DRAFT SERDP 2025 Workshop – poster abstract submittal

General Info

Poster title: From Demo to Field: Comparison and Evaluation of Supercritical Water Oxidation (SCWO) Systems for PFAS Destruction

Proposing Organization: Bay West LLC

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Abstract:

Removal of per- and polyfluoroalkyl substances (PFAS) from impacted sources is of increasing interest to impacted Department of Defense (DoD) facilities, communities, and environmental systems. Many existing treatment approaches—such as foam fractionation, granular-activated carbon, or ion exchange resin—transfer and concentrate PFAS but do not destroy the carbon-fluorine bonds responsible for the molecules' persistence in the environment. This research encompasses two years of study using Supercritical Water Oxidation (SCWO) to test destruction of target PFAS compounds.

Bay West created a research design focusing on SCWO system efficiencies to destroy PFAS compounds in a variety of test materials. Research was conducted using both a permanent demonstration unit and a full-scale field deployed unit, allowing comparison of results at test and field scales. Research design and study conditions addressed the overarching study objectives: 1) Replicate a range of optimal operating conditions determined at the test facility in the field; 2) Compare demonstration unit and field scale results using PFAS destruction and removal efficiency (DRE); and 3) Evaluate operational costs. Conducted under a U.S. Army Corps of Engineers – Engineer Research and Development Center (USACE-ERDC) contract, the research used the General Atomics (GA) PERSES™ system to assess PFAS destruction while processing foam fractionation concentrates from groundwater and leachate treatment sites and aqueous film-forming foam (AFFF) from Minnesota fire departments.

The PERSES™ system operates at conditions suitable for organic chemical destruction, typically between 600–700 degrees Celsius (°C) and 175–230 Bar. At these conditions, the carbon-fluorine bond within a PFAS molecule will disassociate, allowing for oxidation to form carbon dioxide, water, and inorganic acids like hydrogen fluoride. Sodium hydroxide is added to neutralize these acids and prevent them from traveling through the system. A PERSES™ process schematic is provided in **Figure 1** of the attached supporting information.

Analytical methods were selected to evaluate destruction of PFAS target compounds in the different materials and to define a range of optimal operational conditions. A variety of analytical methods were used over the two-year research period and included U.S. Environmental Protection Agency (EPA) Method 1633 (pre- and post- total oxidizable precursor analysis) for aqueous samples, Method TO-13 for PFAS in air, EPA Method OTM-45 for PFAS in air, and EPA Method OTM-50 for volatile fluorinated compounds (VFCs) in air. These methods were implemented to develop an understanding of the total PFAS and PFAS precursors in various

PFAS waste media and throughout the SCWO destruction process, and to validate that PFAS is in fact destroyed via SCWO and not simply transformed to other PFAS or VFCs, or transferred from aqueous to gaseous media. Comparisons of effluent air data from methods TO-13 and OTM-45 are presented in **Figures 2 through 6** of the supporting information.

The demonstration unit phase of the research design was conducted at GA's permanent PERSES™ unit in San Diego, California, from October 2023 to June 2024 across three separate testing events. During these events, the efficacy of PFAS destruction for AFFF, surface-active foam fractionation (SAFF), and landfill leachate was evaluated. Research conditions were designed to explore how influent PFAS concentrations, reactor temperatures, waste feed flow rates, and auxiliary fuel types affect PFAS DRE and operational costs. Results from the demonstration unit were used to determine operational parameters for the field scale implementation in 2025.

The full-scale field implementation was completed in the City of Lake Elmo, Minnesota, between April and June 2025, and used a transportable version of the GA PERSES™ system with the same general construction as the permanent demonstration unit located in San Diego. Electrical supply for the system was provided by portable diesel-powered generators. The system's dilution and quench water was supplied by the City of Lake Elmo and was tested for PFAS and other analytes such as metals and anions. Permits were completed for the field-scale system in accordance with City of Lake Elmo regulations and included a site grading permit for construction of a gravel pad on which to stage the equipment, fencing and signage permits, and a temporary heating permit for the aboveground diesel fuel tank used to supply diesel to the system. Testing was completed using the same AFFF mixture used for the San Diego demonstration, as well as SAFF concentrate from a local groundwater treatment pilot study, and foam fractionation concentrate derived from landfill leachate, provided by a local landfill.

