MATHMATICAL MODELING OF THE PROCESSES OF WASTEWATER PURIFICATION FROM PHENOLS AND RHODANIDES USING GLAUCONITE

Purpose. To choose the optimal dose of the natural mineral glauconite in combination with cationic flocculant to extract phenols and rhodanides from industrial effluents. To substantiate the advantages of using natural glauconite as an adsorbent with a developed cationic ability to absorb toxic substances. To develop a mathematical model of the adsorption treatment of phenolic wastewater at a flotation plant.

Methodology. Chemical studies were carried out according to the methods of V. M. Kagasov, E. K. Derbisheva. When conducting experiments to determine the concentration of phenols in industrial effluents, a photometric method was used, based on the formation of red-colored phenol compounds with 4-aminooantipyrine in the presence of potassium hexacyanoferrate. To establish the concentration of thiocyanates in phenolic wastewater, a photometric method was used, based on the interaction of the rhodanides ion in an acidic medium with iron (III) chloride ions. The determination of the optical density of the solutions was carried out on a concentration KFK-2 photocolorimeter with subsequent use of calibration graphs.

Findings. It was experimentally shown that when applying the intervals of doses of glauconite 2–6 g/dm³, an effective purification of liquid waste from phenols is achieved as well as a decrease in the concentration of the initial phenolic water from 510 to 330–390 mg/dm³ in the time interval of 110–140 min at the mechanical stage. A decrease in the maximum permissible concentration (MPC) of phenols in the initial wastewater of a coke chemical plant has been achieved, regulated – not more than 415 mg/dm³. The process of purification of industrial effluents from rhodanides with the selection of the optimal dose of adsorbent using mathematical processing of experimental data, which amounted to 2–3.5 g/dm³ with flotation duration of 120 min, was studied. The initial concentration reduction of rhodanides from 475.2 to 328–348 mg/dm³ was obtained. The MPC of rhodanides, with a norm of not more than 400 mg/dm³ before biological treatment was reached.

Originality. The process of sorption removal of phenols and rhodanides from liquid wastes with different doses of glauconite to describe a mathematical model of the adsorption process was studied. For the first time, kinetic regularities of the process of phenol extraction from wastewater by glauconite in an amount of 2–5 g/dm³ in combination with a cationic flocculant with a volume of 5 ml/dm³ in a time interval of 20–120 min were established. The opportunity to predict the optimal dose of adsorbent, to influence the time of the sorption process and reduce the content of polluting agents to environmentally friendly indicators was obtained.

Practical value. A mathematical description of the process of purification of phenolic wastewater using glauconite is given. Based on the description of the mathematical model, for industrial implementation, it is proposed to use the natural adsorbent glauconite in the optimal dose range of 2–6 g/dm³ in combination with a cationic flocculant in an amount of 5 ml/dm³ with optimal adsorption process duration of 110–140 min.

Keywords: coke-chemical effluents, adsorption, phenols, rhodanides, natural glauconite, cationic flocculant

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Dniprovsk State Technical University, Kamenskoye, Ukraine, e-mail: karina.havikova@gmail.com
class II requiring additional purification at the mechanical stage before biochemical purification. Since the conversion of dissolved organic substances (phenols, rodanides, and others) into mineral compounds occurs at the expense of the activity of phenol- and rod-destroying microorganisms, the biological oxidation of high concentrations of contaminants leads to a toxic effect on symbiosis of active sludge [3, 8, 9].

Critical analysis of the literature data on the study and use of dispersed sorbents and filtering materials has shown that the search for new sorption materials and effective extraction of phenols and related substances from wastewater remains relevant [10, 11].

The efficiency of the sorption purification process is largely determined by the choice of the sorbent. Solid sorbents are now used as natural, artificial and synthetic materials. The adsorbents based on coal [10] find widespread use in the practice of sorption purification of aqueous media, but they are expensive material. Synthetic adsorbents are generally biodegradable and can be a source of secondary pollution of natural ecosystems. Therefore, one of the promising areas in water treatment is the use of adsorbents from natural raw materials, the advantages of which are availability, cheapness, availability of sufficient raw material resources, non-toxicity [12, 13].

