https://doi.org/10.32010/mpmc2024.060

FEATURES OF ADSORPTION OF HEAVY METAL IONS Pb2+, Cd2+ AND Zn2+ FROM WASTEWATER IN ENVIRONMENTAL PROTECTION

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ABSTRACT
Research work is devoted to studying the adsorption properties of heavy metal ions Pb^{2+}, Cd^{2+} and Zn^{2+} in industrial wastewater. Natural clinoptilolite was used to adsorb heavy metal ions. Clinoptilolite belongs to the Ai-Dag deposit of Azerbaijan. The isotherm and kinetic curves of adsorption of heavy metal ions Pb^{2+}, Cd^{2+} and Zn^{2+} were determined . The dependence of the adsorption of heavy metal ions on the pH value is also shown. It was revealed that the separation process occurs more intensely at pH values of 6,5-7. It was determined that the maximum adsorption equilibrium is achieved after 57 minutes.
It was found that maximum adsorption capacity of clinoptilolite adsorbent for the adsorption of Pb^{2+}, Cd^{2+} and *Zn* $^{2+}$ *ions* was 7.51, 6.68 and 5.89 mmol/g, respectively.
Keywords: wastewater, heavy metals, adsorption, kinetics, regression model.

It is known that, currently, one of the most pressing problems of our time is the problem of environmental protection. In connection with the development of science and technology, environmental issues are becoming increasingly relevant. At the same time, engineers, scientists, and ecologists are faced with the global problem of solving these issues. Therefore, the issue of separating heavy metal ions from industrial wastewater remains relevant today. Common industrial wastewater treatment methods include chemical precipitation, membrane separation, ion exchange, evaporation and electrolysis, etc. These methods are often expensive or ineffective, especially when the amount of heavy metal ions in the solution is small . Among the traditional methods used for treating wastewater from heavy metals, the adsorption method is especially used. However, the advantages of this method are offset by the increased cost of adsorbents such as activated carbon and synthetic ion exchangers. Inexpensive and widely available adsorbents, as well as natural adsorbents such as natural zeolites, have prompted researchers to focus on them. Natural clinoptilolite, one of the natural zeolites, is widely distributed in many countries around the world. At the same time, it is known that our country has rich deposits of natural clinoptilolite. As a result, it was found that the adsorption method is more effective in matters of environmental protection and food safety and is also economically beneficial [1-5].

The purpose of this research work is to study the adsorption properties of heavy metal ions Pb^{2+}, Cd^{2+} and Zn^{2+} from industrial wastewater (Fig. 1). Heavy metals and their compounds have a toxic effect on humans, flora and fauna. These toxic effects cannot be eliminated without restrictions. They exist only in certain chemical compounds and in certain concentrations. A large amount of lead was found in the Azerbaijani sector of the Caspian Sea, in transboundary rivers and lakes of neighbouring countries. Zinc and cadmium are major water pollutants. The amount of lead in food consumed by the population is large [6]. From this point of view, recent attention has been paid to the prevention of environmental pollution and food safety due to their high toxicity and non-biodegradability. heavy metal ions . Studied in laboratory conditions the inetic patterns of adsorption of heavy metal ions Pb^{2+}, Cd^{2+} and Zn^{2+} from industrial wastewater (Fig. 1). It was determined that the maximum adsorption equilibrium was achieved after 57 minutes.

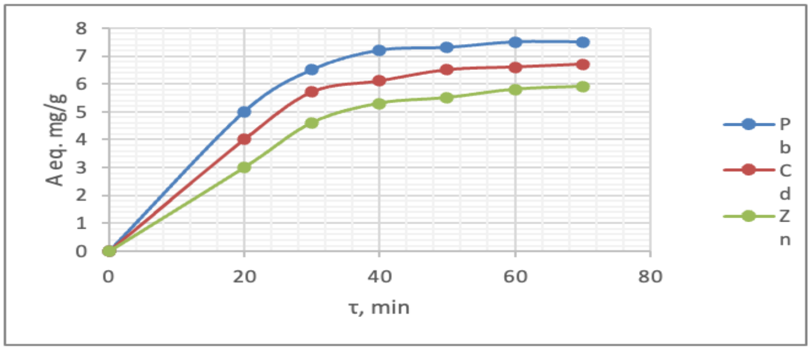


Figure 1. Kinetic patterns of adsorption of heavy metal ions Pb^{2+}, Cd^{2+} and Zn^{2+}

Based on data from experiments on the absorption of heavy metals Pb^{2}, Cd^{2+}, Zn^{2+}, matrices for multifactorial experimental planning were compiled, which are presented in Table 1.

