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pioneering a new era
in sustainability

Supercritical Water Oxidation for PFAS Destruction in Various Matrices

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374Water° Company overview

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- Social impact, cleantech company founded in 2018
- Spinoff from Duke University; HQ in Durham, NC
- Revenue generating; recognized $3M in 2022
- Projects: OC San + DoD
- Publicly traded as “SCWO”

What is SCWO ?

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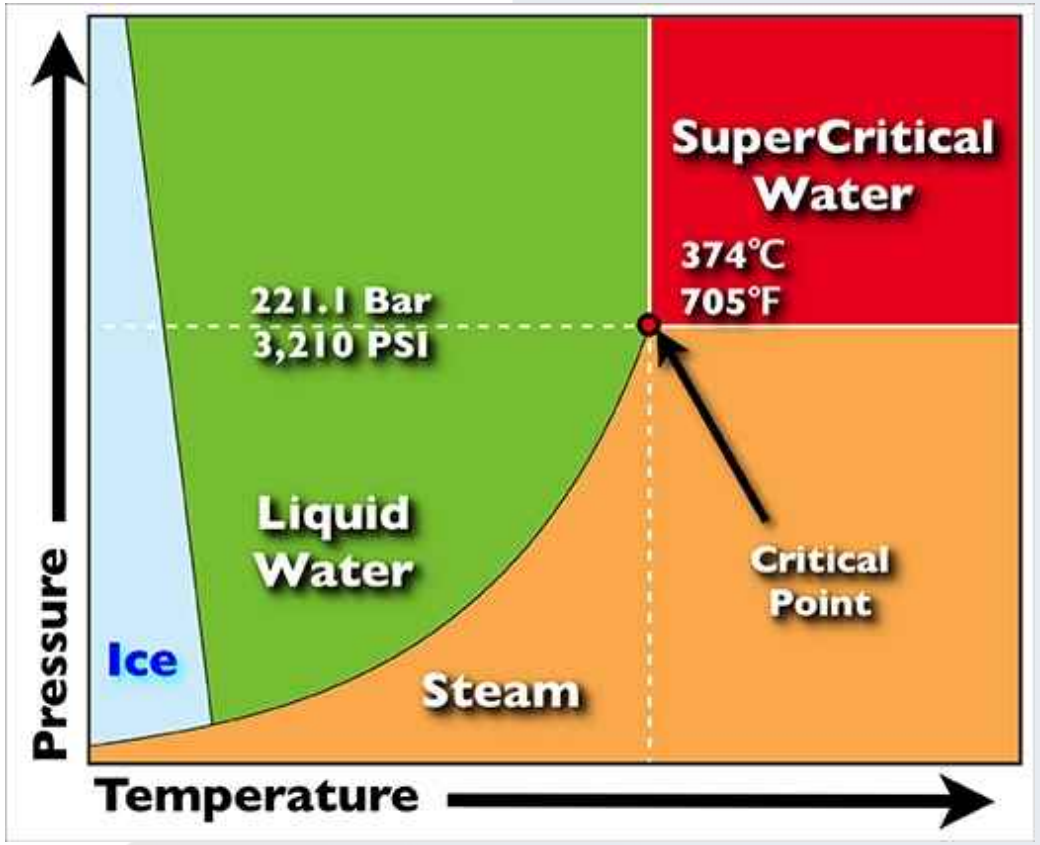

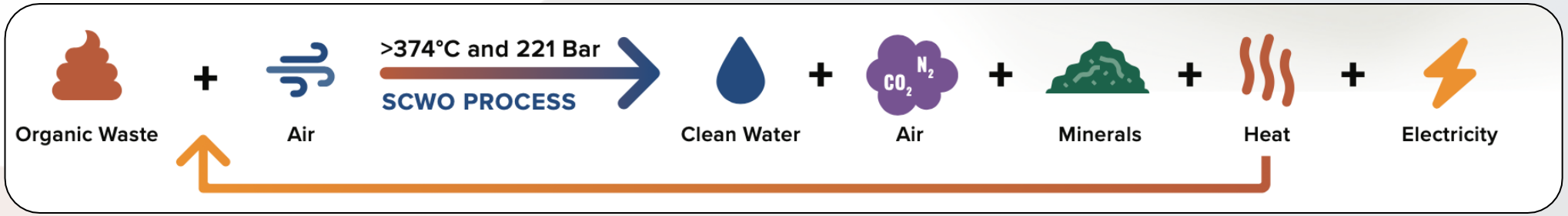

*SCWO converts organic waste into clean water, heat, electricity and CO_2 in **seconds!***