The use of clay materials as adsorbents in the process of industrial wastewater treatment is becoming more widespread every year [13]. Along with the adsorbents that are traditionally used in these processes (activated carbon, zeolites, bentonites, silicates) there is a natural mineral — glauconite [3, 8]. It is a complex ecological sorbent, a mineral of the class of silicates of the group of mica hydrogens monoclinic. Glauconite is widespread in the sands, sandstones, clays, marls and limestones of all geological systems, turning these rocks greenish. Glauconite has a high porosity, a large active specific surface area and a cation exchange capacity (substitution) of isomorphic, chemical and physical nature, filtration capacity, absorption capacity of phenols, petroleum products and highly toxic substances of organic and inorganic origin. Glauconite refers to a layered silicate with a rigid structure. All the minerals in this group are characterized by the presence of only the outer adsorption surface, and their porosity is due to the gaps between the contacting particles. The specific surface area of such silicates is determined by the dispersion of the particles. The structure of the layered silicates is such that one grid of Al- and Mg-octahedrons is coupled to two grids of Si–O tetrahedrons. The main advantage of using natural glauconite adsorbent is not only complex purification of coke-chemical effluents from phenols and rodanides, but also related substances — asphaltenes, general ammonia and others [8].

The addition of a cationic type (floculant) surfactant to glauconite increases the rate of flake deposition and increases the efficiency of the adsorption-flocculation process, connecting its sorbent molecules with their polymer bridges. Typically, synthetic macromolecular compounds such as polyacrylamides are used under industrial conditions. During flocculation the optimal flow of floculant plays an important role, because at small and large doses destabilization of the dispersed system can be observed. At low concentrations of floculant in water there are not enough macromolecules to bind the solid phase to the flocules, and at excess, a spatial grid of associated polymer molecules is formed, which impedes the convergence and aggregation of particles [8, 14]. Recycling of formed sludge with the extraction of valuable components allows their complex utilization.

**Purpose.** To create a mathematical model of adsorption purification of phenolic sewage by adsorption-flocculation method with the help of the natural mineral of glauconite, to identify the optimal parameters of the process at which the highest degree of purification of effluents from phenols and rodanides is achieved.

**Methods.** Phenolic wastewater of the site of biochemical treatment of the coke-chemical enterprise of Kamianske PJSC “YUZHKOXS” was selected as the object of the research. In the conditions of the existing coke-chemical enterprise the normative values of the quality of sewage and wastewater were approved. The approved normative content of phenols in the wastewater of the coke oven enterprise is 415 mg/dm³, the rodanides — 400 mg/dm³; the actual concentration of C₆H₅OH (mean per year) is 962 mg/dm³, SCN⁻ is 943 mg/dm³. The above data indicate that the irregularity of the biological wastewater treatment process during the year should be expected, which will lead to a negative effect of toxic substances on the symbiosis of activated sludge. In order to improve the quality of the phenolic water supplied to the aeration tanks, there is a need to refine the effluent at the mechanical stage.

In a study to determine the concentration of phenols in the source and purified effluents, a photometric method with 4-aminoantipyrine was applied, which was carried out by the standard series on a graduated graph. A photometric method based on the interaction of the rhodanide ion in acidic medium with iron (III) chloride ions was performed to determine the concentration of rhodanides in phenolic wastewater; it was carried out using a calibration graph. The optical density of the solutions on the photocalorimeter concentration KFK-2 was measured. Chemical studies were carried out according to the methods of V. M. Kagaros, E. K. Derbisheva.

**Results.** To solve the problem of reducing the concentration of phenols to normative values and to describe the mathematical model of the adsorption process, we created a laboratory flotation unit [6], which tested flotation. The experiment was as follows. To conduct studies on phenolic water of 0.5 dm³ in flotation reactor with a volume of 1 dm³, various doses of natural glauconite were added in combination with a cationic flocculant of 5 ml/dm³. Then, by means of a compressor, aeration of water was carried out for 20—120 min at an air flow rate of 0.5 dm³/min. Subsequently, 50 cm³ of floated sewage was selected from the upper reactor layers to determine the residual concentration of phenols and rodanides in the samples. The experiments were conducted at a temperature indicator of phenolic fluid — 20.5 °C, which corresponds to the average annual temperature of liquid waste entering the flotator. The initial concentration of phenols in the wastewater was 510 mg/dm³ and the rodanides 475.2 mg/dm³.

