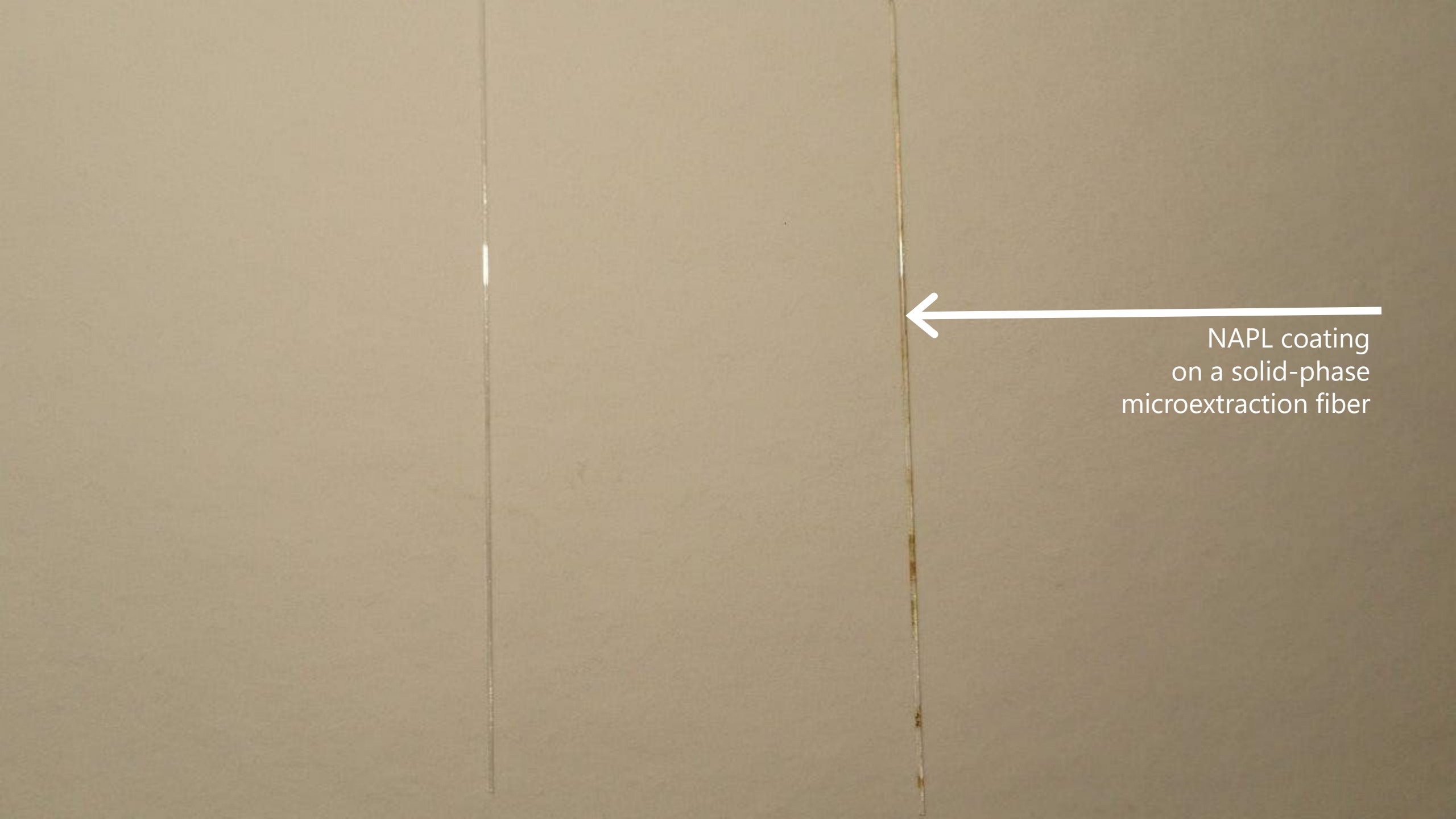
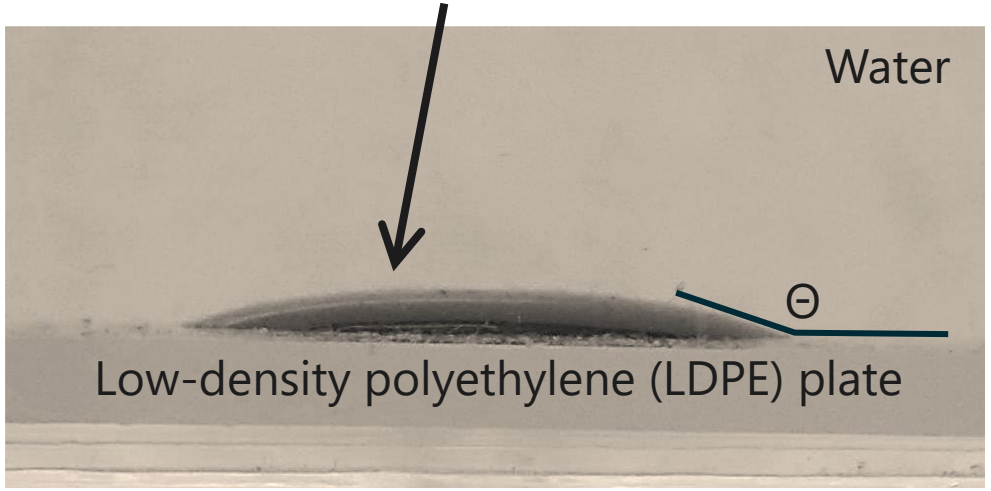

