



Surface Active Foam Fractionation® (SAFF®) Technology

Pairing for complete closed loop
Separation, Concentration, and
Destruction

May 2, 2023, 11:00 a.m.



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Pairing for Complete Closed Loop Separation, Concentration, and Destruction

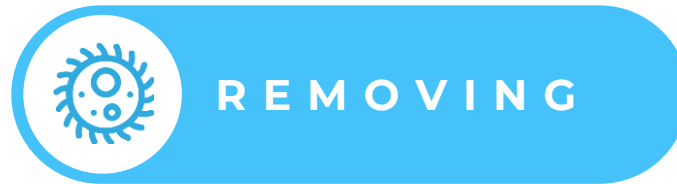
Zach Pierce, Environmental Engineer, Allonnia



Solving PFAS Contamination



Analyzing and evaluating waste streams to detect trace amounts of PFAS and inform solutions like remediation.

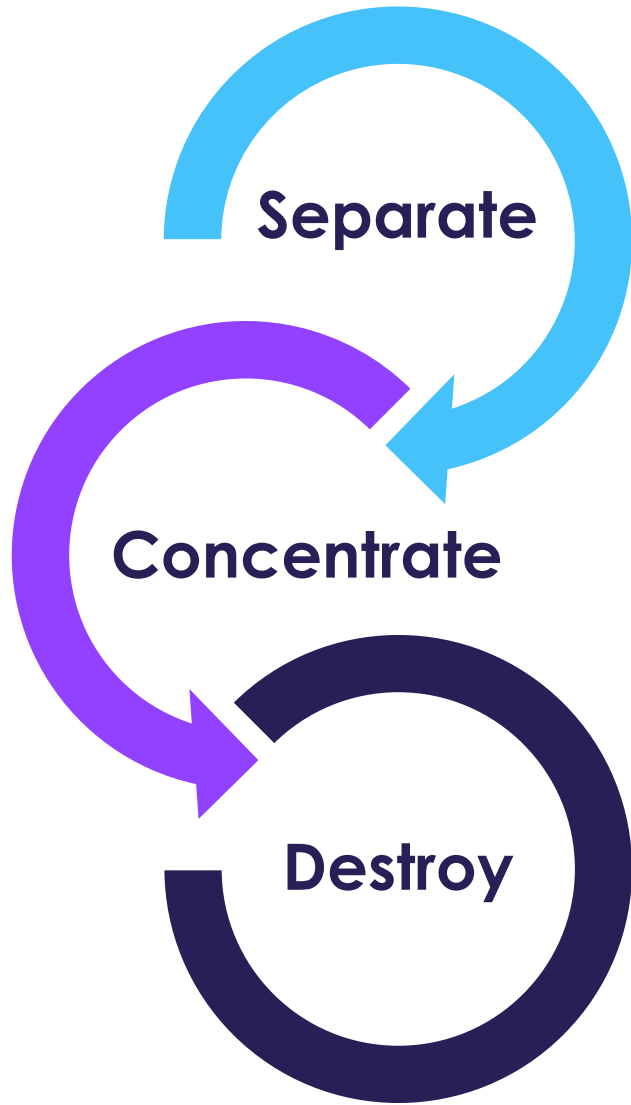


Separating and concentrating PFAS from contaminated water.



Destroying the removed PFAS by enzymatically breaking the C-F bond.

Comprehensive PFAS Treatment Solution



Treatment Goals

- Protect human health and the environment
- Meet safe drinking water and discharge requirements

Example Treatments

- GAC, AIX
- RO
- Foam Fractionation

- Reduce waste stream volume

- Regenerable media → regenerant waste
- Foam fractionation → foam concentrate

- Zero PFAS waste discharge

- Several pilot scale technologies for concentrate destruction coming to market: SCWO, EO, HALT, Plasma, UV Sulfite





