ADSORPTION ISOTHERM DETERMINATION AND HEAVY METAL REMOVAL BY ACID-WASHED SOFTWOOD BIOCHAR

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Heavy metal concentrations above critical range in soils may pose environmental and economic problems by hindering plant growth and limiting land usage. Biochar used as soil amendment is a low-cost, natural remediation technique, which has the capability to immobilize and reduce metals (exchangeable, oxide-bound, and organic matter-bound) bioavailable for plant uptake. Its large surface area provides high capacity for binding metals through sorption reactions.

However, arising from the feedstock used for biochar production, metals are also known to become major components usually present in the ash. These metals may be released upon amending soil with biochar through cation exchange processes. This will impose the risk of increased bioavailable metals present in soil. Therefore, treatment prior to soil amendment is needed to eliminate the existing metals that have been incorporated into the biochar. In this study, commercial biochar produced from softwood by pyrolysis at 550 °C was acid washed with 0.05 M HCl to leach existing metals; and 0.1 M KOH was applied to restore the hydroxyl functional groups in biochar.

Biochar binding characteristics of heavy metals are generally represented by adsorption isotherms. These can be used to calculate maximum adsorption capacity and affinity of metals towards biochar. These parameters are important in identifying the sorption capability of biochar to uptake contaminants. Experiments were performed to investigate biochar as adsorbent for removing Zn(II), Ni(II), and Pb(II) from aqueous solution at pH 5. Divalent metals were chosen due to resembling bioavailable forms of metals plants may uptake. The results showed that adsorption of Zn(II) and Ni(II) was well described by a Freundlich isotherm, with maximum adsorption capacities of 0.09 and 0.13 mg/g, respectively. The maximum adsorption capacity for Pb(II) was found to be 11.90 mg/g, which was obtained from fitting with a Langmuir isotherm. These results suggest that the commercial biochar was able to adsorb Zn(II), Ni(II), as well as Pb(II) and reduce their availability in solution. Resemblance with the Freundlich isotherm may suggest the presence of heterogenous binding sites on the biochar surface with regards to Zn(II) and Ni(II). The biochar affinity to Zn(II) (0.04 L/mg) is greater than towards Ni(II) and Pb(II) (0.02 and 0.03 L/mg, respectively). This implies that Zn(II) may be able to compete with both Ni(II) and Pb(II) to biochar binding sites, yet biochar is expected to adsorb less Zn(II) than of the other two metals. In order to determine competition capability of each metal to the biochar binding sites, further competitive adsorption experiments are expected.

Biochar adsorption capacity results were then used to determine the amount of biochar added into soil in a pot experiment to measure plant stress. Biochar was mixed with soil in five different doses (0, 0.5, 1, 3, 5%) with three replications. *Arabidopsis thaliana* was used to assess the effect of biochar application in reducing bioavailable metals for plant uptake. Results suggest that soil amendment by commercial biochar reduces plant stress caused by excessive metal concentrations in soil. These findings prove that the presence of biochar plays a role in decreasing heavy metal bioavailablity via immobilizing and reducing their distribution in soils. However, further investigations on metal fractionations after soil amendment and metal content in plants are needed to verify the mechanism of biochar-mediated reduction of bioavailable metal fractions for plants.