

PFAS Pilot at Belmont WTP

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PHILADELPHIA
WATER
— DEPARTMENT —



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Outline

Project Background

PFAS Treatment Technologies

Rapid Small-scale Column Test

Pilot Operation

Pilot Data

Questions

Outline

Project Background

- ▶ Overview
- ▶ PWD PFAS Planning Approach

PFAS Treatment Technologies

Rapid Small-scale Column Test

Belmont PFAS Pilot

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Project Background

Overview

- **Philadelphia Water Department (PWD)**

- Service area of about 130 square miles
- Serves ~1.58 million people: > 220 MGD
- 3 water treatment plants (WTPs)
 - Baxter WTP (Delaware River)
 - Belmont WTP (Schuylkill River)
 - Queen Lane WTP (Schuylkill River)

- **PFAS Regulations**

- April 2024: PFOS and PFOA MCLs to 4 ppt
- Hazard Index
- Initial monitoring to begin within 3 years of rule promulgation.
 - Final rule takes effect 5 years after promulgation (2029).
- Piloting required for permitting (PADEP)
- PWD would face compliance challenges with PFOA and PFOS at the Belmont and Queen Lane WTPs with the rule as currently written



PWD WTPs and service area

4 ppt equals approx. 1 drop of water in an Olympic sized pool

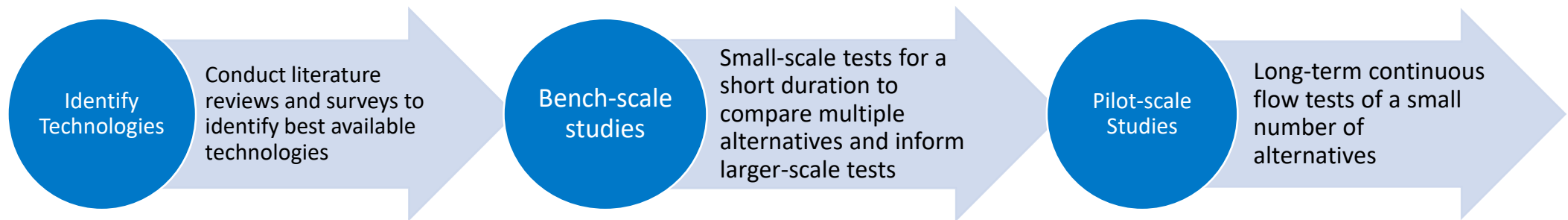


Project Background

PWD PFAS Planning Approach

- Established PFAS workings groups composed of interdepartmental stakeholders
- Utilized consultant support
- Planning team began PFAS treatment alternatives analysis
 - PFAS Technology Evaluation will inform analysis for full scale implementation

Phases of PFAS Technology Evaluation



Outline

Project Background

PFAS Treatment Technologies

- ▶ Selected Technologies
 - ▶ Treatment Mechanisms
-

Rapid Small-scale Column Test

Belmont PFAS Pilot

Pilot Outcomes

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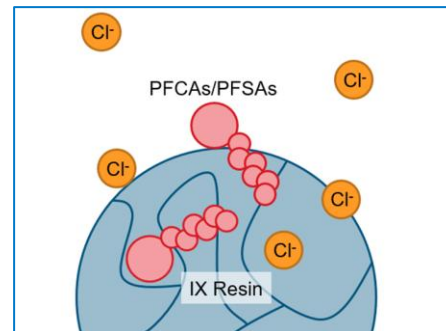
PFAS Treatment Technologies

Selected Technologies

- **Ion exchange (IX)** and **granular activated carbon (GAC)** selected for piloting:
 - IX selected based on industry survey and PWD's water quality characteristics
 - GAC selected based on rapid small-scale column test (RSSCT) evaluation
- Nanofiltration and reverse osmosis removed due to corrosivity, operating cost, and concentrate handling concerns

Ion Exchange (IX)

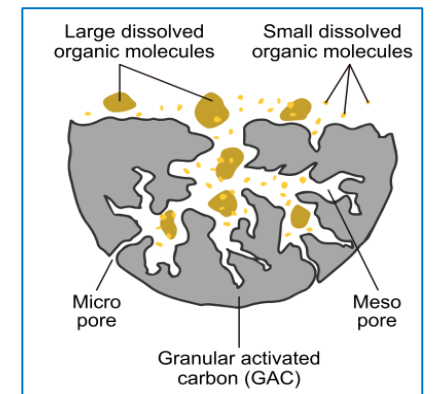
- Cross linked organic polymers shaped into small beads
- Charged functional groups covalently bound to polymer backbone attract oppositely charged ions
- Selectivity based on functional groups



IX resin example illustration

Granular Activated Carbon (GAC)

