From Pilot to Practice: Full-Scale PFAS Destruction Using Foam Fractionation and Electrochemical Oxidation in Industrial Wastewater

Speaker:

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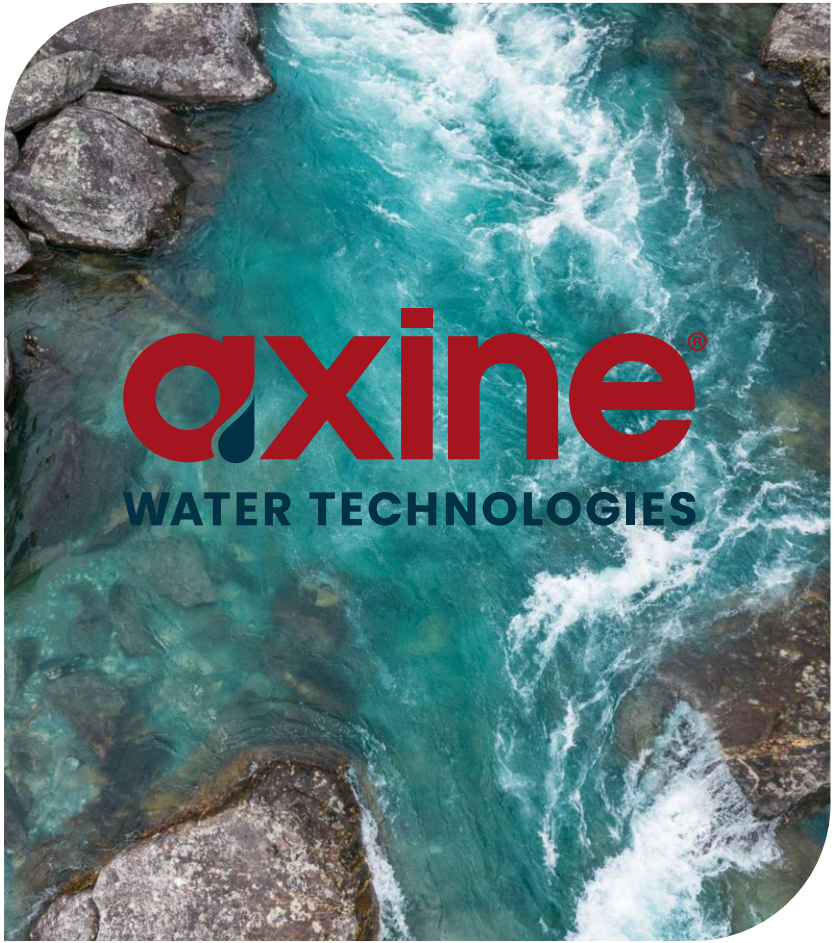
axine® WATER TECHNOLOGIES

Today’s Agenda

1. An onsite destruction system, from the permit side
2. Where destruction fits, and how EOx works
3. Case study: chrome plater, bench to full scale
4. Demonstrating destruction and key takeaways



Who We Are

Axine is a technology company focused on the destruction of persistent contaminants in industrial wastewater.

What We Do

electraCLEAR™ electrochemical oxidation (EOx) is purpose-built for difficult-to-treat organics, including PFAS, APIs, solvents, and other persistent contaminants.

Who It's For

Industrial, Landfill, Pharmaceutical, Semiconductor, and other wastewater producers needing a PFAS or other contaminate destruction ***onsite***.

Axine's solutions are designed to complement industry, not stop it.

The PFAS Challenge in Metal Finishing

Project Location

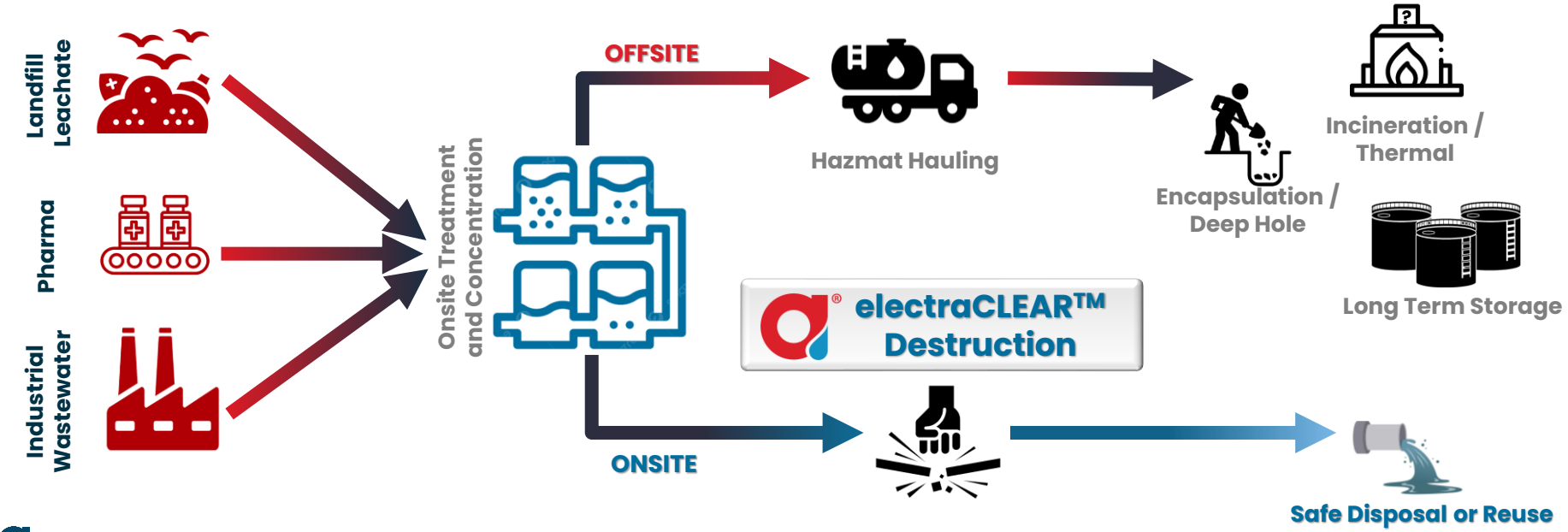
Electroplating/Metal Finishing Facility, Michigan USA

Legacy contamination driving demand for permanent solutions

- PFAS persists in electroplating and metal finishing due to decades of accumulations and posing long-term liability
- Traditional approaches—GAC, ion exchange, and incineration—transfer contamination rather than eliminate it, shifting risk without resolving it
- Tightening regulations and litigation exposure are driving demand for onsite PFAS destruction
- Elimination of one PFAS can open door to another

The Disposal Challenge

PFAS and Other Compounds need to be permanently stored or destroyed to prevent outbound contamination.



