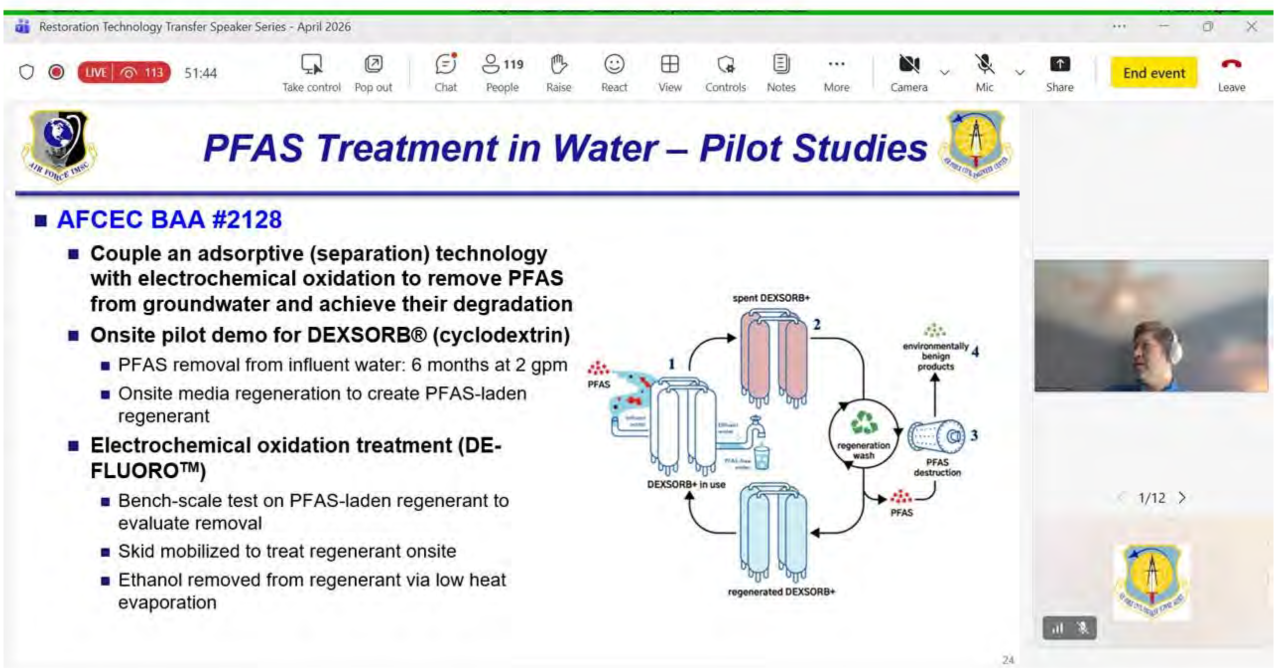
Air Force Civil Engineer Center

Restoration Technology Transfer Speakers Series
April 2026

Per- and Polyfluoroalkyl Substances (PFAS) Treatability: Lab Case Studies & Technology Development

Presenters: Dr. Francisco Barajas-Rodriguez (AECOM)

This webinar presented results from an innovative treatment train for PFAS remediation in groundwater. The treatment train includes two main steps, 1) surface active foam fractionation (SAFF) for PFAS removal and concentration and 2) an ultraviolet (UV)/sulfite-based EradiFluor for PFAS destruction. PFAS in the feedwater were removed through SAFF processes, where PFAS were concentrated into a small volume of foamate waste. The generated SAFF foamate, which is highly enriched in PFAS but with reduced volume, were subsequently destroyed using EradiFluor. The effluent from the PFAS destruction treatment was be sent back to the influent of the overall process to achieve “closed-loop” treatment, eliminating the need for offsite waste disposal. Field results showed that 1) PFAS in groundwater were effective removed by the SAFF; 2) Near-complete destruction of PFAS (including long-, short-, and ultrashort-chain) was achieved with EradiFluor based on target PFAS analysis, fluorine mass balance, and total organic fluorine analysis; 3) “closed-loop” PFAS treatment was achieved using the treatment train; 4) the system operates under ambient pressure and near-room temperature and therefore requires low energy; and 5) the system performs reliably with high operation uptime.



Dr. Francisco Barajas-Rodriguez discusses a pilot study for PFAS treatment in water.

This event and future events are updated and posted on the AFIT website at: https://www.afit.edu/CE/index.cfm.

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Webinar Structure

	Restoration Technology Transfer Webinar Series – eDASH Archive
5 min	Welcome and Administrative Business
45 min	Main Presentation – *PFAS Treatability Lab Case Studies & Technology Development*
10 min	Questions and Answers
5 min	Final Thoughts

PFAS Treatability Case Studies & Technology Development

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April 2026

Agenda

- AECOM CleanTech Hub (CTH) Treatability Laboratory
  - Capabilities
  - New in-house instrumentation
- PFAS Treatment via Adsorption
  - Water
  - Landfill Leachate
  - Soil
- PFAS R&D
- Take Home Message

AECOM CleanTech Hub

AECOM CleanTech Hub

- **Technology development**
- **Process and treatability labs**
- **Lab, bench, and pilot tests support**

Decarbonization
- Solvents, Sorbents & Membranes/ Fuel Cells
- Direct Air Carbon Capture
- Compression & Transportation
- Process Modeling

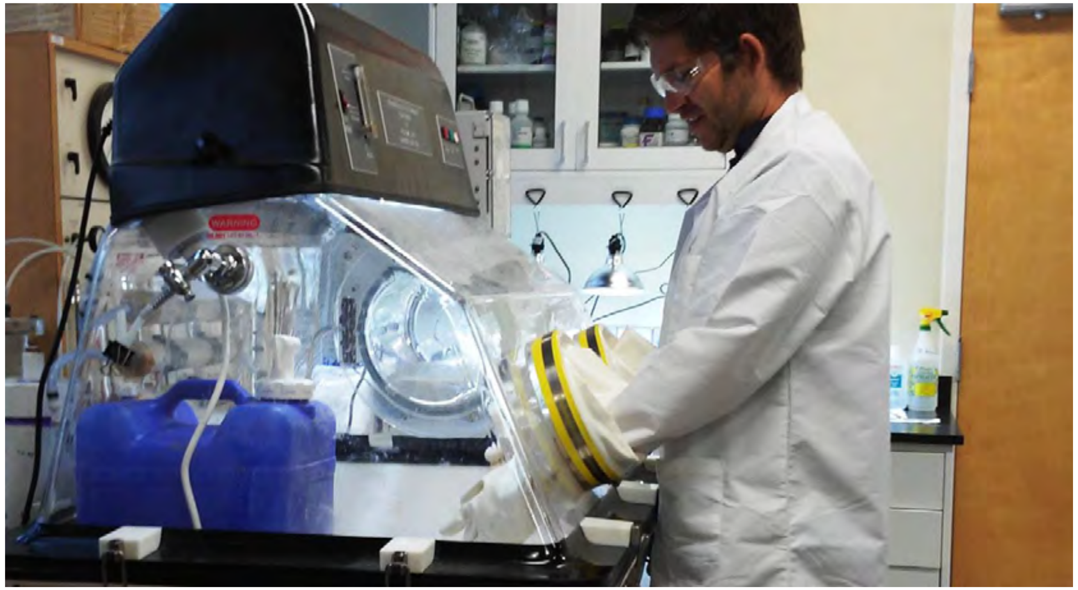
Traditional & Future Fuels
- Natural Gas
- H2
- Biogas & Bio Fuel, Gasification
- SMR
- WTE
- Solar
- Wind
- Air Pollution Control & Monitoring
- Computational Fluid Dynamics (CFD) Modeling

Sustainable Solutions
- Long Duration Energy Storage
- EV & H2 Vehicle Infrastructure
- Energy Resilience
- REE Recovery
- Soil & Water Treatability Studies
- PFAS
- 1,4,-Dioxane, Microplastics
- Focus on Natural Solutions

Technology Development
- Independent Reviews
- Techno-Economic Analysis
- Feasibility Studies
- Conceptual Design
- Detailed Engineering
- Lab, Bench, Pilot & Demonstration Support

AECOM CleanTech Hub

- Located in Austin, TX, USA
- Support AECOM projects across the US, Canada, Australia and Europe
- 10,000+ square feet research complex facility
- LC/MS for in-house PFAS analysis



Treatability Studies

- Sorbent Evaluation (100+ tests)
- Water Pretreatment
- Biodegradation Studies
- Soil Studies
- Mixed Media Columns
- Leachability Studies (LEAF)

AECOM CleanTech Hub

- Services
  - Treatability studies; +100 projects
    - Bench-scale
    - Pilot-scale
  - Research: AFCEC, SERDP/ESTCP, State Funded, Privately Funded
  - Technology development
  - Technology demonstration
  - Commercial deployment

The Need for In-House PFAS Analysis

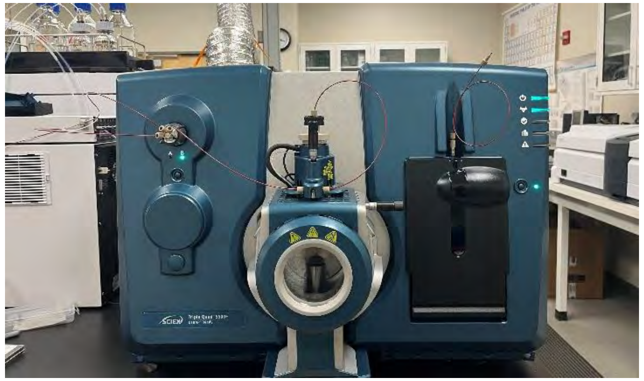
Long Turnaround Times

Slow Communication with Laboratories

Increasing Demand of PFAS Projects

Price of Analysis

Data Quality Limitations



EPA PFAS Methods Comparison

537.1

Drinking Water Method

18 Analyte Compounds

7 Internal Standards

Standard SPE Procedure

533

Drinking Water Method

25 Analyte Compounds

19 Internal Standards

Standard SPE Procedure

1633A

Multiple Matrices Method

Drinking Water, Surface Water, Groundwater, Landfill Leachate, Soil, Biosolids, Fish Tissues