Table 1. Results of calculating the dependence after adsorption of the concentration of heavy metals Pb^{2+}, Cd^{2+}, and Zn^{2+} from water.

No.	X_1 - adsorption temperature	X_2 - concentration of metals mg/l	X_3 - pH number	X_4 - granule size	Y- Metal concentration		
					Pb^{2+} mg/l	Cd^{2+} mg/l	Zn^{2+} mg/l
1	20	1	10	0.50	0.02	0.001	1
2	20	2	5.5	0.75	0.02	0.0009	1
3	20	3	10.0	1.00	0.19	0.0009	0.9
4	40	1	5.5	1.00	0.19	0.0008	0.9
5	40	2	10.0	0.50	0.19	0.0008	0.8
6	40	3	1.0	0.75	0.18	0.0007	0.8
7	60	1	10.0	0.75	0.18	0.0007	0.8
8	60	2	1.0	1.0	0.17	0.0006	0.7
9	60	3	5.5	0.50	0.17	0.0006	0.7

As a result of calculations based on experimental planning, a regression equation was obtained

$$Y_{Pb} = 0.022324 - 0.000058Ta - 0.000500C_{Pb} + 0.000002Ph - 0.000007R \quad (1)$$

$$Y_{Cd} = 0.001216 - 0.000008Ta - 0.000050C_{Cd} + 0.000001Ph - 0.000001R \quad (2)$$

$$Y_{Zn} = 1.2324 - 0.005833Ta - 0.0500C_{Zn} + 0.000184Ph - 0.000667R \quad (3)$$

Equations (1)-(3) constitute a regression model of the adsorption process of heavy metals.

Table 2 gives the values of the levels and ranges of variation in the parameters of the adsorption process . The output parameter of the adsorption process is the concentration of the metals Pb^{2+} , Cd^{2+} , and Zn^{2+} . It is required to find the minimum concentration value at the outlet. To analyze the results of experiments, process statistical data and interpret them, we used the software package Minita b – "Design of Experiment (DOE)" [7-9]. The concentration of heavy metals at the outlet was chosen as an optimization parameter. From an analysis of literary sources, as well as based on the results of multifactor experiments, the following factors influencing the efficiency of the adsorption process were identified for further study : adsorption temperature Ta, metal concentration C, pH number, granule size R. Based on the results of multifactor experiments, the optimal values of technological factors were found:

- adsorption temperature – 21.8°C, metal concentration: Pb^{2+} - 0.019, Cd^{2+} - 0.00008, Zn^{2+} - 0.7 mg/l., pH number – 6.7, granule size – 0.5 mm

Graphs of the influence of factors on the output parameter of the adsorption process are presented in Fig. 2 . An increase in the temperature of the adsorption process leads to a decrease in the absorption capacity (yield). With an increase in the concentration of Pb^{2+} metals , the absorption capacity of the absorbent decreases. Consequently, by increasing the pH number from 1 to 5.5, the absorption capacity of the adsorbent increases, but from 5.5 to 10 it does not change. Increasing the size of adsorbent granules from 0.5 mm to 0.75 mm, the absorption capacity increases, after 0.75 mm to 1 mm it decreases. To assess the influence of a combination of factors, as well as the most significant influences (adsorption temperature, metal concentration, pH number and size of adsorbent granules), a Pareto scheme was constructed (Fig. 3.) The probability value for assessing the significance of the influences of factors is 0.95-0.98. The resulting Pareto diagram displayed the absolute value of the influence. All influence values crossing the control line are significant.

