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Sorption of priority pollutants to biochars and activated carbons for application to soil and sediment remediation

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The effectiveness of different biochars in comparison to 2 commercially available activated carbons (ACs) to sorb polychlorinated biphenyls (PCBs) and mercury (Hg) was assessed, with the aim of identifying promising materials for application to soil and sediment remediation and elucidating material properties that may enhance pollutant binding potential. Biochars studied were produced from pine dust, peanut hull, barley straw, and acai pit in addition to steam-activated biochars made from poultry litter (chicken and turkey). Aqueous concentrations of PCBs were measured using a polyoxymethylene passive sampling technique allowing a very low environmentally-relevant concentration range to be examined. Mercury pH-edge isotherms were conducted at relatively high concentrations in a wide pH range (pH 3-11). Sorption of Hg at low concentrations was also performed with ACs and two other biochars made from a marsh reed and a hard wood.

Organic contaminant isotherms were analyzed by the Freundlich model, and Freundlich sorption coefficients (KFr) were normalized to a single concentration to allow comparison among materials (i.e. Kd). Values of Kd were related to the sorbent surface area, with sorption being greater for ACs than activated biochars, followed by unactivated biochars. ACs also had higher carbon content (80-90%) than biochars (22 – 77%). This sorption trend would thus be expected for adsorption of hydrophobic compounds to black carbon surfaces.

In contrast, at high concentration all biochars removed more Hg from solution than ACs. Steam-activated poultry litter biochars showed the best performance, with consistent removal of >99.7% Hg over the entire pH range. The relatively high sulfur and phosphate content of these materials likely contribute to this enhanced Hg sorption. Also, owing to their lower pyrolysis temperatures relative to ACs, biochars are reported to have a greater surface group functionality which can enhance cation sorption. The importance of acidic surface groups is demonstrated by the lower performance of unactivated biochars at high pH>9. However, at low concentrations AC performed better than the biochars made from marsh reed and hard wood. Thus, biochars as a class of sorbents are highly variable and their sorption properties depend on source material and pyrolysis treatment. Also, ACs contain some surface functionality and perhaps these higher energy sorption sites are not saturated at low Hg concentrations.

For sites with mixed organic and inorganic contamination it is feasible that sustainable remediation may be most efficiently performed using biochar amendments that are tuned during production to optimize their surface area and functionality. High temperature oxidation to produce large surface areas has an energy and carbon cost, yet producing activated sorbents with renewable biomass residues improves sustainability. Biochars may be re-applied over time to account for lower sorptivity of organic pollutants which also augments the benefit to carbon sequestration.