Where PFAS Destruction Fits

PFAS is easiest to deal with where it is most concentrated: at the industrial user

At the POTW

- Diluted into the full plant flow
- Conventional treatment does not remove PFAS
- Leaves in effluent or concentrates in biosolids
- Treated at plant scale, after dilution

Remove and haul off

- GAC, IX or RO captures PFAS from the IU's discharge
- Spent media / brine is hauled to landfill, incineration or deep well
- Recurring cost; PFAS and liability move, they are not eliminated

Concentrate + destroy onsite

- Foam fractionation shrinks the PFAS stream 500–1,000x
- EOx breaks C–F bonds: F^-, CO_2, H_2O
- Nothing hauled; PFAS mass leaving to sewer drops sharply
- Verifiable at the IU sampling point

Poor fit for destruction
Extreme volume, dilute PFAS

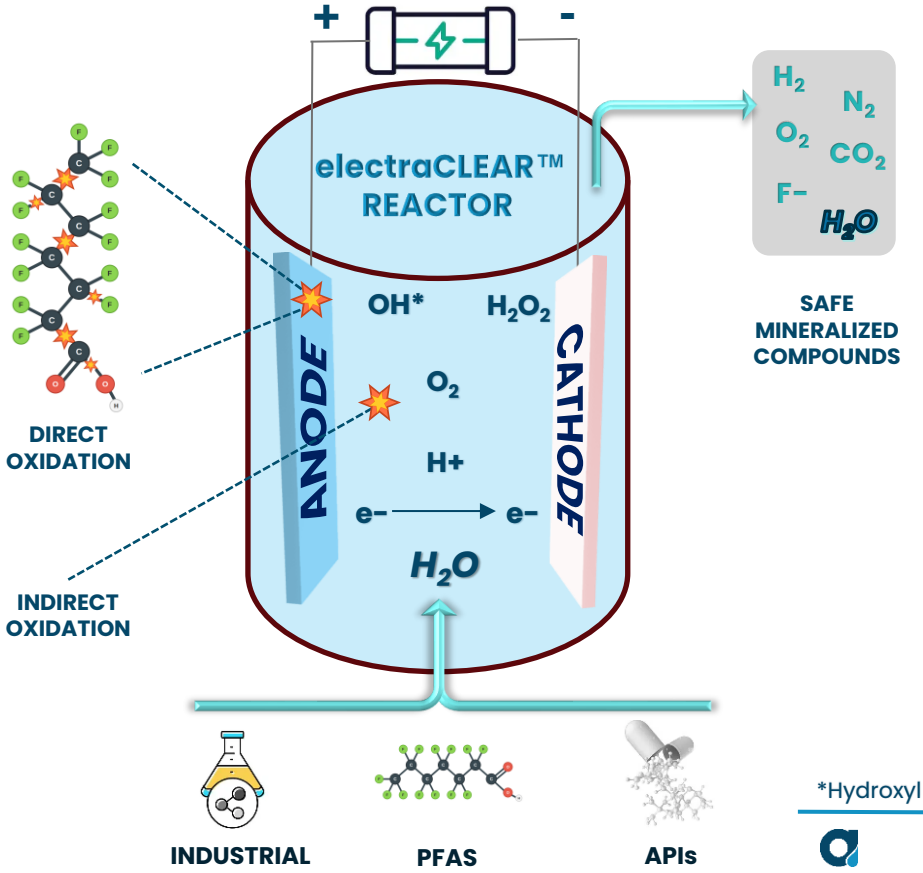
Right place, costly path
Costly haul to few sites

Most economical
Sewer discharge stays open

At the case-study site: 70,000 GPD at ~100 µg/L becomes 100 GPD of foamate at ~67,000 µg/L. **EOx treats <1% of the total water and destroys >99.9% of the PFAS.**

Electrochemical Oxidation

How EOX Destroys Contaminants



Applied DC current drives both direct and indirect oxidation.

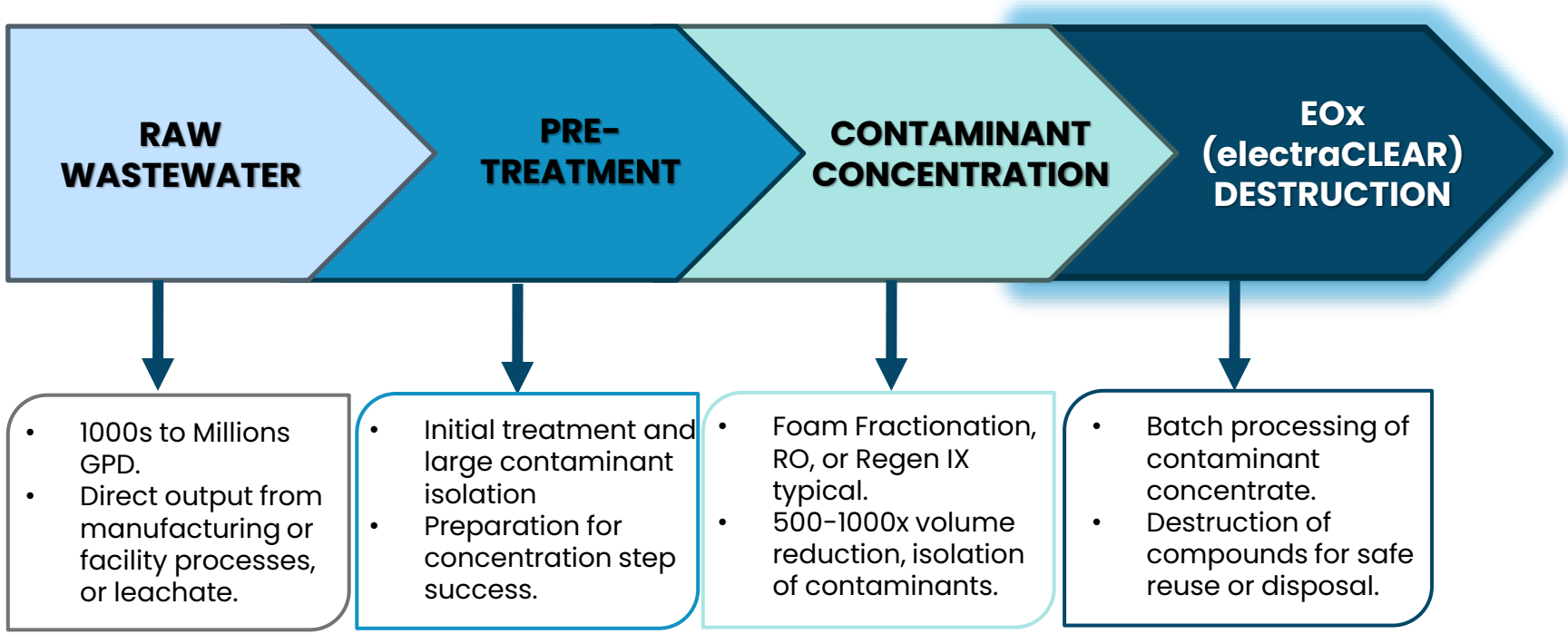
Direct electron transfer to destabilize compounds that hydroxyl radicals cannot.