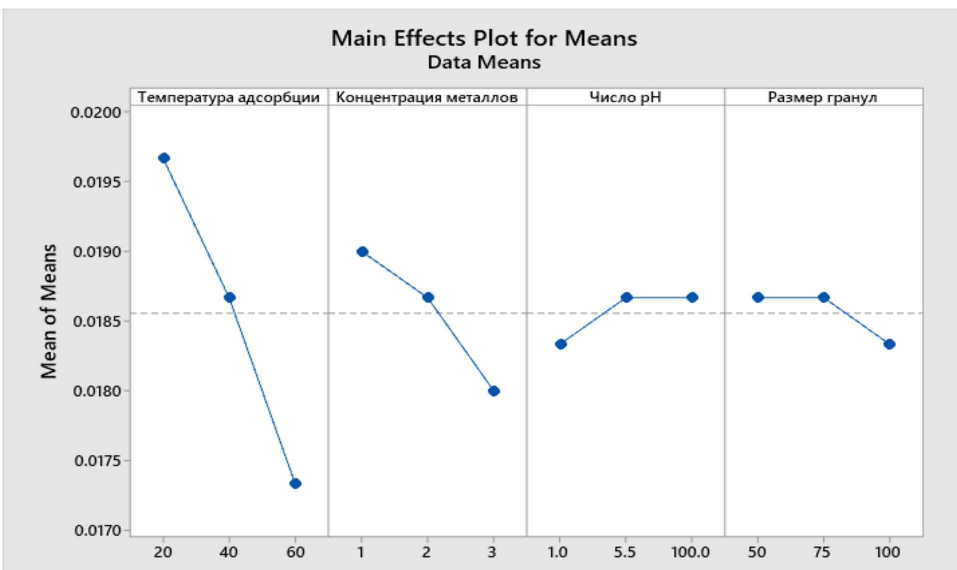


Figure 2 . Graphs of the influence of factors on the output parameter of the adsorption process

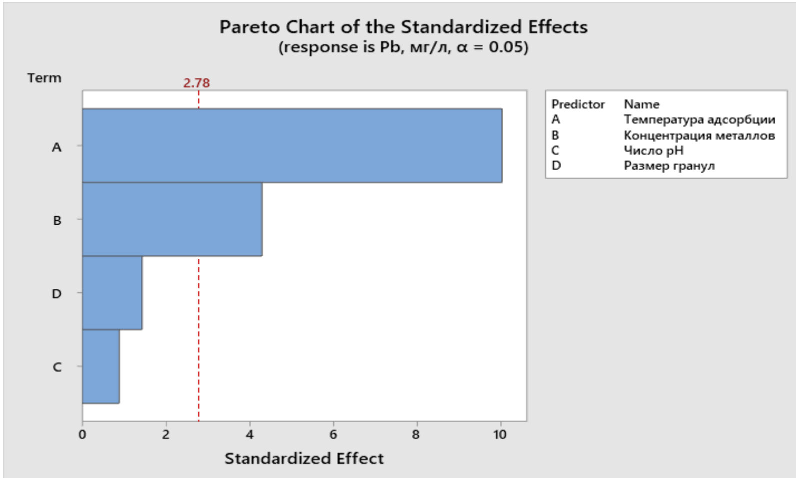


Figure 3 . Probability value for assessing the significance of the influences of factors

In Fig. 4, the normal probability graph of adsorption capacity is shown. As can be seen from the figure, the error is low. Figure 5 shows the change in the adsorption capacity of the adsorbent for heavy metals depending on the adsorption temperature and the concentration of heavy metals in the solution. A surface area has been obtained that has surface area, flat surface shape.

Table 2. The meaning of levels and intervals of varying parameters of the adsorption process.

Designation of factors	Level of variation			Variation interval
	-1	0	+1	
Ta, ^{o}c	20	40	60	20
C, mg/l	1	2	3	1
pH, -	1	5.5	10	4.5
R, 1 mm	0.5	0.75	1.0	0.25

As can be seen from Fig . 5a, the maximum values of the absorbent capacity of the adsorbent are achieved at a temperature of 21.8 °C, the concentration of heavy metals in the solution is 2 mg/l.

