EGU24-7899, updated on 09 May 2024
https://doi.org/10.5194/egusphere-egu24-7899
EGU General Assembly 2024

Immobilization of Per- and Polyfluoroalkyl Substances (PFAS) – Experimental and Model-based Analysis of Leaching Behavior

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Per- and polyfluoroalkyl substances (PFAS) are persistent organic chemicals. Within the diverse PFAS class with thousands of individual species, the perfluoroalkyl acids (PFAAs) are of environmental concern due to their pronounced stability, prevalent occurrence at contaminated sites globally, and their detrimental health impacts.

On contaminated sites, soil contamination often originates from sources like firefighting foams, industrial waste, or fertiliser from processed waste. This study is closely linked to the “Rastatt case”, where more than 1000 ha agricultural land are contaminated with PFAS due to the application of paper-fiber biosolids, and investigates PFAS immobilization as a strategy to mitigate the risk of groundwater contamination.

The current understanding of the fate and transport of PFAS within the subsurface is limited, largely due to the complex sorption processes and unidentified precursor compounds and transformation rates. The efficacy and long-term stability of PFAS immobilization are crucial parameters for field applications but have not been verified to date. Furthermore, a standardized experimental methodology for testing PFAS immobilization has not been established.

This presentation characterizes PFAS leaching behaviors, examines the efficacy and long-term stability of PFAS immobilization, and assesses the applicability of experimental methods in investigating PFAS immobilization. Mathematical models are employed to characterize various sorption processes.

We found that the complexity of PFAS leaching with rate-limited sorption and biotransformation contribute to long-term leaching. Sorption to air-water-interfaces (AWIs) was highlighted as a potentially dominant retention mechanism under variably-saturated conditions.

The influence of PFAS chain length on the immobilization efficacy was evident. Delayed breakthrough of short-chain PFAAs and prolonged leaching at low rates indicate that PFAS sorption to the immobilization agents is reversible.

Long-term effects of PFAS immobilization were examined in column experiments with extended durations. The prediction of leaching based on this column data is compromised by indistinct precursor transformation and unaccounted AWI sorption. A thorough examination of PFAS leaching dynamics was achieved through lysimeter experiments, revealing the AWI sorption influence. However, moderate acceleration in PFAS leaching compared to field scenarios constrains long-term predictions.

This presentation sheds light on the benefits and constraints on the application of PFAS immobilization for a large non-point source.