Non-selective destruction. Treats the full organic load.

Ambient temperature and pressure, no hazardous chemicals.

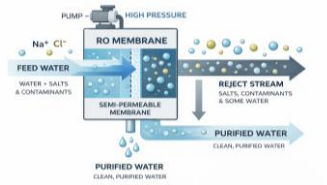
*Hydroxyl radical – highly reactive, short-lived oxidant

electraCLEAR™ Treatment Train Summary



Pre-Concentration Technologies

Reverse Osmosis

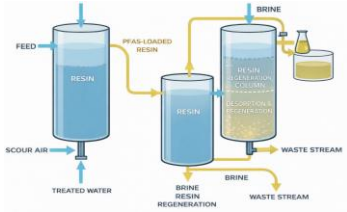


Water forced through membrane, removing PFAS, organics and salts

PROs
- Captures long, short, ultrashort chain PFAS
- Permeate often sufficiently clean for discharge

CONs
- Low concentration factor
- High volume (EOx feed)
- Rejects TDS and other organics (lower conductivity)

Regenerable IX

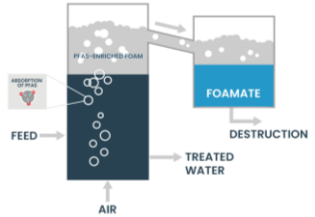


Contaminant adsorption on resins which can be extracted by brine solution

PROs
- Very high concentration factor (> 10,000X possible)
- Low hardness in regenerant

CONs
- High TDS in brine
- Many use chloride for regeneration (perchlorate generation)
- PFAS rejection less than RO and traditional IX

Foam Fractionation

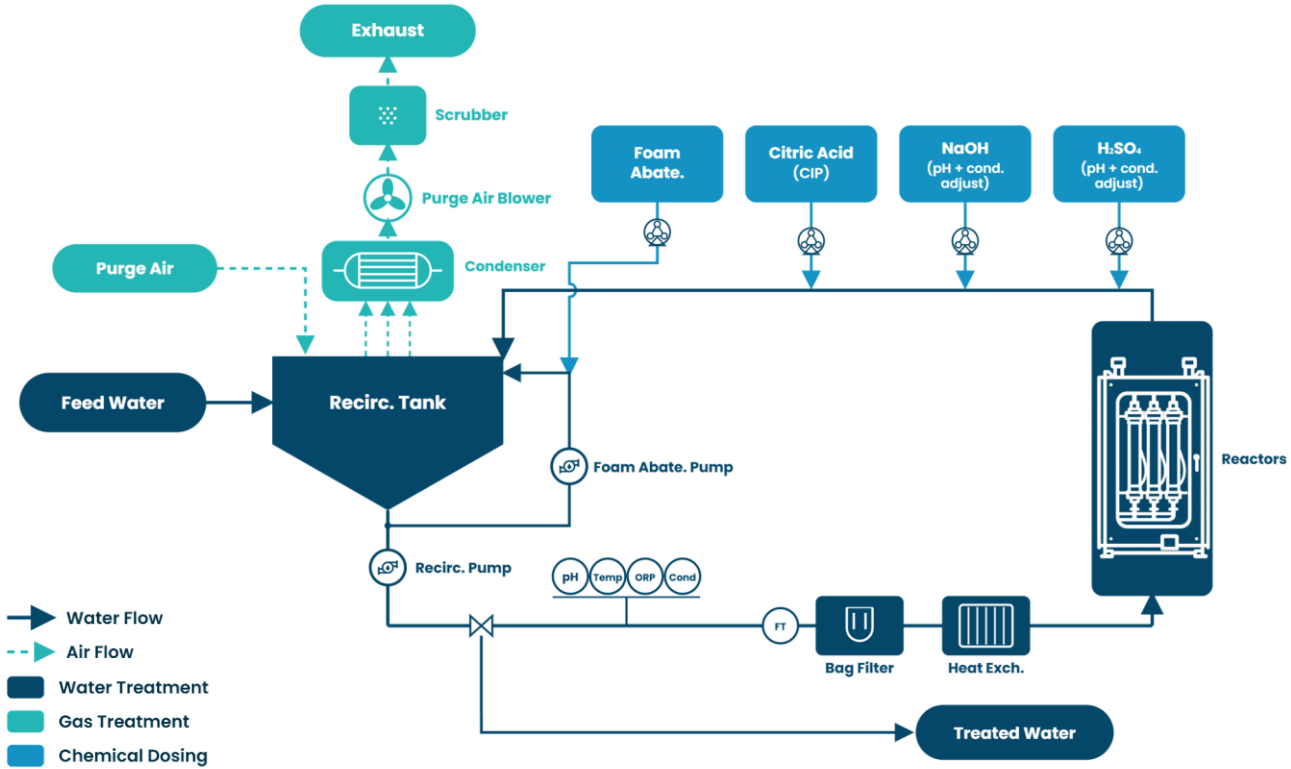


Surface active contaminants removal by gas bubbles which can be skimmed and coalesced