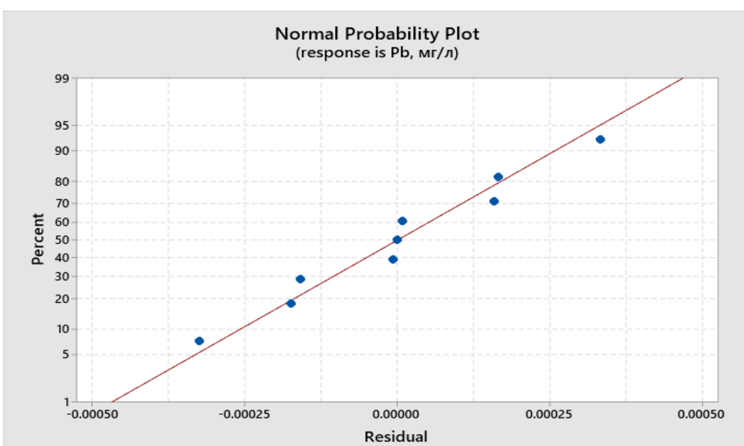
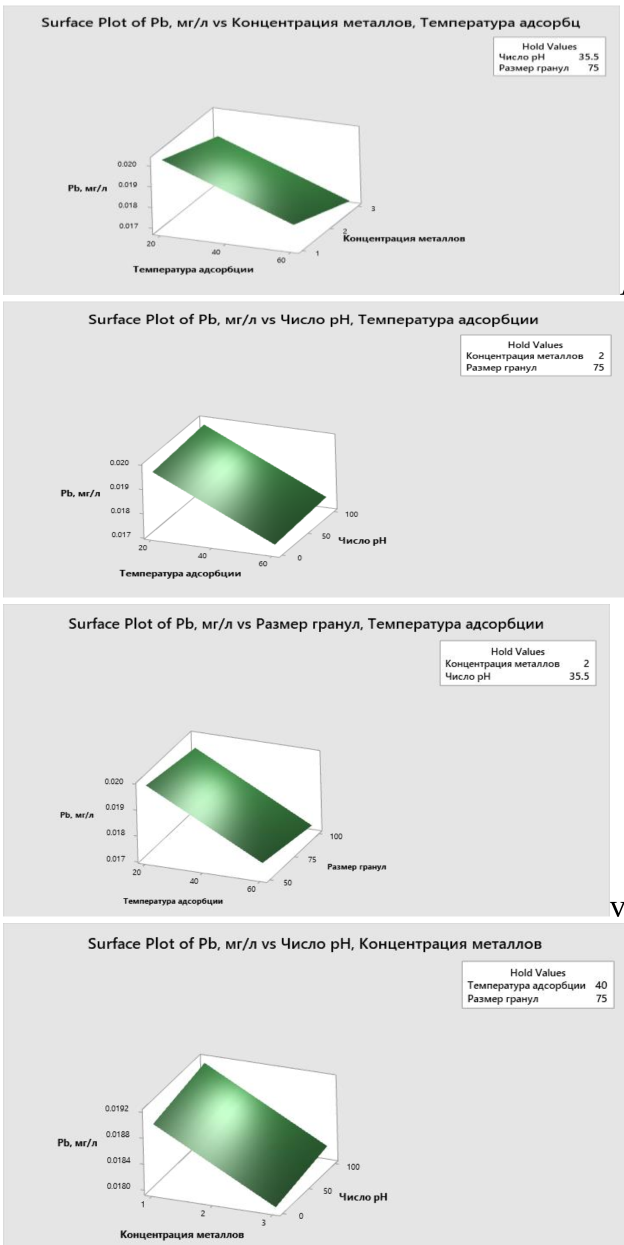


Figure 4 . Normal probability plot of adsorption capacity

Fig. 5b shows the change in absorption the ability depends on the adsorption temperature and pH number. The surface area has the shape of a flat plane . The maximum value of the absorption capacity is achieved at a pH value of 6.7 . In Fig. 5b shows the change in the absorption capacity of the process absorption from the adsorption temperature and the size of the granules; the surface area is flat, the maximum absorption capacity is achieved at a temperature of 21.8 ° C; the size of the adsorbent granules is 0.5 mm.



A

b

v

q

Figure 5. Change in the absorption capacity of the adsorbent for heavy metals Pb^{2+}

Fig. 5g indicates the change in the absorption capacity of the absorption process from the concentration of metals P b $^{2+}$ pH number. The surface area is flat. The maximum value of the absorption capacity of the absorption process at a metal concentration of Pb $^{2+}$ 1 mg/l, number 6.7.

