PFAS Cleanup
Challenges and Solutions

By James Peeples

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Per- and polyfluoroalkyl substances (PFAS) are a class of about 5,000 human-made chemicals whose management and remediation present a challenging task for site owners and government agencies. PFAS have unique chemical and physical properties that have led to their widespread use in industrial and consumer products, ranging from aqueous film-forming foams (AFFF) used for fighting flammable liquid fires to spray-on products for fabrics that repel water and stains.

PFAS, except in the polymerized form (e.g. Teflon), typically consist of two parts: (1) a hydrophobic and lipophobic carbon backbone where all the carbon atoms are bound to fluorine atoms (perfluoroalkyl) or there is a mix of hydrogen and fluorine atoms bound to the carbon backbone (polyfluoroalkyl), and (2) a hydrophilic functional group, which can be a carboxylic or sulfonic acid, as in the case of two widely used PFAS, perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS). The carbon-fluorine bonds within the backbone of these molecules rank among the strongest bonds in organic chemistry and this strength together with the protective "shell" around the carbon backbone formed by the fluorine atoms impart an extreme chemical and physical stability to PFAS molecules (ITRC, 2020).

If it were only for their extreme chemical and physical stability, PFAS would likely have found many uses in industrial and consumer products; however, many of these "forever chemicals" also dissolve well in water, due to their hydrophilic functional group, and the carbon-fluorine backbone exhibits both hydrophobic and lipophobic properties allowing it to repel both water and oils. Collectively, these properties result in a substance that is slippery, noncorrosive, chemically stable and has a high melting point (ITRC, 2020); PFAS chemicals add oil and grease repellency and chemical/physical stability to products (ATSDR, 2020). These properties have resulted in widespread use of PFAS in industrial and commercial/retail products such as nonstick coatings (e.g., Teflon®), chemical- and temperature- resistant plastics and tubing, stain treatments for fabric (e.g., Scotchgard™, STAINMASTER®), photographic antireflective coatings, car wax, waterproof/breathable clothing (e.g., GORE-TEX), architectural composite resins, aerospace/aviation products, mist-suppressant foams in electroplating, AFFF, and paper/cardboard coatings (e.g., popcorn bags and pizza boxes) and many other products/uses (ITRC, 2020).

The key takeaway is that PFAS substances are incredibly useful and incredibly stable, leading to their widespread distribution and their long-term persistence in the environment (USEPA, 2020). These factors have resulted in a challenging situation for both the regulated and regulatory communities.

Virtually all people have been exposed to PFAS either directly, through products we use, or indirectly, through environmental exposure (ATSDR, 2020; USEPA, 2020).

The Agency for Toxic Substances and Disease Registry (ATSDR) reports PFAS are found in “the blood of people and animals all over the world and are present at low levels in a variety of food products and in the environment” (ATSDR, 2020). Toxicological and epidemiological studies have found links between exposure to some PFAS and significant health effects. Some studies in humans with PFAS exposures indicate the potential for PFAS to interfere with the body’s natural hormones, increase cholesterol levels, affect the immune system, and increase the risk of some cancers (ATSDR, 2020). While the PFAS family contains thousands of human-made compounds, only a few have received significant testing or study. Much more work is yet to be done to evaluate the health effects of a broader range of this very large and useful family of compounds.

As the health and toxicological studies raise concerns over the potential effects of PFAS on humans and other organisms, regulators have taken notice. PFAS compounds began to receive attention as emerging contaminants of concern in the early 2000s (ITRC, 2020). By 2002, PFOS, was voluntarily phased out of production in the United States (ITRC, 2020). Additional voluntary phaseouts of global production by eight PFOA manufacturers occurred in 2006 (ITRC, 2020). The United States Environmental Protection Agency (USEPA) announced a Lifetime Drinking Water Health Advisory of 70 parts per trillion (ppt or ng/L) of combined concentrations for PFOA and PFOS, two of the more commonly detected PFAS in 2016 (USEPA, 2016). Health advisories are unenforceable guidance providing information on contaminants that can cause health effects and are known or anticipated to occur in drinking water (USEPA, 2016).

