Don’t Move PFAS. Destroy It. PFAS ANNIHILATOR™ Destruction

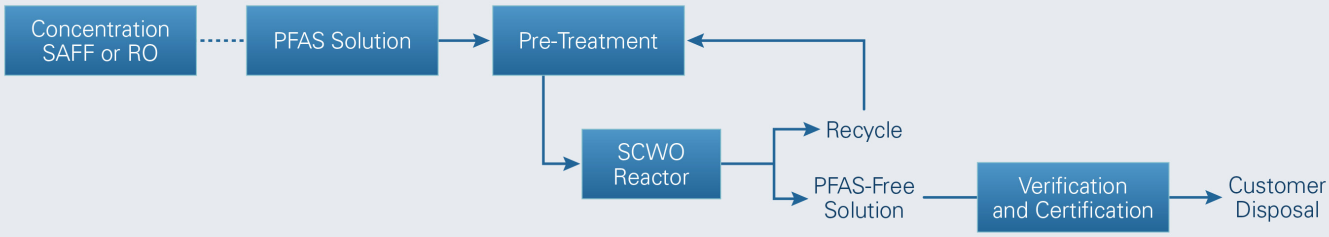
Battelle’s closed-loop, on-site destruction solution powered by supercritical water oxidation (SCWO) destroys per- and polyfluoroalkyl substances (PFAS), prevents them from transferring elsewhere and doesn’t create harmful byproducts.

How It Works

SCWO leverages the unique properties of supercritical water to break down PFAS chemicals. A supercritical fluid is a substance held at a temperature and pressure above its critical point. In this state, the fluid is neither a liquid nor a gas and has properties of both. For water, the critical point is 374°C (705°F) and 221-bar (3,200 lbs/in2).

Substances begin to act differently above the critical point. Polar substances (e.g., salts) become immiscible, and non-polar substances (such as petroleum products) become completely miscible. Supercritical water is highly expandable and compressible. Without distinct liquid and gas phases, mass transfer is unrestricted, facilitating chemical reactions.

The properties of supercritical water can be leveraged to break down PFAS and other recalcitrant chemical compounds. Supercritical oxidation processes can rapidly break down compounds that do not oxidize readily at standard temperatures and pressures, destroying chemicals that would otherwise persist for decades or centuries in the environment. SCWO has already been used successfully to destroy recalcitrant waste products including nerve agents, radioactive waste and polychlorinated biphenyls.

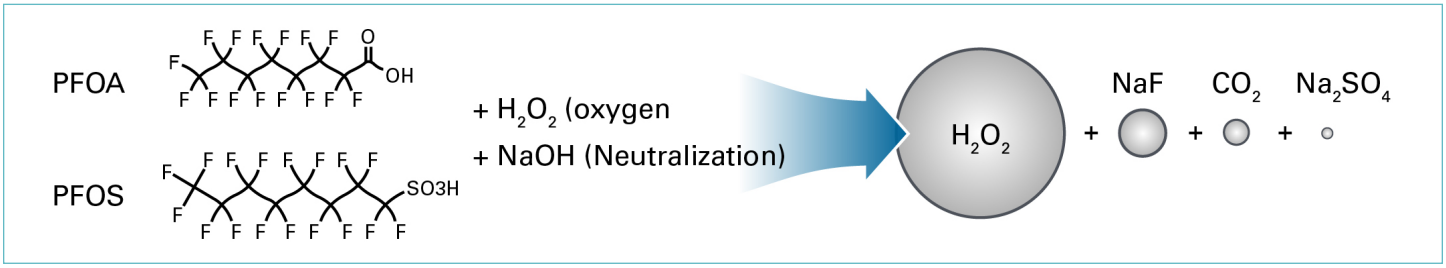


Revive environmental

Understanding PFAS Destruction Using SCWO

Battelle has adapted SCWO for PFAS destruction. In bench-scale trials of more than 30 PFAS-contaminated sample types, PFAS Annihilator demonstrated more than 99.99% destruction of total PFAS on multiple occasions.

