Society of American Military Engineers

Environmental Community of Interest
Industry-Government Engagement PFAS Project
Avoiding PFAS Information Overload:
Targeted Training for Operational Entities

Per- and Poly-Fluoroalkyl Substances (PFAS) Environmental Mobility and Conceptual Site Models

Understanding the routes in which per- and polyfluorinated alkyl substances (PFAS) are transported is critical to hazard assessment and remediation. Moving through complex surface and groundwater pathways, integrated numerical models can be a valuable tool to track these chemicals.

Where are PFAS found?

Due to their extensive use in industrial and consumer products, PFAS are present at a wide variety of cleanup sites, including those associated with firefighting training and response, such as military bases, airports, and training facilities. PFAS are long-lasting chemicals, and once released into the environment, can remain in surface and groundwater over extended periods.

What are typical transport routes for PFAS?

PFAS are transported primarily through surface water and groundwater, where PFAS can enter rivers, lakes, and aquifers via industrial discharges or seepage, wastewater treatment plant effluents, or runoff from contaminated sites. The interaction between groundwater and surface water is a critically important and complex process. When contaminated groundwater discharges into surface water bodies, it can act as a long-term source and introduce PFAS to otherwise uncontaminated areas continuously over time. Likewise, surface water can infiltrate into groundwater systems, potentially carrying PFAS to underlying aquifers, as well as transporting PFAS long distances downstream to potentially impact ecosystems or water supplies.

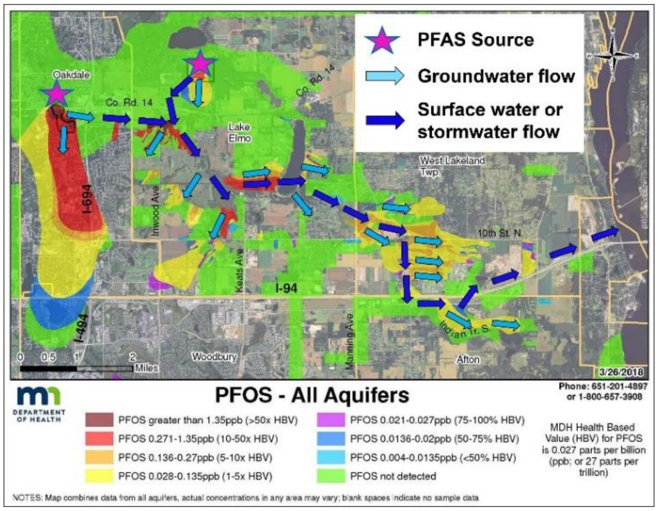
While a less significant route, atmospheric transport can also provide a pathway to receptors, as PFAS can be released into the air from industrial emissions, landfill sites, or volatilization from source-area releases. Once in the atmosphere, PFAS can be transported over long distances and deposited onto land or water surfaces through rainfall.

What processes impact PFAS migration?

Despite their relative stability, PFAS interact with the environment in several ways. One important aspect is partitioning, where PFAS can attach to or detach from surfaces in soil/sediment. This process depends on the chemical and physical properties of specific PFAS and environmental factors like soil/sediment properties, organic carbon content, presence of cationic clays, and soil pH. Bioaccumulation represents another process, with PFAS uptake to aquatic organisms, resulting in higher concentrations up the food chain for certain PFAS. Lastly, PFAS can undergo transformations, both biotic and abiotic, leading to the formation of shorter-chain PFAS. Likewise, PFAS precursors can transform into target PFAS.

Are there any examples of this dynamic?

PFAS transport from surface water to groundwater has been documented in multiple investigations. This includes military bases where PFAS contaminated stormwater or wastewater infiltrates the ground and follows underground utilities, conduits, or other paths of least resistance. One notable example, highlighted in the figure below, illustrates the suspected flow of PFAS from two private sector industrial release sites (highlighted as stars) through groundwater (light blue arrows) into surface water (dark blue arrows). Ultimately, this interaction resulted in an extensive spread of PFAS despite a lack of a direct surface-water pathway. In this case, it produced several groundwater plumes that were disconnected from the original sources and many miles long.