SCWO is a transformative technology

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- Process is **compact and scalable**
- **Treat waste at the source** eliminating transportation and greenhouse gases
- **Recover and reuse** water, energy and nutrients
- Decentralized, **prefabricated, compact and modular** units
- **Energy efficient**, sustainable and resilient

Duke pilot SCWO system (1 ton/day)

How AirSCWO™ works

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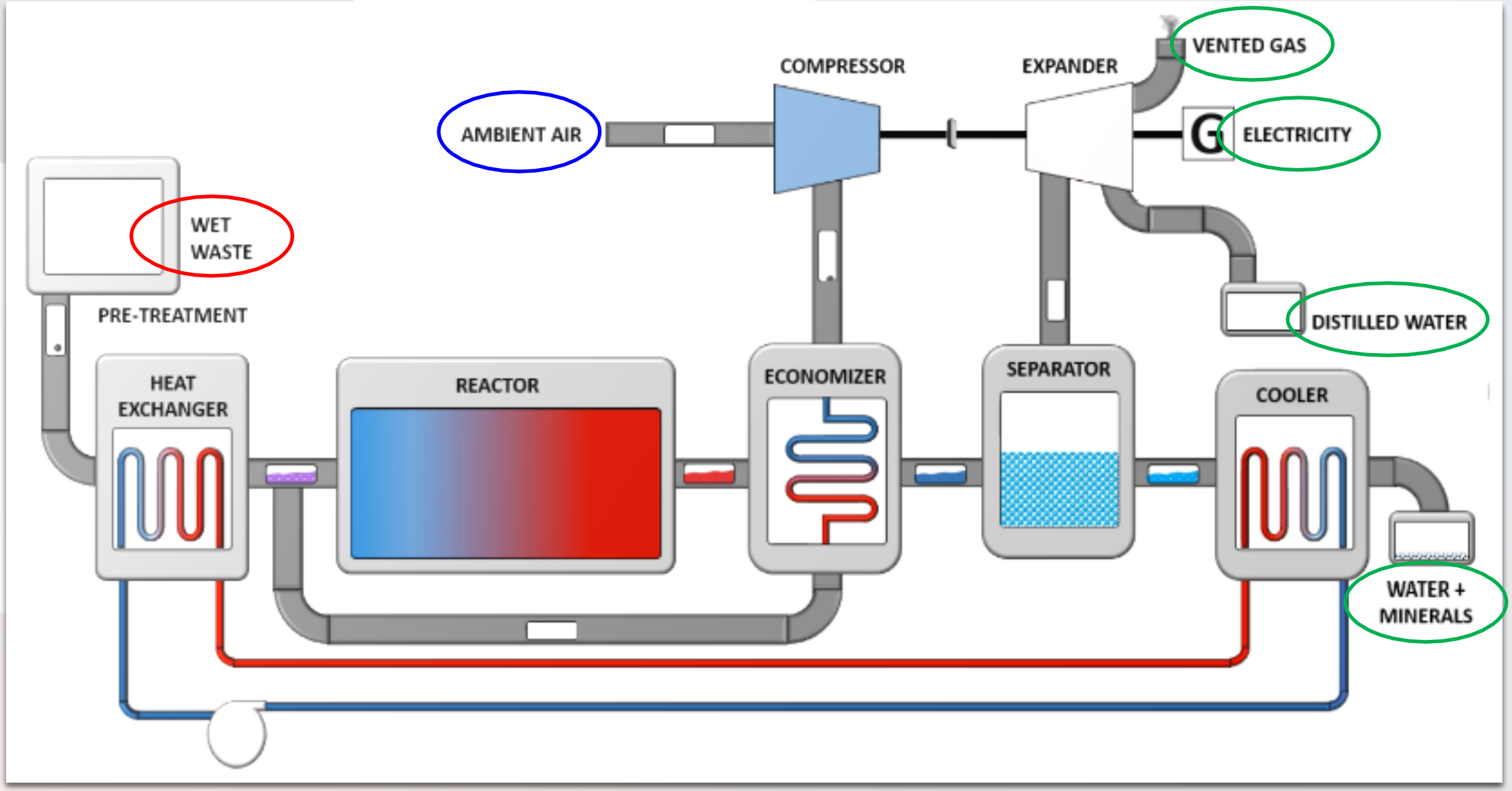