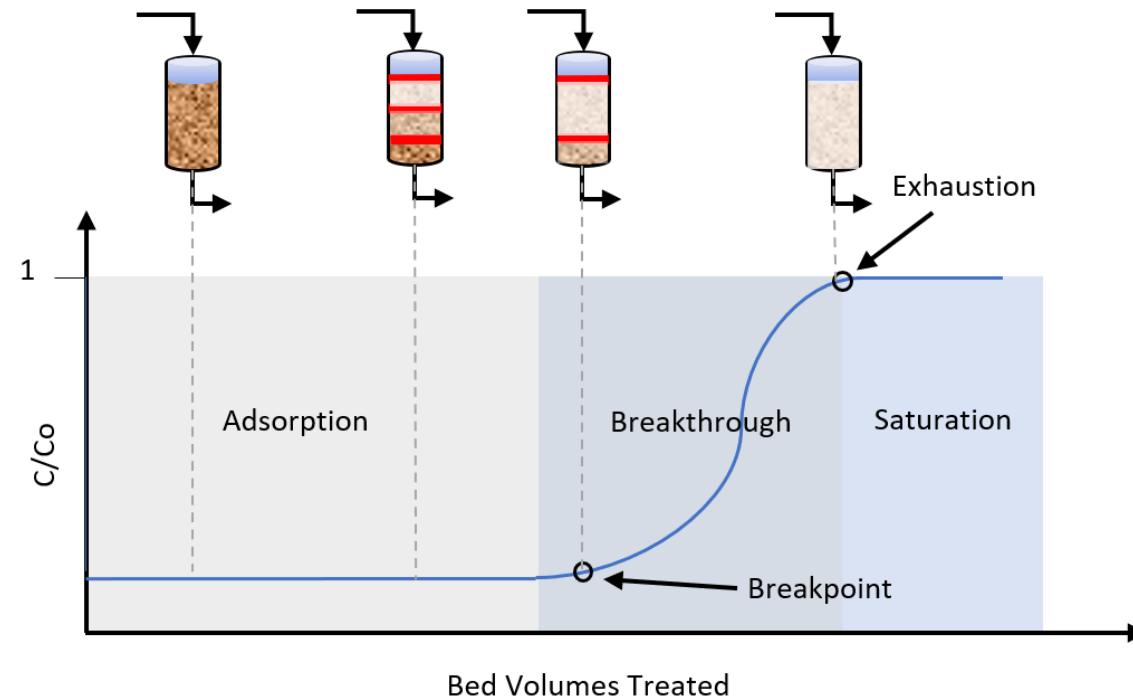
- Carbon activation improves pore volume and specific surface area
- Adsorption not Absorption
 - Contaminants “stick” and adhere
- Removes contaminants **unselectively**
- Secondary water quality benefits including TOC and taste and odor compounds removal



GAC example illustration

PFAS Treatment Technologies

Breakthrough Curves



Example breakthrough curve (adapted from Civardi 2021)

- C_0 represents the influent concentration of a contaminant, and C is its effluent concentration
- The ratio of C/C_0 is referred to as the 'normalized' effluent concentration and accounts for variations in influent concentration

Outline

Background on PFAS

PFAS Treatment Technologies

Rapid Small-scale Column Test

- ▶ Overview
 - ▶ Results
-

Belmont PFAS Pilot

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Rapid Small Scale Column Test

Overview

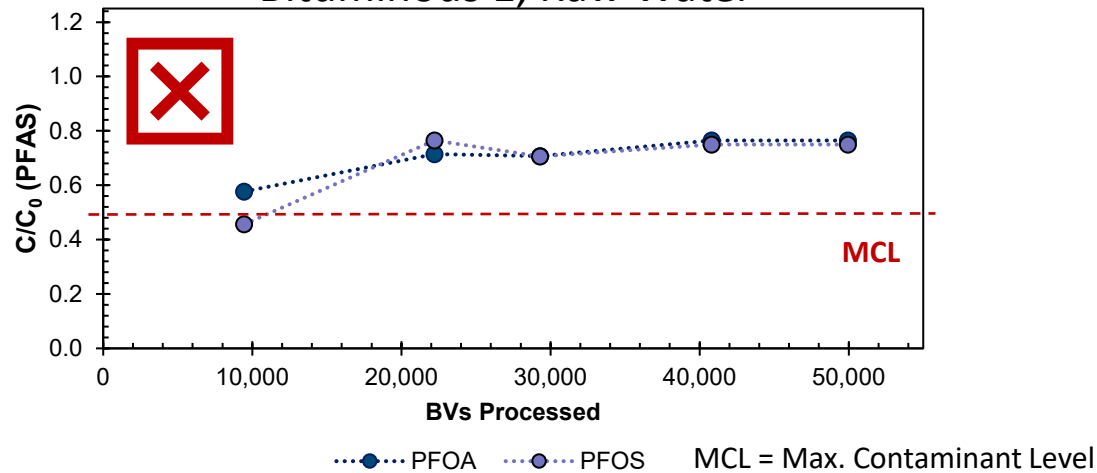
- **Purpose:** analyze **fatal flaws** of specific treatment strategies and compare **between** different media – does not necessarily give accurate prediction of bed life
- 2 test locations
 - Raw water (RW)
 - Clearwell influent (CI)
- 4 types of GAC (8 total columns)
 - 2 bituminous coal
 - 1 sub-bituminous coal
 - 1 coconut-based
- GAC media is ground down to smaller size proportional to column diameter
- Sample water spiked with PFAS for uniform influent concentration and to ensure that breakthrough would occur (mimics “worst-case” scenario)