In the presence of a wide range of variation of the studied parameters in the purification of phenolic effluents, it is advisable to apply the technique of planning experiments to solve the problem with the required accuracy [9]. The factors on which the degree of purification depends (residual concentration of phenols and rodanides) are selected as follows: X₁ is glauconite dose, g/dm³, X₂ is time interval, min; Y₁ is the concentration of phenols, mg/dm³; Y₂ is the concentration of rodanides, mg/dm³.

The results of a series of laboratory experiments are summarized in Table 1, which shows the values of the initial parameters — X₁, X₂ and residual concentrations of phenols and rodanides — Y₁, Y₂.

| Table 1 |
| --- |
| | X₁ | X₂ | Y₁ | Y₂ |
| Glauconite dose | 1.0 | 150 | 100 | 60 |
| Time interval | 10 | 200 | 130 | 70 |

Table 2 shows descriptive statistics of ranges of values of initial parameters and the results of experimental studies.

To identify the relationship between the parameters of the studied wastewater treatment process from phenols and rhodanides, a correlation analysis was performed, in particular the calculation of the Pearson linear correlation coefficient, confidence intervals, the hypothesis of the significance of paired correlation coefficients, the results of which are given in Table 3.

The selected correlation coefficients are significant at the level of p < 0.05000, which determine the significant effect of the parameter X₁ (purification time interval) on the purification efficiency of both phenols and rodanides.

**Analysis of experimental data.** As a result of processing the experimental data by methods of mathematical statistics, the correlation coefficients (Table 3) and the regression equation for the whole array of the studied variables were determined; graphs of the output parameters (Y₁, Y₂) of the input (X₁, X₂) in the form of graphs Y₁(X₁), and the multiple regression equa-
The values of input parameters and results of experiments

|   | X1 | X2 | Y1 | Y1(Y1, X2) | X1% | Y2 | Y2(Y2, X2) | X2% |
|---|----|----|----|------------|-----|----|------------|-----|
| 1 | 2  | 20 | 420| 402.57     | 4.15| 407.316 | 411.73     | 1.08 |
| 2 | 2  | 40 | 383| 380.55     | 0.64| 398.83 | 389.75     | 2.28 |
| 3 | 2  | 60 | 372| 363.40     | 2.31| 390.345| 372.73     | 4.51 |
| 4 | 2  | 120| 328| 341.24     | 4.04| 322.459| 351.44     | 8.99 |
| 5 | 4  | 20 | 365| 408.19     | 11.83| 398.83 | 417.67     | 4.72 |
| 6 | 4  | 40 | 383| 383.45     | 0.12| 390.345| 394.42     | 1.04 |
| 7 | 4  | 60 | 348| 363.60     | 4.48| 390.345| 376.13     | 3.64 |
| 8 | 4  | 120| 348| 332.32     | 4.22| 381.859| 351.02     | 8.08 |
| 9 | 6  | 20 | 425| 423.18     | 0.43| 415.802| 418.31     | 0.60 |
| 10| 6  | 40 | 420| 395.74     | 5.78| 381.859| 393.78     | 3.12 |
|11| 6  | 60 | 392| 373.17     | 4.80| 373.373| 374.22     | 0.23 |
|12| 6  | 120| 335| 334.77     | 0.07| 339.42 | 345.30     | 1.73 |
|13| 8  | 20 | 452| 447.54     | 0.99| 441.259| 413.64     | 6.26 |
|14| 8  | 40 | 440| 417.39     | 5.14| 390.345| 387.85     | 0.64 |
|15| 8  | 60 | 348| 392.12     | 12.68| 339.43 | 367.01     | 8.13 |
|16| 8  | 120| 348| 345.59     | 0.69| 339.43 | 334.27     | 1.52 |

Relative error, % 3.90 3.54
Standard deviation 3.82 2.95

Table 2
Descriptive statistics of ranges of values of initial parameters and research results

| Options | Minimum | Average | Maximum | Standard deviation |
|---------|---------|---------|---------|--------------------|
| X1      | 2.00    | 5.00    | 8.00    | 2.31               |
| X2      | 20.00   | 60.00   | 120.00  | 38.64              |
| Y1      | 328.00  | 381.69  | 452.00  | 39.36              |
| Y2      | 322.46  | 381.33  | 441.26  | 31.82              |

