PFAS Treatment Technologies Update: Non-Destructive vs. Destructive technologies

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Acknowledgements


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SERDP DOD · EPA · DOE

NSF

AIR FORCE CIVIL ENGINEER CENTER

ESTCP

SRC® Semiconductor Research Corporation

NAVFAC Naval Facilities Engineering Systems Command NAVFAC SOUTHEAST

The Water Research Foundation

NAWI National Alliance for Water Innovation

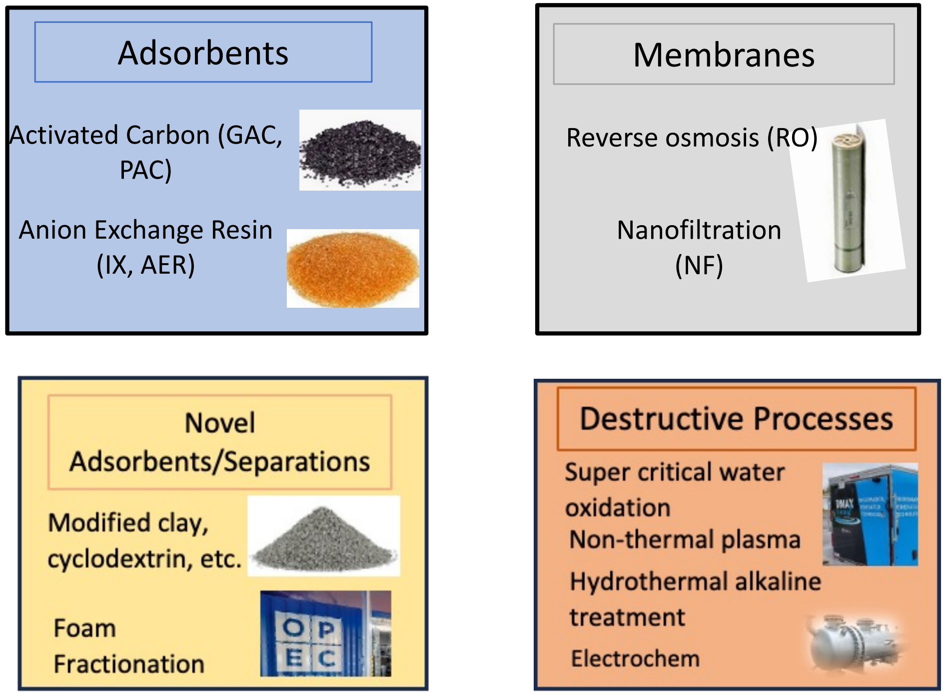
- Mines is and has been involved in numerous PFAS treatment projects
- Projects have involved numerous students, post-docs and research faculty
- Collaborations include various universities, consulting companies, utilities and industry partners

PFAS Treatment Evolution

ELSEVIER
Journal of Hazardous Materials 260 (2013) 740–746
Journal of Hazardous Materials

Nanofiltration and granular activated carbon treatment of perfluoroalkyl acids

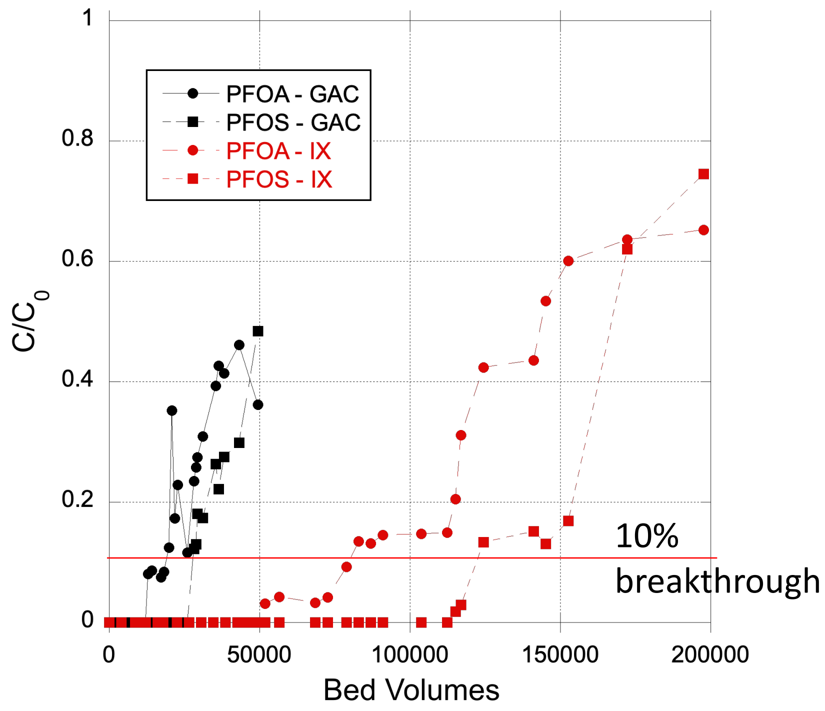
Timothy D. Appleman[a], Eric R.V. Dickenson[a,b,**], Christopher Bellona[c], Christopher P. Higgins[a,*]