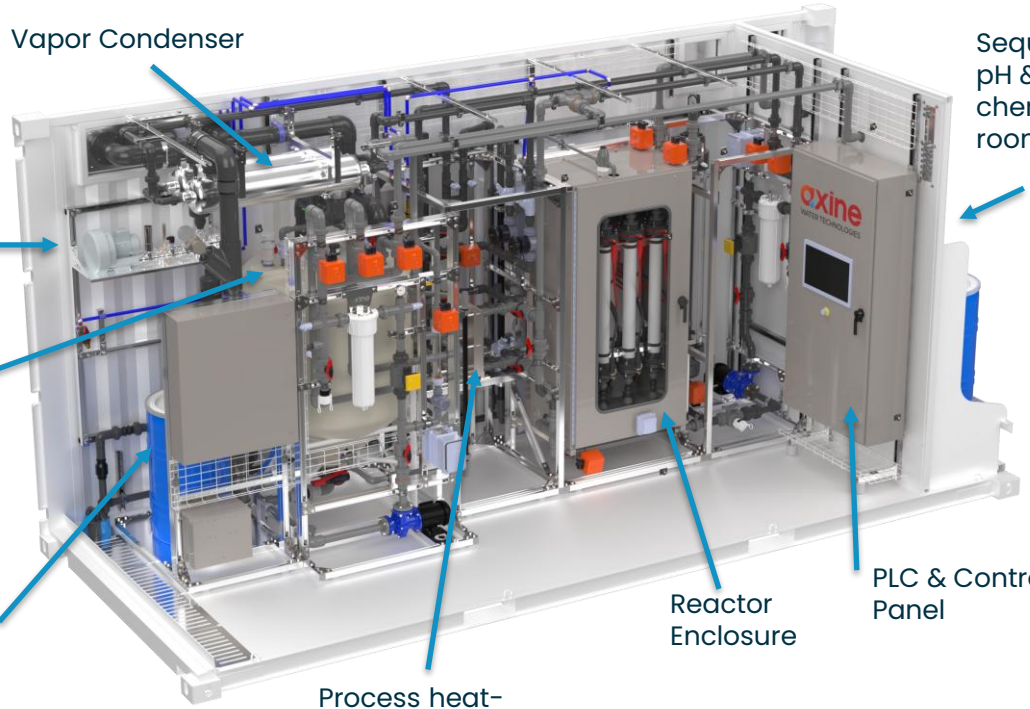
PROs
- High concentration factor (100 – 1,000X)
- Selectivity on organics
- TDS not concentrated

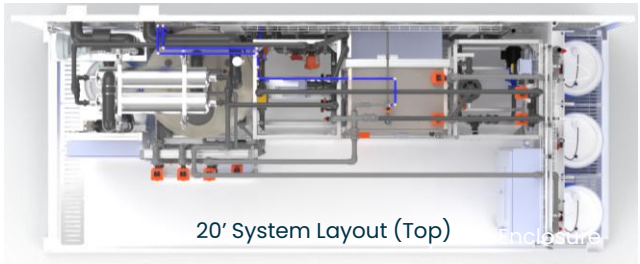
CONs
- Lower short and ultrashort chain PFAS removal
- Overall PFAS removal lower than RO

electraCLEAR™ Process Diagram



- Batch Operation
- Temperature control
- pH Control
- Gas Management
- Foam Mitigation





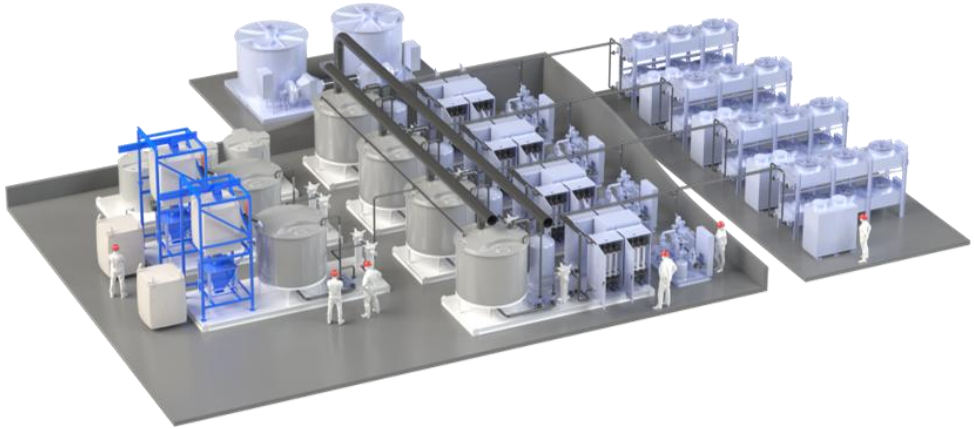
20' Container (6m)

Up to 8 Reactors
200 – 350 Gal Reactor Tank (~1-1.5m³)
Up to 1,000 GPD (Concentrated)

Additional System Sizes

Up to 24 Reactors
200 – 850 Gal Reactor Tank (~1–3 m³)
Up to 3,000 GPD (Concentrated)

40’ Container (12m)



~1,700 Gal Reactor Tank (~6.5 m³)
Modular 32 reactor trains
Up to 4,000 GPD (Concentrated)