Table 3
Matrix of pairwise correlation coefficients of extraction of phenols and rhodanides from initial parameters

|   | X1 | X2 | Y1 | Y2 |
|---|----|----|----|----|
| X1| 1.000   | 0.000  | 0.281 | -0.0691 |
| X2| 0       | 1.000  | -0.765 | -0.801 |
| Y1| 0.281   | -0.765 | 1.000  | 0.000   |
| Y2| -0.0691 | -0.801 | 0.000  | 1.000   |

The values of glauconite dose (X1) in purified water on the residual concentration of phenols (Y1) simultaneously on glauconite dose (X1) and on the interval of purification time (X2) was obtained, which has the form

\[ Y_1 = 451.3377 - 1.6703 \cdot X_1 + 0.0061 \cdot X_2^2 . \]  

The average relative error of the equation is 4.69 % with a standard deviation of 4.04.

Plots of regression equation of phenol extraction (Y1, mg/dm3) versus glauconite dose (X1, g/dm3) and purification time interval (X2, min.) are shown in Figs. 1 and 2.

According to the experiments shown in Table 1, the multiple regression equation, the dependence of the extraction of phenols Y1 simultaneously on glauconite dose X1 and on the interval of purification time X2 was obtained, which has the form

\[ Y_1 = 430.5341 - 2.8705 \cdot X_1 - 1.3319 \cdot X_1 + 1.1719 \cdot X_2^2 - 0.0677 \cdot X_1 \cdot X_2 + 0.0061 \cdot X_2^2 . \]  

The average relative error of the equation is 3.90 % with a standard deviation of 3.82.

The multiple regression equation Y1 (X1, X2) (3) is represented by a graph of 3D response surfaces in Fig. 3 and a graph of 2D maps of the phenol extraction lines (Y1) and the purification time interval (X2) shown in Fig. 4.

The graph (Fig. 4) shows that the maximum reduction of phenols – 330–350 mg/dm3, can be obtained at the dose values of glauconite X1 (5.5–6 g/dm3) and the purification time interval of X2 (125–140 min) corresponding to the global minimum of the surface of equation (3). However, a practical reduction of phenols – 330–390 mg/dm3 can be obtained at the dose values of glauconite X1 (2–6 g/dm3) and the interval of purification time X2 (110–140 min), which corresponds to the economically expedient dose of glauconite X1 – 2 g/dm3 at the duration of the experiment X2 – 120 min. The quality of waste-water does not exceed the MPC of phenols – it is no more than 415 mg/dm3.

The obtained regression equations to determine the residual concentration of phenols in purified water are as follows:

- for the regression equation Y1(X1) – dependence of the residual concentration of phenols (Y1) in purified water on glauconite dose (X1)

\[ Y_1 = 381.1875 - 6.9313 \cdot X_1 + 1.1719 \cdot X_1^2 . \]  

The average relative error of the equation is 8.3 % with a standard deviation of 5.03;
- for the regression equation Y2(X2), the dependence of the residual concentration of phenols (Y2) in purified water on the purification time interval (X2) is as follows

\[ Y_2 = 11381.1875 - 6.9313 \cdot X_2 + 1.1719 \cdot X_2^2 . \]  

The graph (Fig. 4) shows that the maximum reduction of phenols – 330–350 mg/dm3, can be obtained at the dose values of glauconite X1 (5.5–6 g/dm3) and the purification time interval of X2 (125–140 min) corresponding to the global minimum of the surface of equation (3). However, a practical reduction of phenols – 330–390 mg/dm3 can be obtained at the dose values of glauconite X1 (2–6 g/dm3) and the interval of purification time X2 (110–140 min), which corresponds to the economically expedient dose of glauconite X1 – 2 g/dm3 at the duration of the experiment X2 – 120 min. The quality of waste-water does not exceed the MPC of phenols – it is no more than 415 mg/dm3.
The obtained regression equations to determine the residual concentration of Y₂ rhodanides in purified water are as follows:

- for the regression equation $Y_2(X_1)$ — dependence of residual concentration of rhodanide ($Y_2$) in purified water on glauconite dose ($X_1$)

$$Y_2 = 372.8459 + 5.6732 \cdot X_1 - 0.6628 \cdot X_1^2.$$ (4)

The average relative error of the equation is 6.37 % with a standard deviation of 5.57;

- for the regression equation $Y_2(X_2)$, the dependence of the residual concentration of $Y_2$ rhodanides in purified water on the purification time interval $X_2$ is as follows

$$Y_2 = 22444.1826 + 1.5664 \cdot X_2 - 0.0062 \cdot X_2^2.$$ (5)

The average relative error of the equation is 3.52 % with a standard deviation of 3.18.

