Comprehensive PFAS Treatment: Separate/Concentrate/Destroy

May 3, 2023, 4:00 p.m.

Comprehensive PFAS Treatment: Separate / Concentrate / Destroy

Moderator: Rhonda Hampton, P.E., ECT2

Speakers:

- Hunter Anderson, Ph.D, PFAS Subject Matter Specialist, AFCEC/CZTE
- David Kempisty, Ph.D, P.E., Director, Emerging Contaminants, ECT2/Montrose
- Brian Pinkard, Ph.D, P.E., CTO, Aquagga, Inc.

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Hunter's Fun Facts

- From the Oklahoma plains… decedent of homesteaders from the land runs
- Survived two tornadoes!

SPEAKER

Dave's Fun Facts

- Knows the majority of the 1984 Detroit Tigers' lineup only because he continues to wait & hope for their next championship season.
- Edited two books – on PFAS!
- Has completed a marathon and has gotten married … on the same day.

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SPEAKER

Brian’s Fun Facts

- Seattle Mariners fan for many disappointing years
- First time visiting Texas
- Hobbies: rock climbing, skiing, backpacking, running… anything active & outside

Challenges for the DoD

Dr. Hunter Anderson
AFCEC/CZTE

Challenges for the DoD

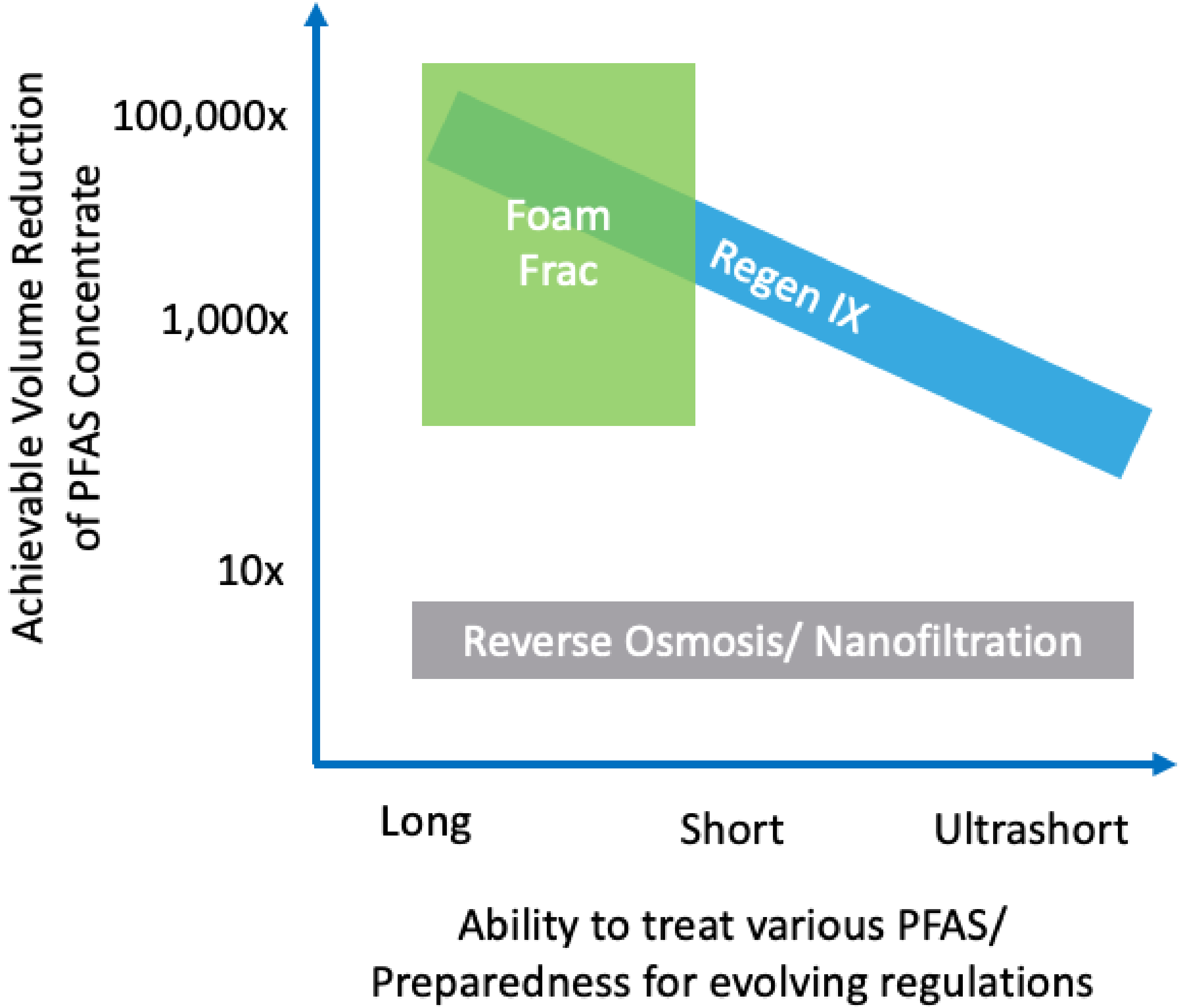
- **How "dirty" is "dirty"**
  - Thousands of AFFF-impacted source areas: when is remediation required?
  - Novel retention mechanisms
  - Background contamination from decades of atmospheric deposition
- **How "clean" is "clean"**
  - What are realistic performance objectives for treatment systems
  - Legal discharge requirements are highly variable
  - Long- vs short-chain treatment efficiencies
- **Desire for destructive technologies**
  - What premium are we willing to pay for destruction?
  - Mobile (on-site) vs regional (hub and spoke) capabilities

