A STUDY OF THE SORPTION OF HEAVY METALS FROM AQUATIC SOLUTIONS BY SORBENTS BASED ON CELLULOSIC WASTE

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OUTLINE

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- The effects of zinc ion on human body

Research aim and objectives

- Conduct literature review
- Prepare samples and analyze cellulose content
- Perform sorption experiments with cellulose-containing sorbents

Methodology

- Literature review and experimental part

Results and Discussion

- Key findings and visual representation of findings

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RESEARCH RELEVANCE

– The flagship profile production in Kazakhstan;
– A plant producing up to **193,000 tons** of zinc per year;
– Over 75 years, the plant has produced **13,686,126** tons of zinc.

KAZZINC

– The total volume of **drainage is 194,508.7 m³/year.**
– Volume of industrial **wastewater is 190,611.0 m³/year.**

Relevance of the study: Wastewater enters groundwaters, contaminating them. Ions of heavy metals present in wastewaters pose a threat to human health and environment. Addressing water pollution is essential for improving public health and environmental sustainability.

THE EFFECT OF ZINC ON THE HUMAN BODY

Excess zinc can cause:

- Nausea
- Vomiting
- Diarrhea
- Headaches
- Fatigue
- Reduced immunity
- Liver and kidney damage
- Impaired absorption of other trace elements, such as iron and copper.

RESEARCH AIM AND OBJECTIVES

Research aim: examine different chemical activation methods to optimize sorption conditions and establish optimal conditions for zinc ion removal .

Research objectives:

1) Conduct literature review and select research methods;
2) Data collection and preparation of samples for experiments;
3) Determine the cellulose content in samples;
4) Conducting experiments on the sorption of zinc ions from model solutions using cellulose-containing sorbents and determining optimal sorption conditions.

SORBENTS FOR REMOVAL OF Zn^{2+}

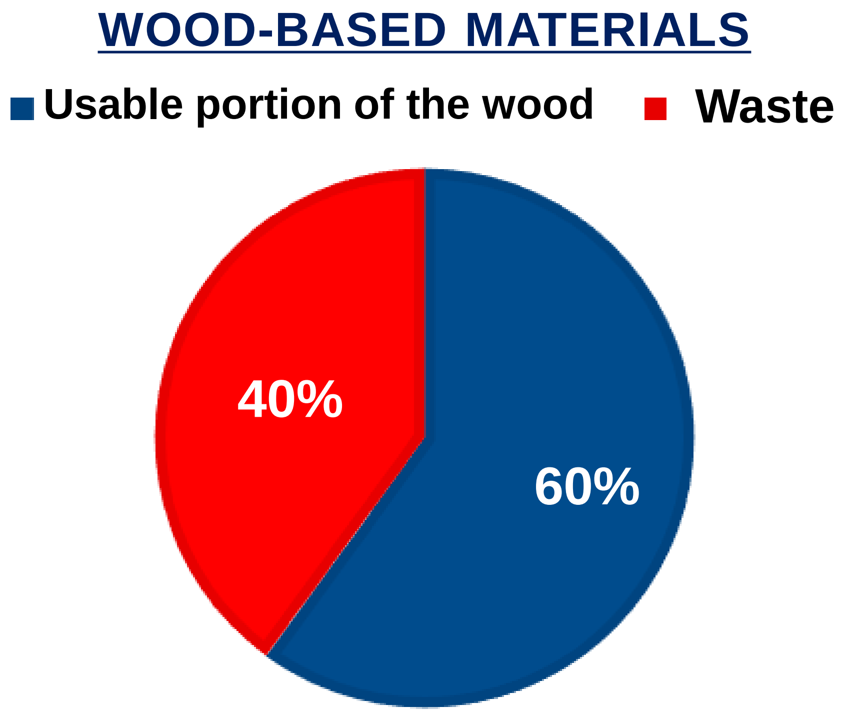
Sorbents for zinc ion removal	Conditions	Authors
Activated carbon	Mass of sorbent: varied from 5 g/L to 20 g/L, duration: 30 minutes.	(Mishra & Patel, 2009)
Humic substances	Mass of sorbent: 20 g/L, duration: 3 hours.	(Bogatryov, Dmitrieva, Leontyeva, & Syundyukova, 2017)
Modified bentonite	Mass of sorbent: 20 g/L, duration: 3 hours.	(Xue & Huang, 1995)
Kaolin	Mass of sorbent: varied from 5 g/L to 20 g/L, duration: 3 hours.	(Mishra & Patel, 2009)

Table 1. Sorbents that can be used to remove Zn^{2+}

ADVANTAGES OF USING SAWDUST AS A SORBENT

- Wood shavings;
- Sawdust;
- Small pieces of wood.

account for **up to 40%** of the mass of wood-based materials.