NAPL coating
on a solid-phase
microextraction fiber

Wettability Test—DNAPL on LDPE Underwater

Weathered, polycyclic aromatic hydrocarbon (PAH)-rich dense nonaqueous phase liquid (DNAPL)



1 day; contact angle (Θ) = 162°

NAPL is wetting phase

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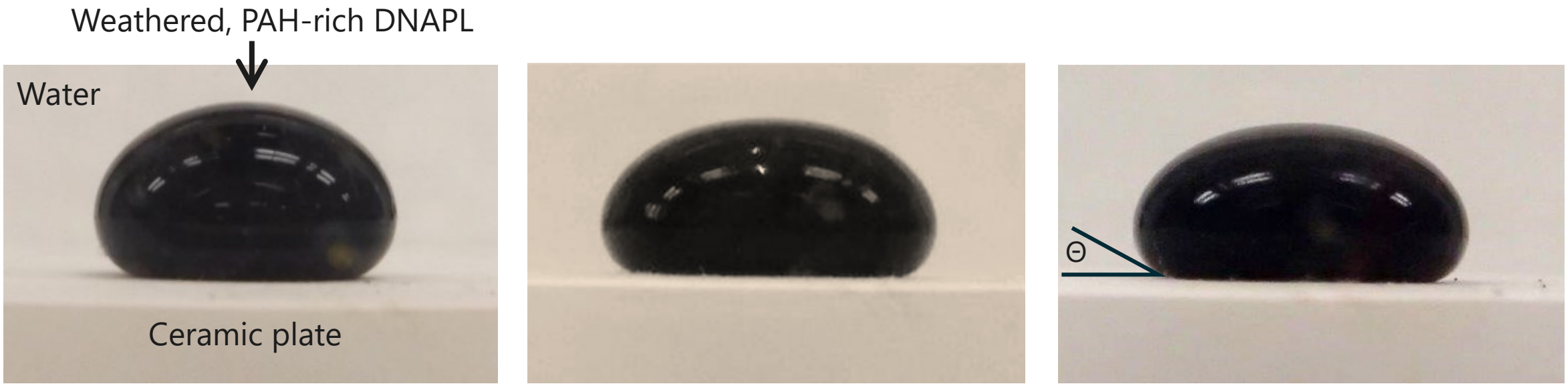
Wettability Test—Same DNAPL on Porous Ceramic Plate Underwater