Separate – Concentrate - Destroy

Separate and Concentrate: Preparedness for Destruction

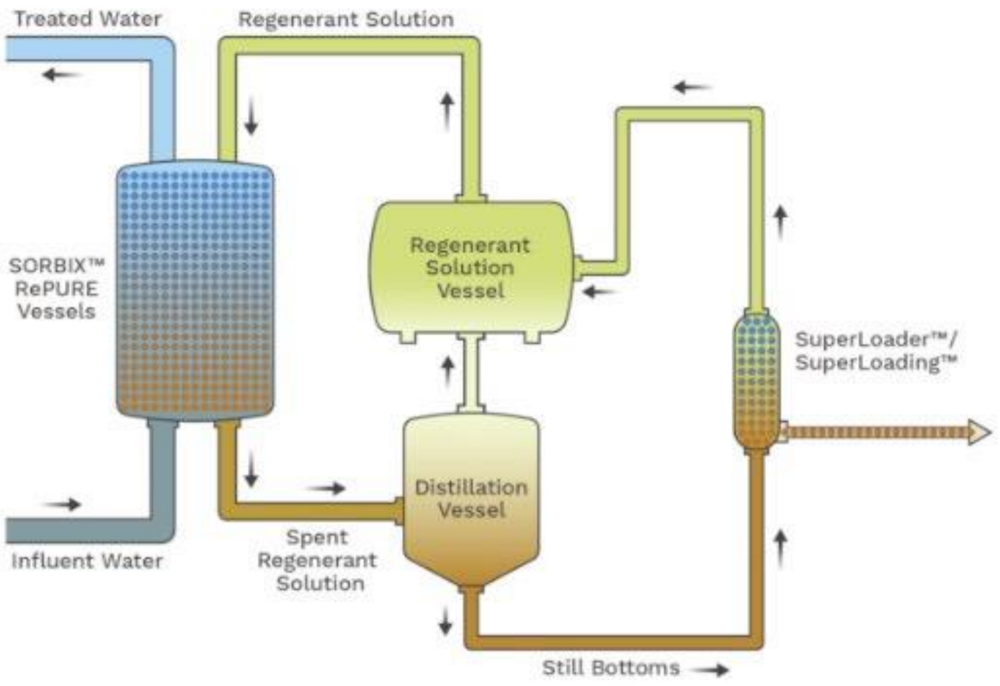
Tomorrow's destructive technologies require a volume reduction and concentration step

- FF and RIEX
- Membranes



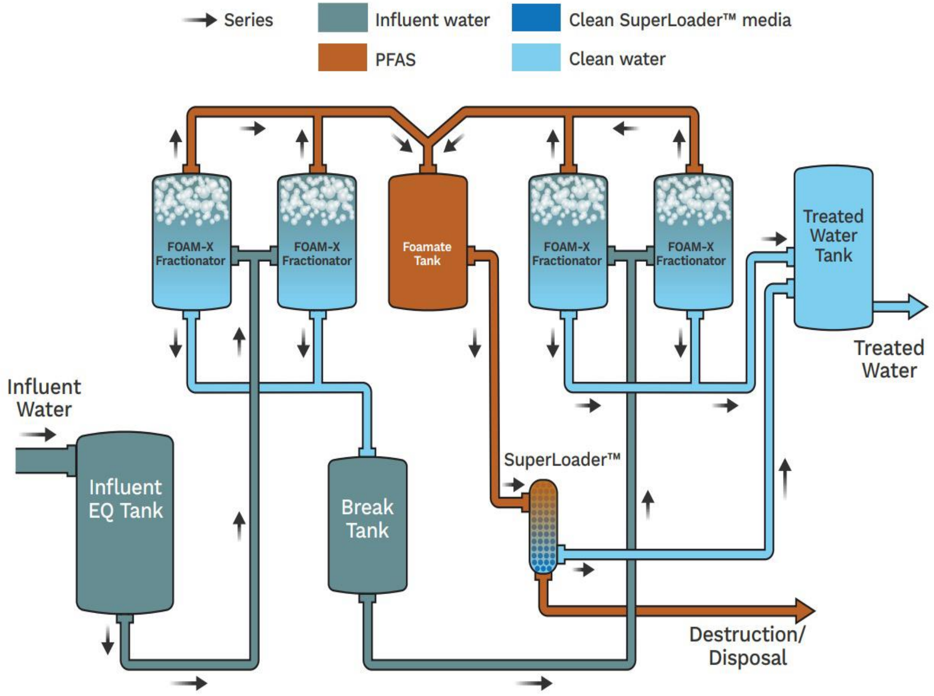
Separate and Concentrate – Two Technologies

