

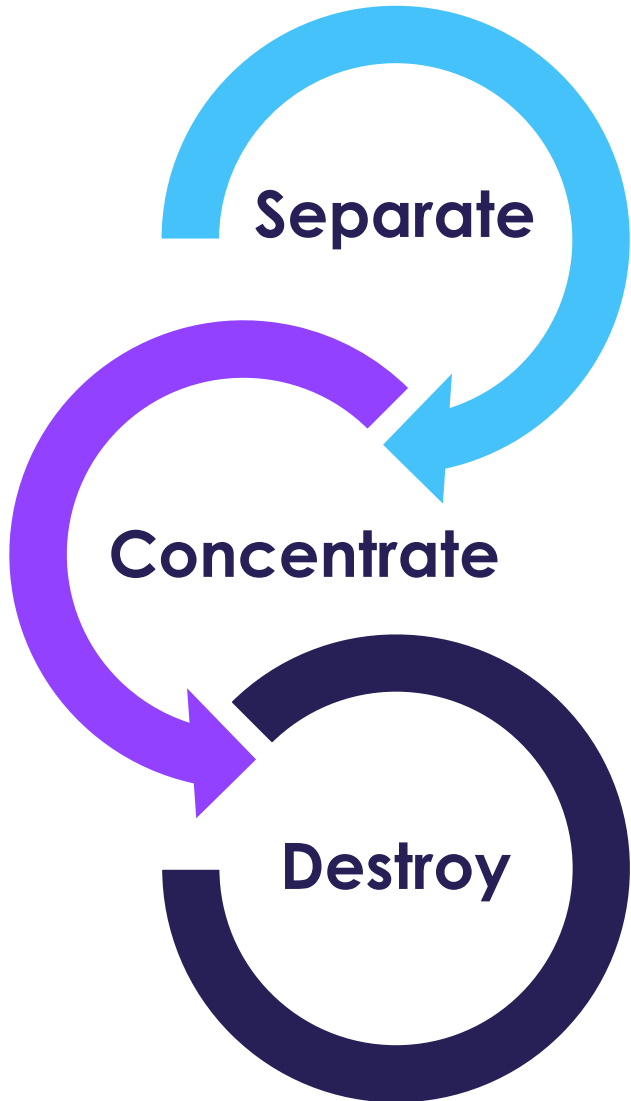
The image features a dark blue background with a repeating pattern of colorful, stylized circular shapes in shades of purple, blue, and green. These shapes are arranged in a grid-like pattern, with some overlapping. The shapes resemble a combination of the letters 'C' and 'S' or similar abstract forms.