6 days

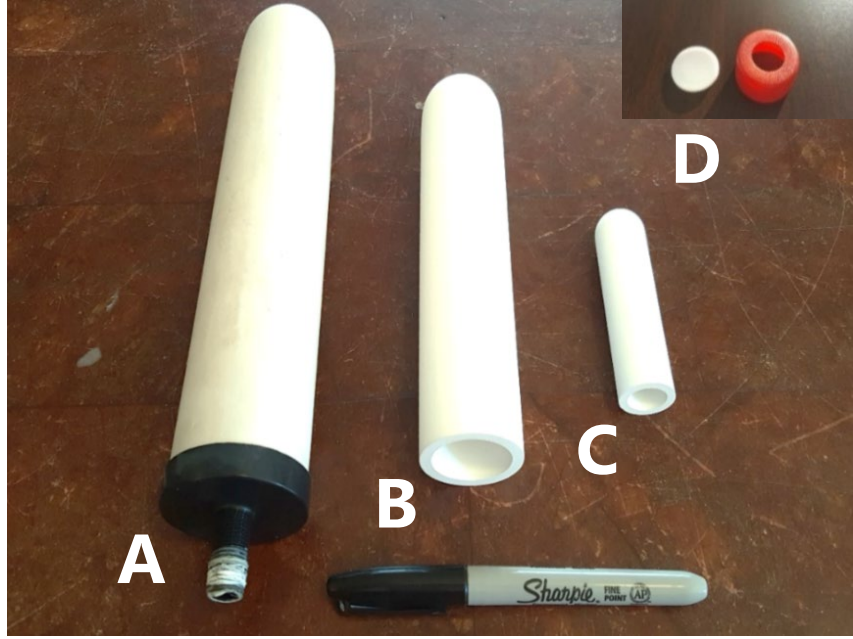
15 days

100 days

Contact angle Θ = 24°

NAPL is non-wetting phase

Porous Ceramics are NAPL Barriers



ID	Shape	Pore Size (µm)	K (cm/s)	Porosity	Length (cm)	Outer Diameter (cm)	Approximate Cost (U.S. dollars)
A*	Tube	11.2	8×10^{-5}	0.22	24	4.9	$25
B	Tube	2.5	9×10^{-6}	0.45	17	4.0	$110
C	Tube	2.5	9×10^{-6}	0.45	8.9	2.2	$50
D	Disk	2.5	9×10^{-6}	0.45	NA	2.2	$50

Notes:

*: Physical parameters estimated based on laboratory testing by Anchor QEA. All others provided by manufacturer.

K: hydraulic conductivity

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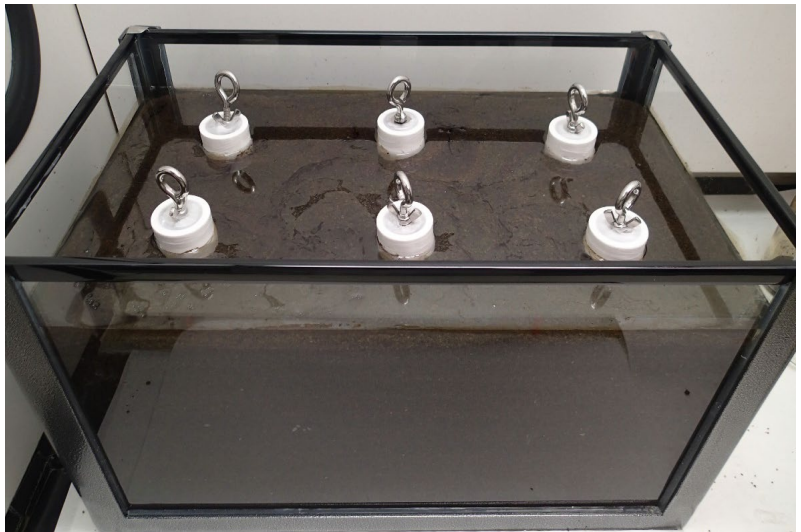
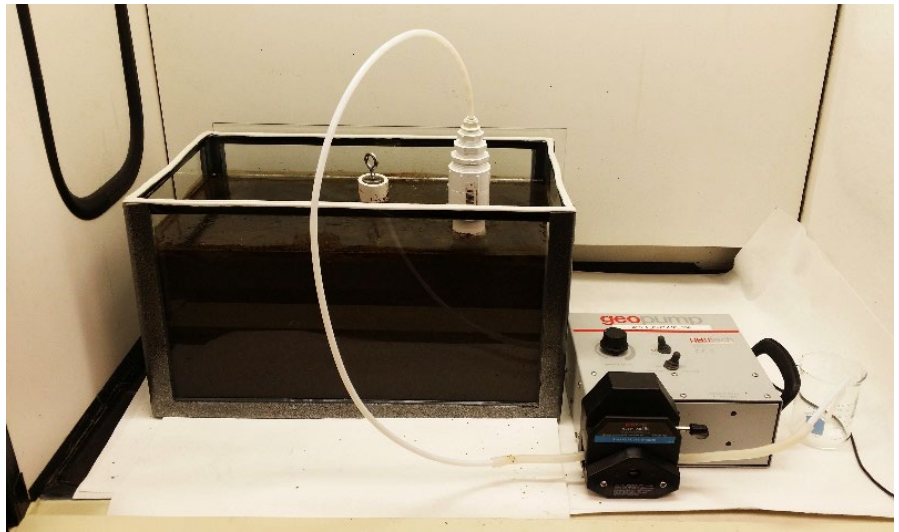
Porewater Sampling Tests with Diffusive Equilibration and Pumping (With NAPL)