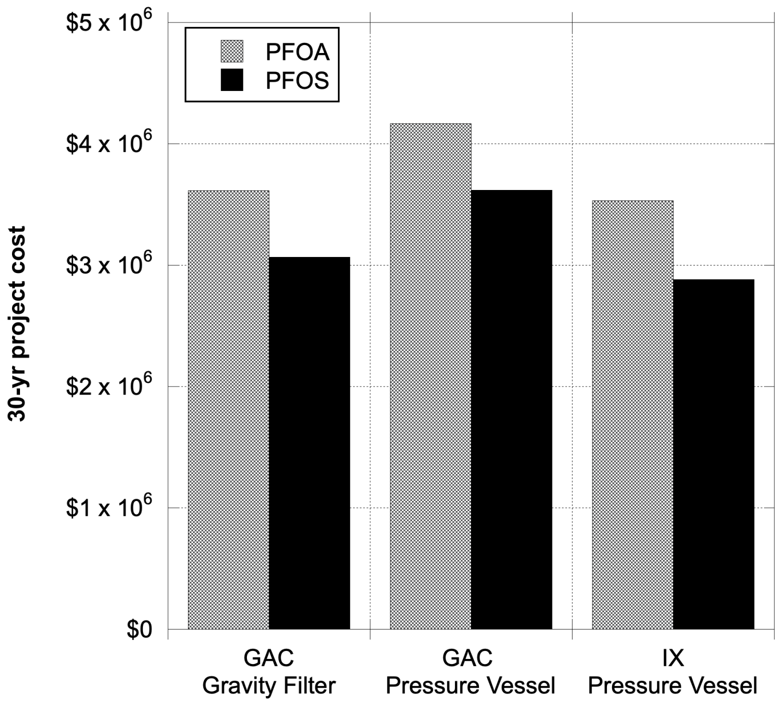
- In 2012, best available technologies included adsorbents and membranes
- Since then, significant research conducted to develop 'silver bullet' PFAS treatment process
- 100's of papers per year on PFAS treatment technologies
- In 2024, adsorptive treatment most implemented
- Push towards more selective adsorbents
- Foam fractionation being implemented at scale
- Destructive PFAS technologies are being commercialized
- Currently, no 'silver bullet' technology

Adsorptive PFAS Treatment - Groundwater

- Groundwater treatment comparison between GAC and IX

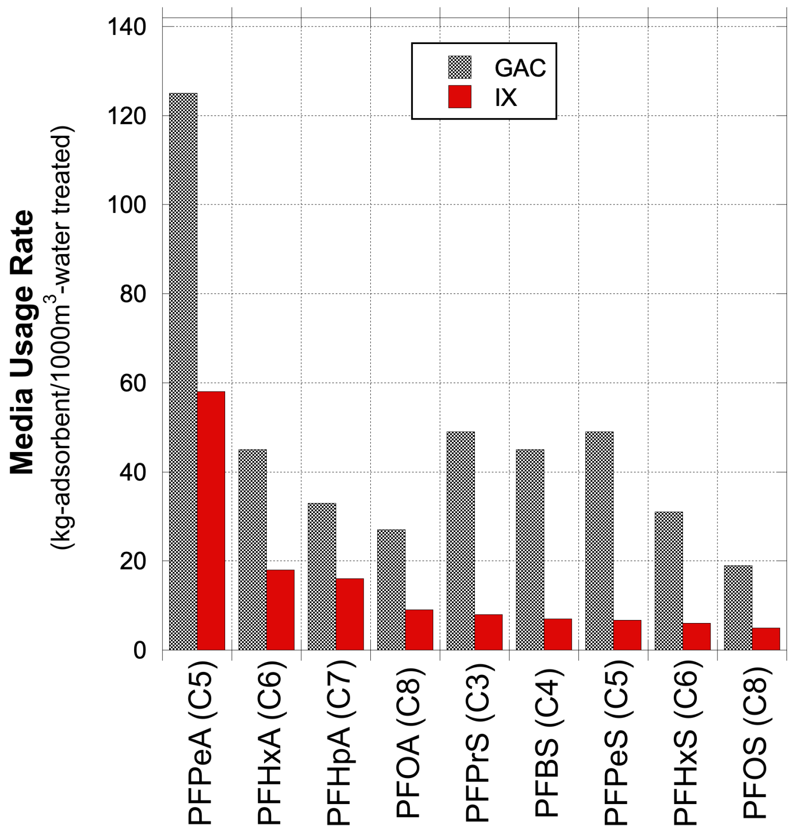


Data from pilot-scale comparison of GAC and IX performed at the City of Fountain, CO (Liu et al., 2019 and 2022)



30-yr project cost for treating 1000 m^3/d (0.38 MGD)

Rapid breakthrough of short-chain PFAS



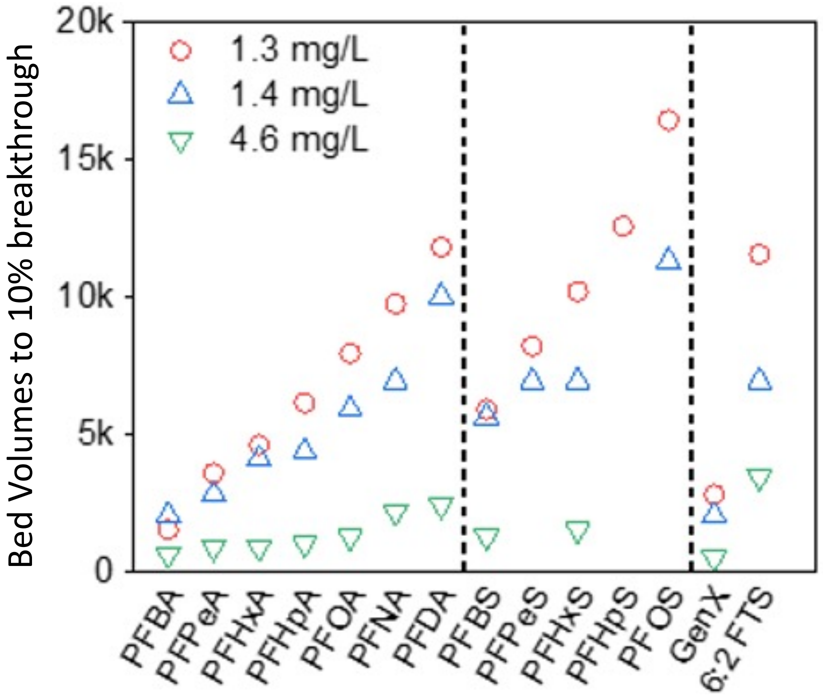
Adsorptive PFAS Treatment – Impact of Organic Matter

