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Date Palm Wastes Turning into Biochars for Phosphorus Recovery from Aqueous Solutions: Static and Dynamic Investigations

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Abstract : Huge amounts of agricultural biomasses are worldwide produced. At the same time, large quantities of phosphorus are annually discharged into water bodies with possible serious effects onto the environment quality. The main objective of this work is to turn a local Omani biomass (date palm fronds wastes: DPFW) into an effective material for phosphorus recovery from aqueous and the reuse of this P-loaded material in agriculture as ecofriendly amendment. For this aim, the raw DPFW were firstly impregnated with 1 M salt separated solutions of $CaCl_2$, $MgCl_2$, $FeCl_3$, $AlCl_3$, and a mixture of $MgCl_2$/$AlCl_3$ for 24 h, and then pyrolyzed under N2 flow at 500 °C for 2 hours by using an adapted tubular furnace (Carbolite, UK). The synthetized biochars were deeply characterized through specific analyses concerning their morphology, structure, texture, and surface chemistry. These analyses included the use of a scanning electron microscope (SEM) coupled with an energy-dispersive X-Ray spectrometer (EDS), X-Ray diffraction (XRD), Fourier Transform Infrared (FTIR), sorption micrometrics, and X-ray Fluorescence (XRF) apparatus. Then, their efficiency in recovering phosphorus was investigated in batch mode for various contact times (1 min to 3 h), aqueous pH values (from 3 to 11), initial phosphorus concentrations (10-100 mg/L), presence of anions (nitrates, sulfates, and chlorides). In a second step, dynamic assays, by using laboratory columns (height of 30 cm and diameter of 3 cm), were performed in order to investigate the recovery of phosphorus by the modified biochar with a mixture of Mg/Al. The effect of the initial P concentration (25-100 mg/L), the bed depth height (3 to 8 g), and the flow rate (10-30 mL/min) was assessed. Experimental results showed that the biochars physico-chemical properties were very dependent on the type of the used modifying salt. The main affected parameters concerned the specific surface area, microporosity area, and the surface chemistry (pH of zero-point charge and available functional groups). These characteristics have significantly affected the phosphorus recovery efficiency from aqueous solutions. Indeed, the P removal efficiency in batch mode varies from about 5 mg/g for the Fe-modified biochar to more than 13 mg/g for the biochar functionalized with Mg/Al layered double hydroxides. Moreover, the P recovery seems to be a time dependent process and significantly affected by the pH of the aqueous media and the presence of foreign anions due to competition phenomenon. The laboratory column study of phosphorus recovery by the biochar functionalized with Mg/Al layered double hydroxides showed that this process is affected by the used phosphorus concentration, the flow rate, and especially the column bed depth height. Indeed, the phosphorus recovered amount increased from about 4.9 to more than 9.3 mg/g used biochar mass of 3 and 8 g, respectively. This work proved that salt-modified palm fronds-derived biochars could be considered as attractive and promising materials for phosphorus recovery from aqueous solutions even under dynamic conditions. The valorization of these P-loaded-modified biochars as eco-friendly amendment for agricultural soils is necessary will promote sustainability and circular economy concepts in the management of both liquid and solid wastes.

Keywords : date palm wastes, Mg/Al double-layered hydroxides functionalized biochars, phosphorus, recovery, sustainability, circular economy
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