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Mobilization of PFAS from heterogeneous soils: Desorption by ethanol/xanthan gum mixture

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Poly- and perfluoroalkyl substances (PFAS) have been manufactured since the 1950s. One of the main applications of PFAS is as a low-viscosity sealant in aqueous film-forming foam (AFFF) to extinguish hydrocarbon fires. The irrational use of AFFF in firefighting sites contaminated the soil and water system,signaling a serious and complex sanitary and environmental risk. It is therefore important to improve PFAS remediation technologies. The conventional remediation techniques might not be functioning effectively because of the strong C-F bonds, surfactant properties, solubility, and adsorption capacity of these substances. However, some studies showed that in-situ soil flushing with solvent is a successful method for PFAS mobilization. Despite their high desorption performance in removing PFAS, their effectiveness in soils with heterogeneous pore sizes may be constrained. In this context, the use of a non-Newtonian fluid (NNF) can improve the solvent flow in heterogeneous soils and consequently the PFAS desorption. In this study, we show the efficiency of the mixture of polymer and alcohol on PFAS mobilization in heterogeneous soils.

The flushing solution to solubilize PFAS is an aqueous ethanol solution at a fixed volume fraction of 50%. Xanthan gum as a biopolymer was added to this solution at different concentrations to induce a shearthinning behavior of the mixtures. The rheometer was used to examine the ethanol-xanthan rheological behavior of the mixtures. The soil was a blend of 3% of organic materials, 92% of silica sand, and 5% of clay with the same range of grain sizes as representatives of the soil layers usually reported for real polluted sites. At a fixed concentration of PFOS, PFOA, PFBS, and PFHxS, batch studies for understanding the adsorption and desorption behavior were conducted. An aqueous PFAS stock solution containing CaCl2 was added to the soil. The mixture was then stirred and centrifuged. The remaining contaminated soil was used for desorption experiments by adding various solutions such as water, ethanol, and a mixture of ethanol-xanthan with different concentrations of xanthan. To assess the polymer performance in transporting alcohol to solubilize PFAS, 1D column experiments were carried out.

The ethanol-xanthan mixtures homogeneity was confirmed by rheological analyses, which revealed that the addition of ethanol reduces the bulk viscosity of the mixture while maintaining a similar shear thinning behavior. Batch analysis revealed that the longer the PFAS chain, the greater the adsorption capacity, which corresponds to the solubility of each component. The main reason for adsorption is hydrophobic interactions with soil organic matter. In addition, ethanol desorbed more than 85% of the four PFAS components. Furthermore, the presence of xanthan in the mixture has a minor effect on the extraction capacity of ethanol. The efficacy of the injection of the ethanol-xanthan mixture on PFAS desorption and mobilization for various soil grain sizes was assessed using 1D-column experiments.

Depending on the length of the PFAS carbon chain, each component exhibits a different adsorption behavior. Ethanol flushing, as a promising method, has the potential to improve PFAS-contaminated soil remediation. In heterogeneous soils, the presence of xanthan in the flushing solution improves PFAS removal.PFAS contamination is frequently reported due to its applications in various fields. This study fills a gap in existing research by investigating the use of a mixture of ethanol and xanthan as a non-Newtonian fluid for in situ solvent flushing method aiming at removing PFAS from heterogeneous soils. While other PFAS desorption methods have been investigated, this is the first comprehensive study to evaluate the efficiency of this method in heterogeneous soils

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