Surface Water

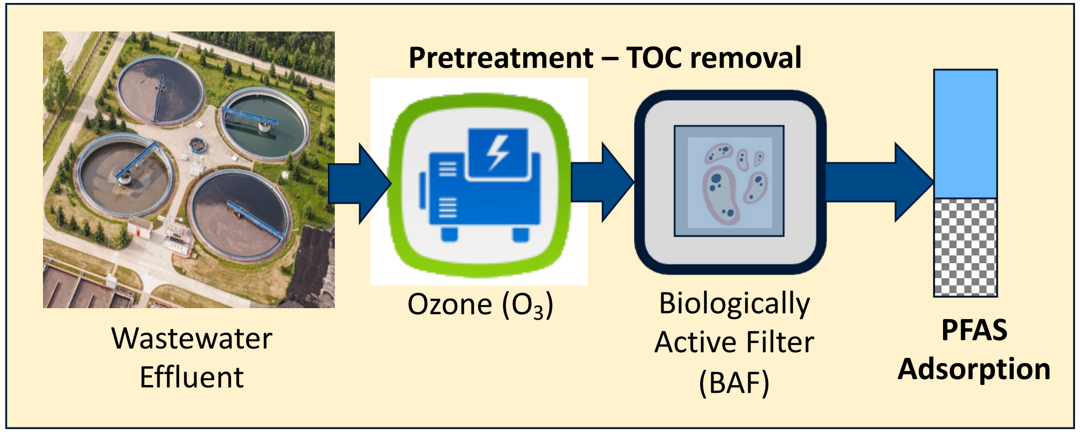
Wastewater

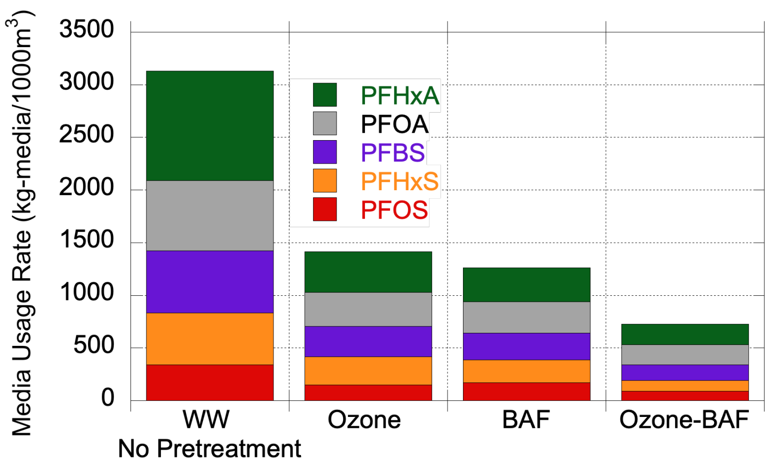
Organic matter reduces effectiveness

IX

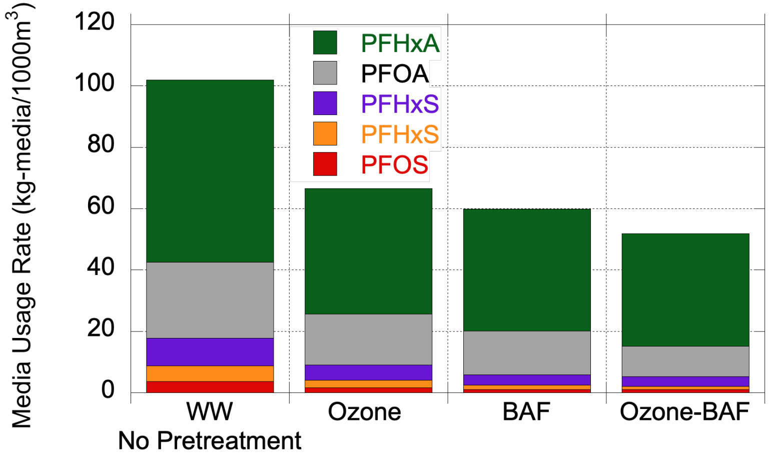


Data generated through RSSCTs by Detlef Knappe as part of ESTCP ER18-5053