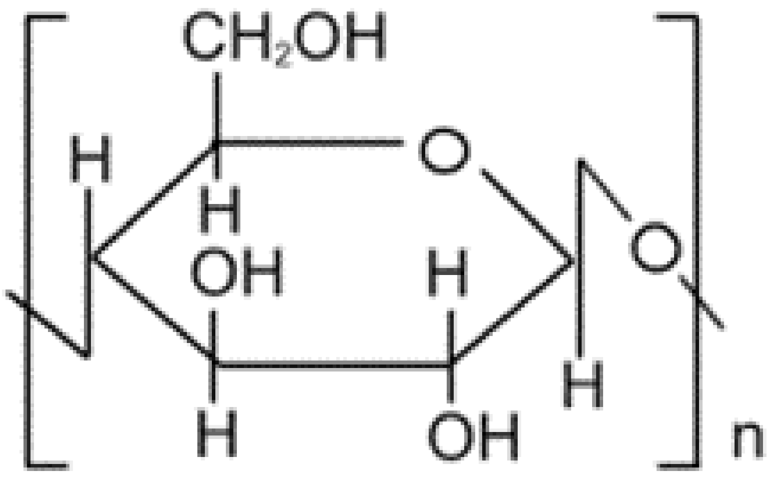


Advantages of using sawdust as a sorbent:

- Eco-friendly (Support sustainability);
- High sorption capacity;
- Acceptable price compared to synthetic materials.

ADSORPTION CAPACITY OF CELLULOSE-BASED MATERIALS

The macromolecule of **cellulose** is composed of a large number of β-glucoses linked by 1,4-β-glycosidic bonds.



Cellulose molecules contain at least 10,000 glucose residues and can reach lengths of 6-8 μm.

The mechanism of sorption involves the interaction of metal ions with hydroxyl groups, primarily through **ion exchange,** with additional complex formation between metal ions and sorbent functional groups.

EXPERIMENTAL PART OF THE PROJECT

01 Data collection and preparation for analysis of fir sawdust

02 Determination of cellulose content in fir sawdust

03 Preparation of sorbents and study of adsorption processes

04 Calculation of extraction efficiency and construction of adsorption isotherms

05 Analysis of results

DATA COLLECTION AND PREPARATION FOR ANALYSIS OF FIR SAWDUST

Sampling location: Wood processing enterprise in Ust-Kamenogorsk (September 2023)

Stages of work:

- Sample preparation;
- Grinding;
- Drying.

Figure 1. Samples of fir sawdust

Relative humidity of wood, %

$$W = \frac{m_1 - m_2}{m_1 - m} \times 100\%$$

(1g wood sample in a crucible until constant mass at a temperature of 100-105°C)

Fir sawdust samples	Humidity, %
Sample 1	6.04
Sample 2	6.26
Sample 3	5.92
Average value	**6.07**

Table 2. Humidity content in fir sawdust

DETERMINATION OF CELLULOSE CONTENT IN FIR SAWDUST

Methods: the nitric acid-ethanol treatment by boiling, filtering, and drying the obtained cellulose on glass filters.

$$C = \frac{m_1 - m_2}{g} \times 100\%$$

m_2 - mass of the empty filter, g;

m_1 - mass of the filter with cellulose after drying, g;

g - mass of absolutely dry wood sample, g;

C - mass fraction of "raw" cellulose, %

Cellulose content in fir samples

Fir sawdust sample	**Cellulose content, %**
Sample 1	40.07
Sample 2	40.79
Sample 3	39.48
Average value	**40.11**