Readily available oxidants such as air or hydrogen peroxide are used in the oxidation reaction, which breaks the strong carbon-fluorine bond that forms the backbone of PFAS molecules. In just seconds, the reaction is complete, leaving behind PFAS-free water and inert salts. Sodium hydroxide is added to the water to neutralize hydrofluoric acid created by the reaction before discharging it to the environment.



SCWO is a promising solution for destruction of PFAS in contaminated soils, groundwater, wastewater and concentrated waste streams. It can be applied to all types of PFAS, including aqueous film forming foam (AFFF) and unknown PFAS in investigative waste.

A Scalable Solution for PFAS Destruction

It started with our bench-scale program two years ago. Now we have systems available for deployment in the field.

	Bench-Scale	Mobile 1	Mobile 2	Site Scalable
Volume	n/a	Small, finite volumes	Larger, finite volumes	Higher volume
Capacity	n/a	40-60 gpd (up to 10x capacity with concentration)	300-500 gpd (up to 10x capacity with concentration)	Max ≈15 gpm (up to 10x capacity with concentration)
Mobility	No, in the lab	Yes	Yes	Mobile or brick and mortar
Application	Prep for field characterization and optimization	Stockpiled waste, secondary waste streams and concentrated regenerant	Stockpiled waste, secondary waste streams, concentrated regenerant, and process wastewater	Site remediation and stored waste destruction
Length of Use	n/a	Episodic, periodic	Episodic, periodic	Long-term operation

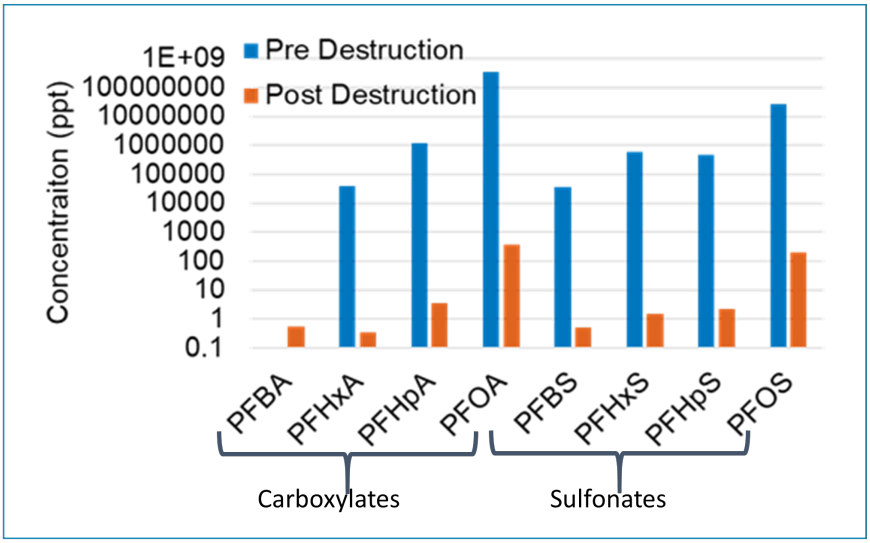
The Unique Benefits of PFAS Annihilator:

- Achieves near complete destruction of PFAS, regardless of carbon chain length or structure
- Generates few or no unwanted byproducts
- Can be used in the presence of common co-contaminants (petroleum, hydrocarbons, chlorinated solvents)
- Can be conducted at or near the contamination source
- Uses inexpensive oxidation and neutralization chemicals