allonnia™

Surface Active Foam Fractionation® (SAFF®) Technology

*Closed Loop PFAS Treatment Case Study: Separation,
Concentration, Destruction*

Comprehensive PFAS Treatment Solution



Treatment Goals

Example Treatments

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

- GAC, AIX
- RO
- Foam Fractionation

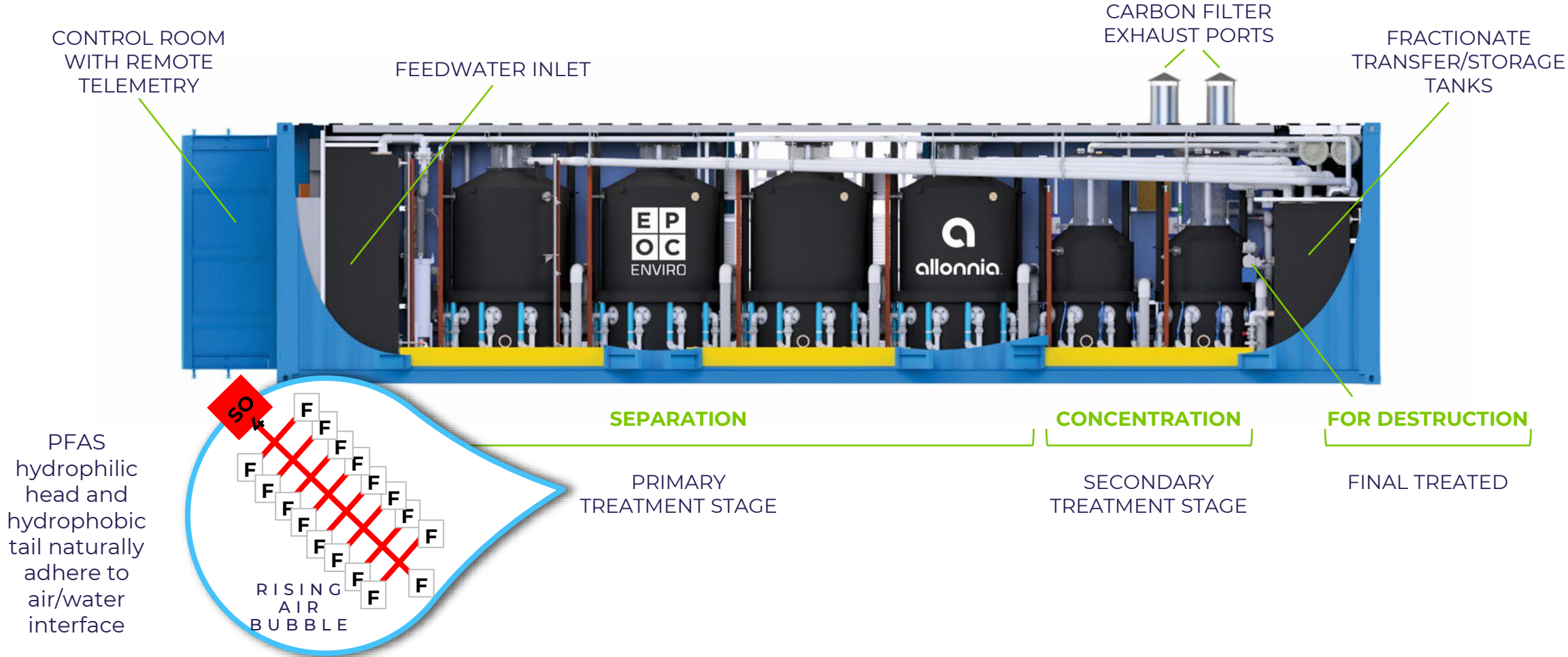
- Reduce waste stream volume

- 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

Concept of Foam Fractionation



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: Up to 100 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

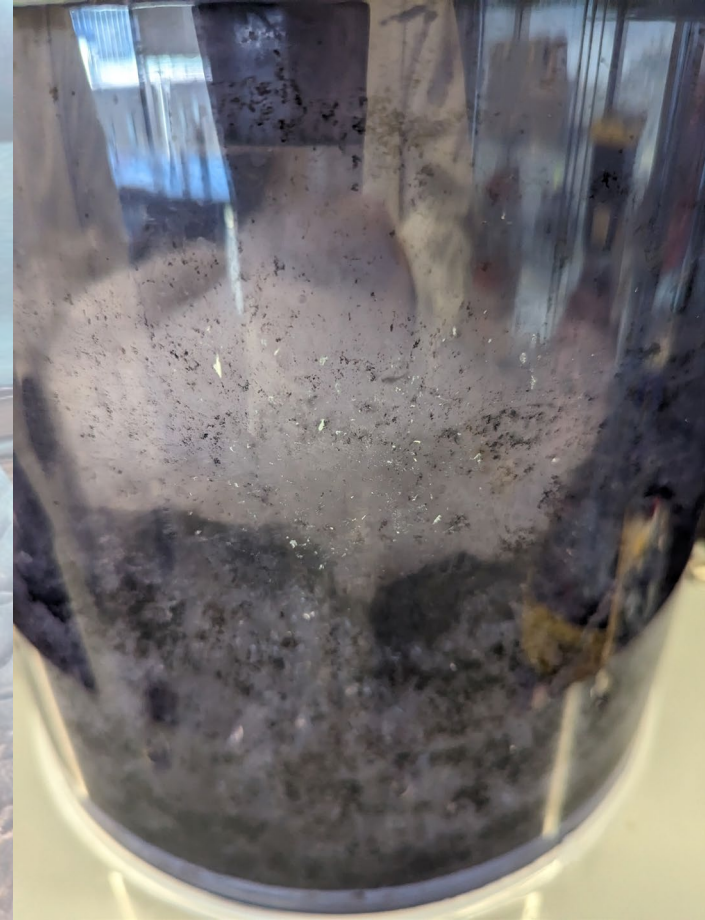
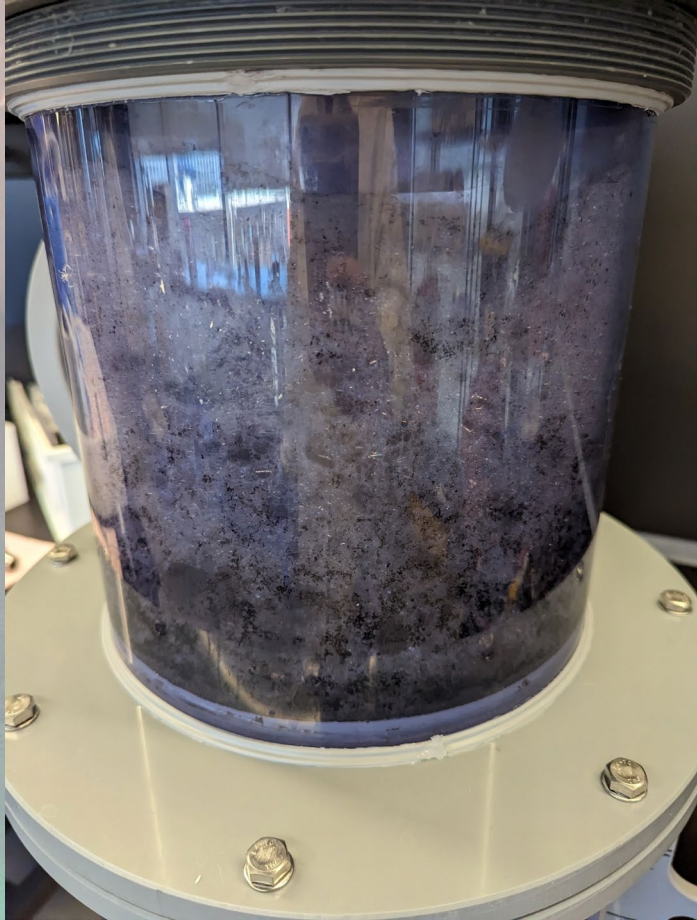