SAFF Process

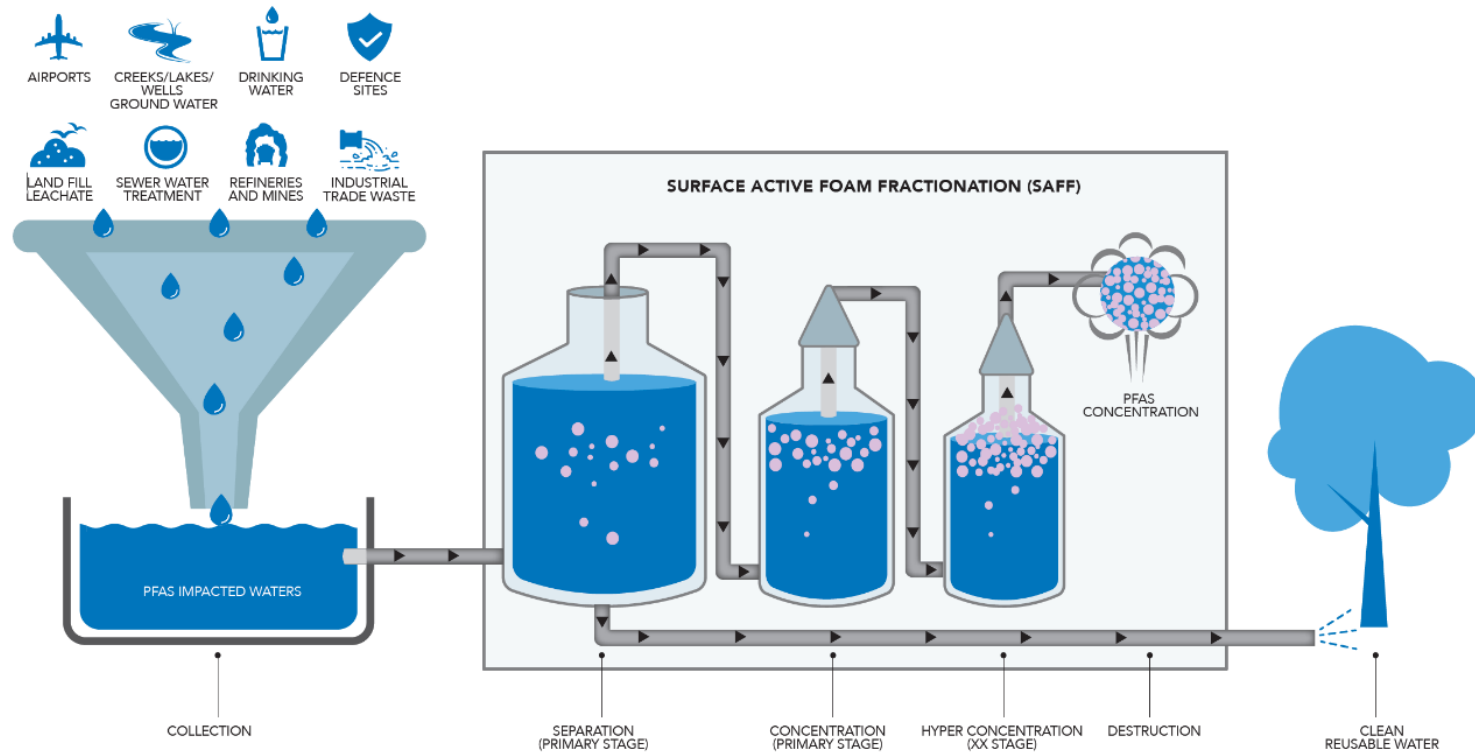


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SAFF: The Basic Concept of Foam Fractionation



