How Can Nature-Based Approaches Play a Role in PFAS Remediation?

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Background/Objectives. Per- and polyfluoroalkyl substances (PFAS) have been identified as recalcitrant contaminants of concern due to their relatively long half lives in plant and animal tissue, their high toxicity, widespread usage and their fate and transport behavior in the environment. The strength of the carbon-fluorine bond makes these compounds long lasting in the environment that is further complicated by bio-oxidative transformation of long chain "precursor" compounds to "dead-end" compounds (i.e., PFOS and/or PFOA). In contrast to other classes of chemicals (e.g., VOCs), the difficulty in destroying PFAS has limited remedial technologies to address PFOS and PFOA and has fostered a reliance primarily on mechanical or physical driven treatment and containment systems. Nature-based approaches to mitigate or remediate PFAS in soil or groundwater have thus far been limited, partly due to the state of the available science. Efforts to identify a phytoremediation approach to address PFAS has been limited by the current understanding of PFAS uptake in plants (e.g., Globelius, 2017) and PFAS fate in the rhizosphere. This study intends to preliminarily assess the possibilities of combining various nature-based processes with engineering optimization to control PFAS leaching and migration.

Approach/Activities. A nature-based treatment approach was developed to address PFAS impacts related to the suspected use of AFFF at a former tannery site. The approach was initiated in a stepwise manner. The project started with in situ shallow soil mixing and injection of low-cost carbon-based immobilization media (biochar) in 2018 for soil and groundwater mitigation. Of the sorbent materials considered, biochar was determined to be a more resilient and sustainable choice. A phytoremediation pilot study was initiated in 2022 using TreeWells® to withdraw groundwater from the impacted area and reduce offsite migration. For each TreeWell® "cell", biochar was mixed into the affected aquifer along the sides and bottom of each TreeWell® cell to remove PFAS in the withdrawn groundwater and reduce potential PFAS accumulation in tree tissues. TreeWells® include a plastic sleeve placed in a large diameter auger hole advanced to a target depth in the aquifer. The sleeve restricts the tree from using precipitation-derived moisture and forces vertical root growth. Each TreeWell® cell becomes an isolated station for biostimulation and bioaugmentation experimentation; potentially creating individual microbial degradation bioreactors.

Results/Lessons Learned. Biochar was shown to significantly reduce PFAS concentrations in the application area and provide long-term removal of PFAS in the groundwater flux. Like other immobilization technologies, while biochar reduced the overall groundwater contaminant flux, some desorption of PFAS still occurs. Biochar sorption efficiency is affected by groundwater pH. Biochar has reduced groundwater contaminant levels available to the trees by 52% (pH>9) to 99% (neutral pH). This is the first study to report the use of biochar coupling with phytoremediation to reduce PFAS mass flux entering into a nature-based hydraulic control system (i.e., Treewell®). The initial development of a cone depression below the Treewell® pilot study area in the first season of growth is drawing contaminant flux into the treated area and reducing potential offsite migration of PFAS due to desorption from the biochar. Uptake of PFAS into the plant tissue (leaves, shoots, trunk and roots) will be presented with current state of microbial bioaugmentation/bioreactor development. Resilient, nature-based long-term remedies that include phyto-based containment may compliment efforts to stabilize PFAS

plumes and open the door for inclusion of a viable offsite monitored natural attenuation treatment approach.