40 Analyte Compounds

31 Internal Standards

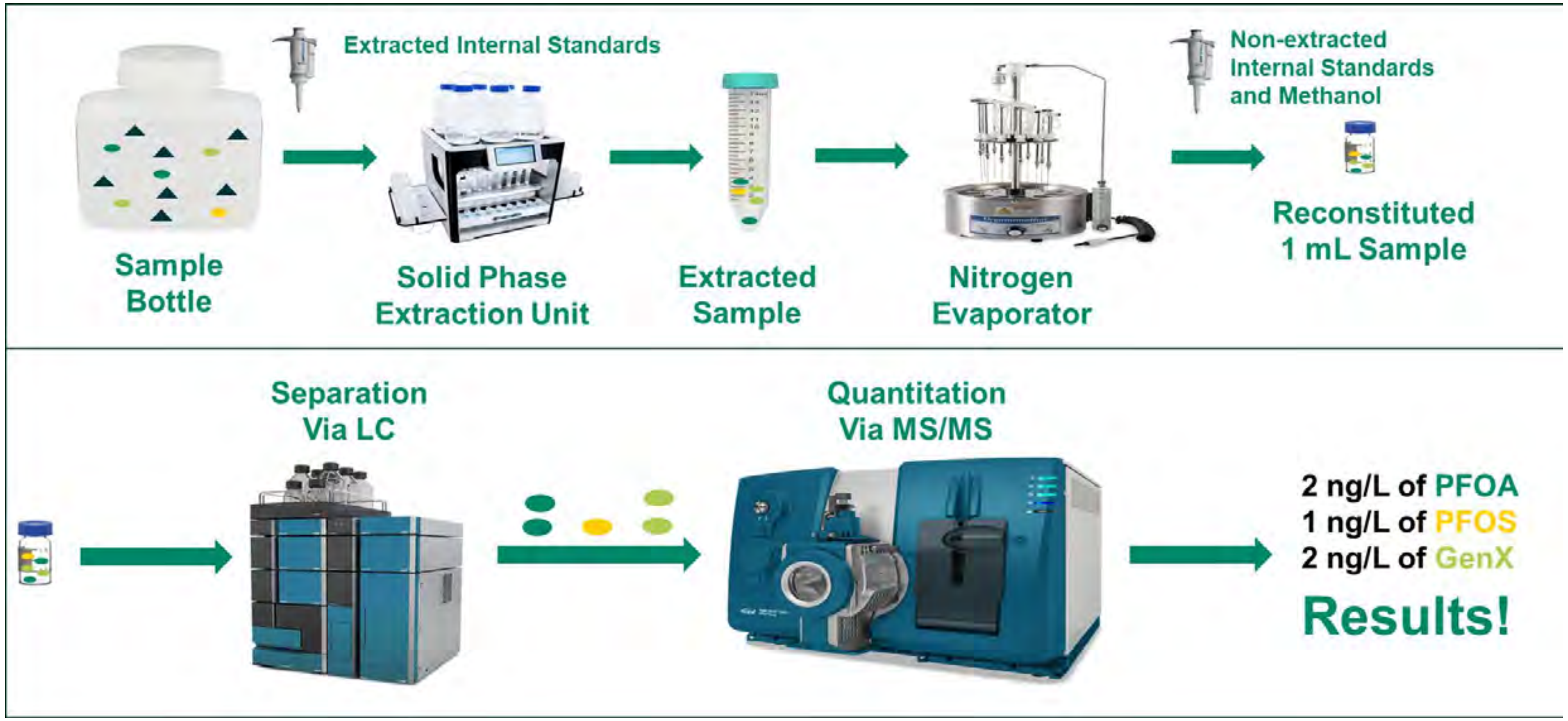
Additional Sample Prep

LC/MS In-House Capability

- Optimized sample preparation and extraction
  - Streamlined workflow
  - Lower detection and reporting limits
  - Up to 80 samples per week

Best used for time-sensitive projects; not a volume routine lab

Currently considered for bench-scale and pilot-scale treatability study proposals



EPA 537.1 Comparison with External Laboratory

Compound	Sample 1 CTH Result (ng/L)	Sample 1 EL Result (ng/L)	Sample 2 CTH Result (ng/L)	Sample 2 EL Result (ng/L)
PFHxA	*<0.19*	*<0.28*	**5.24**	**5.0**
PFHpA	*<0.08*	*<0.34*	**2.79**	**2.6**
PFOA	**0.241**	*<0.31*	**5.21**	**5.4**
PFNA	*<0.14*	*<0.30*	**0.85**	**0.98 J**
PFDA	*<0.14*	*<0.26*	*<0.13*	*<0.27*
PFUnA	*<0.06*	*<0.31*	*<0.05*	*<0.31*
PFDoA	*<0.13*	*<0.28*	*<0.12*	*<0.29*
PFTrDA	*<0.13*	*NA*	*<0.12*	*NA*
PFTeDA	*<0.12*	*NA*	*<0.11*	*NA*
PFBA	*<0.17*	*<0.40*	**4.29**	**3.7**
PFHxS	*<0.11*	*<0.27*	**3.77**	**3.7**
PFOS	**0.155**	*<0.38*	**4.18**	**3.9**
N-MeFOSAA	*<0.07*	*NA*	*<0.07*	*NA*
N-EtFOSAA	*<0.09*	*NA*	*<0.08*	*NA*
HFPO-DA	*<0.03*	*<0.96*	**0.102**	*<0.98*
ADONA	*<0.11*	*<0.33*	*<0.11*	*<0.34*
9Cl-P3ONS	*<0.06*	*<0.39*	*<0.06*	*<0.39*
11Cl-3OUdS	*<0.11*	*<0.45*	*<0.10*	*<0.46*

Yellow – detectable and reportable only by CTH

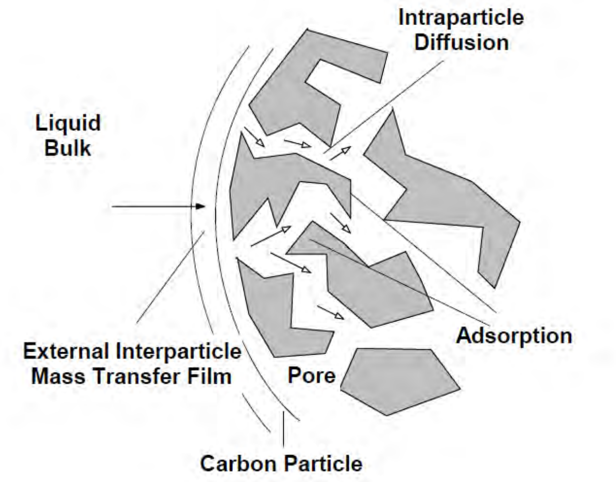
Blue – detectable compounds within 15% between labs

"J" – below the MRL but above the MDL

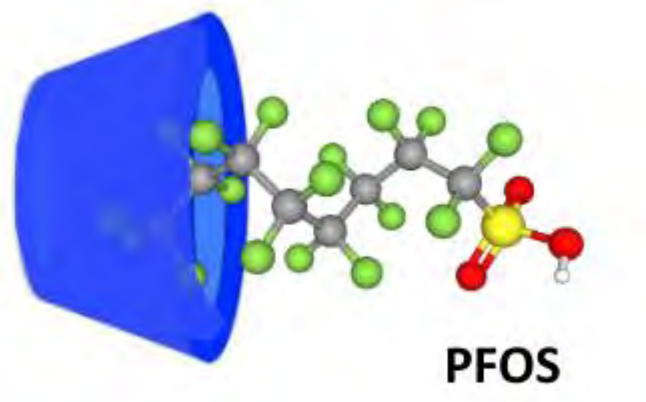
PFAS Treatment Via Adsorption

PFAS Treatment via Adsorption

- Aqueous treatment
  - Well established and large-scale availability
  - Traditional adsorbents
    - Granular Activated Carbon (GAC), Ion Exchange Resins (IXR)
  - Novel adsorbents (commercially available)
    - Cyclodextrins, modified organoclays
  - Adsorbent selection
    - Costs and implementability
    - Specific water matrix interactions → effect on specific throughput (breakthrough)
  - Importance of treatability testing
    - No water matrix is the same
- Soil treatment
  - Sorbents used as additive for in-situ stabilization



GAC Adsorption, Armenante (1991)



Cyclodextrin Adsorption, Ling (2021)