Regenerable Ion Exchange Resin



- Effective
- Future Proof
- Waste Minimization
- Future Proof
- Hub and Spoke

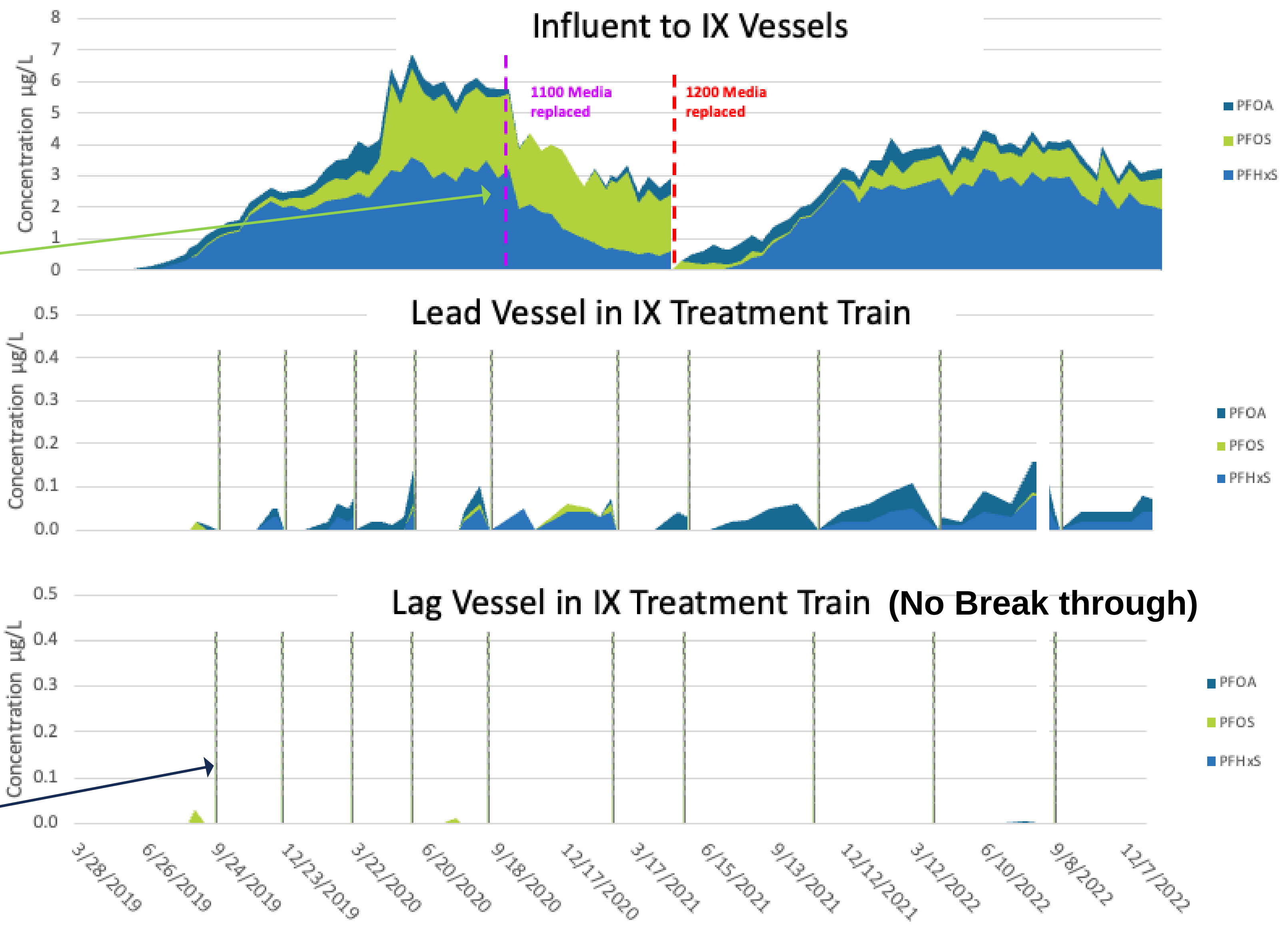
Foam Fractionation



- Simple
- Low cost
- Avoided Pre-treatment
- Additives
- Short Chain Challenges
- Off-ramp to destruction

Separate & Concentrate – Data Regenerable IX Resin

Dashed lines indicate pre-treatment media replaced



Across 4+ years of regeneration cycles, the IX resin continues to achieve PFAS treatment objectives