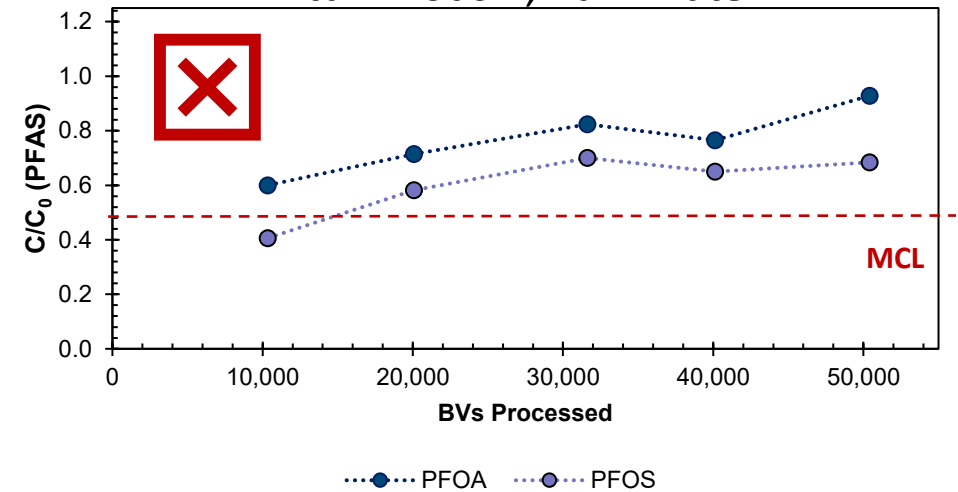
Rapid Small Scale Column Test

Breakthrough Curves – Raw Water

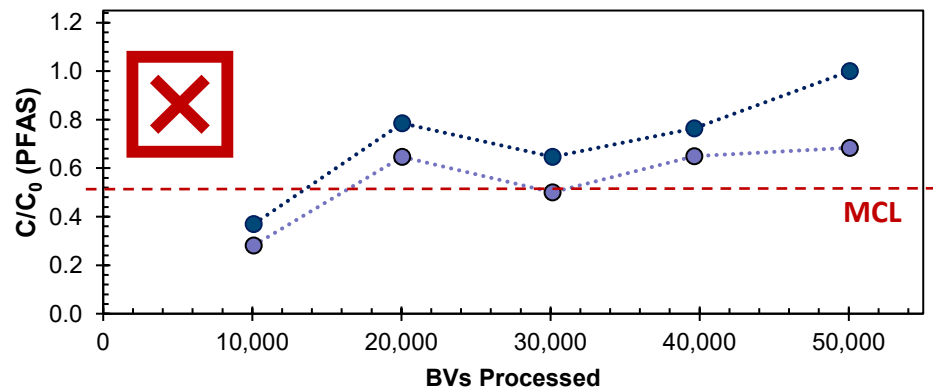
Bituminous 1, Raw Water



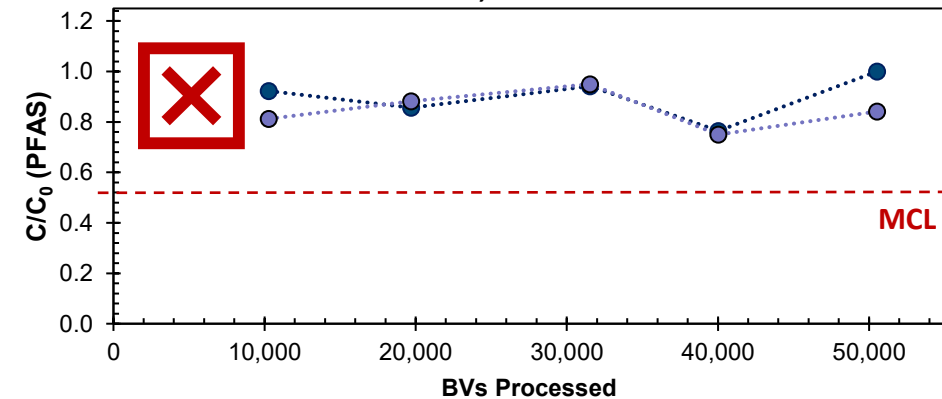
Bituminous 2, Raw Water



Sub-bituminous, Raw Water



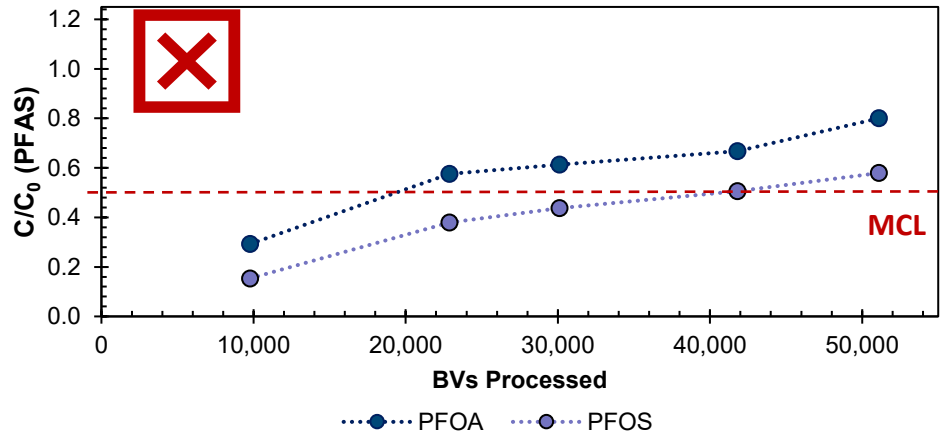
Coconut, Raw Water



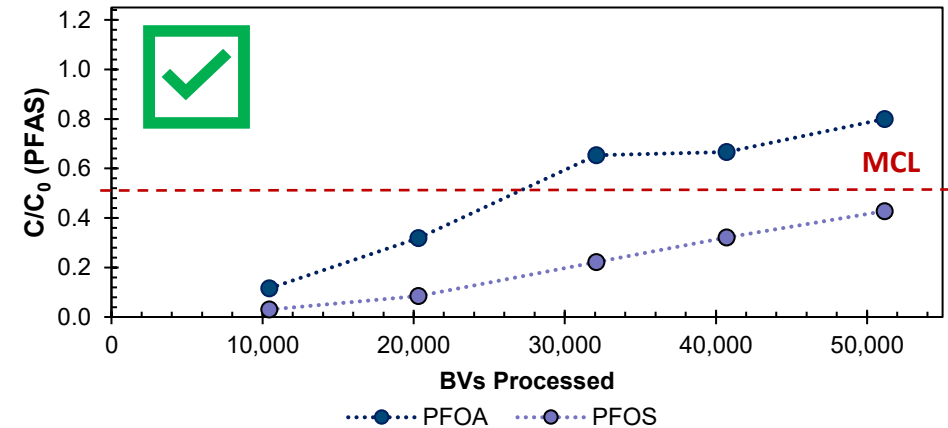
Rapid Small Scale Column Test

Breakthrough Curves – Clearwell Influent (CI)

