Influence of Various Factors on the Metal-Binding Capacity of Cellulose

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Abstract. The article deals with the influence of such parameters as pH and temperature on the metal-binding capacity of cellulose obtained from various natural sources of vegetable origin. An attempt to describe the mechanism of copper ions interaction with cellulose samples has been made. When describing the binding process according to the Langmuir equation, the equation of linear logarithmic form parameters have been determined.

1. Introduction

Cellulose is the most widespread polysaccharide of vegetable origin; its structure belongs to the class of linear homopolysaccharides. Cellulose is widely used in various sectors of the national economy, for example, in the production of paper, plastics and fabrics [1, 5–8]. Cellulose is the most important component of any organism of vegetable origin [2–4, 9, 10], however, its effect on the organism of animal origin is underestimated.

At a given time, scientists are especially interested in the metal-binding properties of cellulose. The very structure of this polysaccharide creates the ability to bind metal ions. This is especially true when it comes to heavy metal ions.

Cellulose macromolecules are formed by β-D-glucopyranose units connected by β-(1 → 4)-glycoside bonds.

The general structure of this polymer is depicted by the formula shown in figure 1.

Figure 1. Structural formula of cellulose macromolecule [1–5].
2. Objects and methods of research
Vegetable raw materials of various origins, which contain cellulose, were the material for the research. One of the determining factors was the availability factor of natural raw materials (this factor was especially relevant when choosing raw materials for obtaining cellulose from linen raw materials, since not all types of this plant are cultivated in Novgorod region) and the ability to obtain cellulose from it at minimal cost. The following materials were used as objects of research in the work:
1. A product of processing the fiber flax fibers (hereinafter – linen cellulose or sample no. 1).
2. A product of processing the stalks of wheat fibers (hereinafter – wheat cellulose or sample no. 2).
3. Product of processing the spruce fir chips (hereinafter – spruce cellulose or sample no. 3).

The plants have been processed to obtain cellulose according to generally accepted methods [2, 4]. Determination and the analysis of the chemical reactions’ products have been carried out spectrophotometrically and potentiometrically.

3. Results and discussion
Studying the effect of parameters such as temperature and pH on the metal-binding capacity of copper ions cellulose has been carried out. These parameters influence the metal-binding capacity of metal ions cellulose.

The data obtained are presented in figures 2 and 3.

![Figure 2](image_url)

**Figure 2.** Dependence of the metal-binding capacity of cellulose samples on temperature at an initial concentration of 0.1 mg/cm³ copper ions.

Temperature does not affect the metal binding capacity of cellulose samples as strongly as expected. Therefore, the efficiency of the process of binding metal ions with cellulose increases insignificantly.

The increase in the binding efficiency of copper ions Cu²⁺ at pH within the range from 2.0 to 6.5 can be explained by the fact that the binding process takes place involving a large number of functional groups in the material macromolecules composition, to a greater extent due to the complexation. Complexation, in turn, significantly depends on the solution pH, but up to certain limits. In the alkaline pH range, the Cu(OH)₂ deposit formation will compete with the complexation process. As the research results show, the optimal pH at which the maximum binding values will be achieved is 6 ± 0.2 pH.
Figure 3. Dependence of the metal-binding capacity of cellulose samples on pH at an initial concentration of 0.1 mg/cm³ copper ions and a temperature of 298 K.

An attempt to describe the mechanism of copper ions interaction with cellulose through the Langmuir equation has also been made.

In the references [4, 5, 9], among the potential mechanisms of metal ions, copper ions in particular, sorption on cellulose-containing materials the following ones are indicated:

– processes of ion exchange on carboxyl groups;
– complexation due to interaction with hydroxyl groups;
– complexation involving all oxygen atoms in the cellulose elementary unit.

Based on the data obtained, isotherms of Langmuir sorption by cellulose of Cu²⁺ copper cations have been constructed and numerical values have been determined in the sorption equation – table 1.

Table 1. Parameters of linear logarithmic form equation.

| Cellulose type | K     | n       | Correlation coefficient |
|----------------|-------|---------|------------------------|
| Sample 1       | 1.22±0.50 | 0.28±0.07 | 0.96                   |
| Sample 2       | 1.18±0.40 | 0.18±0.07 | 0.96                   |
| Sample 3       | 1.22±0.50 | 0.32±0.07 | 0.98                   |

4. Conclusion

Experiments carried out to determine the effect of such parameters as temperature and pH on the metal-binding capacity of cellulose samples, have shown that temperature does not have a significant effect on the process.

The dependence of the copper binding process by cellulose of various origins on pH has been established. The optimal value for the most efficient copper ions extraction from solution is pH=6.0.

The results of studying the sorption capacity of cellulose of various types have shown that the sorption process can be described by the Langmuir equation. Sorption isotherms have been constructed and process parameters calculated.
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