Testing showed that altering system influent flow rates and using alternate fuels (ethanol and acetone) had the least impact on PFAS DRE. Tests with temperatures less than 650°C, or total influent PFAS mass flow rates above 350 milligrams per minute (mg/min) and below 100 mg/min, were identified as having the lowest DREs. **Table 1** in the supporting information details operational parameters and corresponding effects on PFAS destruction. When temperatures were at or above 650°C and total influent PFAS mass flow rates were between 100 and 250 mg/min, PFAS DREs greater than 99.999% were achievable. **Figure 7** and **Table 2** of the supporting information provide DREs from all tests.

No VFCs were detected using method OTM-50 for effluent air, further supporting the conclusion that PFAS are destroyed by the SCWO process and do not form VFCs as biproducts. Fluorine mass balances were conducted for select tests to verify that the analytical methods used were sufficient for tracking total fluorine through the system and ensure that there were no fluorine losses to the system (i.e., mineralization and deposition of fluorine-containing salts). Results of these fluorine mass balances are presented in **Table 3.**

Field scale testing achieved higher DREs than tests completed using the demonstration unit; destruction is estimated at >99.999% for four of the six test runs for the field implementation.

Current laboratory limits of detection and available data resolution (significant figures) provided by the lab prevent accurate calculation of DREs greater than 99.999%.

Costs at both the San Diego demonstration unit and Lake Elmo field unit were primarily attributed to energy from high pressure air compressors and diesel usage. Energy usage at the San Diego demonstration unit was approximately 418 kilowatt hours, and total hourly operational costs (including diesel, propane, water, sodium hydroxide, etc.) were approximately $150/hour. A full cost breakdown is provided in **Table 4** of the supporting information. Based on preliminary data, the field unit had comparable energy usage and is likely to have a similar total hourly operational cost.

Supporting Information

From Demo to Field: Comparison and Evaluation of Supercritical Water Oxidation (SCWO) Systems for PFAS Destruction

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The following graphics and tables are provided in support of the referenced Bay West LLC Poster Abstract submittal to the SERDP DOD Applied Innovation Workshop 2025.