- Aquarium with well-graded sand, water, and 10% creosote NAPL saturation
- Duplicate samples
  - Diffusion-based water samples at 10, 20, and 31 days
  - Pumped-water samples also collected from ceramic tubes at 31 and 60 days





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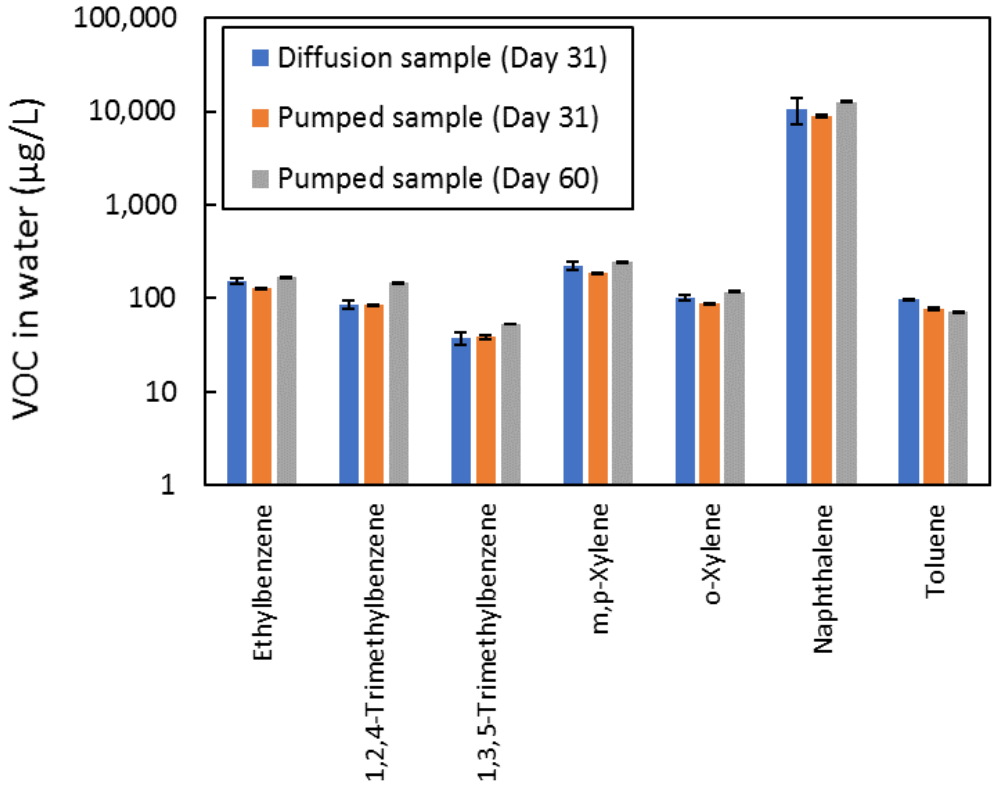
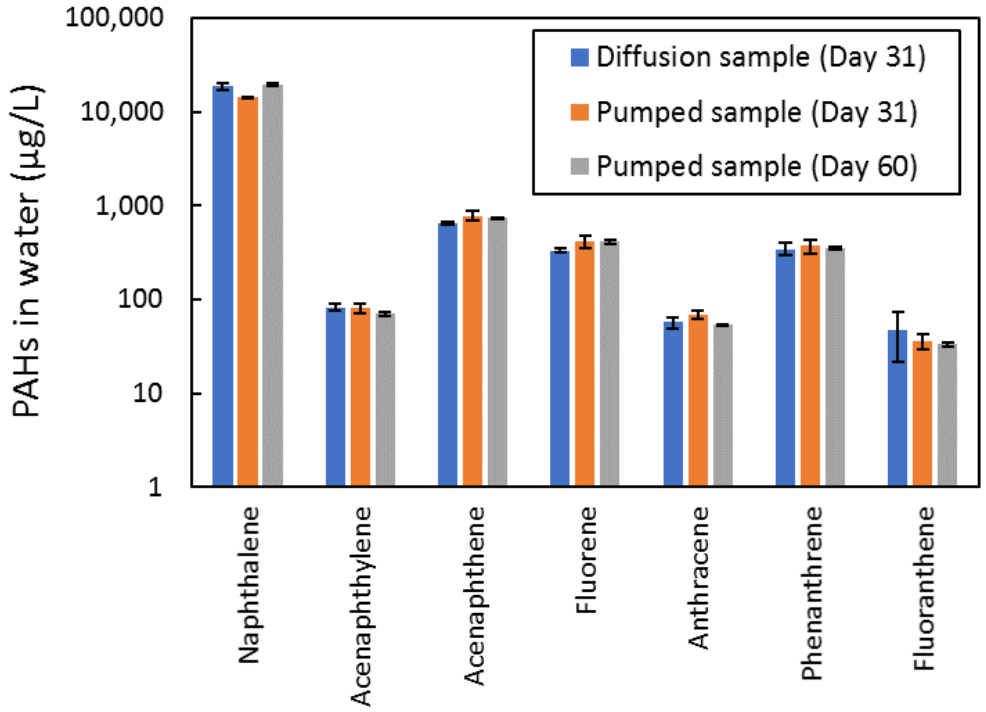
Porewater Sampling Tests with Diffusive Equilibration and Pumping (with NAPL)

