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Water Purification From Heavy Metals Using Aerogel-Modified Clinoptilolite

Abstract

In this research we aimed to obtain a more effective material by combining clinoptilolite and polymer aerogel. In order to combine the natural adsorption properties of clinoptilolite with the porous structure of polymer aerogel, we processed them in acetone solvent under certain conditions. During the process, the synthesis was carried out at a temperature of 70-90°C and for 3-9 hours. We found that the composite material obtained as a result of this modification was very effective for wastewater treatment, especially for the removal of heavy metals such as cadmium (Cd^{2+}) and nickel ($As3^{+}$). The obtained material attracted attention with both its high porosity and durability. This approach shows that the combination of clinoptilolite and polymer aerogel can play an important role in solving environmental problems such as wastewater treatment.

Keywords: *Apophyllite, Polymer aerogel, Modification, Acetone, Wastewater treatment, Heavy metal ions ($As3^{+}$, Ni^{2+}), Porosity*

Introduction

Due to population growth, the inexhaustible supply of water resources, and the pollution caused by industry and households, polluted water resources are becoming an increasingly critical problem (Ahmed et al., 2022). Wastewater treatment has long been a focus of attention in both industrial and domestic sectors (Baku, 2018, pp. 339–346). The protection and treatment of water resources aims to remove pollutants from water (Calabrò et al., 2021).

In particular, dissolved and soluble heavy metals and organic substances can seriously poison the aquatic environment and human health and have carcinogenic effects (Chen et al., 2020). For this reason, various modern methods have been developed to limit pollutants and toxins (Crini et al., 2019). These include technologies such as ultrafiltration, oil-water separation, hydrocyclones, chemical clarification, and gas flotation (Dionisiou et al., 2013).

Research

Zeolite is a mineral composed mainly of aluminum and silicon (Gupta et al., 2017). Its crystal structure is lattice-like, meaning it has many small voids and a large surface area (Hammond et al., 2010). The pore sizes of zeolites range from 3.0 Å to 10 Å (Hembach et al., 2019).

Zeolites can be found naturally, but they are also produced synthetically (Inglezakis et al., 2021). Synthetic zeolites are made from substances such as natural clays or agricultural waste (Javanshir et al., 2014). These materials are mainly used in industry and have special properties due to their small voids (Kizas et al., 2018).

Wastewater treatment from industrial and domestic sources has been in the spotlight for many years (Kinoti et al., 2022). The purpose of wastewater treatment is to remove pollutants from water resources (Pérez-Calderón et al., 2018). Water pollutants, such as soluble and insoluble heavy metals and organic substances, can be highly toxic and carcinogenic to humans and the aquatic environment (Ahmed et al., 2022). Currently available methods for the reduction of pollutants and dissolved toxins include ultrafiltration, advanced oil-water separation, the use of hydrocyclones, chemical clarification, and gas flotation (Baku, 2018, pp. 339–346).

Material and Methods

Materials

Clinoptilolite, activated carbon aerogels and other necessary materials imported from Tovuz will be used in the treatment process.

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These materials will effectively absorb and clean pollutants in wastewater. Clinoptilolite is a natural zeolite mineral and has a high surface area and good ability to absorb pollutants. Activated carbon aerogels have smaller pores and absorb more pollutants. Working together, these materials will effectively remove heavy metals and other harmful substances in water.

Carbon aerogel is taken in the size range of 1-3 mm, and clinoptilolite is taken in the size range of 1-2 mm. These sizes are the most suitable sizes for ensuring effective adsorption properties of both materials. These sizes allow for better capture of pollutants by increasing the surface area of the materials.

Method

General Plan of the Experiment

The main objective of the experiment is to evaluate the ability of selected sorbent materials to remove heavy metal ions from wastewater. For this purpose, the following three different systems were constructed:

1. A column of clinoptilolite,
2. A column of carbon aerogels,
3. A column consisting of a mixture of clinoptilolite and carbon aerogels.

The columns were made of transparent material and each had a height of 50 cm and a diameter of 5 cm. 100 grams of sorbent material was placed in each column. The columns were cleaned by washing with distilled water before the experiment.

Conducting the Experiment

1. First, synthetic dirty water was prepared. Cd^{2+} and Ni^{2+} ions were added to each liter of distilled water at a concentration of 20 mg/L and mixed.
2. The prepared wastewater was passed through various columns at a flow rate of 5 ml/min.
3. Water samples passing through the columns were taken every 10 minutes and analyzed using an AAS device.

Measuring and Evaluating Results

The pollutant removal efficiency of each sorbent was calculated using the following formula:

$$\text{Effektivlik } (\%) = \frac{\text{Başlanğıc konsentrasiya } (C_0) - \text{Son konsentrasiya } (C)}{\text{Başlanğıc konsentrasiya } (C_0)} \times 100$$

Here:

- **Initial concentration (C_0):** The amount of a pollutant present in the water before the experiment begins (e.g., the concentration of Cd^{2+} or Ni^{2+} ions, measured in mg/L).
- **Final concentration (C):** The amount of pollutant remaining in the treated water after the experiment is over (measured in mg/L).

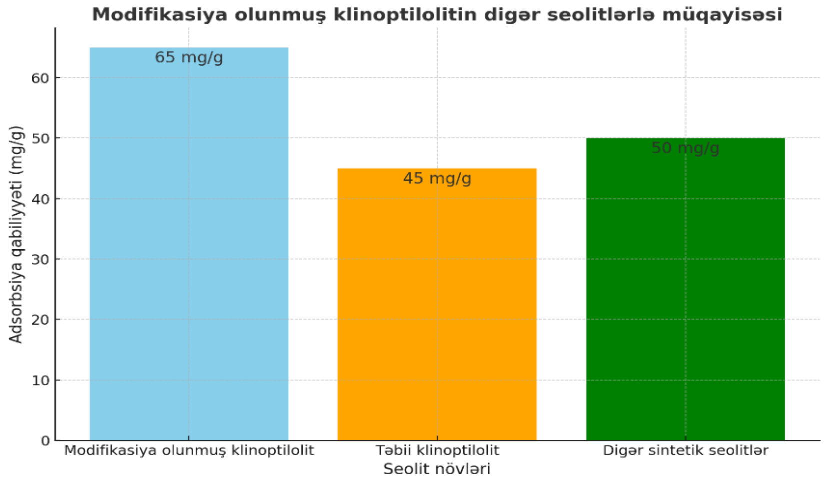
The analyses were repeated three times for each column and the average results are presented.

Important Technical Requirements

- Filtration layers were added to the bottom and top of the columns to ensure contaminant movement and sorbent performance.
- The experiment was performed at room temperature (25°C ± 2°C).

Graphic

The graph shows the higher purification capacity of modified clinoptilolite compared to other zeolites



This methodology allows us to investigate the potential applications of both materials, as well as their combined use, in wastewater treatment. The results may contribute to the development of more efficient technologies in this field.

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