Cutting the Chain: Innovation to Destroy PFAS in Wastewater

Hosted by the University of Washington Tacoma
Friday, November 21, 2025 | 9:00 am – 12:00 pm (PST)
Zoom Virtual Workshop

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Welcome!

A Few Notes on Logistics:

- **Audio:** Please ensure your speakers are off unless asking questions during the Q&A sessions.
- **Questions:** We welcome your questions! Please submit them using the **Chat** feature at any time during the presentations. We have two dedicated Q&A sessions planned.
- **Recording:** This session is being recorded, and materials will be shared with all registrants after the event.

Acknowledgement of Funding

This project has been funded by the United States Environmental Protection Agency under assistance agreement PC-01J95801-2 to the Washington State Department of Ecology (i.e. EPA Puget Sound Geographic Funds through the Stormwater Strategic Initiative). The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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DEPARTMENT OF ECOLOGY State of Washington

Why Innovation to Destroy PFAS is Critical

- Per- and polyfluoroalkyl substances (PFAS) are persistent environmental contaminants (forever chemicals)
- Traditional wastewater treatments isolate but don't destroy PFAS
- We've successfully piloted an innovative, two-step process to isolate AND destroy PFAS in municipal wastewater
- Learn about the results, implementation strategies, and key lessons learned from this groundbreaking project

Who We Are

University of Washington Tacoma:

- Emese Hadnagy, Project Manager and Principal Investigator, Associate Professor of Civil Engineering
- Joel Baker, Co-Principal Investigator, Professor of Civil Engineering and Director of the Puget Sound Institute at the Center for Urban Waters
- Ansaf Karim, Postdoctoral Researcher at the School of Engineering and Technology

Aquagga, Inc.:

- Brian Pinkard, Co-Principal Investigator and Pilot-Scale Study/HALT Technology Lead, CTO and Co-founder
- Calvin Rhodes, Field Engineer

ECT2:

- Erika Houtz, Foam Fractionation Technology Lead, Director
- Lottie Franck, Field Engineer

City of Tacoma:

- Teresa Peterson, Tacoma Central Wastewater Treatment Plant Liaison, Principal Engineer at the City of Tacoma
- Monica Herbert, Environmental Lab Scientist, City of Tacoma, Environmental Services Laboratory
- Tiffany Ryan, Assistant Division Manager, City of Tacoma, Environmental Services Laboratory

Today's Agenda

9:00 am: Welcome and Overview

9:15 am: Foam Fractionation Treatment (Erika Houtz, ECT2)

9:45 am: Destroying Concentrated PFAS with HALT (Brian Pinkard, Aquagga)

10:15 am: Q&A Session 1

10:45 am: Break

10:50 am: Treatment of PFAS Precursors (Ansaf Karim, UWT)

11:10 am: Challenges in PFAS Analysis (Tom Chontofalsky, City of Tacoma)

11:30 am: Q&A Session 2 & Wrap-Up

Overview of PFAS Treatment and Foam Fractionation

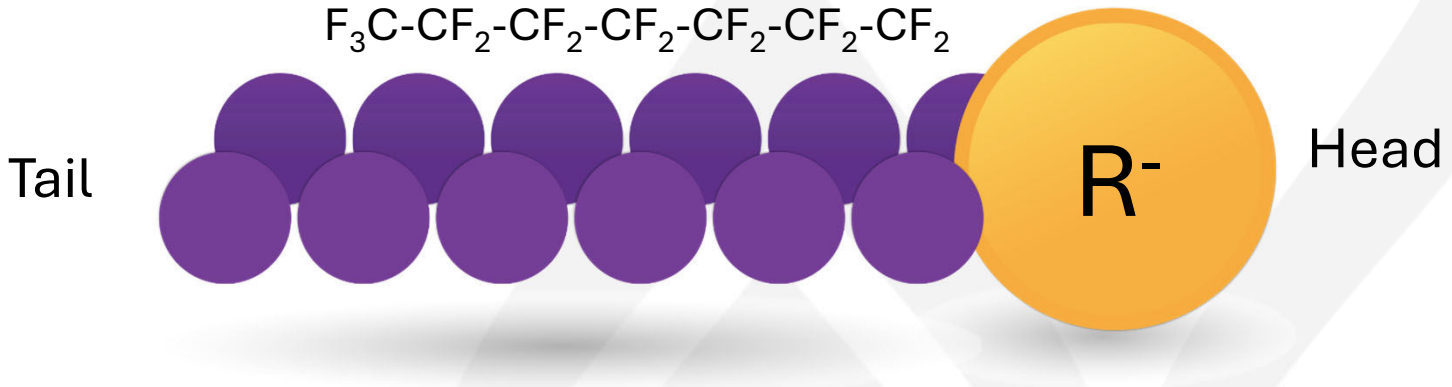
Montrose Environmental Group

November 21, 2025

Erika Houtz, PhD, PE

Lottie Franck

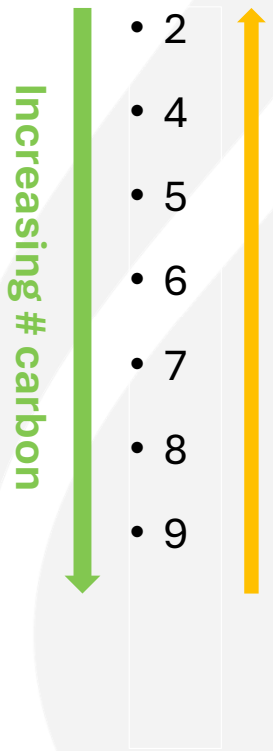
PFAS Structure



- Hydrophobic tail, hydrophilic head
- Charged head, typically sulfonate or carboxylate
- Family of compounds, many thousands
- Focused on handful from a toxicity perspective, a couple dozen from a measurement perspective
- Carbon fluorine bond is a challenge to disrupt – destruction requires a lot of energy

PFAS Names, Carbon Chains, & Removal Difficulty

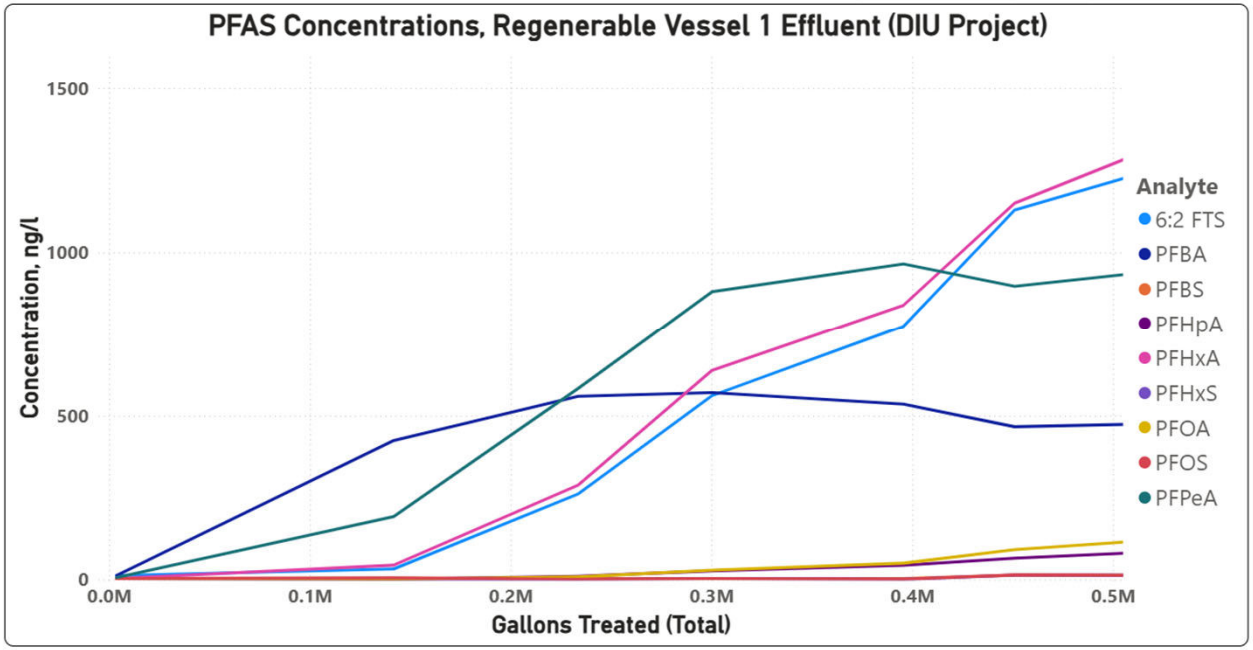
- Trifluoroacetic acid (TFA)
- Perfluorobutanonic acid (PFBA)
- Perfluoropentanoic acid (PFPeA)
- Perfluorohexanoic acid (PFHxA)
- Perfluoroheptanonic acid (PFHpA)
- Perfluorooctanoic acid (PFOA)
- Perfluorononanoic acid (PFNA)



- Perfluorobutane sulfonic acid (PFBS)
- Perfluoropentane sulfonic acid (PFPeS)
- Perfluorohexane sulfonic acid (PFHxS)
- Perfluoroheptane sulfonic acid (PFHpS)
- Perfluorooctanesulfonic acid (PFOS)
- Perfluorononane sulfonic acid (PFNS)

PFAS Adsorption Capacity Varies by Species: Ion Exchange Example

- From a recent project, the relative bed life of various PFAS observed in the lead vessel in a high PFAS concentration groundwater source
- Both chain length and terminal group have an impact

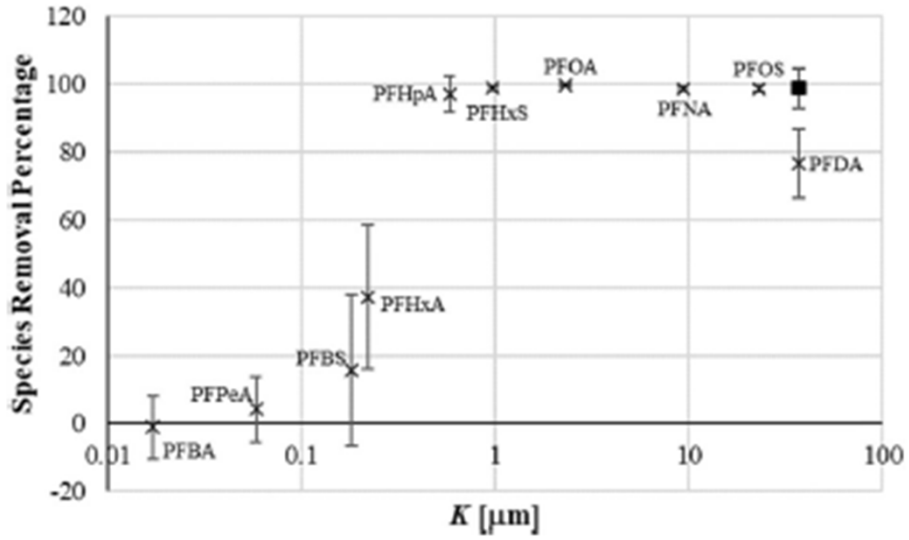


	Approximate Bed Life (lead vessel)
PFBA (C4)	1,500
PFPeA (C5)	3,100
PFHxA (C6)	5,000
PFHpA (C7)	11,000
PFOA (C8)	12,500
5:3 FtCA (C5)	5,000
6:2 FtS (C6)	5,000
PFBS (C4)	>70,000
PFOS (C8)	>70,000

Foam Fractionation's Removal Ability Varies by Species

- PFBA, PFPeA, PFHxA, and PFBS have a low tendency to partition to air because their air water partitioning coefficient (K) is <1 micron
- Removal can be enhanced somewhat with ion pairing additives, particularly for PFBS and PFHxA

Removal of PFAS vs. Air-Water Partitioning Coefficient in Foam Frac



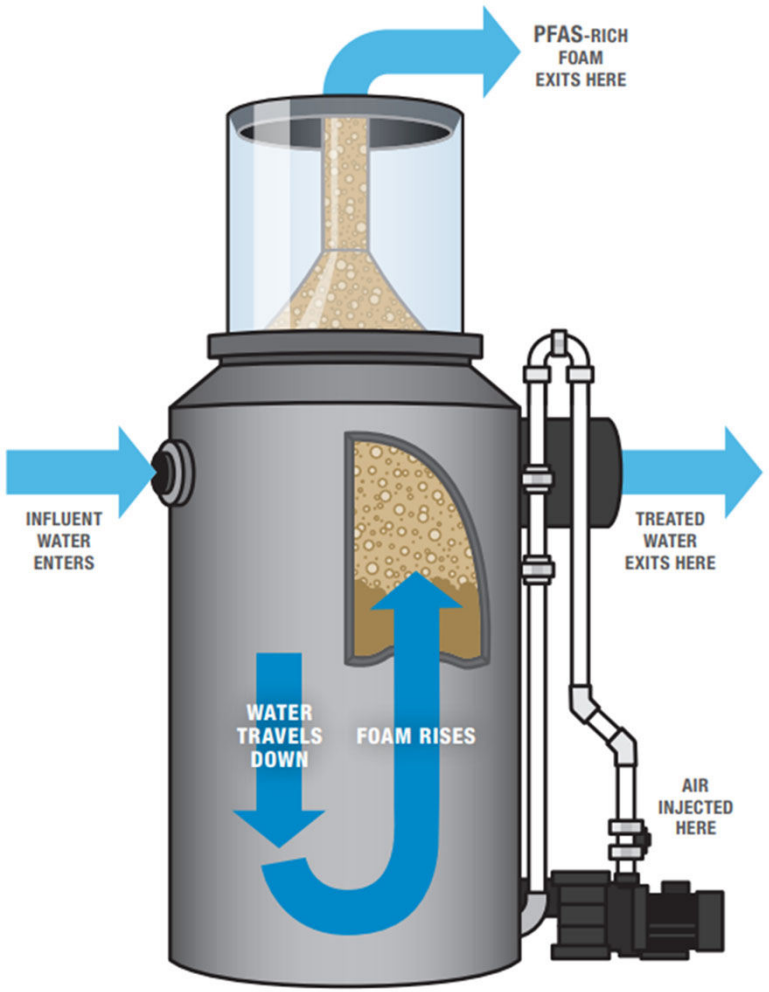
From Burns et al. 2022, *Remediation*

PFAS in Water
Separation + Concentration Treatment Options

	GAC	Single Use/ Regenerable IX	Foam Fractionation	RO Membrane
Treatment Mechanism	Adsorption	Adsorption and ion exchange	Air/Water Partitioning	Membrane rejection
Pretreatment	Filtration	Filtration and/or GAC	Minimal/Filtration	Filtration
Contact time	10-15 min	2-3 min	10-30 min	NA
Footprint	Large	Small/Medium	Large	Medium
Spent Media	Incineration / Landfill / Reactivation	Incineration / Landfill/ Media Regeneration	NA	NA
Key Advantage	Tried and True	Tried and True; High capacity; Suitable for short chain PFAS	Compatible with complex matrices	Broad spectrum efficacy; Used to concentrate flow
Disadvantages	High waste / Limited effectiveness for short chain PFAS	Low efficiency in some challenging waters	Limited effectiveness for short chain PFAS	Expensive OpEx

Foam Fractionation Basics

- Water and air are mixed in countercurrent flow
- PFAS adsorb to the bubbles, which rise to the top and are removed as a foam
- Treated water exits the reactor
- Fractionators often operated in lead/ lag for enhanced PFAS removal
- Hydraulic retention time per reactor is 15 to 60 minutes
- Foamate can be further concentrated in a secondary foam fractionation process



Different Scales of Foam Fractionation Equipment

Bench scale
(<1 gpm)