Volatile organic carbons



PAHs



Experience at 11 Sites Across United States and Canada

Groundwater

Technology Spotlight/

Aqueous-Phase Sampling with NAPL Exclusion Using Ceramic Porous Cups

by Michael J. Gefell[1], Masa Kanematsu[2], Dimitri Vlassopoulos[2], and David S. Lipson[3]

Source: Gefell et al. (2018)

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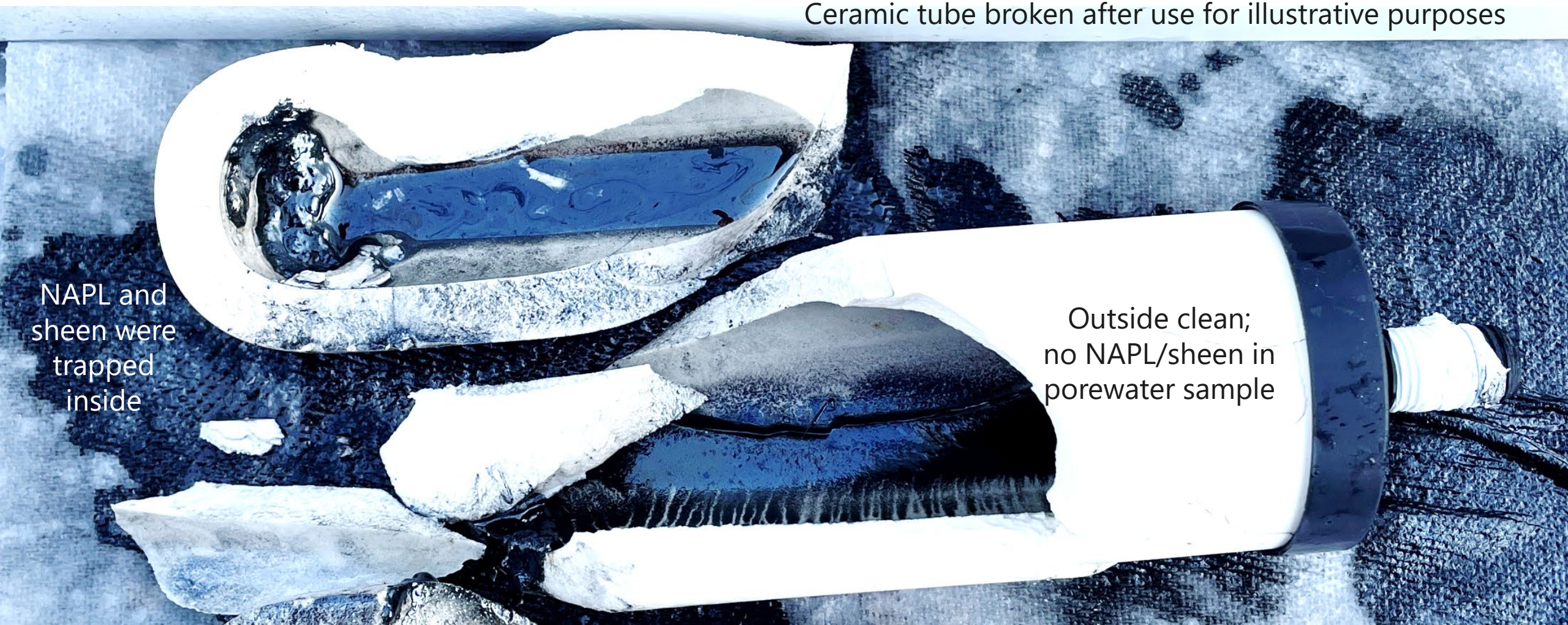
Pumping from Push-Point, Well, Piezometer, or Drill Casing

