



Overview

A study conducted under the US Department of Defense (DoD) Strategic Environmental Research Program (SERDP) explored the application of smoldering combustion (STAR/STARx) to treat per- and polyfluoroalkyl substance (PFAS)-impacted soils and media.

Due to the high thermal stability of PFAS, temperatures greater than 700°C are required to destroy these compounds and temperatures at or above 1000°C are necessary to minimize production of short-chained volatile organic fluorines (VOFs) and fluorinated dioxins and furans (PFDD/F). Hydrofluoric acid (HF) will be produced in greater abundance, and VOF and PFDD/F in lesser abundance, with increasing completeness of PFAS combustion.

As the PFAS are not contaminants that can support smoldering combustion in and of themselves like hydrocarbons and coal tars, a surrogate fuel is required. This study examined treating: (1) PFAS-impacted soils amended with a surrogate fuel (e.g., granular activated carbon [GAC]); (2) PFAS-impacted liquid by absorbing the PFAS in the liquid to a solid surrogate fuel (e.g., GAC); and, (3) co-treatment of PFAS contaminated soils with PFAS containing GAC.

Conclusions

The overall conclusions of this proof-of-concept research are:

- GAC can be used to support smoldering combustion to achieve temperatures that destroy PFAS when added to soils at ~40 to 60 g/kg.
- PFAS absorbed to GAC or soils can be treated via smoldering combustion resulting in non-detectable levels in soils, sand and ash.
- HF was generated suggesting that complete decomposition of PFAS via smoldering combustion is possible.
- Some decomposition products may form that can be scrubbed from gas emissions using GAC.

Technical Approach and Results

This study was conducted in two phases. The first phase (Phase I) evaluated if GAC could smolder at the required temperatures (700°C to 1000°C) when mixed with sand, while the second phase (Phase II) examined the treatment of PFAS-impacted materials amended with a surrogate fuel by measuring: (1) PFAS concentration in soil before and after treatment; (2) PFAS in emissions; (3) and hydrofluoric acid (HF) concentrations as a measure of total mineralization of PFAS.

A total of eight column tests were conducted in Phase I. GAC was found to produce the required temperatures when mixed with sand between 40 and 60 g/kg, with higher GAC concentrations yielding higher average peak temperatures (IMAGE 1).

The first two Phase II tests (II-1 and II-2) examined treating three PFAS compounds, PFOA, PFOS, and PFHxS, absorbed to GAC at a target ratio of 40 g GAC/kg sand. As illustrated in Table 1, post-smoldering concentrations of all compounds were ND at a detection limit of 0.4 µg/kg.

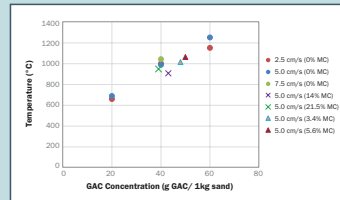


IMAGE 1: Average Peak Temperature as a Function of GAC Concentration, Injected Air Flux and Moisture Content.

TABLE 1: Tests II-1 and II-2 Pre- and Post-Treatment PFAS Concentrations

PFAS	Test II-1		Test II-2	
	Pre	Post	Pre	Post
PFOA	590,000	<0.4	510,000	<0.4
PFOS	140,000	<0.4	120,000	<0.4
PFHxS	240,000	<0.4	220,000	<0.4

Notes:

All Results in µg/kg
D.L. 0.4 µg/kg

Test II-3 and II-4 used a surrogate soil mixture with a known organic fraction on which the PFAS compounds were absorbed. Test II-3 examined the treatment of the same three PFAS compounds used in tests II-1 and II-2, and Test II-4 used six PFAS compounds (PFOA, PFOS, PFHxS, PFNA, PFBS, PFHpA). In test II-3, all PFAS was removed from the soil (N.D. at a detection limit of 0.5 µg/kg) with 82% of the available fluorine captured as HF. In test II-4, PFAS was non-detect after treatment; however, some PFAS was detected in the emissions. Emitted PFAS could be captured in an off-gas GAC treatment system, however, and the GAC subsequently used/treated by smoldering.

TABLE 2: Tests II-3 Pre- and Post-Treatment PFAS Concentrations

Sample	PFAS (mg/kg)		
	PFHxS	PFOA	PFOS
Blank Soil	N.D.	N.D.	N.D.
PFAS Loaded Soil	16.86	13.41	23.3
Loaded Soil with Sand & GAC	7.06	6.14	9.54
Post-Treatment Ash/Soil	N.D.	N.D.*	N.D.

Notes:

*2 of 3 samples were non-detect for all 3 PFAS compounds. 1 sample had a measured PFOA concentration of 0.0002 mg/kg
N.D. = not detected at Detection Limit of 0.00005 mg/kg

TABLE 3: Tests II-4 Pre- and Post-Treatment PFAS Concentrations

Sample	PFAS (mg/kg)					
	PFBS	PFHpA	PFHxS	PFOA	PFNA	PFOS
Blank Soil	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PFAS Loaded Soil	3.19	13.32	10.84	14.91	28.73	10.87
Loaded Soil with Sand & GAC	1.3	9.75	7.21	11.49	25.58	6.67
Post-Treatment Ash/Soil	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Notes:

N.D. = not detected at Detection Limit of 0.0005 mg/kg