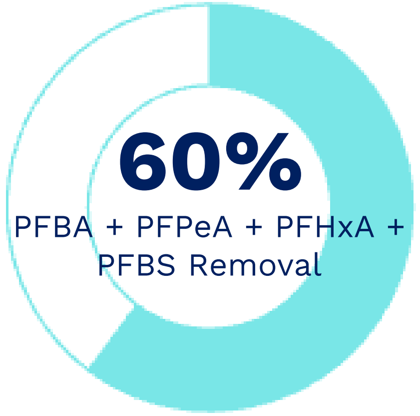
No IX Resin Disposed in Landfills

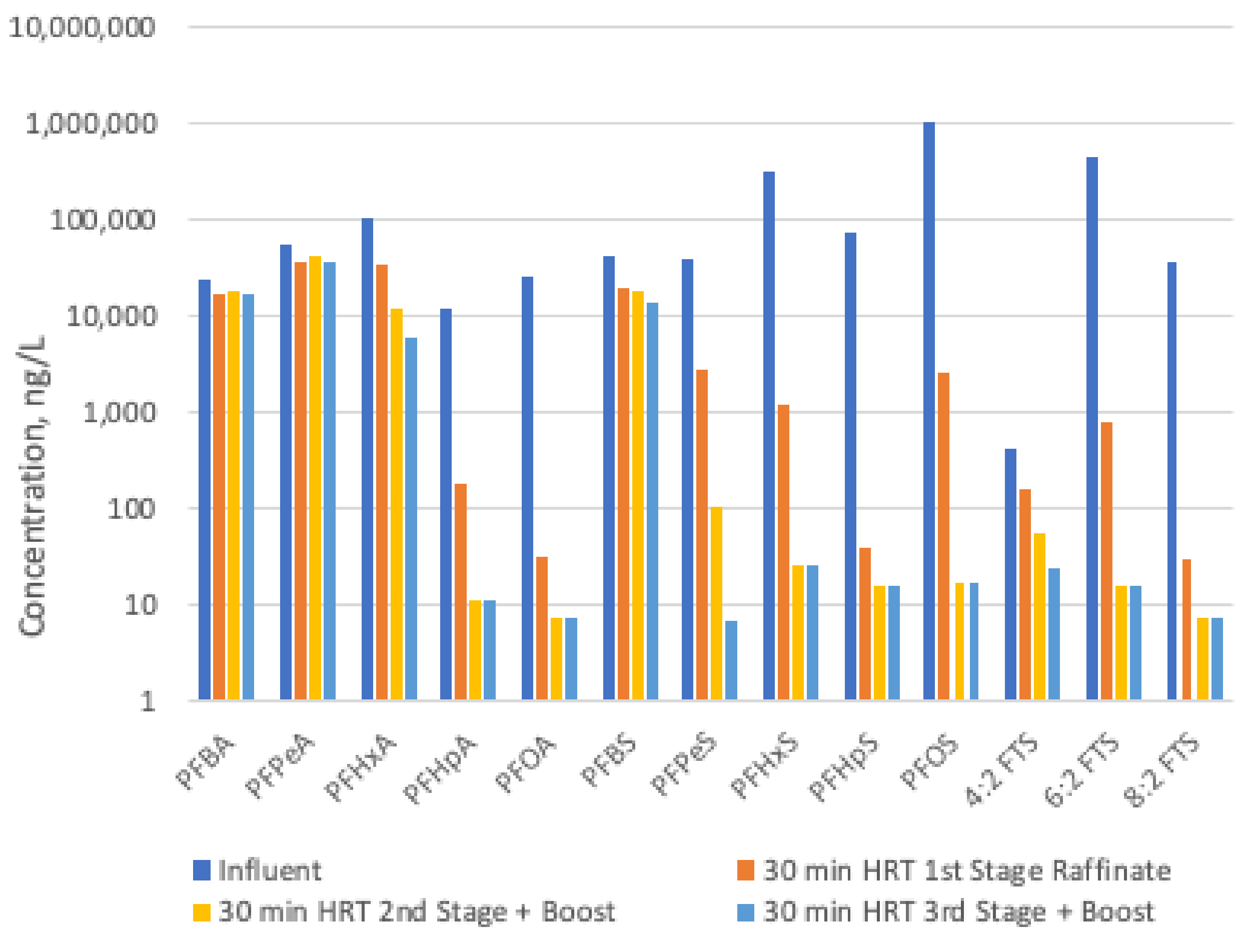
** Actual site performance*

Vertical lines indicate resin regeneration in lead vessel

Separate & Concentrate – Data
Foam Fractionation

FF Results Only
2 Stage; 30 min HRT

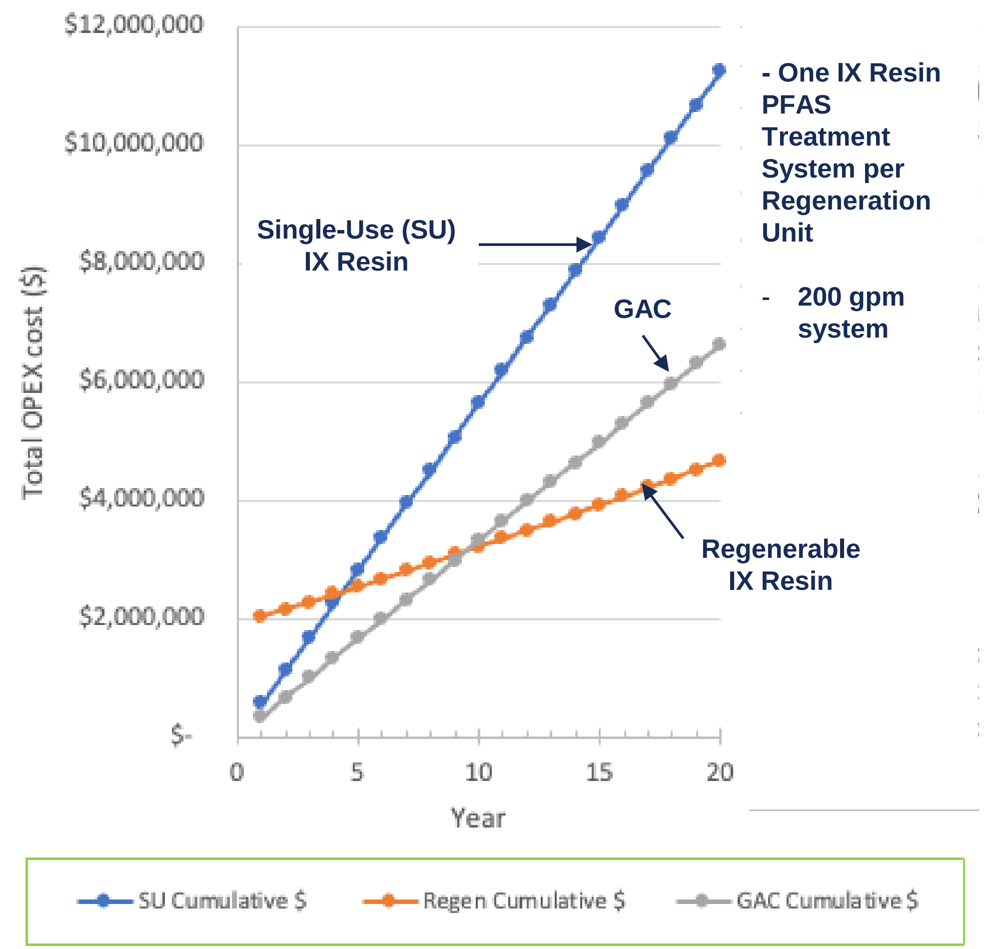




HRT: Resonance time

- **FF effectively removed mg/L concentrations to ng/L**