Figure 1 – PERSES^{TM} Process Flow Diagram

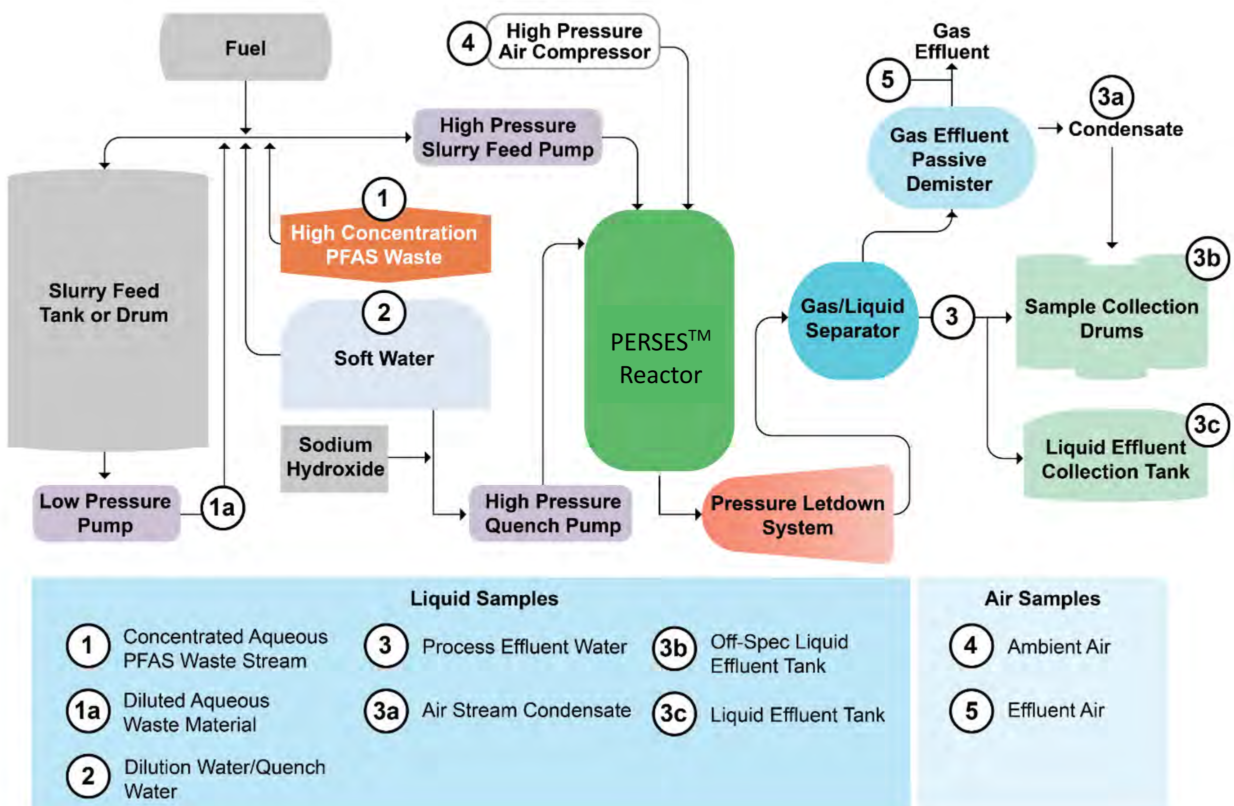

Figure 2: OTM-45 vs TO-13 PFAS Mass Flow Results

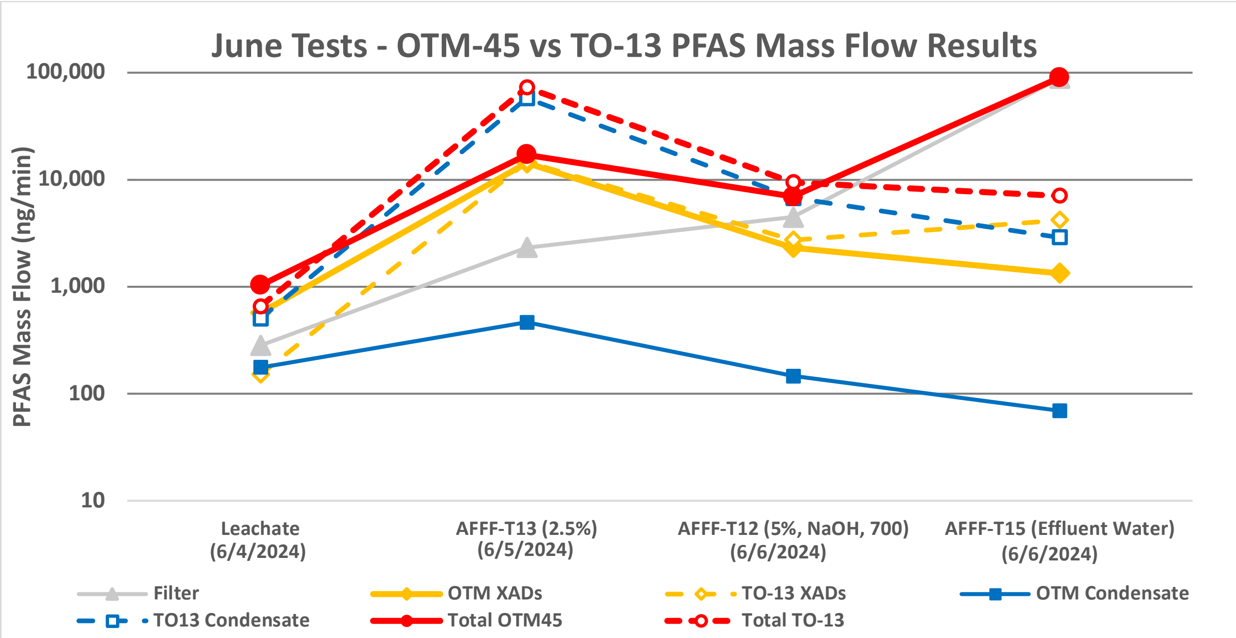

Figure 3: Leachate Test TO-13 Effluent Air + Condensate Results (ng/min)