- No adsorbent media required
- Achieves concentration factors >1,000,000:1
- PFAS concentrate suitable for closed loop onsite destruction

SUSTAINABILITY



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



Foam Fractionation Additive Advancements

Allonnia SAFF® Additives: Progress and Benefits

PERFORMANCE



- Improved removal speed and total removal capability for all compounds, but especially short chains
- PFBS removal of up to 95% demonstrated in cleaner matrices, up to 36% without optimization
- Foam fractionation feasible standalone treatment for non-foaming water

VALUE



- New patent pending compounds identified with lower cost than conventional alternative (CTAB)
- Automated dosing system integrated in standard SAFF system
- Faster treatment times and further reduces loading on polishing systems (if applicable)

WASTE REDUCTION



- Compound fully removed during SAFF process without additional treatment needed
- Production of drier, lighter foam may reduce final waste concentrate volume after optimization

SUSTAINABILITY



- Testing for non-toxic alternatives ongoing
- Quantities needed for full scale treatment relatively low, requiring only weekly or biweekly operator intervention and semi-annual or annual restocking onsite

Generate a Closed-Loop Solution

1

SEPARATION

2

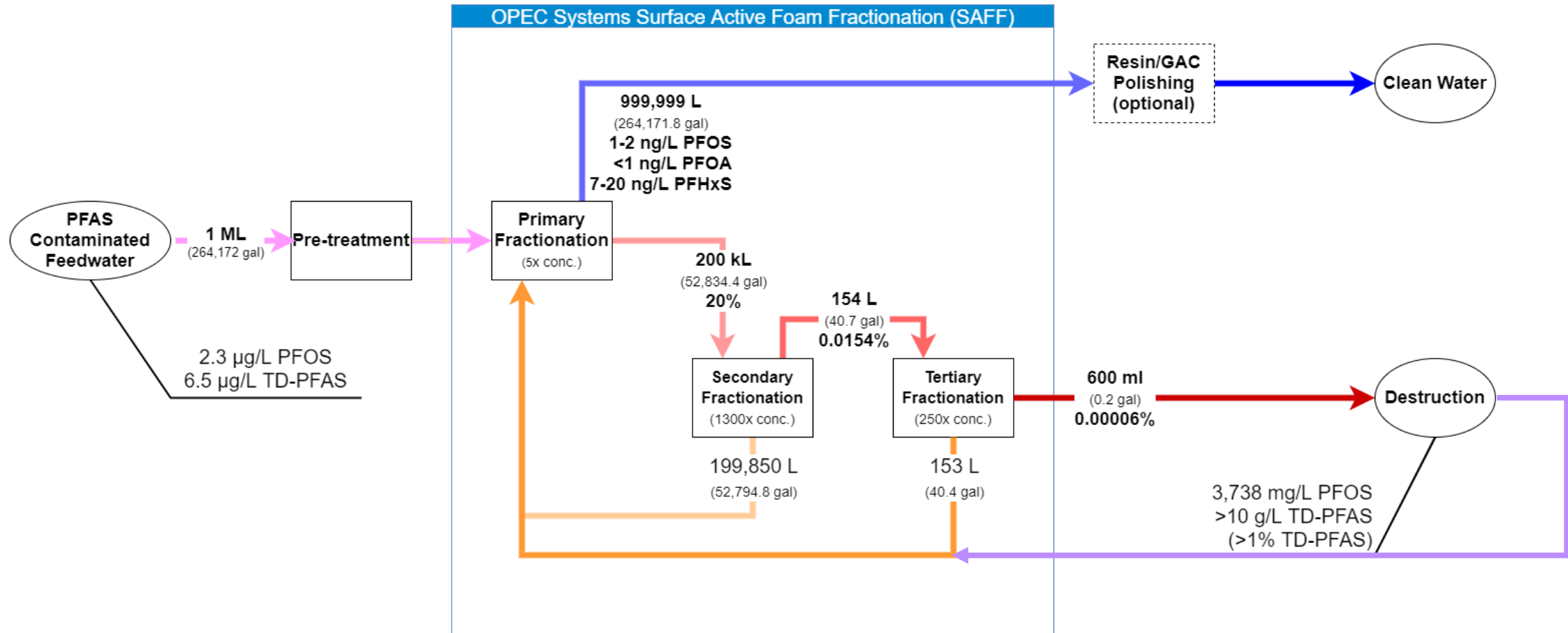
CONCENTRATION

3

DESTROY



SAFF™ Concentration Process



Closed Loop PFAS Treatment in Action

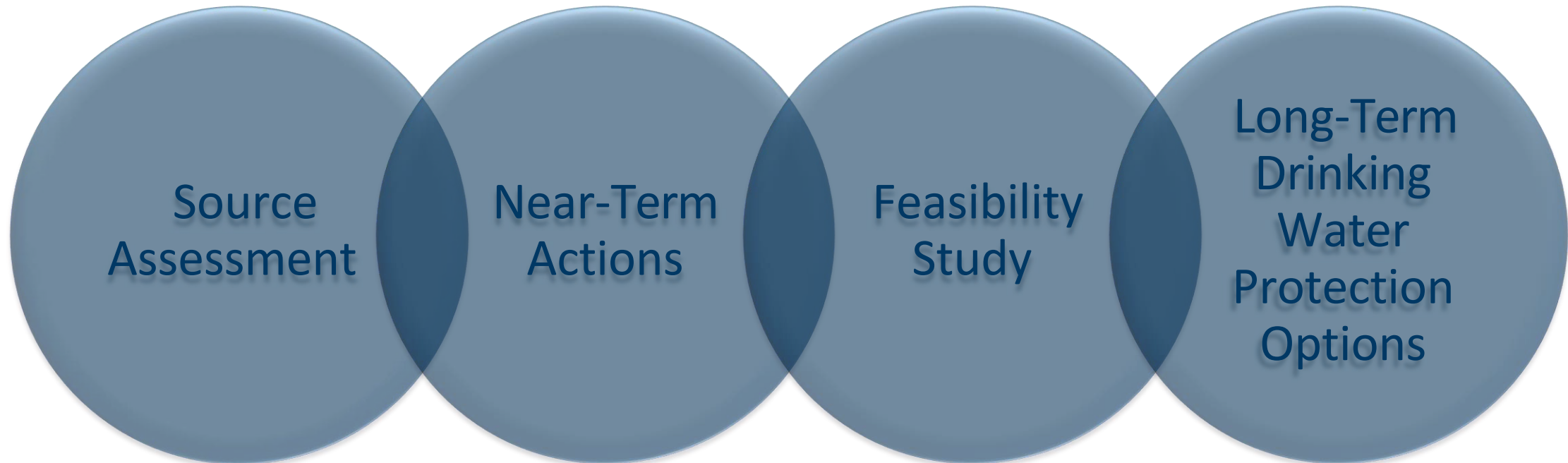
- Full scale combination of SAFF and destruction technology demonstrated in Minnesota



Slides courtesy of Rebecca A. Higgins, PG | MPCA

Project Process and Objectives

“The MPCA shall conduct a source assessment and feasibility study regarding the role of the Valley Branch Water District's project known as Project 1007 in the conveyance of PFCs in the environment.” - 3M Settlement



Effluent PFAS Concentrations in Optimized Method

PFAS Analyte	Influent Concentration (ng/L)	Effluent Concentration (ng/L)	Percent Removal	HBV/HRL (ng/L)
PFBA	372	361	2.96	7,000
PFPeA	24.8	24.4	1.61	
PFHxA	44.3	36.1	18.51	200
PFHpA	33.1	9.49	71.33	
PFOA	281	<0.887	>99.68	35
PFNA	2.12	<0.887	> 58.16	
PFDA	3.62	<0.887	>75.50	
PFuNA	<0.865	<0.887		
PFDoA	<0.865	<0.887		
PFBS	15.4	13.5	12.34	100
PFHxS	34.1	1.62	95.25	47
PFOS	939	2.67	99.72	15