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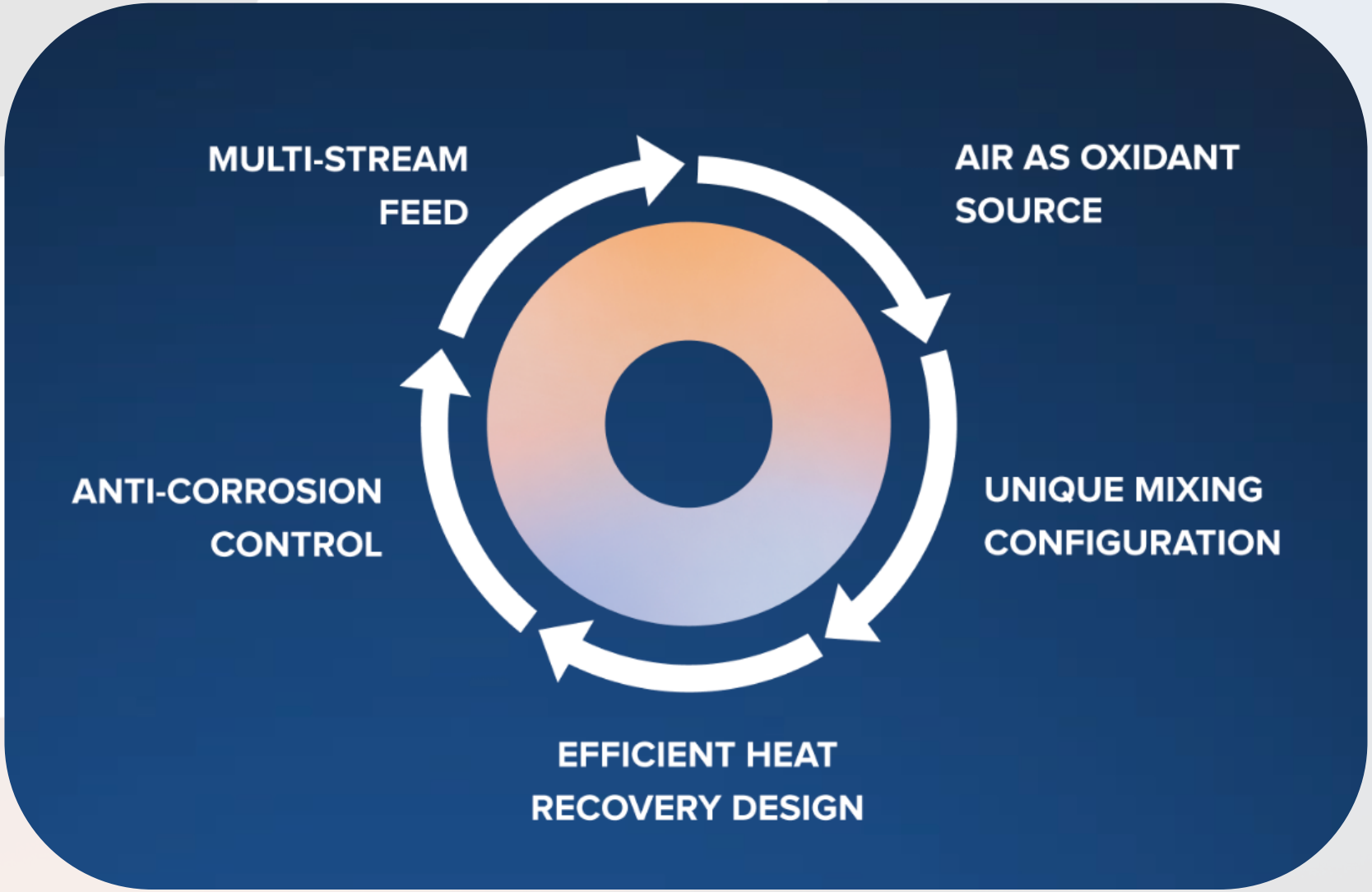
Key differentiators