PFAS Treatment in Water - RSSCTs

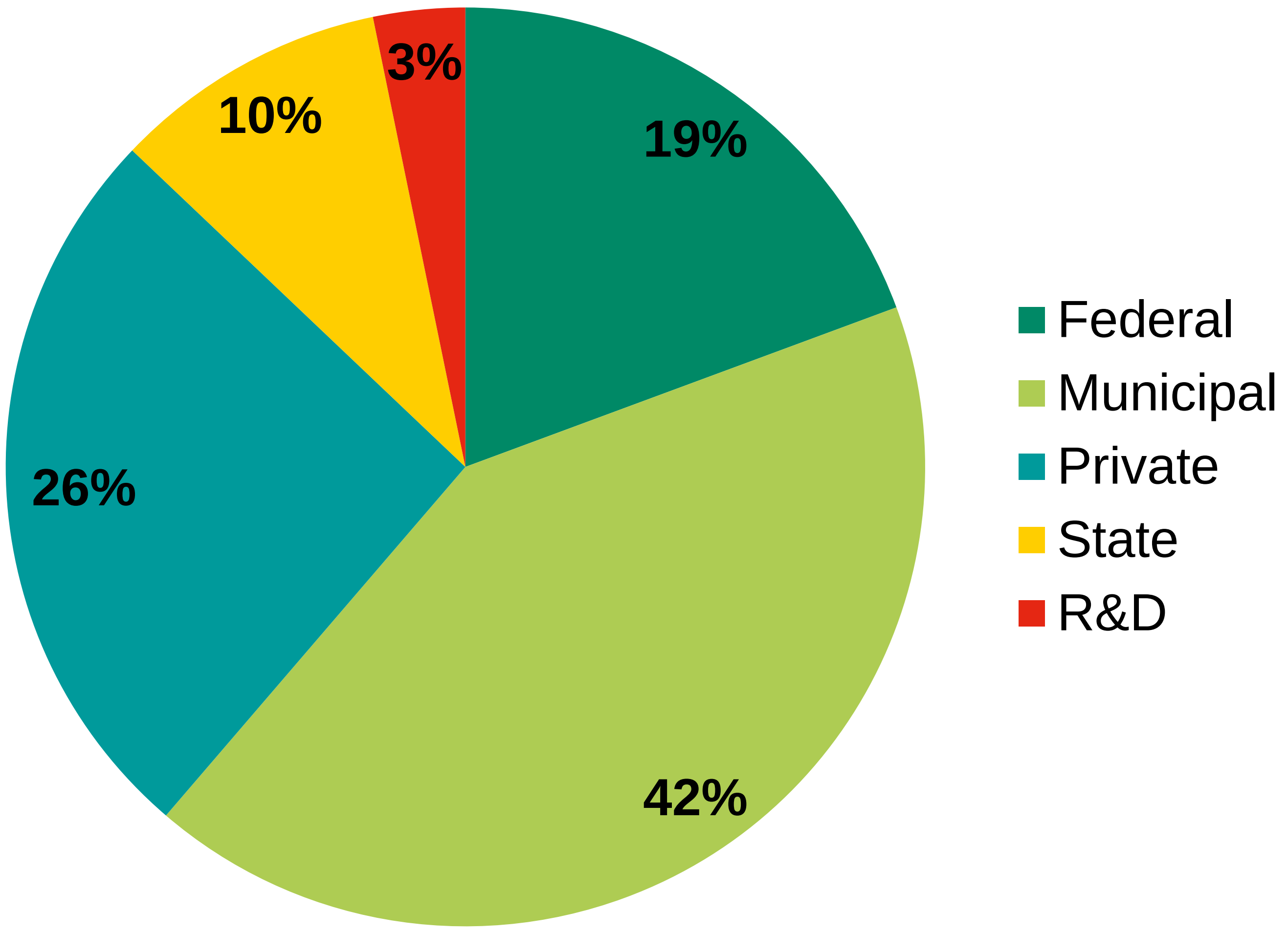
Rapid Small Scale Column Tests (RSSCTs)