Skidded System

Proven PFAS & Contaminant Destruction

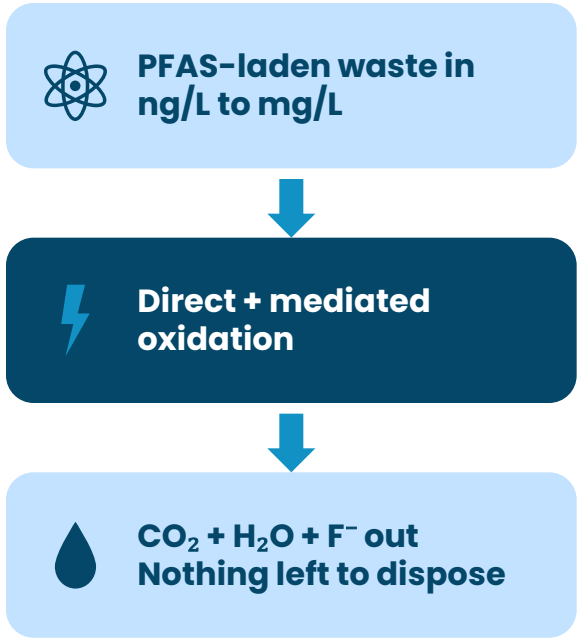
Industry	Influent Concentration		Destruction % Achieved											
	TOC [mg/L]	Total PFAS [µg/L]	PFTeDA (C14)	PFDA (C10)	PFNA (C9)	PFOA (C8)	PFOS (C8)	6:2 FTS (8)	GenX (C6)	PFHxA (C6)	PFBS (C4)	PFBA (C4)	PFPrA (C3)	TFA (C2)
Landfill Leachate (RO)	3,200	114			-	>99.9%*	>99.9%*	-	-	-	93.049%	>99.9%*	-	-
Landfill Leachate (FF)	20	6,040			>99.9%*	99.999%	99.999%	-	-	-	-	>99.9%*	-	-
Textiles	5	0.868	< L.O.Q.	> 98.863%	> 96.875%	> 99.285%	> 90.00%	< L.O.Q.	< L.O.Q.	> 99.473%	–	> 95.833%	> 90.384%	–
Surface Finishing	230	72,582	< L.O.Q.	< L.O.Q.	< L.O.Q.	< L.O.Q.	99.999%	99.999%	< L.O.Q.	> 99.970%	< L.O.Q.	< L.O.Q.	–	–
Semicon - FF	288	27,316	> 99.917%	99.916%	99.933%	99.929%	< L.O.Q.	-	-	99.914%	-	99.974%	-	-
Semicon - RIX	3,180	856	< L.O.Q.	< L.O.Q.	> 99.510%	99.552%	98.607%	–	–	–	> 99.974%	> 99.963%	–	–
WWTP Waste (RO)	7,580	200			-	>99.9%	-	-	-	-	96.562%	97.273%	>99.9%*	-
WWTP Waste (FF)	1,750	4,660			-	>99.9%*	99.948%	-	-	-	-	>99.9%*	>99.9%*	-
Manufacturing Wastewater (RO + GAC)	30	79,950			-	-	-	-	-	-	-	-	>99.99%	97.259%
AFFF Wastewater	700	10,600			99.992%	99.995%	99.995%	-	< L.O.Q.	-	99.979%	99.3%	-	-
Industrial FF + TFA	915	113,313			-	-	99.996%	99.99%*	-	99.79%	-	-	-	< L.O.Q.

**** = Below Reporting Limit /*** ***(-) = Not present in water sample***

Proven PFAS Destruction over >99.9%

PFAS Compound	Carbon Number	PFAS Before Treatment [ng/L]	PFAS After Treatment [ng/L]	% PFAS Reduction
PFDA	C10	16,800	< 2*	> 99.988%
PFNA	C9	13,600	< 2*	> 99.985%
PFOS	C8	4,160,000	3.8	99.9999%
PFOA	C8	1,380,000	3.8	99.9997%
PFecHS	C8	202,000	< 2*	> 99.999%
PFHpS	C7	36,000	< 2*	> 99.972%
PFHpA	C7	71,400	< 2*	> 99.997%
PFHxS	C6	137,000	< 2*	> 99.999%
PFHxA	C6	2,200	< 2*	> 99.909%
PFPeA	C5	6,800	< 2*	> 99.971%
PFBA	C4	15,800	< 20*	> 99.873%

** Indicates that results were under reporting limits of the compounds tested*



Successful multi-log destruction of long and short chain PFAS in foamate.

Concentrate First to Cut Energy

Same source water, concentrated two different ways before EOx

	Concentration factor	Energy per gal of concentrate	Energy per gal of total flow
Reverse osmosis	10x	4.46 kWh	0.45 kWh
Foam fractionation	500x	2.89 kWh	**0.0058 kWh**

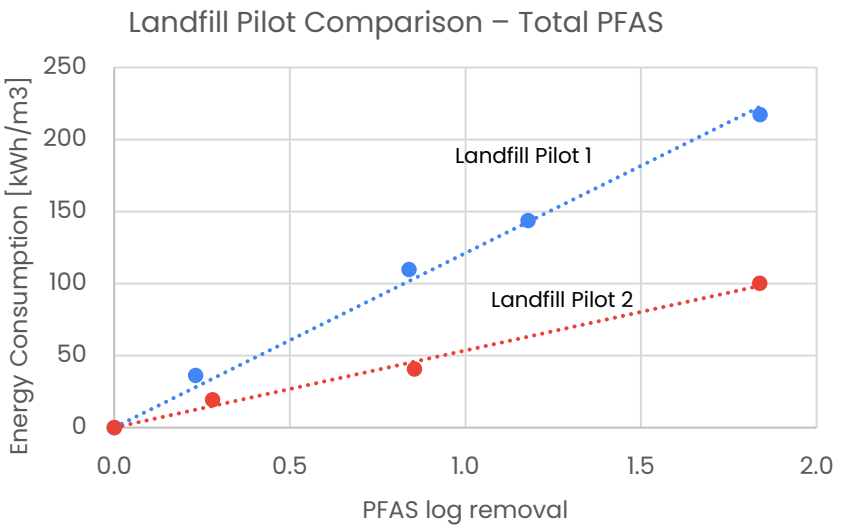
~80x

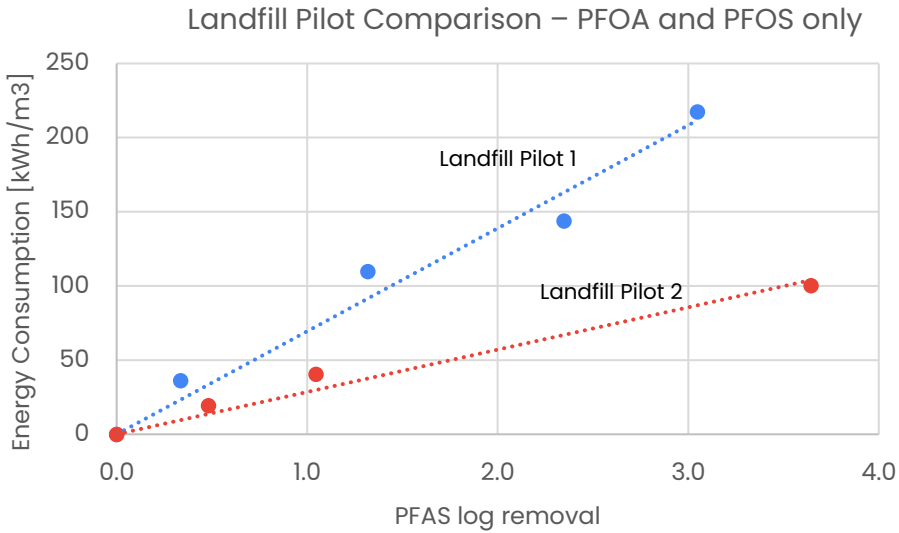
less EOx energy per gallon of wastewater treated

Water chemistry sets the energy bill. EOx energy rises with what competes with PFAS at the electrode: organics (COD/TOC), salts (TDS) and nitrogen (TKN). **A tighter, more PFAS-selective concentrate means less water and fewer competing species to treat.**

Energy basis: first-order PFAS destruction to target, Axine bench data on a shared source water. Site-specific values require bench testing.