Tuning of Secondary Fractionation

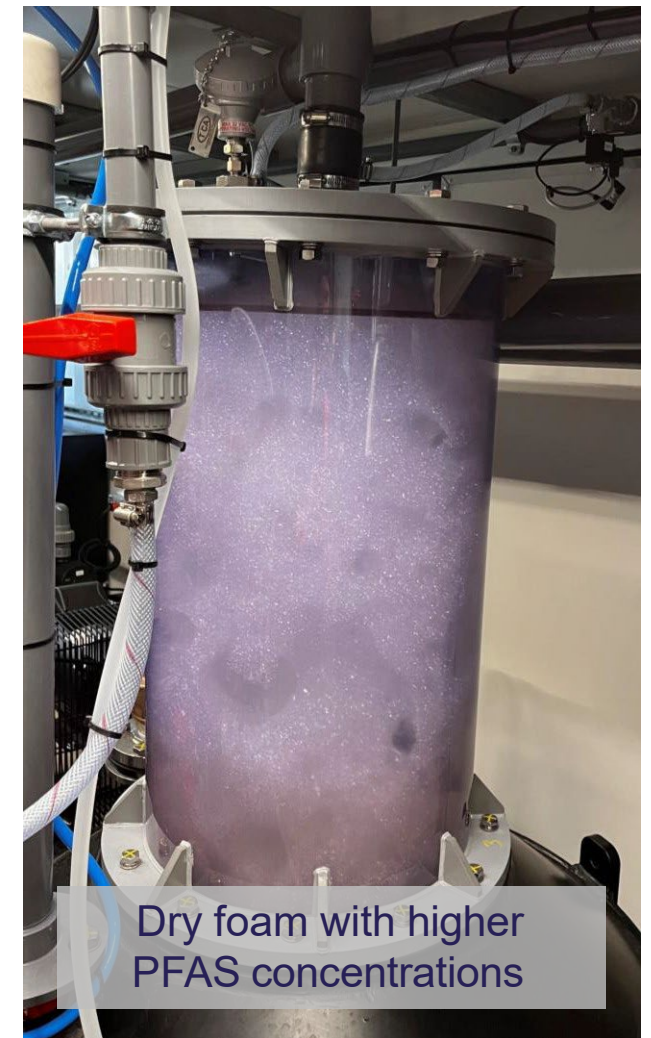
Variables

Primary concentrate
Air flow rate
Length of top-up

Reconcentration is possible

Initial Runs: Highest PFOS concentration: 1.2 mg/L

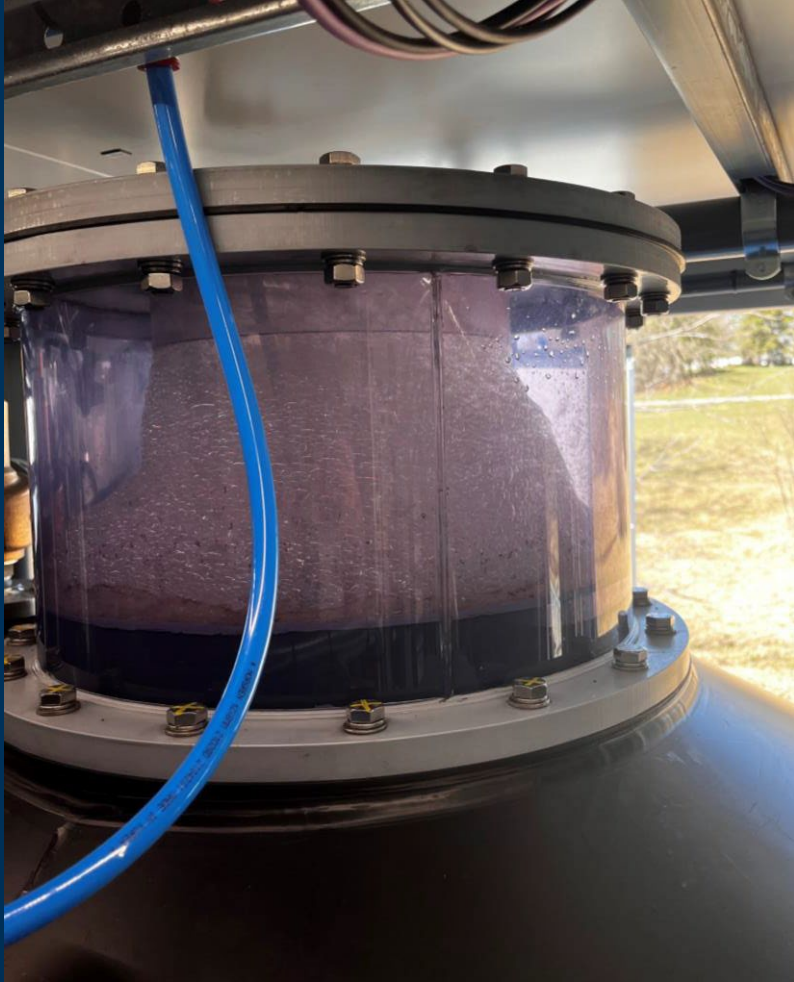
Current Runs: Highest PFOS concentration: 4.5 mg/L



SAFF Phase II: Surface Water



Raleigh Creek: Summary of Results



PFAS Analyte	Influent Concentration (ng/L)	Vessel 1 Effluent Concentration (ng/L)	Vessel 1 Percent Removal	Vessel 2 Effluent Concentration (ng/L)	Vessel 2 Percent Removal	HBV/HRL (ng/L)
PFBA	265	260	1.9	250	5.7	7,000
PFPeA	40.1	37.5	6.5	36.7	8.5	
PFHxA	64.1	60.2	6.1	54.1	15.6	200
PFHpA	75.1	36.4	51.5	20	73.4	
PFOA	543	10	98.2	2.57	99.5	35
PFNA	6.06	ND	ND	ND	ND	
PFDA	7.02	ND	ND	ND	ND	
PFuNA	ND	ND	ND	ND	ND	
PFDoA	ND	ND	ND	ND	ND	
PFBS	24.3	22.2	8.6	21.1	13.2	100
PFHxS	64.5	6.64	89.7	2.05	96.8	47
PFOS	1310	10.8	99.2	3.92	99.7	15