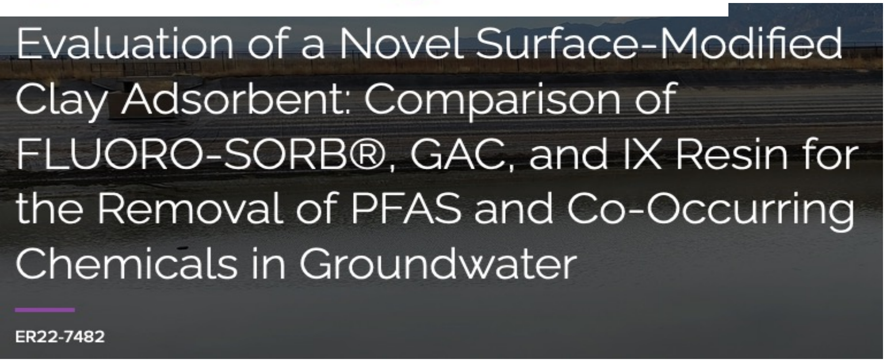


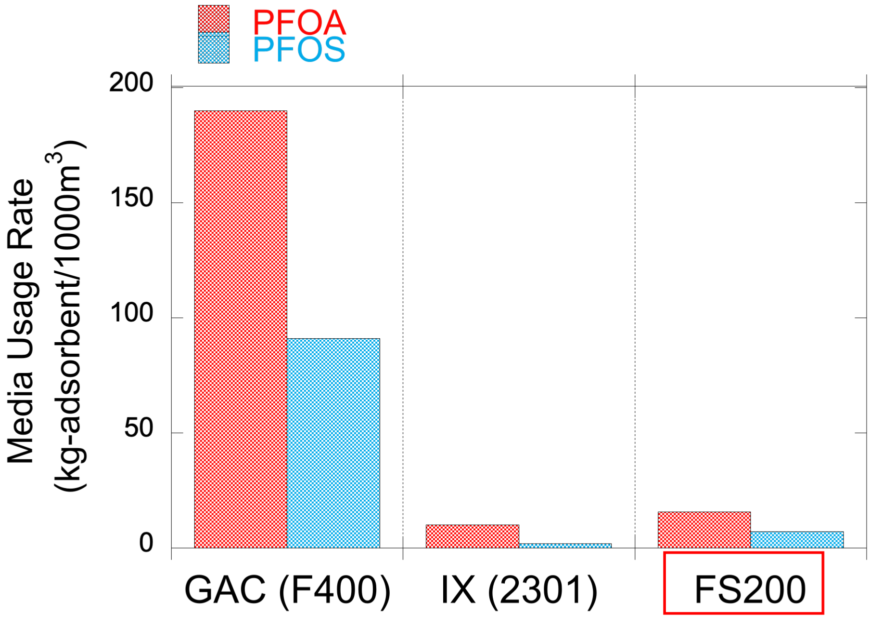
GAC



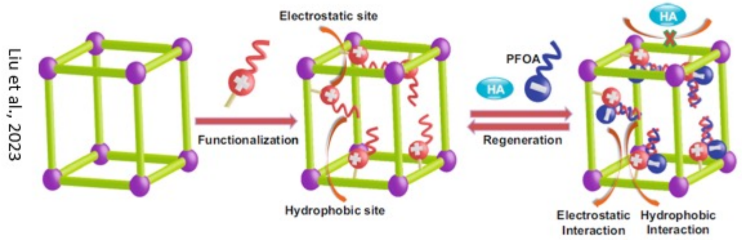
IX

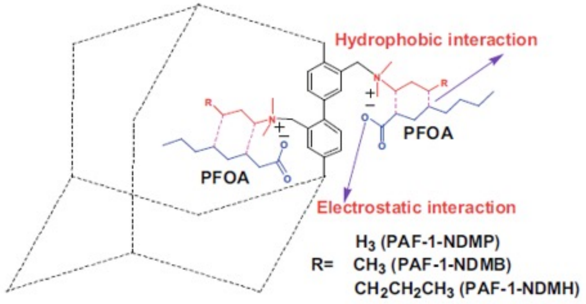
Adsorptive PFAS Treatment – Novel Adsorbents

