Lysimeters to Evaluate PFAS Leaching at AFFF-Impacted Sites

Charles E. Schaefer (schaeferce@cdmsmith.com) (CDM Smith, Edison, NJ)
Yida Fang (fangy@cdmsmith.com) (CDM Smith, Bellevue, WA)
Stephanie Shea (sshea@mines.edu), Nicholas Gonda (ngonda@mines.edu), and Christopher P. Higgins (chiggins@mines.edu) (Colorado School of Mines, Golden, CO)

Background/Objectives. Further insight into the leaching of poly- and perfluoroalkyl substances (PFAS) from soil to underlying groundwater in aqueous film-forming foam (AFFF)-impacted source areas is needed for improved site management. Critical questions, including those regarding the nature and concentration of the PFAS in percolating porewater, the relationship between measured PFAS soil concentrations and the corresponding porewater concentrations, and the impact of varying moisture content on PFAS porewater concentrations, need to be answered to determine impacts to groundwater and remedial strategies. Herein we explore both laboratory- and field-based approaches to provide insights into these questions in an effort to develop improved approaches for source area characterization coupled with further mechanistic insights into PFAS leaching.

Approach/Activities. This study investigated PFAS-impacted unsaturated soils in seven source areas that have been historically impacted with AFFF. Multiple rounds of porewater samples were collected from each of these source areas using porous cup suction lysimeters. Porewater was also investigated in soil cores sent to the laboratory using small-scale lysimeters that were inserted into the cores. Collected soils also were evaluated with respect to PFAS desorption, grain size, and organic carbon content. PFAS soil concentration profiles with depth also were measured in the field. Finally, the air-water PFAS partition coefficient was measured using multiple techniques to determine PFAS accumulation at the porewater-air interface in the unsaturated zone.

Results/Lessons Learned. Results to date showed that results among closely spaced replicate lysimeters, and among replicate temporal sampling events, generally were reasonably repeatable (within a factor of 2). The nature of the PFAS in the porewater varied among sites, with some porewaters consisting predominantly of perfluoroalkyl acids (PFAAs), while others consisted of either quantified precursors (e.g., fluorotelomer sulfonates) or suspect analytes identified in both ESI- and ESI+ modes. Evaluation of PFAS concentration profiles with depth clearly showed impacts of PFAS hydrophobicity/chain length on the extent of vertical migration. These migration lengths were also compared to “apparent” K_d values measured using lysimeter-derived porewater concentrations, and these K_d values corresponded to the PFAS vertical migration lengths. Field-measured PFAS porewater concentrations were similar (same order of magnitude) to equilibrated laboratory-measured porewater concentrations, suggesting that field samples couple be reasonable approximated assuming local equilibrium conditions. A notable exception was when field porewater samples were collected during heavy rainfall events, in which field-based PFAS porewater samples were substantially less than laboratory-based samples; this observation was likely due to dilution of the PFAS in the porewater due to rapid infiltration of rain. Based on results employing three different experimental methods (batch film method, screen sampling of the microlayer, and unsaturated column experiments), PFAS accumulation at the air-water interface is well-described by a Freundlich isotherm. This interfacial adsorption behavior is consistent with results observed in the field, and highlights the importance of air-water interfacial sorption on PFAS leaching.