SYNTHESIS OF CELLULOSE-BASED SORBENTS FOR HEAVY METAL ADSORPTION

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Contamination of natural water resources by heavy metal ions poses significant environmental and health risks to humans. Reversible polymeric adsorbents, especially those based on cellulose, are of great interest for addressing this problem. This paper investigates the conditions for grafting maleic anhydride onto cellulose macromolecules and the ability of the obtained product to adsorb heavy metals.

Contamination of natural water resources by heavy metal ions presents significant environmental and health risks to humans. Reversible polymeric adsorbents, particularly those derived from cellulose, have garnered considerable interest as a solution to this issue. This study investigates the conditions for grafting maleic anhydride onto cellulose macromolecules and evaluates the resulting product's capacity to adsorb heavy metals.

Polymer-molded sorbents are of great practical importance today. They offer a number of advantages over other sorbents, such as high sorption capacity, selectivity, modification ability, chemical and mechanical stability, cost-effectiveness, and reusability [1]. Currently, synthetic polymers are predominantly used in the practice of sorbent production. When these polymers are used for extended periods or improperly stored, they undergo degradation and change their properties.

The disposal of used synthetic polymers poses a significant challenge, contributing to environmental and ecological pollution. As a result, numerous studies have focused on developing sorbents from natural, biodegradable polymers [2,3].

Cellulose is one of the most abundant natural polymers on Earth, comprising approximately 40–50% of the planet's total biomass. Each year, around 1.5 trillion tons of cellulose are regenerated globally through biological processes.

Consequently, extensive research has been conducted to develop cellulose-based materials with enhanced sorption properties [4].

Cellulose is a natural, stable biopolymer, with three hydroxyl groups in each monomer unit. These hydroxyl groups form numerous intra- and intermolecular hydrogen bonds, which reduce cellulose's reactivity. As a result, its sorption properties are relatively low, though they can be enhanced through modification. Grafting maleic anhydride onto cellulose and its subsequent interaction with urea creates a modified form of cellulose that can form chelates with metal ions. This modification improves the hydrophilicity, mechanical stability, and adsorption capacity of the polymer.

The optimal reaction conditions for grafting maleic anhydride onto cellulose macromolecules were investigated. A cellulose-to-maleic anhydride mass ratio of 1:1, at a temperature of 50°C, pH 2, and a reaction time of 3 hours, yielded a product with a high exchange rate. The resulting product was analyzed using IR spectroscopy, SEM, TGA, and XRD techniques.

IR spectroscopy revealed the formation of new absorption bands in the cellulose macromolecule, corresponding to carbonyl (-C=O) and amine ($-NH_2$) groups. SEM micrographs identified microscopic pores in the modified cellulose.

The sorption properties of the obtained product for Cu(II), Mn(II), Cd(II), Fe(III), and Pb(II) ions were evaluated, and the influence of factors such as pH, temperature, contact time, and metal concentration on sorption efficiency was assessed. The highest sorption was achieved after 90 minutes at pH 7, using 0.2 g of sorbent.

Based on the results, the Langmuir model suggests that the sorption process is acceptable for values of RL greater than 0 and less than 1. In contrast, the Freundlich model coefficient corresponds to values of 1/n between 0.1 and 1. However, the sorption process based on the Langmuir model exhibited R^2 values higher than those of the Freundlich model, indicating a better fit to the Langmuir isotherm.

Modified cellulose, treated with maleic anhydride, demonstrated high efficiency in the sorption of Cu(II), Mn(II), Cd(II), Fe(III), and Pb(II) ions from aqueous solutions. Analysis of the equilibrium data indicated that the Langmuir isotherm provides the best fit for the sorption process. The ion release percentage ranged from 80% to 100%. These findings have both scientific and practical significance for the development of biodegradable, environmentally friendly sorbents for treating wastewater contaminated with heavy metals.

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