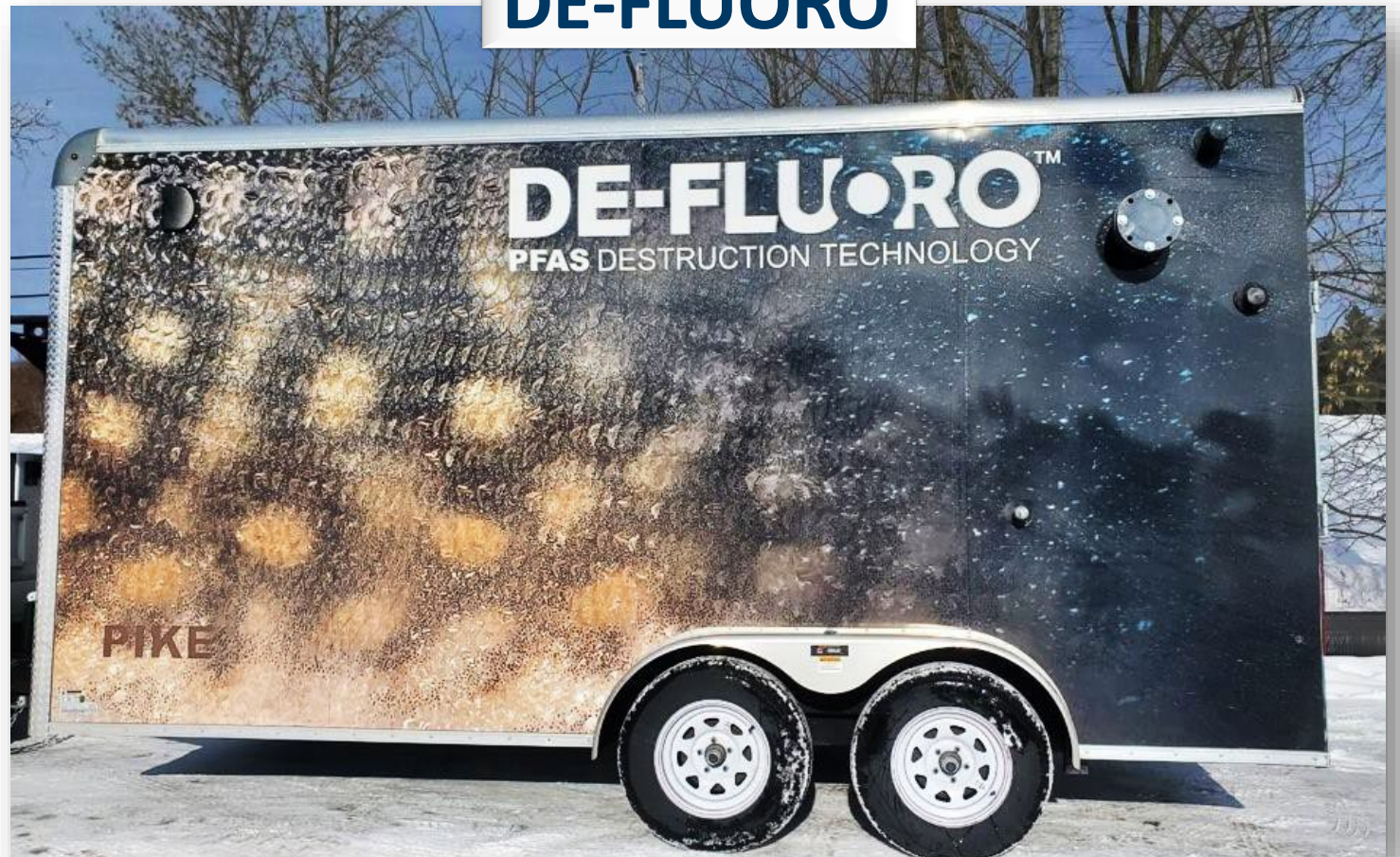
Pilot Study Part 2: Destructive Technology Testing: Electrochemical Oxidation

SAFF



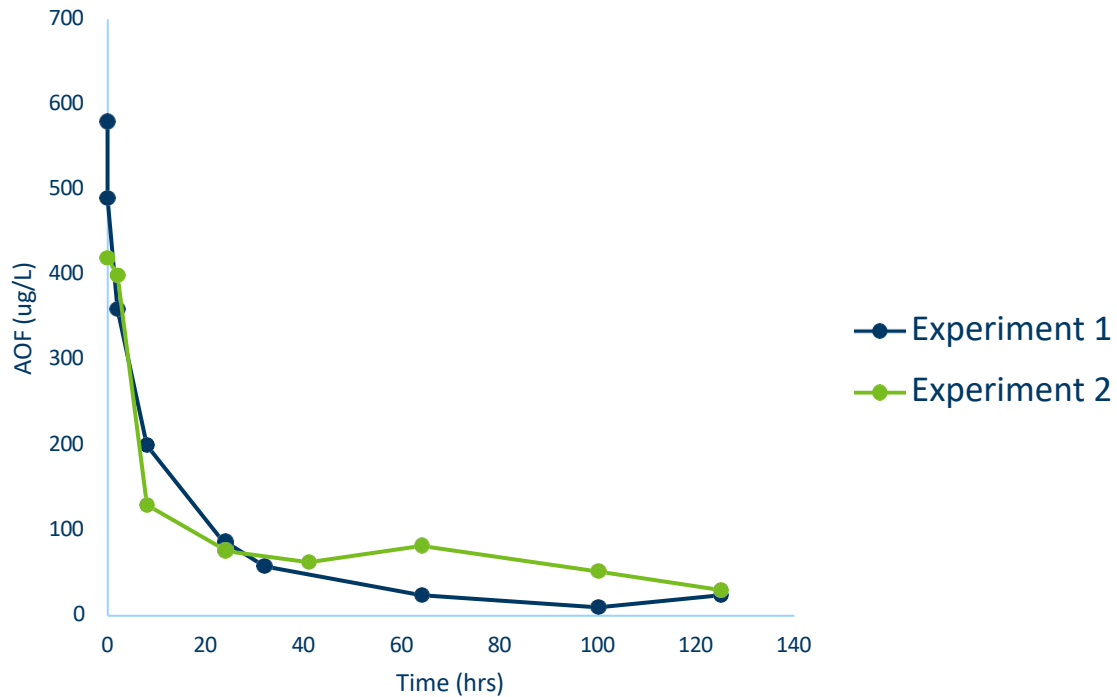
Concentrate from SAFF
sent through
Electrochemical Oxidation
in-field testing