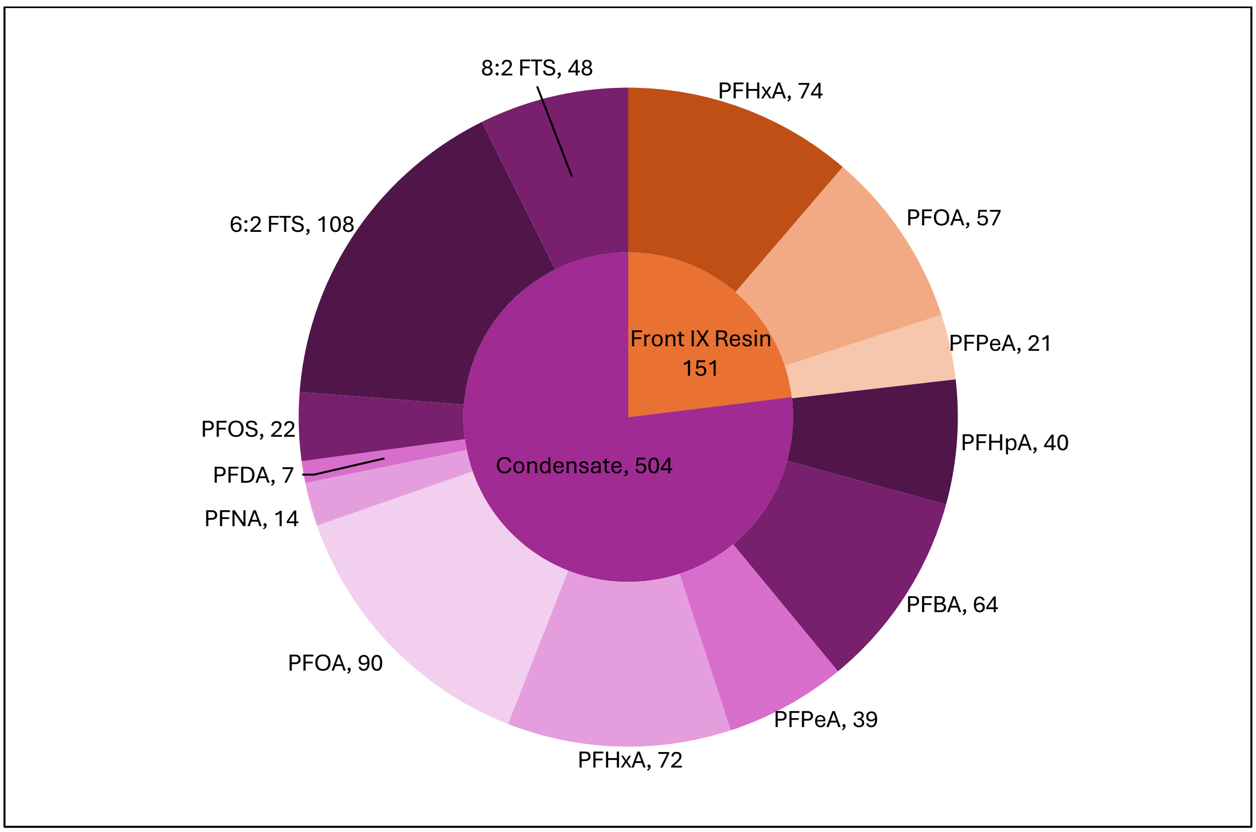

Figure 4: Leachate Test OTM-45 Effluent Air Results (ng/min)

