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Wastewater treatment using natural zeolite materials

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ABSTRACT

Today, there is an urgent need in our country to develop and implement new energy - and resource-saving technologies for wastewater treatment and water treatment. The need for such a system is determined by the urgency of the tasks of protecting the health of the population, agricultural products and other biological objects. Wastewater is contaminated with radioactive substances, heavy metal ions, toxic substances and pathogenic microbes. During the work, wastewater contaminated with heavy metal ions Cd^{2+} , Pb^{2+} was treated with a natural zeolite material. The mechanism of water purification from metal ions is based on the porous structure and adsorption capacity of zeolite. Heavy metal ions diffuse into the pores of the zeolite material, displacing sodium ions, which are structural modifiers. The zeolite treatment process was carried out by measuring the permeability of wastewater using a conductometer and comparing its results with the value of the permeability of distilled water. According to the results obtained, this method can be used to completely purify wastewater from heavy metal ions.

Keywords: Waste water, purification, sorbents, ions, zeolite.

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Introduction

The source of water released in human life and industrial activities is called wastewater [1].

Prerequisites for this project are the treatment of wastewater from oil and oil products, organic compounds in the framework of previous research [2].

Today in our country there is an urgent need to develop and implement new energy and resource-saving technologies for wastewater treatment and

water treatment. The need for such a system is determined by the urgency of the problems of protection of public health, agricultural products and other biological objects. Wastewater after industrial use contains a lot of pollutants: heavy metal ions, acids, alkalis, salts, large amounts of organic matter, etc.

Zeolites are microporous, natural or synthetic aluminosilicate materials with a specific structure. Their structure consists of a tetrahedral crystal lattice consisting of SiO_4^{4-} and AlO_4^{5-} ions. Due to

their unique porous properties, zeolites are used in various fields. Chemical formula of natural zeolite used for wastewater treatment: $(\text{Na}, \text{K}, \text{Ca})_{2-3}\text{Al}_3(\text{Al}, \text{Si})_2\text{Si}_{13}\text{O}_{36} \cdot 12\text{H}_2\text{O}$ [3, 4].

The peculiarity of the work is the use of a comprehensive approach to the treatment of wastewater, which includes a combination of physicochemical and effective natural sorbents. In addition, for the first time domestic sorbents based on zeolite materials were used in the implementation of the work [4]. Integrated wastewater treatment methods are currently recognized as the most promising and economical, as they reduce energy and reagent consumption several times, and increase the speed and depth of treatment [5, 6, 7].

Experimental part

The study studied the effects of sorbent concentration and temperature on the sorption process of heavy metals. Natural zeolite from the Taizhuzgen deposit was used as an adsorbent. Chemicals and materials: 30 g of natural zeolite; aqueous solution of heavy metal salts (Cd^{2+} , Pb^{2+}) with a concentration of 0.0025 mole/dm³ for each ion 200 cm³; conductivity meter; pH meter; filter paper; clips, 3 glass filters; 2 glass jars and 4 measuring cups.

The permeability of wastewater contaminated with Cd^{2+} , Pb^{2+} ions was determined using a conductometer. The cascade wastewater filter consists of a vertically placed metal support on which glass funnels and tanks are attached with clamps and rings. The filter paper is mounted on a glass filter. Each filter, which forms a three-layer cascade, is filled with 2 g of natural zeolite. Water permeability and pH are measured after each purification to form a clear idea of the heavy metal purification process.

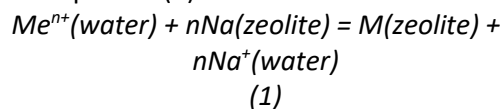
The effect of temperature. 2 g of sorbent was placed in a beaker, containing a solution of Cd^{2+} , Pb^{2+} ions, concentration 0.0025 mole/dm³, 200 cm³ and kept at a temperature of 289, 298, 308 K. The temperature was set and adjusted by means of a thermostat.

Results and Discussion

Heavy metal ions are removed from water by ion exchange and adsorption processes. During adsorption in the microporous structure of zeolite, Na^+ ions are easily displaced from water by Cd^{2+} , Pb^{2+}

ions. The mechanism of ion exchange is based on the high value of electrical negativity of heavy metals, which allows low-negative sodium ions to leave the zeolite structure and form a strong ionic chemical bond with anions in wastewater.

The mechanism of ion exchange follows the chemical equation (1):



where [M] represents the oxidation number of heavy metal ions (Cd^{2+} , Pb^{2+}), and [n] the number of oxidation of metal ions.

Experimental results in the determination of electrical conductivity showed that the water permeability and pH value increase after each treatment (after the ion exchange reaction between heavy metal ions and zeolite), as shown in Table 1. This is because the permeability of sodium ions displaced from zeolite is higher than that of heavy metal ions.

Table 1 - Electrical conductivity and pH values after filtration of wastewater with zeolite

Water	Electrical conductivity (χ)	pH indicators
1. Contaminated water:	50.0 Cm	3.8
2. After the first filtration:	68.5 Cm	6.6
3. After the second filtration:	86.0 Cm	7.1
4. After the third filtration:	91.0 Cm	7.6

Figures 1 and 2 show graphs of the degree of extraction of lead and cadmium ions from natural zeolite to the sorption time.