Example Data

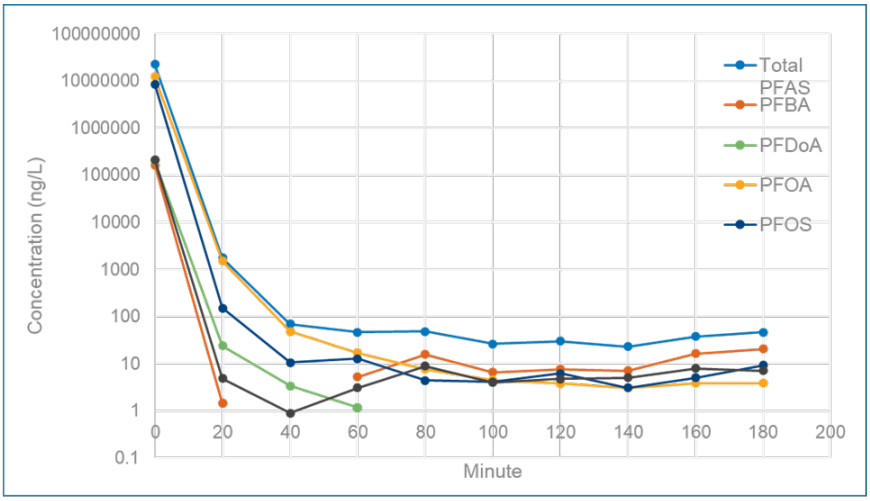
With all the runs we've done with the bench-scale unit, we've tested a variety of media and have lots of data.

Here are some highlights.



Laboratory Spike Water

We conducted a single run of a high-level spiked sample to simulate AFFF concentrations. We reduced the concentration of six out of eight PFAS analytes (that were initially present) to below 5 ppt. The overalldestruction efficiency was better than 99.999%

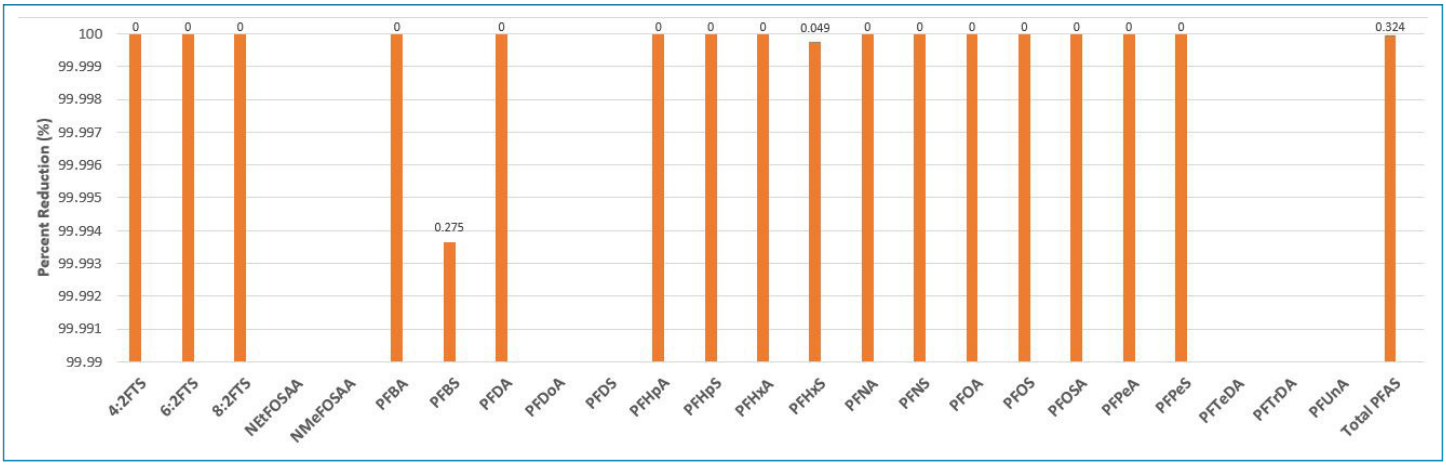


Evaluation of Steady State Destruction

We evaluated the destruction of PFAS over extended time in PFAS-spiked reverse osmosis water. The destruction remained fairly consistent over the test duration. Most compounds reached steady state destruction between 40 to 60 minutes. The PFOA destruction did not reach steady state until ~2 hours.

