Building a Robust Fate and Transport Model for PFAS Using Vertical Aquifer Profiling and a Novel Linear-to-Branched Ratio Approach

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Background/Objectives. Per- and polyfluoroalkyl substances (PFAS) have been used in aqueous film-forming foams (AFFF) at many Department of Defense (DoD) facilities since the 1970s. The U.S. Navy Research Laboratory (NRL) in collaboration with the 3M Company developed AFFF in the late 1960s. Two main processes used for the manufacturing of PFAS were electrochemical fluorination (ECF) and telomerization. The ECF process used by the 3M Company produces approximately 70% straight chained PFAS with the remaining branched and cyclic isomers (Lindstrom et al. 2011). The telomerization process produces primarily or exclusively linear PFAS (Buck et al., 2011). The 3M AFFF was produced using ECF while the remaining AFFFs were produced using telomerization. In 2004, 75% of the DoD AFFF inventory was an ECF-based product (Darwin, 2004). Many AFFFs are complex mixtures of various PFAS. A total of 57 PFAS classes and over 240 individual PFAS have been identified in AFFF formulations or groundwater from AFFF-impacted sites (Barzen-Hanson et al. 2017). To better understand the fate and transport of complex PFAS mixtures found at AFFF sites a novel investigation approach was used. Vertical aquifer profiling (VAP) and analysis of linear to branched isomers and short to long ratios were used to build a robust fate and transport Conceptual Site Model at a current AFFF-impacted site.

Approach/Activities. The release of AFFF at the current DoD facilities occurred at various locations and many years using different formulations from multiple vendors. The presence of various PFAS of varying chain lengths as well as branched and linear isomers were identified. The PFAS investigation was performed using a phased approach. Initially, the off-site migration of potential PFAS plumes at the base boundary was evaluated using the collection of 38 VAP locations. A comprehensive evaluation of residential wells was performed using the collection of over 650 samples. During the first remedial investigation, a total of up to six interval samples were collected from 50 VAP locations. The first remedial investigation was followed with the installation of multilevel wells at 20 locations. Both remedial investigations provided a significant dataset to define the lateral and vertical extent of contamination and evaluate PFAS plumes over time. A specific analytical approach was used for the development of a fate and transport conceptual site model (CSM) by separately quantifying the branched and linear isomers for PFOA, PFOS, and PFHxS during both remedial investigation activities. The branched isomers and short-chain PFAS have been found to adsorb less to soil and sediment, bioaccumulate less in biota, and as a result, are expected to travel further in the environment.

Results/Lessons Learned. A total of over 1,000 samples were collected during the multiple phases of the investigation. A results summary will be presented including the detection frequency of individual PFAS collected during all of the different stages of the investigation. Enhanced plume delineation using VAP will be presented, including the correlation between residential wells and VAP samples. A novel approach to building a robust fate and transport CSM using chain length and isomer ratios will be presented. The approach can be used to determine the potential location within a plume and distance from the actual AFFF source.