Landfill Leachate Pilots





Item	Unit	Landfill Pilot 1	Landfill Pilot 2
Total PFAS	µg/L	3,500-5,100	3,500-4,700
TOC	mg/L	1,750	765
Ammonia	mg/L	~1,500	~500
Hardness	mg/L	~2,000	~500
TDS	mg/L	~30,000	~8,000

Case Study: Bench to Full Scale

Project Sequence

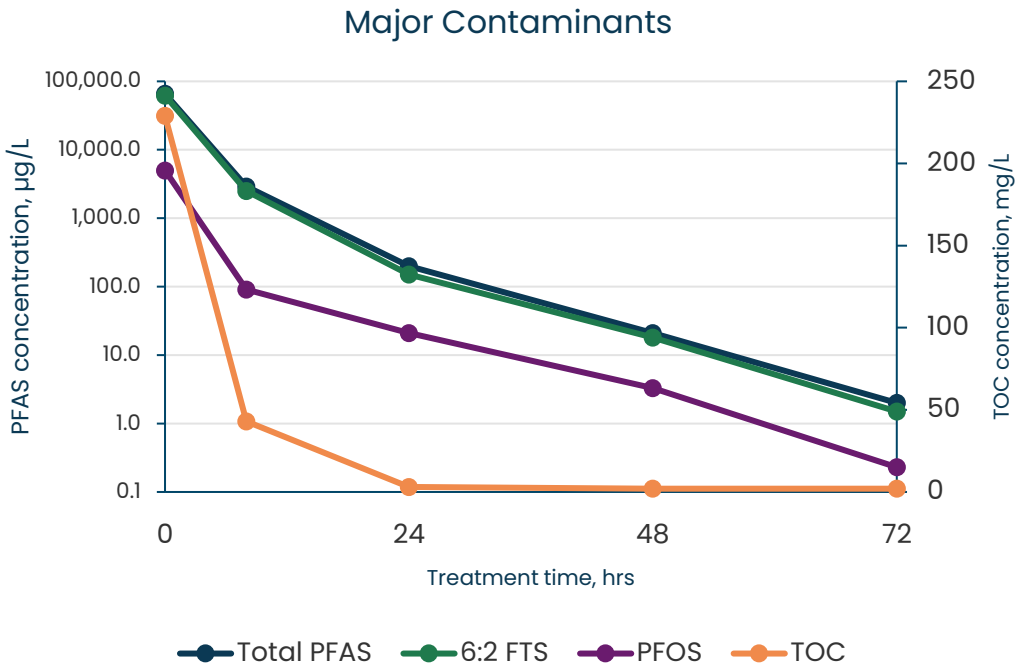
Bench Test (5-20 USG)
June 2023
Small scale proof of concept

Pilot (20-100 USG/day)
Jan. 2024
Process and energy optimization

Full Scale System
April 2025
Scalable to various applications

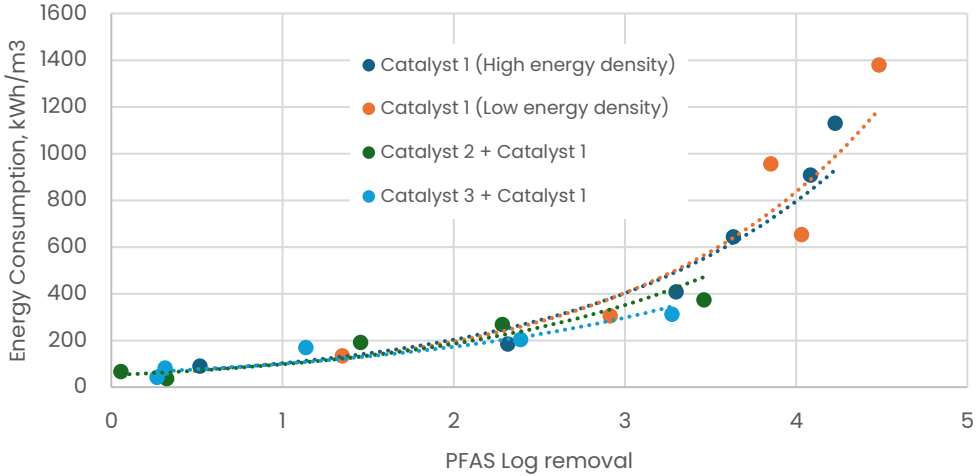
Proof of Concept at Benchtop Scale

Parameter	Unit	Concentration
Perfluoroalkyl substances (PFAS)		
Sum of Detectable PFAS	µg/L	75,000 – 83,000
PFOS	µg/L	700 – 1,400
PFOA	µg/L	2,500 – 3,000
6:2 FTS	µg/L	69,000 – 82,000
PFBS	µg/L	<2,500
Other major water quality parameters		
TOC	mg/L	610 – 950
TDS	mg/L	12,000 – 14,000
TSS	mg/L	42 – 160
Chloride	mg/L	804 – 1,200
Fluoride	mg/L	<6.70
Hardness	mg/L	200



- ✓ PFAS destruction to target levels (> 99.9%)
- ✓ Identified candidate electrode materials/combinations
- ✓ Preliminary estimates for full-scale installation

Pilot Demonstration at Project Site



- ✓ 4-week pilot using multiple electrodes/combinations
- ✓ Repeatable, consistent PFAS destruction
- ✓ Pilot capacity – 100 GPD at 99.9% destruction or 50 GPD at 99.999% destruction
- ✓ Process optimization to minimize energy and improve process safety