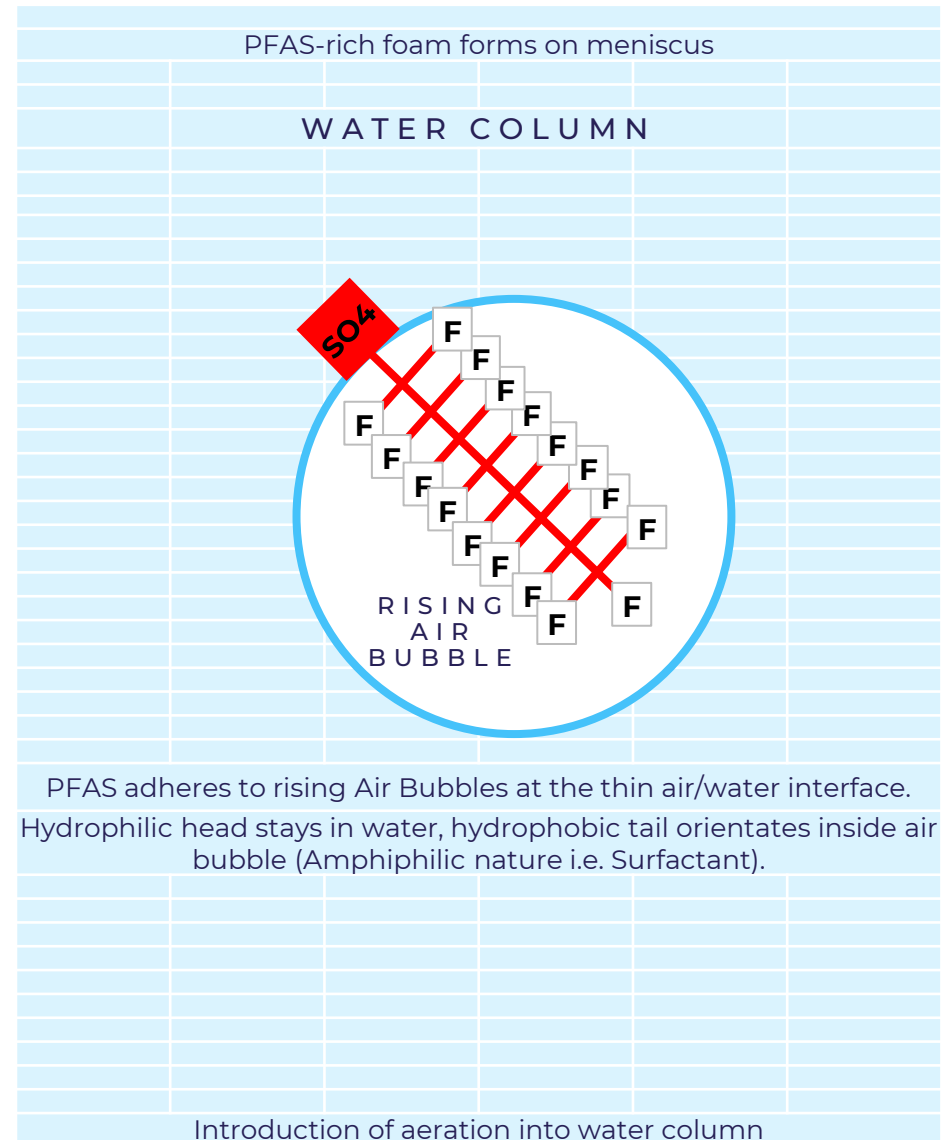
SAFF™ Separation Mechanism



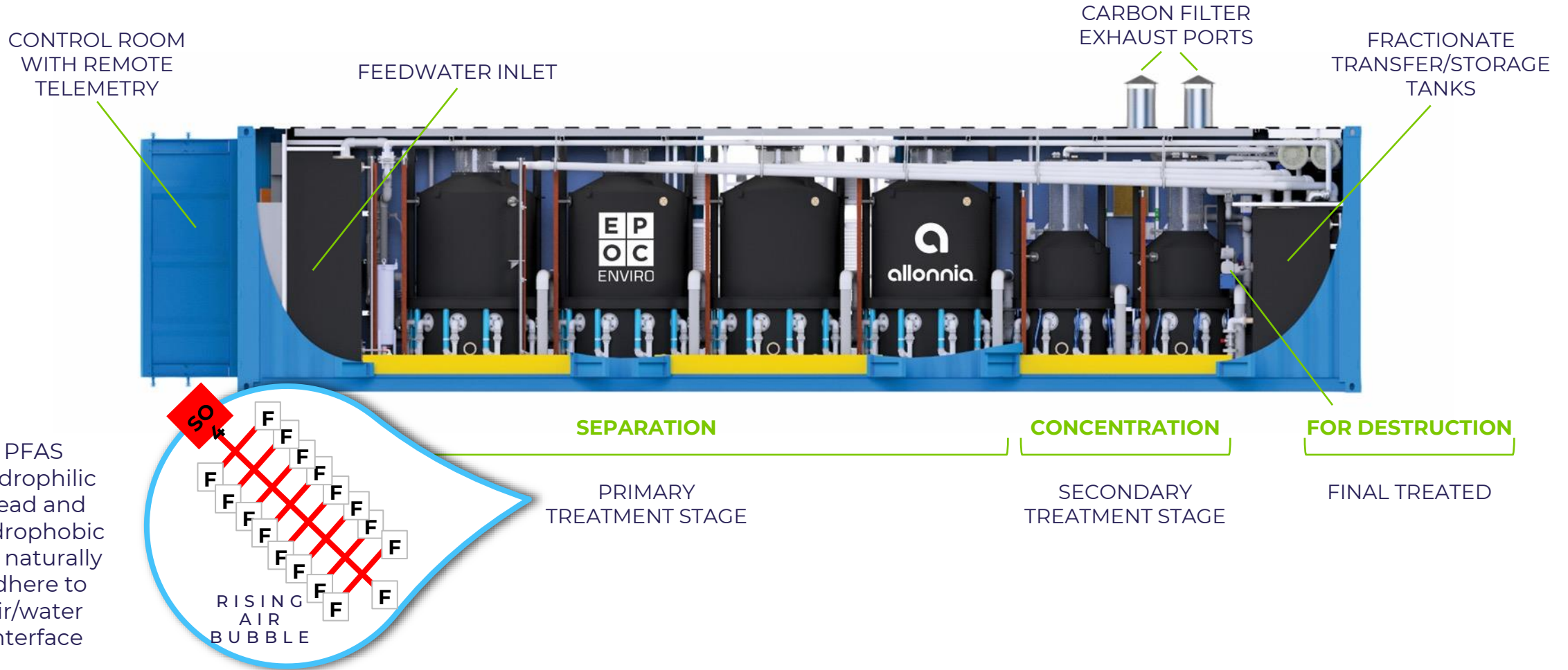
RISING AIR BUBBLES

Separates PFAS to surface

- Hydrophilic Head: Orientates in water
- Hydrophobic Tail: Orientates in air-bubble



Concept of Foam Fractionation



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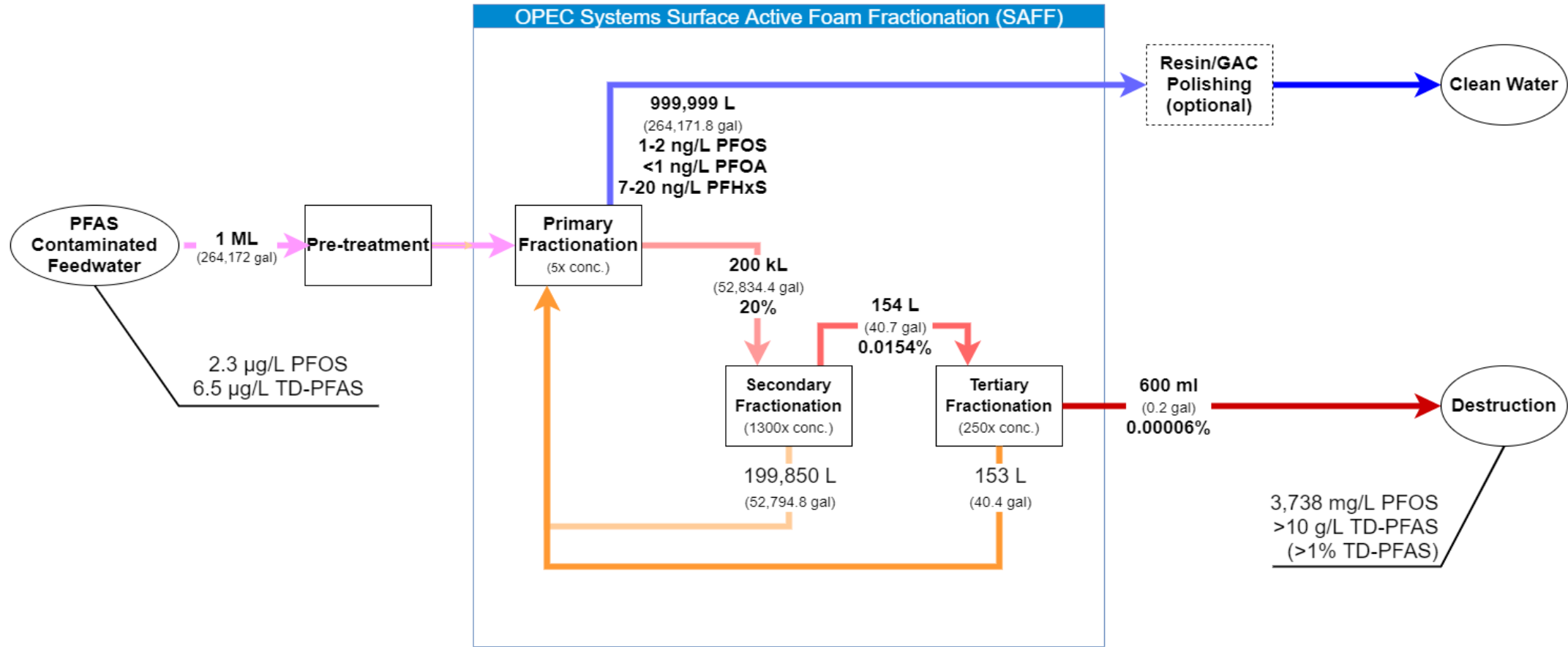
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SAFF™ Concentration Process