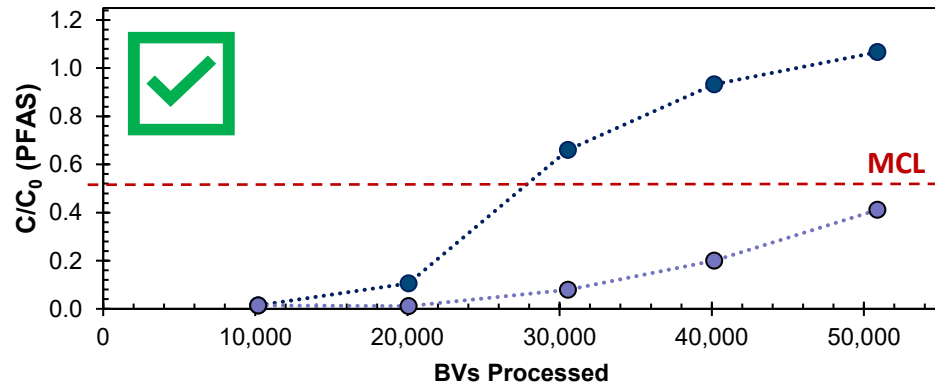
Bituminous 1, CI



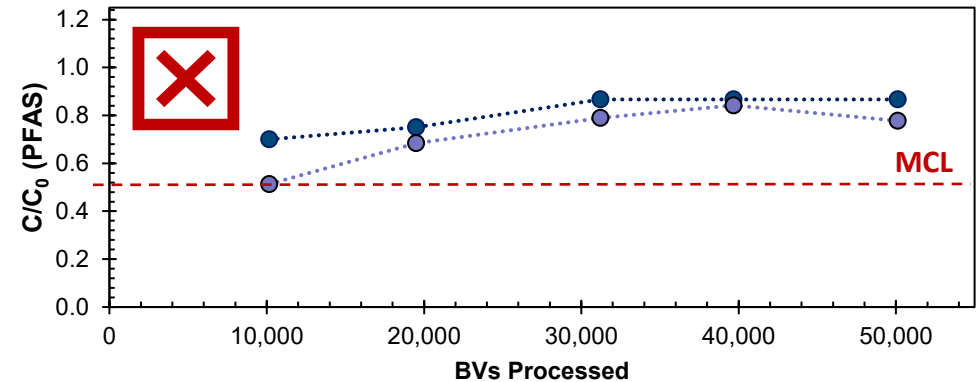
Bituminous 2, CI



Sub-bituminous, CI



Coconut, CI



Rapid Small Scale Column Test

Conclusion: Bed volumes to Reach Proposed MCLs

RWB	PFOA	PFOS
Bituminous 1	<<10,000	11,000
Sub-bituminous	13,000	22,000
Bituminous 2	<<10,000	15,000
Coconut	<<10,000	<<10,000

CI	PFOA	PFOS
Bituminous 1	23,000	39,000
Sub-bituminous	29,000	56,000
Bituminous 2	26,000	58,000
Coconut	<<10,000	9,000

(Extrapolated from linear portion of breakthrough curves using a constant diffusivity approach)

Rapid Small Scale Column Test

Conclusion: Hazard Index

$$\text{Hazard Index} = \left(\frac{[GenX]}{10 \text{ ppt}} \right) + \left(\frac{[PFBS]}{2000 \text{ ppt}} \right) + \left(\frac{[PFNA]}{10 \text{ ppt}} \right) + \left(\frac{[PFHxS]}{9 \text{ ppt}} \right)$$

RWB	Hazard Index
Column Influent	0.0026
Bituminous 1	0.0025
Sub-bituminous	0.0026
Bituminous 2	0.0025
Coconut	0.0024

CFE	Hazard Index
Column Influent	0.0025
Bituminous 1	0.0026
Sub-bituminous	0.0025
Bituminous 2	0.0027
Coconut	0.0024

- If the running annual average Hazard index (HI) is greater than 1.0, it is a violation of the proposed HI MCL.
- HI compounds are not expected to approach the MCL of 1.0.

Rapid Small Scale Column Test

Key Takeaways

- RSSCT results are used for **fatal flaw analysis** – Certain GAC media or locations can be **ruled out**, but further pilot testing is needed
- Results summary from full report
 - RW columns showed much higher breakthrough than CI
 - HDR expert conducting the study referred to our water as “challenging to treat” for lower molecular weight compounds.
 - Bituminous and sub-bituminous coal GAC products out-performed coconut-based GAC
- **These results generally align with reported results in literature**
 - Short-chain compounds (<C6 for sulfonic acids; <C8 for carboxylic acids) tend to break through first; saw complete breakthrough of these compounds prior to long-chain compounds
 - Surface water is typically more challenging to treat than groundwater, as dissolved organic matter competes with PFAS compounds for sorption sites – this leads to earlier breakthrough in surface water systems
 - Bituminous coal tends to be the best source for GAC products for PFAS removal, with coconut GAC performing poorly
- Further testing of GAC products will be performed at pilot-scale starting in April 2024