33 projects spanning 2020-2025

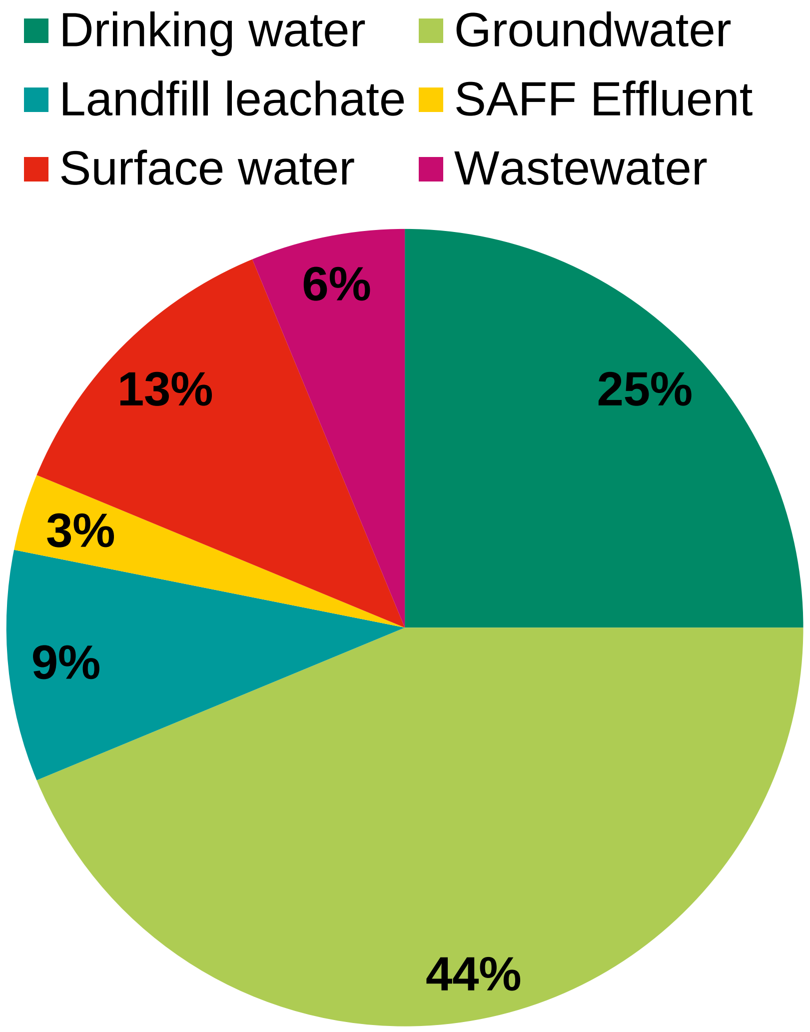
+100 individual RSSCTs

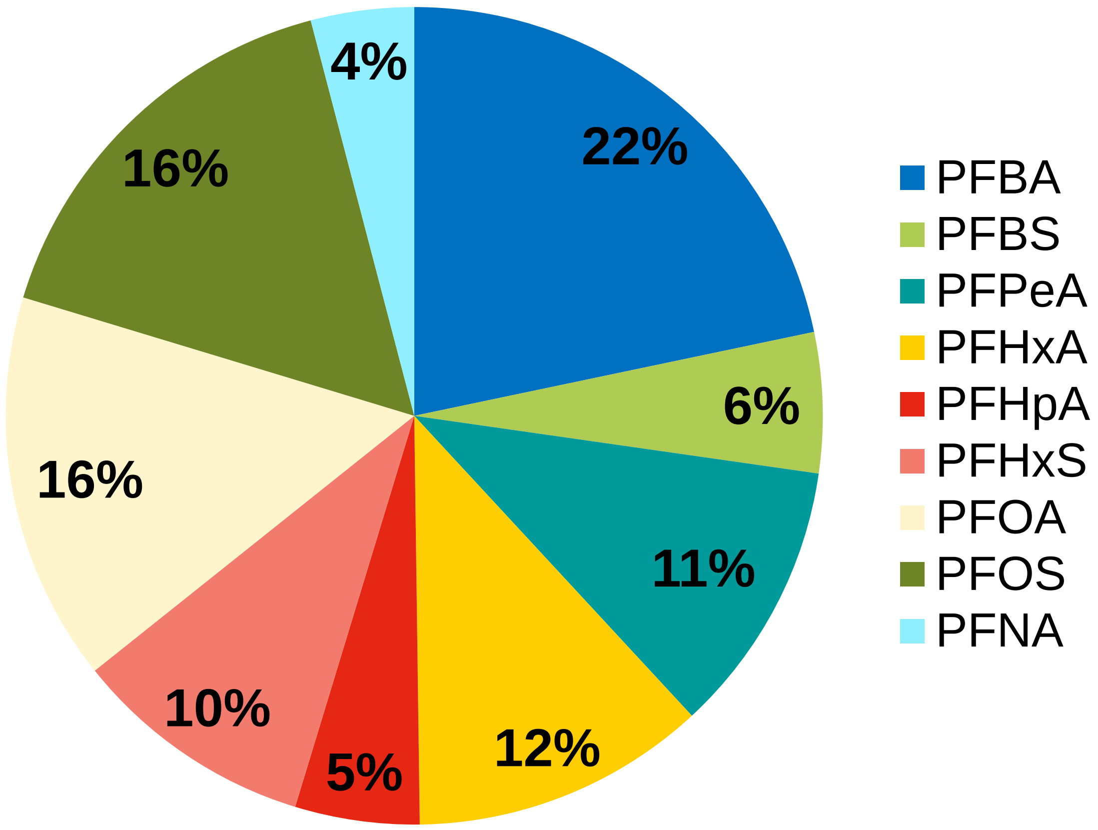
+2,500 PFAS samples

Dominated by municipal projects



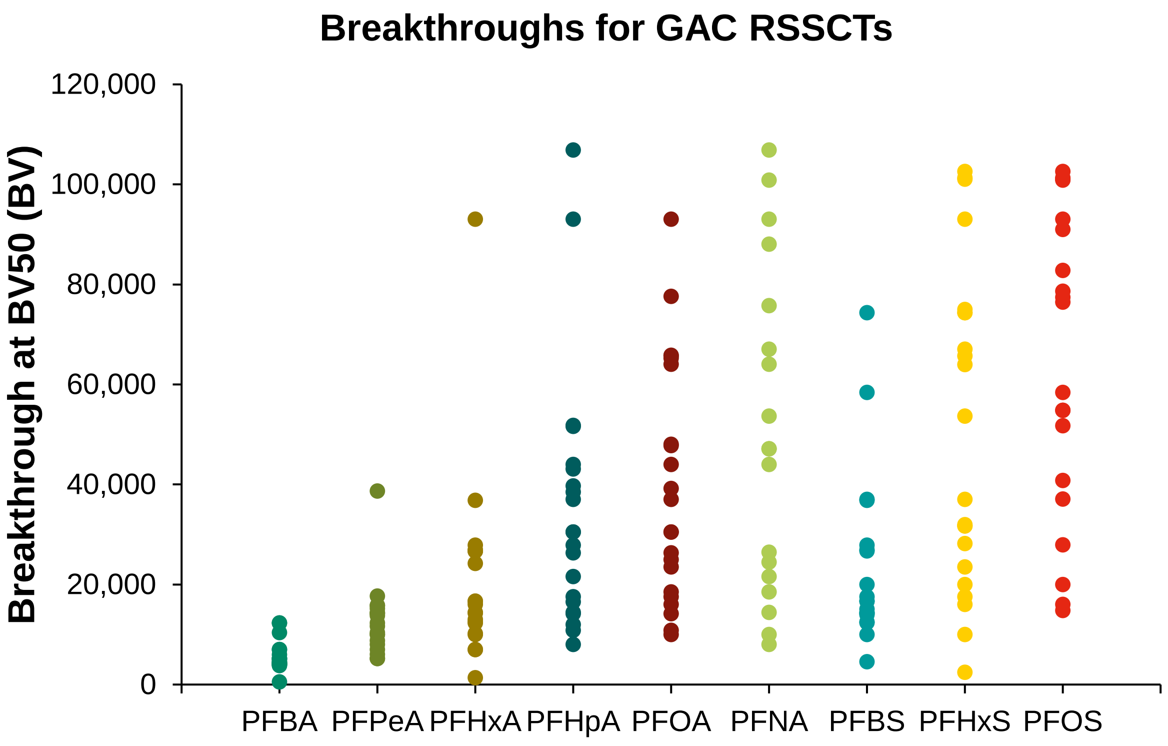
PFAS Treatment in Water - RSSCTs

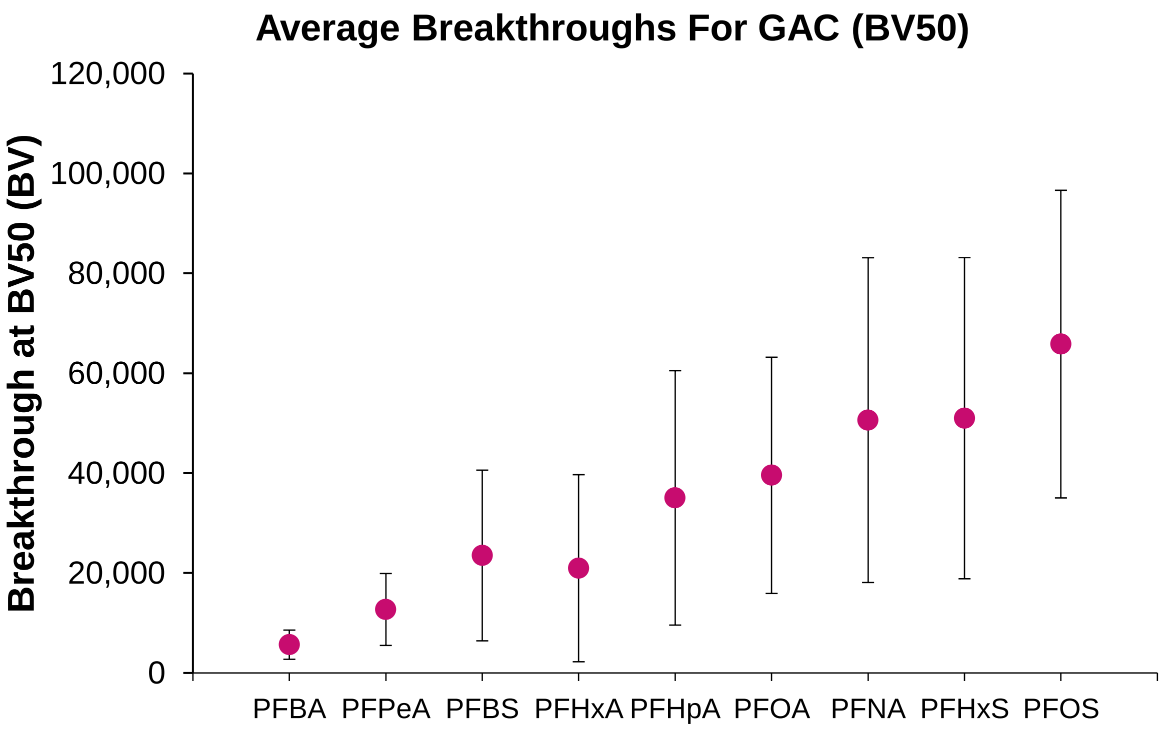




PFAS Treatment in Water - RSSCTs

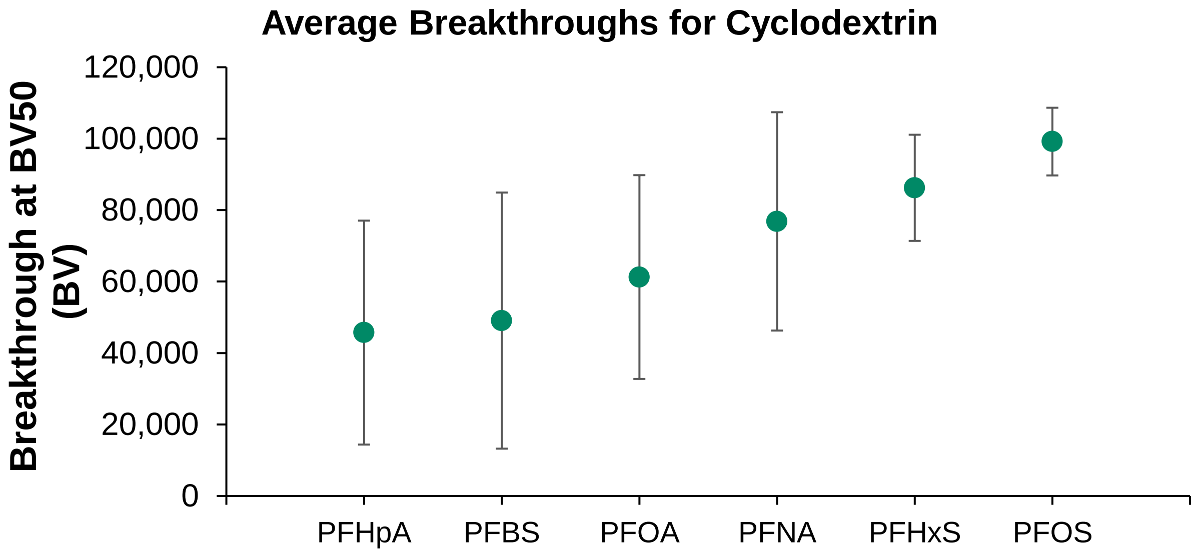
- 20 water matrices compiled for FiltraSorb® 400 GAC
- Short chain PFAS break through earlier than long chain PFAS
- PFSAs break through later than their PFCA counterparts