Based on data collected during field trial from Oakey plant (May 2019 - June 2020)

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Generate a Closed-Loop Solution

1

SEPARATION

2

CONCENTRATION

3

DESTROY



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Treatability Study Results – Hanscom AFB

Without SAFFactant

Analyte	Predicted Treatment	Treatment % Decrease	Influent Pretreatment (ng/L)	Effluent Remaining PFAS (ng/L)
PFHpA	100%	27%	16.8	12.2
PFHxS	100%	77%	107	24.7
PFDS	100%	--	ND	ND
PFNA	100%	100%	3.56	ND
PFOS	100%	98%	324	4.99
PFOA	100%	72%	38	10.4
Total PFAS	90%	71%	731	212

With Biodegradable SAFFactant

Analyte	Predicted Treatment	Treatment % Decrease	Influent Pretreatment (ng/L)	Effluent Remaining PFAS (ng/L)
PFHpA	100%	71%	16.8	4.88
PFHxS	100%	97%	107	3.18
PFDS	100%	--	ND	ND
PFNA	100%	100%	3.56	ND
PFOS	100%	100%	324	1.5
PFOA	100%	100%	38	0.0
Total PFAS	90%	80%	731	146

Concentrate – Transferred for Destruction

	Concentrate, No SAFFactant (ng/L)	Concentrate, With SAFFactant (ng/L)
PFOS	9268	8646
PFOA	803	1011
Total PFAS	15304	15851

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AECOM's DE-FLUORO

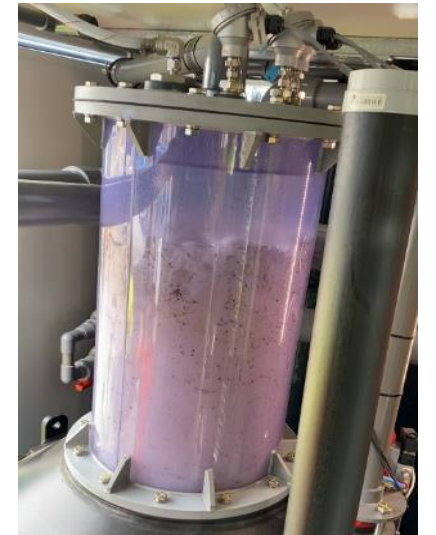
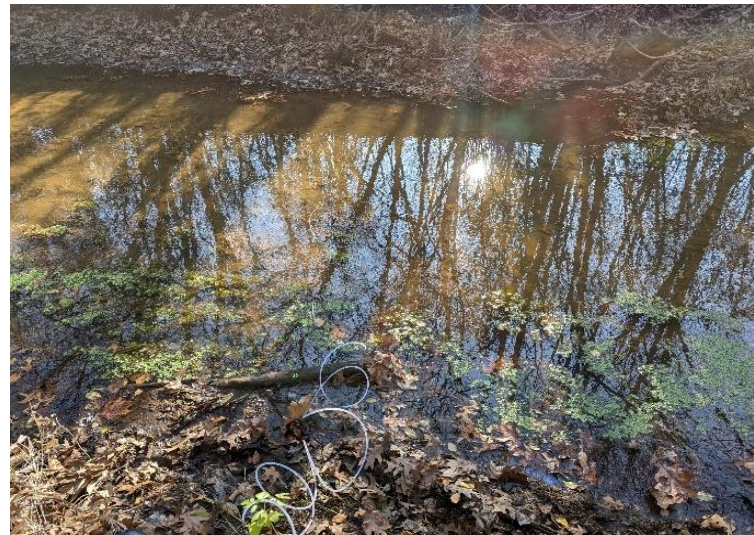
- Electrochemical Oxidation, proven to work on
 - Source area groundwater
 - Untreated wastewater
 - AFFF concentrate
 - Remediation derived waste
 - IX still bottom
 - Soil washing wastewater
 - Foam fractionation concentrate
- Uses electrode to mineralize PFAS (complete defluorination and desulfurization of PFAS molecules)

PFAS concentration reductions after DE-FLUORO™ treatment of various waste streams