Outline

Background on PFAS

PFAS Treatment Technologies

Rapid Small-scale Column Test

Belmont Pilot Operation

- ▶ Overview
 - ▶ Start Up Sampling
 - ▶ Ion Exchange Challenges
-

Pilot Outcomes

Questions

Belmont Pilot Operation

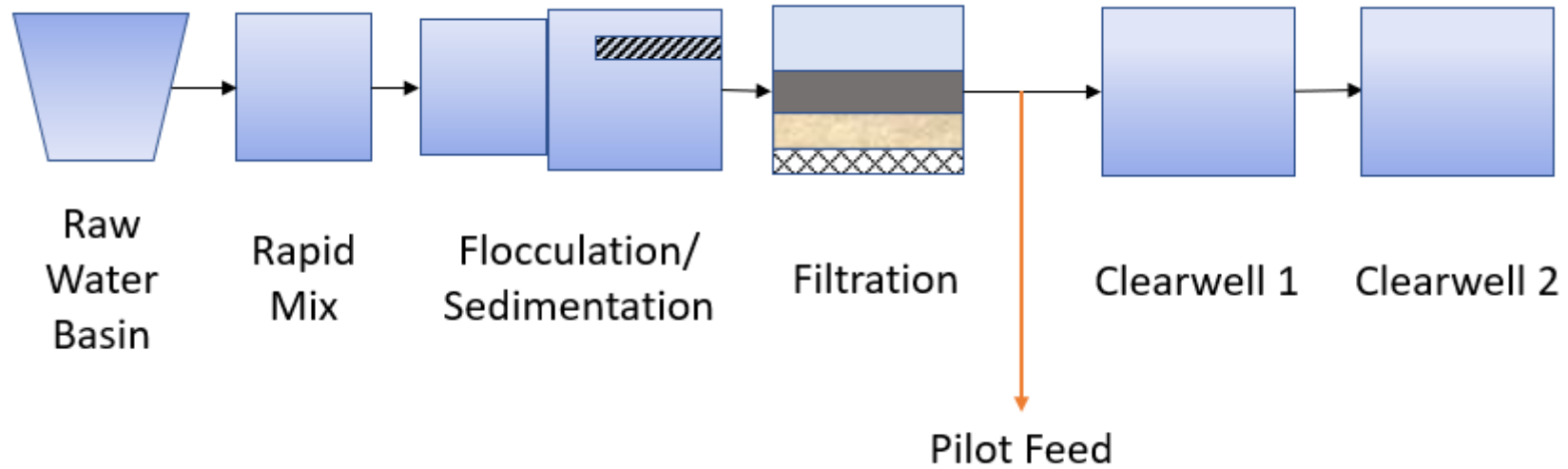
Overview

- PADEP requires piloting of GAC and IX treatment technologies for PFAS removal
 - Pilot Application accepted by PADEP in April 2024
- Developed extensive start-up and year-long sampling plans
- Key Study Goals
 - Determine expected bed life and breakthrough characteristics for PFAS removal alternatives
 - Determine secondary water quality benefits and downstream impacts of alternatives (e.g., distribution system corrosion)
 - Plan for future regulations beyond the draft EPA PFAS Rule
 - Removal of extended PFAS species in UCMR5
 - Removal of other contaminants of emerging concern (CECs; e.g., PPCP, 1,4-dioxane, unregulated DBP species)



Belmont Pilot

Location

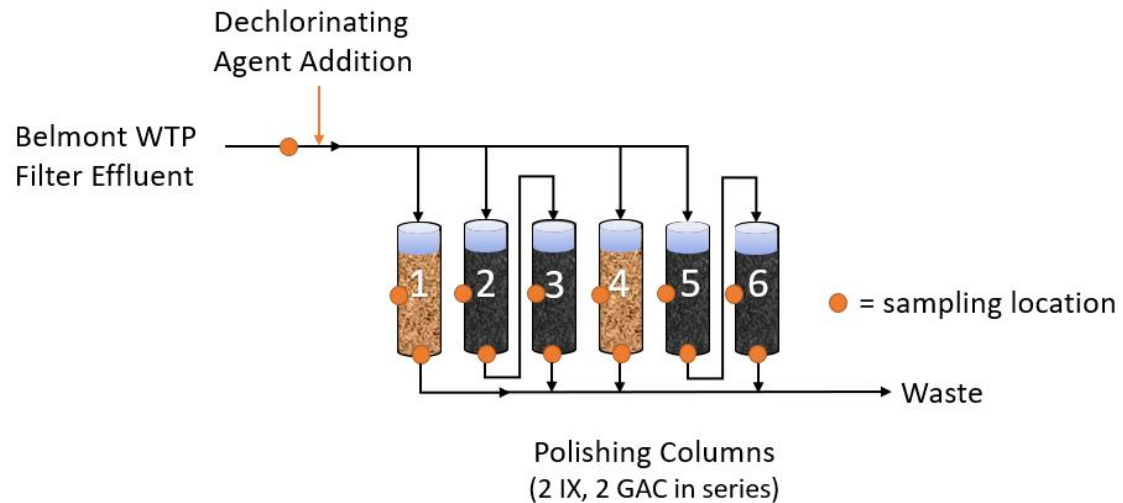


Belmont Pilot

Process Flow Diagram

Columns	Media	EBCT (min)	Notes
1	IX	2.5	PFAS-selective AER*
2 and 3	GAC	20	Bituminous coal
4	IX	2.5	PFAS-selective AER*
5 and 6	GAC	20	Sub-bituminous coal