In Fig. 6 . Contour graphs of the dependence of the yield on various parameters of the Pb $^{2+}$ absorption process are presented . The obtained patterns for the heavy metals P b $^{2+}$, Cd $^{2+}$ and Zn $^{2+}$ are the same , only the numerical values of absorption change (Fig. 7, 8).

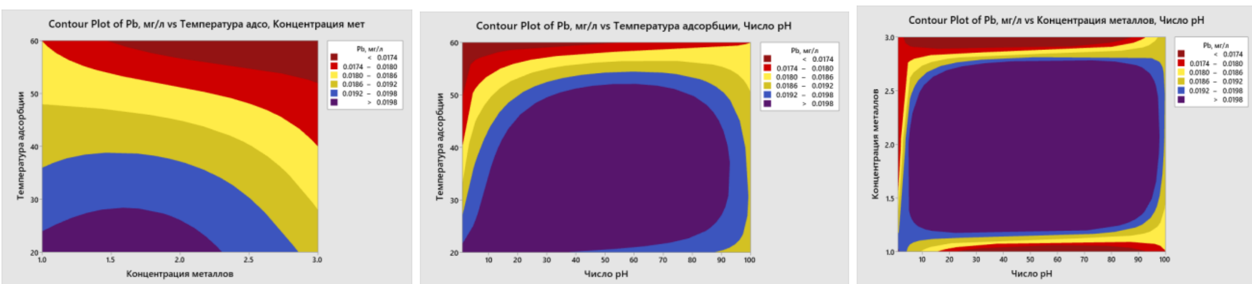


Figure 6 Contour graphs of the yield depending on various parameters of the Pb $^{2+}$ absorption process

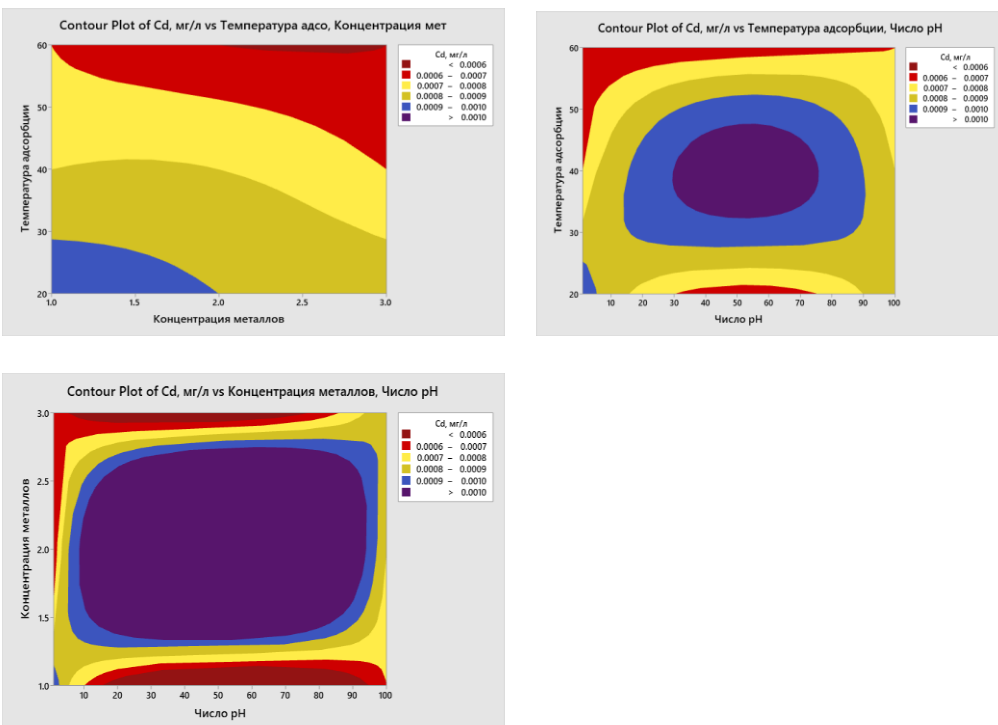


Figure 7. Contour graphs of the yield depending on various parameters of the absorption process of C d $^{2+}$