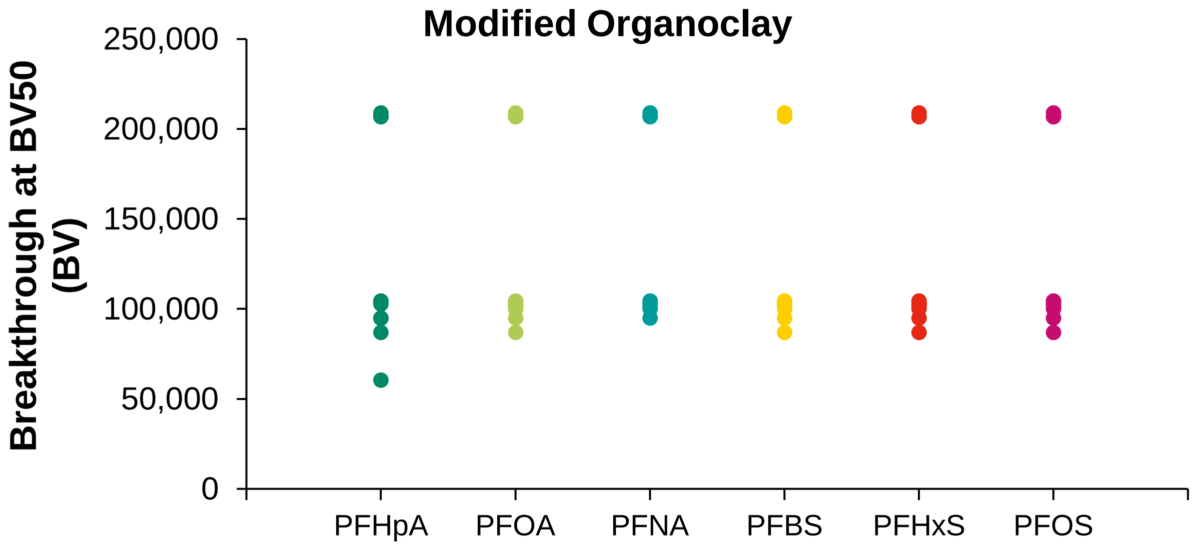


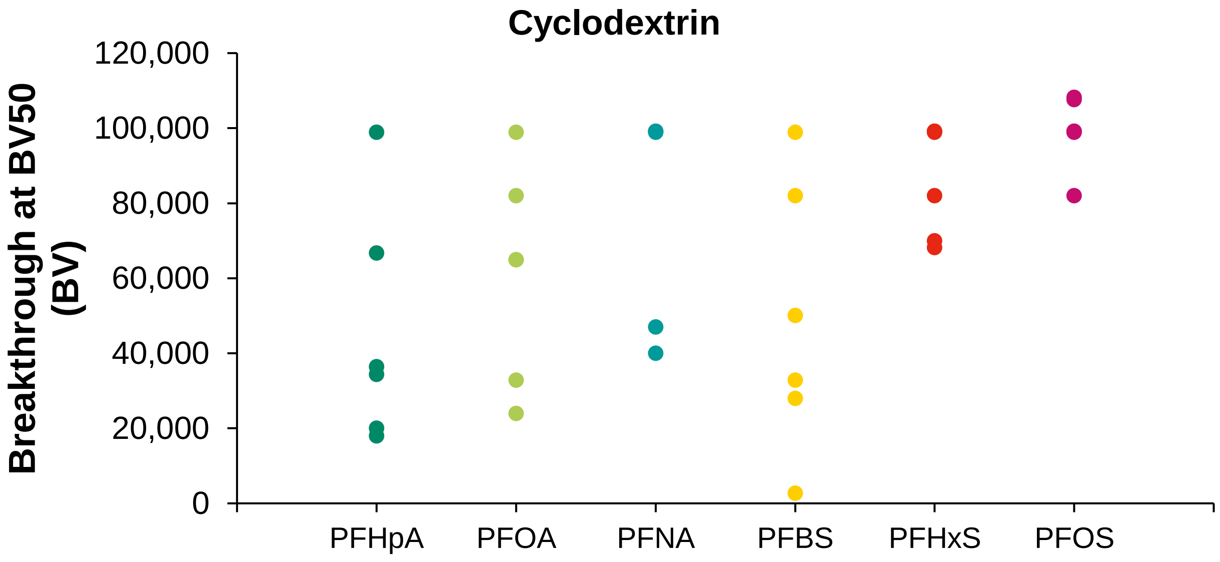


PFAS Treatment in Water - RSSCTs

- **Modified organoclay**
  - **11 water matrices compiled**
  - **Columns generally run to test completion without seeing 50% influent breakthrough**
- **Cyclodextrin**
  - **6 water matrices compiled**
  - **Short chain PFAS, on average, break through earlier than long chain PFAS**







PFAS Treatment in Water - RSSCTs

■ Case Study: Evaluation of Nine Alternatives to Treat PFAS and VOCs in Untreated and Air-Stripped Groundwater

- Removal of per- and polyfluoroalkyl substances (PFAS) and volatile organic compounds (VOCs) at an existing Groundwater Treatment Plant (GWTP) in Massachusetts
- Massachusetts Department of Environmental Protection (MassDEP) Maximum Contaminant Levels (MCL) of 20 ng/L on six PFAS **MassDEP PFAS6**
  - Perfluorooctane sulfonic acid (PFOS)
  - Perfluorooctanoic acid (PFOA)
  - Perfluorohexanesulfonic acid (PFHxS)
  - Perfluorononanoic acid (PFNA)
  - Perfluoroheptanoic acid (PFHpA)
  - Perfluorodecanoic acid (PFDA)
- Total PFAS = 375 ng/L in untreated groundwater

PFAS Treatment in Water - RSSCTs

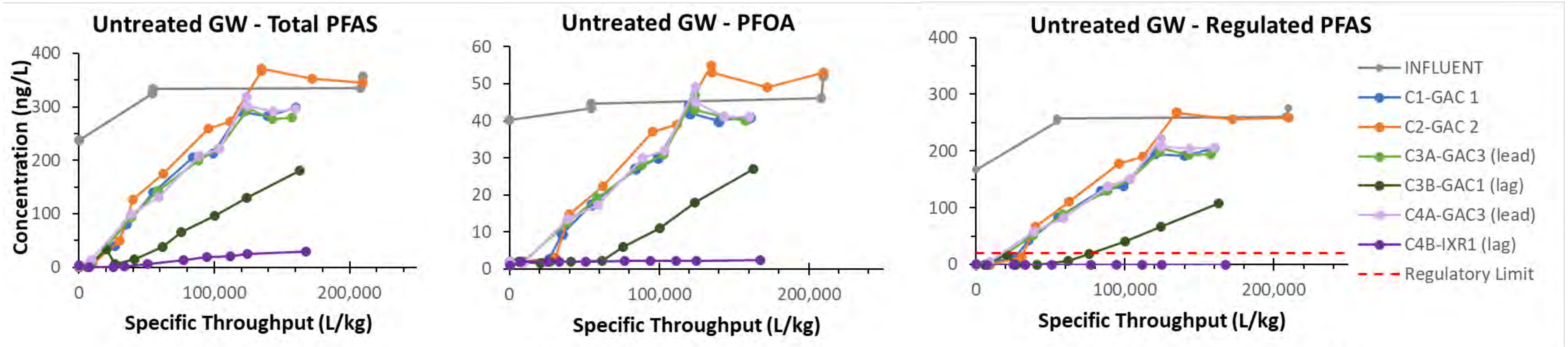
Case Study: Evaluation of Nine Alternatives to Treat PFAS and VOCs in Untreated and Air-Stripped Groundwater

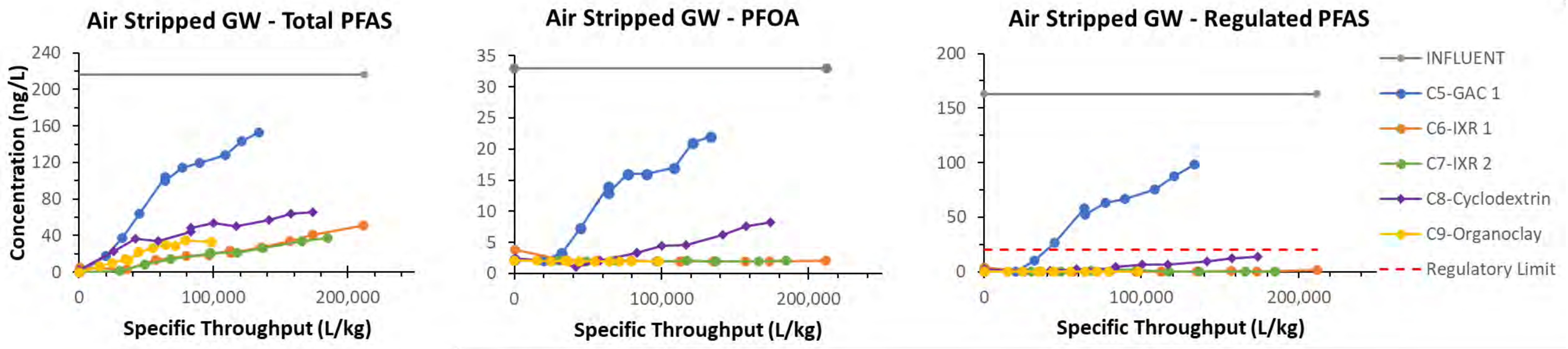
Goals

- Determine the best treatment option to meet MassDEP PFAS6 MCL
- Meet a National Pollutant Discharge Elimination System (NPDES) permit discharge for VOCs
- Collect performance data for other PFAS compounds to future-proof the study
- Evaluate two treatment scenarios:
  - Treatment of VOCs and PFAS in GWTP Influent (untreated water)
  - Treatment of only PFAS for GWTP Effluent (post-air stripper treated water)
- Evaluate multiple sorbent medias
- Determine the bed lives of the sorbents evaluated

RSSCT	Sorbent Media	Simulated EBCT (min)	Test Water Matrix
1	GAC 1	12	GWTP Influent
2	GAC 2	12	
3	GAC 3 + GAC 1	12 + 16	
4	GAC 3 + Single Use IXR 1	12 + 6	
5	GAC 1	16	GWTP Effluent Post Air Stripper
6	Single Use IXR 1	6	
7	Single Use IXR 2	6	
8	Cyclodextrin	6	
9	Modified Organoclay	6	

PFAS Treatment in Water - RSSCTs





PFAS Treatment in Water - RSSCTs

Specific Throughputs

- Untreated GW
  - PFAS6 the limiting factor for GAC 1 and GAC 2
  - Cis-1,2-DCE the limiting factor for media in tandem
- Air Stripped GW
  - VOCs do not apply (NA) as they were not in the influent
  - IXR 1 exhibited the highest specific throughput
  - IXR 2 and novel sorbents performed well: PFAS6 threshold was not crossed

	Specific Throughput (L/Kg)		
Treatment	**PFAS6 20 ng/L**	**cis-1,2-DCE 70 µg/L**	**TCE 5 µg/L**
GWTP Influent - GAC 1	27,500	55,000	67,500
GWTP Influent - GAC 2	33,000	63,000	80,500
GWTP Influent - GAC 3 + GAC 1	75,000	64,500	>112,000
GWTP Influent - GAC 3 + IXR 1	>167,500	55,000	80,500
GWTP Effluent – GAC 1	40,000	NA	NA
GWTP Effluent – IXR 1	**>211,700**	NA	NA
GWTP Effluent – IXR 2	>184,800	NA	NA
GWTP Effluent – Cyclodextrin	>174,000	NA	NA
GWTP Effluent – Organoclay	>173,700	NA	NA