Table 3. Cellulose content in fir sawdust

ADSORBENTS BASED ON FIR SAWDUST

Sorbent 1

Dried fir sawdust

Sorbent 2

Thermally activated sawdust at 300°C

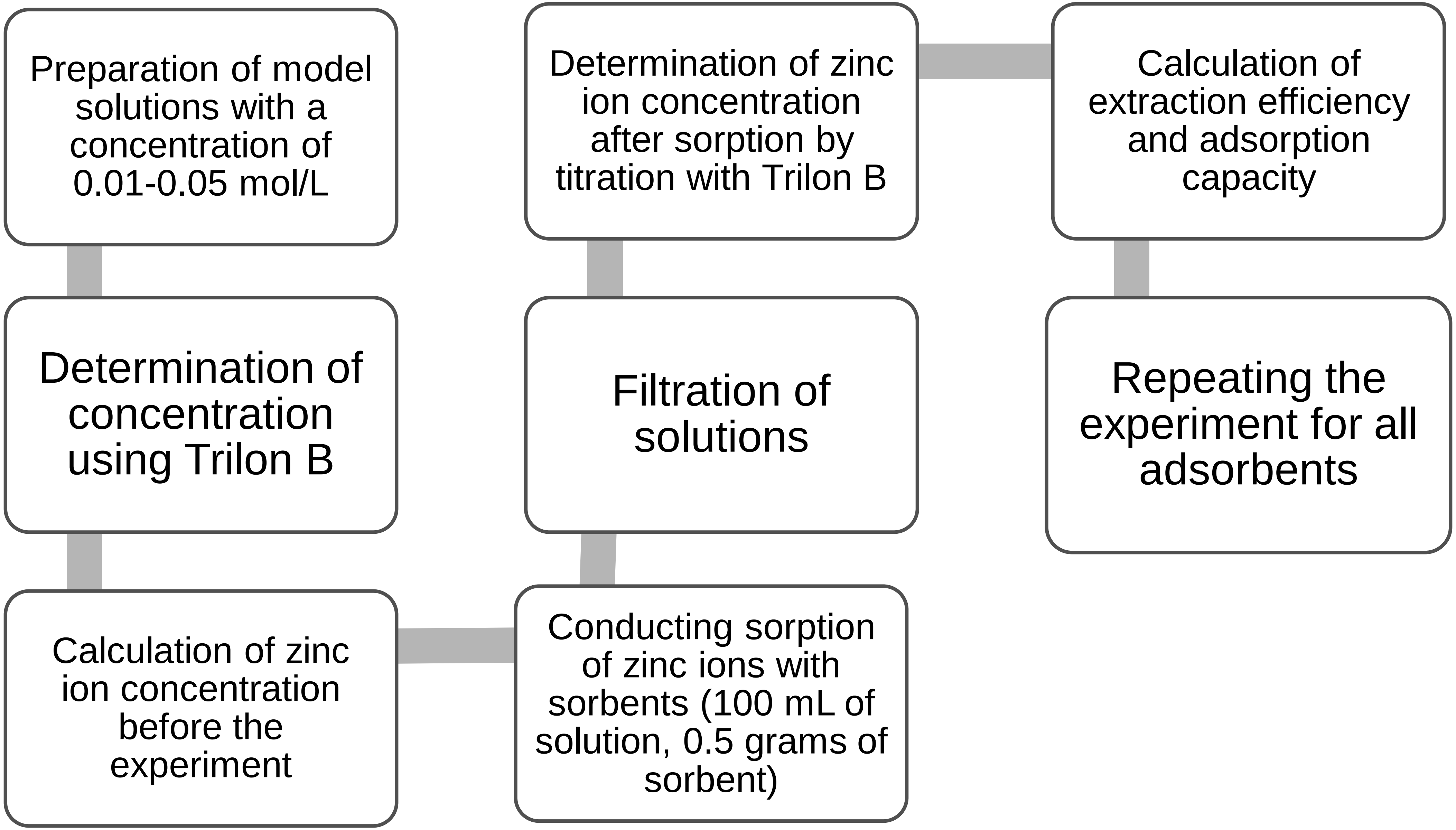
Sorbent 3

Sawdust activated with 1M H_2SO_4 solution

Sorbent 4

Sawdust activated with 1M NaOH solution

STUDY OF ZINC ION ADSORPTION PROCESSES



STUDY OF ZINC ION ADSORPTION PROCESSES

Figure 2. Preparation of model solutions with a concentration of zinc (0.01-0.05 mol/L)

STUDY OF ZINC ION ADSORPTION PROCESSES

Figure 3-5. Determination of zinc ion concentration

STUDY OF ZINC ION ADSORPTION PROCESSES

Figure 6. Preparation of sorbents

Figure 7. Filtration of model solutions using each sorbent

CALCULATION OF EXTRACTION EFFICIENCY

The extraction efficiency α is calculated using the formula:

$$\boldsymbol{\alpha} = \frac{(C_0 - C_s)}{C_0} \times 100\%$$

- C_0 – initial concentration of the component in the solution, g/L;
- C_s – concentration of the component in the solution after sorption, g/L.