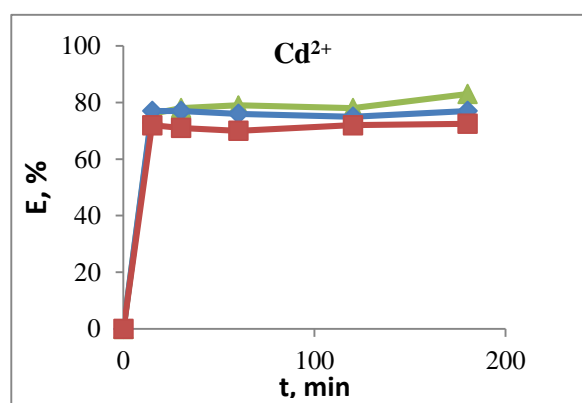


Figure 1 - Dependence of the degree of purification of Cd^{2+} ions on the sorption time

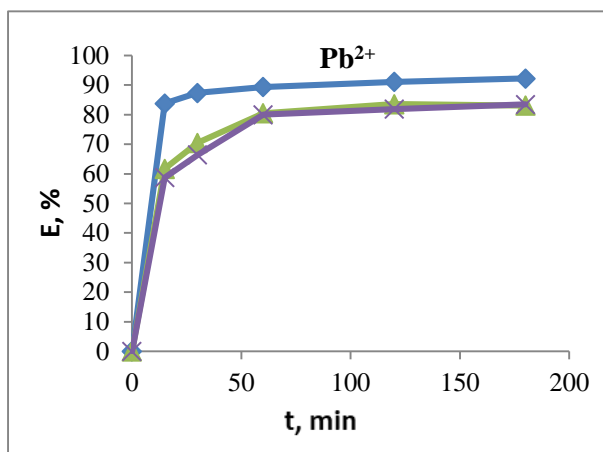


Figure 1 - Dependence of the degree of purification of Pb^{2+} ions on the sorption time

The results of the studies shown in Figures 1 and 2 show that with increasing duration of contact with the aqueous phase containing metal ions in the zeolite, the degree of purification in their initial stage increases and then becomes stable. As can be seen from the proposed graphs, the sorption equilibrium during the purification of lead and cadmium ions is within 30 minutes.

Conclusions

Experimental results show that natural zeolite is based on ion exchange capacity, microporous structure and adsorption capacity, this method of wastewater treatment is very effective and allows almost complete removal of heavy metal ions. Based on the results obtained, the optimal conditions for the sorption of Cd^{2+} , Pb^{2+} ions by natural zeolite were determined: the mass of the sorbent per 200 cm^3 of solution is 2 g, $T = 298$ K. This method can be used for wastewater treatment, mainly in the metallurgical industry, as well as for water softening.

Conflicts of interest. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Табиғи цеолиттік материалдарды қолданып ағынды суды тазалау

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ТҮЙІНДЕМЕ

Бүгінгі күні біздің республикада ағынды суларды тазарту және суды тазарту бойынша жаңа энергия және ресурстарды үнемдеу технологияларын әзірлеу мен енгізудің шұғыл қажеттілігі туындауда. Мұндай жүйенің қажеттілігі халықтың денсаулығын, ауылшаруашылық өнімдерін және басқа биологиялық объектілерді қорғау проблемаларының өзектілігімен айқындалады. Ағынды су радиоактивті заттармен, ауыр металл иондарымен, улы заттармен және патогендік микробтармен ластанады. Жұмыс барысында ауыр металдар Cd^{2+} , Pb^{2+} иондарымен ластанған ағынды су табиғи цеолит материалдарымен тазартылды. Металл иондарын судан тазарту механизмі цеолиттің кеуекті құрылымы мен адсорбциялық қабілеттілігіне негізделген. Ауыр металл иондары цеолитті материалдың кеуектеріне еніп (диффузияланып), құрылымның модификаторы болып табылатын натрий иондарын ығыстырады. Цеолитпен тазарту ағынды судың өткізгіштігін кондуктометр көмегімен өлшеу және оның нәтижелерін дистилденген су өткізгіштігінің мәнімен салыстыру арқылы жүргізілді. Алынған нәтижелерге сәйкес, бұл әдісті қолдану арқылы ағынды суларды ауыр металл иондарынан толық тазартуға болады.

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Очистка сточных вод с применением природных цеолитных материалов

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	АННОТАЦИЯ
	Сегодня в нашей стране существует острая необходимость в разработке и внедрении новых энерго- и ресурсосберегающих технологий очистки сточных вод и водоподготовки. Необходимость такой системы определяется актуальностью задач защиты здоровья населения, сельскохозяйственных продуктов и других биологических объектов. Сточные воды загрязнены радиоактивными веществами, ионами тяжелых металлов, ядовитыми веществами и патогенными микробами. В ходе работ сточные воды, загрязненные ионами тяжелых металлов Cd ²⁺ , Pb ²⁺ , обрабатывались природным цеолитным материалом. Механизм очистки воды от ионов металлов основан на пористой структуре и адсорбционной способности цеолита. Ионы тяжелых металлов диффундируют в поры цеолитного материала, вытесняя ионы натрия, которые являются модификаторами структуры. Процесс обработки цеолита проводился путем измерения проницаемости сточных вод с помощью кондуктометра и сравнения его результатов со значением проницаемости дистиллированной воды. Согласно полученным результатам, с помощью этого метода можно полностью очистить сточные воды от ионов тяжелых металлов.
	Ключевые слова: Сточные воды, очистка, сорбенты, ионы, цеолит.
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