8’ x 6’ Skid-mounted
pilot scale
2-6 gpm

14’ High
Permanent Install
50 to 150 gpm

Fully Automated Containerized System with Foamate SuperLoaders

Treats flows up to 120 gpm

Foamate Concentrator Equipment

Piloting Equipment
1 gph

Permanent Install
5 gpm

Foamate Handling

Destruction

Use a process such as HALT to degrade PFAS to benign products

Media Adsorption

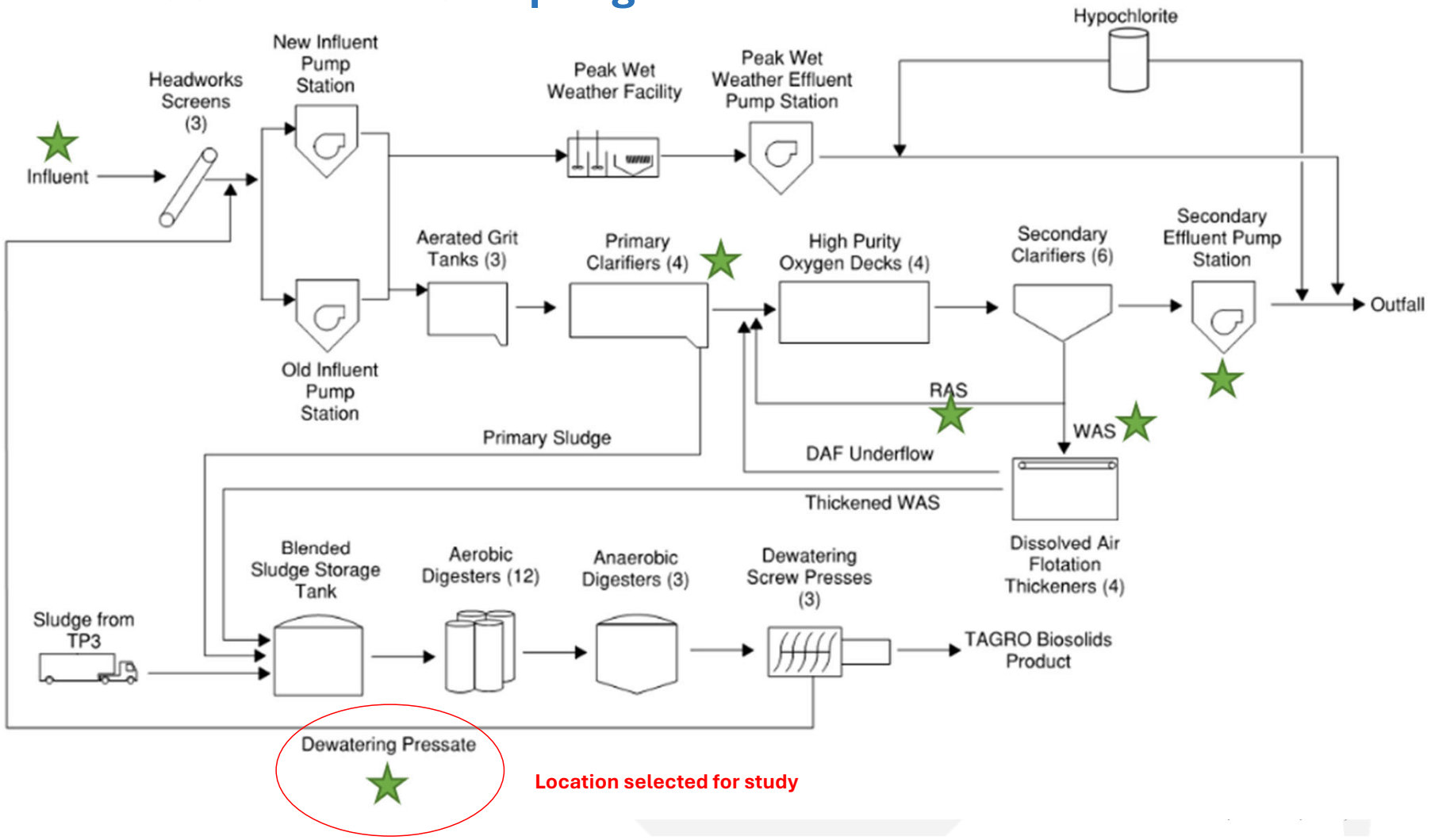
Convert to a solid waste via Superloading

Introduction to the Project

- PFAS are common in wastewater treatment plants (WWTPs) due to their nature as central collection points
- Effective reduction of PFAS discharges to the environment requires treatment at logical points, typically involving separation, destruction, and recirculation of treated residuals
- This study focused on evaluating two emerging PFAS treatment technologies for application in a municipal wastewater setting:
  - Foam fractionation (PFAS separation/ concentration)
  - Hydrothermal alkaline treatment (PFAS destruction)

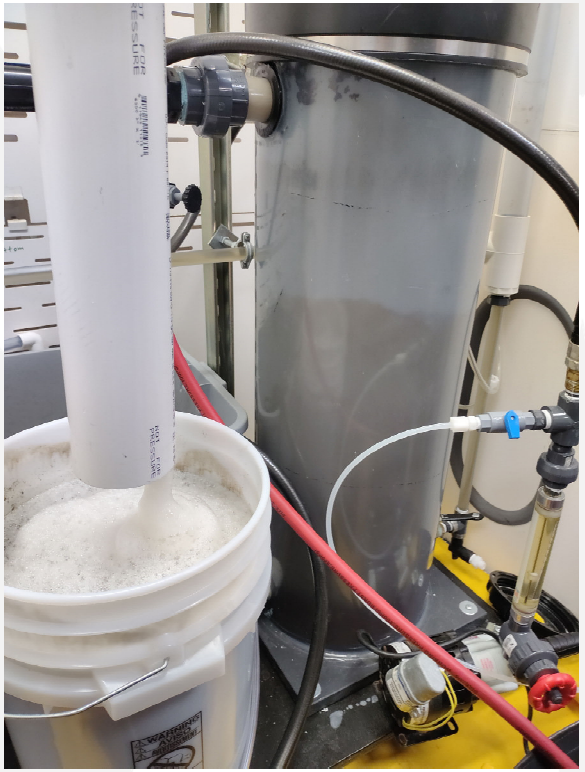
Image from: https://tacoma.gov/government/departments/environmental-services/wastewater/

Tacoma Central WTP Sampling Locations



Bench testing

- 2 Totes of water shipped to ECT2 Treatability Lab
- Primary foam fractionation tests conducted



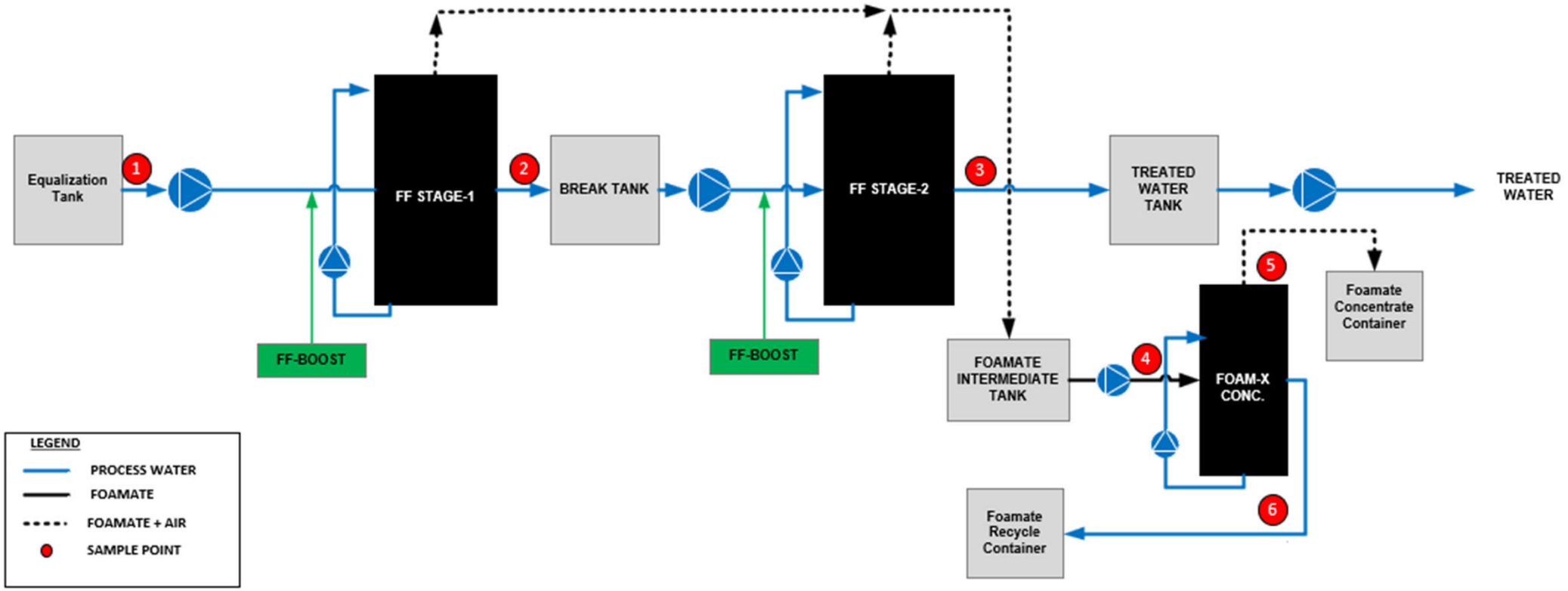
Bench Testing – Key Outcomes

- Water foamed well without additives
- High air flow rates greatly improved removal
- One stage of removal met PFAS MCLs
- Two stages of treatment enhanced removal
- >90% removal of PFAS was achievable
- Boost agents offered little benefit to treatment process

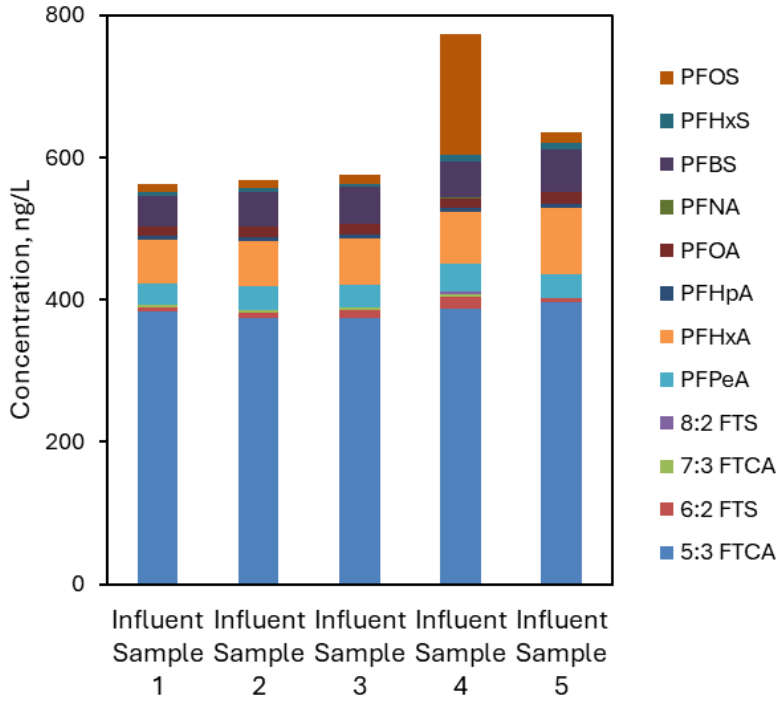
Tacoma Pilot

Mobile System Container Onsite at Tacoma CTP

Process Flow Diagram



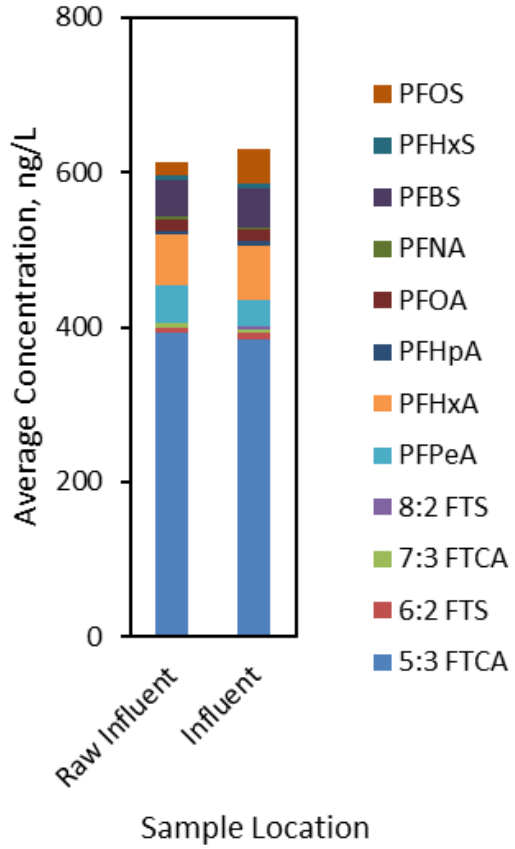
Pilot Results – Sludge Dewatering Filtrate Influent



Analyte	Concentration	Units
Chloride	68	mg/L
Hardness	150	mg/L
Iron	1.1	mg/L
pH	7.7	SU
TDS	1200	mg/L
TOC	860	mg/L
TSS	110	mg/L

Pilot Results – Total Suspended Solids

- High levels of total suspended solids (TSS) in the pressate stream presented challenges for continuous processing
- Filter box installed upstream of FF unit to separate solids
- Successful in mitigating TSS challenge and enabling continuous FF operations
- Filtration did not impact PFAS concentrations

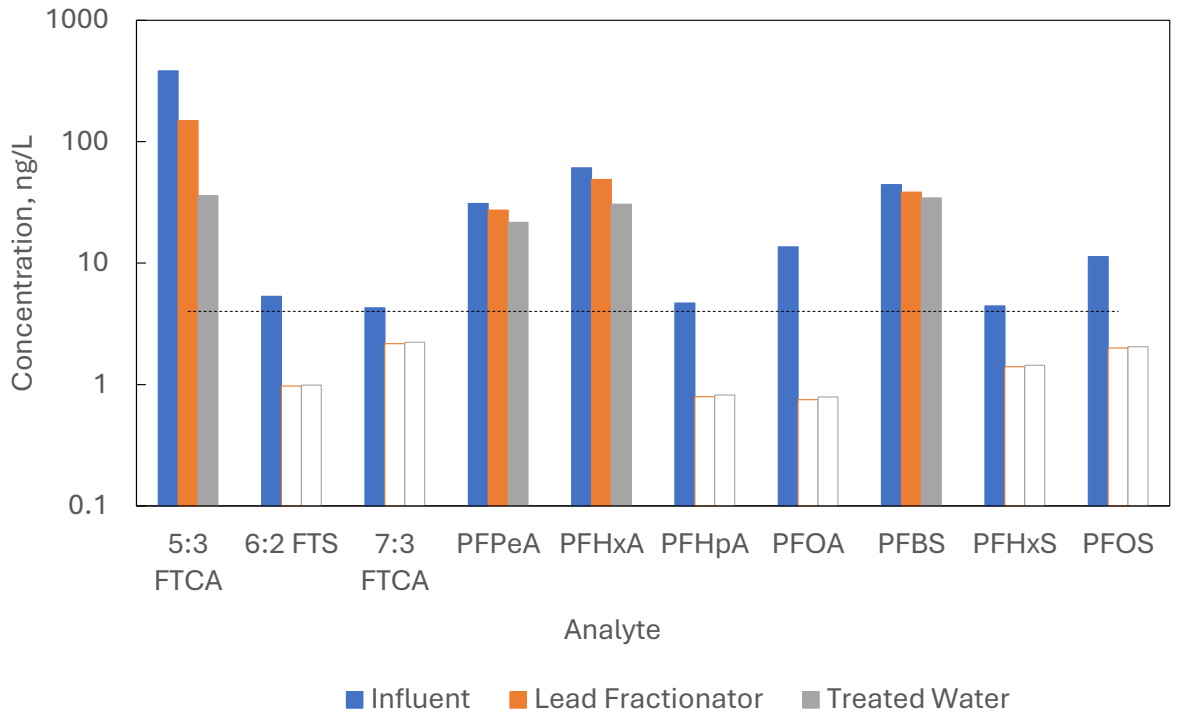


Foam Fractionation – Experimental Conditions

- Flow rate: 4 to 8 gpm
- Foam suppressant and boost agents tested
- Air flow rates varied in both stages of fractionation
- Small volume of primary foamate re-processed to generate foam concentrate

Trial Condition	Flow rate, gpm	Boost Agent (Fractionator A/ Fractionator B)	Air Flow Rate, Fractionator A	Air Fow Rate, Fractionator B
Trial 1	4	None	Low	Low
Trial 2	8	None	Low	Low
Trial 3	4	Foam Suppressant/ none	High	High
Trial 4	8	Foam Suppressant/ none	High	High
Trial 5	8	Foam Suppressant/ FF Boost	High	High

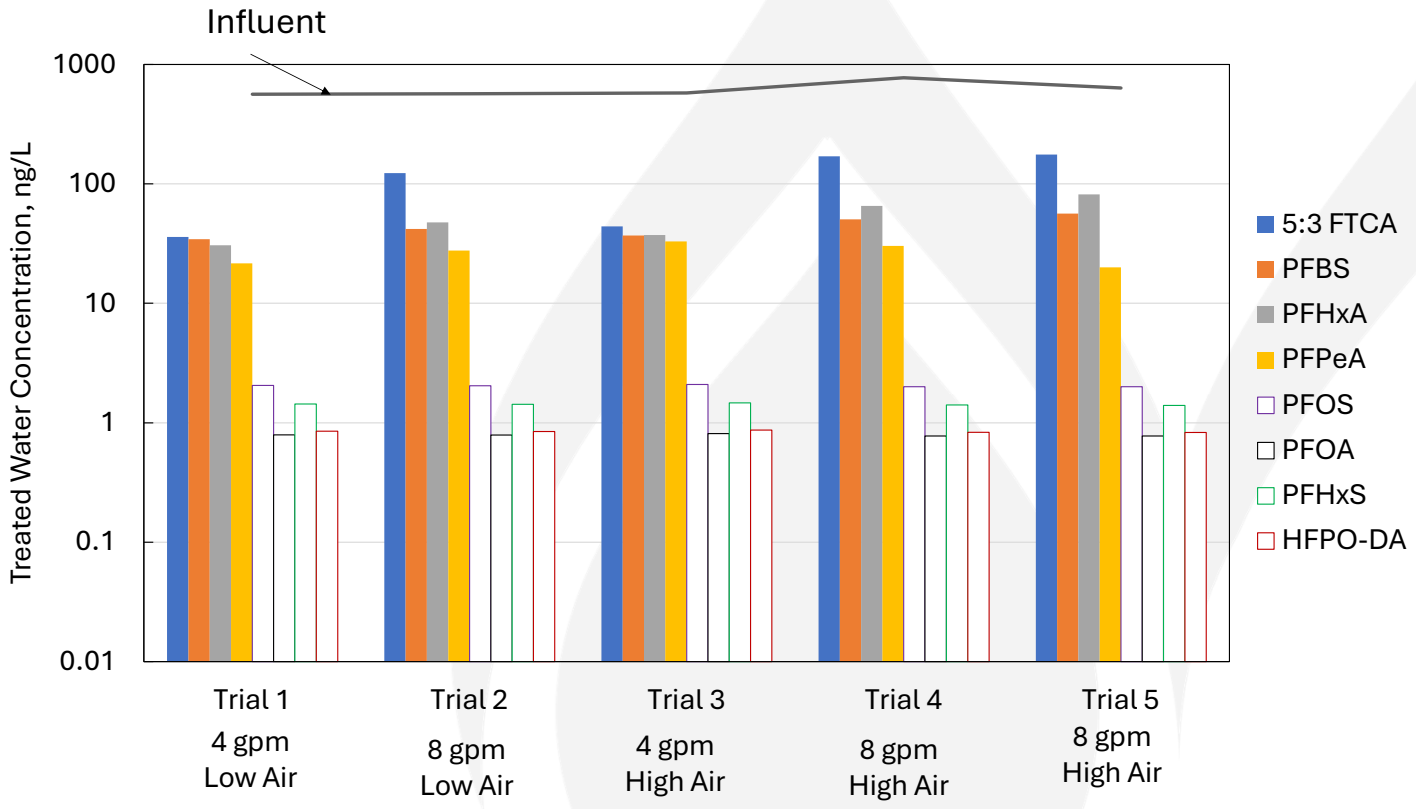
Pilot Results – Treatment Under Optimized Foam Fractionation Conditions



