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Water Purification with Natural Sorbents: Effect of Surface Modification with Nano-Structured Particles

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Abstract

Modified nanostructured sorbents are widely used in water treatment processes. In this work, aluminum and iron particles prepared by electro-spark dispersion have been applied as modifiers. Zeolite samples from "Holinskoe" mineral deposit (Russia, Republic of Buryatia), with a size smaller than 0.1 mm, have been modified with aluminum and iron particles, using a sol-gel process. The properties of the modified materials have been determined by means of sorption test, when removing ions Pb^{2+}, Fe^{3+} and Cd^{2+} from the model solutions in static conditions. Using the method of thermal desorption of nitrogen (BET) it has been shown that increasing the iron content in the samples of nanostructured modified sorbents does not affect the increase in specific surface area and pore volume of the samples. Ions concentrations have been analyzed by stripping voltammetry and photocolorimetry. As a result, modified sorbents revealed a high efficiency sorption of heavy metals.

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Keywords: nanoparticles; sorbent; water purification; lead; iron; cadmium; heavy metals; electro-spark dispersion; sol-gel process.

1. Introduction

One of the important problems, currently facing the society, is the provision of clean drinking water. According to the forecasts, the situation will worsen in the future due to the reduction of fresh water supplies and population

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growth[1,2]. Among the various methods of water purification, filtration plays a major role. That is why new types of nanostructured materials become more and more widely used[3-5]. Heavy metals are among the most common of the various types of hydrosphere pollution[6,7]. Ions of heavy metals are toxic and bioaccumulative, with further biomagnification. Therefore, the purification of drinking water of heavy metal compounds is an important process for life safety, and the design of new types of nanostructured sorbents for the removal of heavy metals from water is a very relevant task. There are various physical and chemical methods for preparing samples of nanostructured materials, such as a sol-gel process, electro-spark dispersion, and electric explosion[8]. The choice of nanoparticles preparation approach depend on the physical and chemical characteristics required for the final product, such as size, dispersion, chemical miscibility and total cost of it, especially for widely used products[9]. In this work, we consider the method of electro-dispersion for preparation of nanostructured materials, for the purpose of their further application to create modified zeolites. The resulting nanostructured product can be used in designing a new filter system for water purification. Detail process description and confirmation nanoscale size of the materials prepared by this method, are reflected in works[9-11]. The aim of this work was to crate and study the physicochemical and sorption properties of new modified sorbents with nanostructured surface based on aluminum and iron, obtained by the electro-dispersion method. The sorption studies of the samples were carried out in aqueous solutions containing ions of lead Pb^{2+}, iron Fe^{3+} and cadmium Cd^{2+}.

2. Materials and methods

2.1 Preparation of modifiers for sorbent surface

Electric-spark dispersion method was used for preparation of nanostructured materials based on aluminum and iron, as following. The dispersion was carried out in an aqueous medium. Figure 1 shows the scheme of the experimental apparatus for nano-powder preparation. The experimental device consisted of a pulsed power supply and reactor made of a dielectric material (porcelain container, V = 1.0 dm^3), in which aluminum electrodes, metal loading and a working fluid were placed. Under the action of the pulse, many micro discharges appeared between the aluminum granules, causing erosion of granules with evaporation in the contact area and spraying of the small metal particles from the granules. The power supply generated voltage pulses with a duration of 15 μs with the voltage amplitude of 500 V, the current amplitude of 250 A, and pulse frequency of 400 Hz. The inter-electrode gap was filled with cylindrical aluminum granules with the diameter from 3 to 5 mm, total weigh 100 g. Thickness of the granular layer was 10 mm. Aluminum rods with a diameter of 4mm were used there as electrodes. The distance between the electrodes was 100 mm. The general scheme of the reactor for electric spark dispersing is shown in Figure 1.

Distilled water was used as a working fluid for preparation of the sample #1. For preparation of the samples #2, 3, 4, an aqueous solution of iron sulfate (containing 1 g, 2 g and 3 g of $FeSO_4$ respectively) was used as a working fluid. The volume of the working fluid was 500 cm^3 for all samples. The working solution was treated by pulsed electric discharge within 5 minutes. The samples were obtained as colloidal solutions, which were placed in glass beakers for further procedure.