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Investigation of Nanocomposite Based on Cationic Starch and Na-montmorillonite as Adsorbent for dye Removal

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Nanocomposite based on cationic starch and Na-montmorillonite was obtained by solid-state procedure in a vibration mill with balls. Adsorption capacity of the nanocomposite towards Acid Scarlet dye was evaluated. This sorbent was found to provide a high degree of the dye removal from aqueous solutions.

Keywords: Cationic starch, Na-montmorillonite, Vibration mill, Adsorption, Acid Scarlet dye.

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1. INTRODUCTION

A removal of dyes by adsorption process is an effective method for the purification of textile industry wastewater. A variety of adsorbents were proposed to this purpose, including biosorbents based on modified starches [1-3]. It was shown that loading of starch matrix with layered silicates (mainly montmorillonite), having large specific surface area provided an improvement of the starch adsorbent quality [4].

In this study nanobiocomposite based on cationic starch and Na-montmorillonite was obtained by resource saving solid-state procedure in a homemade vibration mill with balls. Such device has some advantages over other equipment, for example extruders, traditionally used for solid-state processing of plastic. Namely, it is possible to control more flexibly the treatment conditions by varying the vibration amplitude and frequency, and also the size and weight of balls loaded into the reaction chamber. Contamination of the composites with wear products of milling bodies can be eliminated by making the milling bodies of high-strength materials, e.g., of porcelain, ceramics, or agate. The working chamber is sealed, which allows the process, if necessary, to be performed in an inert medium. The process can be performed in the batch mode.

The work was aimed to investigation of the nanobiocomposite produced in a vibration mill as adsorbent for acid dye removal from aqueous solution.

2. EXPERIMENTAL

2.1 Preparation and Characterization of Nanocomposite Based on Cationic Starch and Na-MMT

Cationic starch (CS) with the substitution degree of 0.026 was kindly provided by All-Russian Institute of Starch Products of RAAS. Bentonite clay was purchased from Bentonite Company Ltd. and treated by the procedure described in [5] to separate out Na-montmorillonite (Na-MMT). The components in the weight ratio CS : Na-MMT : water = 70 : 3.5 : 26.5 were charged into a cylindrical vessel packed with balls and subjected to milling for 2 h. The vessel and balls were made of high-strength porcelain. The activator vibration frequency was 50 Hz, and the vibration amplitude was 8 mm. To enhance the efficiency of mechanical action on the components and intensify their mixing, we used a mixture of balls 20 and 15 mm in diameter.

The X-ray phase analysis of the composite was performed with a DRON-3 diffractometer using nickel filtered CuKα radiation.

2.2 Adsorption Experiments

Adsorption studies were performed by the batch technique at the temperature of 295 K. Nanocomposite or CS (0.025 g) was placed into cone flask and 25 ml of Acid Scarlet dye solution (C = 0.2-100 mg/L) was added. In all experiments, the reaction mixture pH value was 7.4. This system was stirred for a given contact time (t) varied in the range of 5-360 min. After that the solution was subjected to centrifugation at 8000 rpm for 15 min. The residual concentration of dye in the supernatant was determined by spectrophotometry. The amount of adsorbed dye Q_t (mg/g) was calculated from the differences between the concentrations of dye added to that in the supernatant.

3. RESULTS AND DISCUSSION

The X-ray patterns of the obtained CS / Na-MMT composite and pure Na-MMT are shown in Fig. 1. The results demonstrate that Na-MMT under study had the typical basal reflex at the diffraction angle $2\theta = 6.90$ corresponding to a distance of 1.28 nm between silicon-oxygen layers. After the mechanical treatment in a mixture with starch, the diffraction maximum of Na-MMT shifted toward smaller angles, $2\theta = 4.80$. This fact indicated an expansion of the interplanar spacing up to 1.84 nm in the clay structure