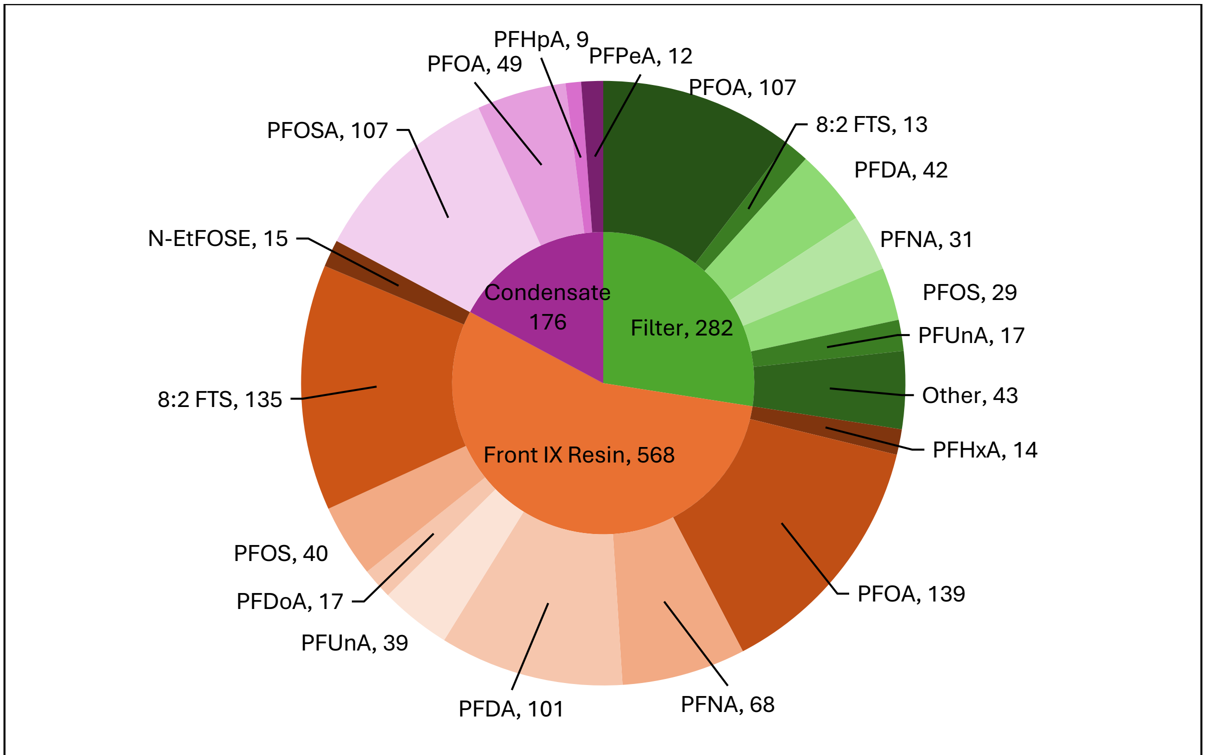

Figure 5: AFFF-T12 TO-13 Effluent Air + Condensate Results (ng/min)

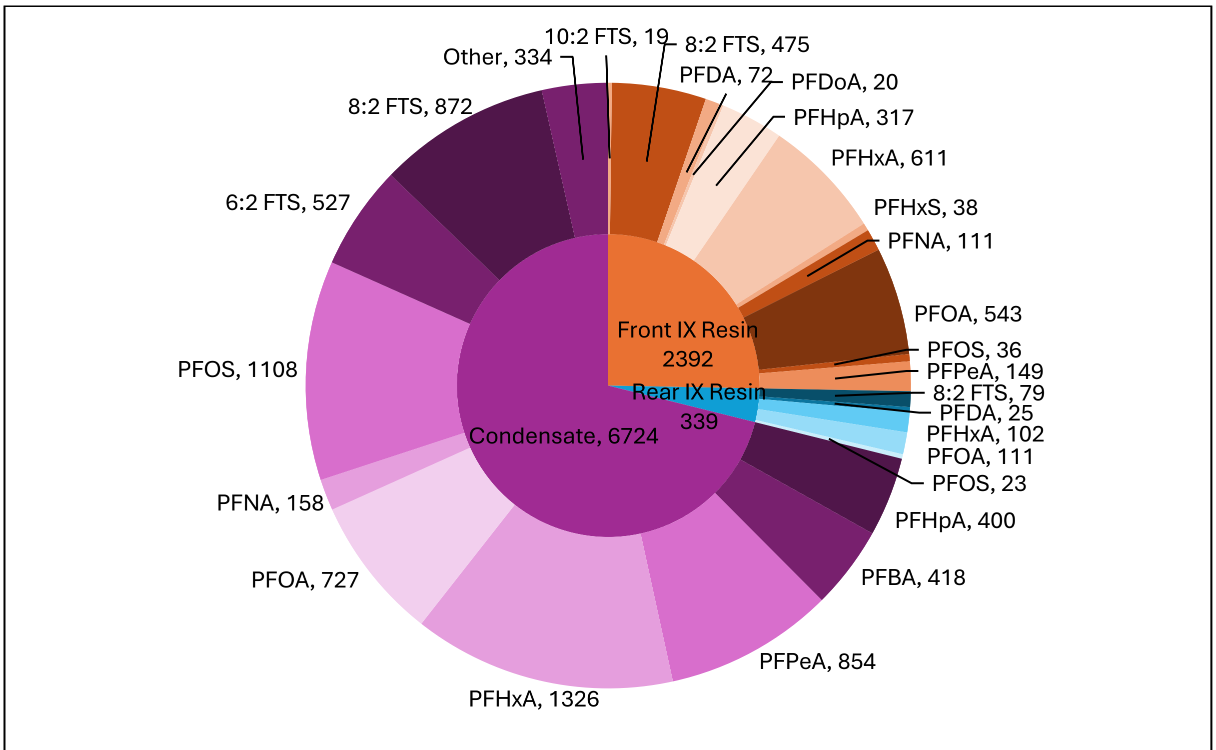

Figure 6: AFFF T-12 Effluent Air OTM-45 Results (ng/min)

