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Microbial Communities and Natural and Enhanced Biodegradation of Per- and Polyfluoroalkyl Substances in Arid Region Soils Contaminated with Aqueous Film-Forming Foams

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Aqueous film-forming foam formulations contain large amounts of perfluoroalkyl acids (PFAAs) such as perfluorooctanesulfonic acid (PFOS) and polyfluoroalkyl substances, or precursors, such as 6:2 fluorotelomer sulfonate (6:2FTS) that can transform to more persistent PFAAs. Understanding PFAA and precursor (PFAS) fate is critical for site characterization, risk assessment, and remediation. Studies of PFAS biotransformation and soil microorganisms are lacking, however, especially under anaerobic conditions and for arid region soils. We evaluated microbial communities in soil cores from background sites and PFAS source areas in an arid region of New Mexico and conducted anaerobic microcosms experiments with homogenized soil from a fire training area to compare changes in PFOS, 6:2FTS, and other PFAS with and without addition of an anaerobic dehalogenating culture.

Microbial communities were highly diverse in shallow soil (<0.61 m depth) at the background and contaminated sites, consisting of many genera of Bacteria and Archaea with relative abundances of less than 3%. Microbial abundance and diversity decreased in soil from 0.9 to 4.9 m depth, with aerobic bacteria in the Burkholderiales order dominant (>50% relative abundance). In the microcosm treatments with only the native soil microbes, sulfide production occurred immediately, while methane production occurred after 14 days. High methane and sulfide concentrations occurred immediately in microcosm treatments with the added dehalogenating culture. Total mass of PFOS and 6:2FTS (microcosm water plus sediment) initially increased during incubation, and the mass increase was greatest in treatments with the added culture. Precursor transformation is the apparent cause of the increase in PFOS and 6:2FTS mass, and reduction of sulfur moieties in the precursors may be partly responsible for observed sulfide production. PFOS mass subsequently decreased substantially over the 56-day experiment in the culture-amended treatments compared to the mass decrease in killed controls or treatments with only the native microbes. Fluoride concentrations increased in both native and culture-amended treatments. These results show that anaerobic biotransformation of precursors may be important in arid region soils and indicate the potential for enhancement of anaerobic biodegradation, particularly of PFOS, as part of remediation actions. Microbial community analyses of microcosm samples are underway to further elucidate PFAS biodegradation.