4 ng/L PFOS, PFOA MCL

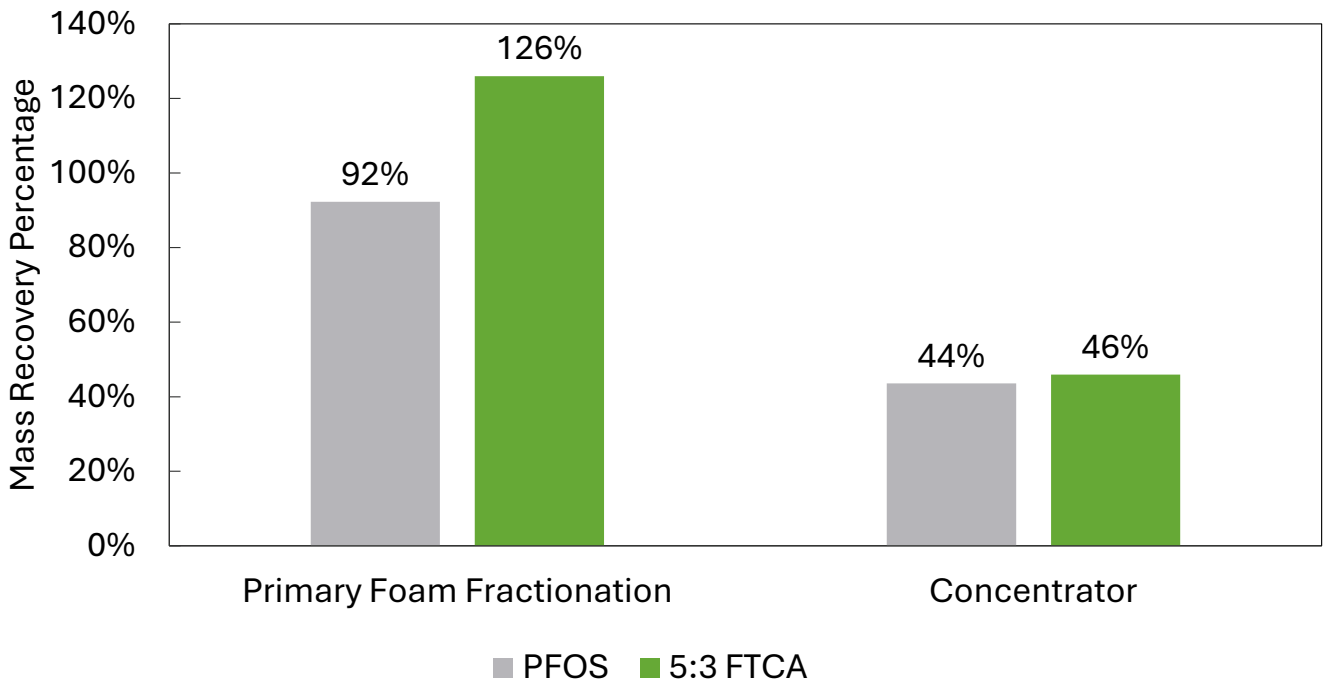
Note: Colorless bars represent non-detect values

Pilot Results – Treated Water Under Different Operating Conditions



Note: Colorless bars represent non-detect values

Pilot Results – Mass Balance of Primary PFAS Removed



Foamate Residuals – Delivered to Aquagga for Destruction

- Foamate Treated By Aquagga
  - 120 gallons of primary foamate
  - 15.6 gallons of concentrated foamate
- Overall process concentration factor: ~500

Key Findings

- The complexity of the wastewater matrix made foam fractionation an appealing PFAS treatment technology
- Total suspended solids (TSS) in the pressate stream presented an operational challenge, mitigated with prefiltration
- Foam fractionation was successful in reducing long chain PFAS with MCLs to non-detect levels
- Foam fractionation was successful in reducing total PFAS in the pressate stream by ~80%

Key Findings

- Moderate air flow, shorter hydraulic retention, and single stage treatment achieved MCLs – all factors that can lower OpEx and/or CapEx of full-scale system
- Total mass removal and destruction must be considered in the context of total PFAS mass flow through the WWTP
- Foam fractionation helps improve the economics of PFAS destruction; overall waste concentration factor to Aquagga was ~500x

Questions?

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Lottie Franck (Field Engineer)

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Randy Marks (Foam Frac Product Lead)

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Aquagga

Destroying PFAS in Concentrated Wastewater Foam with HALT

Brian Pinkard, Ph.D. - CTO & Co-Founder
brian@aquagga.com

aquagga.com

Company Overview

💼 Founded in 2019 as a UW spinout

🤝 Leadership team

- Dhileep Sivam, CEO
- Brian Pinkard, CTO
- Chris Woodruff, COO

👫 23 full-time employees

🌲 Based in Tacoma, WA

📈 Actively growing

Keeping PFAS Out of People and Planet

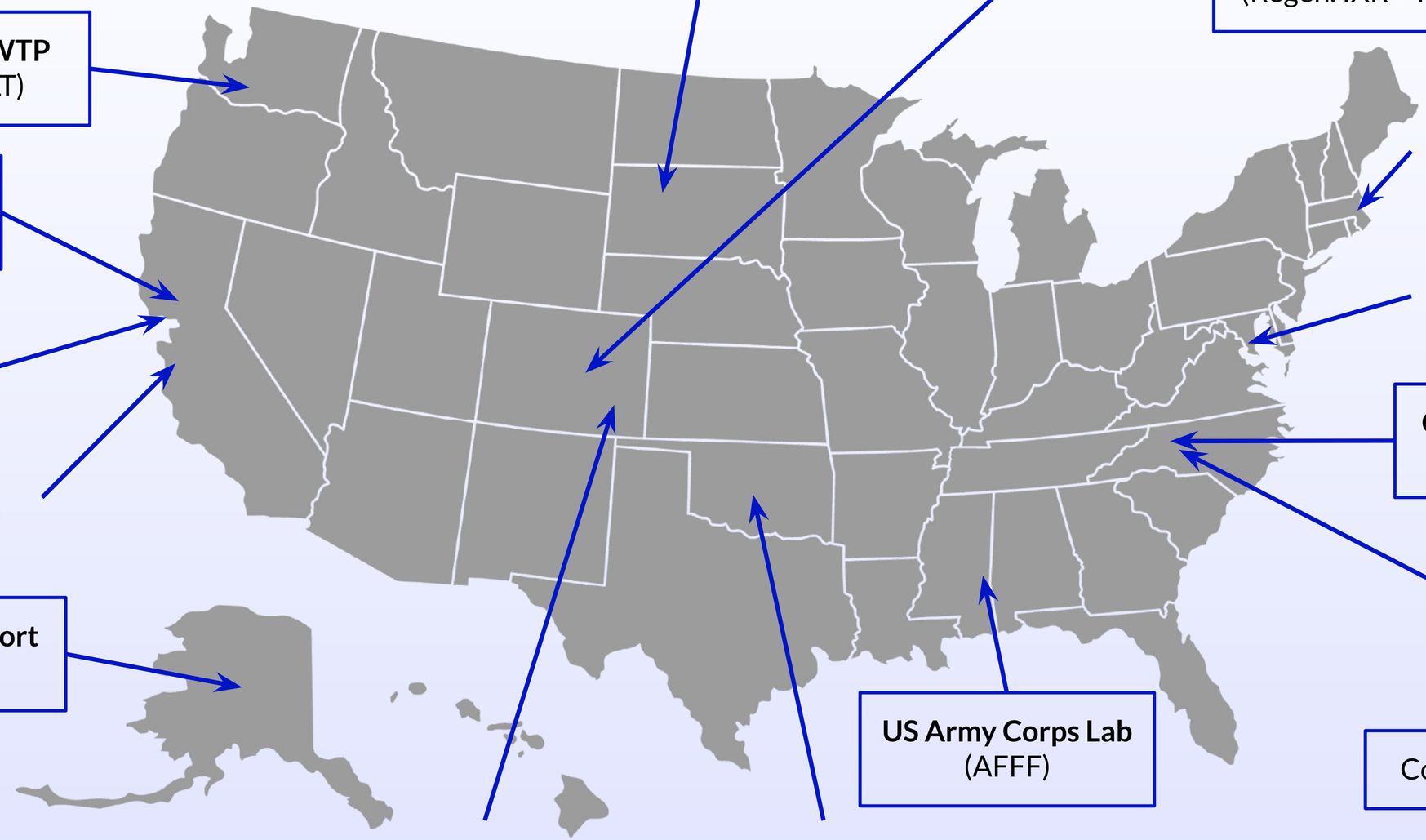
What We Do

Aquagga provides PFAS destruction equipment and services for the **environmental remediation** & **industrial wastewater treatment** industries.

Benefits include:

- 🗑️ Safe disposal of PFAS-rich wastes
- 📉 Reduction of future liability
- 💰 Reduction of overall project costs
- 📋 Compliance with emerging regulations
- ✅ Prevention of future contamination

Demonstration Projects



Tacoma WWTP
(FF + HALT)

Beale AFB
(FF + HALT)

Beale AFB
(AFFF)

Travis AFB
(CCMS + FF + HALT)

Fairbanks Intl. Airport
(FF+ HALT)

Ellsworth AFB
(FF + HALT)

Peterson SFB
(FF + HALT)

Confidential Industrial Site
(Regen. IXR + HALT)

Nantucket Airport
(FF + HALT)

Confidential Landfill
(FF + HALT)

Clean Earth / DIU
(Various + HALT)

UNC / NC
(AFFF)

US Army Corps Lab
(AFFF)

CDPHE
(AFFF)

Tinker AFB
(FF + HALT)

Key

Completed Project

Aquagga aquagga.com

Example Demo Project (April 2024)

- 3M Manufacturing Facility
- Using HALT to destroy concentrated industrial wastewater residual liquids from regenerable ion exchange resin & reverse osmosis
- >1,100 gallons of PFAS-rich liquid processed over two weeks in a real operational environment
- >99.9% destruction of target PFAS analytes
- No significant downtime or operational interruptions

Example Demo Project (April 2025)

- Centralized hazardous waste processing facility (Clean Earth, Charlotte NC)

- DoD-funded demonstration through ESTCP and DIU

- Processed nearly 1,000 gallons of concentrated PFAS-rich liquids from:
  - Foam fractionation
  - Regenerable ion exchange resin
  - Regenerable cyclodextrin
  - AFFF

- Up to >99% destruction of target and total PFAS

- Extensive characterization and quantification of the fate of fluorine via wide range of commercial analytical methods

PFAS Treatment Process

Concentrate

PFAS-containing wastewater is treated to discharge requirements using a PFAS concentration technology, which reduces the volume of PFAS-containing water by >1,000x.

Destroy

The PFAS-rich liquid concentrate is processed through HALT to destroy and mineralize >99% of the total PFAS. Less than 1% of the total PFAS mass remains.

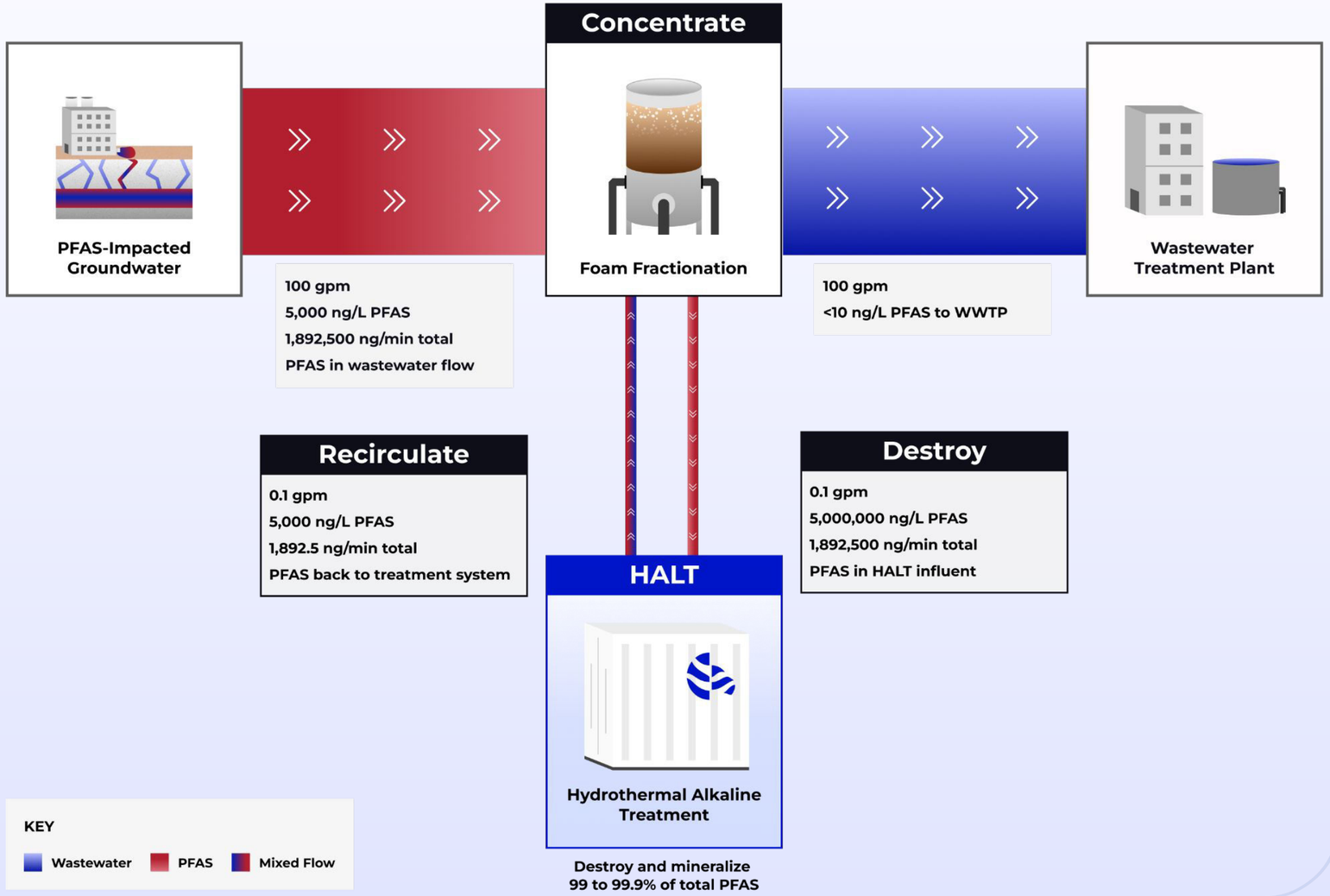
Recirculate

The small volume of HALT effluent water, now nearly PFAS-free, is recirculated back to the concentration technology in a closed-loop treatment train.

Closed-Loop Treatment Train

Traditional PFAS treatment technology produces a byproduct that requires off-site disposal for incineration or landfill. The result is moving the problem, not solving it.

