Biotransformation of 8:2 Fluorotelomer Alcohol Using Microbial Communities from AFFF-Impacted Soils

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Background/Objectives. The use of aqueous film-forming foam (AFFF) to extinguish fuel-based fires has resulted in widespread contamination of environmentally persistent perfluoroalkyl acids (PFAAs) and their precursors. Most prior biotransformation studies of AFFF-derived PFAA precursors were conducted under oxic conditions, utilizing bacteria from activated sludge, pristine soils, and enrichment cultures. However, it is likely that documented precursor biotransformation will differ from that at AFFF-impacted sites, leading to different transformation rates and products. To address this need and improve our understanding of precursor fate at AFFF-sites, this study investigated the biotransformation of 8:2 fluorotelomer alcohol (8:2 FTOH), a component of new generation AFFF formulations, under conditions (i.e., oxic, nitrate-, iron-, and sulfate-reducing) representative of AFFF-impacted sites.

Approach/Activities. Microcosms were prepared with soils collected from two AFFF-impacted sites in the United States, Robins Air Force Base (AFB) and the former Loring AFB. Soils were emplaced in serum bottles at a 1:10 ratio (wt./vol.) with synthetic groundwater. All reactors were sealed with Teflon®-free septa; however, for aerobic microcosms, a needle was connected to a SPE C18 cartridge to trap volatile PFAS and maintain aeration. Goethite (100 mM), sodium sulfate (20 mM) or sodium nitrate (20 mM) was added as the electron acceptor to microcosms under iron-, sulfate-, and nitrate-reducing conditions, respectively. Live treatment and abiotic control reactors were spiked with approximately 170 µg/L 8:2 FTOH prepared in diethylene glycol butyl ether (DGBE), which is the primary organic solvent in AFFF formulations. In the anaerobic reactors, two live treatment biotransformation scenarios were evaluated. One set mimicked natural attenuation (NA treatment) where 5 mM DGBE was introduced as the sole external potential electron donor, while the other set mimicked biostimulation (ED treatment) where 20 mM sodium lactate was added as an additional electron donor and carbon source with DGBE to enhance the microbial activity. The molar yields of known biotransformation products were determined using liquid chromatography tandem mass spectrometry (LC-MS/MS). High-resolution mass spectrometry (HRMS) was employed to identify the potential unknown transformation products.

Results/Lessons Learned. The biotransformation of 8:2 FTOH was measured under all redox conditions. Under oxic conditions, the 8:2 FTOH half-life was 3 days, and 8:2 fluorotelomer carboxylic acid (8:2 FTCA), 8:2 fluorotelomer α,β-unsaturated carboxylic acid (8:2 FTUA), 7:2 secondary fluorotelomer alcohol (7:2 sFTOH), 7:3 fluorotelomer carboxylic acid (7:3 acid), and perfluorooctanoic acid (PFOA) were identified as biotransformation products. The total molar recovery of 8:2 FTOH and biotransformation products decreased with incubation time (i.e., <30% of the initial introduced 8:2 FTOH by day 90). Non-targeted HRMS analysis identified several novel 8:2 FTOH transformation products including 1H-perfluoroheptane, 1H-perfluorohexane, and perfluoroheptanal. Under nitrate-reducing conditions, most of the same oxic condition byproducts were observed, including PFOA. Additionally, the half-life of 8:2 FTOH under nitrate-reducing conditions was calculated as approximately 36.5 days for the NA treatment, while the ED treatment greatly enhanced the biotransformation rate by reducing the 8:2 FTOH half-life to approximately 12.5 days. In comparison to oxic and nitrate-reducing

conditions, biotransformation was much slower under sulfate- and iron-reducing conditions. Here, >60 mol% of initial 8:2 FTOH remained after 400 days and transformation did not proceed to the same extent (e.g., no PFOA). Overall, this study highlights the importance of accounting for redox condition in the assessment of PFAS transformations in natural environments.