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Synthesis of porous MgO-biochar nanocomposites for removal of phosphate and nitrate from aqueous solutions

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HIGHLIGHTS

- ▶ A new synthesis method for MgO-biochar nanocomposites was developed.
- ▶ MgO nano-flakes within a biochar matrix have uniform morphologies.
- ▶ Biochar matrix is mesoporous with average pore size of 50 nm.
- ▶ Nanocomposites showed excellent removal efficiencies to phosphate and nitrate.

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ABSTRACT

A new synthesis was developed to create highly porous nanocomposite material consisting of MgO nanoflakes within a biochar matrix that has high sorption ability for ionic contaminations. The synthesis method was used in laboratory to produce MgO-biochar nanocomposites from a variety of carbon-rich biomass. Physical and chemical properties of the synthesized nanocomposites were studied systematically with X-ray powder diffraction, thermogravimetric analysis, scanning electron microscopy, high-resolution transmission electron microscopy, and energy-dispersive X-ray analysis. In addition, batch sorption experiment was conducted to determine the sorption ability of the MgO-biochar nanocomposites to aqueous phosphate and nitrate. The results showed that the MgO nano-flakes have uniform morphologies and disperse uniformly on the surface of the biochar matrix. HR-TEM indicated that the biochar matrix is mesoporous with average pore size of 50 nm and the MgO nano-flakes have spacing between 2 and 4 nm, which can serve as adsorption sites for anions. As a result, all the tested MgO-biochar nanocomposites showed excellent removal efficiencies to phosphate and nitrate in water. Nanocomposites made from sugar beet tailings and peanut shells had the best performances with Langmuir adsorption capacities as high as 835 mg g^{-1} for phosphate and 95 mg g^{-1} for nitrate, respectively, much higher than the reported values of other adsorbents.

1. Introduction

Excessive phosphorous (P) and nitrogen (N) release into runoff from human activities is considered as the major cause of eutrophication, which degrades fresh water and imposes great risk to the ecosystem [1–5]. Biological, chemical, and physical treatment methods have been developed for various applications to remove P and N from aqueous solutions prior to their discharge into runoff and natural water bodies [6–8]. Because the cost of these treatment technologies is substantial, there is a need to develop more cost effective and high efficiency technologies for P and N removal.

Biochar is a stable solid, rich in carbon and is resistant to decomposition an mineralization [9]. When applied to soils, biochar can increase soil fertility, raise agricultural productivity, increase soil nutrients, and enhance soil water holding capacity [10–12]. In addition, it can also serve as carbon storage to reduce CO_2 emissions and mitigate climate change [13–16]. During the past several years, considerable research effort has also been made on biochar-based adsorbents for removal of aqueous contaminants. In this practice, biochar adsorbents are often made from various precursors, such as wood, grass, manure, without any modifications and then are evaluated in laboratory to select the ones with the best performance for desired application [17–23]. Through this method, a number of biochars have been identified as effective adsorbents for some common water pollutants, such as organic compounds and heavy metals [24–31].

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