PFAS Treatment in Water - RSSCTs

■ Life Cycle Cost Assessment

PARAMETER	ALT 1 GAC3 + IXR 1	ALT 2 AIR STRIPPER + IXR 1	ALT 3 AIR STRIPPER + CYCLODEXTRIN	ALT 4 AIR STRIPPER + ORGANOCLAY	ALT 5 GAC 1 + CYCLODEXTRIN
Estimated Capital Costs (2024)[1]	$1,720,000	$880,000	$860,000	$830,000	$1,700,000
Annual Operational Costs	$76,000	$59,000	$74,000	$67,000	$101,000
Media Replacement/Bag Filter Replacement[2]	$67,000[6]	$48,000[6]	$63,000	$56,000	$92,000
Electrical Cost[3]	$9,000	$11,000	$11,000	$11,000	$9,000
Annual Maintenance Costs	$35,000	$18,000	$18,000	$18,000	$35,000
Labor Cost[4]	$27,000	$14,000	$14,000	$14,000	$27,000
Replacement Parts Costs	$8,000	$4,000	$4,000	$4,000	$8,000
Total Annual O&M Costs	$111,000	$77,000	$92,000	$85,000	$136,000
Total Life Cycle Cost (20 years upon 2025 Project Completion)[5]	**$4,760,000**	**$3,020,000**	**$3,400,000**	**$3,180,000**	**$5,410,000**

[1]Includes the following markups: 25% contractor overhead and profit, 30% for final design elements not considered in the estimate, and 35% engineering and construction contingency.

[2]In addition to the considerations above, the cost includes price for media disposal. For GAC, the unit cost includes disposal through carbon reactivation. For IXR, cyclodextrin, and organoclay, the unit cost includes a cost for shipping and disposal of the saturated media at a Subtitle C Hazardous Landfill.

[3]Assumed energy cost of $0.28/kWh.

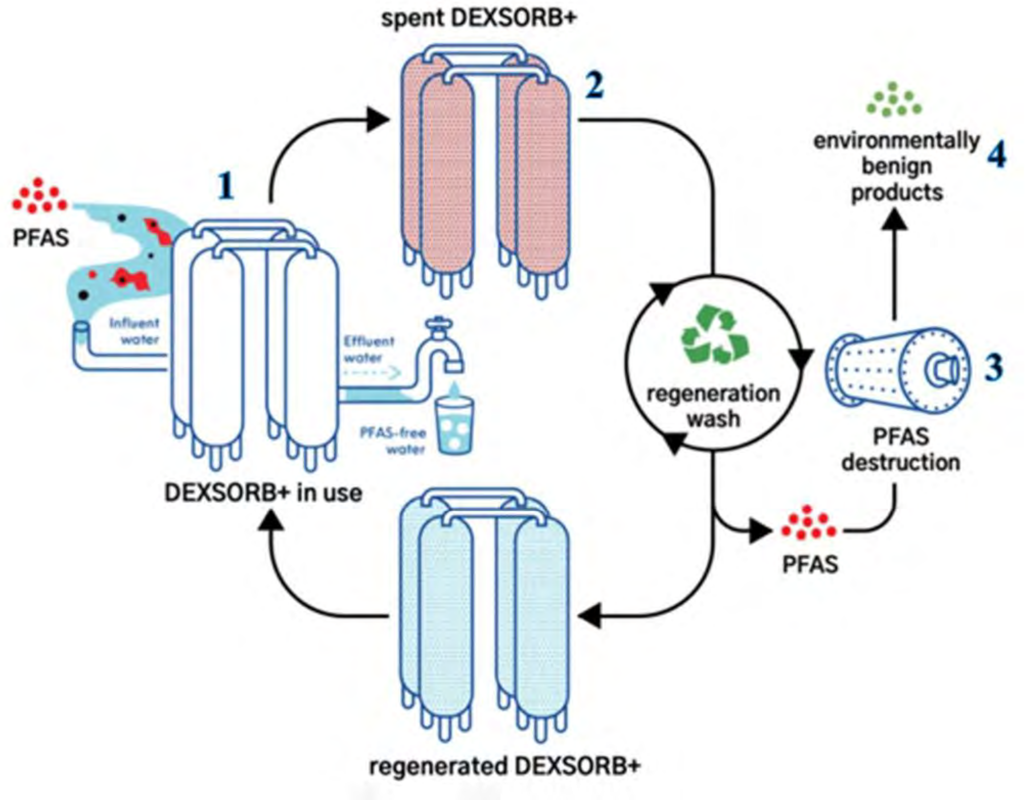
[4]Assumed labor rate of $65/hour.

[5]Based on an assumed inflation rate of 3% and energy escalation rate of 5%.

[6]Media replacement for IXR based on specific throughput observed in treatability study. IXR showed to be near non-detect throughout the experiment and was operated for 210,000 L/kg. This cost reflects media changeout based on that throughput, although media changeout cost will decrease the longer it runs past the observed specific throughput.

PFAS Treatment in Water – Pilot Studies

- **AFCEC BAA #2128**
  - **Couple an adsorptive (separation) technology with electrochemical oxidation to remove PFAS from groundwater and achieve their degradation**
  - **Onsite pilot demo for DEXSORB® (cyclodextrin)**
    - PFAS removal from influent water: 6 months at 2 gpm
    - Onsite media regeneration to create PFAS-laden regenerant
  - **Electrochemical oxidation treatment (DE-FLUORO™)**
    - Bench-scale test on PFAS-laden regenerant to evaluate removal
    - Skid mobilized to treat regenerant onsite
    - Ethanol removed from regenerant via low heat evaporation



PFAS Treatment in Water – Pilot Studies

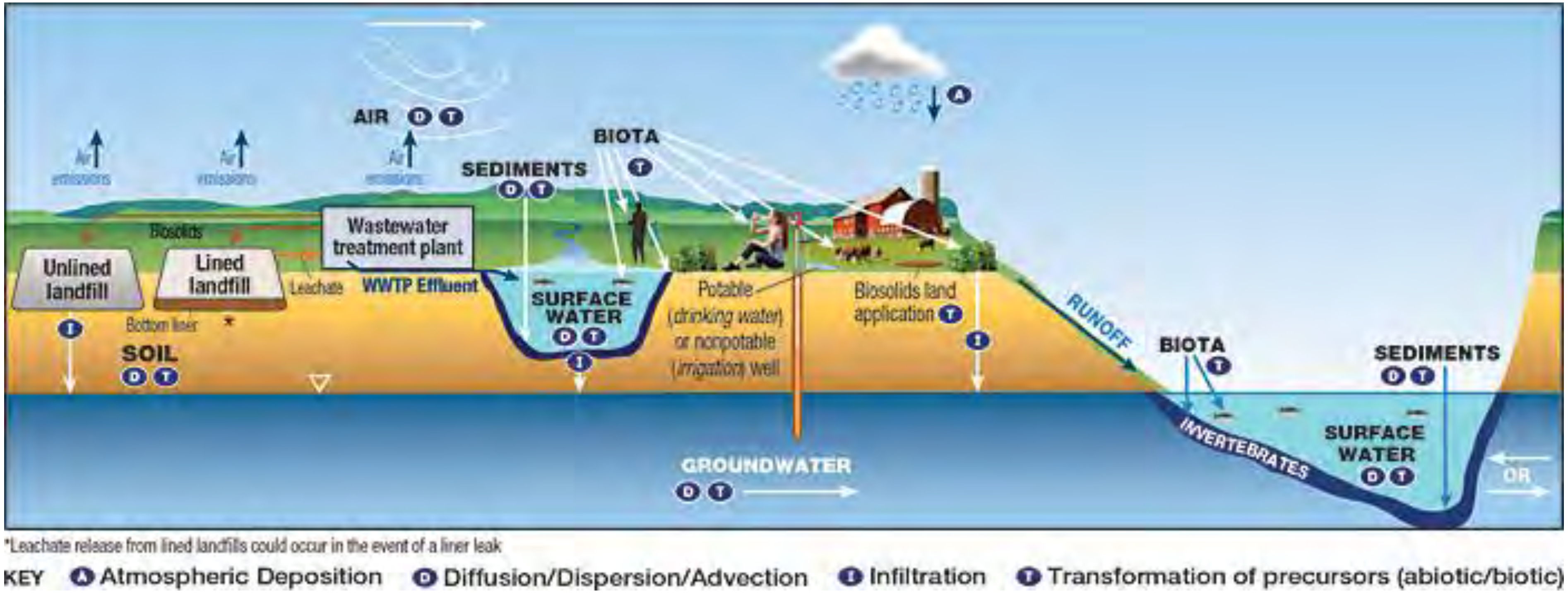
- Sorbent skid
  - AECOM supported vendor to improve data collection system
  - Enhanced telemetry for remote data acquisition
  - From analog to digital
  - Instrumentation added at CTH facility prior mobilization

PFAS Treatment in Water – Pilot Studies

- **Municipal Drinking Water Project – Florida**
- **AECOM CTH supported our East Water Business Line**
- **Pilot study to evaluate PFAS removal from drinking water**
  - **Four 4-inch diameter columns**
  - **CAD designed and built in-house**
  - **User manual generated**
- **Skid is currently on its second pilot study and it is scheduled for a third project after Q2 of 2026**

PFAS Treatment in Landfill Leachate

- Landfill leachate treatment facilities are relevant chokepoints in the PFAS cycle
- Landfill leachates are inherently complex matrices
- High organic content loading competes against PFAS in conventional treatment
- GAC and IXR struggle with the organic loading and the high concentration inorganic dissolved species
- PFAS concentrations are high, with PFAS precursors dominating the composition