*AER: Anion Exchange Resin



Belmont PFAS Pilot

Start Up Sampling

- **Purpose:** to inform our understanding of potential water quality issues during start-up of systems
- **Only once during initial start-up of pilot!**
- Samples collected every **30 minutes** until organics stabilize, as measured by UV 254 transmittance (literature says typically 4 – 6 hours)
- Concerns during start up:

GAC	IX
<ul style="list-style-type: none">• Spikes in pH• Arsenic leaching• Alkalinity changes	<ul style="list-style-type: none">• pH and alkalinity changes• Nitrosamines• Chloride/Nitrates• Total Dissolved Solids (TDS)

Belmont PFAS Polishing Pilot

Start Up Sampling Observations

GAC

- Both GAC contactors saw a spike in pH and alkalinity that persisted even after backwashing
- The initial BVs from GAC contactors saw release of arsenic, but concentrations never reached 50% of the MCL

Lessons learned

- **Robust backwashing** of contactors is necessary prior to bringing GAC vessels online
- A combination of blending and wasting is recommended if GAC is selected for full-scale buildout

IX

- Both IX columns saw large drops in pH and alkalinity
- Release of chlorides and exchange of sulfates may pose corrosion challenges during start-up
- Release of nitrosamines may pose future regulatory challenges during start-up

Lessons learned

- IX columns started immediately with **no interruption** or need for backwashing
- Initial BV water quality would necessitate robust wasting or blending capabilities

Pilot Outcomes

Ion Exchange Challenges

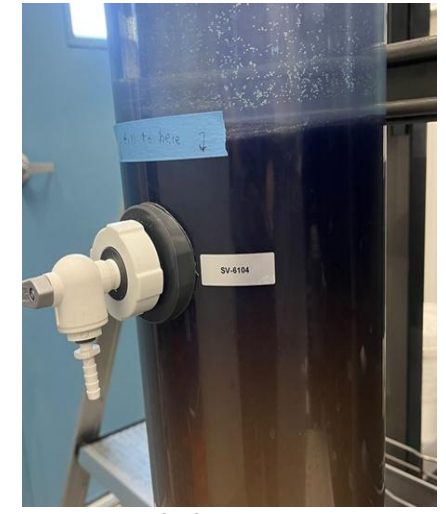
- Dechlorination challenges
 - Clogged feedline
 - Loss of dechlorination Media loss
- Fouling on Resin
 - IX resin became discolored
 - Analysis showed excessive organics accumulation
 - A sharp increase in headloss was observed
- System shut down due to headloss
- Vendors recommended 5-micron filtration upstream



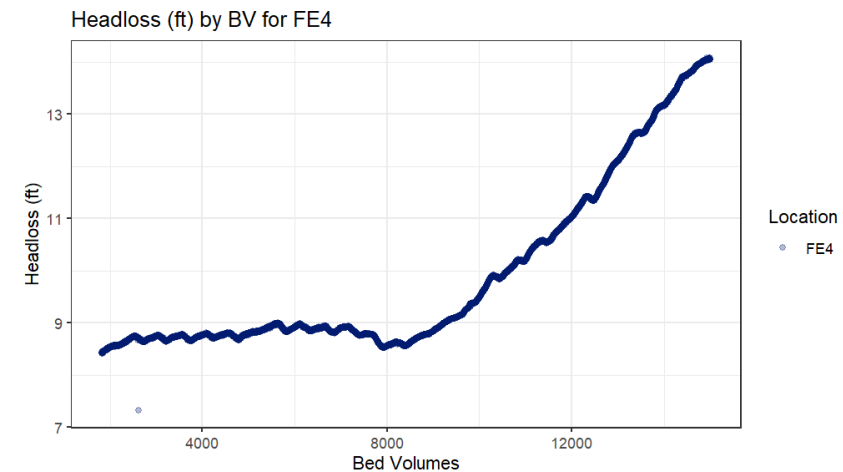
Start-up



1 day later



1 week later



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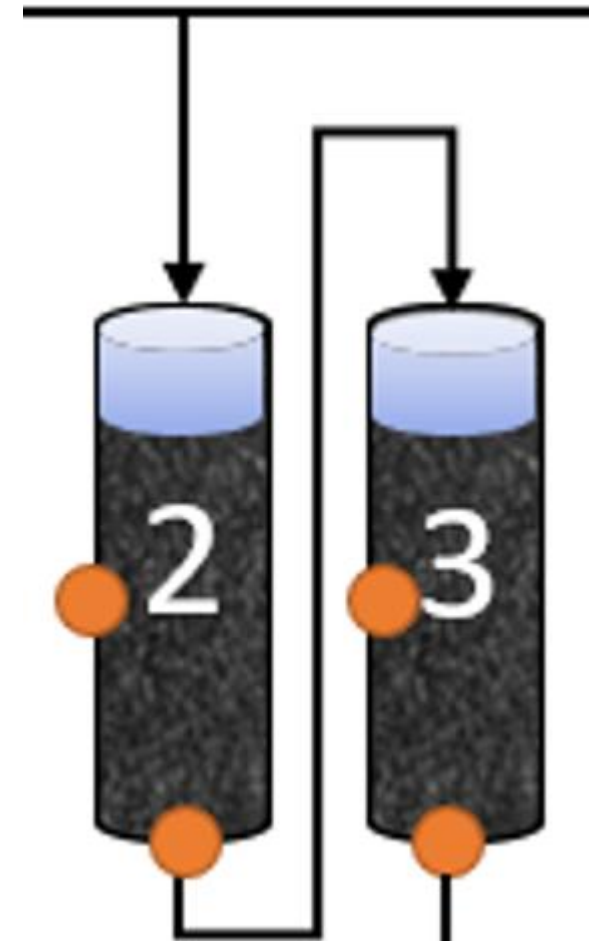
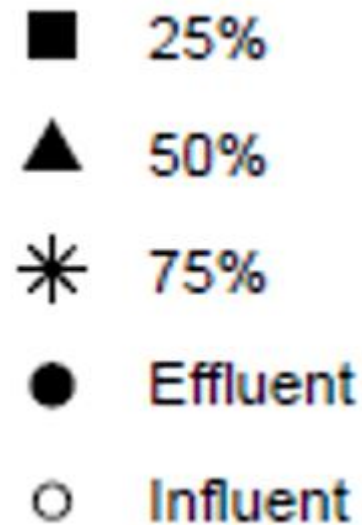
- ▶ GAC PFAS Results
-

