Characterization and Management of Per- and Polyfluorinated Alkyl Substances (PFAS) Remediation Residuals

June 2022

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Report #

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ACKNOWLEDGEMENTS

This research was funded by the Hinkley Center for Solid and Hazardous Waste Management. We would like to thank the undergraduate students that helped with this project including Farid Ahmed, Ignacio Alejandro, and Keyla Virgilio along with Clarke Environmental for providing samples of AFFF-impacted soil. Additional funding and technical support were provided by the US Environmental Protection Agency Office of Research and Development. The researchers would also like to express appreciation for the efforts of the Technical Advisory Group for their contributions.

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LIST OF ABBREVIATIONS, ACRONYMS & UNITS OF MEASUREMENT

AFFF	Aqueous Film Forming Foam
CFC	Chlorofluorocarbons
EPA	Environmental Protection Agency
FDEP	Florida Department of Environmental protection
GAC	Granular Activated Carbon
HDPE	High-density Polyethylene
IS	Internal standard
LEAF	Leaching Environmental Assessment Framework
LOI	Loss on Ignition
MCL	Maximum contaminant levels
MS	Mass Spectrometry
MSW	Municipal Solid Waste
PCB	Polychlorinated Biphenyls
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutanoic sulfate
PFDA	Perfluorodecanoic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexanoic sulfate
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanic acid

PFOS	Perfluorooctane sulfate
PGCTL	Provisional Groundwater Cleanup Target Levels
PID	Products of Incomplete Destruction
QC	Quality Control
RSL	Regional Screening Level
SPLP	Synthetic Precipitation Leaching Procedure
SSL	Soil Screening Level
TC	Toxicity Characteristic
TCLP	Toxicity characteristic leaching procedure
UHPLC	Ultra-High-Pressure Liquid Chromatography
WWTP	Wastewater Treatment Plant

g	gram
kg	kilogram
L	liter
mg	milligrams
mg/kg	milligrams per kilogram
mL	milliliter
mL/g	milliliter per gram
mg/L	milligram per liter
pH	measurement of the hydrogen ion activity
µg/L	microgram per liter
ng	nanogram
ng/L	nanogram per liter

ABSTRACT

The historic use of PFAS-containing solutions in military and industrial sectors has resulted in the contamination of thousands of sites which continue to release PFAS into the environment through surface runoff and infiltration into groundwater. This study aims to compare established soil screening levels and to assess the use of bulking agents for the disposal of PFAS-containing liquid wastes. Recently, screening levels for soils have been developed at the state and federal level to help protect populations through either direct exposure or leaching into groundwater. These soil screening levels differ between regulatory agencies, highlighting the need to compare risk-based thresholds to laboratory leaching tests. Additionally, these newly developed soil screening levels will drive remediation efforts at PFAS impacted sites. However, information is lacking on how to best manage PFAS-containing remediation wastes such as contaminated soil, spent granular activated carbon (GAC), or used resins so that PFAS do not reenter the environment. This work provides a summary of the recently developed EPA and FDEP soil screening levels for PFAS and the current management strategies of remediation wastes. Significant leaching of PFAS was observed from AFFF-impacted soils which underwent EPA leaching methods 1316 and 1313. This leaching data was compared to predicted leaching values derived from a risk analysis used to compute values for EPA's regional screening levels and Florida's provisional cleanup target levels; EPA's values used to model the expected release of PFAS from soil to groundwater matched closely with laboratory leaching data while FDEP's model underestimated the true leaching of PFAS. The management of PFAS-containing liquid wastes was investigated through the leaching of AFFF and PFAS-impacted remediation wastewaters which had undergone stabilization/bulking. Results of this showed that different bulking agents such as cement, biochar, sawdust, and bentonite clay had impacts on the leachability of total PFAS. These results are consistent with previous studies which have investigated immobilizing PFAS in solid wastes such as AFFF-impacted soil. This suggests that stabilizing agents could be used prior to landfill disposal to minimize the mobility of PFAS.