Source: ITRC PFAS Guidance Document, Section 2.6.3 Solid Waste Management Facilities

PFAS Treatment in Landfill Leachate

- Treatability Case Studies
- Evaluated raw, biologically treated, and ultrafiltered landfill leachate

- Batch (isotherms + kinetics) – Study 6
  - Organoclay and Cyclodextrin
  - Adsorption capacities, Freundlich parameters
  - Adsorption rates
- Determine specific throughputs:
  - Rapid Small-Scale Column Tests (RSSCTs) – Study 1
  - Large Column Tests – Studies 2-5

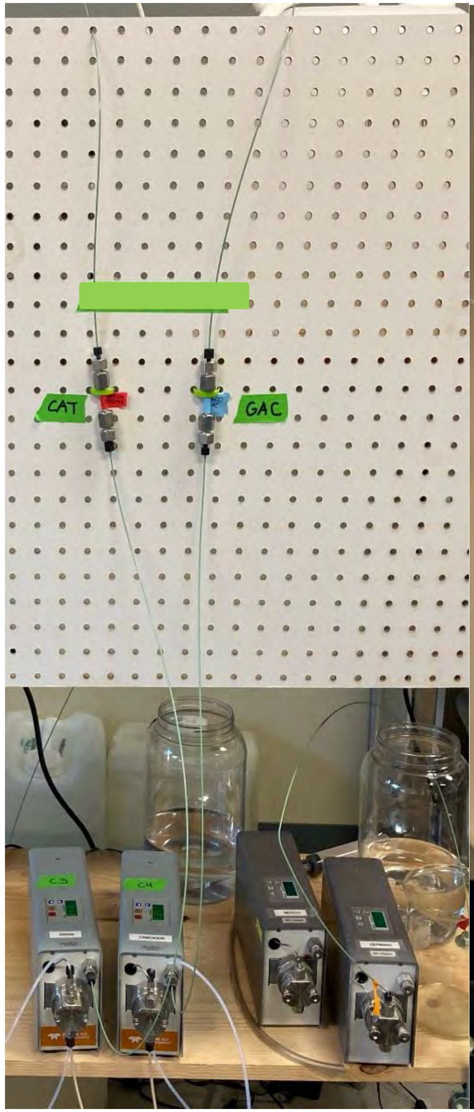
PFAS Treatment in Landfill Leachate

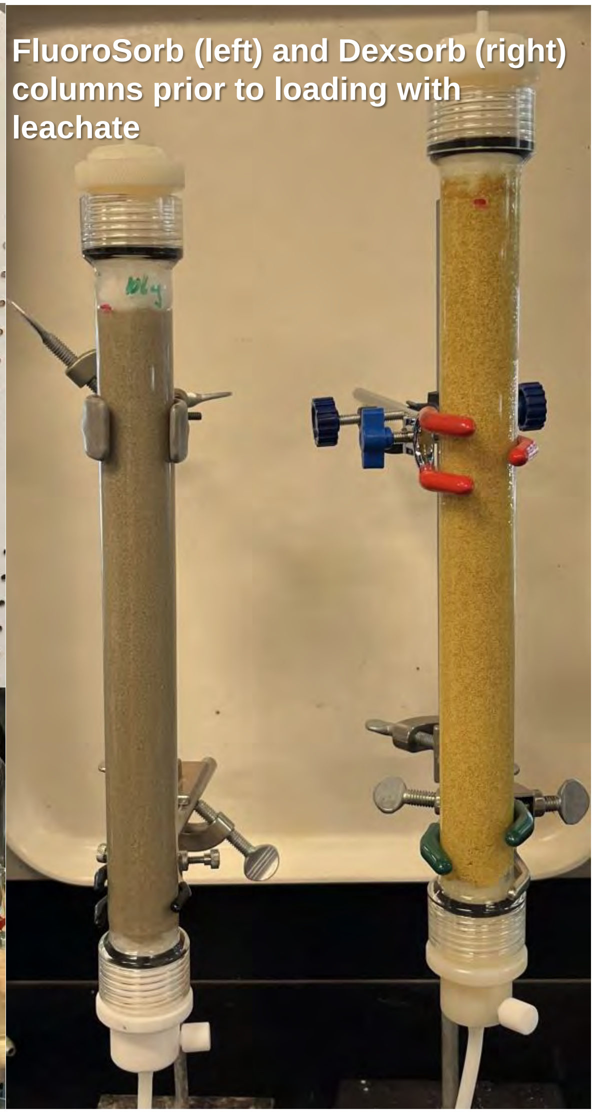
- Landfill leachate from different U.S. facilities
- High chemical oxygen demand (COD), TOC, and PFAS concentrations
- Evaluated FluoroSorb® 200 and DEXSORB® as sorbents for PFAS removal

Study Number	Liquid Matrix	Objective	Sorbents Evaluated	Test Type
1	Raw landfill leachate	Evaluate removal of PFAS by novel adsorbents	FluoroSorb® 200 and DEXSORB®	RSSCT
2	Raw landfill leachate	Evaluate removal of PFAS by novel adsorbents	FluoroSorb® 200 and DEXSORB®	Large columns
3	Raw landfill leachate	Evaluate removal of PFAS by novel adsorbents	FluoroSorb® 200	Large columns
4	SAFF Effluent	Evaluate removal of PFAS by novel adsorbents	FluoroSorb® 200	Large columns
5	Raw landfill leachate	Evaluate removal of PFAS by novel adsorbents	FluoroSorb® 200	Large columns
6	Raw, filtered raw, and biologically treated landfill leachate	Evaluate adsorption capacities and kinetics for PFAS by novel adsorbents	FluoroSorb® 200 and DEXSORB®	Batch tests
7	Raw and filtered raw landfill leachate	Evaluate PFAS removal by powder sorbents	Powder Activated Carbons (x2) and FluoroSorb® P	Batch tests

PFAS Treatment in Landfill Leachate

- **Studies 1 and 2 – Column Studies**
  - **RSSCTs**
    - DEXSORB® vs FluoroSorb®
    - 0.5 cm diameter columns
    - Large number of bed volumes treated in a few days
    - Media needs particle size reduction
  - **Large Columns**
    - As-received media
    - 3.8 cm diameter columns
    - More volume of water (larger bed volume): 110 gallons = 1,000 bed volumes

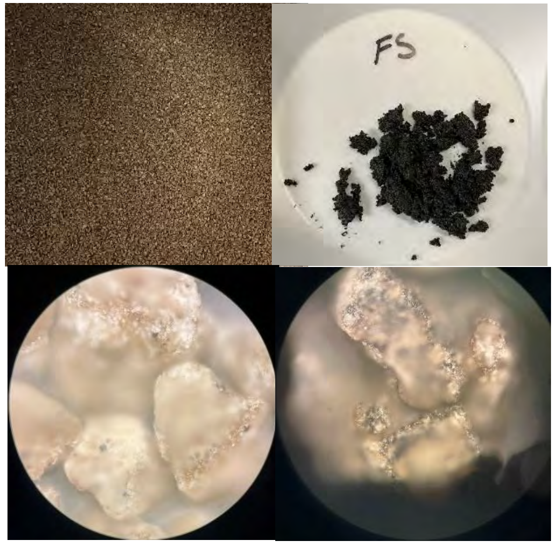




FluoroSorb (left) and Dexsorb (right) columns prior to loading with leachate

PFAS Treatment in Landfill Leachate

- **Highlights from Column Studies**
  - **High strength leachate with high TOC contributes to RSSCT challenges**
  - **Large columns with larger diameter and bed volume provide more accurate scaling to full-scale performance**
  - **PFOS did not break through either sorbent after treatment of 1,000 bed volumes (Study 3)**
  - **Breakthrough was observed for some PFAS**
  - **Biomass (biofilm) growth issues observed in large column studies**
    - Pretreatment necessary; filtration alone is not enough
    - Dissolved organics are the issue
  - **Evaluated powder sorbents → results indicated good performance by powder activated carbons and excellent performance for powder organoclay**



PFAS Treatment in Soil

PFAS In situ stabilization (ISS) and leachability case studies:

1. **Former Reese AFB, Lubbock County, Texas**
   - Demonstrate that PFAS can be stabilized via ISS to reduce leaching and eliminate the soil-to-groundwater pathway
   - Select a range of additives applicable for use at the former Reese AFB
2. **U.S. Army Garrison Ansbach, Germany: US Army Corps of Engineers, Europe District**
   - Select a range of amendments for potential application at the site
   - Assess whether stabilization can be used to meet German and Bavarian soil reuse criteria
   - Determine most efficient and cost-effective stabilization method to mitigate future leaching

- **Stabilization additives evaluated: cement, GAC, PAC, biochar, and organoclay**

Results not shown here for brevity. However, AECOM would be pleased to provide a follow up presentation focused on these two studies.

