# The Effect of Biochar on Heavy Metal Fate in Soil

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## Background

Biochar is a form of charcoal produced by the pyrolysis of biomass. The global production of biofuels is increasing necessitating an economic and environmentally sustainable solution for its waste (biochar) disposal. The addition of biochar to soils has been suggested as a method of disposal and to improve crop production, carbon sequestration and reduce greenhouse gases. Therefore, it is important to study all of the chemical and physical effects of biochar soil amendment. Preliminary data collected in the Parikh lab shows high sorption capacity of dissolved organic carbon (DOC) from water to walnut shell biochar, while wood feedstock biochar shows low sorption capacity. Previous studies show the decrease of heavy metals with the application of different types of biochar and biosolids (Namgay et al., 2010; Mohan et al., 2010). Increasing biomass pyrolysis temperature leads to high surface area, higher pH, high ash content, high aromatic, and low surface charge. In this research, the effect of biochar on the transport of heavy metals and organics in a soil ecosystem were investigated. The results of this investigation contribute to understanding of metal and organic transport on a multi spatial level (i.e.. soil aggregate to field to watershed). A possible application of this research is biochar use for remediation of contaminated soils, to prevent leaching into the water supply and harmful plant uptake (Xinde and Harris, 2010).

## Objectives

The primary objective of this project is to examine the effects of biochar soil amendments on the transport of heavy metals which are present in soil due to the application of biosolids. In order to examine these effects, the following conditions for metal sorption were investigated:

1) nickel, copper, lead and cadmium independently to sorbent surfaces (walnut shell biochar, wood biochar, kaolinite, activated carbon)
2) nickel, copper, lead and cadmium in competition with one another to sorbent surfaces
3) nickel, copper, lead, and cadmium in competition with one another to sorbent surfaces in the presence of biosolids

## Methods

Experiments were conducted using high temperature (900°C) walnut shell and wood feedstock biochar, activated carbon, kaolinite, and biosolids as the sorbent surfaces in which to determine sorption capacity. Batch experiments were conducted with 5 mM NaCl at pH of 7. The soil solutions were spiked with the heavy metal over various concentrations (0-200 mg $L^{-1}$) and reacted for a constant contact period (24 hr, 24° C, 8 rpm) on an end-over-end shaker. The solution was then centrifuged (8 min at 8,000 RCF) and supernatant filtered (0.8 µm). The heavy metal/organics sorption was quantified using atomic absorbance spectrometry. The amount of metal adsorbed by the biochar was taken as the difference between the initial and final ion concentration of the solutions. A sorption isotherm was constructed for each solution.

## Results

The resulting isotherms showed walnut shell biochar and activated carbon had the highest capacity for heavy metal sorption, as expected based on their high surface area, high experimental sorption of dissolved organic carbon, and high cation exchange capacity of walnut shell biochar. Copper and lead had the highest amount of sorption. Walnut shell biochar sorbed 5043-5091 mg Cu $kg^{-1}$ solid and 4917-

4915 mg Pb kg$^{-1}$ solid. Cadmium was close behind with 4554-4555 mg Cd kg$^{-1}$ solid (Figure 1). Activated carbon sorbed 5226-5230 mg Cu kg$^{-1}$ solid and 4982-4987 mg Pb per kg solid (Figure 2). When the experiment was conducted with combined metal solutions the general pattern was an overall decrease in sorption, with the exception of copper and lead onto walnut shell biochar. Copper had about the same amount of sorption as in the individual metal sample experiment with slightly less sorption of 4699-4717 mg copper per mg solid. Lead increased slightly with sorption of 5339-5343 mg lead per kg solid (Figure 3).

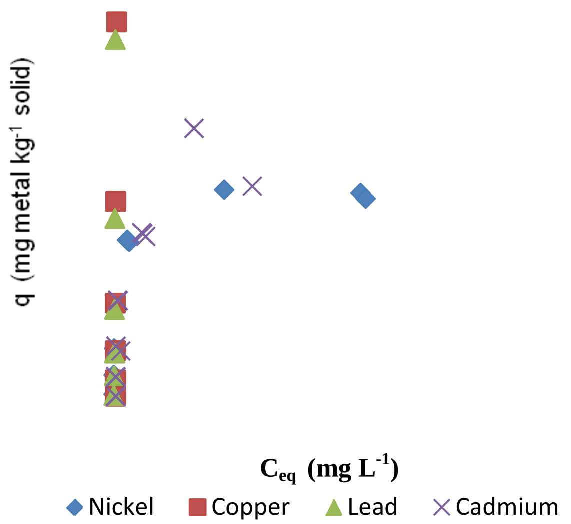


Figure 1. Sorption isotherms for Ni, Cd, Pb, and Cd to walnut shell biochar (no metal competition).