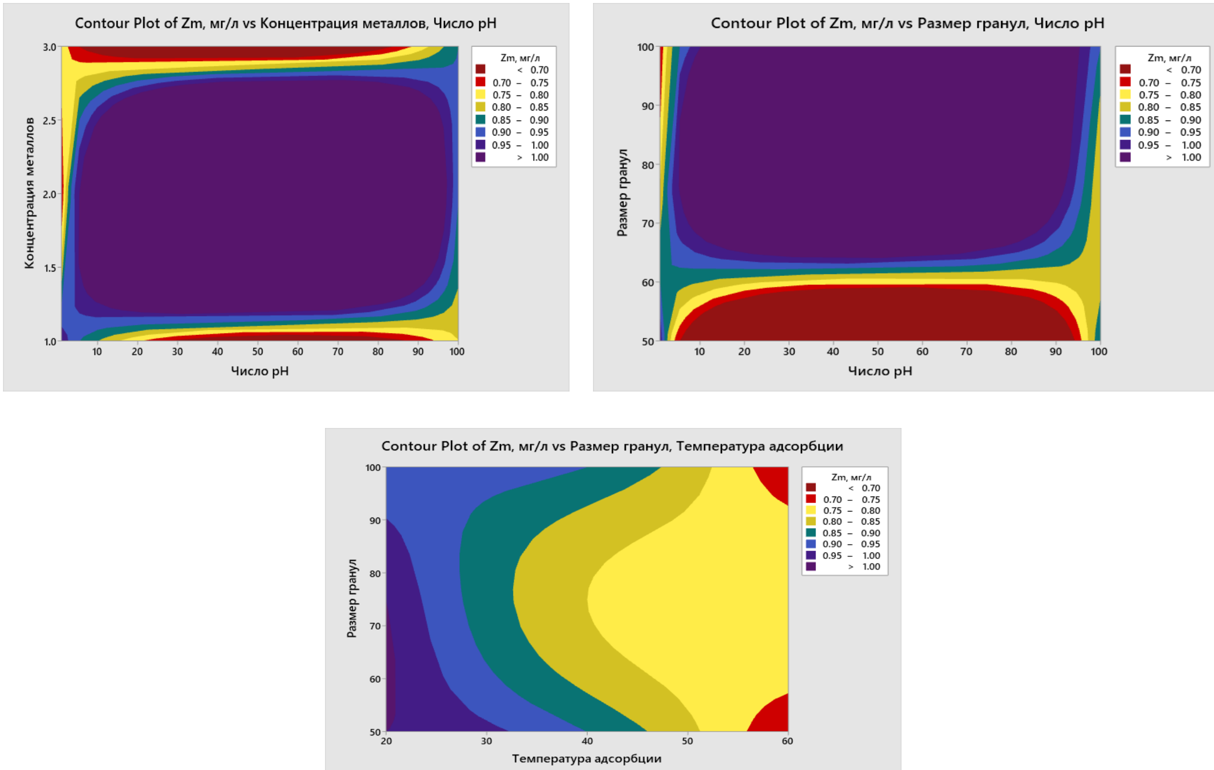


Figure 8. Contour graphs of the yield depending on various parameters of the Zn^{2+} absorption process

Conclusions

1. It was determined that the maximum adsorption equilibrium was achieved after 57 minutes.

2. Based on data from experiments on the adsorption of heavy metals Pb^{2+}, Cd^{2+} and Zn^{2+}, a matrix for the multifactorial planning of experiments was compiled.

The following factors affecting the efficiency of the absorption process were identified: adsorption temperature, concentration of heavy metals, pH number, and granule size. A regression model of the adsorption process has been developed.

3. Based on the results of multifactor experiments, the optimal values of the technological parameters of the absorption process were found: adsorption temperature 21.8 ^{o} C, metal concentration: Pb^{2+} - 0.019, Cd^{2+} - 0.00008, Zn^{2+} - 0.7 mg/l, pH number – 6.7, granule size – 0.5 mm

