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Mechanisms of Metals Stabilization in the Soil by Biochar Material as Affected by the Low Molecular Weight Organic Acids

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Abstract : Immobilizing trace elements by reducing their mobility and bioavailability through amendment application, especially biochar (BC), is a cost-effective and efficient method to address their toxicity in the soil environment. However, the low molecular weight organic acids (LMWOAs) in the rhizosphere could affect BC's efficiency to immobilize trace metals as the LMWOAs could either mobilize or fix metals in the soils. Therefore, understanding the BC's and LMWOAs' interaction mechanisms on metals stabilization in the rhizosphere is crucial. The present study examined the impact of BC derived from rice husk, tartaric acid (TA), and oxalic acid (OA), and the combination of BC and TA/OA on the changes of cadmium (Cd), lead (Pb), and zinc (Zn) among their geochemical forms through incubation experiment. The changes of zeta potential and X-ray diffraction (XRD) pattern of BC and BC-amended soils to investigate the probable mechanisms of trace elements' immobilization by BC under the attacks of TA and OA were also examined. The rice husk BC at 5% (w/w) was mixed with the air-dry soil (an Anthrosols) contaminated with Cd, Pb, and Zn in the plastic pot. The TA and OA each at 2, 5, 10, and 20 mM kg-1 (w/v) were added separately into the pot. All the ingredients were mixed thoroughly with the soil. A control (CK) treatment was also prepared without BC, TA, and OA addition. After 7, 15, and 60 days of incubation with 60% (w/v) moisture level at 25 °C, the incubated soils were determined for pH and EC and were sequentially extracted to assess the metals' transformation in soil. The electronegative charges and XRD peaks of BC and BC-amended soils were also measured. The BC, low level of TA (2 mM kg-1 soil), and BC plus the low concentration of TA (BC-TA2) addition considerably declined the acid-soluble Cd, Pb, and Zn in which BC-TA2 was found to be the most effective treatment. The trends were reversed concerning the high levels of TA (>5-20 mM kg-1 soil), all levels of OA (2-20 mM kg-1 soil), and the BC plus high levels of TA/OA treatments. BC-TA2 changed the highest amounts of acid-soluble and reducible metals to the oxidizable and residual fractions with time. The most increased electronegative charges of BC-TA2 indicate its (BC-TA2) highest metals' immobilizing efficiency, probably through metals adsorption and fixation with the negative charge sites. The XRD study revealed the presence of P, O, CO32-, and Cl1- in BC, which might be responsible for the precipitation of CdCO3, pyromorphite, and hopeite concerning Cd, Pb, and Zn immobilization, respectively. The findings demonstrated that the low level of TA increased metals immobilization, while the high levels of TA and all levels of OA enhanced their mobilization. The BC-TA2 was the best treatment in stabilizing metals in soil.

Keywords : biochar, immobilization, low molecular weight organic acids, trace elements contaminated soil
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