Wastes treated so far …

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Primary sludge

Dewatered secondary sludge

Digested sludge

Animal wastes

Food waste

Landfill leachate

Stockpile AFFF

AFFF rinsate

Microplastics

… and the list goes on

- Pharmaceuticals
- Chemical wastes (F, Br, Cl)
- Ag waste/fermentation waste
- Waste cooking or motor oil
- FOG (fat, oil and grease)
- GAC
- Spent IX resin

It always comes out the same…

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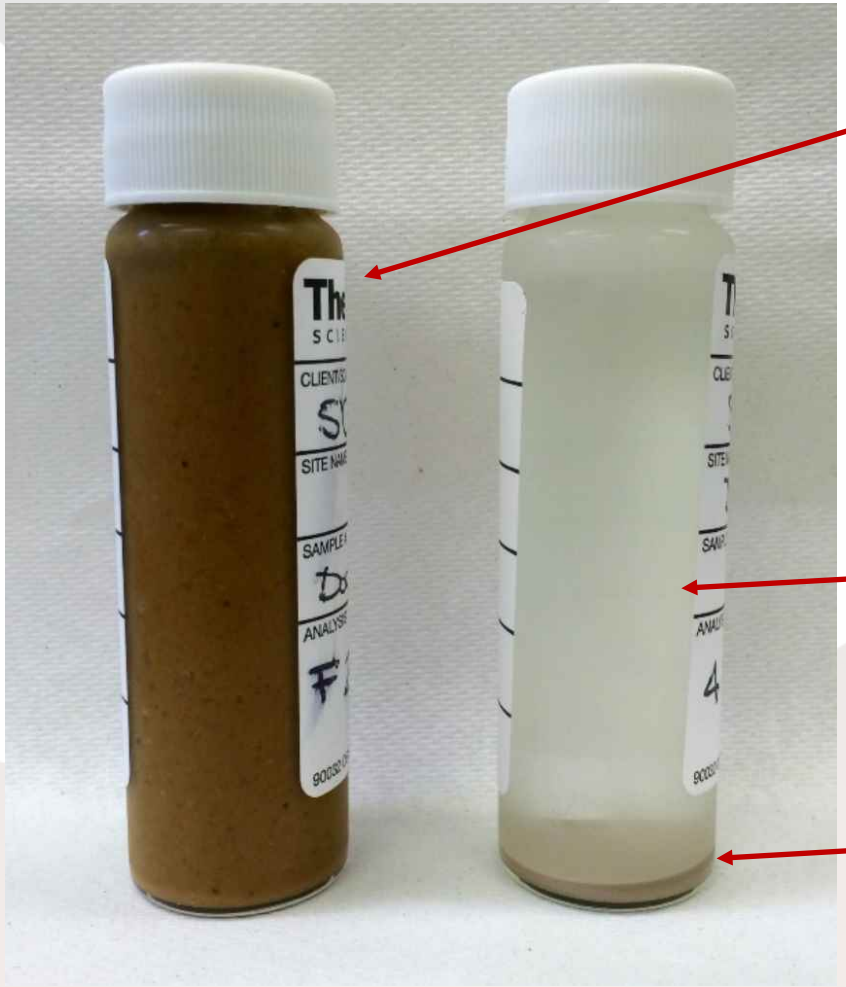

