LOW TEMPERATURE DESORPTION of Per- and Polyfluoroalkyl Substances

Bench and field pilot scale test results for thermal desorption indicate it may be a viable option for treatment of per- and polyfluoroalkyl substances from aqueous film forming foam.

By William DiGuiseppi, PG, M.SAME, Roger Richter, and Michael Riggle, PG

Per- and polyfluoroalkyl substances (PFAS) are of interest where aqueous film-forming foam (AFFF) has been stored or used. AFFF, which is one of many industrial uses for PFAS, is designed to quickly extinguish flammable liquids and was in common use at facilities at risk for petroleum fires, including U.S. military installations.

Because of this, PFAS were released to soil, sediment, surface water, and groundwater at fire training areas, fire stations, storage facilities, hangers, and emergency response locations. AFFF source areas have been studied by the Department of Defense, and substantial PFAS mass has been found in vadose zone soils, which represent an ongoing source to underlying groundwater.

Regulations to address soil impacts are evolving rapidly. The Environmental Protection Agency has released Regional Screening Levels for groundwater protection. Recently, the Alaska Department of Environmental Conservation promulgated soil migration to groundwater standards. Maine, Michigan, North Carolina and Texas also have groundwater protection guidelines for soil. More states will likely promulgate enforceable soil clean-up standards in the future.

The only well-demonstrated technologies for remediating soils are excavation with landfilling or incineration, neither of which is desirable, cost-effective, or sustainable. Soil stabilization with carbon-based sorbents has been demonstrated in Australia and carries merit—but it is a non-destructive technology, leaving long-term liability and potential land-use controls restricting the future use of the site. Other soil treatment options like soil washing have been pilot tested outside of the United States and appear to be effective, but result in generation of multiple waste streams requiring disposal or further treatment.

The concept of low-temperature thermal desorption is not new. However, only recently has data been generated with respect to PFAS treatment.

THERMAL TREATMENT

Several ex situ batch-feed thermal desorption studies have been conducted over the past several years. In 2014, CH2M Hill

Portable infrared thermal treatment unit. PHOTO COURTESY IRON CREEK GROUP (now Jacobs) worked with Endpoint Consulting to conduct a bench-scale proof-of-concept study with approximately 1-T of PFAS-impacted sandy soils from an Air Force base in California. Endpoint's Vapor Energy Generator full-scale system employs indirect-fire thermal treatment to desorb the organic compounds and subsequently treats the vapors with a variety of technologies. Analytical testing for four carbon (C4) through eight carbon (C8) perfluorinated carboxylates and sulfonates (total of 10 PFAS) was performed using high pressure liquid chromatography tandem mass spectrometry at the Colorado School of Mines. The feed soils were subsequently spiked with a 50:50 mixture of 3 percent Ansulite fluorotelomer-based AFFF and 1999-era 3M electrochemical-based AFFF to bring the estimated total concentration of the 10 PFAS analyzed to above 40,000-ug/kg, which represents the high end of environmentally relevant source area concentrations.

Study	Thermal Method	Initial Total PFAS Conc. (µg/kg)	% Decrease in Total PFAS	Exposure Temperature/Time	Number of PFAS Analyzed #
Endpoint/ Jacobs	Vapor Energy Generator	40,000	Minimal 50 >99.9*	482˚C for 15 mins 593˚C for 15 mins 954˚C for 30 mins	10
Iron Creek/ Jacobs	Infrared Heating	200	26	250˚C for 8 days	29
Iron Creek/ Jacobs	Infrared Heating	151	40 99.4	300˚C for 4 days 350˚C for 2 days	29
Iron Creek/ Jacobs	Infrared Heating	290	89.3-99.8 97.3->99.9* 99.8->99.9*	400˚C for 60 mins 550˚C for 50 mins 700˚C for 80 mins	29

* >99.9% decreases are based on the limited analytical suite performed and based on decreases below the Limits of Detection
\# PFAS analyzed are described in the text.

PFAS-impacted soils thermal treatment testing summary.

The mixed soil then was separated into several batches for treatment as follows: 482°C for 15 minutes; 593°C for 15 minutes; and 954°C for 30 minutes. Minimal removal occurred at the lowest temperature and 50 percent removal occurred at the middle temperature, both over 15 minutes duration. At higher temperature and 30-minute duration, all PFAS were removed to levels below the Limits of Quantitation, corresponding to an estimated mass removal of >99.9 percent.

Jacobs and Iron Creek Group conducted a series of temperature optimization studies using AFFF-impacted silty sand coastal plain soils from a U.S. Navy installation, which included support from Naval Facilities Engineering Command, Battelle, and SGS AXYS Analytical Services Ltd.

Bench scale testing was conducted using a 1-ft^3 chamber to simulate the commercially-available batch-feed infrared heating unit. Iron Creek's Tech Zero unit utilizes infrared heat to treat contaminated soil in batches through conduction and convection, with associated volume increase in heated gases driving out the volatilized PFAS. The design incorporates a "core" heating system that can utilize propane, natural gas, or diesel. This system produces a very low amount of exhaust gas, which is routed through air extraction ducts to an off-gas treatment system. It functions as a thermal oxidizer, destroying organic vapors at temperatures in excess of 1,300°C, or sorption to vapor-phase granular activated carbon, which is then returned to the vendor for high temperature reactivation, thereby destroying the PFAS.

During the three separate bench tests, temperatures of 250°C, 300°C, 350°C, 400°C, 550°C, and 700°C were evaluated at heating times ranging from 50 minutes to eight days. The results indicate lower temperatures for longer durations are as effective as higher temperatures and shorter durations; 350°C was identified as the lowest effective temperature. This testing showed 99.4 percent removal for the total of the 29 PFAS analyzed within two days at 350°C. Only 40 percent total PFAS removal was observed at 300°C over a four-day duration. Longer heating durations did not improve removal at either temperature. Infrared heating for low-temperature thermal desorption will be tested further during an ongoing Strategic Environmental Research and Development Program project aimed at utilizing a portable unit intended for onsite treatment of PFAS-impacted investigation derived waste.

A key to establishing the time-temperature relationship is that lower temperature and longer duration allows the flexibility to use not only batch thermal boxes, but opens up the prospect of remediating excavated soil piles for larger scale treatment, or implementing as an in situ solution for areas where excavation is logistically difficult. Heating in situ source area soils to 350°C is feasible and can be coupled with a soil vapor extraction system to capture the volatilized PFAS for treatment.

ANALYZING THE DATA

Low temperature thermal treatment studies demonstrate effective removal of PFAS from soil at temperatures as low as 350°C, making low-temperature thermal desorption a potentially viable technology for treatment of PFAS-impacted source area soils.

The cost per ton for this technology has not been estimated, but it is anticipated that it would be substantially less than the only other destructive technology (incineration), and slightly higher than non-destructive options, such as ex situ stabilization. It should also be noted that previous studies were focused exclusively on PFAS, and additional testing is needed to confirm removal of chlorinated solvents or petroleum co-contaminants.

TME

William DiGuiseppi, PG, M.SAME, is Principal Hydrogeologist, Jacobs; bill.diguiseppi@jacobs.com.

Roger Richter is Vice President of Operations, Iron Creek Group; roger@ironcreekgroup.com.

Michael Riggle, PG, is Project Geologist, USACE Omaha District; michael.a.riggle@usace.army.mil.

Doug Simpleman and Paul Gedbaw, USACE Omaha District; Tim Fitzpatrick and Richard Grace, SGS AXYS Analytical Services Ltd; and Jim Hatton, Scott Grieco, Katie Rabe, and Tiffany Hill, Jacobs, contributed to this article.