The adsorption capacity of zinc ions is calculated using the formula:

$$\Gamma = \frac{\Delta C \times V}{m(\text{sorbent})}$$

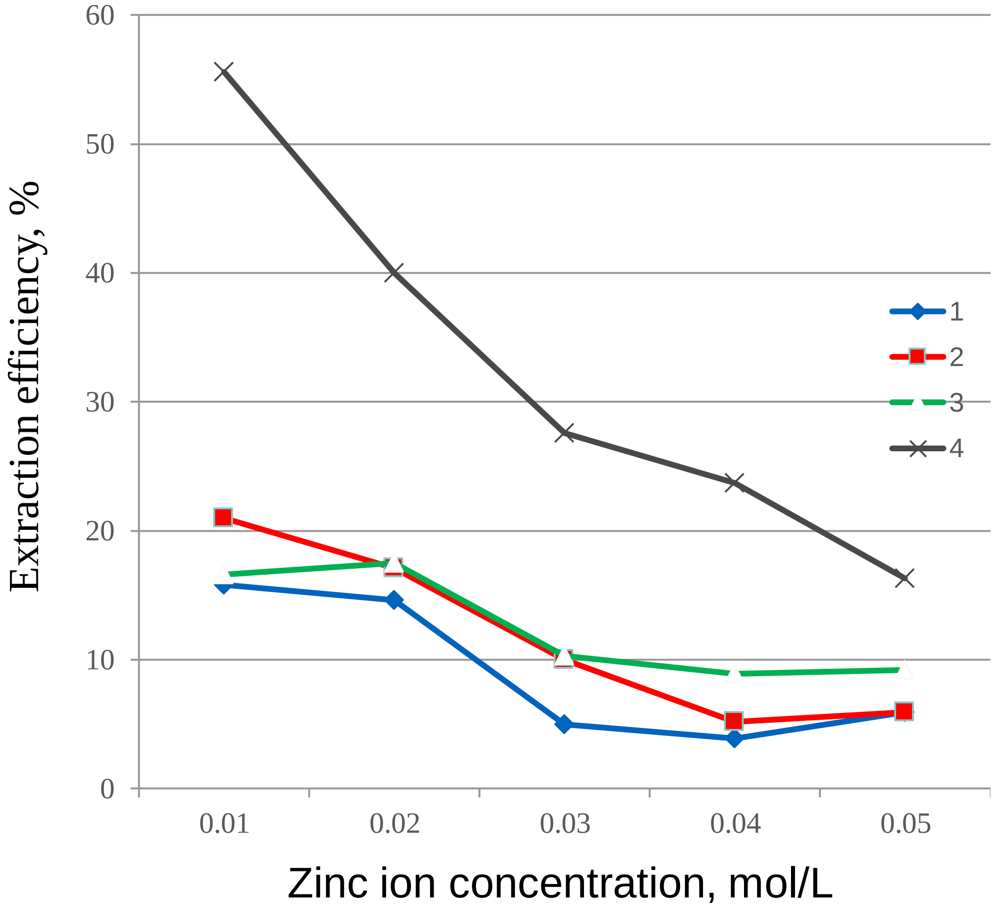
- ΔC – difference between the concentrations, mol/L;
- V – volume of the zinc model solution, L;
- m – mass of the sample (0.5 grams).

EXTRACTION EFFICIENCY IN DIFFERENT SORBENTS

Concentration of solutions, mol/L	Sorbent 1	Sorbent 2	Sorbent 3	Sorbent 4
0,01	15,8	21	16,6	55,6
0,02	14,6	17,1	17,5	40,0
0,03	5,0	10	10,3	27,6
0,04	3,9	5,2	8,9	23,7
0,05	5,9	5,9	9,2	16,3

Table 4. Dependence of zinc ion extraction efficiency on solution concentration

The lowest extraction efficiency is observed with non-activated sawdust. The highest extraction efficiency occurs with sawdust activated by 1M NaOH solution. The maximum extraction efficiency, 55.6%, is observed at a zinc ion concentration of 0.01 mol/L.