Intake mode (after sampling groundwater below light nonaqueous phase liquid in well)

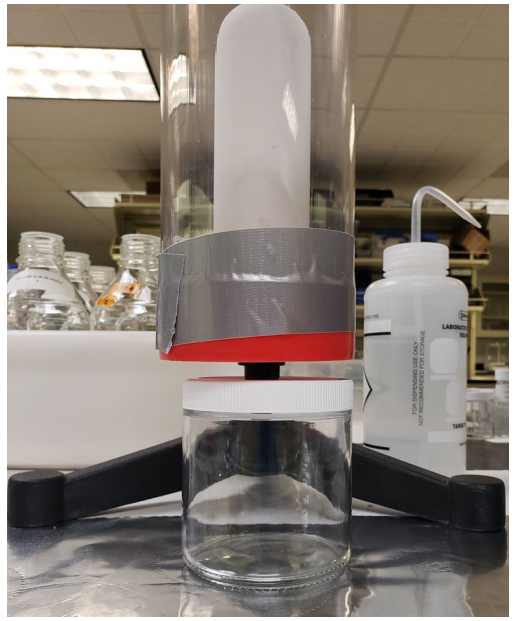
Discharge mode

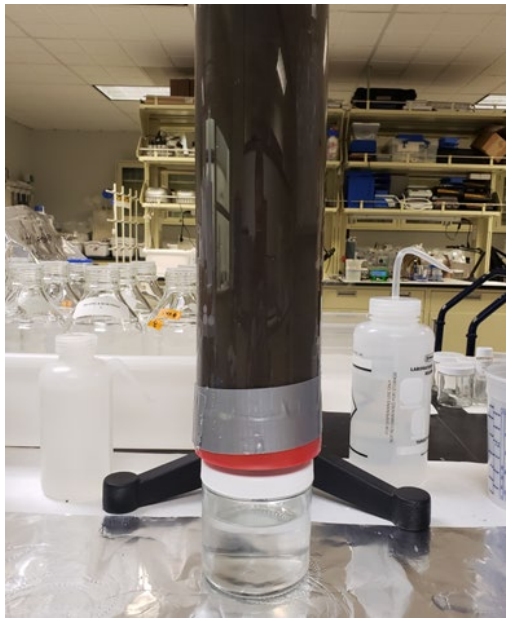
After Porewater Sampling at Coal Tar Site (Discharge Mode)



Other Sampling Methods

- In situ, diffusion-based equilibration (≥30 days)
- Ex situ porewater: gravity drainage from sediment through filter
- Ex situ porewater: centrifuge from sediment, then pump through filter





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LESSONS LEARNED

- Pumped discharge mode
  - Clogging/breaking due to excess turbidity or trapped air
- In situ diffusion-based equilibration
  - Detection levels can be affected by limited sample volume
  - Tubes may be washed away during long deployment (several months) in fast-moving river