- **One FF Stage removed PFOS/PFOA ~ 3 OOM**
- **97%+ total PFAS removed**
- **60 min singe stage HRT saw small improvement vs 30 min HRT**
- **3rd FF stage only saw slight improvement**
- **Foamate for destruction: 58 mg/L TOT PFAS**

Separate & Concentrate – Economics Regeneration of IX Resin



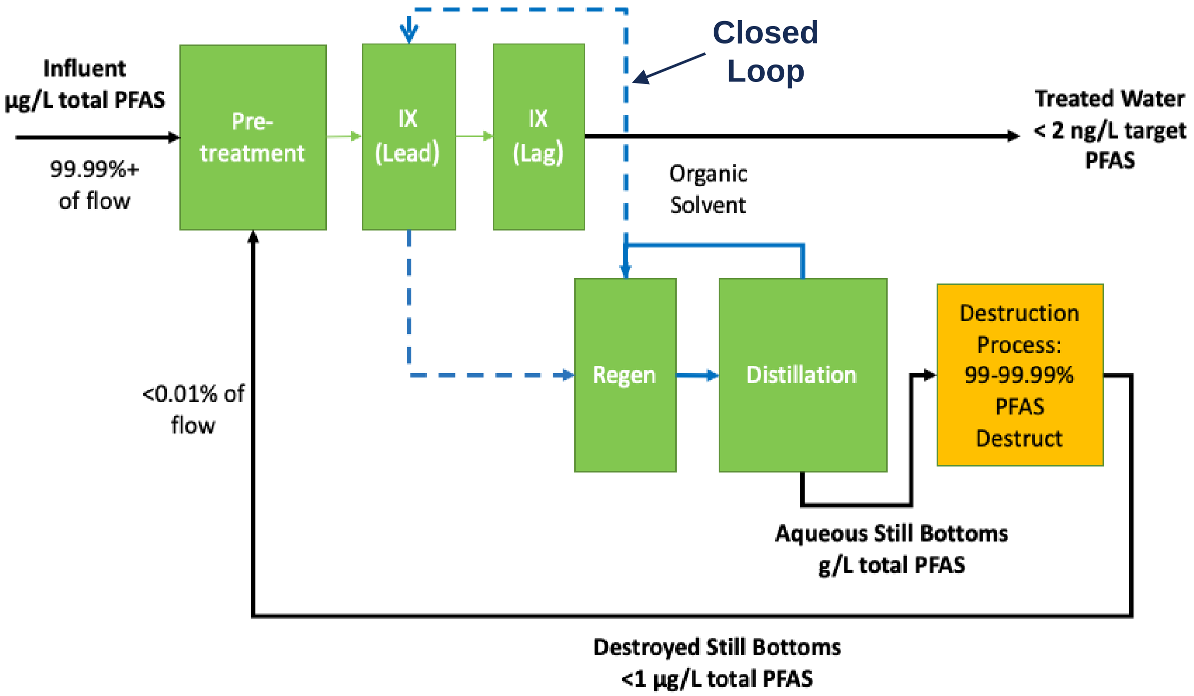
Optimized Return on Investment:

(by # of IX systems per Regeneration plant)

- **1 system per regen plant: ROI ~ 4 years**
- **2 systems per regen plant: ROI ~ 2 years**
- **3 systems per regen plant: ROI ~ 1.5 years**

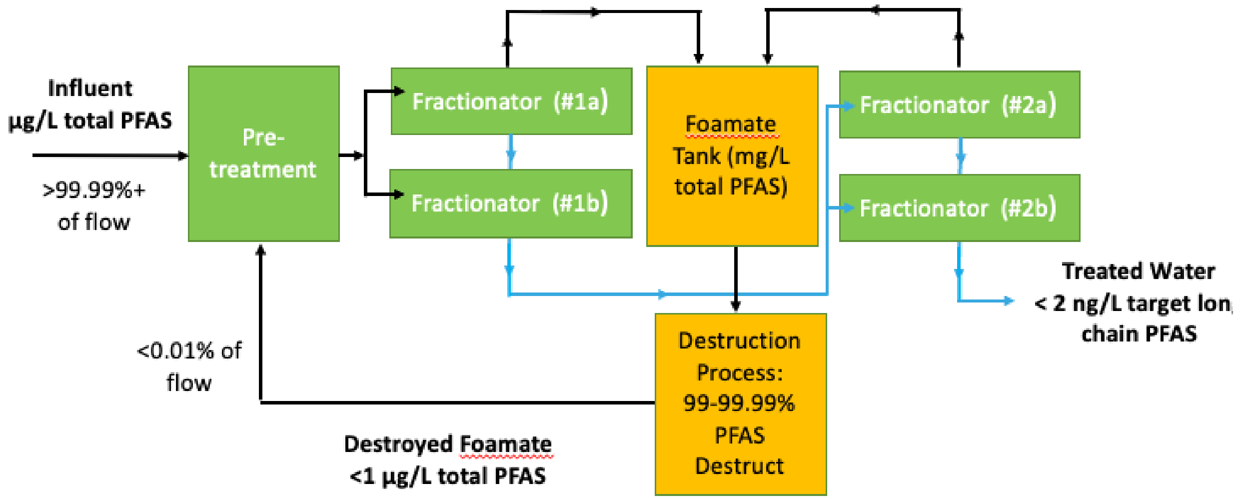
Regeneration of IX Resin provides concentration of PFAS 500,000:1 for destruction… and is also cost-effective long term vs. other options and is future-proof