Graph 1. Extraction efficiency and solution concentration

(1 – sorbent without activation, 2 – thermal activation at 300°C, 3 – chemical activation with 1M H_2SO_4, 4 – chemical activation with 1M NaOH)

SORPTION DATA FOR CHEMICALLY ACTIVATED FIR SAWDUST WITH 1M NaOH

C theoretical, mol/L	C experimental before sorption mol/L	C experimental after sorption, mol/L	ΔC, mol/L	R,%	Γ, mol/g
0.01	0.0090	0.0040	0.0050	55.6	0.0010
0.02	0.0200	0.0120	0.0080	40.0	0.0016
0.03	0.0290	0.0210	0.0080	27.6	0.0016
0.04	0.0380	0.0290	0.0090	23.7	0.0018
0.05	0.0490	0.0410	0.0080	16.3	0.0016

Table 5. Sorption data for activated fir sawdust with 1M NaOH

Effect of NaOH concentration on extraction efficiency

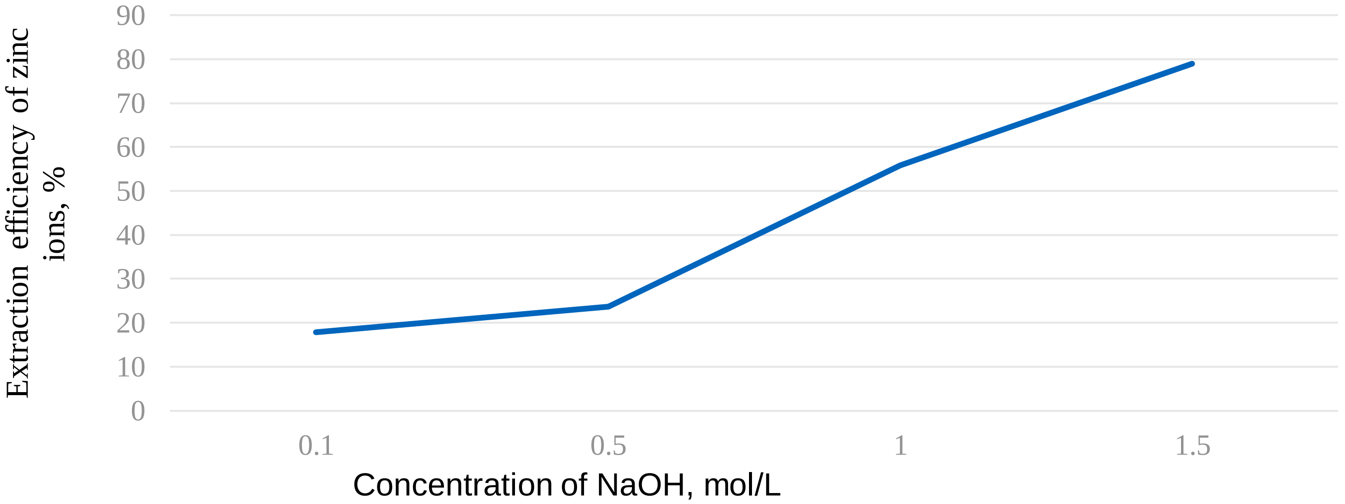
Figure 8. Sorbents activated by NaOH with concentrations from 0.01 to 1.5 mol/L

The highest extraction efficiency is observed with sawdust modified using a 1.5M NaOH solution, reaching 78.9%.

As the concentration of sodium hydroxide solution used for activation increases, the extraction efficiency of zinc ions from salt solutions also rises.

Concentration of NaOH, mol/L	0.1	0.5	1.0	1.5
Extraction efficiency of zinc ions, %	17.9	23.2	55.6	78.9

Table 6. Sorption data for activated fir sawdust with 1M NaOH



Graph 2. The dependence of the degree of extraction on the concentration of NaOH solutions

Conclusion

Within the framework of this project, a literature review was conducted on the sorption process of heavy metals, including zinc ions. Various types of sorbents and the factors influencing the sorption process were examined.

The humidity content of the sawdust was determined to be 6.07%, with cellulose content at 40.11%.

The optimal sorption conditions involve using a sorbent activated with a 1.5M NaOH solution (activation time of 24 hours) and a zinc ion concentration of 0.01 mol/L. The maximum extraction degree for these sorbents, reached 78.9%.

As the concentration of NaOH increases, the extraction efficiency also rises.

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