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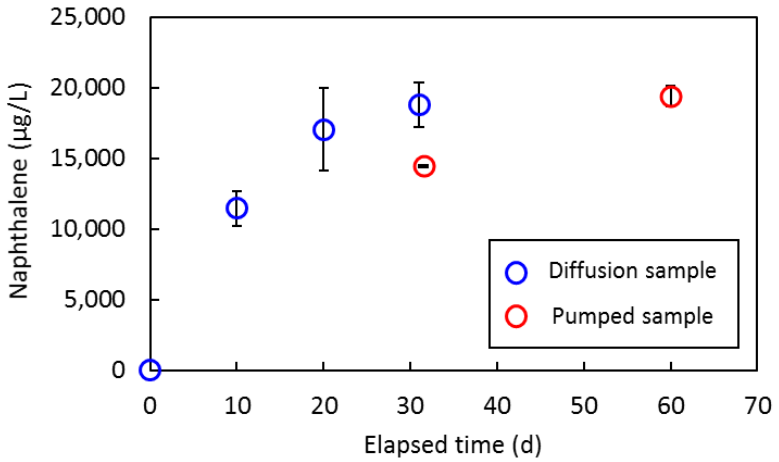
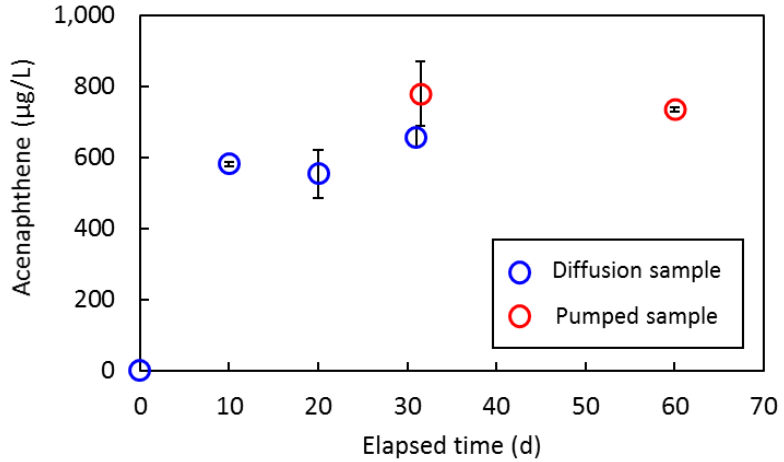
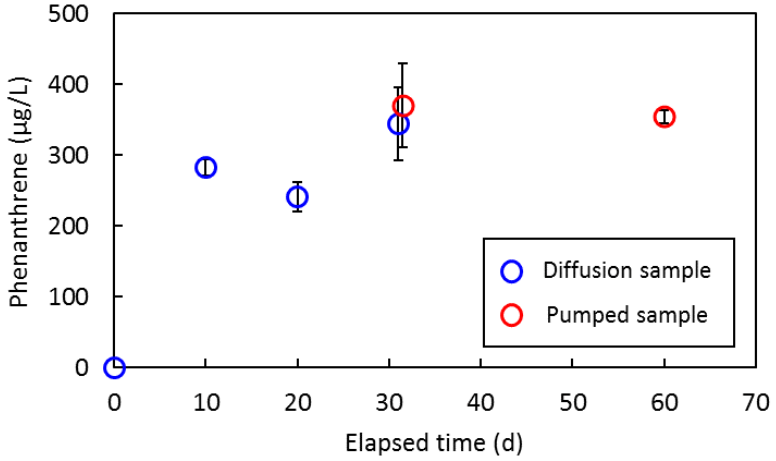
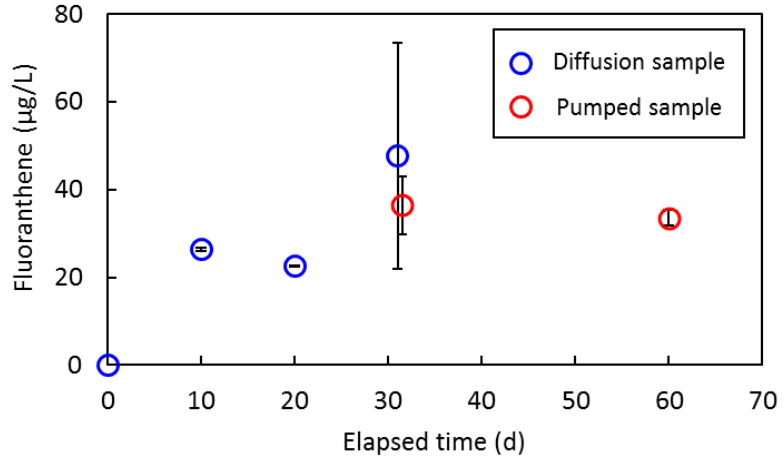
Porewater Sampling Test Results









