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ORIGINAL RESEARCH

Modification of Fe_2O_3-contained lignocellulose nanocomposite with silane group to remove nitrate and bacterial contaminations from wastewater

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Abstract

Natural composite containing iron oxide in lignocellulose (L/IO) was obtained from an extract of apricot tree wood by heating it in a wood coal furnace. This method provided a facile, "green" pathway for the fabrication of magnetic carbon substrate without using chemical reactions. Ion exchange technology was used to remove the nitrate using (L/IO) modified with 3-chloropropyltrimethoxysilane and 1,4-diazabicyclo[2.2.2]octane (Dabco) (ML/IO). The physicochemical properties were characterized by field emission scanning electron micrographs (FESEM), energy-dispersive X-ray analysis (EDX), alternating gradient force magnetometer (AGFM), thermogravimetric analysis (TGA) and Fourier transform infrared (FTIR) spectra for both (L/IO) and (ML/IO) as adsorbents. Preliminary experiments indicated less favorability of (L/IO) in removing nitrate from water compared to (ML/IO). Batch adsorption experiments were performed and the effects of pH, contact time, adsorbent dosage, initial nitrate concentration (C_i), temperature and competing anions were assayed on nitrate adsorption by (ML/IO). The obtained data were modeled using four kinetic models including the pseudo-first order (PFO), pseudo-second order (PSO), Weber–Morris and Elovich. The best fit of experimental adsorption data was exhibited by means of the pseudo-second-order model (R^2 0.99). Also, the equilibrium data were fitted to the Langmuir, Freundlich, Temkin, Redlich–Peterson isotherm equations and the favorable fit exhibited with two Langmuir and Redlich–Peterson isotherms (R^2 0.98). Finally, the desorption and regeneration studies showed a promising reusability of the (ML/IO). Antimicrobial activities of both (L/IO) and (ML/IO) were investigated by disc diffusion method against two Gram-positive bacteria, namely *S. aureus* and *B. cereus*, and four Gram-negative bacteria, namely *E. coli*, *K. pneumoniae*, *P. aeruginosa* and *S. typhi*, and two fungi, namely *Aspergillus niger* and *Saccharomyces cerevisiae*, in vitro. The antimicrobial effects were more prominent in all cases for (ML/IO) compared to (L/IO). The investigations confirmed that (ML/IO) was more active against Gram-negative (IZD 8–19 mm) than Gram-positive (IZD 6–8 mm) bacteria. The highest antibacterial activity of (ML/IO) was exhibited against *E. coli* with IZD value of 19 mm.

Keywords Iron oxide-loaded lignocellulose · 3-Chloropropyltrimethoxysilane · Pseudo-second-order kinetic model · Antimicrobial activities · Disc diffusion method

Introduction

In recent decades, many natural materials such as carbon-based adsorbents, agricultural wastes and synthetic resins [1] have been applied as adsorbents for the removal of nitrate from groundwater and surface water resources. Some important advantages of these materials include low operational expense and reuse after saturation as fertilizer to agricultural lands [2]. Studies have proven that among agricultural wastes, rice hull, sugarcane bagasse, coconut shells, wheat straw and almond shell had more favorable effects for the removal of nitrate ions from water [3]. Generally, the

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