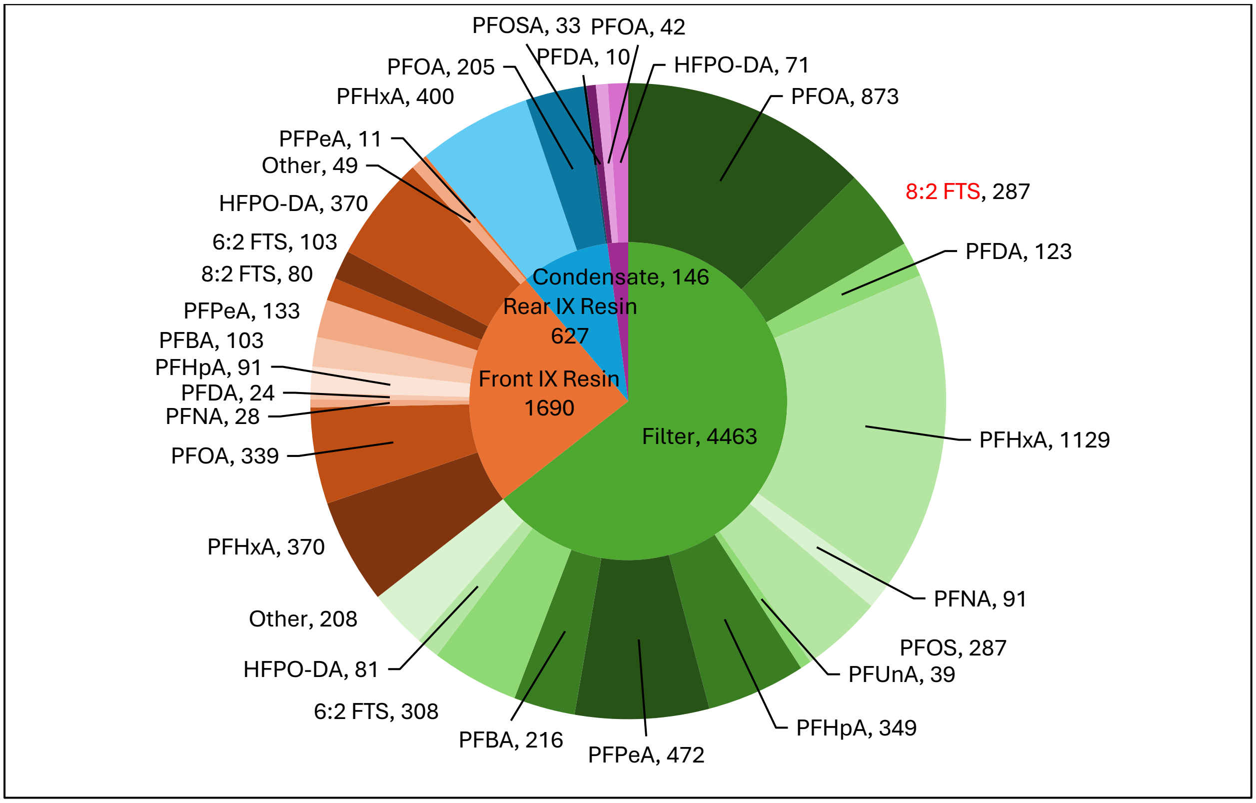

Figure 7: Influent PFAS Mass Flow vs Destruction Removal Efficiency

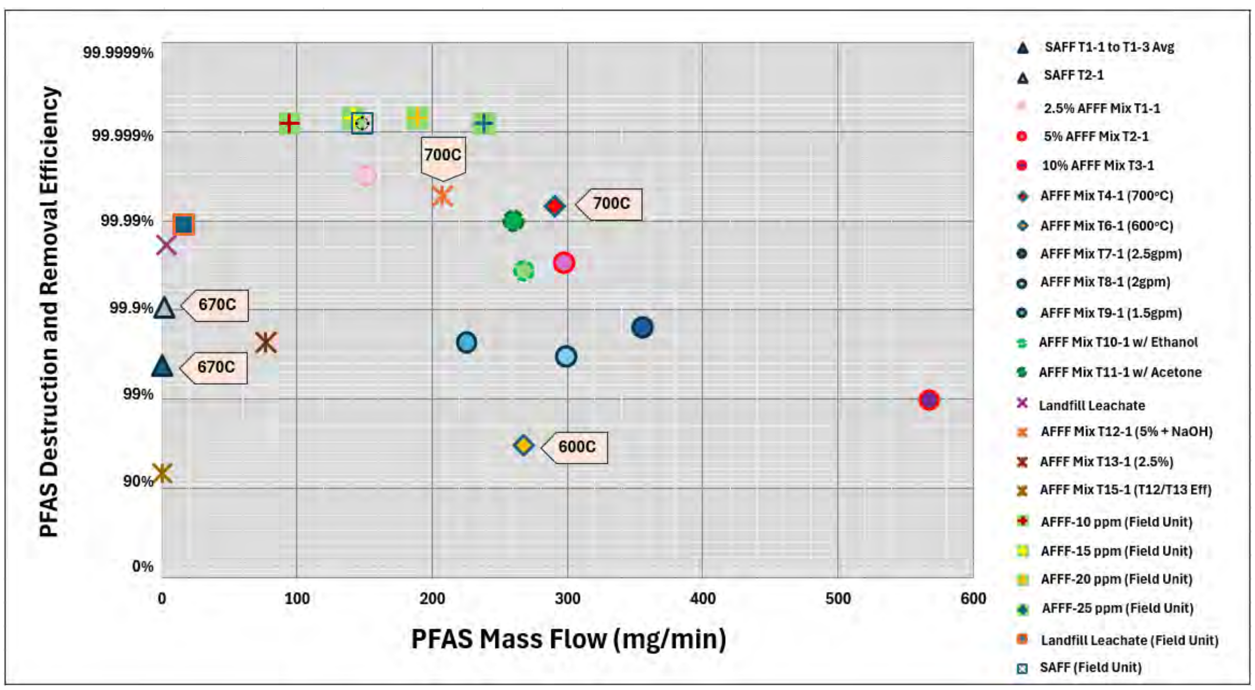

Table 1: PERSES™ Variables Affecting DRE and Optimal System Performance

Variables	Details	Optimal Range	Correlation With DRE Identified
Operator Controlled			
Influent Mass Flow	Controlled by adjusting concentration and flow rate	140-200 mg/min	X
Reactor Temperature	Set point programmed by operator	650°C +	X
Analytical Methods	Different analytical methods have different sensitivities, and affect calculated DRE	--	X
System Controlled			
Total Process flow	System automatically adjusts to maintain reactor conditions	--	
Diesel Flow	System automatically adjusts to maintain reactor conditions	If the waste material being processed has sufficient BTU content, less diesel is required to maintain appropriate reactor temperatures.	
Reactor Pressure	System automatically adjusts to maintain reactor temperature	Once supercritical conditions met, pressure is ancillary to temperature	
Reactor Residence Time	Dependent upon other reactor conditions and total process flow	--	
Air flow from compressor	System automatically adjusts to maintain reactor conditions	--	
Quench feed rate	System automatically adjusts to maintain reactor conditions	--	
Miscellaneous Variables			
Site access/ location	Site modifications may result in higher costs	--	