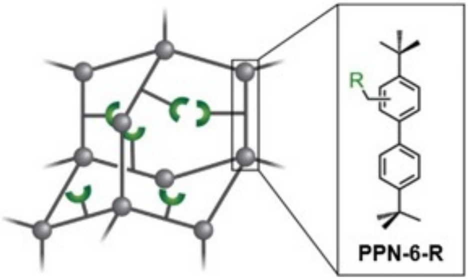


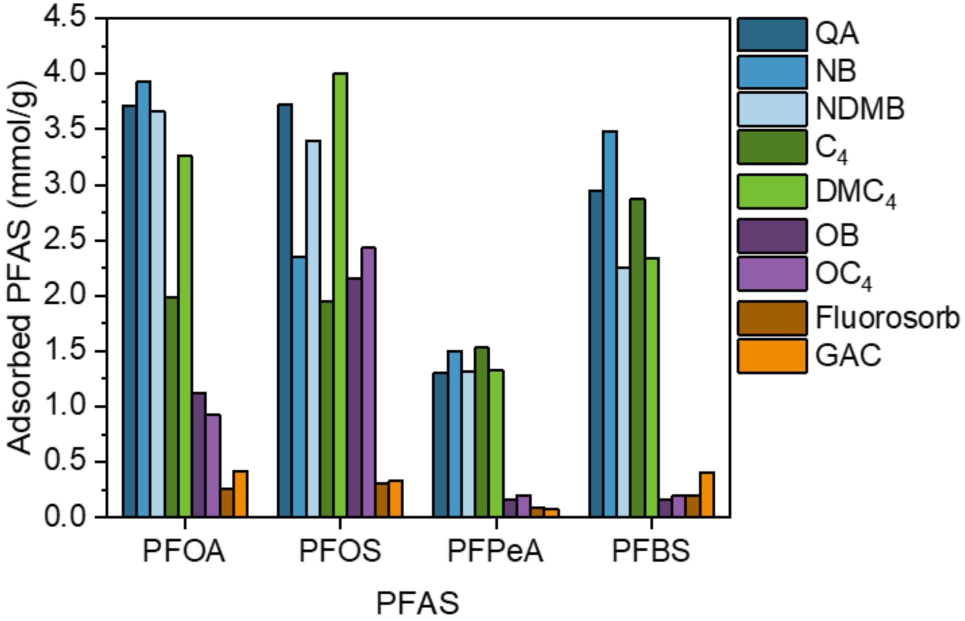


Engineered Adsorbents



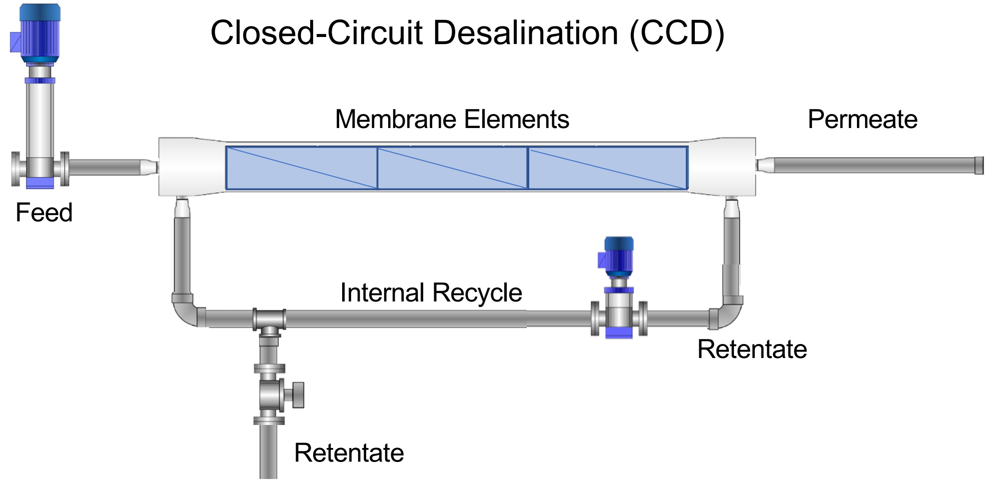


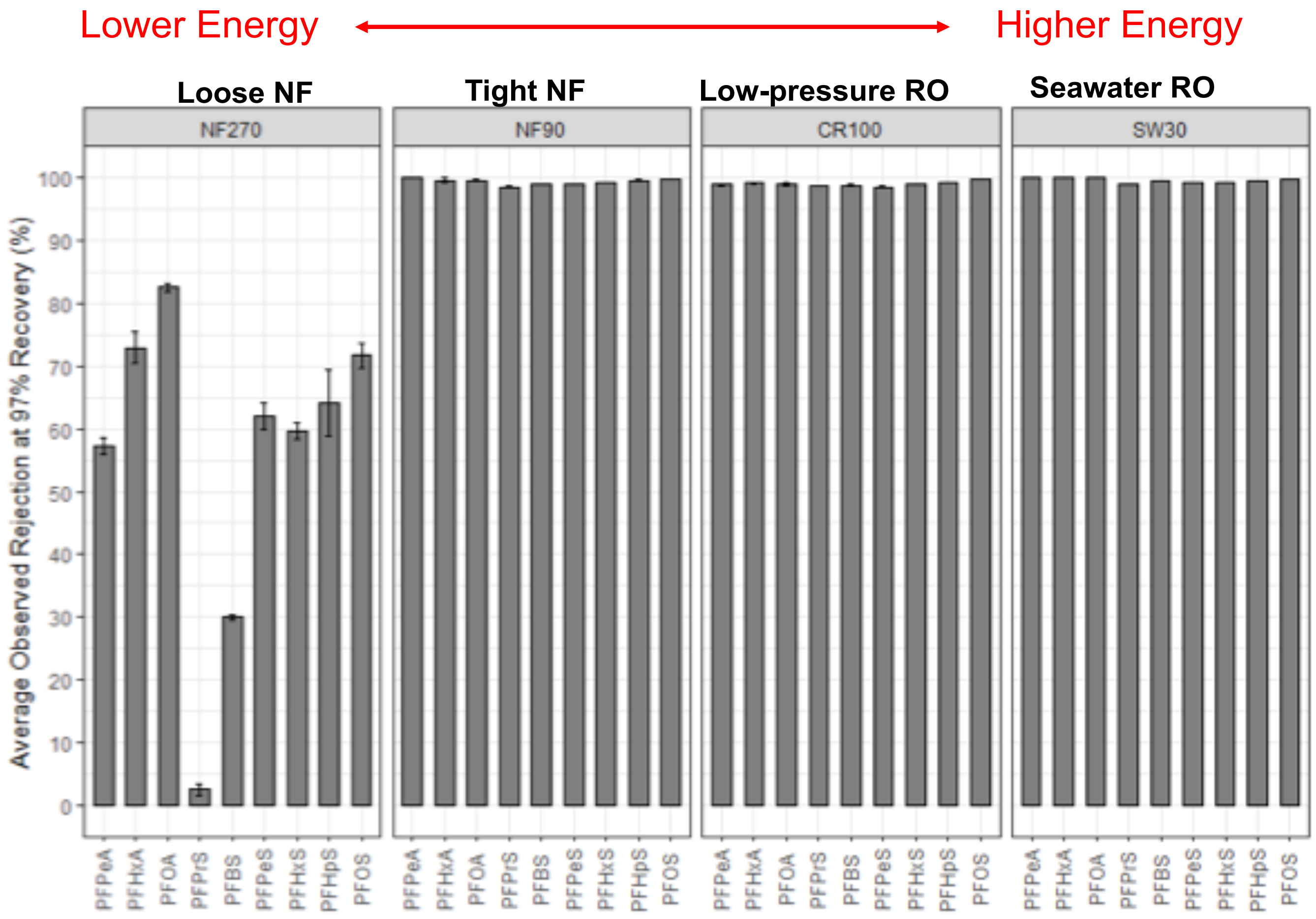




In collaboration with Jeffrey Long (UC-Berkeley)