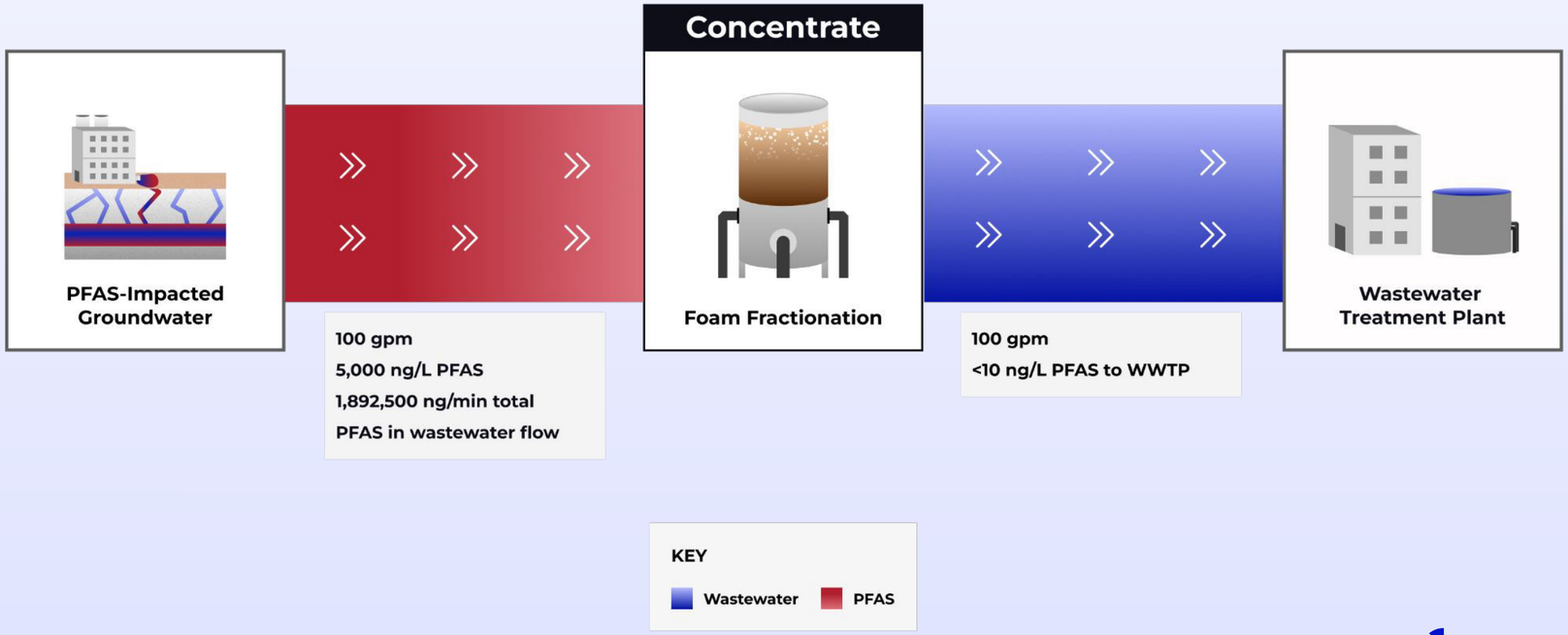
Reduce cost and liability by keeping treatment on-site, utilizing HALT.



Concentrate

Wastewater is treated using existing concentration or separation technologies to produce **discharge-compliant water**. A small quantity of PFAS-rich liquid is generated as a byproduct of the concentration/separation technology.

Normally, the contaminated waste would be trucked off-site. With HALT, the contaminated waste stream can be treated on-site to ensure safe, compliant water discharge.



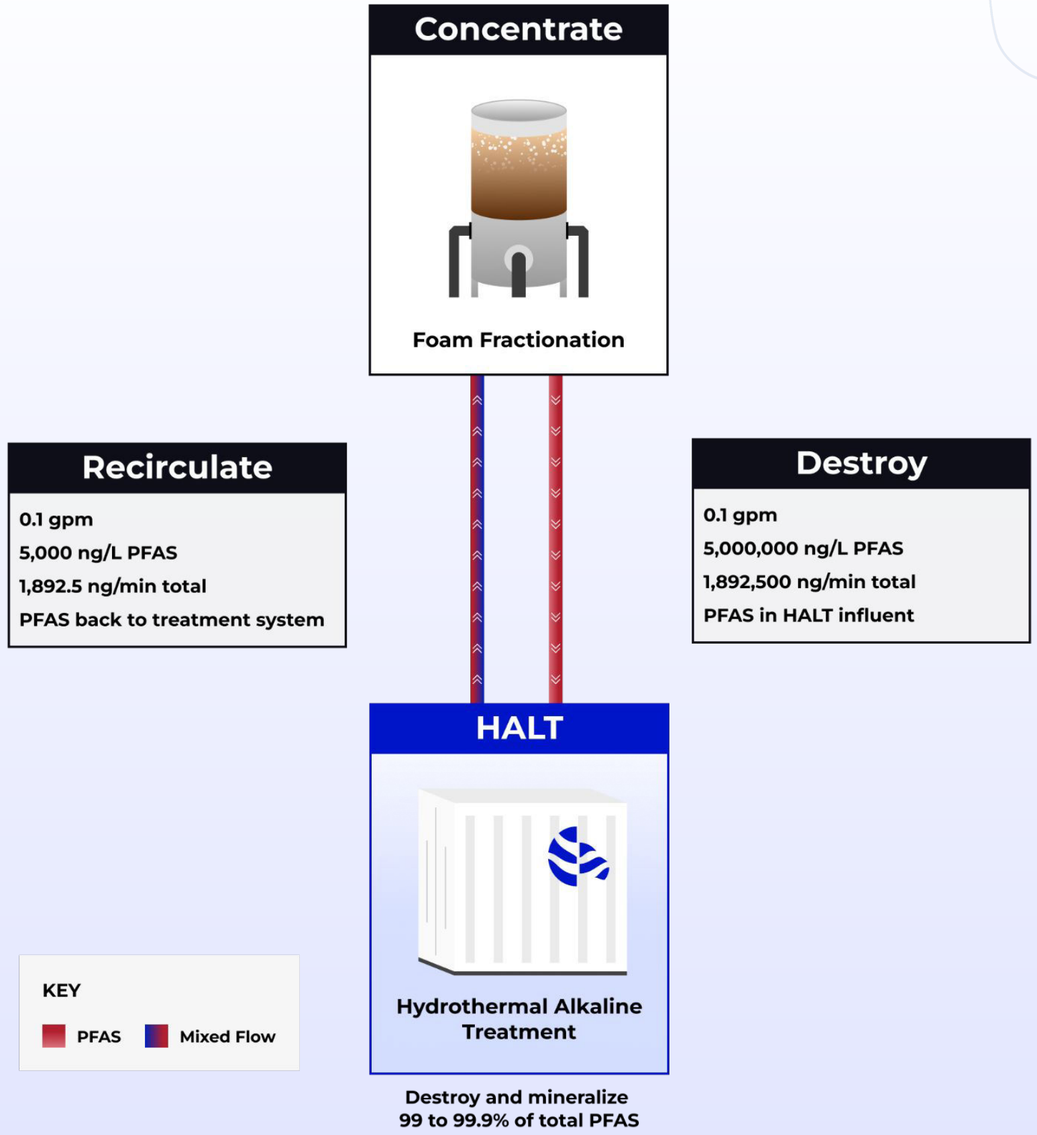
Destroy

Following the concentration step, a destruction technology ensures PFAS are permanently destroyed.

Metrics of Success:

- Achieves >99% PFAS destruction and fluorine mass balance.
- Handles high-TDS, high-strength, and variable flows.
- Effective on long, short, and ultra short-chain PFAS.
- Industrial-scale, reliable, and simple to operate.

HALT meets all of these metrics to achieve optimal PFAS mass removal.

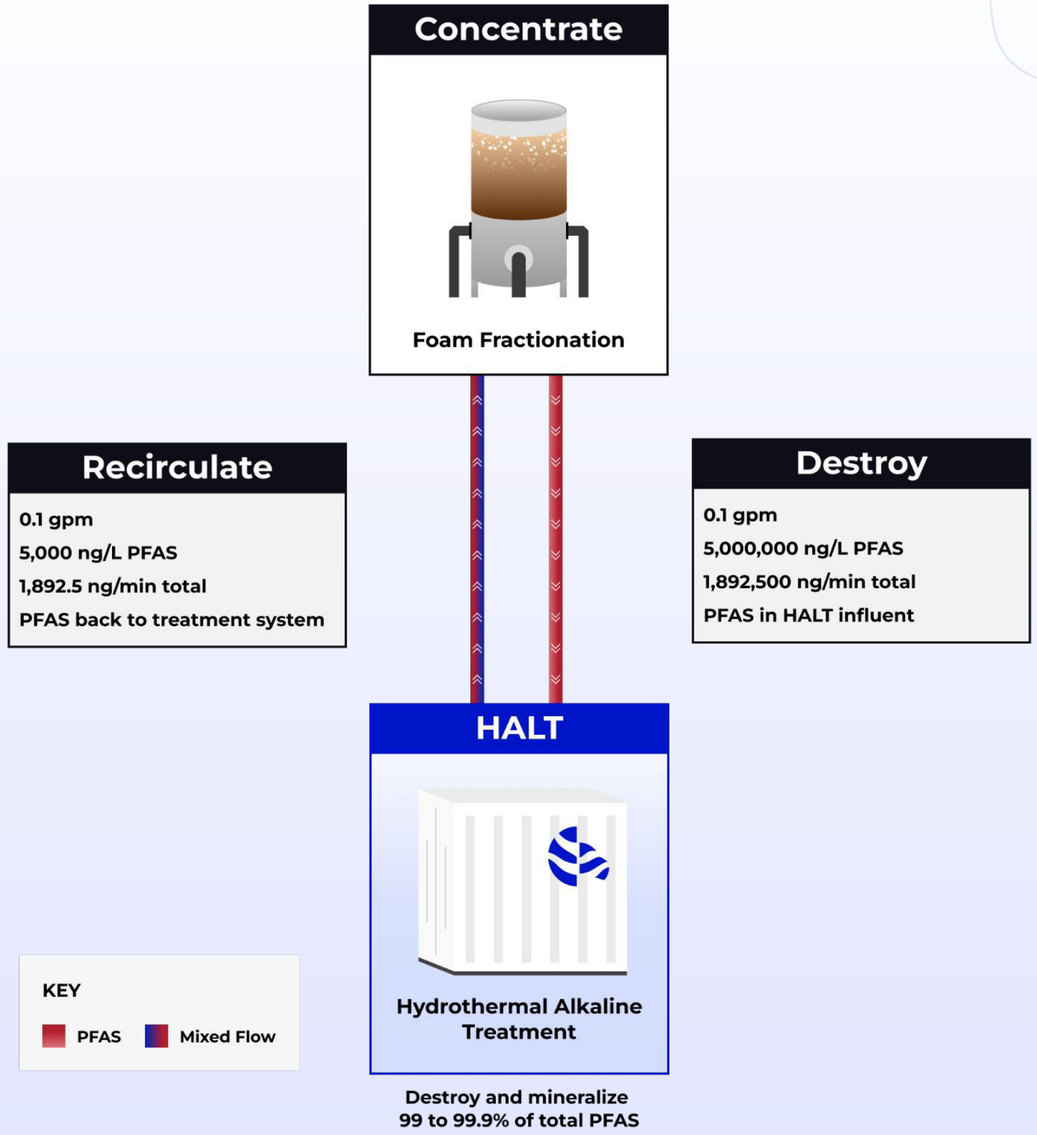


Recirculate

After 99% of the PFAS are destroyed in the concentrate, some PFAS still remain. These residual PFAS exist in a low volume, and can be polished using the same concentration technology. The total mass of PFAS recirculated is a tiny fraction of the overall mass flux. The overall objectives are achieved:

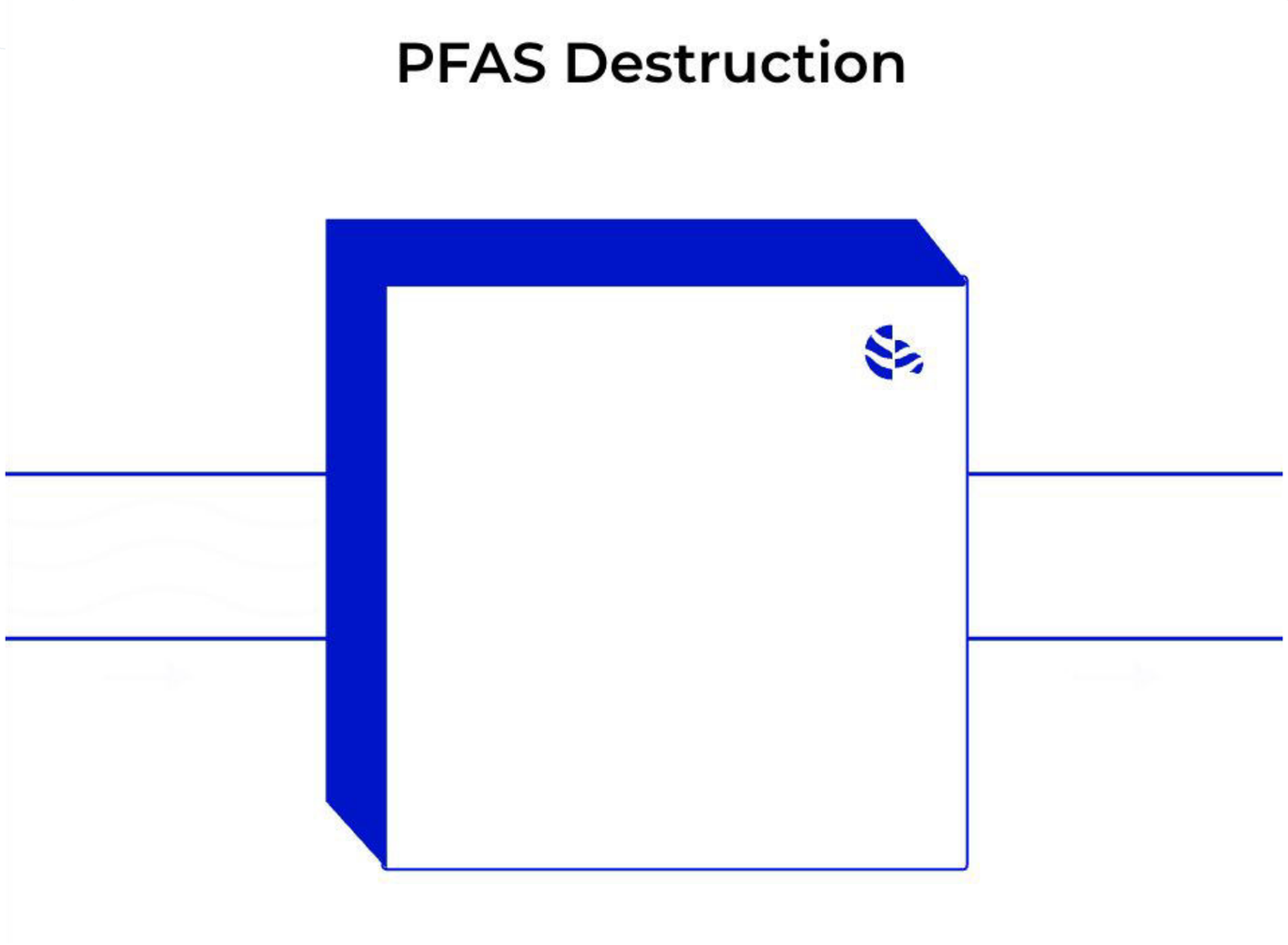
- Water is treated to the necessary specifications.
- PFAS is destroyed on-site.

The closed-loop approach enables significant cost savings, with HALT operating more efficiently than traditional methods.



How It Works

Hydrothermal alkaline treatment (HALT) completely destroys all PFAS compounds under subcritical water conditions through thermal decarboxylation and nucleophilic substitution reactions.



Hydrothermal Alkaline Treatment (HALT)

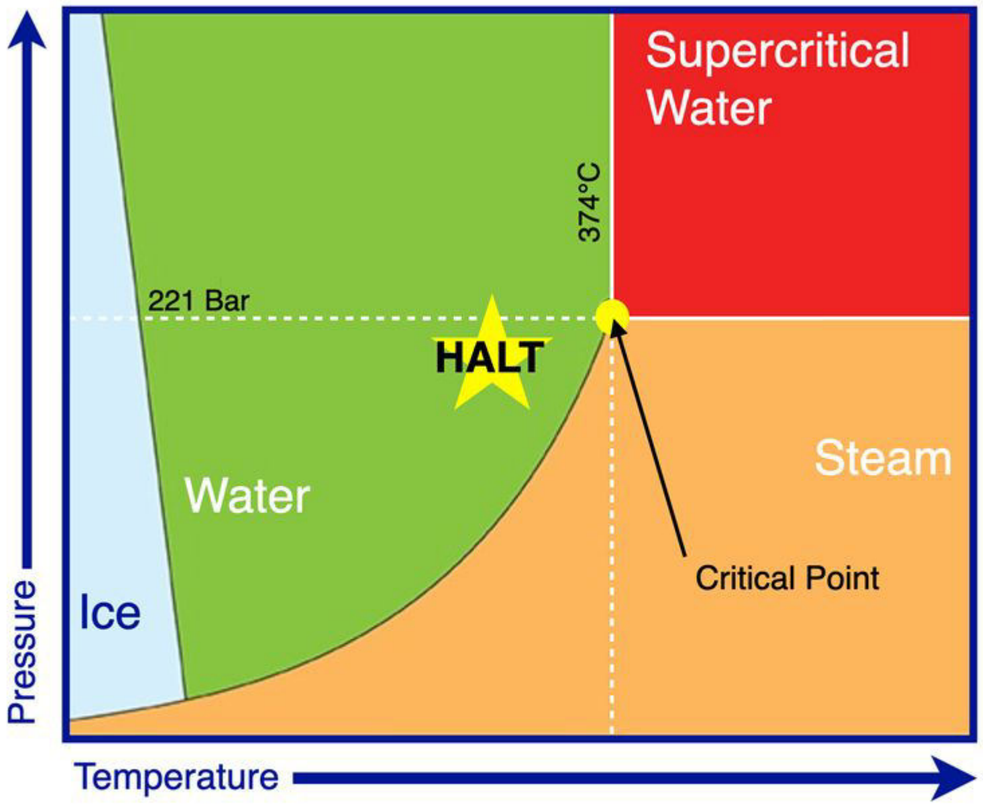
PFAS destruction under subcritical water conditions (300 to 350 °C, ~3,000 psi, pH > 14)

Sodium hydroxide used for high pH

Capable of >99% destruction of individual and total PFAS, with complete conversion to inorganic fluoride (mineralization)

🔬 First developed under SERDP project ER18-1501 at Colorado School of Mines (Strathmann et al.)