Sample Description	Initial PFAS Concentration (ppb)	Reduction (%) Post-DE-FLUORO™ Treatment		
		PFOA	PFOS	Total PFAS (31 compounds)
Untreated wastewater	400	100	100	100
Source zone groundwater	500	100	99.9	98.6
Fractionation wastewater	1,800	99.7	99.6	99.4
Soil washing wastewater	14,000	100	99.9	99.2
Ion exchange resin regenerant	400,000	98.5	98.5	92.9



SAFF in Action



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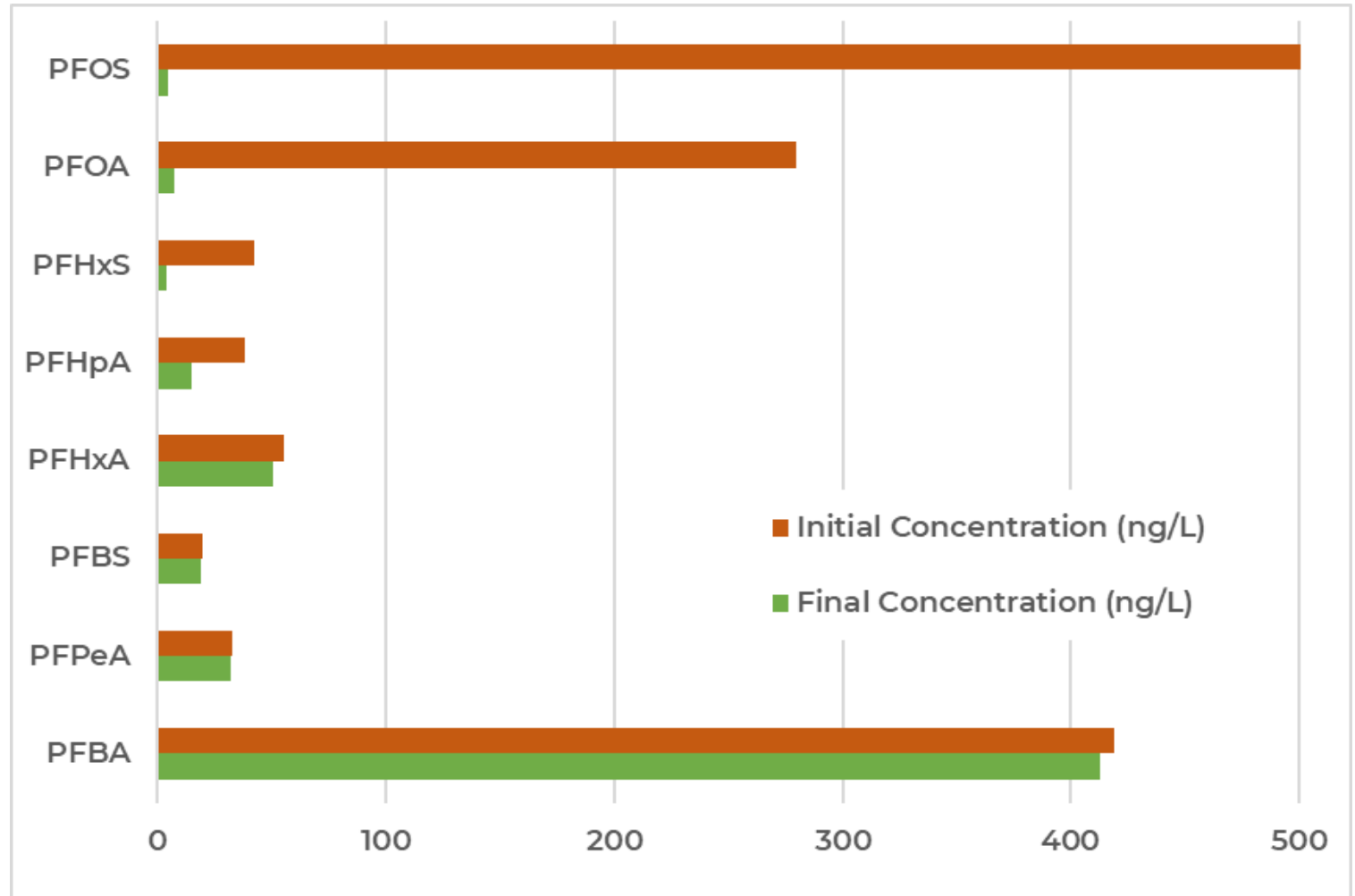
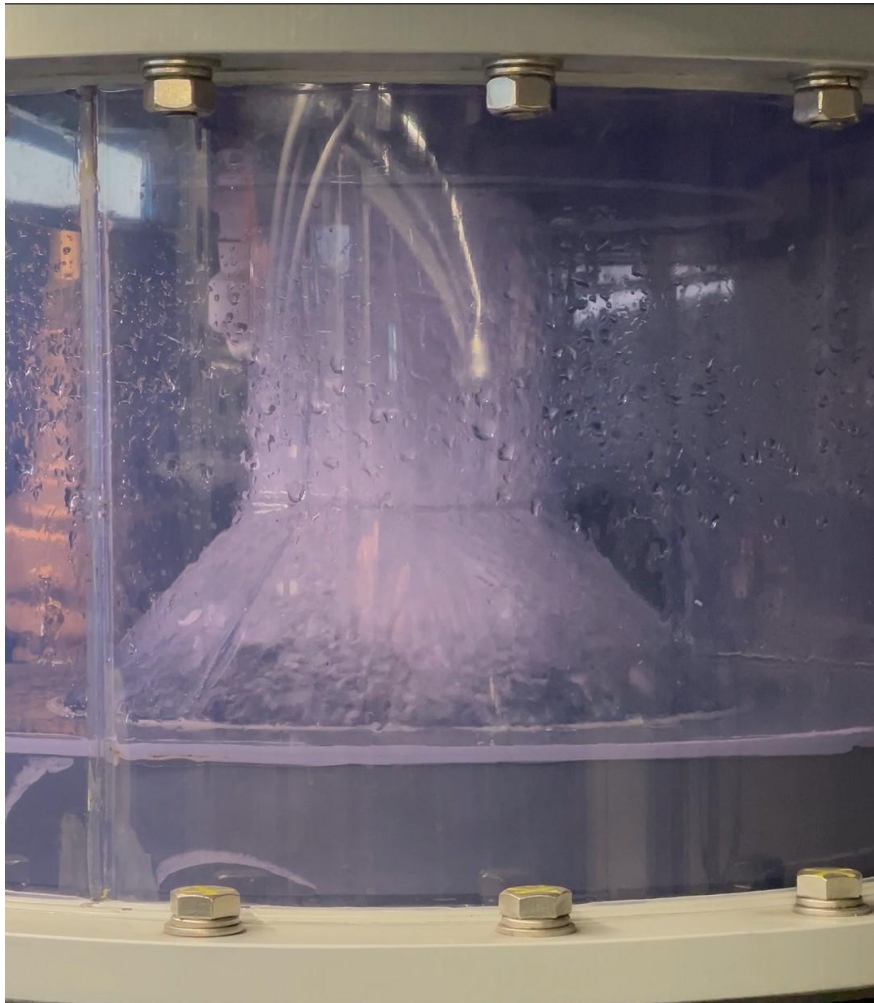
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US SAFF® Groundwater Treatment with Destruction, Minnesota

