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Natural Minerals Coated by Biopolymer Chitosan: Synthesis, Physicochemical, and Adsorption Properties

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Abstract

Natural minerals are widely used in treatment technologies as mineral fertilizer, food additive in animal husbandry, and cosmetics because they combine valuable ion-exchanging and adsorption properties together with unique physicochemical and medical properties. Saponite (saponite clay) of the Ukrainian Podillya refers to the class of bentonites, a subclass of layered magnesium silicate montmorillonite. Clinoptilolits are aluminosilicates with carcase structure. In our work, we have coated biopolymer chitosan on the surfaces of natural minerals of Ukrainian origin — Podilsky saponite and Sokyrnitsky clinoptilolite. Chitosan mineral composites have been obtained by crosslinking of adsorbed biopolymer on saponite and clinoptilolite surface with glutaraldehyde. The obtained composites have been characterized by the physicochemical methods such as thermogravimetric/differential thermal analyses (DTA, DTG, TG), differential scanning calorimetry, mass analysis, nitrogen adsorption/desorption isotherms, scanning electron microscopy (SEM), and Fourier transform infrared (FTIR) spectroscopy to determine possible interactions between the silica and chitosan molecule. The adsorption of microquantities of cations Cu(II), Zn(II), Fe(III), Cd(II), and Pb(II) by the obtained composites and the initial natural minerals has been studied from aqueous solutions. The sorption capacities and kinetic adsorption characteristics of the adsorbents were estimated. It was found that the obtained results have shown that the ability of chitosan to coordinate heavy metal ions Zn(II), Cu(II), Cd(II), and Fe(III) is less or equal to the ability to retain ions of these metals in the pores of minerals without forming chemical bonds.

Keywords: Adsorption, Chitosan, Composite, Heavy metals, Calorimetry, Thermal analysis

Background

Application of chitinous products in wastewater treatment has received considerable attention in recent years in the literature [1–8]. In particular, the development of chitosan-based materials as useful adsorbent polymeric matrices is an expanding field in the area of adsorption science [9]. Chitosan is a type of natural polyaminosaccharide, obtained by deacetylation of chitin [10], which is a polysaccharide consisting predominantly of unbranched chains of β-(1→4)-2-acetoamido-2-deoxy-*D*-glucose [11]. Composites based on chitosan are economically feasible because they are easy to prepare and involve inexpensive chemical reagents [11]. Recently, chitosan composites have been developed to adsorb heavy metals and dyes from wastewater [10, 12–15].

Chitosan composites have been proven to have better adsorption capacity and resistance to acidic environment [11]. Various methods of preparation of hybrid materials based on inorganic materials and polysaccharides such as chitin [1–8] and chitosan for different applications have been studied [9, 11, 16–18]. Different kinds of substances have been used to form composite with chitosan such as silica, montmorillonite, polyurethane, activated clay, bentonite, polyvinyl alcohol, polyvinyl chloride, kaolinite, oil palm ash, perlite, and magnetite [19–23]. Although such minerals possess high adsorption capabilities, the modification of their structure can successfully improve their capabilities. In work [24], chitosan/attapulgite composites are applied as an adsorbent for the removal of chromium and iron

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