Feed

Effluent

Minerals

Landfill Leachate

Plastic

Primary Sludge

Biosolids

Food Waste

Treatment of micro-pollutants

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Experimental Approach

- Spiked contaminants in IPA/water and in biosolids

Results

- **Ibuprofen** and **acetaminophen**: spiked 10 mg/L each

Effluent: ND at < 1 µg/L Elimination > 99.99%

- **Triclosan**: spiked: 100 µg/L

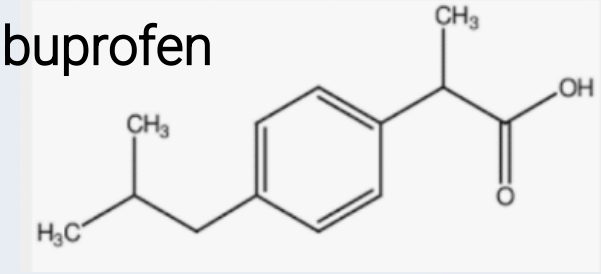
Effluent: ND at < 0.1 µg/L Elimination > 99.9%

- **Tetrabromobisphenol A**: spiked: 13 g/L

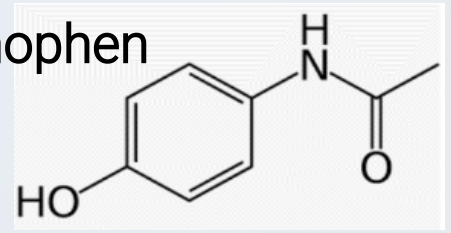
Effluent: ND at < 1 mg/L Elimination > 99.99%

SCWO treatment is waste agnostic

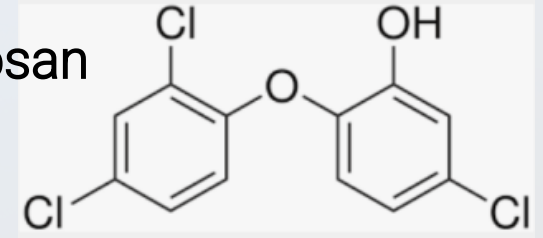
Ibuprofen



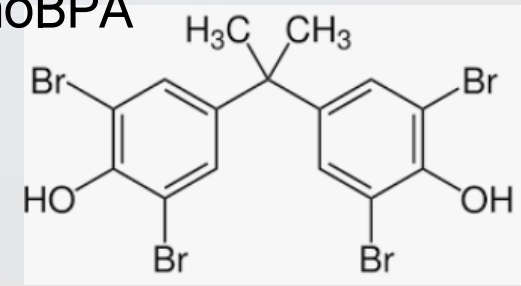
Acetaminophen



Triclosan



TetrabromoBPA



We destroy and mineralize PFAS

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Treated:

- Biosolids, sludges
- Stockpile AFFF (diluted)
- Groundwater
- Landfill leachate
- Rinsates from DOD decontamination activities
- Spent GAC & IX

$$\text{PFAS} + O_2\,(\text{air}) \xrightarrow[>240\ \text{bar}]{>374\ ^\circ\text{C}} H_2O + CO_2 + F^- + CaF_2 + \text{heat}$$

Treatment of lime stabilized sludge

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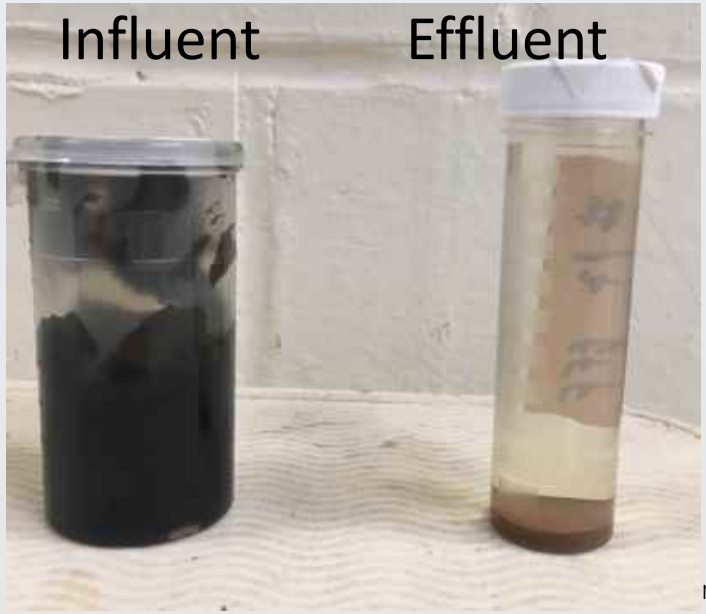
Waste type	Influent	Effluent	Removal
Lime stabilized sludge	**Σ target = 186,000 ppt**	**Σ target = 29 ppt** Mostly PFBA, PFPeA, PFHxA, PFHpA PFOA = 3 ppt PFOS = 0.65 ppt	Most individual PFAS > 99.9% PFOS 99.998%