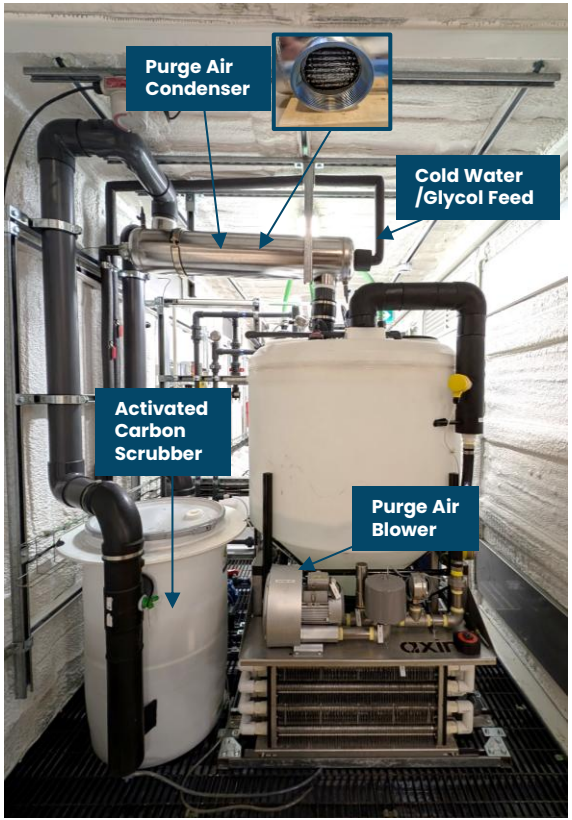
Scale-up Challenge 1 – Gas Management

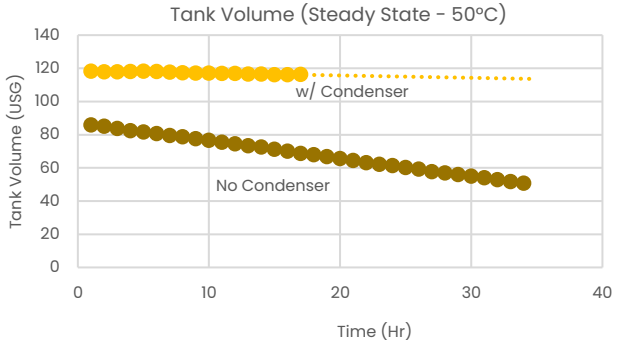
Two considerations: PFAS emission and HF gas

HF emission primarily prevented via pH control

Prevent PFAS emission via water vapor (ensure destruction only)

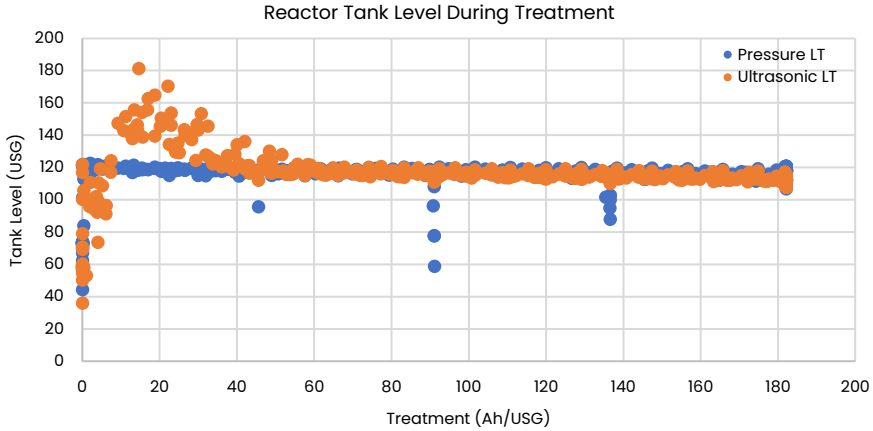
Prevent VOC, HF, Cl2 emission (Fail-safe against pH control)

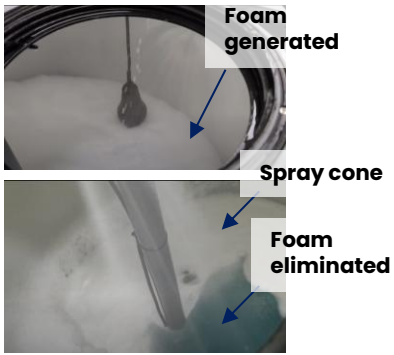




Analyte	Unit	Influent	Condensate
Total PFAS	µg/L	53,734	**69,468**
PFOS	µg/L	1,250	**16,500**
6:2 FTS	µg/L	52,200	**48,100**
PFecHS	µg/L	35	**64**

