Engineered Technologies for Management of PFAS on Army Installations

FACT SHEET: General Atomics Industrial Supercritical Water Oxidation (iSCWO) for Destruction of Per- and Polyfluoroalkyl Substances (PFAS)

Technology Demonstrated:
The Engineer Research and Development Center (ERDC) coordinated demonstration and validation efforts to investigate the destruction of PFAS using different mature and commercially-available technologies. General Atomics demonstrated their industrial supercritical water oxidation system (iSCWO) on 100 gallons of AFFF-concentrate from 13-17 May 2024. General Atomics was founded in 1955 for research/development and focuses on solving problems in energy, defense, aircraft, and various commercial endeavors.

Background / Problem Statement:
Disposal of AFFF concentrate presents a challenging issue to land managers on military installations due to the toxic and recalcitrant nature of PFAS. Destruction of PFAS represents an attractive option that may have benefits over disposal given successful performance of destructive technologies available. The 100-gallon AFFF concentrate pilot study performed by ERDC with demonstration of iSCWO (Fig 1; General Atomics) highlights current capabilities of industry for destroying PFAS.

Figure 1. Transportable PFAS destruction system (General Atomics).

Approach:
100 gallons of AFFF concentrate (consisting of Lightwater 3% by 3M and Ansulite 1% by Ansul, homogenized) was processed through the iSCWO system (General Atomics) during 13-17 May 2024 (Fig 2). Comprehensive technical data on energy consumption, water usage, and effluent chemistry were compiled and performed to achieve a comprehensive picture of the degradation of PFAS including remaining target analytes, non-target screening, volatile PFAS, fluoride, and total organic fluorine. Percent reductions in the effluent were calculated and multiple tests were performed, overall.

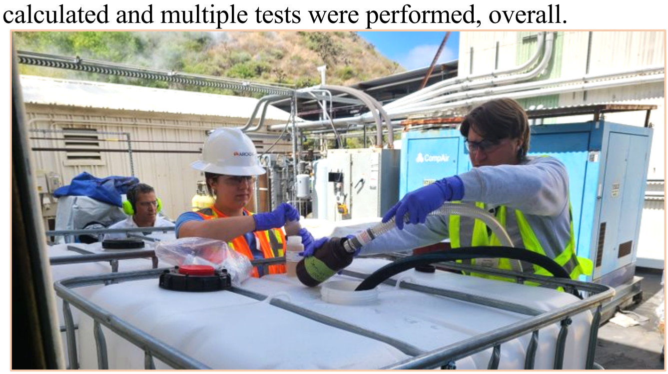


Figure 2. Collection of treated effluent for PFAS analysis.

Benefit to the Army / Return on Investment:
Per- and polyfluoroalkyl substances represent a burden for the Department of Defense (DOD) due to aqueous firefighting foam (AFFF) trainings on military bases. Providing the Army with cost-effective technologies that can destroy PFAS will aid to decrease overall burden and provide implementation guidance for characterization, removal, and destruction of PFAS contaminated materials.

Results – PFAS Destruction:
The treated effluent was measured for level of target PFAS degradation and final concentrations, including hourly and daily degradation. The main findings show complete destruction is feasible as indicated by the % reduction percentages (Fig 3). Overall, significant destruction of the PFAS analytes studied occurred using AFFF concentrate feed rates at 0.195 L/min and 1 L/min.

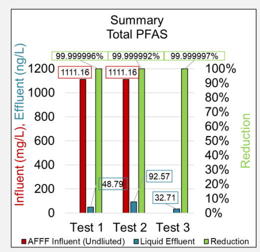
General Atomics (iSCWO)
100-gallon demonstration

GA iSCWO performed 3 test
1) AFFF concentrate feed at 0.195 L/min
2) AFFF concentrate feed at 1 L/min
3) Reprocessing of test 1 & 2 effluent at 7.7 L/min

- Achieving 99.999997% reduction in PFAS in final liquid effluent.
- Analysis of stack emissions suggest some potential loss of volatiles, but results may be confounded as a consequence of moisture in sampling stream.

	Test 1		
	Influent (mg/L)	LE (ng/L)	Reduction
PFOS	0.139	4.09	99.997060%
PFOA	31.9	1.99	99.999994%
PFHxS	0.056	1.97	99.996488%
PFBS	0.177	3.02	99.998296%
8:2 FTS	0.022	2.27	99.989692%
6:2 FTS	0.084	7.10	99.991552%
PFHxA	198	8.93	99.999995%
PFBA	194	2.60	99.999999%

	Test 2		
	Influent (mg/L)	LE (ng/L)	Reduction
PFOS	0.139	4.38	99.996847%
PFOA	31.9	1.27	99.999996%
PFHxS	0.056	1.24	99.997779%
PFBS	0.177	3.21	99.998184%
8:2 FTS	0.022	4.92	99.977621%
6:2 FTS	0.084	6.85	99.991844%
PFHxA	198	11.56	99.999994%
PFBA	194	6.51	99.999997%



✔ Bench Scale Optimization

✔ 100-gal field demonstration

⊖ Larger volume field demonstration

Figure 3. Results from the 100-gallon destruction pilot study.