DE-FLUORO



Destruction Pilot Test: DE-FLUORO Groundwater Results

Adsorbable Organofluorine Results

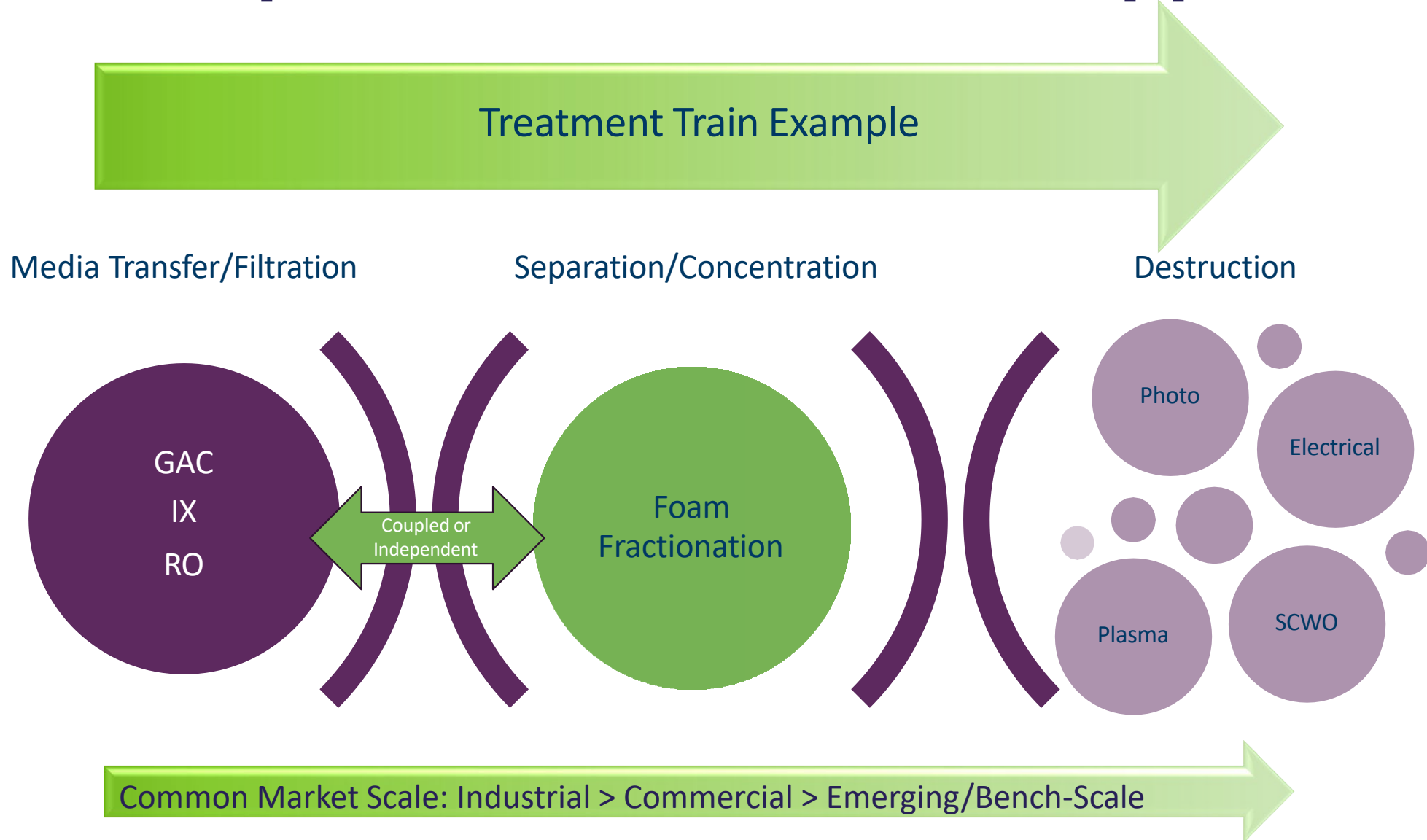


DE-FLUORO technology was used to destroy the PFAS in the SAFF concentrate by electrochemical oxidation

SAFF concentrate from groundwater treatment showed a 98.3% reduction in adsorbable organofluorine

Surface water results are pending

Conceptual Treatment Train Approach





Foam Concentrate Destruction Testing

Aquagga's HALT System

Bench scale hydrothermal alkaline treatment technology used for PFAS destruction in secondary SAFF concentrate. PFASs mineralized to primarily NaF salts and CO₂ byproduct under very high pH, subcritical temperature and pressure.

