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Environmental occurrence and biotransformation potentials of novel polyfluoroalkyl betaines

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Fluorotelomer betaines (FTBs) with n:3 and n:1:2 (n = 5, 7, 9, 11, 13 and 15) polyfluoroalkyl chains are major components of some aqueous film-forming foams (AFFFs) in use today. In recent years, researchers have reported several detections of these chemicals in the environment (e.g., soil, surface water, sediments) and biota that AFFFs have impacted, and trace amounts of these compounds are even found in drinking water. However, as new chemical substitutes, their environmental fate, particularly their biotransformation potential, has not been thoroughly explored. For the first time, we investigated biotransformation potential in aerobic soil microcosms of 5:3 and 5:1:2 FTBs and a commercial AFFF primarily containing n:3 and n:1:2 FTBs (n = 5, 7, 9, 11, and 13) as major components. It was found that 5:3 and 5:1:2 FTBs exhibited remarkably high persistence with no significant changes after 120 days at ambient temperature, contrary to other polyfluoroalkyl compounds that are precursors to perfluoroalkyl acids. Specifically, degradation of 5:3 FTB into suspected products, such as n:3 fluorotelomer acids (n = 2~5 FTCA) or perfluoroalkyl carboxylic acids (C3~C6 PFCA), could not be positively confirmed. The only likely biotransformation product identified so far is 5:3 fluorotelomer methyl amine, which was detected at low levels sporadically. Similarly, the degradation of 5:1:2 FTB did not produce short-chain hydrogen-substituted polyfluoroalkyl acids (n:2 H-FTCA, n = 2~5), hydrogen-substituted PFCA (2H-PFCA, C3~C7), or any other products. The incubation of a commercial Ansulite AFFF in four soils with different properties and microbial communities resulted in 0.023~0.25 mol% perfluoroalkyl carboxylates by Day 120. Most of the products are postulated to be derived from n:2 fluorotelomers, which are minor components of the AFFF. The surprisingly high persistence of these structures may be partly due to the quaternary ammonia group. We cannot explain the persistence of these emerging polyfluoroalkyl compounds based on the existing understanding of structure-biodegradability. More studies are necessary to examine other factors that might prevent the breakdown of chemicals that are continuously released into the environment up to this date.