Smoldering Combustion Treatment of PFAS-Impacted Materials

SERDP Project Number: ER18-1593

Overview

A study conducted under the US Department of Defense (DoD) Strategic Environmental Research Program (SERDP) explored the application of smoldering combustion (STAR) 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.

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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 PFAS concentration in soil/ash 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 ug/kg.

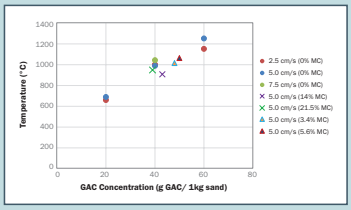

IMAGE 1: Average Peak Temperature as a Function of GAC Concentration, Injected Air Flux and Moisture Content.

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 ug/kg
D.L. 0.4 ug/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 ug/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