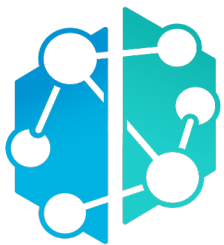
- Total Starting PFAS (only major constituents listed):
 - 879 ppb total PFAS (349 ppb PFOS, other compounds in the 10-200 ppb range)
- HALT Treated Effluent:
 - 7.08 ppb (3.96 ppb PFOS, ND on all PFCAs and FTSs, balance is single digit ppb PFASs)
 - Most PFOS in this case study effluent likely cross contamination resulting from previous study treating >mg/L concentrations

Total PFAS destruction is >99%

Field scale commercial units may operate around 200-500 gpd depending on influent conditions

Field Deployments of 4never Technology Partnership

- **Revive Environmental's Annihilator on-site destruction solution case study: supercritical water oxidation (SCWO)**
 - Primary unit processes 350 to 500 gallons per day.
 - 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 destruction vendor partner for disposal, all labor provided



4never



Landfill Leachate

Annihilator™-treated Landfill Leachate



Industrial Wastewater

Annihilator™ treated Wastewater

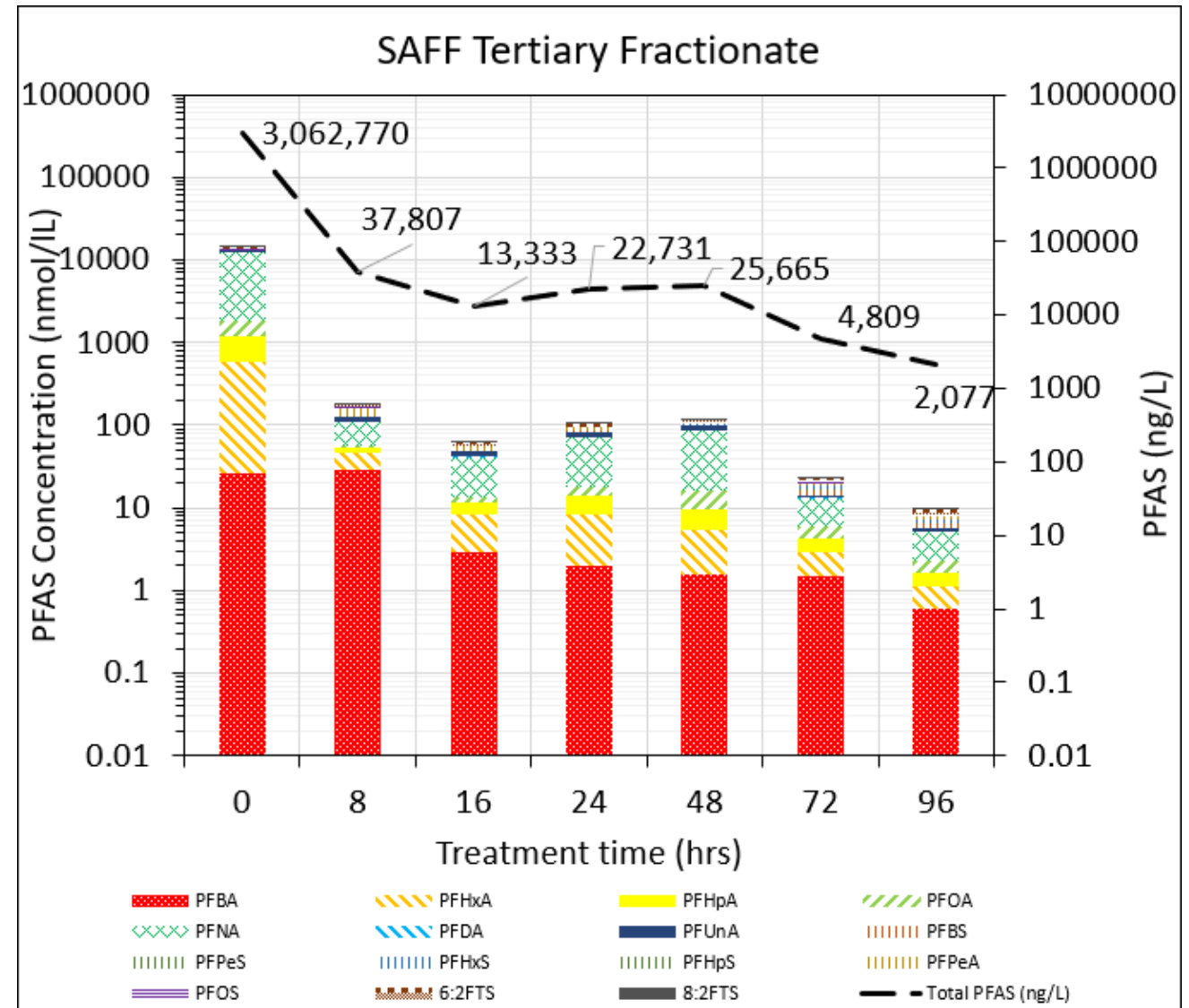
Destruction of PFAS in SAFF Fractionates: Pilot ECO System

Secondary Fractionate removal rates:
100X – 10,000X

- PFOS < 68 ng/L
- PFOA < 14 ng/L
- PFNA < 100 ng/L
- 99% total fluorine removal (TOF)

EEO = 132 W-h/L

Foaming agent – degraded/removed



Thank You



Confidential

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)