Water Chemistry	PFAS concentrations and water quality of process and quench water can affect system performance and calculated DREs	Hard process water can increase mineralization/deposition within the system, which can decrease reaction (destruction) efficiency	X
Power availability	System requires stable power supply	420 kW-hrs	

Notes:
°C = degrees Celsius; BTU = British thermal unit; DRE = destruction removal efficiency; kW-hrs = kilowatt hours; mg/min = milligrams per minute

Table 2: Summary of DREs for All Completed Tests

Test	Reactor Temp (°C)	Influent Mass Flow (mg/min)	DRE
San Diego Demonstration Unit			
SAFF T1-T3 AVG	674.7	0.67	99.581%
SAFF T2-1	669.9	2.03	99.906%
2.5% AFFF Mix T1-1	650.2	151.12	99.997%
5.0% AFFF Mix T2-1	650.3	297.23	99.971%
10% AFFF Mix T3-1	649.7	567.38	98.987%
AFFF Mix T4-1 (700 °C)	700.4	290.57	99.993%
AFFF Mix T6-1 (600 °C)	600.6	267.63	96.676%
AFFF Mix T7-1 (2.5 GPM)	650.4	354.75	99.846%
AFFF Mix T8-1 (2.0 GPM)	651.0	298.42	99.669%
AFFF Mix T9-1 (1.5 GPM)	651.6	225.58	99.774%
AFFF Mix T10-1 w/ Ethanol	650.0	267.63	99.964%
AFFF Mix T11-1 w/ Acetone	650.2	260.39	99.990%
Landfill Leachate	650.6	3.71	99.981%
AFFF Mix T12-1 (5% + NaOH)	694.9	207.18	99.995%
AFFF Mix T13-1 (2.5% Mix)	650.0	76.41	99.769%
AFFF Mix T15-1 (T12/T13 Eff)	650.4	0.22	93.201%
Lake Elmo Field Unit			
AFFF-10 ppm	649.1	94.37	>99.999%
AFFF-15 ppm	650.4	141.55	>99.999%
AFFF-20 ppm	649.0	188.73	>99.999%
AFFF-25 ppm	649.8	237.80	>99.999%
Landfill Leachate	649.2	16.34	99.9890%
SAFF	651.3	148.45	>99.999%