Questions

Pilot Outcomes

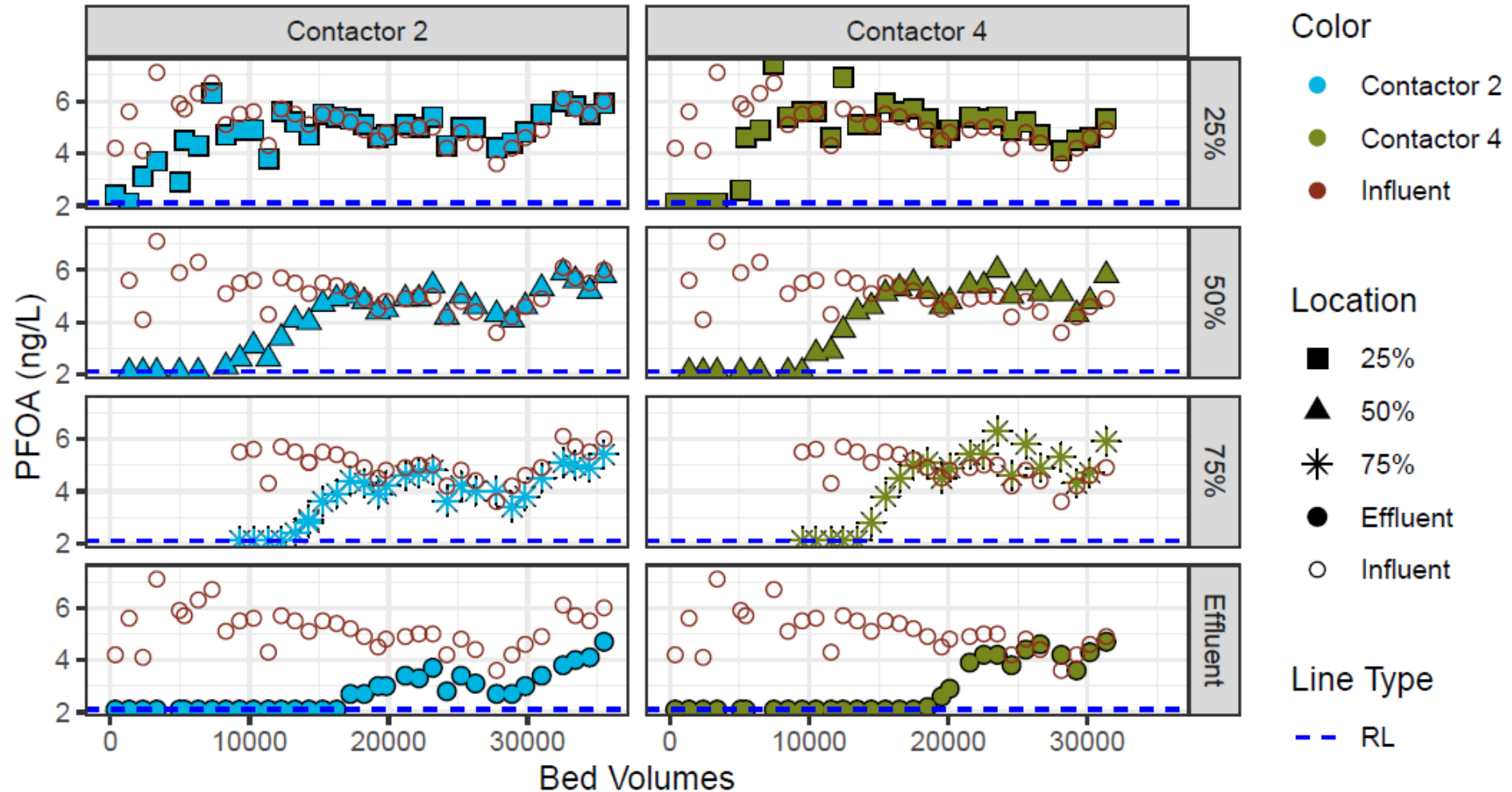
Data Presentation

- Contactor data is presented by showing the influent (hollow dots) and contactor effluent (filled dots)
- Midpoint values can help to show the breakthrough characteristics of a given compound
- **Note: these results show a single contactor; a full-scale buildout would include many contactors at different points of breakthrough**