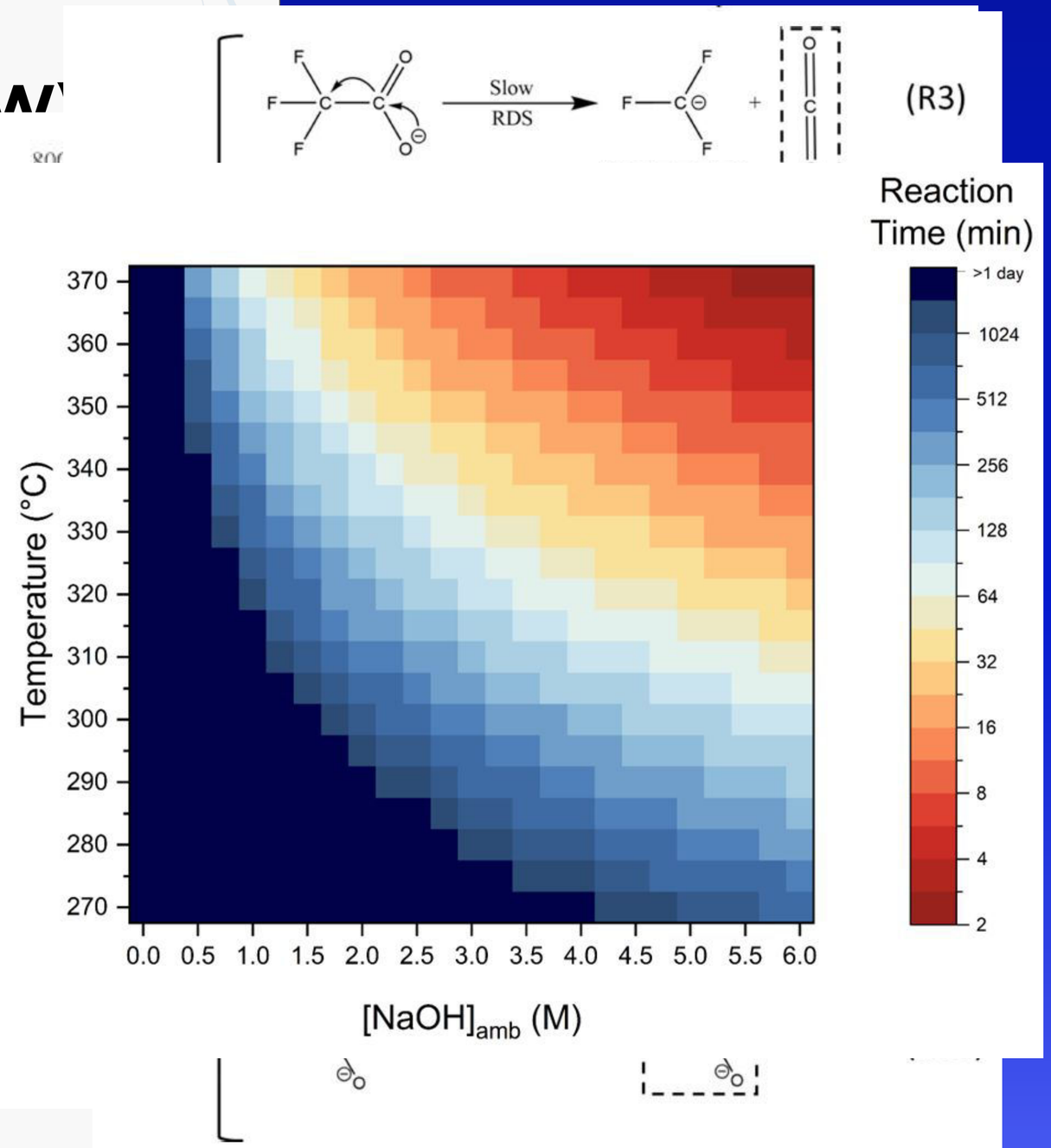
Foundational HALT patent exclusively licensed to Aquagga



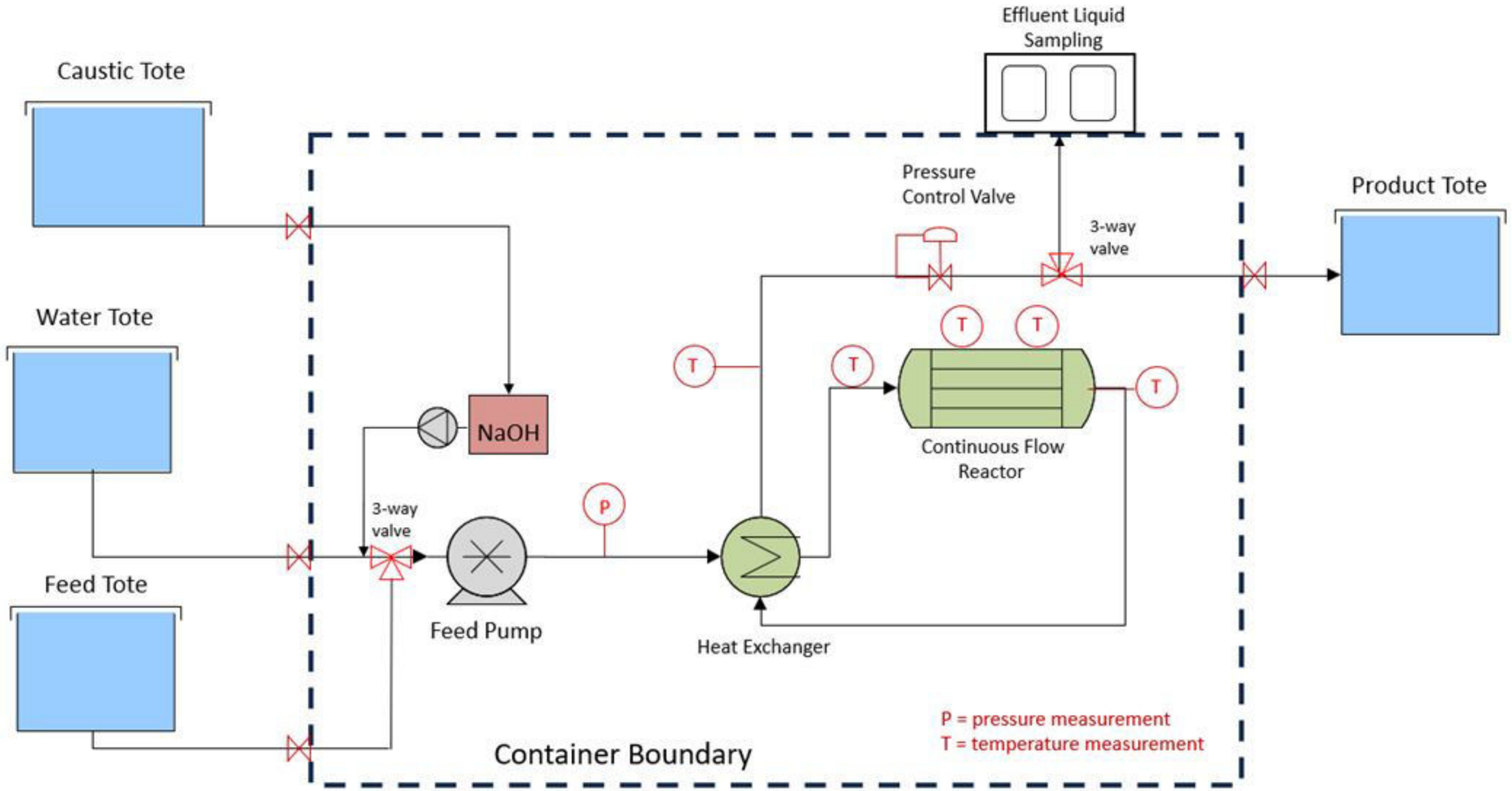
HALT operates at subcritical conditions, eliminating complexities associated with containing supercritical water

Basic HALT Research (CSM & UW

- 2019 - alkaline hydrothermal conditions successful in destroying PFOS (Wu et al.)
- 2021 - HALT successful in destroying all PFAS in AFFF matrices, non-target analysis confirms no fluorinated byproducts (Hao et al.)
- 2022 - 2024 - Applications for groundwater, foam fractionate, fire training pit water, and high TDS wastewater, no significant matrix effects (Hao et al., Pinkard et al.)
- 2024 - PFCA mechanism elucidated, TFA reaction kinetics determined (Austin et al.)
- 2025 - PFSA mechanism elucidated, detailed TFMS kinetics measured (Ellis et al.)



Containerized HALT System - Process Flow Diagram



Containerized HALT System

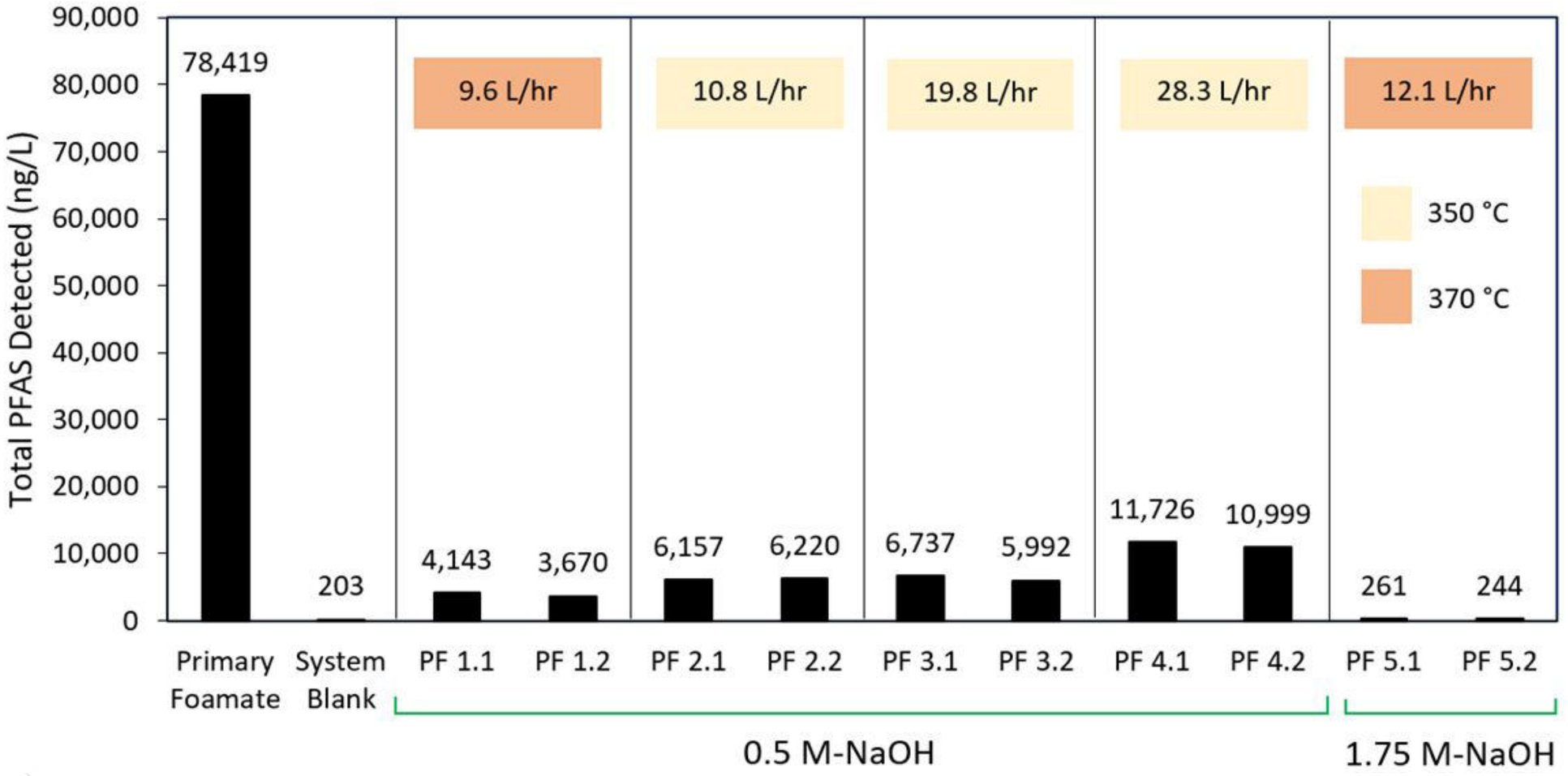
Study Objectives & Key Questions

- Can HALT be used to destroy PFAS in a concentrated municipal wastewater matrix?
- What are the effects of operating condition on PFAS destruction performance?
    - Specifically, how will certain PFAS subtypes such as fluorotelomer carboxylic acids (FTCAs) behave during HALT?
- What are the resulting projected operating costs? (e.g., electricity, chemicals)
- Practical considerations
    - Footprint
    - Power
    - Operations

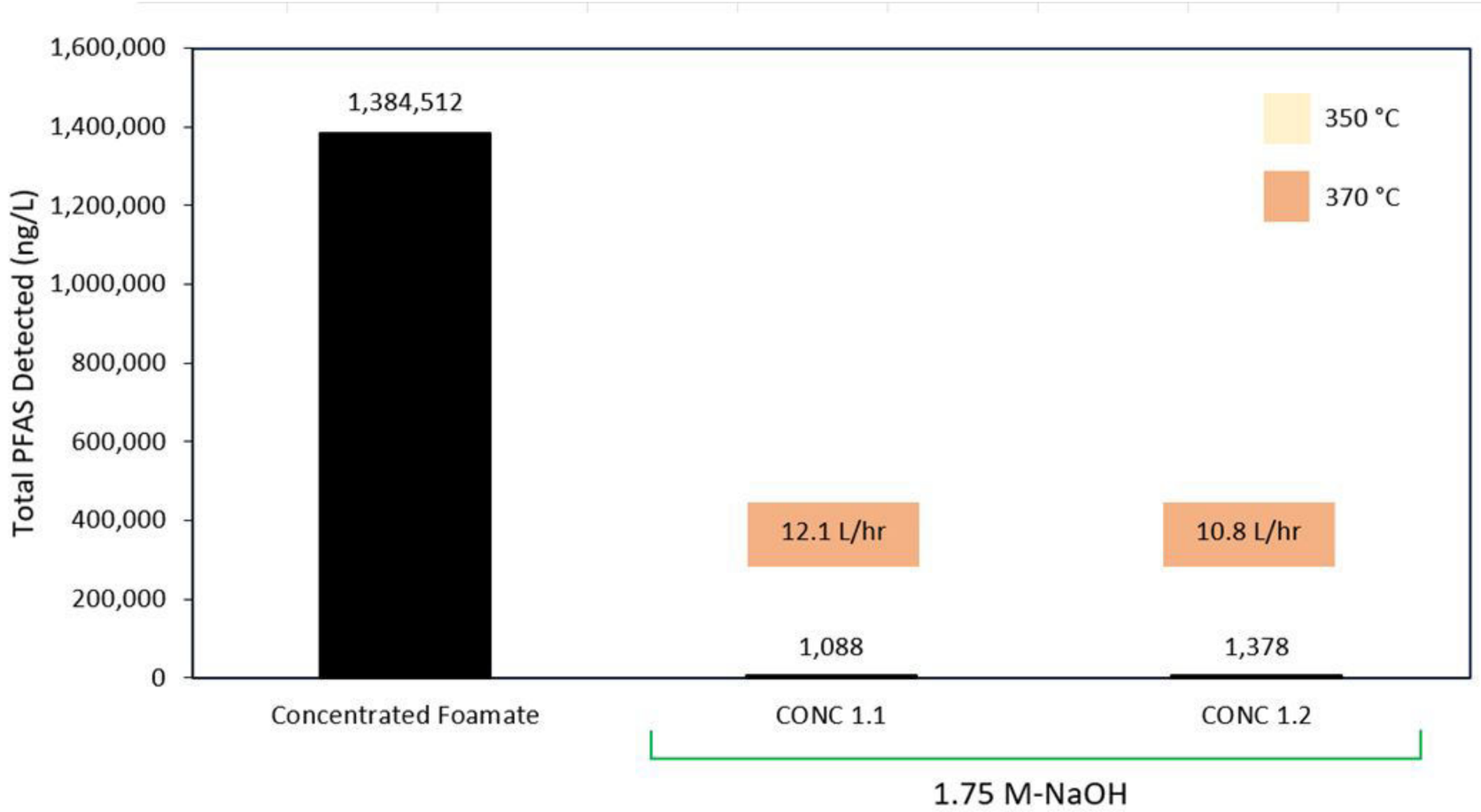
HALT - Experimental Conditions

- Temperatures = 350 to 370 °C
- NaOH = 0.5 to 1.75 M-NaOH
- Pressure ~ 20 MPa
- Flow rate = 9.5 to 28.5 L/h
- Replicate samples collected at six different operating conditions
- Two foam concentrates tested:
  - ~78,000 ng/L starting PFAS
  - ~1,385,000 ng/L starting PFAS
- PFAS destruction assessed via established EPA methods (commercial LC-MS/MS)
- Effluent neutralized with sulfuric acid and discharged to headworks of WWTP