Separate, Concentrate, Destroy – Closed Loop Processes



Regeneration of IX Resin

Two Complete Closed-loop PFAS Treatment Schematics to Concentrate PFAS



Foam Fractionation

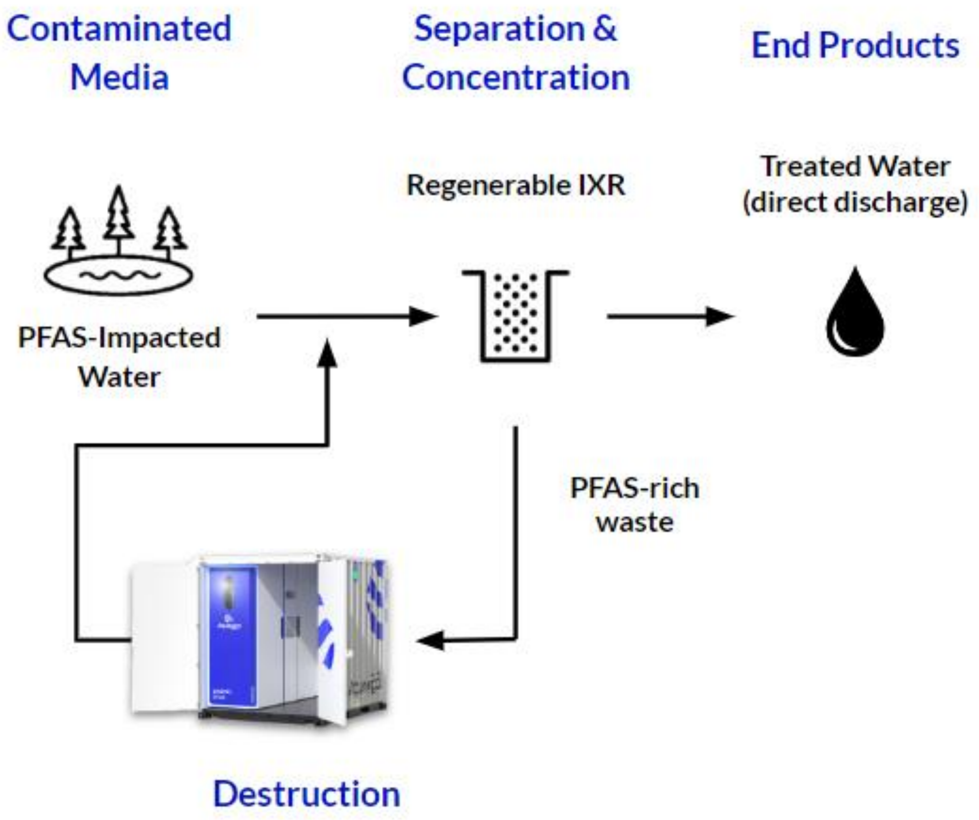
Hydrothermal Alkaline Treatment (HALT) for PFAS Destruction

Hydrothermal Alkaline Treatment

- PFAS Destruction technology
- Rapid treatment time (minutes)
- Leverages liquid water at high temperature, high pressure, high pH
- Effective for **complete mineralization** of **all PFAS**
- Commercial units currently being fabricated and available for field demonstrations

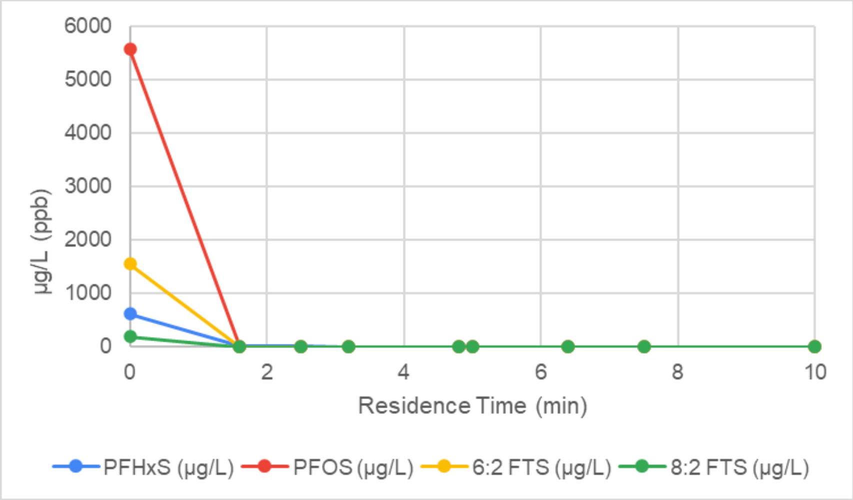
Integrating PFAS Destruction Technology

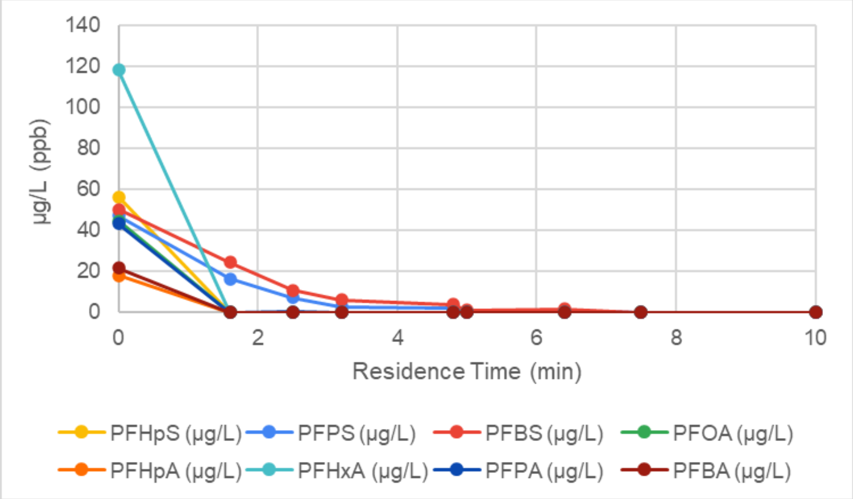
- Example: Regenerable IXR with HALT
  - Use IXR to remove PFAS from contaminated liquid and produce concentrated liquid waste stream
  - Use HALT to reduce PFAS levels in concentrate by ~99.99%
  - Blend HALT effluent into IXR influent to capture residual PFAS
  - Keep PFAS in the loop
- Same strategy for foam fractionation with HALT