- PFAS was eliminated to very low levels
- There was no transformation to lower molecular weight PFAS
- ALL PFAS were eliminated



Treatment of spent GAC and IX resin

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- Ran spent GAC (10% with cofuel)
- Ran two spent IX resin (8%, without cofuel)

Findings

- Runs were smooth. Slurries processed without problems
- High destruction of IX, PAC/GAC and their PFAS

Spent IX and treated effluent

Spent GAC and treated effluent

Results (IX treatment)

PFAS	Input Range (ng/kg$_{IX}$)	Percent Elimination	
		as is	blank corr.
Total PFCA	240,000 - 280,000	99.97%	99.9994%
Total PFSA	900,000 - 1,200,000	99.56%	99.95%
Precursors	30,000 - 36,000	98.85%	99.7%
Short chain (C<6)	700,000 - 790,0000	99.91%	99.91%
TOTAL	**1,000,000 - 1,500,000**	**99.59%**	**99.95%**

Test runs with materials and co-funding from Wood/WSP. Results pending publication (J. Haz. Mat.)
https://tinyurl.com/374water-IXpaper

Gaseous emissions of PFAS are negligible

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- EPA PITT team did gas-phase PFAS emission tests
- Deployed 2 methods:
  - Passivated, evacuated canisters
  - Sorbent tubes (Markes with Carboxen 1003, Tenax, and Carbograph 1)

- Only traces were detected in the gas vent
  - Fluoroform
  - Pentafluoroethane
  - Perfluorohexane/heptane