PFAS Treatment – High-Pressure Membranes



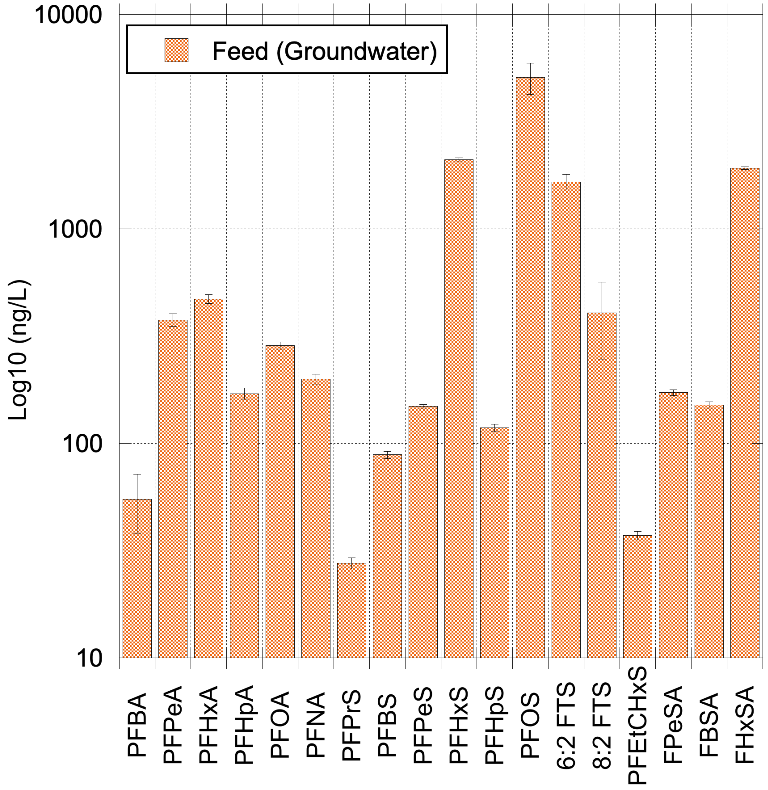


Rejection data for 97% recovery experiment – synthetic groundwater; Safulko et al., 2023

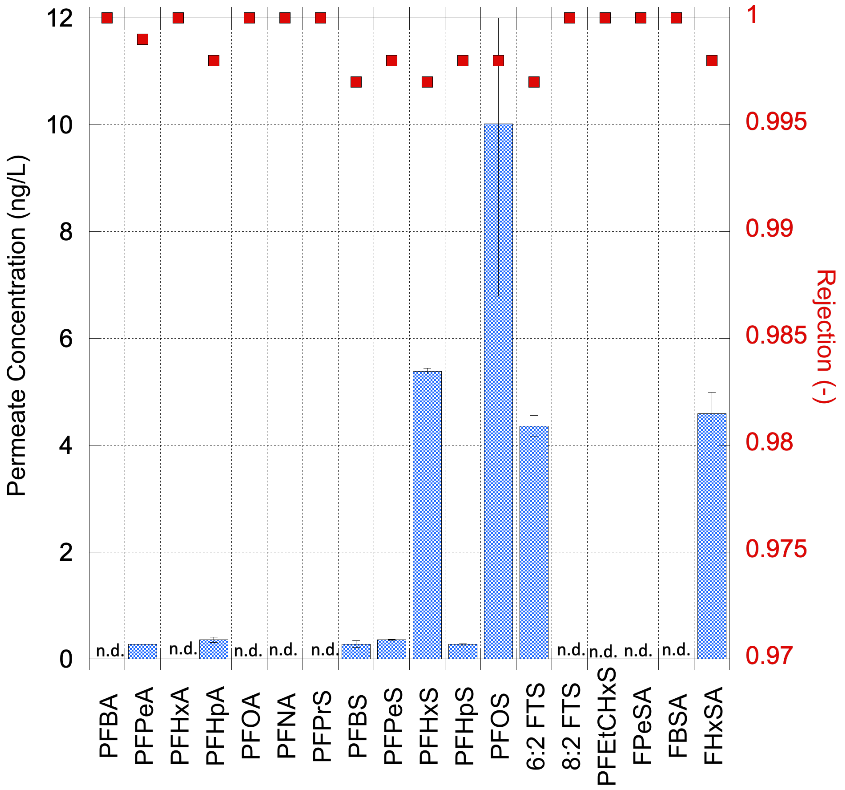
- Designed to operate at high recovery (minimize retentate)
- Semi-batch operation
- Feed water brought into system at permeation rate
- Once achieved desired recovery – retentate is discharged and process starts over

PFAS Treatment – High-Pressure Membranes

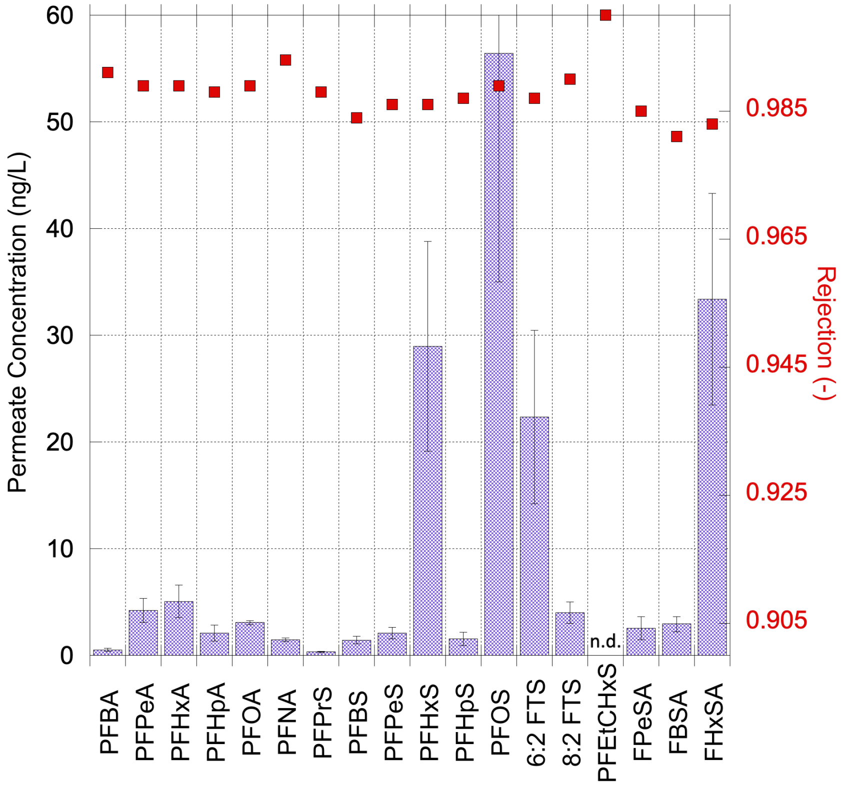
- Groundwater treatment at Wright-Patterson AFB using CCD



