Immobilization of Per- and Polyfluorinated Alkyl Substances (PFAS) in 14 Soils from Airport Sites across Australia

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Introduction

Aqueous Film Forming Foams (AFFFs) are a class of fire-fighting foams that contain per- and polyfluoroalkyl substances (PFAS). In 2009, perfluorooctane sulfonic acid (PFOS) was listed as a Persistent Organic Pollutant (POP) by the Stockholm Convention due to its potential toxicity effects, persistency, and bioaccumulation and biomagnifying properties. PFASs are generally soluble in water and so tend to readily leach from contaminated soil into groundwater, thus posing a potential risk to human health and ecological receptors.

In this study, 14 AFFF-impacted soils from fire training grounds in Australia were assessed in terms of their PFAS leachability characteristics under different environmental conditions. The ability of a novel aluminium hydroxide-based adsorption product, RemBind Plus, to reduce PFAS leachability in these soils was also tested.

Figure 1: PFAS impacted soil being treated with RemBind

Methods

The 14 test soils were air-dried, de-agglomerated, screened and thoroughly homogenized before analysis. Duplicate samples of each soil were sent to Australian Laboratory Services (ALS) and analyzed for an extended suite of 20 PFAS compounds, including PFOS and perfluorooctanoic acid (PFOA), using LC-MS/MS for total concentrations (mg/kg) and leachable concentrations (µg/L). Leachates were prepared using the Toxicity Characteristic Leaching Procedure (TCLP; USEPA Method 1311) or the Australian Standard Leaching Procedure (ASLP) at pH 5.

Based on the initial analysis, duplicate sub samples of each soil were treated with various addition rates of RemBind Plus and sent for leachability analysis as above. Selected samples were also analyzed using the stringent Multiple Extraction Procedure (MEP; USEPA Method 1320) simulating 1,000 years of acid rain in an improperly designed sanitary landfill.

Table 1: A summary of the PFAS leachability characteristics of 14 soils from fire training grounds in Australia

				PFAS Concentrations in Soil Leachates*								
				Before Treatment			After Treatment					
Site	Soil Type	Product	Product Addition Rate % (w/w)	PFOS mg/kg	PFOS µg/L	PFOA µg/L	PFOS µg/L	PFOA µg/L	Below NSW EPA Landfill Criteria? 50 µg/L**	PFOS Reduction %	Passed USEPA Method 1320?	PFOS/Total PFAS*** %
1	Silty clay loam	RemBind Plus	5.0	0.74	34	0.65	0.29	<0.02	Yes	99.20	Yes	86
2	Silty clay	RemBind Plus	7.5	2.24	376	5.6	0.1	<0.02	Yes	99.97	Yes	67
3	Clay	RemBind Plus	5.0	20.9	695	11	1.5	<0.02	Yes	99.80	nt	99
4	Clayey silt (organic)	RemBind Plus	10.0	3.15	38	1.17	1.9	<0.02	Yes	95.00	Yes	99
5	Sand	RemBind Plus	5.0	1.26	1	1	<0.02	<0.02	Yes	>98.00	nt	99
6	Heavy clay	RemBind Plus	5.0	3.01	87	1.54	<0.02	<0.02	Yes	>99.98	nt	nt
7	Silty sand	RemBind Plus	5.0	7.25	190	0.05	0.05	<0.02	Yes	99.97	Yes	99
8	Clayey loam	RemBind Plus	5.0	1.45	62.5	2.7	<0.02	<0.02	Yes	>99.97	Yes	98
9	Clay/gravel (spill)	RemBind Plus	10.0	184	4,780	222	3.52	0.21	Yes	99.90	Yes	nt
10	Clay/gravel	RemBind Plus	5.0	1.24	72	0.7	0.1	<0.01	Yes	99.90	nt	66
11	Heavy clay	RemBind Plus	5.0	0.67	36	1	0.1	<0.01	Yes	99.70	nt	40
12	Clay	RemBind Plus	5.0	0.78	43	0.6	0.1	<0.01	Yes	99.80	nt	57
13	Silty clay	RemBind Plus	2.5	nt	120	0.51	0.16	<0.02	Yes	99.90	nt	67
14	Silty clay	RemBind Plus	2.5	nt	184	1.84	0.2	<0.02	Yes	99.89	nt	67

* As prepared by TCLP or ASLP at pH 5
** NSW landfill guidelines stipulate a soil leachate criteria of 50 µg/L for PFOS + PFHxS for general solid waste
*** Ratio of total PFOS/total PFAS extended suite (20 analytes) run by Australian Laboratory Services

TCLP = Toxicity Characteristic Leaching Procedure
ASLP = Australian Standard Leaching Procedure
nt = not tested

Results and Discussion

- PFOS concentrations in the neat soil leachates varied from 1 to 376 µg/L, with an average concentration of 149 µg/L (Table 1). The exception was soil #9, which had a PFOS leachate concentration of 4,780 µg/L; this is consistent with the fact that this soil originated from a neat AFFF liquid spill.
- For 12 of the 14 soils, RemBind Plus addition rates of 2.5% to 7.5% by weight were sufficient to achieve a 95%-99% reduction in PFOS and PFOA concentrations in soil leachates. The other 2 soils required RemBind Plus doses of up to 10% to achieve the same reductions in PFAS concentrations probably because;
  - o Soil #4 had a high Total Recoverable Hydrocarbons content (57,000 mg/kg) which may have competed with PFAS for RemBind Plus binding sites.
  - o Soil #9 originated from a neat AFFF liquid spill and so had extremely high starting concentrations of leachable PFAS (4,780 ug/L).

Results and Discussion

- For 11 out of the 14 soils, final leachate concentrations after treatment with RemBind Plus were below the Minnesota Department of Health PFOS drinking water guideline of 0.3 µg/L. Leachate concentrations of PFOS in the other 3 soils ranged from 1.5 to 3.5 µg/L, which is still a magnitude below the New South Wales (Australia) landfill leachate guideline for general solid waste of 50 µg/L (PFOS + PFHxS).
  www.epa.nsw.gov.au/resources/wasteregulation/Addendum%201%20to%20the%20Waste%20Classification%20Guidelines.pdf
- All soils that were subjected to the rigorous MEP passed the test, indicating long-term stability in an acidic landfill environment.
- For all 14 soils, PFOS made up 40% to 99% of the total PFASs tested (20), and was always the dominant chemical; this indicates that the older style of firefighting foams (e.g. Light Water®), rather than the newer fluorotelomer-based foams, were most likely used at the source sites.

Conclusions

- This study proves the efficacy and long term stability of the binding reaction between RemBind Plus and PFASs in a wide range of soils from across Australia; this is particularly important proof given that immobilization is not a destructive technology.
- RemBind Plus provides a rapid, easy and low-cost solution for the safe off-site disposal of PFAS-contaminated soil. It also opens up the possibility of in-situ treatment options to reduce the source of groundwater contamination at airport fire training grounds.

Figure 2: Bulk RemBind being loaded for transport

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