PlumeStop® Technical Bulletin 5.1

In Situ Containment of PFOA and PFOS Using Plumestop® Liquid Activated Carbon™

Introduction and Background

Per- and polyfluorinated alkyl substances (PFAS) are a class of man-made organic chemicals with robust carbon-fluorine bonds that impart chemical, thermal, and biological resistant properties. The stability of these compounds have led to their use in a variety of industrial and consumer products, including stain resistant materials, non-stick surfacing, and aqueous film-forming foams (AFFF) for fire suppression.

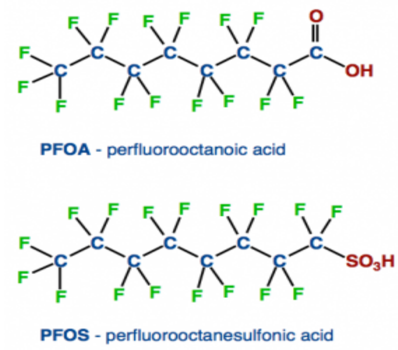

Figure 1: PFOA and PFOS chemical structure

The widespread use of these compounds together with advances in analytical chemistry have resulted in routine, low-level detections of PFAS in water and soil environmental samples as well as in mammals and humans. Once in the environment or exposed to humans, the durability of PFAS becomes problematic as they do not readily degrade or metabolize, making them extremely persistent.

Two of the most commonly encountered PFAS are perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), shown in Figure 1. The health effects of PFOA and PFOS for humans are not yet fully understood, however, the US Environmental Protection Agency has considered them emerging contaminants with potential carcinogenic properties. Based on these health risks, the EPA has set a lifetime health advisory limit for the combined concentrations of PFOA and PFOS at 0.07 µg/L, a limit that was lowered in May 2016 from previous levels set in 2009. As a result of these new advisory values, there has been a large focus on effective remediation approaches for PFAS in contaminated soils and groundwater.

To date, conventional *in situ* remediation technologies, e.g. chemical oxidation, have not effectively demonstrated the ability to destroy these contaminants. Additionally, no known microbial strains have been discovered that are capable of biodegrading these substances. The currently accepted method of treatment for PFAS is through an *ex situ* pump-and-treat system equipped with activated carbon filters. While generally effective, this process can be complicated and expensive due to the large and dilute nature of many PFAS plumes, which are often difficult to treat completely. A recent study[1] reported on the typical characteristics of these PFAS plumes, which include:

- Average plume length is over a mile
- More than 75% of the plume is <10 μg/L
- Large, dilute plumes typically do not have a high concentration source area
- PFOS and PFOA are likely present at the highest concentrations at the leading edge of the plume.

Technology Description

REGENESIS® has developed an *in situ* sorbent technology to physically remove PFOA and PFOS from the aqueous phase in order to prevent further migration of the plume and to remove the inherent risk associated with dissolved phase contaminants. This new *in situ* sorbent technology offers a new tool to address these challenging contaminant plumes. The key elements of this technology include the ability to:

- Distribute a sorbent composed of colloidal activated carbon widely in the aquifer under low pressure injections
- Adsorb contaminants and quickly reduce their groundwater concentrations
- Inhibit further transport of contaminants in the aquifer

PlumeStop® Liquid Activated Carbon™ is comprised of very fine particles of activated carbon (1-2 μm) suspended in water through organic polymer dispersion chemistry. This patented formulation allows PlumeStop to travel through the aquifer under low pressure application without clogging.

Once applied, PlumeStop coats the surface of the soil where contaminants can adsorb and immediately reduce dissolved phase concentrations. For a more extensive review on the ability of PlumeStop to distribute in the subsurface, refer to PlumeStop Technical Bulletin 1.1.

Experimental

To test the adsorption efficacy of PlumeStop, individual adsorption isotherms for PFOA and PFOS were measured in the REGENESIS laboratory. The isotherms were fitted according to the Freundlich model and the parameters were then used to model the expected treatment efficiencies with PlumeStop.

Isotherm samples sets were prepared with a constant contaminant concentration and varied PlumeStop doses. The samples were mixed for a minimum of 48 hours and then a clear aliquot, free of PlumeStop, was sampled and analyzed for the equilibrium contaminant concentration in water. PFOS and PFOA were analyzed by LC/MS/MS (Test America) and LC-ELSD (REGENESIS).

Results and Discussion

The isotherms with Freundlich parameters of PFOA and PFOS are show below in Figures 2 and 3.