References

19. Teoh Wah Tzu, Takuma Tsuritani , Kazunori Sato Sorption of Pb(II), Cd(II), and Ni(II) Toxic Metal Ions by Alginate-Bentonite Journal of Environmental Protection, 2013, 4, 51-55
20. Yusubov FVJ Water Chem and Tech. 2019, V.41, No. 1, pp.57-62
21. Sharififard H., Nabavinia M., Soleimani M. // Adv. Environ . Technol. 2016. V. 2. I. 4. P. 215.
22. Saleh TA, Gupta VK // Environ. Sci. Pollut . Res. 2012. V. 19. P. 1224.
23. Jacob JM, Karthik C., Saratale RG, Kumar SS, Prabakar D., Kadirvelu K., Pugazhendhi A. // J. Environ. Manage. 2018. V. 217. P. 56

24. Abbasov R. Sanitation and Pollution Action Plan. The Republic of Azerbaijan. Global Alliance on Health and Pollution. Baku. 2021, 143 p.
25. Dyakonov VP MATLAB. Complete tutorial. – M.: DMK Press, 2012. – 768 p.: ill.
26. StevenI.. Gordon, Brian Guilfoos Introduction to Modeling and Simulation with MATLAB (R) and Python CRC Press, 2020 .p: 191
27. George Lee Sye Minitab Statistical Analysis Handbook: A Handbook for Lean Six Sigma Professionals Paperback – May 17, 2022, RUR 163

ОСОБЕННОСТИ АДСОРБЦИИ ИОНОВ ТЯЖЕЛЫХ МЕТАЛЛОВ Pb^{2+}, Cd^{2}+ И Zn^{2+}.ИЗ СТОЧНЫХ ВОД В ОХРАНЕ ОКРУЖАЮЩЕЙ СРЕДЫ

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АБСТРАКТ
Научно-исследовательская работа посвящена изучению адсорбционных свойств ионов тяжелых металлов Pb^{2+},Cd^{2+} и Zn^{2+} в промышленных сточных водах. Для адсорбции ионов тяжелых металлов использовали природный клиноптилолит. Клиноптилолит относится к месторождению Ай-Даг в Азербайджане. Определены изотермы и кинетические кривые адсорбции ионов тяжелых металлов Pb^{2+},Cd^{2+} и Zn^{2+}. Также показана зависимость адсорбции ионов тяжелых металлов от значения pH. Выявлено, что процесс разделения протекает более интенсивно при значениях pH 6,5-7. Установлено, что максимальное адсорбционное равновесие достигается через 57 минут.
Установлено, что максимальная адсорбционная емкость клиноптилолитового адсорбента по адсорбции ионов Pb^{2+} , Cd^{2+} и Zn^{2+} составила 7,51, 6,68 и 5,89 ммоль/г соответственно.
Ключевые слова: сточные воды, тяжелые металлы, адсорбция, кинетика, регрессионная модель.

ƏTRAF MÜHİTİN MÜHAFİZƏSİNDƏ AĞIR METAL İONLARININ Pb2+, Cd2+ və Zn2+ TULLANTI SULARINDAN ADSORBSİYA XÜSUSİYYƏTLƏRi

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XÜLASƏ
Tədqiqat işi sənaye çirkab sularında ağır metal ionlarının Pb^{2+}, Cd^{2+} və Zn^{2+} adsorbsiya

xüsusiyyətlərinin öyrənilməsinə həsr edilmişdir. Təbii klinoptilolit ağır metal ionlarını adsorbsiya etmək üçün istifadə edilmişdir. Klinoptilolit Azərbaycanın Ay-Dağ yatağına aiddir. Pb^{2+}, Cd^{2+} və Zn^{2}+ ağır metal ionlarının adsorbsiyasının izotermləri və kinetik əyriləri müəyyən edilmişdir.
Ağır metal ionlarının adsorbsiyasının pH dəyərindən asılılığı da göstərilir. 6,5-7 pH dəyərlərində ayrılma prosesinin daha intensiv getdiyi aşkar edilmişdir. Müəyyən edilmişdir ki, maksimum adsorbsiya tarazlığı 57 dəqiqədən sonra əldə edilir.
Müəyyən edilmişdir ki, Pb^{2+}, Cd^{2+} və Zn^{2+} ionlarının adsorbsiyası üçün klinoptilolit adsorbentinin maksimal adsorbsiya qabiliyyəti müvafiq olaraq 7,51, 6,68 və 5,89 mmol/q olmuşdur.
Açar sözlər: tullantı suları, ağır metallar, adsorbsiya, kinetik, reqressiya modeli.