Notes:
°C = degrees Celsius; AFFF = aqueous film-forming foam; DRE = destruction removal efficiency; GPM = gallons per minute; mg/min = milligrams per minute; SAFF = Surface Active Foam Fractionation
All DRE values are based on effluent results from TO-13 air sampling and aqueous samples analyzed via Method 1633

Table 3: DRE Comparison with AOF Percent Reduction and TF Mass Balance Ratio

Test	DRE - 1633 Pre-TOPs + TO-13	AOF % Reduction	TF out/TF in
San Diego Demonstration Unit			
AFFF-T3-1	98.9867%	99.68%	2.43
AFFF-T9-1	99.7740%	95.44%	2.62
AFFF-T10-1	99.9639%	99.66%	2.19
AFFF-T11-1	99.9901%	99.75%	2.06
LEACH-T1-1	99.9795%	88.64%	1.29
AFFF-T12-1	99.9958%	99.20%	0.68
AFFF-T13-1	99.8136%	N/A	0.45
AFFF-T15-1	93.2389%	88.19%	0.20
Lake Elmo Field Unit			
AFFF-10 ppm	>99.999%	99.92%	0.69
AFFF-15 ppm	>99.999%	99.81%	0.79
AFFF-20 ppm	>99.999%	99.87%	0.92
AFFF-25 ppm	>99.999%	99.86%	0.89
SAFF	>99.999%	99.31%	1.19

Notes:
% = percent; AFFF = aqueous film-forming foam; AOF = Adsorbable Organic Fluorine; TF = total fluorine

Table 4: ERDC Demonstration Unit PFAS Destruction Tests Material & Energy Cost Summary

Material	Average Hourly Use	Unit Price[1]	Unit Price Date[2]	Estimated Hourly Cost	Notes
Water	304.49 gal/hr	$0.006/gallon	2025	$1.70/hr	
Diesel	21.08 gal/hr	$3.51/gallon	1/26/2025	$73.97/hr	
5% NaOH	0.36 kg/hr	$15.96/kg	1/27/2025	$5.67/hr	Price includes shipping
Propane	5.15 gal/start	$1.21/gallon	1/20/25	$6.21/start	Propane only used at start-up
Electricity	418.56 kW-hr	$0.17/kW-hr	12/24/24	$69.48/hr	
Average Hourly Material & Energy Cost (less start-up Propane)				**$150.82/hr**	

Notes:
Qty = Quantity; gal/hr = gallons per hour; kg = kilograms; kg/hr = kilograms per hour; kW-hr = kilowatt-hour
1 = Source of Unit Prices:
Water: https://www.minneapolismn.gov/resident-services/utility-billing/rates-fees/
Diesel: https://gasprices.aaa.com/?state=MN#state-metro
5% NaOH: https://alliancechemical.com/products/sodium-hydroxide-50-solution-acs-grade?variant=41291577622570
Propane: https://www.eia.gov/dnav/pet/pet_pri_wfr_dcus_smn_w.htm
Electricity: https://www.bls.gov/regions/midwest/data/averageenergyprices_selectedareas_table.htm
2 = Date unit price data were determined or effective per the sources listed above

SERDP Poster Citations

[1] McDonough, J. T., Kirby, J., Bellona, C., Quinnan, J. A., Welty, N., Follin, J., & Liberty, K. (2022). Validation of supercritical water oxidation to destroy perfluoroalkyl acids. Remediation Journal, 1–16. https://doi.org/10.1002/rem.21711

[2] Scheitlin, C. G., Dasu, K., Rosansky, S., Dejarme, L. E., Siriwardena, D., Thorn, J., … Stowe, J. (2023). Application of Supercritical Water Oxidation to Effectively Destroy Per- and Polyfluoroalkyl Substances in Aqueous Matrices. *ACS ES&T Water*, *3*(8), 2053–2062. doi:10.1021/acsestwater.2c00548

[3] Pusey, L. A. (2023). Super-critical Water Oxidation Special Study: Final Report. US Army. https://apps.dtic.mil/sti/trecms/pdf/AD1203630.pdf

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[9] United States Environmental Protection Agency. (2025). Final PFAS National Primary Drinking Water Regulation. Per- and Polyfluoroalkyl Substances (PFAS) | US EPA