- Fall 2022, operating at Lake Elmo, MN operated by Minnesota Pollution Control Agency and EPOC Enviro
- Successful treatment of non-foaming water, without use of SAFFactant additive
- Now treating surface water with similar PFAS, which is foaming
- Concentrate is generated and stored onsite for later destruction



US SAFF[®] Groundwater Treatment with Destruction, Minnesota



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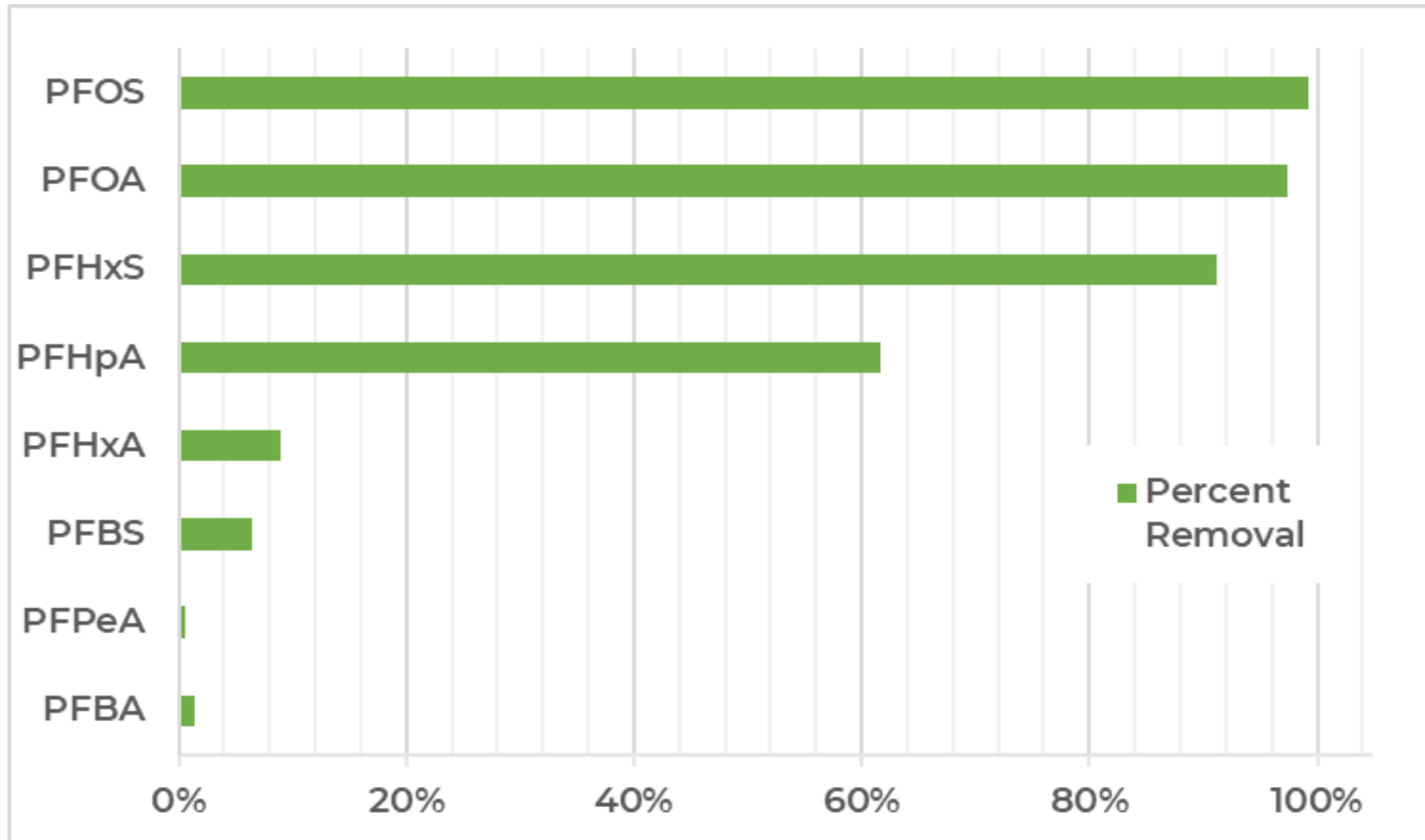
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US SAFF[®] Groundwater Treatment with Destruction, Minnesota