Yingling, G. (2018, July 26). *State Perspective on PFOS/PFOA (and other PFAS)*. Air Force Eastern Regional Environmental Restoration Summit.

How can numerical modeling support remediation?

Because of the intrinsic complexity of PFAS mobility, numerical models (or “simulations”) may help improve the understanding and evaluation of remediation options, particularly when accounting for the full range of processes affecting PFAS distribution. By simulating an entire project area, including all transport routes and their interactions, these models can assess the spread of contaminants to focus data sampling to critical areas. Validated numerical models can also provide information on key areas to limit the future spread of PFAS, as well as evaluate the effectiveness of various remediation options. Presently, the adequacy of existing groundwater models in representing the unique behavior of PFAS is an active area of research.

What is a conceptual site model?

A conceptual site model (CSM) is graphical or written summary of what is understood about site conditions and environmental contamination at a site. An essential element to the systematic planning process, CSMs conceptualize the relationship between contaminant sources, site hydrogeology, and receptor exposure pathways. CSMs inform investigation and remediation work by characterizing site conditions, identifying data gaps and needs, facilitating remedy selection and evaluating effectiveness, post-remedy monitoring, and optimization. CSMs also provide a communication tool for decision-making and the public. CSMs are important to have, and update, at every step of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) process for PFAS sites.

What factors go into the development of a CSM?

Key elements of a CSM include contaminant release history and characterization (chemistry), surface and subsurface geologic setting (geology/ hydrogeology), migration and exposure pathways (fate and transport), and ecological and human receptors (risk assessment). Finally, it is important to emphasize high-resolution data which can be used to update the CSM as a “living document” throughout the cleanup.

CSM Best Practices for PFAS

The rapidly evolving state of the science and regulations for PFAS pose a challenge in balancing anticipated scientific breakthroughs and regulatory action versus making forward progress in addressing contamination. Therefore, new best practices in developing PFAS CSMs are becoming essential for site characterization and remediation.

Environmental Sequence Stratigraphy (ESS) is an emerging PFAS CSM tool in characterizing subsurface architecture in the context of the site’s depositional and erosional history, as it provides a better understanding of the controls on migration patterns for PFAS plumes and supports optimization of groundwater remediation strategies.

Due to decades of AFFF releases to stormwater and wastewater utility lines, and the often-deteriorated condition of this infrastructure, PFAS plumes may be present outside of expected downgradient plume dimensions due to migration through utility lines via inflow, infiltration, and exfiltration. Therefore, it is important to investigate surrounding stormwater and wastewater utility lines while developing PFAS CSMs.

Characterizing PFAS distribution in the vadose zone, specifically PFAS concentrations in soil vs. soil porewater, is essential to understanding site-specific risk of PFAS leaching from soil to groundwater (Brusseau and Guo, 2022). As PFAS adsorbs at air-water interfaces during transport in unsaturated porous media, surfactant-induced flow and enhanced retention can complicate site characterization under unsaturated conditions (Brusseau et al, 2021).

Monitored natural attenuation (MNA) is currently being evaluated as a potential tool to address the challenges in PFAS remediation such as low cleanup objectives, limited information on natural PFAS degradation in the subsurface, and the mobility and persistence of PFAS. Two important retention processes may provide a scientific basis for applying MNA to PFAS contamination: (1) chemical retention in the form of PFAS precursors, and (2) geochemical retention, sorption and matrix diffusion. These processes are likely acting on PFAS at many sites and may help mitigate the expansion of PFAS plumes in groundwater systems (Newell et al, 2021).

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References

M.L. Brusseau, B. Guo. PFAS concentrations in soil versus soil porewater: Mass distributions and the impact of adsorption at air-water interfaces. 2022.

M.L. Brusseau et al. Ideal versus Nonideal Transport of PFAS in Unsaturated Porous Media. 2021.

C.J. Newell et al. Monitored Natural Attenuation to Manage PFAS Impacts to Groundwater: Scientific Basis. Groundwater Monitoring and Remediation 41, no.4, 2021.