Pilot Results - HALT of Primary Foamate



Pilot Results – HALT of Foam Concentrate



Pilot Results – Tabulated Data

PFAS Subclass	Primary Foamate	System Blank	PF 1.1	PF 1.2	PF 2.1	PF 2.2	PF 3.1	PF 3.2	PF 4.1	PF 4.2	PF 5.1	PF 5.2
PFCA	11,284	5	47	45	45	54	35	28	20	24	ND	37
PFSA	13,643	53	3,984	3,569	6,063	6,139	6,634	5,927	11,685	10,947	241	188
Sulfonamide	634	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFECA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFESA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FTOH	73	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FTCA	40,865	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FTS	11,920	140	112	55	49	28	68	38	22	28	20	18
Total PFAS Detected	**76,006**	**203**	**4,143**	**3,670**	**6,157**	**6,220**	**6,737**	**5,992**	**11,726**	**10,999**	**261**	**244**
DRE%	-	-	**94.7%**	**95.3%**	**92.1%**	**92.1%**	**91.4%**	**92.4%**	**85.0%**	**86.0%**	**99.7%**	**99.7%**

Key Takeaways

PFAS destruction is technically feasible in a municipal wastewater matrix via HALT

Total mass flow through WWTP must be considered

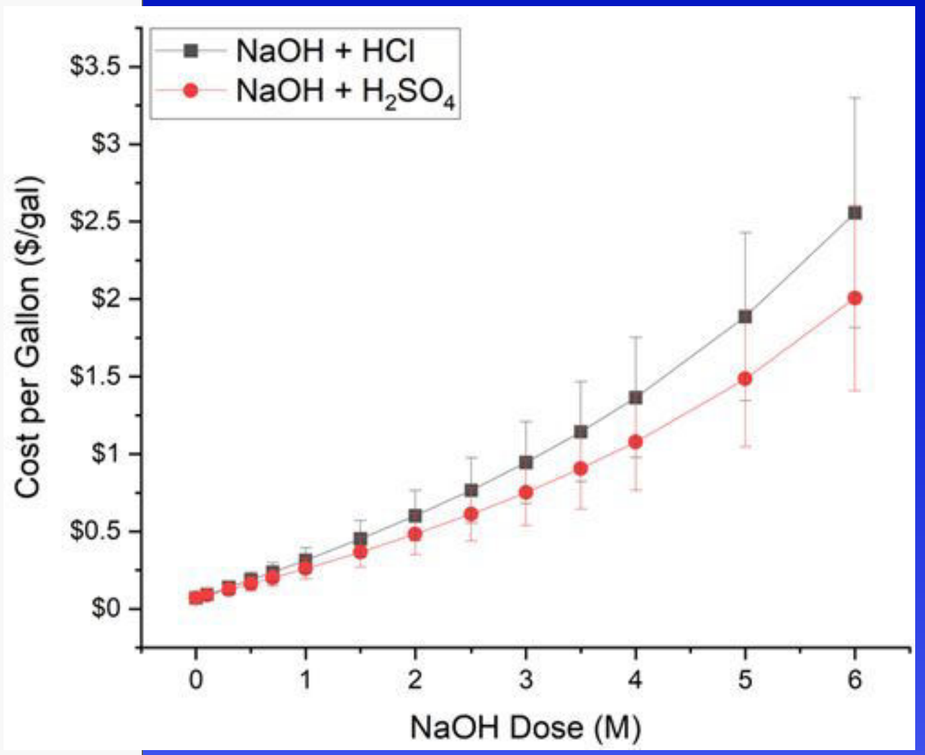
The role of HALT is to achieve **overall PFAS mass reduction**, in support of discharge goals. HALT must be part of a systems-based treatment approach

🔬 Different PFAS subtypes have different susceptibility to HALT. PFSAs require more aggressive treatment

Future work will focus on the ideal locations to apply PFAS treatment and destruction

HALT - Technoeconomic Analysis

- At mildest condition (350 °C, 0.5 M-NaOH, 28.3 L/h), HALT OpEx projected at ~$0.16/gal, inclusive of energy, NaOH and H_2SO_4
  - Mild condition delivered:
    - ~85% total PFAS destruction
    - >99% destruction of non-PFSAs
- At harshest condition (370 °C, 1.75 M-NaOH), HALT OpEx projected at ~$0.48/gal, inclusive of energy, NaOH and H_2SO_4
  - Harsh condition delivered:
    - >99% total PFAS destruction
    - >99% destruction of non-PFSAs

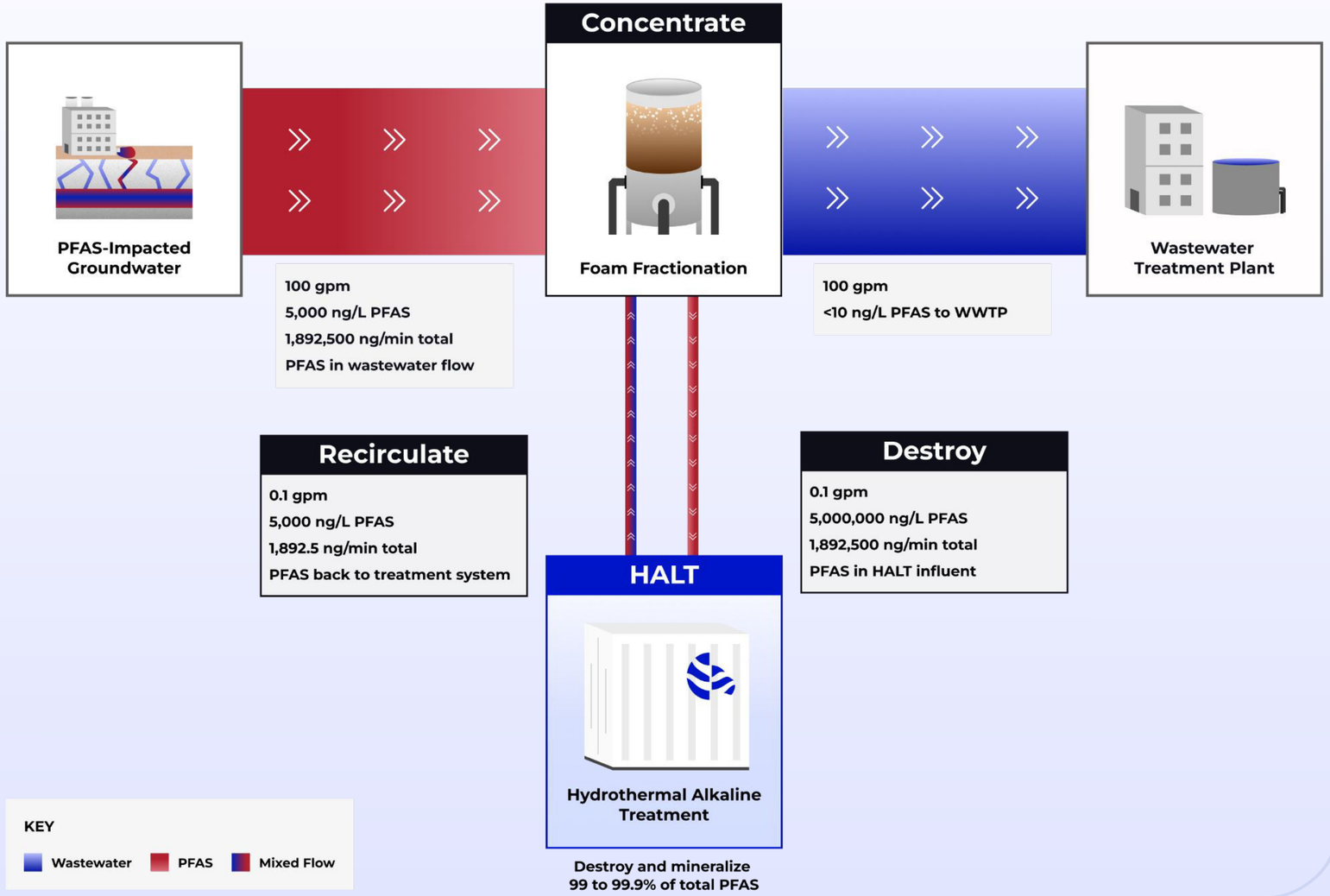


Closed-Loop Treatment Train

HALT is a tunable portion of the overall PFAS treatment train

Optimizing the HALT operating condition can reduce overall treatment costs while still enabling desired treatment outcomes

HALT displaces hauling + incineration or landfilling as the final disposal option for PFAS-rich concentrates



Future Directions

- HALT can be an important component of industrial pretreatment for PFAS, at landfills and industrial facilities
- Centralized treatment and disposal facilities at existing TSDFs for AFFF and concentrated PFAS residuals
- Direct treatment of concentrated industrial wastewater for the pharmaceutical and semiconductor industry

Aquagga

Thank You

Please feel free to contact me

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Hydrothermal Alkaline Treatment of PFAS Precursors under Mild Conditions

Ansaf V. Karim[a], Brian Pinkard[b], Annie Heble[b], Conrad Austin[b], Joel Baker[a], and Emese Hadnagy[a]

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[b] Aquagga, Inc., Tacoma, WA

November 21 2025

UNIVERSITY of WASHINGTON

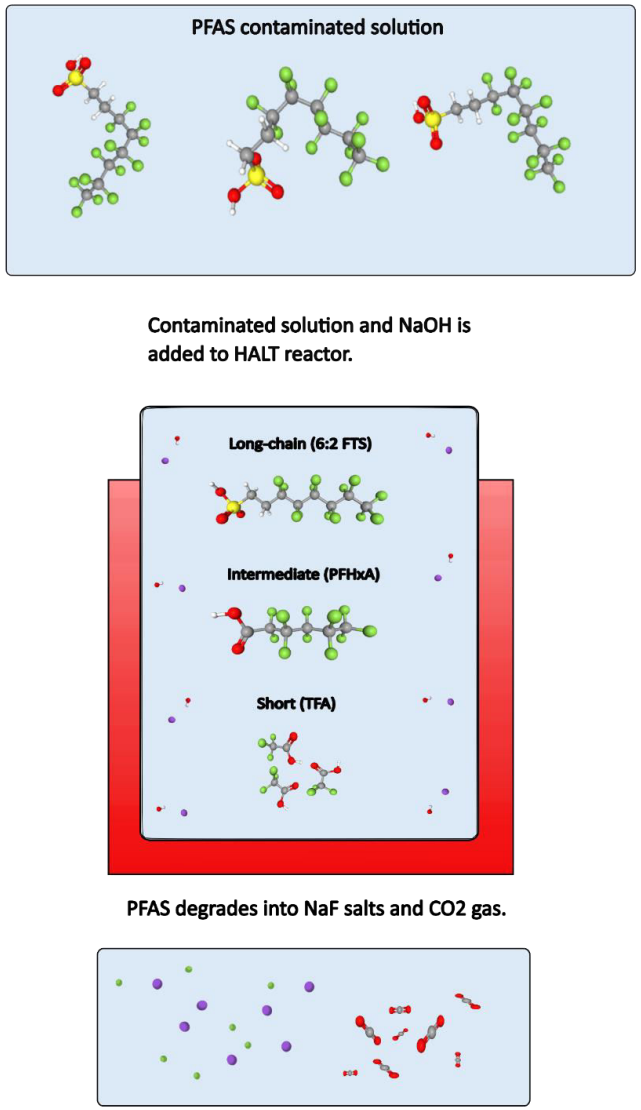
Hydrothermal Alkaline Treatment (HALT)

Advanced thermochemical process

Uses high temperature (<374 °C), pressure (<25MPa), and alkaline conditions (pH >13)

Efficiently treats diverse contaminated media such as industrial wastewater, aqueous film-forming foams, groundwater, PFAS-laden solids, etc.

Continuous flow systems are energy efficient and rapidly degrade long, short, and ultra short-chain PFAS compounds



Hao et al, 2021, 2022 Pinkard et al. 2023

Research Gaps and Objectives

Research Gaps:

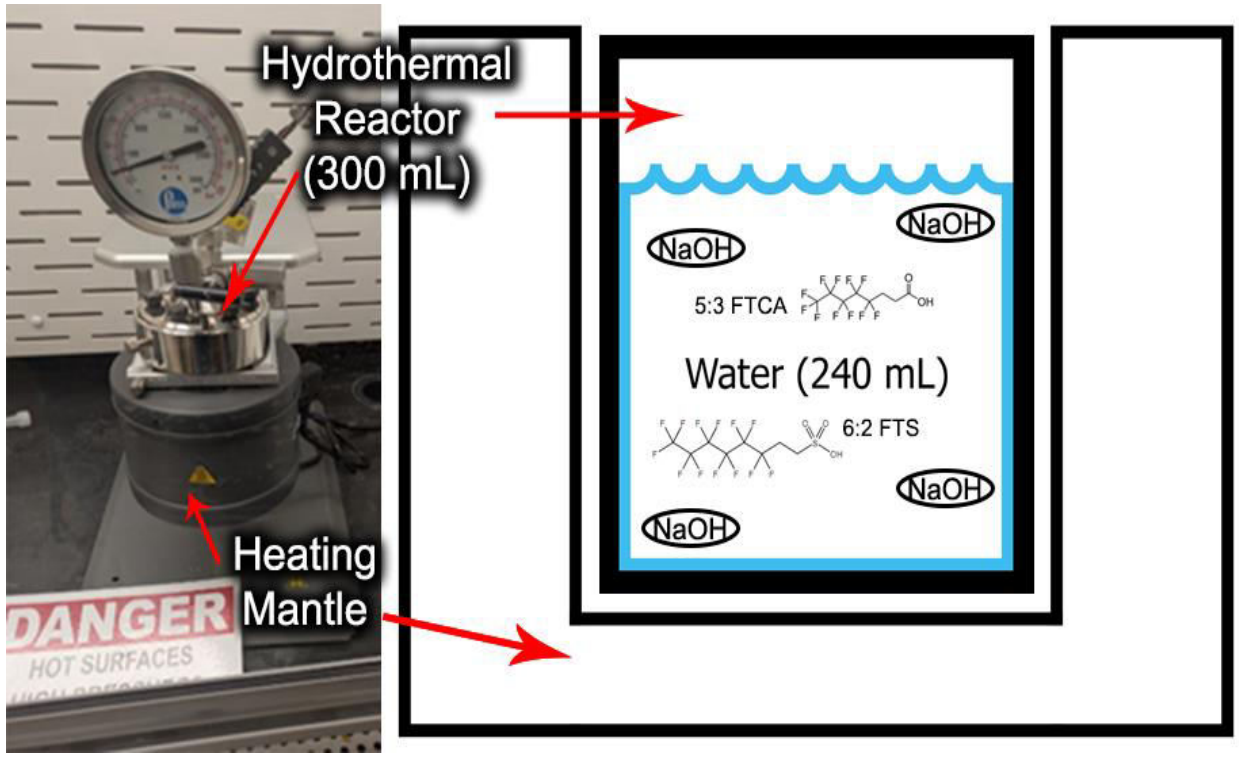
- Understanding of reaction kinetics at lower temperatures
- Highly alkaline HALT effluents complicate post-treatment processes
- Variable degradation efficiency across PFAS classes

Research Objective:

To evaluate HALT's effectiveness under milder conditions to develop a more energy- and chemical-efficient PFAS destruction approach

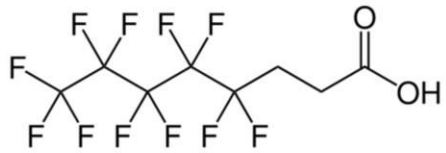
Methodology

- Experiments were conducted in a high-pressure-temperature Parr Reactor
- 6:2 FTS and 5:3 FTCA as the model pollutants
- The effect of temperature and NaOH dosage was studied
- Initial PFAS concentration of 50 µg/L was used
- Samples were analyzed using EPA Method 1633A

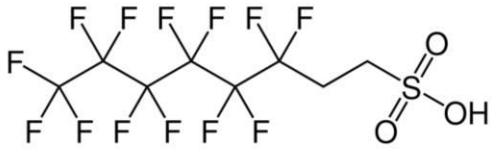


Experimental Setup

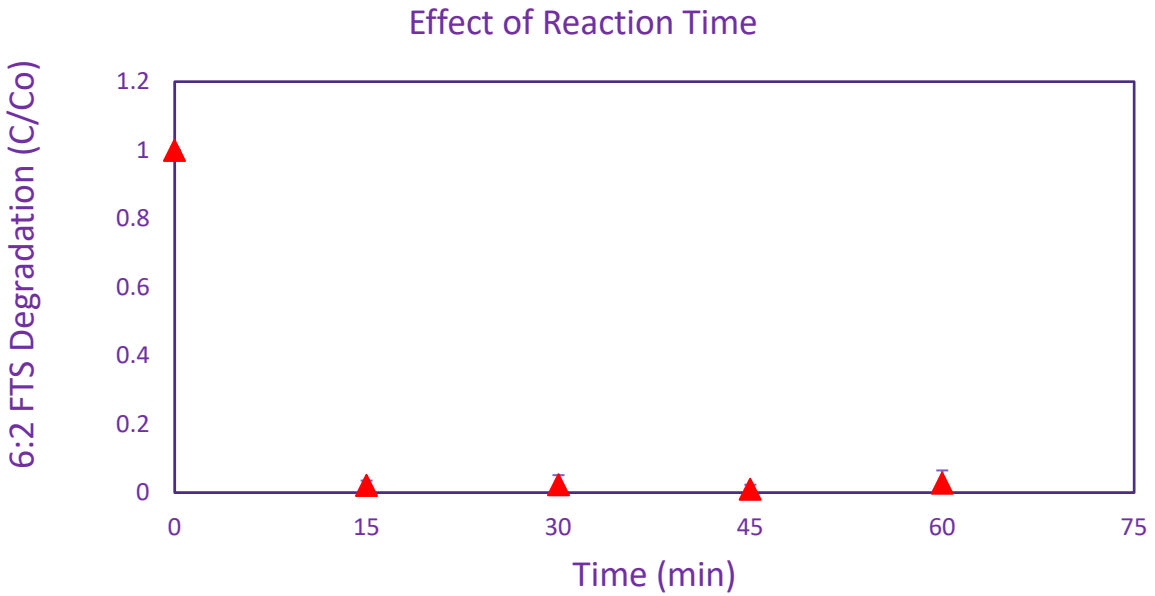
5:3 Fluorotelomer Carboxylic Acid (5:3 FTCA)