US SAFF® Groundwater Treatment Using Additive for Enhanced Stripping

- Summer 2022 in the Northeast US with CDM Smith and EPOC Enviro
- Full scale demonstration additive removed to 10 ug/L
- Water did not foam, moderate treatment demonstrated without additive, great treatment demonstrated with additive
- Concentration factor: 90,000x



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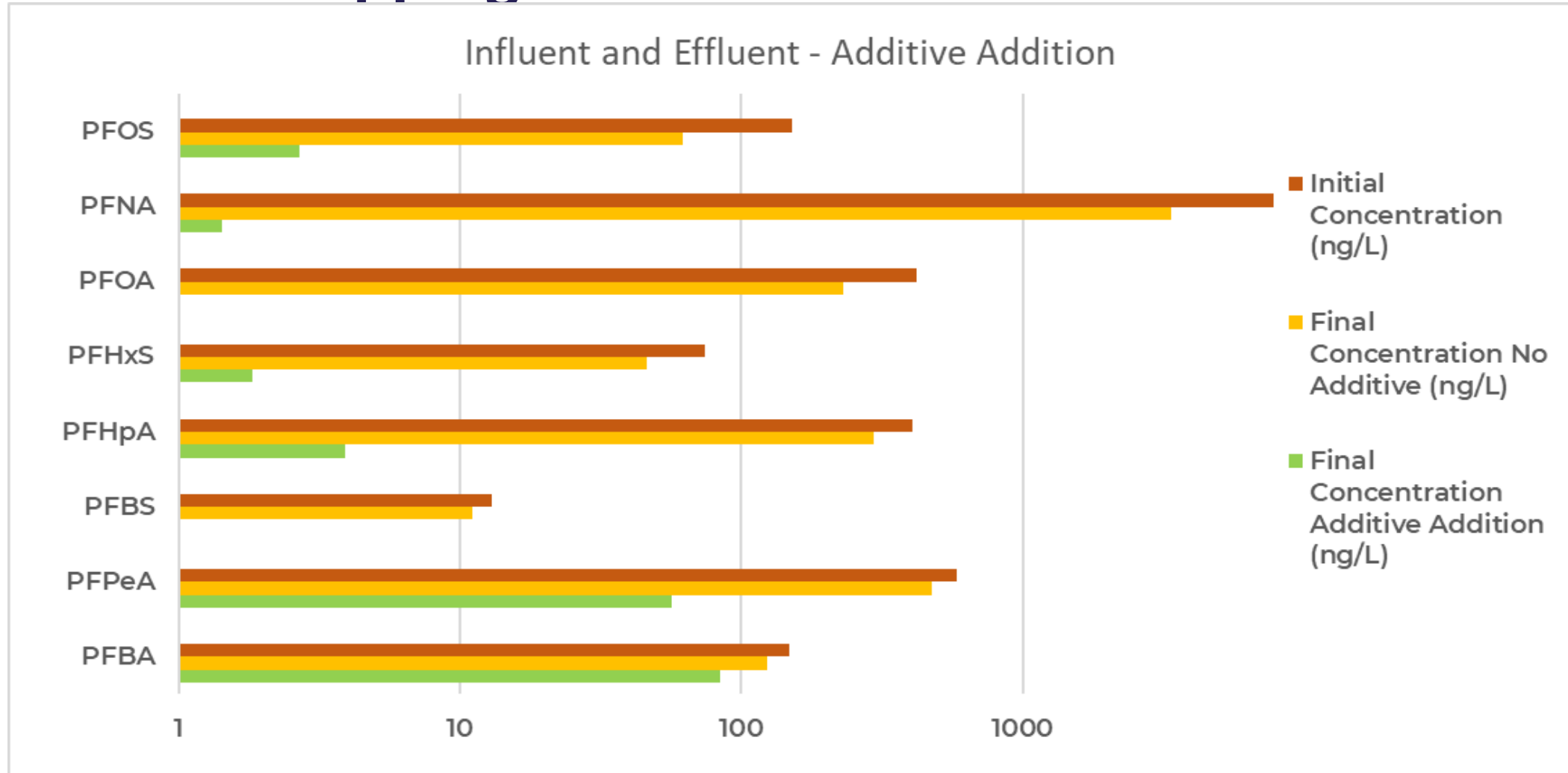
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US SAFF® Groundwater Treatment Using Additive for Enhanced Stripping





The Closed Loop PFAS Solution

Combining SAFF® and PFAS Annihilator™

<https://www.crystal-clean.com/renewable-solution/pfas-solution-4never/>



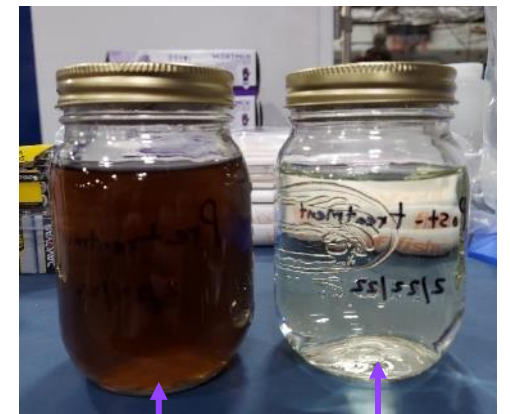
Field Deployments of 4never Technology

- **Revive Environmental's Annihilator on-site destruction solution powered by supercritical water oxidation (SCWO)**
 - Primary unit processes 350 to 500 gallons per day.
- **Recent Field Demonstration (February/March 2022)**
 - PFAS in at mg/L scale -> PFAS out <10 ng/L.
 - Part per million concentrations of VOCs and SVOCs also destroyed to non-detect levels.
- **Hands-off, turnkey solution with a hub and spoke model**
 - “hub” located in Grand Rapids MI, with shipping network set up to transport SAFF concentrate to Annihilator for disposal, all labor provided