Reverse Osmosis



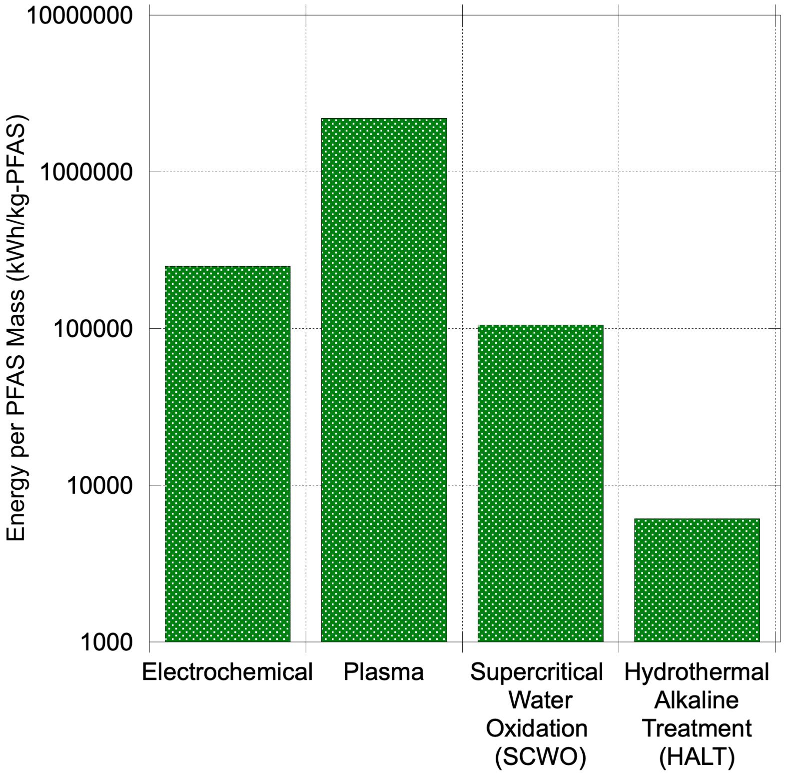
Nanofiltration



Acknowledgement to Mines and GSI field team: Adria Lau and Nicole Masters (Mines), Allison Denn, Cassidy Powell Katie Welch and Sage Clay (GSI)

PFAS Treatment – Destructive Technologies

- Various destructive technologies developed and evaluated for PFAS treatment
- Generally, energy intensive: $10^4 – 10^6$ kWh/kg-PFAS[1]



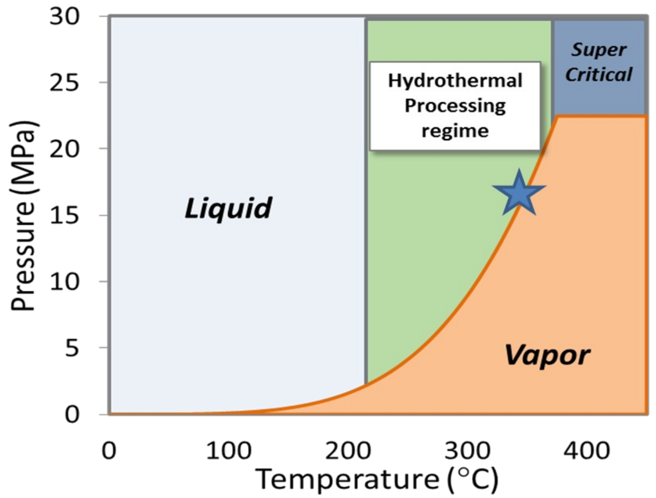
[1]Adapted from McDonough et al., *Remediation*, 2021

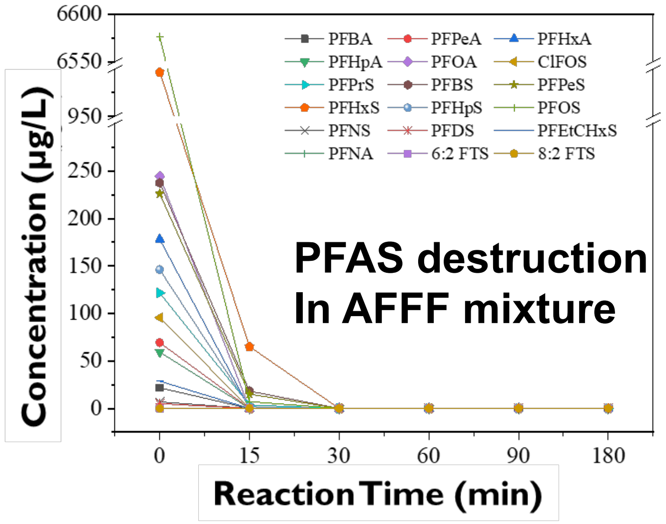
Challenges (and opportunities):

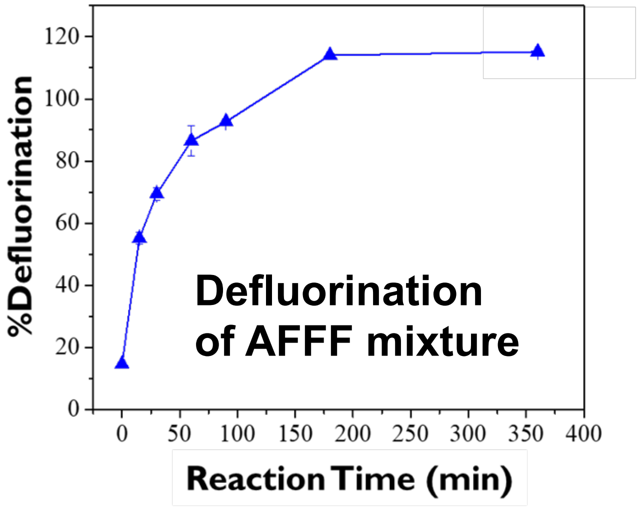
- Certain destructive technologies challenged by short-chain PFAAs (e.g., plasma, electrochemical)
- SCWO and HALT effective for a wide range of PFAS and water matrices but operate under very aggressive conditions
- Limited on treatment capacity due to cost and robustness
- Limited data for long-term operation