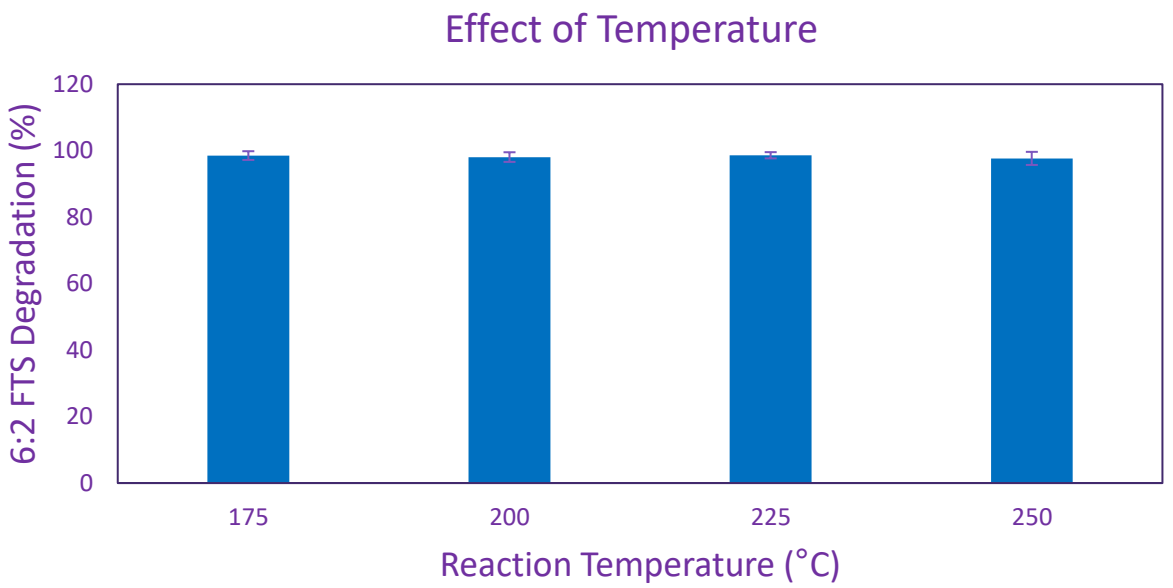
6:2 Fluorotelomer Sulfonic Acid (6:2 FTS)



Results and Discussion



50 µg/L 6:2 FTS, 250 °C, 2 M NaOH

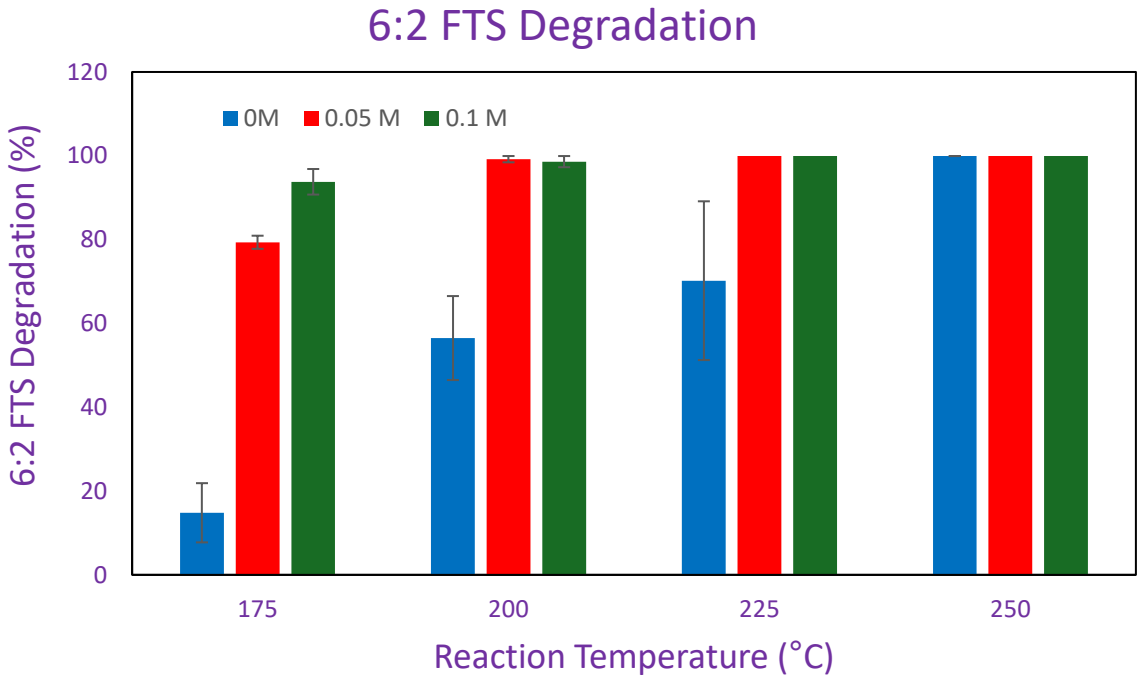


50 µg/L 6:2 FTS, 30 min, 2 M NaOH

- 6:2 FTS degraded rapidly at 250 °C in the presence of 2 M NaOH
- Negligible variation in degradation efficiency between 15 and 60 min indicates that 6:2 FTS undergoes a rapid initial breakdown under high concentration of OH^-

- Similar degradation observed under a strongly alkaline environment
- The temperature effect was insignificant at these alkaline concentrations

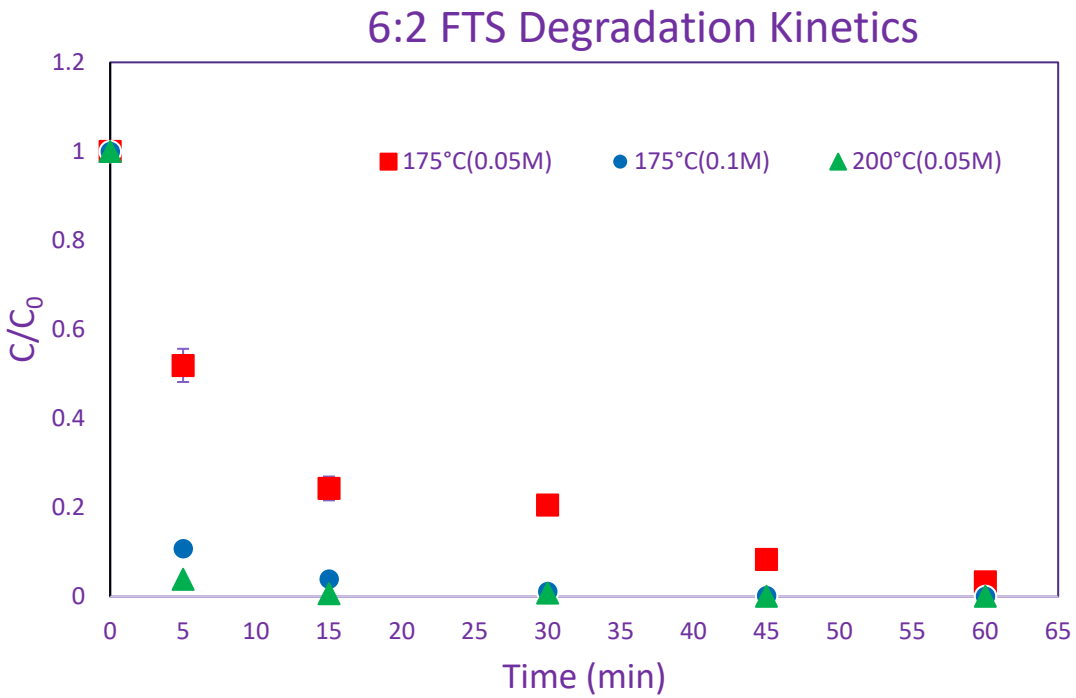
Results and Discussion



50 µg/L 6:2 FTS, 30 min, 0, 0.05 and 0.1M

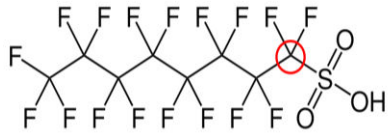
- Near complete degradation at 0.05 M NaOH with 200 °C
- At lower temperature and 0 M, only thermal degradation due to limited nucleophiles
- Base-catalyzed degradation with the addition of NaOH

Results and Discussion

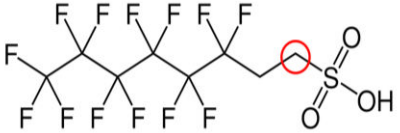


6:2 FTS Degradation Kinetics

- Significant increase in degradation at 200 °C
- The sulfonate group and telomer segment could make it more prone to cleavage due to the electron distribution, particularly around the methylene group.
- 6:2 FTS was more effectively degraded in the HALT system compared to perfluoroalkyl sulfonic acids due to its sterically hindered α-C



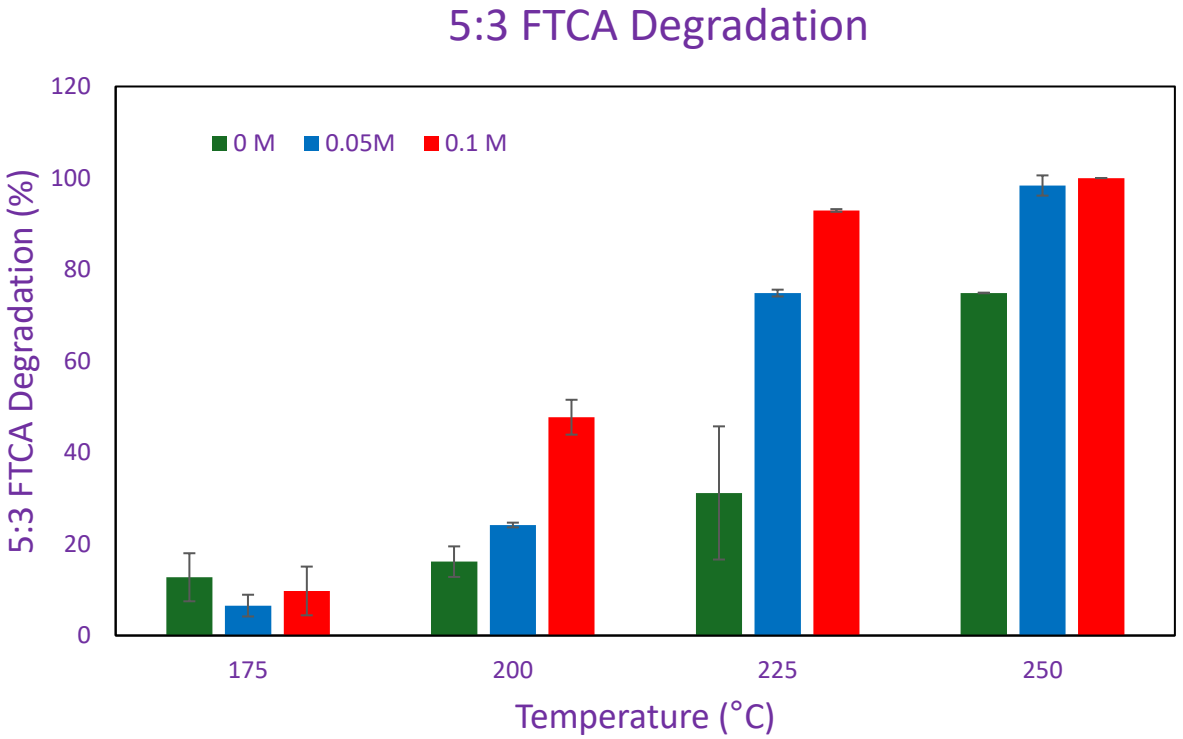
Perfluorooctanesulfonic Acid
(PFOS)



6:2 Fluorotelomer Sulfonic Acid
(6:2 FTS)

Monsky et al. 2024, Kim et al. 2025, Cai et al. 2025

Results and Discussion

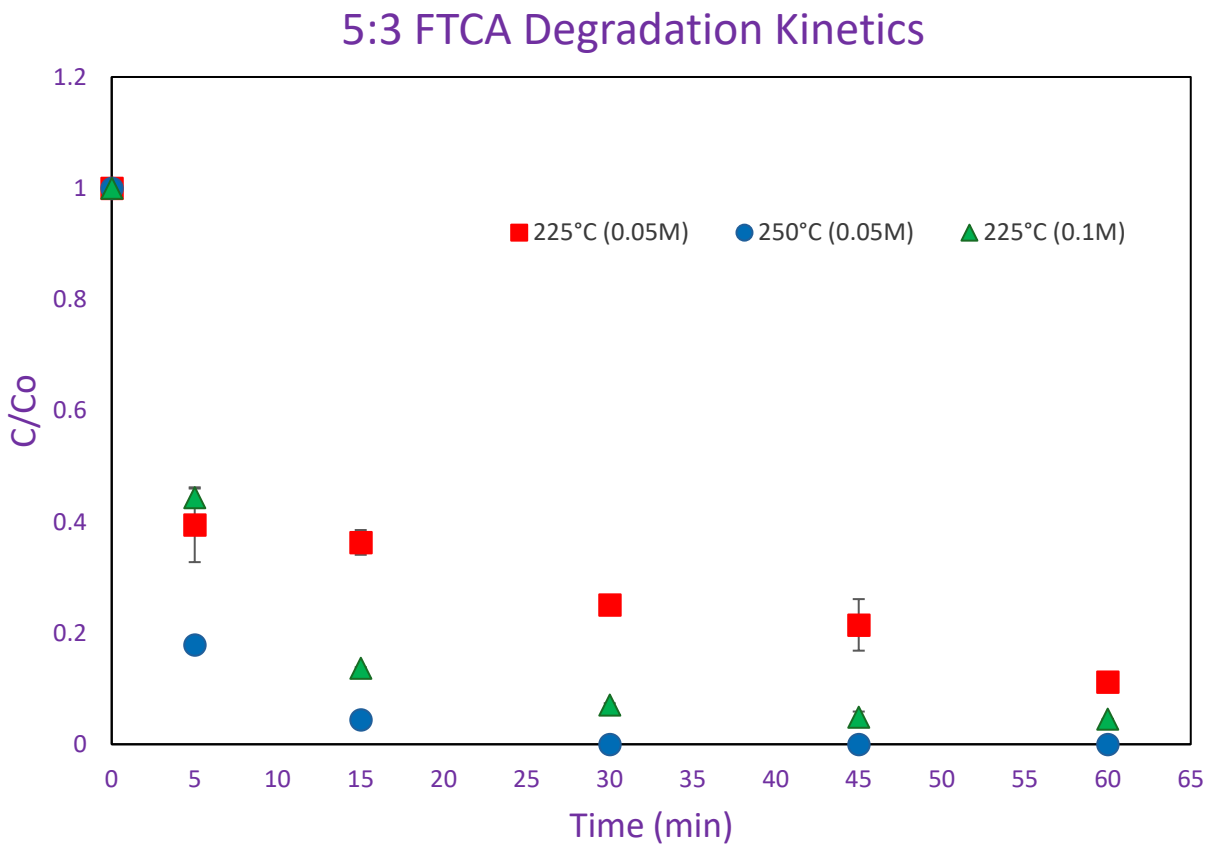


50 µg/L 5:3 FTCA , 30 min, 0 M, 0.05 M & 0.1 M NaOH

- Degradation observed at 0 M indicates that thermal processes drive the initial mechanistic step
- An increase in temperature and molarity significantly enhanced 5:3 FTCA degradation
- Moderate concentration of OH^- ions limits nucleophilic attack

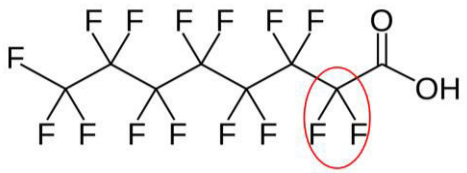
Austin et al. 2024, Monsky et al. 2024

Results and Discussion

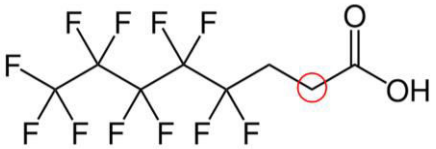


5:3 FTCA Degradation Kinetics

- Degradation rate varied with a rise in temperature
- Although PFCA's typically degrade more readily than PFSA's under HALT, 5:3 FTCA in this study required higher temperature and alkalinity than 6:2 FTS
- C-C bond near the carboxylic acid in 5:3 FTCA could decrease the electron density due to the electron-withdrawing effect, making it less prone to nucleophilic attack