Landfill Leachate

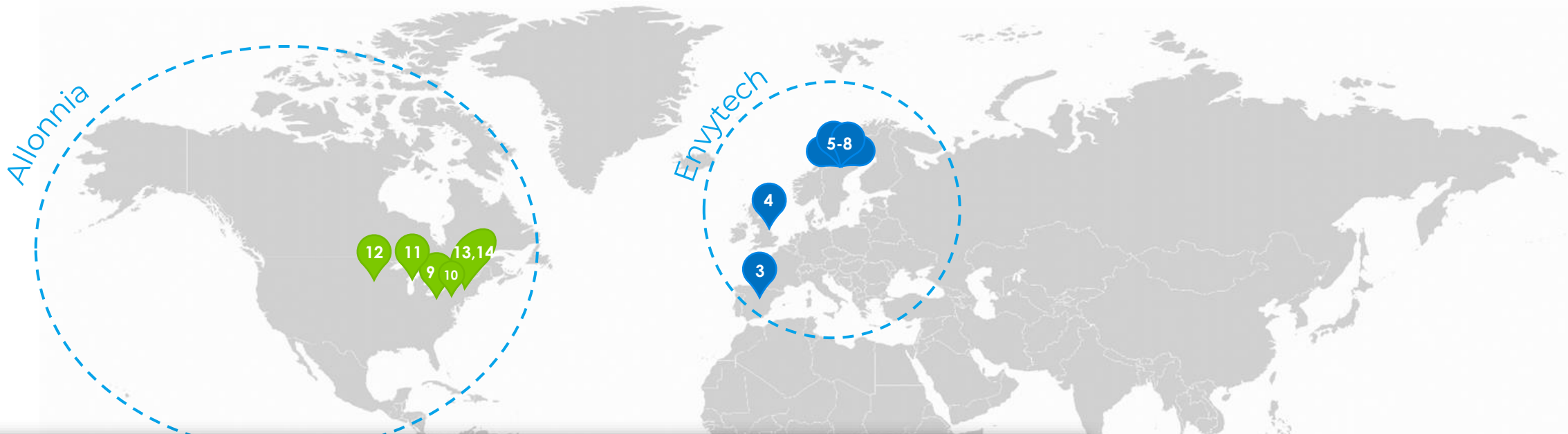
Annihilator™-treated Landfill Leachate



Industrial Wastewater

Annihilator™ treated Wastewater





- 1. Queensland, Australia
- 2. New South Wales, Australia
- 3. Confidential Site, Spain
- 4. Confidential Site, UK
- 5. Helsingborg, Sweden
- 6. Brottby, Sweden
- 7. Stockholm, Sweden
- 8. Stockholm, Sweden
- 9. Confidential Site, East Coast USA
- 10. Massachusetts, USA
- 11. Michigan, East Coast USA
- 12. Minnesota, USA
- 13. Vermont, USA
- 14. Maine, USA

UPCOMING DoD Funded Projects at

- Beale AFB, CA (SAFF + HALT Destruction)
- March ARB, CA (SAFF + UX Destruction)
- Hanscom AFB, MA (SAFF + DE-FLUORO)
- Wurtsmith AFB (SAFF + Annihilator)
- Confidential DoD Site (SAFF + Biosensor)





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MISSION
SUCCESS
STARTS
HERE
SAMEJETC.ORG

MAY
2-4
2023

San Antonio,
TEXAS



THANK YOU

- Zach Pierce, zpierce@allonnia.com
- Rob Rappold, rrappold@allonnia.com
- Bob Sinkler, rsinkler@allonnia.com

SAFF[®]: Sustainable PFAS Treatment

PERFORMANCE



- Removes >99.9% PFOS/PFOA (below detection limits)
- Proven full-scale, global technology
- Working range: 0.005 – 50,000 ug/l PFAS
- Daily treatment capacity: Over 120-150 gpm per unit

VALUE



- Lowest cost per treated gallon
- Lowest cost per mass of PFAS removed
- Automated system with remote telemetry control – minimal labor
- Energy efficient: estimated rate of 2.5kw/ 1,000 gallon treated

WASTE REDUCTION



- No adsorbent media required
- Can achieve concentration factors >10,000:1
- PFAS concentrate suitable for onsite destruction
- Closed loop with onsite destruction

SUSTAINABILITY



- Suitable for ISO-18504 (2017) Sustainable Remediation rating
- Green chemistry and sustainable engineering design
- Modular systems produced using agile manufacturing
- Minimal consumables



OPEX Costs for Removing PFAS from Telge Landfill Leachate

FIRST 5 MONTHS OPEX DATA

- 1 Labor**
USD \$0.05/m³ (treated)
- 2 Consumables**
Zero
- 3 Energy**
USD \$0.05/m³ (treated)
- 4 Waste**
USD \$0.02/m³ (treated)