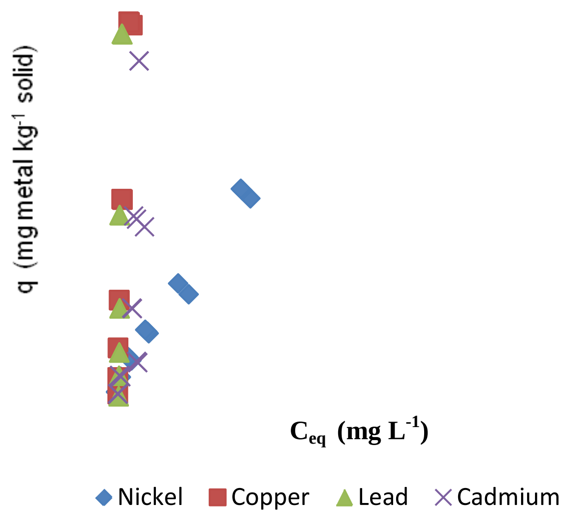


Figure 2. Sorption isotherms for Ni, Cd, Pb, and Cd to activated carbon (no metal competition).

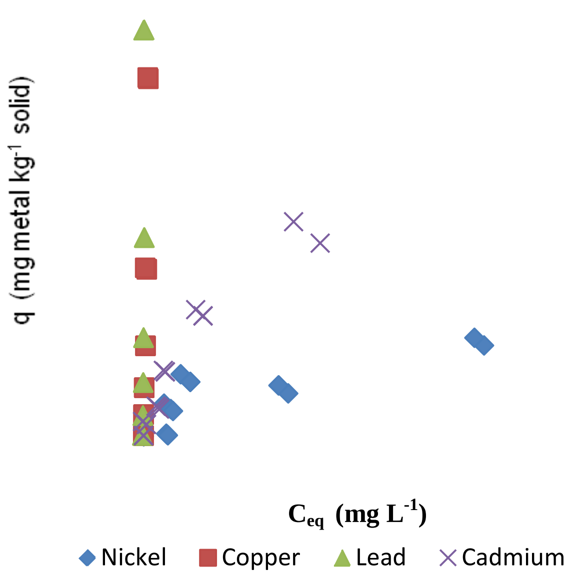


Figure 3. Sorption isotherms for Ni, Cd, Pb, and Cd to walnut shell biochar (with metal competition).

An isotherm for the combined metals with biosolids was attained as well as an isotherm for a solution with each solid (both biochars, kaolinite, activated carbon), combined metals, and biosolids. Definitive results were not attainable from the combined metal plus biosolids experiment. This was in part due to the fact that the lead and cadmium concentrations were so high that when the metals were added to only biosolids solution they were completely sorbed. This allowed no room for comparison of increased sorption with the addition of the other solids. A comparison was made with the Nickel and Copper. All of the isotherms with the addition of the other solids to the biosolids showed a decrease in sorption for nickel. Copper showed a possible increase with the addition of walnut shell biochar. This is inconclusive because twice the mass of total solids were used in this experiment with addition of biosolids and the walnut shell biochar resulting in half of the comparative biosolids isotherm. Therefore direct comparison was difficult.

## Conclusion

Walnut shell biochar shows a high sorption capacity for heavy metals, especially copper and lead. When nickel, copper, lead, and cadmium are present in competition overall sorption decreases with the exception of copper and lead to walnut shell biochar. While the sorption of copper to walnut shell biochar decreases slightly, the sorption of lead to walnut shell biochar is slightly enhanced by the presence of the other metals. The addition of walnut shell biochar to a biosolid solution may enhance the sorption of copper. Possible applications of this research are the use of walnut shell biochar in contaminated soil remediation or wastewater treatment.

**References**

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