In 2018, ATSDR set minimal risk levels in drinking water for four PFAS: PFOA at 78 ppt* (adult) and 21 ppt (child); PFOS at 52 ppt (adult) and 14 ppt (child); perfluorohexane sulfonic acid (PFHxS) at 517 ppt (adult) and 140 ppt (child); and perfluorononanoic acid (PFNA) at 78 ppt (adult) and 21 ppt (child) (ATSDR, 2018). In February 2019, USEPA released a PFAS Action Plan that listed targets and milestones but no hard deadlines. The Action Plan, among other items, includes the following: evaluating PFOA/PFOS for a maximum contaminant level (MCL) in drinking water and as possible hazardous substances, developing interim remediation standards, establishing state/local authorities as the first line of enforcement, finalizing toxicity assessments for and values for some additional PFAS chemicals, completing a significant new use restriction (SNUR) analysis under the Toxic Substance Control Act, considering the addition of PFAS to Toxics Release Inventory (TRI) reporting, and developing consistent informational materials across various governmental agencies.

***ppt = parts per trillion**

In the absence of quick action and clear leadership at the federal level, individual states have enacted their own regulations with respect to drinking water and in some cases biosolids and soils. This has resulted in a patchwork of varying standards and health advisories across the country, with those states that have established more stringent levels for the presence of PFAS in environmental media taking the lead role in enforcement. This presents a difficult environment for the regulated community with varying standards being applied throughout the country and being implemented under different timetables. It appears this challenging regulatory environment will remain in place well into the future until a consistent federal standard for PFAS, which is also acceptable to state regulators, is enacted. A quick resolution to this problem is not expected.

Once released into the environment, some PFAS have been shown to be relatively mobile and most have been found to be stable and persistent. At the current time, remediation of soil containing PFAS has been limited largely to landfilling and incineration. Incineration is an expensive process, particularly if the soil must be transported great distances to the location of an incinerator that is permitted for incineration of PFAS. It is expected that landfills will be more reluctant to accept PFAS-containing material as they become required to deal with PFAS present in their leachate.

In situ remediation of PFAS in groundwater is not currently feasible, and due to the chemical stability of PFAS molecules, in situ destructive technologies for PFAS in groundwater is likely to be very challenging. Technologies are available for adsorbing and containing PFAS in place within an aquifer. This approach can be effective for containing PFAS and preventing its spread through a broader area of an aquifer. However, these technologies do not destroy the PFAS in the aquifer, but merely hold them in place.

For the present time, the most effective approach for containing and treating PFAS in groundwater is a pump-and-treat system. These systems can contain a plume of PFAS in groundwater and allow removal of the PFAS at the ground surface, through a variety of readily available treatment technologies. The treated groundwater can be used as a drinking water source, released to a surface water body or reinjected into the aquifer. The most commonly used technologies for treating PFAS in water are granular activated carbon (GAC), ion exchange resins, and membrane technologies. Of these technologies, GAC is the most prevalent at this time and is effective for removal of some of the most commonly encountered PFAS. Ion exchange resins have been shown to be effective for a wide range of PFAS compounds and research is ongoing to improve the range of PFAS treated and the capacity of the ion exchange resins. Membrane technologies, such as nanofiltration and reverse osmosis are quite effective for removal of a broad range of PFAS but can be costly to implement and operate and will also result in the generation of a waste stream that still contains the removed PFAS in a concentrated form.

References

Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological Profile for Perfluoroalkyls (June 2018). https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR), accessed May 14, 2020. Per- and Polyfluoroalkyl Substances (PFAS) and Your Health. https://www.atsdr.cdc.gov/pfas/index.html.

Interstate Technology and Research Council (ITRC), 2020. PFAS Technical and Regulatory Guidance Document and Fact Sheet PFAS-1. Washington, D.C.: Interstate Technology and Research Council, PFAS Team. https://pfas-1.itrcweb.org/.

United States Environmental Protection Agency (USEPA), November 2016. Drinking Water Health Advisory for Perfluorooctanoic acid ("PFOA") and Perfluorooctane sulfonate ("PFOS"). https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_health_advisory_final_508.pdf, https://www.epa.gov/sites/production/files/2016-05/documents/pfos_health_advisory_final_508.pdf.

United States Environmental Protection Agency (USEPA), accessed May 14, 2020. Per- and Polyfluoroalkyl Substances (PFAS). https://www.epa.gov/pfas.

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