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Calcium-rich Biochars Synthesis and Valorization for Phosphorus Recovery from Effluents: Dynamic Investigations

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Abstract

Phosphorus (P) is a vital element for humans, animals and crops growth. P natural reserves are non-renewable, heterogeneously distributed in the world. Due to the important increase in the worldwide population and its food needs, these reserves would be seriously depleted before the end of the current century (Cordell et al., 2009). At the same time, large amounts of P are annually discharged in wastewaters with an important risk of surface water bodies quality deterioration (van Puijenbroek et al., 2019). In parallel to that huge quantities of organic and mineral wastes are produced and not appropriately managed. Finding a sustainable solution for P and other nutrients recovery from wastewaters by using solid wastes is considered as an innovative and promising approach that contribute to the achievement of international initiatives regarding sustainability and circular economy concepts promotion (Jellali et al., 2022; Parasana et al., 2022). The objective of this work is to study the efficiency of using calcium-rich biochars for P recovery from aqueous solutions for a reuse in agriculture as slow release fertilizer. In the current wok, we synthesized three biochars from abundant agricultural activities' wastes (poultry manure and date palm fronds) mixed with calcium rich material: waste marble powder at different temperatures (700, 800, and 900 °C). Then, these biochars were deeply characterized by using various sophisticated analytical equipment. P recovery from both synthetic solutions and urban wastewater was studied under dynamic conditions by using laboratory columns and continuous stirring tank reactors (CSTR). The effect of the P initial concentration, the mass of the biochar (or bed height), and the flow rate (contact time) on P recovery performance was assessed. Moreover, the involved mechanisms were explored. Results indicated that increasing the pyrolysis temperature has resulted in the production of biochars with interesting structural, textural and surface chemistry properties. For instance, the highest surface area, pH of zero-point charge, and calcium content were observed for the biochar produced at 900 °C (B-900) with respective values of 52.3 m2/g, 13.5, and 324 mg/g. The application of B-900 for P recovery from synthetic solutions in column mode showed that this process is jointly affected by the three studied parameters. The highest recovery

capacity (79.7 mg/g) was observed for a P initial concentration, a flow rate, and a biochar mass of 25 mg/L, 5 mL/min, and 10 g, respectively. This biochar also shows a high P recovery efficiency even from P-doped urban wastewater (55.8 mg/g). In CSTR mode, B-900 exhibits excellent P recovery for both synthetic solution and wastewater effluent. Indeed, the P recovered amount in this mode was 43% higher than that observed in column assays. Based on specific analyses, the P recovery process was found to include electrostatic interactions, complexation and mainly precipitation as hydroxyapatite ($Ca_5(PO_4)_3OH$). In real cases, we suggest to recover P from existing wastewater treatment plants through the implementation of a CSTR followed by a decantation device after the secondary treatment step. The P-loaded biochar, collected at the decantation device, could be valorized in agriculture as slow release fertilizer instead of the commercial synthetic ones. Valorization of this P-loaded biochar for the growth of local plants in pot mode is currently under progress.

Keywords: Phosphorus, biochars, recovery, column, CSTR

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