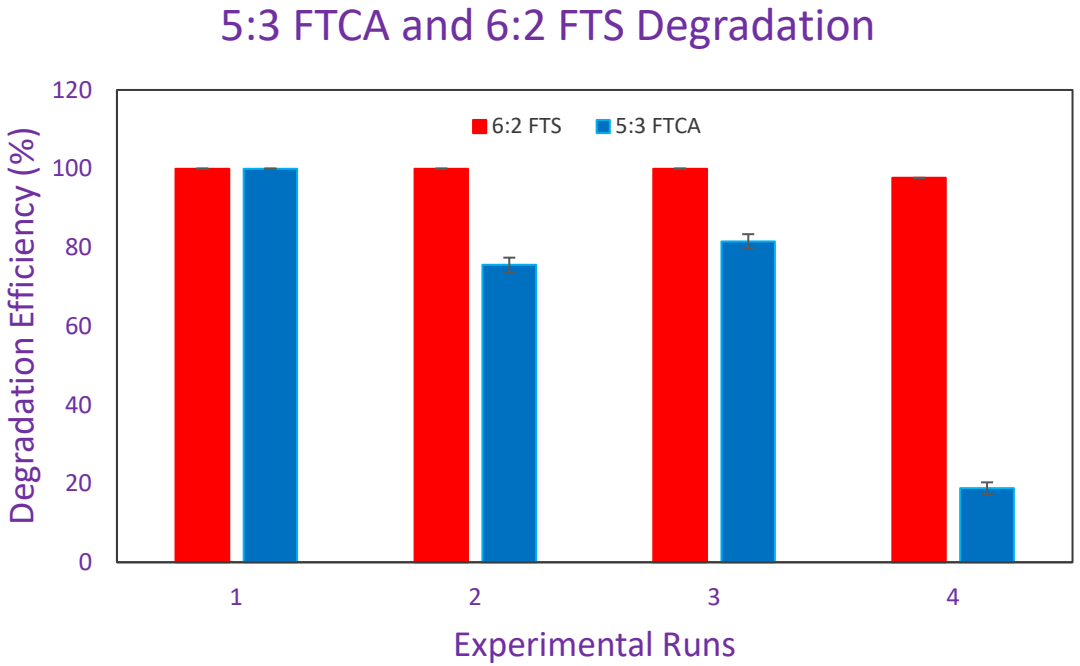
Perfluorooctanoic Acid
(PFOA)



5:3 Fluorotelomer Carboxylic Acid
(5:3 FTCA)

Wu et al, 2019, Endo, J. & Funazukuri, T, 2023, Austin et al. 2024, Monsky et al. 2024

Results and Discussion



50 µg/L 5:3 FTCA and 6:2 FTS Combined Degradation Studies

Experiments	Reaction Time (min)	Temperature (°C)	Molarity (M)
1	30	225	0.1
2	30	225	0.05
3	45	225	0.05
4	30	200	0.05

- 5:3 FTCA remains recalcitrant at milder conditions when compared to 6:2 FTS
- An increase in temperature and molarity significantly enhanced 5:3 FTCA degradation

Summary and Future Work

Low-chemical HALT degradation proved effective for PFAS precursors

Alkaline conditions significantly enhanced the degradation efficiency

5:3 FTCA exhibits greater recalcitrance than 6:2 FTS

A possible mechanism could be the cleavage of the C-S and C-F bond due to electron density shift

Ongoing studies to understand the degradation pathways, defluorination efficiency and plausible mechanism under milder conditions

Acknowledgments

- Department of Ecology, State of Washington
- Prof. Emese Hadnagy and Prof. Joel Baker
- City of Tacoma Environmental Services Laboratory
- Aquagga, Inc.
- ECT2
- Center for Urban Waters, University of Washington Tacoma
- Chauncey Delos Santos and Justin Ray

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8. Hao, S. et al. Hydrothermal alkaline treatment for destruction of per-and polyfluoroalkyl substances in aqueous film-forming foam. Environ Sci Technol 55, 3283–3295 (2021)
9. Monsky, R. J.; Li, Y.; Houk, K. N.; Dichtel, W. R. Low-Temperature Mineralization of Fluorotelomers with Diverse Polar Head Groups. J Am Chem Soc 2024, 146 (25), 17150–17157
10. Wu, B., Hao, S., Choi, Y., Higgins, C.P., Deeb, R., Strathmann, T.J., 2019. Rapid Destruction and Defluorination of Perfluorooctanesulfonate by Alkaline Hydrothermal Reaction. Environ Sci Technol Lett 6, 630–636.

Thank you!

Questions?

1633 PFAS:

From the Analyst's Perspective

[Analysis performed on Agilent 6470 LC/QQQ]

WHAT WILL BE COVERED:

- What is Method 1633 (compared to Method 8327)
- What Instrument do we use to analyze PFAS
- The science/math of how the data is determined
- The experience of analyzing PFAS with various “real-life” samples
- Time for Questions

METHODS:

- Both Method 1633 & Method 8327 are used to measure PFAS in groundwater, surface water, and wastewater samples (non-drinking water)
- Method 8327 measures 24 PFAS compounds. More of a "Dilute & Shoot". Minimal prep is done
- Method 1633 measures 40 PFAS compounds
- More on Method 1633 to come

Agilent 6470 LC-QQQ

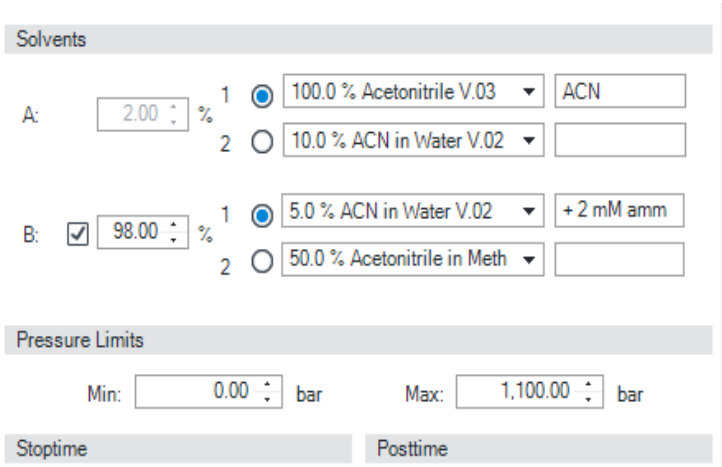
- LC (Liquid Chromatography): Instead using GAS we are using LIQUID mobile phases. Usually an "Organic" (Acetonitrile) and a "Water" (H2O + Acetonitrile + 2mM Ammonium Acetate)

- Very sensitive instrument able to detect at specific ions. MRM Transitions(**499 > 80**)

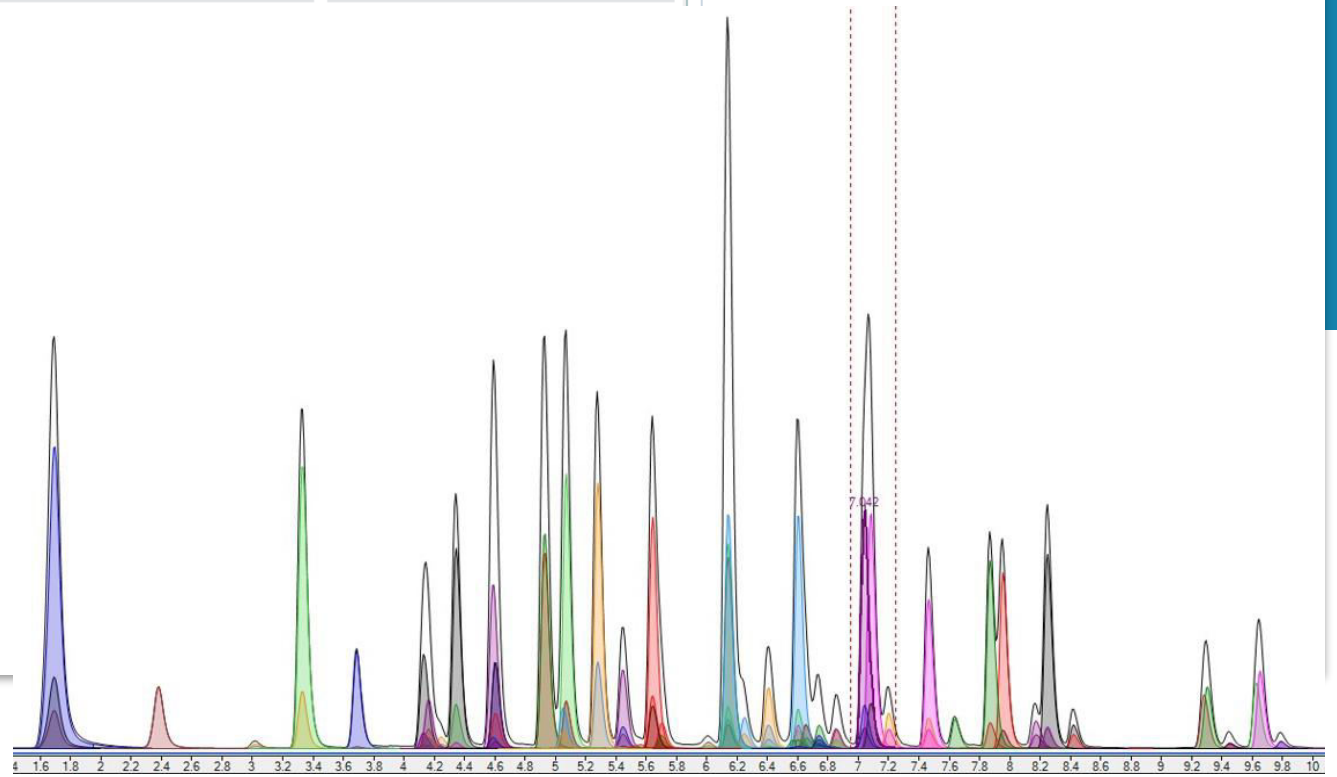
- Pros and Cons of this sort of sensitivity

Gradient Elution

- 2 Eluents (Mobile Phases)
- Mobile Phase Mixing
- Hydrophobic/Hydrophilic
- Peaks development over time

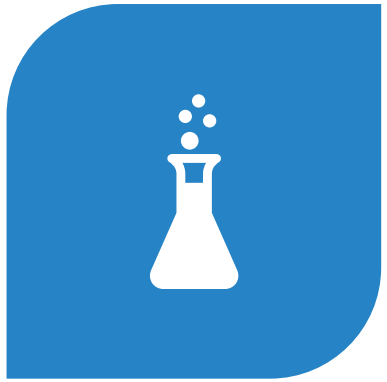


Time [min]	A [%]	B [%]	Flow [mL/min]	Max. Pressure Limit [bar]
0.00	2.00	98.00	0.350	1100.00
0.20	5.00	95.00	0.350	1100.00
4.00	30.00	70.00	0.400	1100.00
7.00	55.00	45.00	0.400	1100.00
9.00	75.00	25.00	0.350	1100.00
10.00	95.00	5.00	0.400	1100.00
10.50	2.00	98.00	0.400	1100.00
11.80	2.00	98.00	0.400	1100.00
13.00	2.00	98.00	0.350	1100.00



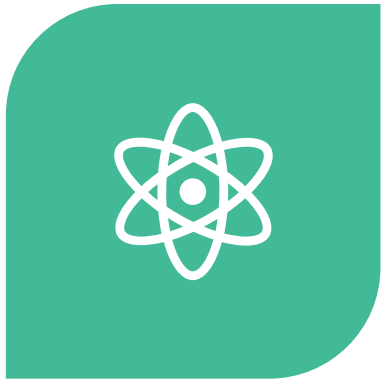
FOR THE ANALYSIS OF PFAS FOLLOWING THE 1633 METHOD

There are 3 sets of compounds…



40 TARGET COMPOUNDS

24 EIS (EXTRACTED INTERNAL STANDARD) COMPOUNDS



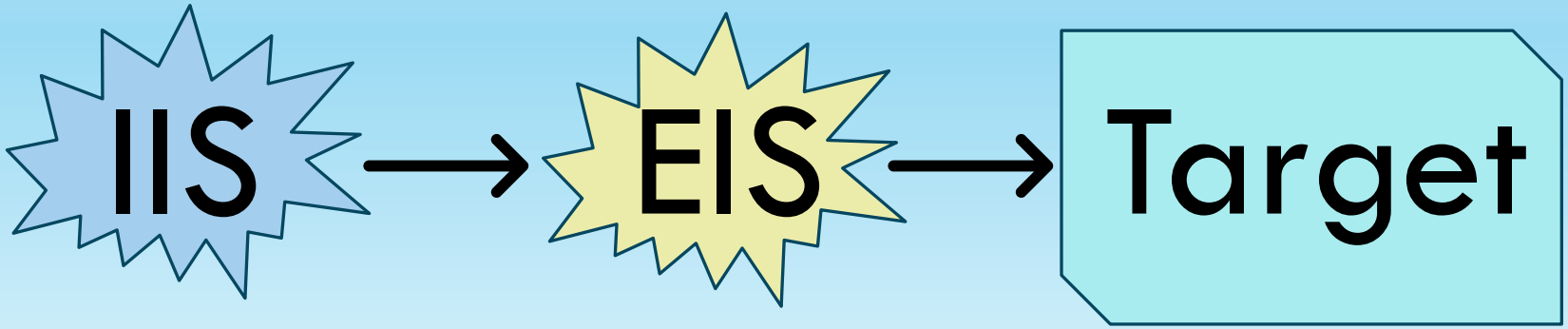
7 IIS (INJECTED INTERNAL STANDARD) COMPOUNDS

71 total compounds

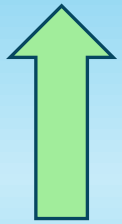
Each of these compounds play an important role in determining the concentration of a sample

Individual compounds in a set
have an influence on the other sets

The order is as such:

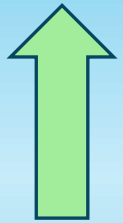


To Further Illustrate this…

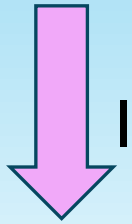


IIS Recovery

EIS Recovery



Target Recovery/ Concentration



IIS Recovery

EIS Recovery

Target Recovery/ Concentration

What affects IIS recovery?

Degraded IIS standard

Mobile Phase (if it differs from those used during calibration)

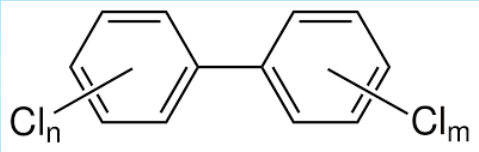
Number one cause is MATRIX!

(Including alkaline and acidic environments)

How do you deal with a nasty matrix?

Many labs will turn to diluting their extracts for re-analysis.

This sort of action is found in many other analyses such as PCB analysis



With other analyses…

Additional Internal Standard is added to the diluted extract

With PFAS analysis…

No additional Internal Standard is added.

Problems with diluting PFAS extracts

Everything is diluted

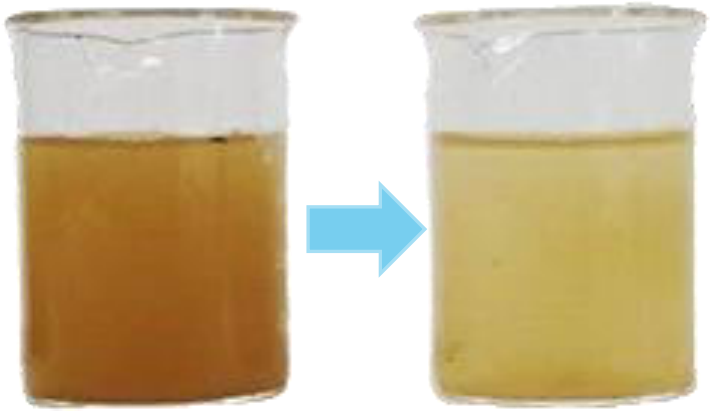
(all compounds including IIS)!

Dilutions can help but minimal is best

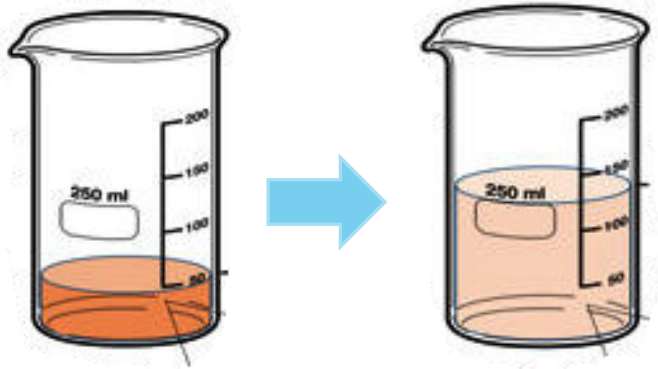
Best Ways To Deal With Nasty Matrices for PFAS

- Use a smaller amount of sample

(especially for Treatment Plant samples!)



- Higher Final Volume



Problem with Higher Final Volume

- Having a higher final volume is basically like diluting the sample prior to adding the IIS

- This makes the matrix cleaner while still having an undiluted IIS introduced

- On the flipside, the way the Quant method was set up, the peaks to the EIS compounds are not integrated (leading to having to manually integrate the peaks).

- We found that lowering the threshold (Peak Area Counts) down to “200” helps resolve this issue and the diluted EIS compound peaks are now intergrated by the Quant method again.

1633 PFAS:

- Method is complex for analyzing PFAS

- Meeting acceptable recovery ranges is important, but being able to measure PFAS in surrounding environments (even if it's "estimated") is just as important for the sake of managing PFAS contamination and lessening its impact on our environment.


ANY
QUESTIONS
?