PFAS R&D

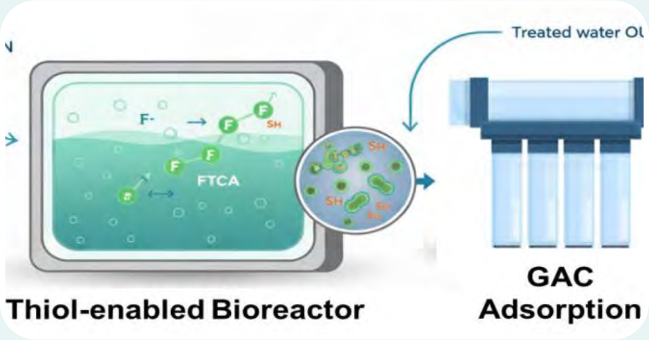
PFAS R&D

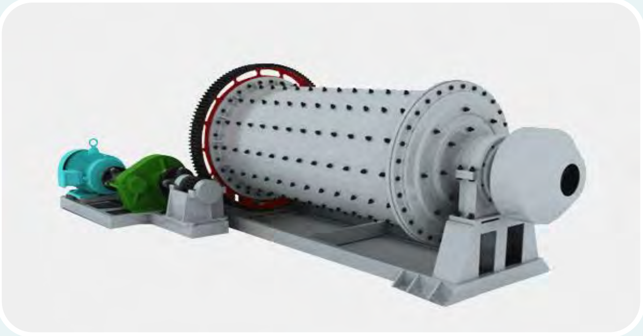
AECOM CTH Collaborates with other AECOM units, academia, and technology vendor to pursue research and technology development and demonstration for PFAS (and other emerging contaminants)

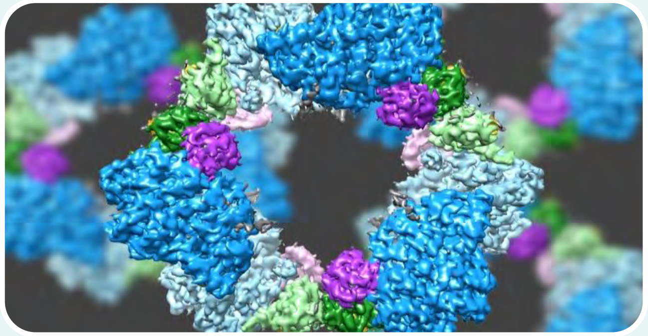
Examples of initiatives

- **Bench-scale evaluation of PFOS effect on chemotaxis of *Physarum* slime mold,** AECOM and private funds
- **Novel solvent-free IXR regeneration process**, privately funded
- **Evaluation of a novel cyclodextrin sorbent (StyDex) for PFAS and trace organics removal in pretreated municipal wastewater,** CoWERC fund, in collaboration with Northwestern University (Shapiro et al. 2023)
- **Hydrothermal liquefaction of biosolids and PFAS destruction**, state funded
- **PFAS Destruction in AFFF Concentrate Via Electrochemical Oxidation Treatment Train**, ESTCP ER24-ES-8951 funded
- **Enzymatic Oxidative Treatment for Perfluorinated Compounds in Groundwater**, AFCEC BAA #765 funded
- **Field Bioaugmentation with *Pseudonocardia dioxanivorans***, CB1190 Using In Situ Bioreactors, AFCEC BAA #844 funded

Collaborative Research Ideas







Biotransformation of PFAS precursors in landfill leachate by novel bacteria

Treatment trains for PFAS in landfill leachate using pre-treatment strategies, adsorption (novel organoclay) and mechanochemistry

Characterization of microplastics, microbial communities, and novel biomarkers for microplastics biodegradation in landfill leachate

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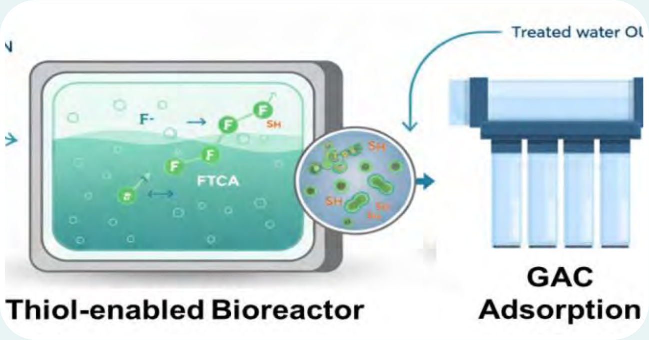


Biotransformation of PFAS precursors in landfill leachate by novel bacteria

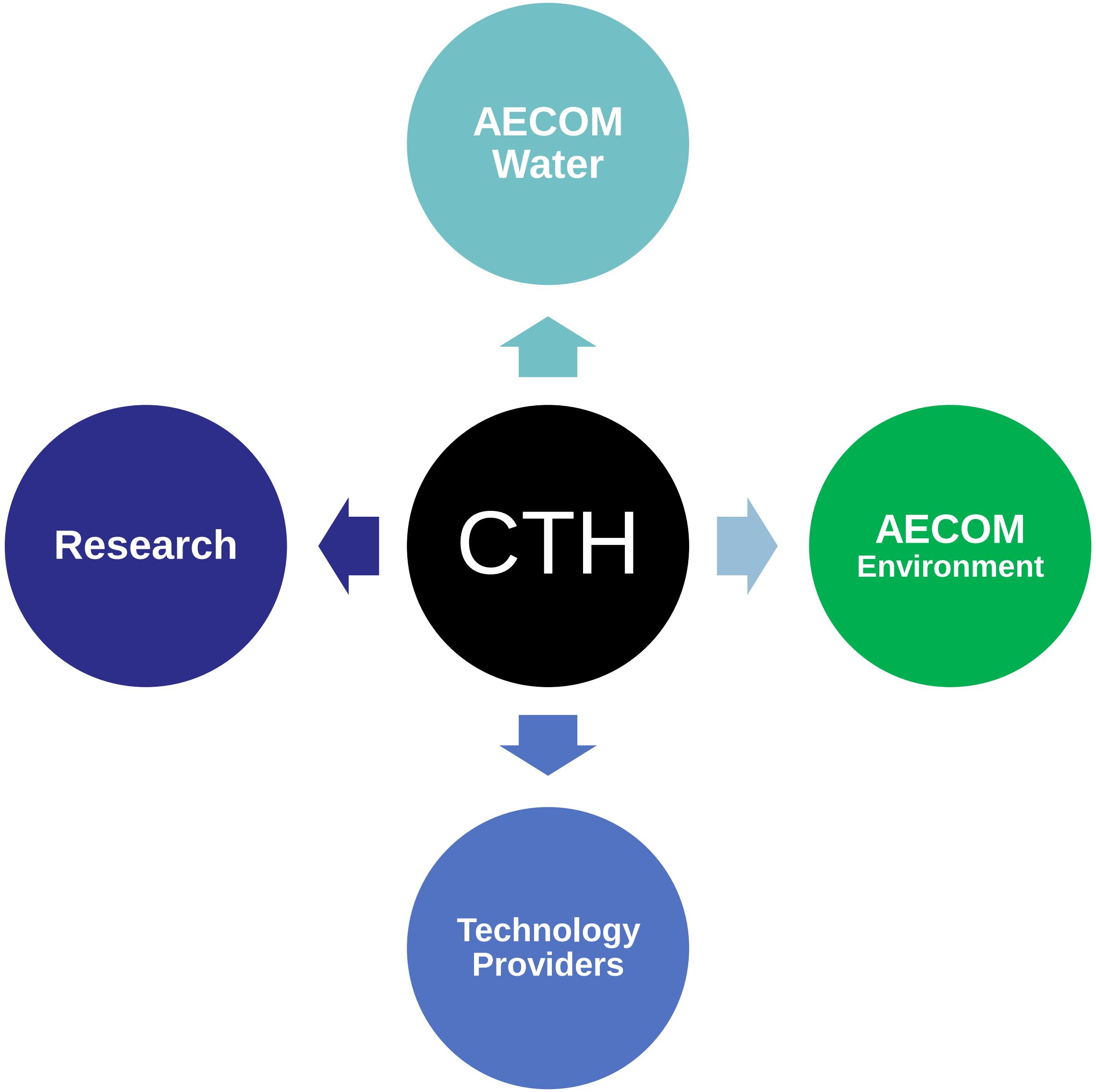
PFAS Precursors (FTCAs) Biotransformation

- Demonstrate a novel **mycothiol-mediated** biotransformation mechanism in real-world environments
- Optimize current processes to yield less PFCAs burden on downstream PFAS treatment systems
- Improve sorbents usage and thus decrease operational costs and residual waste quantities
- Based on the work from and in collaboration with Dr. Mengyan Li (NJIT)

Take Home Messages

Role of AECOM CleanTech Hub

- Leverage our expertise in the USA, Europe and Australia
- Continue supporting Water and Environment projects, especially on complex treatment problems
- Technology evaluation
  - Consolidate as a trusted hub to evaluate traditional and novel technologies
- Research
  - Identify, grow, and consolidate partnerships



Take Home Message Points

- AECOM's CTH Treatability Laboratory is a key asset for Water and Environmental projects
  - Treatability testing reduces uncertainty and evaluates various alternatives
- In-house PFAS analytical capabilities: faster turnaround time and more data access and control
- We continue to grow and deepen our PFAS treatment solutions expertise
- Experience working with difficult matrices like landfill leachate and biosolids
- We pursue readily applicable research with tangible solutions
  - Leveraging our external network : academia, technology vendors, and commercial laboratories
- We are AECOM's technology hub
  - With rich datasets from 100+ sorbent studies

References

- Armenante, P. M. (1991). *Adsorption with Granular Activated Carbon*. New Jersey Institute of Technology.
- Lin, Z.-W., Shapiro, E. F., Barajas-Rodriguez, F. J., Gaisin, A., Ateia, M., Currie, J., Helbling, D. E., Gwinn, R., Packman, A. I., & Dichtel, W. R. (2023). Trace Organic Contaminant Removal from Municipal Wastewater by Styrenic β-Cyclodextrin Polymers. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.3c04233
- Ling, Y. (2021). *Novel β -cyclodextrin Polymer Adsorbents for Removal of PFAS from Diverse Water Matrices*. http://hdl.handle.net/2142/109870

Questions?

Your Success is Our Mission!