Investigation Derived Waste

We have used our bench-scale Annihilator to process many types of investigation derived waste samples from across the country, each having unique chemical and physical properties. We are able to achieve a high level of destruction of PFOS, PFOA and total PFAS, regardless of the starting concentration in the sample. We've also achieved a high level of destruction regardless of the chain length of individual compounds or its functional group (i.e. sulfonates or carboxylates). Effluent concentrations of PFOS and PFOA are generally less than the EPA established health advisory of 70 ppt for PFOS and PFOA.



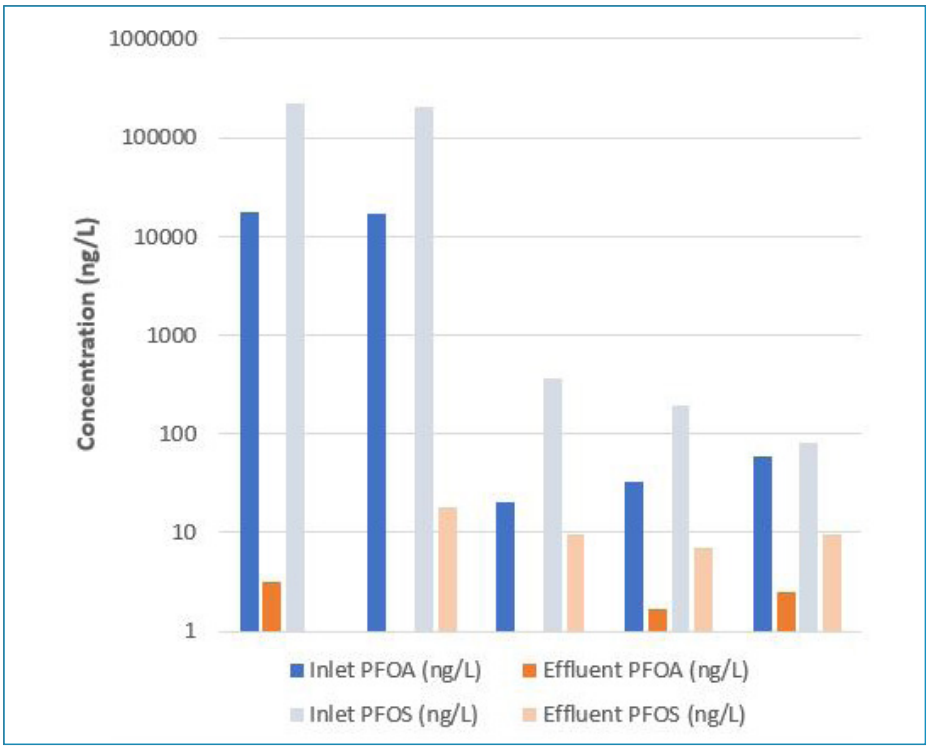
Notes:

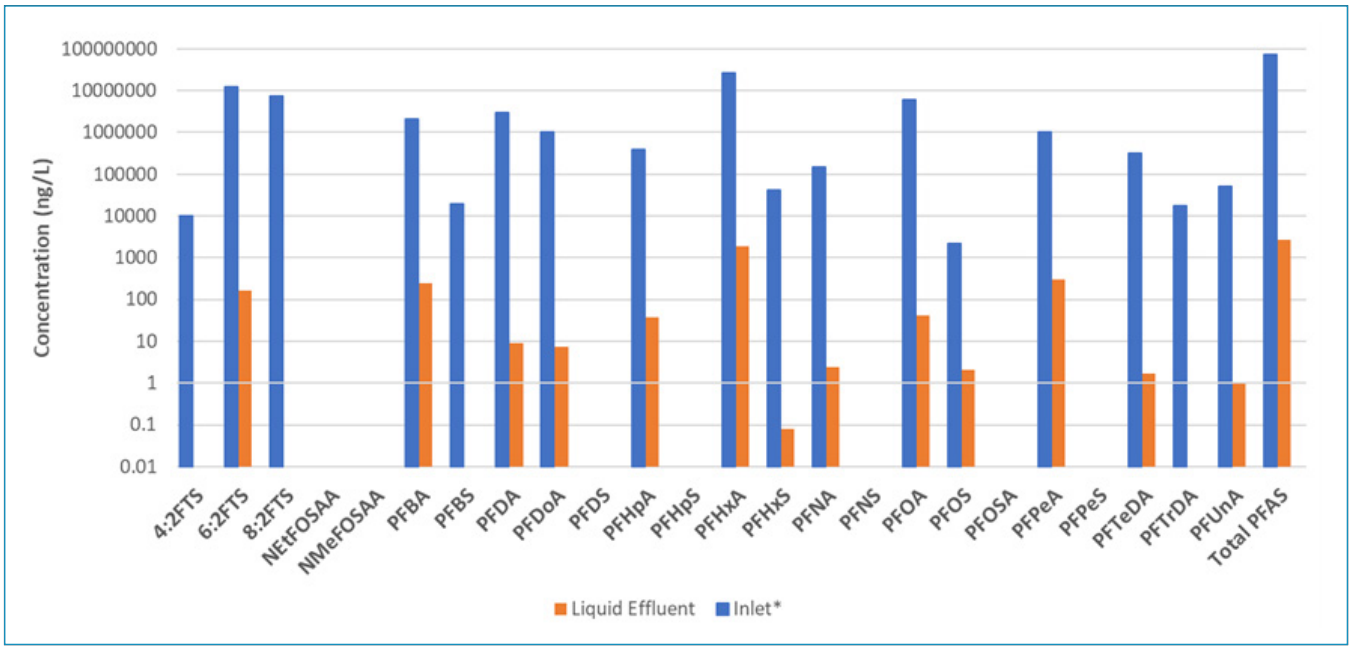
- Values above bars display effluent concentration of the compound in ng/L.
- Non-detectable effluent values are reported as 0.
- Non-zero effluent concentrations were detected below the limit of quantitation; the result displayed is an estimated value.
- Compounds without bars had non-detectable inlet and effluent concentrations.

Sample	Inlet PFOA (ng/L)	Effluent PFOA (ng/L)	Inlet PFOS (ng/L)	Effluent PFOS (ng/L)	% Destruction Target PFAS
Site 1	17,590	3.16	221,300	< 5	99.998
Site 2	16,820	< 5	207,800	17.8	99.996
Site 3	20.62	< 5	369.0	9.51	92.601
Site 4	33.00	1.68	190.0	7.03	98.751
Site 5	59.20	2.51	80.20	9.51	98.334
Site 6	4,849	0	318,002.3	0	99.999939

Concentrated AFFF

We have successfully destroyed several types of concentrated AFFF, with the only dilution required being the oxidant added, achieving up to a 99.99% destruction of PFAS. See the tables below for details.





AFFF Source	Total PFAS (ppb)	Total Organic Carbon (ppm)	Nominal Dilution Factor	Feed Flowrate (ml/min)	H_2O_2 Flowrate (ml/min)	Vapor Flowrate (L/min)	Post-Destruction PFAS (ppb)	% Annihilation
1	13,285	26,500	1:1.63	53.3	86.7	17.9	0.31	99.99
2	13,567	126,000	1:1.45	53.3	82.8	NA	3.08	99.99
3	7,556	124,000	1:2.69	37.9	102	21.3	1.52	99.97

Destruction of GAC Regenerant

We also have developed a technology to regenerate activated carbon and have demonstrated destruction of the resulting regenerant. Blending the organic regenerant with PFAS-impacted water leverages the heating value of the regenerant and has the potential to reduce operating costs.

Run	Inlet PFAS (ng/L)	Effluent PFOA (ng/L)	PFAS Percent Reduction (%)
Field Sample CG-9	32.2	17.6	24.3
1:20 GAC Regen to CG-9	16,900	15.8	99.9
1:15 GAC Regen to CG-9	17,800	17.6	99.9