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Importance of site-specific factors for the immobilization of contaminants using biochar and wood-based activated carbon

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The use of environmentally friendly low-cost sorbents such as biochar and wood-based activated carbon as soil amendment has shown promising results in immobilizing organic and inorganic contaminants. They can be suitable soil remediation options at sites with residual contamination, where the contaminated hotspot has been removed. The effectiveness of biochar and activated carbon application is site dependent. Specifically, dissolved organic carbon (DOC), pH, and ionic strength in the pore water are important factors which can influence the extent of contaminant immobilization. Although there has been significant progress in developing alternative carbonaceous sorbents, the efficiency of these materials in a diverse range of soil and pore water conditions remains an open question. To address this knowledge gap, the present study investigates the influence of pore water chemistry on sorption of organic and inorganic contaminants to biochar and wood-based activated carbon. Sorption of selected non-polar, polar and ionizable polycyclic aromatic compounds (PACs) and inorganic Cadmium (Cd) to biochar and a wood-based activated carbon was studied under different pore water chemistry conditions. Batch sorption experiments were conducted using an experimental design approach (Box Behnken Design) with three different levels of DOC, pH, and ionic strength, yielding background solutions mimicking a wide spectrum of pore water chemistries. Sorption K_D values [L/kg] were calculated from aqueous contaminant concentrations after equilibration. Results were analyzed using a response surface methodology (RSM) approach on Minitab 19 and fitted to a model equation using linear, squared and two-way interactions terms.

Our results show that the ionizable PAC (phenyl phenol) and Cd were most affected by changes in pore water chemistries. For phenyl phenol, the presence of a phenolic group can cause H-bonding and electrostatic attraction and repulsion, while pH-dependent changes in speciation, precipitation and electrostatic attraction can occur for Cd. Sorption of all PACs negatively correlated with DOC, indicating competition of DOC with PACs for sorption sites. Sorption of non-polar (acenaphthene), polar N substituted (carbazole) and ionizable (phenyl phenol) PACs was hindered under acidic conditions, due to precipitation of DOC. For Cd, higher pH and low DOC levels favored sorption. This can be attributed to a lower Cd solubility in the presence of leached phosphate at higher pH, and a predominance of $\text{Cd}(\text{OH})_2$ in the neutral to alkaline regime. Our findings highlight the importance of considering a combination of site- and contaminant-specific factors when planning

to apply carbonaceous sorbents for contaminant immobilization, with pH and DOC generally being more important than ionic strength.