Key Words: PFAS, remediation wastes, stabilization, leaching, AFFF, soil screening levels

EXECUTIVE SUMMARY

(Dates: January 1, 2020 to May 30, 2022)

PROJECT TITLE: Characterization and Management of Per- and Polyfluorinated Alkyl Substances (PFAS) Remediation Residuals

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COMPLETION DATE: May 30, 2022

PROJECT SUMMARY

To protect human health and the environment risk-based thresholds for PFAS in matrices such as drinking water and soil have been developed in the last decade. These standards often vary significantly between regulatory bodies (e.g., federal and state-level) and drive remediation efforts which produces a new waste stream (PFAS-containing remediation wastes). This project aims to address two specific questions: (1) are leachability-based SSL sufficient to screen for likely groundwater contamination or should leaching tests be conducted instead? and (2) which bulking agents would mitigate the release of PFAS into landfill leachate resulting from disposal of stabilized PFAS-containing liquid wastes in a typical MSW landfill? This information will benefit the solid waste community and governing regulatory agencies by providing validation of leachability-based SSLs to laboratory leaching data and provide information on how to best manage PFAS-containing wastes to safeguard human health and the environment.

This report begins with a literature review of management practices and the development of risk-based thresholds for PFAS-impacted soils which highlighted two key points. First, there is a need to explore management practices that would help limit the release of PFAS into landfill leachate during disposal of PFAS-containing wastes. PFAS have been found to migrate into landfill leachate over time which is problematic given that landfill leachate is often sent to wastewater treatment plants which do not remove or destroy PFAS (D'eon et al., 2009; Eriksson et al., 2015). The second key point highlighted in this review is regarding the development of risk-based thresholds for PFAS in soils. For example, Florida (FDEP) and the EPA have released risk-based thresholds for certain PFAS in soils. Notably, the leachability-based soil screening levels tend to be orders of magnitude lower than

direct exposure limits, meaning that leachability limits will dictate remediation. Furthermore, leachability-based limits can also vary dramatically between regulatory groups (e.g., FDEP's leachability based SCTL for PFOS is 0.007 mg/kg while EPA's leachability RSL for PFOS is 0.000038 mg/kg). This highlights a need to validate whether leachability-based SSL are sufficient to screen for likely groundwater contamination or whether leaching tests should be conducted instead.

Following the literature review, leaching tests were conducted on two AFFF-impacted soils to characterize the leaching of PFAS. This was done to validate if leachability-based SSL are sufficient to screen for likely groundwater contamination by comparing estimated PFAS release derived from the equations used to develop SSLs to laboratory leaching tests. Different regulatory bodies can have significant variability in their soil screening levels based on leaching to groundwater. These differences can be largely attributed to the soil-organic carbon partition coefficient (K_{oc}) assumed when using risk-based equations. After comparing the estimated release of PFAS using EPA's and FDEP's assumed K_{oc} values the results showed that in general the values used by EPA for the K_{oc} of PFOS and PFOA more accurately predict the expected leachate concentration compared to the values used by FDEP. Furthermore, using EPA's K_{oc} values for PFNA, PFHxS, and PFBS estimated concentrations were able to approximate laboratory data. This suggests that EPA's leachability-based SSLs are sufficient to screen for groundwater contamination.

As discussed earlier there is a lack of research that explores management options for reducing the release of PFAS into landfill leachate. An option that was explored in this study was determining which materials would most effectively retain PFAS when used as a bulking agent for PFAS-containing liquid wastes. In this experiment, two PFAS-containing liquids (an AFFF and a PFAS-impacted wastewater) were bulked with four common bulking agents (bentonite clay, sawdust, biochar, and Portland cement). The stabilized liquid wastes were then subjected to EPA method 1311 (TCLP) to determine the mass release of PFAS from these bulked liquids during a simulated landfill disposal scenario. The results showed that for the more concentrated PFAS containing liquid (AFFF) the bulking agents with higher organic matter, such as biochar and sawdust, retained higher levels of PFAS. While for the less concentrated PFAS liquid (remediation wastewater) all bulking agents were able to retain significant levels of PFAS.

The results of the literature review and the experiments conducted during this project can be used as guidance to regulators and waste managers of PFAS-containing residuals that will reduce the release of, or exposure to, PFAS. This research includes comparing FDEP and EPA leachability-based SSLs to laboratory leaching tests to examine if the current SSLs are sufficient to screen for likely groundwater contamination and exploring the effects that bulking agents have on the retention of PFAS in liquid wastes during disposal.

METRICS

*Graduate students funded by **THIS** Hinkley Center project*

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Report details are being withheld from public posting pending peer-reviewed journal publication. For more information please contact Principal Investigator Timothy Townsend (ttown@ufl.edu).