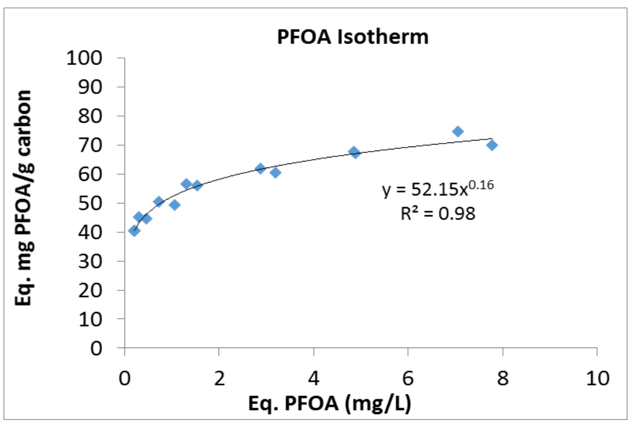

Figure 2: PFOA with PlumeStop isotherm fitted to the Freundlich

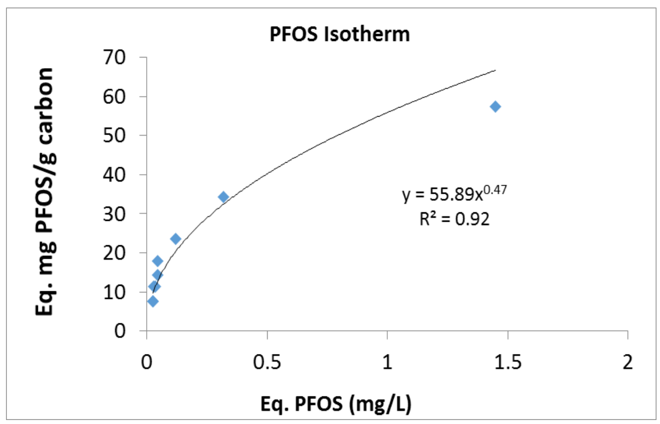

Figure 3: PFOS with PlumeStop isotherm fitted to the Freundlich

Simulated Plume Scenario

A practical way to interpret these isotherm parameters is through a fate and transport model where the capture longevity of a PlumeStop barrier treatment can be estimated by incorporating the isotherm parameters into the model.

In this simulation, a PlumeStop barrier was installed at the leading edge of a plume with the following characteristics:

- Plume contaminant concentration = 50 μg/L
- Target downgradient concentration, maximum = 0.5 μg/L
- Seepage velocity = 120 ft/yr
- PlumeStop barrier = 25 ft at typical field dose
- Assumes sorption only, no destruction or degradation

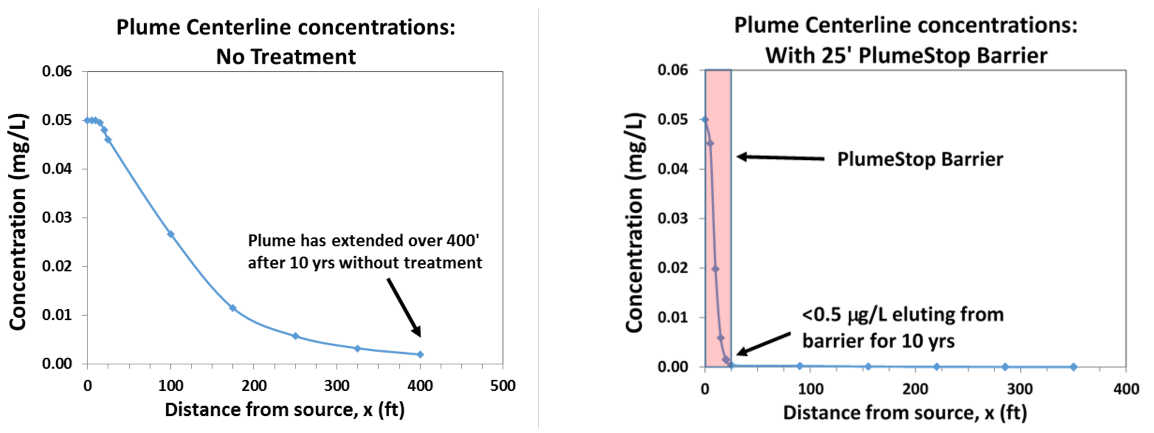

Figure 4: Simulated plume centerline concentration results for PFOA or PFOS. The graph on the left shows the natural migration of the plume after 10 years with no treatment, and the graph on the right demonstrates the capture longevity of a PlumeStop barrier treatment on the same plume.

Outputs from the modeling study are shown in the graphs depicted in Figure 4. The model results indicate that the PFOA/PFOS plume would extend over 400 ft. after ten years under natural conditions and no treatment. In comparison, when a 25 ft. PlumeStop barrier is installed, the Plume is contained for the ten-year period. It is expected that this timeframe could be extended through re-application of PlumeStop or with a higher initial dose.

Conclusion

The results of this study indicate that PlumeStop is capable of physically removing PFOA and PFOS from the aqueous phase in order to provide an *in situ* approach for

PFAS plumes. The ability to inject and distribute a sorbent within the aquifer allows for improved plume containment over pump and treat systems, with the potential to decrease the operating costs of *ex situ* treatment options. Additionally, future advances in destruction technologies could be applied at a later date in the area of the existing PlumeStop barrier to destroy the contaminants.

Key advantages of a PlumeStop treatment for PFAS

- Avoid or decrease O&M costs associated with *ex situ* approaches like pump and treat
- Ability to inject an *in situ* barrier of colloidal activated carbon that distributes widely and evenly under low pressures in the permeable channels
- Cuts off migrating PFAS plumes
- Rapidly adsorbs PFOS and PFOA from water, even at low concentrations
- Years of sorption capacity with a single application
- Higher doses or reapplications can increase capture longevity

References:

1. Woodward, D.; Chiang, D.; Casson, R. "Lessons Learned from Characterizing Several Dozen Sites Impacted by Perfluorinated Compounds." In *Bioremediation and Sustainable Environmental Technologies-2015*, Proceedings of the Third International Symposium on Bioremediation and Sustainable Environmental Technologies, Miami, FL, May 2015; Darlington, R. and Barton, A. C., Eds.; Battelle Memorial Institute: Columbus, OH, 2015; B-057.