Results – Gaseous Effluents:
The potential for mass transfer of PFAS lost to the gas stream was also monitored as any introduction of PFAS to the environment through stack emissions would not be ideal. Volatile PFAS analysis of the stack emissions for this demonstration suggest mass loss in the form of PFOA at an average concentration of 202 ng/m^3 for the three tests, using OTM-45 analysis. Additionally, there were PFHpA, PFHxA, PFNA, PFDA, PFOS, and other compounds present at average concentrations less than 10 ng/m^3. OTM-50 analysis determined all PFAS concentrations were below detection.

Results – Demister Condensate:

The demister is used to separate liquid droplets from the gas stream and the effluent in the demister was found to contain 21 of the 33 USEPA Method 1633 analytes for all three tests. Total PFAS found ranged from 3,202 to 9,315 ng/L versus the liquid and exhaust effluents, which ranged from 39 to 626 ng/L. Therefore, the demister is considered to capture more volatile PFAS precursors than the liquid and exhaust effluents.

Results – Treatment Costs:

The costs associated with the treatment/mobilization of the technology were captured to ensure adequate planning would be known for implementation. Primary costs assessed included labor, transportation, equipment service, utility requirements, and consumables. The primary electricity and fuel consumption needed for the three tests is shown in Table 1. Additionally, the overall energy consumed per mass of PFAS destroyed in shown in Table 2. Here, it is important to note that for test 3, there were lower PFAS concentrations in the influent material, therefore the dollar amount per mass destroyed is significantly larger.

	Diesel (L)	Diesel (kWh)	Compressor (kWh)	System (KWh)
Test 1	557	6,165	2.84	77.68
Test 2	400	4,427	2.84	71.35
Test 3	343	3,796	2.84	84.00

Table 1. Electricity and fuel average requirements for the tests.

Additionally, the overall energy and costs consumed per mass of PFAS destroyed in shown in Table 2. Here, it is important to note that for test 3, there were lower PFAS concentrations in the influent material, therefore the dollar amount per mass destroyed is significantly larger while the operational costs for diesel and power remain similar to the other tests.

	Energy Needs (kWh/g)	Associated Costs ($/g)
Test 1	4.38	0.92
Test 2	6.82	1.43
Test 3	20,597	4,325

Table 2. Energy and costs consumed per mass of PFAS removed.

Mobilization/Demobilization Logistics:

The General Atomics iSCWO system combines organic materials with water, fuel, and air at 650°C to 700°C and 3,200 pounds per square inch in a continuous-flow reactor.

Figure 4. Picture showing the General Atomics iSCWO system on-site.

The main transportation needs for the iSCWO system requires two flatbed trucks and additional crates for pumps, tubing, and spare parts. Due to weight requirements, cranes are needed for loading of the system. Shipment locations could include the lower 48 states; difficulties and additional costs would arise for shipments to Alaska and Hawaii. Once the system arrives on site, cost of utilities would be covered by some other entity. An estimated expense of 1 month (20 working days), assuming average U.S. labor, fuel, and electricity costs), equates to $297K for the temporary deployment and $6.0-6.5M for permanent operations.

Permanent (or Long-term) Installation:

To use this destruction technology long-term or in a permanent site location, the anticipated cost is approximately $4.0M and the high-pressure air compressor is an additional $2.0M, which altogether includes fabrication, factory acceptance testing, shipping, site installation, and a 2-week training session on safety and operations and recommendations. The system can run 24 hours per day with 300 gallons processing rate of AFFF per day, expected.

Lessons Learned and Future Work:

- Future sampling should include total precursor oxidative assay (TOPA) on the gas sample condensates and not just the incoming and outgoing liquid streams.
- It may be practical to add a post-treatment option to future reduce PFAS concentrations to below the maximum contaminant levels (MCLs) or non-detects (NDs), including activated carbon, ion exchange beads, or reverse osmosis.
- There are additional design scenarios not tested in this demonstration that may help in future operations, including elevated temperature treatments, the addition of solvents as an auxiliary fuel, or the addition of sodium hydroxide to encourage C-F bond cleavage.

Conclusions / Recommendations:

PFAS-containing AFFF stockpiles create liabilities with no currently approved cost-effective technologies for destruction for safe disposal. The system demonstrated by General Atomics (iSCWO) represents a promising technology for destruction of PFAS given the pilot-scale results from the 100-gallon dem/val performed by ERDC. This technology successfully removed 99.9913%, 99.9991%, and 98.6076% for Tests 1 through 3, respectively. The gaseous effluent did contain some PFOA in higher concentrations (202 ng/m^3 on average) while PFHpA, PFHxA, PFNA, PFDA, PFOS, and other compounds were present at less than 10 ng/m^3 on average. In contrast, the demister contained 21 PFAS compounds at 3,202 to 9,315 ng/L versus the liquid and exhaust effluents, which ranged from 39 to 626 ng/L, capturing more of the volatile PFAS precursors.

Contact Information:

Engineered Technologies for Risk Mitigation and Management of PFAS on Army Installations

- Dr. John Erik Myrolie, Technical Lead (*John.E.Mylroie@usace.army.mil*)
- Dr. David Moore, Technical Advisor (*David.W.Moore@usace.army.mil*)