HALT of Fire Training Pit Water

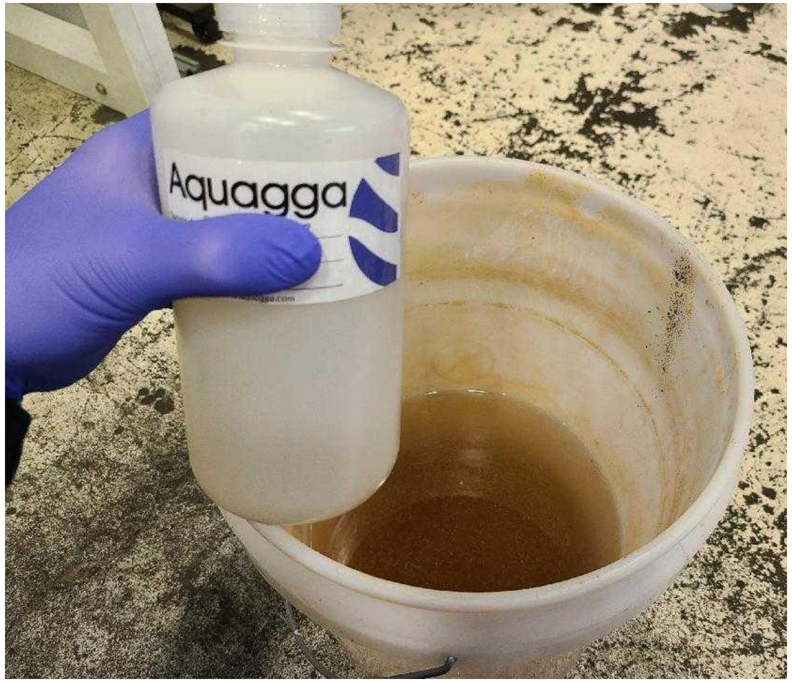
- >99.9% total PFAS reduction within 10 minutes of processing through continuous HALT system
  - PFOS reduction by >99.99%
  - PFHxS reduction by 99.77%
  - PFBS reduction by 99.67%
  - PFOA reduction by 99.997%
  - PFHxA reduction by 99.97%
  - PFBA reduction by 99.94%
- System performance characterized as function of residence time
- Pinkard et al., 2023. *Chemosphere 314*





HALT of Foam Fractionate (Vendor 1)

Analyte	Foamate (ppb)	HALT Effluent (ppb)	Destruction %
PFOS	**2,119**	**5.08**	**99.76%**
PFHpS	66.5	0.0342	99.95%
PFHxS	751	0.261	99.97%
PFPeS	81.8	0.0861	99.89%
PFBS	48	0.291	99.39%
PFOA	**59.6**	**0.200**	**99.66%**
PFHpA	64.2	ND	>99.99%
PFHxA	145	0.0105	99.99%
PFPeA	37.8	0.0144	99.96%
PFBA	14.6	0.0392	99.73%
6:2 FTS	999	ND	>99.999%
Total PFAS	**4,386**	**6.016**	**99.86%**



HALT of Foam Fractionate (Vendor 2)

Analyte	Foamate (ppb)	HALT Effluent (ppb)	Destruction %
PFOS	**36,400**	**10.9**	**99.97%**
PFHpS	522	0.199	99.96%
PFHxS	6,260	3.34	99.95%
PFPeS	1,160	1.09	99.91%
PFBS	552	1.58	99.71%
PFOA	**484**	**0.047**	**99.99%**
PFHpA	334	ND	>99.993%
PFHxA	2,540	ND	>99.999%
PFPeA	196	ND	>99.98%
6:2 FTS	8,800	ND	>99.999%
Total PFAS	**58,280**	**17.16**	**99.97%**

PFAS Destruction Technology Comparison

	Hydrothermal Alkaline Treatment	Supercritical Water Oxidation	Electrochemical Oxidation	UV-Sulfite
Advantages	Ability to handle salts, moderate T & P	Can valorize fuel value to heat process	Low temperature, low pressure process	Low temperature, low pressure process
Disadvantages	Chemical usage	Cannot handle high TDS levels	Perchlorate formation, electrode fouling	Visible light must pass through matrix
PFAS Destruction Performance	Ability to mineralize **all PFAS**	Ability to mineralize **all PFAS**	Good with long-chains, poor with short-chains	Good with carboxylic acids, poor with sulfonic acids
Energy Consumption	Moderate	High	High	Moderate
Ability to Treat IXR Still Bottoms?	Yes - demonstrated	No, challenges with high TDS	No, challenges with perchlorate formation & short-chain PFAS	Currently in testing
Ability to Treat Foam Fractionate?	Yes - demonstrated	Currently in testing	No, challenges with electrode fouling	No, challenges with matrix complexity

Q&A

- Hunter Anderson, richard.anderson.55@us.af.mil
- David Kempisty, dakempisty@ect2.com
- Brian Pinkard, brian@aquagga.com

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