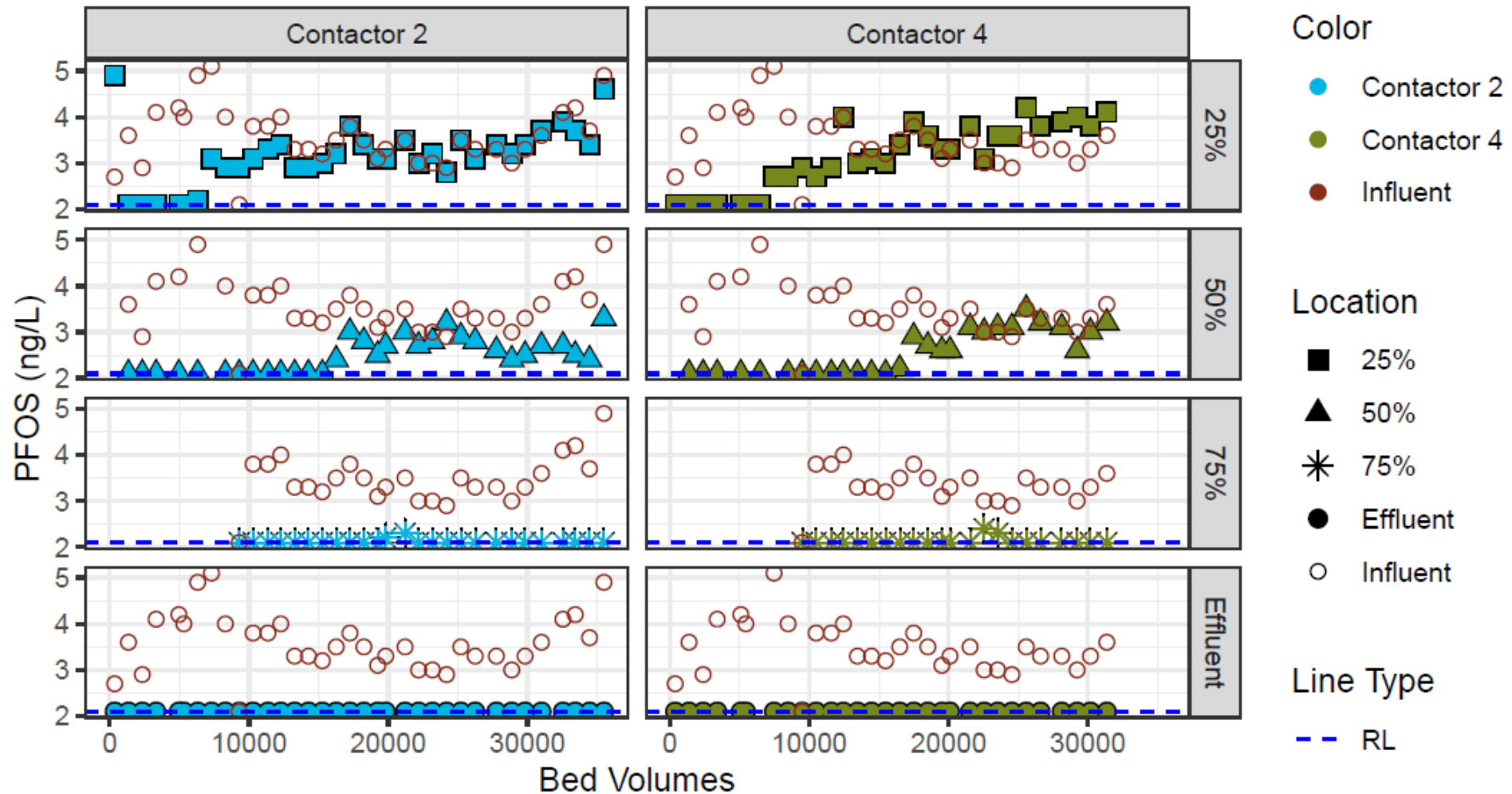
Pilot Outcomes

GAC PFAS Results: PFOA



Pilot Outcomes

GAC PFAS Results: PFOS



Pilot Outcomes

PFAS Data Summary

- **Key Takeaway: Both contactors showed effective removal of PFOA beyond 20,000 BV, with the bituminous GAC contactor effectively treating up to 35,000 BV**
- This aligns relatively well with the bench-scale study which estimated breakthrough of PFOA above the MCL at approximately 26,000 BV
- HI compounds are less of a concern
 - No hits for PFHxS, PFNA, or HFPO-DA
 - PFBS showed complete breakthrough by 20,000 BV in both contactors
 - HI never exceeded 0.003 throughout the study period
- Backwashing GAC contactors did not appear to regain any capacity
- Results for breakthrough characteristics generally align with what is presented in literature

Other Regulatory Considerations

Primary Standards and Contaminants of Emerging Concern

- **Unregulated PFAS (Method 533 and 537.1)**
 - No unregulated PFASs observed
 - Shorter-chain PFCAs broke through first – expected to pose challenges if future regulations affect them
- **DBPs**
 - THMs showed breakthrough after <10k BV, followed by concentration inversion ($C/C_0 > 1$)
 - HAA5 and other unregulated DBPs (HAA4, HANs, chloral hydrate, chloropicrin, chloropropanones) showed effective removal throughout the study
 - TOX was added to the sampling plan after 20k BV and showed between 50 – 75% removal, even after PFAS breakthrough began
- **Pharmaceuticals and Personal care products (PPCPs)**
 - Few PPCPs observed in source water, with many hits very close to the reporting limit
 - Broad removal of most PPCPs detected
 - Some breakthrough observed for highly polar compounds (e.g., sucralose, AceK)
- 1,4-dioxane showed no removal with GAC treatment

Next Steps

- The results of the pilot study will be used to inform the alternatives evaluation, design, and permitting of the GAC treatment system for the Belmont WTP
- Academic: the data generated in this study will aid in the development of a data-driven model with the aim to predict the behavior of compounds during GAC treatment
 - Alternative to the established pore volume and surface diffusion model
 - Develop a tool to consider the public health implications of GAC treatment
- Pilot system will be used to inform the alternatives evaluation and design of the complete reconstruction of the Queen Lane WTP

References

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Thank you!

Questions?

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