➡ SCWO does not emit significant volatile PFAS

F balances – organofluorine eliminated is recovered as inorganic fluoride

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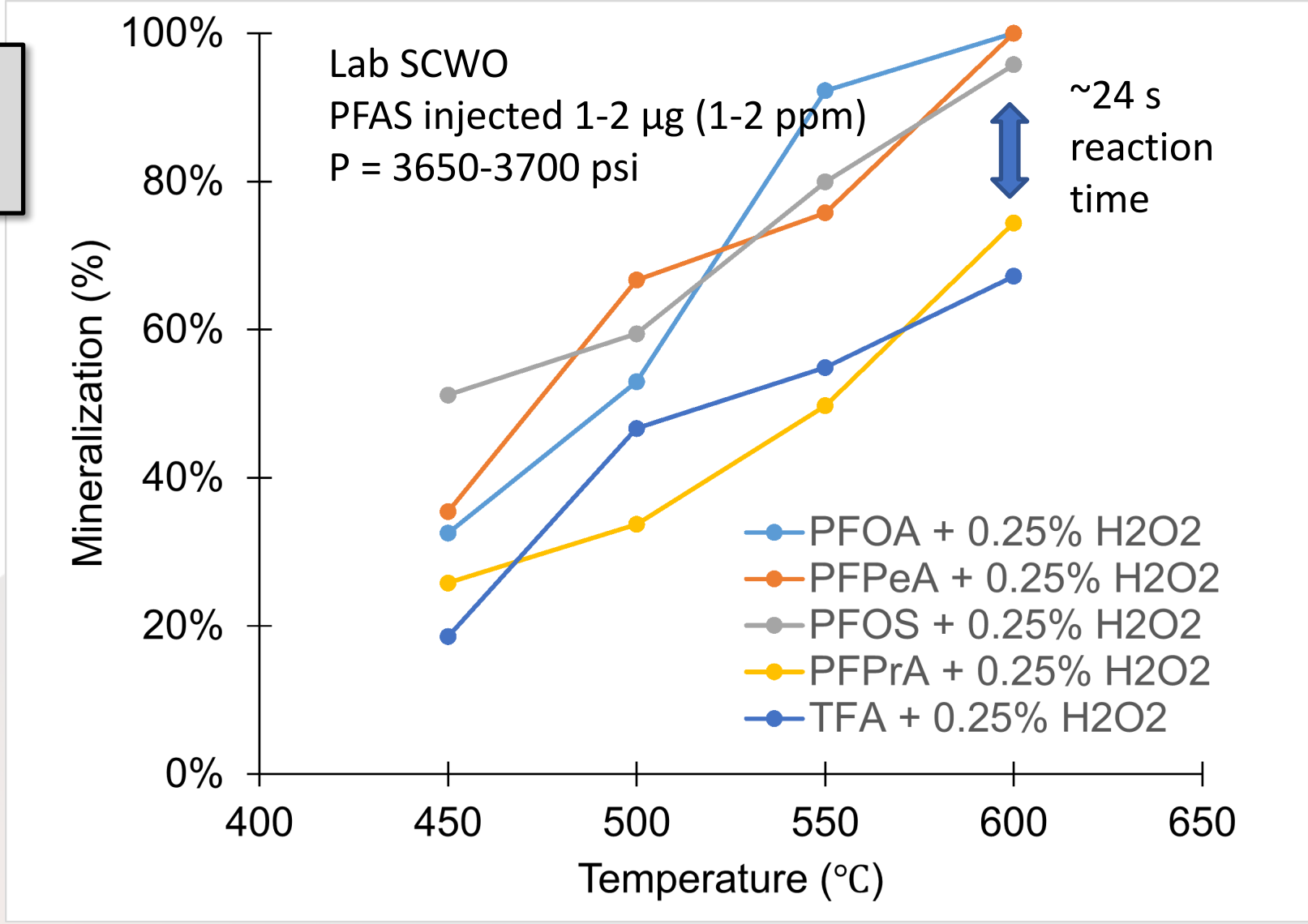
$$\text{Mineralization} = \frac{F^- \text{ recovered}}{\text{F-PFAS injected}}$$

- PFAS are **DESTROYED**
- Target analysis shows most **ND** (>500 °C)
- Conditions can be tuned for **100% mineralization**



Lab results from Duke Univ.

Summary of findings: PFAS and AFFF treatment

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- SCWO effectively eliminated **ALL** PFAS and precursors
- We routinely observed >3-5 log reductions of PFAS
- Log reductions are tunable using temperature x reaction time
- We could treat a broad range of PFAS concentrations inputs (and co-pollutants) from >1000 ppm to low ppt
- There was no transformation of high molecular weight PFAS into smaller PFAS (no TFA or PFPrA)
- PFAS elimination correlated with reactor temperature
- There was no significant emission of volatile F species
- Closing F balance showed 100% mineralization under optimum conditions

Why is SCWO so effective at destroying PFAS?

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- Supercritical water is a dense and very reactive medium
  - Density of supercritical water is 350-1000 greater than that of gas in an incinerator
  - Temperature + Pressure = High frequency of collisions between PFAS molecules and reactive species
  - Supercritical water yields efficient oxidant conversion to high-reactivity radicals (e.g. hydroxyl radical or hydroperoxy radicals)
  - The presence of water favorably influences the reactions (e.g., hydrolysis of COF_2)

- PFAS, oxygen, and reactive species form a homogenous phase

374Water's AirSCWO™ systems

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AirSCWO™ 6 = 6 wet ton/day (1600 ga/day) or 0.5 – 1.5 ton GAC or IX /day
Estimated TOTEX $0.4 /lb IX or GAC or $0.75 /gallon

Conclusions

- SCWO is an effective technology for PFAS destruction in a variety of matrices
- All other organic contaminants are mineralized during treatment
- The process does not require chemicals or consumables
- 100% mineralization can be achieved and documented for certificates of destruction
- AirSCWO™ systems are being deployed

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