Scale-up Challenge 2 – Foaming



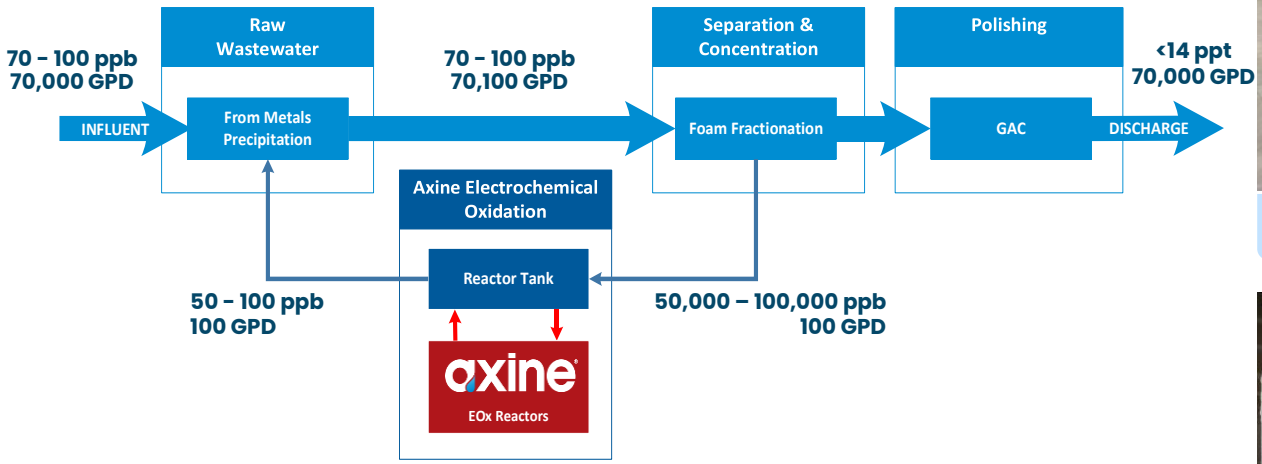


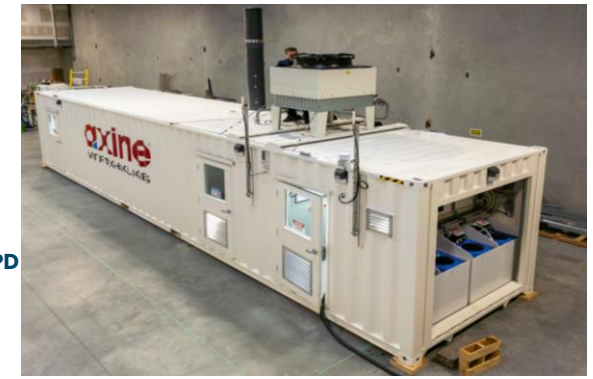
Foaming common in PFAS concentrates

Excessive foaming creates process interruption and safety concerns

Detection and abatement incorporated in system design

Full-Scale System Design





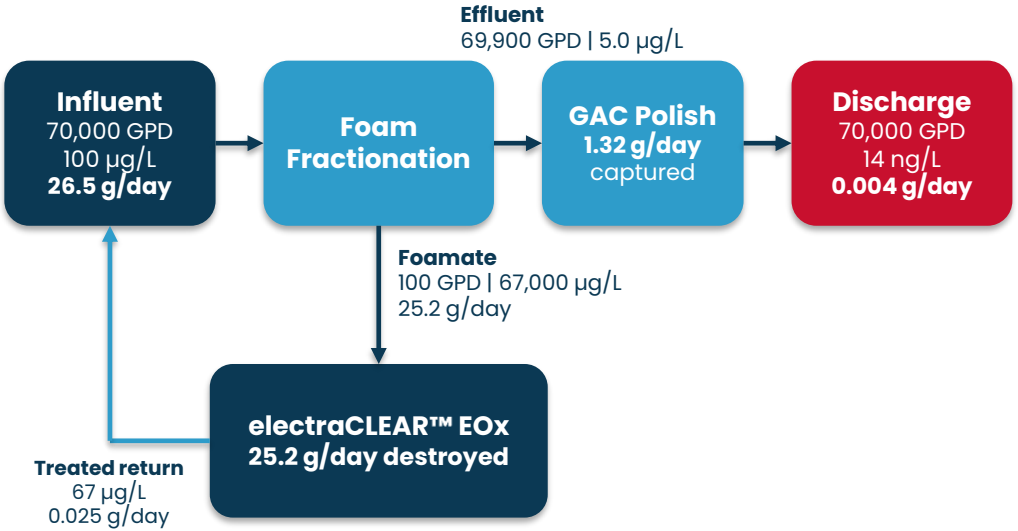
Containerized system design (20 ft or 40 ft)

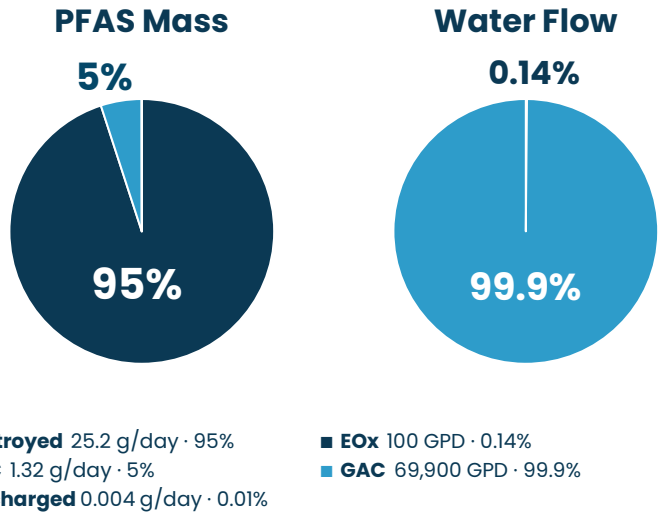
20 ft system sufficient for application

- Closed-loop system targeting 99.9% PFAS destruction
- Treated foamate returned upstream to the influent

Most of the PFAS, a Fraction of the Water

Real-world full-scale design case | 70,000 GPD at 100 µg/L total PFAS | steady state

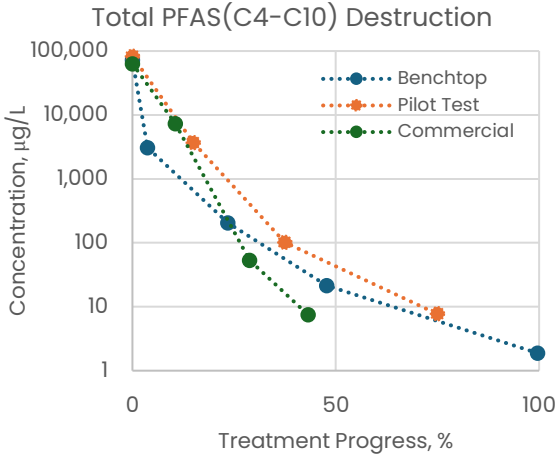


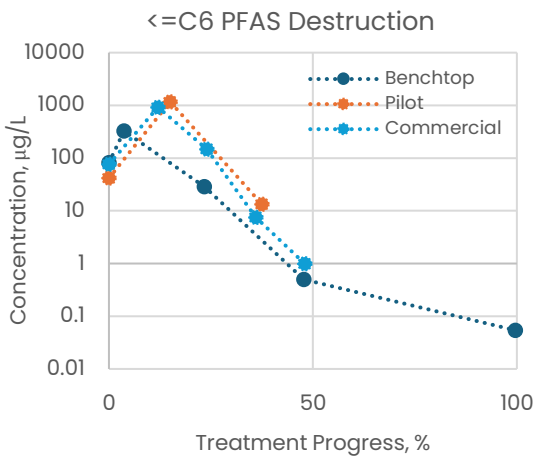


EOx destroys 95% of the PFAS (~9.2 kg/yr) while treating only 0.14% of the water.

Model basis: FF captures 95% of PFAS mass into 100 GPD foamate; EOx DRE 99.9%; GAC polish to <14 ng/L

Full-Scale System Operation





- ✓ Full-scale operation began April 2025
- ✓ ~8 M gal wastewater processed (raw influent), ~2.5 kg PFAS destroyed
- ✓ Treatment results comparable with pilot and benchtop testing
- ✓ In-house FF + EOx (TaaS) overall cost reduction vs GAC

Key Takeaways

1. **Lab and pilot testing are essential**
   EOx efficiency depends strongly on the specific water chemistry.

2. **PFAS treatment is a multi-step process**
   ~500x concentration by FF makes EOx ~80x more energy-efficient.

3. **Small challenges scale up**
   Gas management and foaming shaped full-scale safety controls.

4. **True elimination, not transfer**
   FF + EOx delivers field-proven PFAS destruction at industrial scale.

Thank you!
+ Q&A

Learn more about electraCLEAR™

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