Destructive Technologies – HALT (Hydrothermal Alkaline Treatment)

- Liquid water amended with concentrated alkali at near-critical temperatures (350°C, 1 M NaOH) promotes PFAS destruction and defluorination of PFAS







- Destroys full suite of PFAS detected in AFFF stockpiles, groundwater, soil, waste concentrates (e.g., foam fractionate), and PFAS-contaminated GAC adsorbents

- Technology being commercialized and field demonstrated

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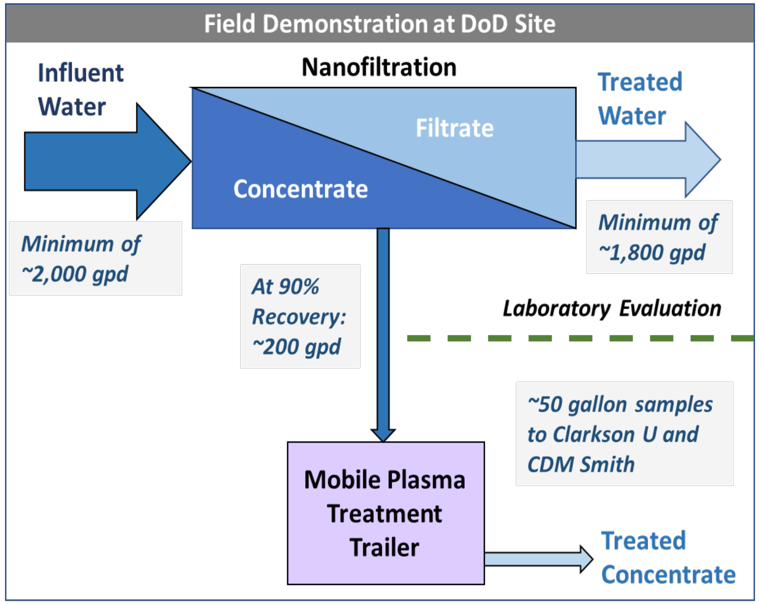
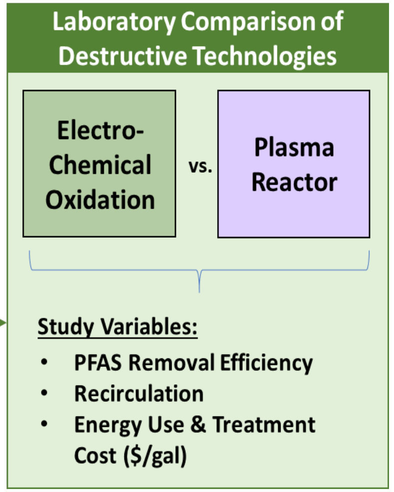
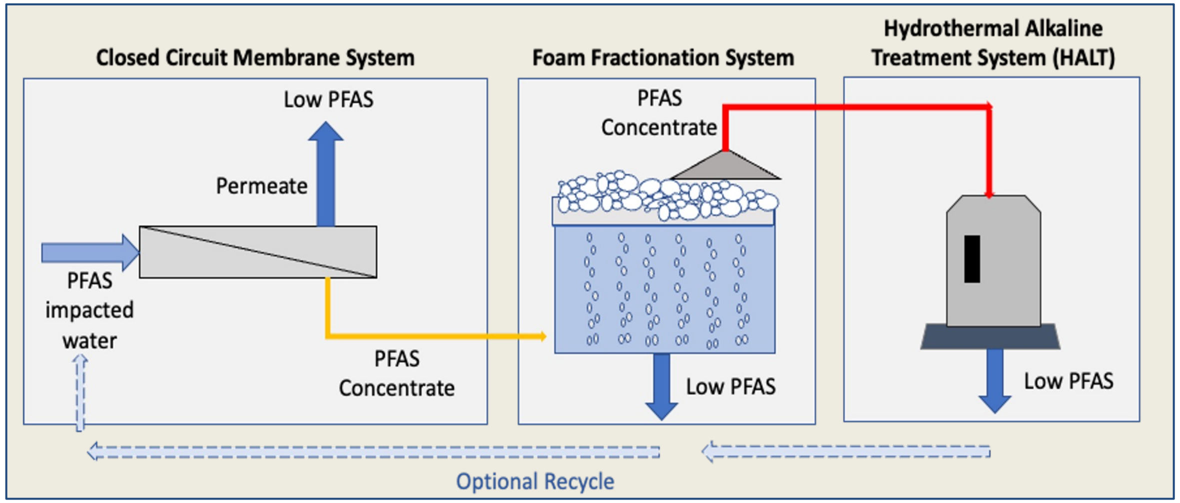
PFAS Treatment – Integration of Separation Processes with Destruction

Concentrate management remains the main challenge impeding widespread adoption of NF and RO

Several completed or ongoing projects evaluating the use of membranes for PFAS concentration leading to PFAS destruction







These projects are in collaboration with companies that are commercializing emerging PFAS treatment options including destructive technologies

Conclusions

- Adsorbents and membranes remain best available technologies for PFAS removal from aqueous matrices
- Low-cost and selective adsorbents needed. Pretreatment can significantly improve PFAS adsorption
- Tight NF and RO provide high separation of variety of PFAS and can be used to concentrate PFAS impacted water matrices and residuals
- Several promising destructive technologies being commercialized but cost remains a challenge

Thank you!

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