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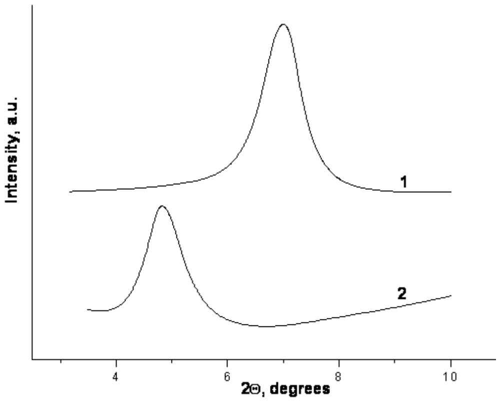

Fig. 1 – X-ray patterns of (1) Na-MMT and (2) CS / Na-MMT nanobiocomposite prepared in vibration mill

due to the intercalation of the polysaccharide molecules between silicate layers. Thus, with processing conditions under study intercalated nanobiocomposite was formed.

For the purpose of evaluating the adsorption of Acid Scarlet dye onto starch-based adsorbents the kinetic of this process was investigated in the first place. It was revealed, that CS / Na-MMT nanocomposite adsorbed the dye faster than CS (Fig. 2). After 30-min contact under comparable initial solute concentrations the amount of Acid Scarlet dye adsorbed by CS / Na-MMT nanocomposite was higher by 15-50 % in comparison with amount of this dye adsorbed by CS.

In order to examine the adsorption mechanisms several kinetic models were employed to fit the experimental data. The best correlation between the experimental values and Dumwald-Wagner intraparticle model [6] was found.

To compare the adsorption capacity of CS / Na-MMT nanocomposite towards Acid Scarlet dye with that of CS adsorption isotherms were plotted and analyzed (Fig. 3). The adsorption capacity of CS / Na-MMT nanocomposite and CS was found to be 40.2 and 12.9 mg/g, respectively.

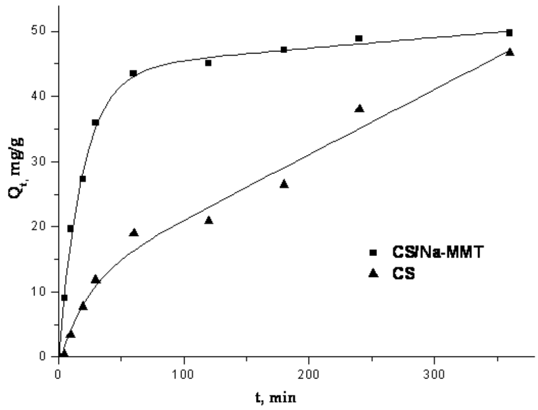

Fig. 2 – Kinetic sorption curves of Acid Scarlet dye onto CS / Na-MMT and CS. The initial dye concentration 50 mg/L

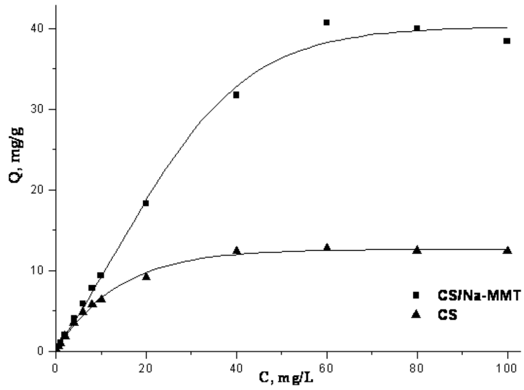

Fig. 3 – Adsorption isotherms of Acid Scarlet dye onto CS / Na-MMT and CS. Adsorption time 30 min

4. CONCLUTIONS

The vibration mill with balls was used as a tool for solid-state preparation of nanocomposite based on CS and Na-MMT. XRD analysis revealed intercalated structure of formed nanocomposite.

The potential for the use of this CS / Na-MMT nanocomposite for the removal of Acid Scarlet dye from aqueous solutions was investigated. Kinetic studies of adsorption were carried out to reveal the adsorption mechanism. CS / Na-MMT nanocomposite obtained in this work was proved to be of high efficiency for Acid Scarlet dye removal.

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