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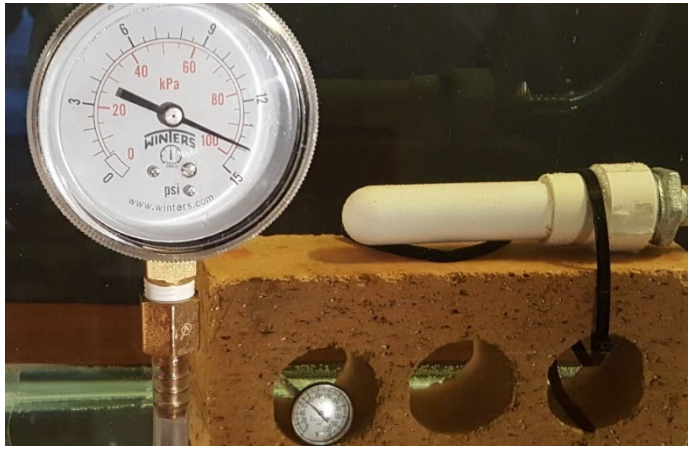
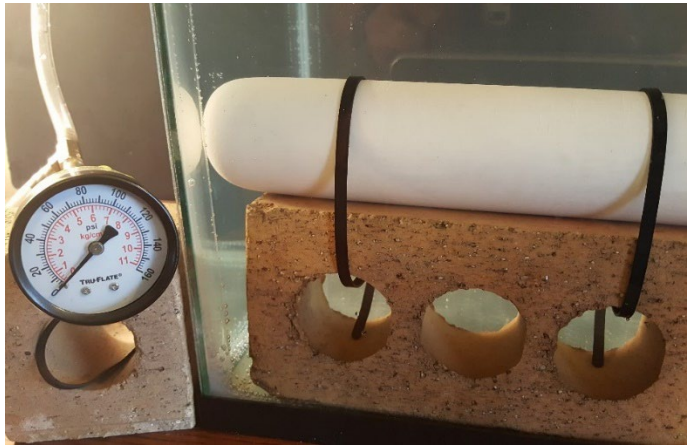
Entry Pressure Test of Ceramics Using Air in Water-Filled Tank



- 2.5-micron pore diameter (reported by manufacturer)
- Measured air entry pressure: 16 psi



- Measured air entry pressure: 4 psi
- Pore diameter: 11 microns (calculated)

Entry pressure testing

Depth Below Top of DNAPL Pool Required for Coal Tar/Creosote to Enter Ceramic Pores Without Water Pumping

$$\mathbf{Z_n = (2\sigma \cos \varphi) / [r\, g\, (\rho_n - \rho_w)]}$$

where:
Z_n = critical DNAPL height above ceramic sampler (cm)
σ = NAPL-water interfacial tension (20 dynes/cm = 20 g/s^2)
φ = contact angle (24°)
r = pore radius (1.25 to 5.6 microns = 0.000125 to 0.00056 cm)
g = gravitational constant (980 cm/s^2)
ρ_n = non-wetting phase (NAPL) density (1.07 g/cm^3)
ρ_w = wetting phase (water) density (1.0 g/cm^3)

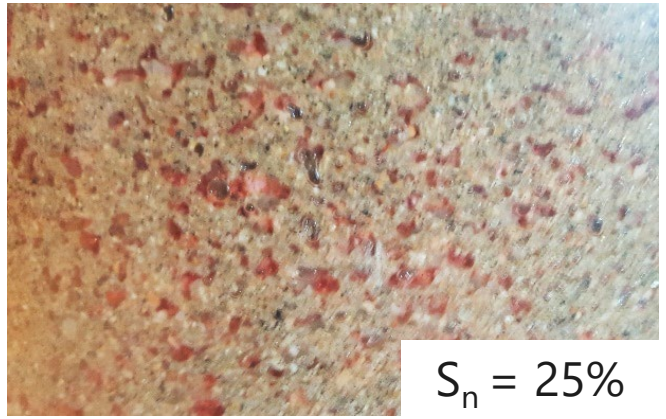
Z_n = 10 to 40 meters

Source: Cohen and Mercer (1993)

Water-Pumping NAPL Exclusion Tests

- Well-graded, fine to course sand
- 25% to 50% NAPL saturation (S_n), red paraffin oil (46 dynes/cm, 3 centistokes)
- Peristaltic pump, water recirculated, monitored vacuum (drawdown), pumping rate, and effluent for visible NAPL/sheen
- Results: converted for typical coal tar interfacial tension (20 dynes/cm)
  - **S_n = 0.25:** Up to 12 feet drawdown and **25 mL/min** water flow with no sheen or NAPL in effluent—**potentially useful**
  - **S_n = 0.50:** Sheen in effluent with 5 feet water drawdown and only 1.5 mL/min water flow—**impractical**

Test setup



S_n = 25%

S_n = 50%

THANK YOU

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REFERENCES

Burgess, R.M., 2013. *Passive Sampling for Measuring Freely Dissolved Contaminants in Sediments: Concepts and Principles*. Training slides from 23rd Annual National Association of Residential Property Manager Training. (Slide 2)

Cohen, R.M., and J.W. Mercer, 1993. *DNAPL Site Evaluation*. Boca Raton, Florida: C.K. Smoley. (Slide 19)

Gefell, M., M. Kanematsu, D. Vlassopoulos, and D. Lipson, 2018. "Aqueous-Phase Sampling with NAPL Exclusion Using Ceramic Porous Cups," *Groundwater* 56(6): 847–851. (Slide 10)