The regression equations of the dependence of rhodanide extraction ($Y_2$, mg/dm³) on glauconite dose ($X_1$, g/dm³) and the purification time interval ($X_2$, min) are shown in Figs. 5 and 6.

As can be seen from the graphs (Figs. 1, 5), increasing glauconite dose affects the efficiency of extraction of $Y_1$ phenols and $Y_2$ rhodanides in the opposite way, but it indicates that the processes of sewage treatment from pollutants occur by the different mechanism. The obtained graphs (Figs. 2, 6) show that the increase in the purification time affects the efficiency of extraction of $Y_1$ phenols and $Y_2$ rhodanides in the same way, that is the purification processes are similar.

According to the experiments shown in Table 1, the multiple regression equation, the dependence of the extraction of rhodanides $Y_2$ simultaneously on glauconite dose $X_1$ and on the interval of purification time $X_2$ was obtained, which has the form

$$Y_2 = 426.1521 + 7.5829 \cdot X_1 - 1.4073 \cdot X_2 - 0.6628 \cdot X_1^2 - 0.0318 \cdot X_2^2 + 0.0062 \cdot X_1 \cdot X_2.$$ (6)

The average relative error of the equation is 3.54 % with a standard deviation of 2.95.

The multiple regression equation $Y_2(X_1, X_2)$ (6) is represented by a graph of 3D response surfaces in Fig. 7 and a graph of 2D maps of the lines of extraction of rhodanides ($Y_2$), depending on glauconite dose ($X_1$) and the time interval of purification ($X_2$), which are shown in Fig. 8.

The graph (Fig. 8) shows that the maximum reduction of rhodanide to 328–348 mg/dm³ can be obtained with the maximum dose of $X_1$ glauconite (2–3.5 g/dm³) and the minimum $X_2$ purification time interval (120 min) corresponding to the saddle point of the surface of equation (6). The quality of the purified phenolic effluent complies with the current standards (MPC of rhodanides not more than 400 mg/dm³). The optimal contact time of the sorbent with the liquid waste is 120 min, which does not exceed the residence time of wastewater in the flotator and meets the technological requirements.

As a result of the studies and their mathematical processing, it should be noted that the spent natural adsorbent after phenols and rhodanides extraction from coke-chemical wastewater does not require regeneration, since its further use as a binding additive to asphalt concrete mixtures is proposed.

**Conclusions.** Based on the experimental data, regression equations were obtained to determine the residual concentration of phenols and rhodanides depending on glauconite dose and the time of contact of the adsorbent with wastewater.
The obtained regression equations adequately describe the results of the experimental studies, the average relative error of the equations and their standard deviation lie within acceptable chemical technology limits.

The optimal glauconite dose in combination with the cationic flocculant in the amount of 5 ml/dm$^2$ according to the first model of purification of phenolic wastewater is 2–6 g/dm$^3$ at a time duration of 110–140 min, which leads to a decrease in the concentration of phenols from 510 to 330–390 mg/dm$^3$.

According to the second model, the maximum degree of extraction of rhodanides is achieved at glauconite dose 2–3.5 g/dm$^3$ at a time interval of 120 min, which leads to a decrease in the concentration of rhodanides from 475.2 to 328–348 mg/dm$^3$.

The results of the research allow us to recommend a natural mineral of glauconite with a minimum dose of 2 g/dm$^3$ with the addition of a cationic flocculant volume of 5 ml/dm$^3$ for effective provision of efficient wastewater treatment of coke production from phenols and rhodanides.

In the future, it is planned to carry out research on the further study of the mechanism of the process of adsorption–flocculation extraction of phenols with optimal dose selection of the cationic flocculant of polyacrylamide, regulated for industrial introduction at coke ovens.

In the world practice, sludge contaminated with various hydrocarbons that are formed during the purification of sediment which in its turn accumulates in the processing of resinous waste is used by asphalt plants. The experience is still poorly researched, but given the considerable similarity in the chemical properties of the pollutants this way of disposal of the substance should be considered possible, which is planned to be carried out in the following experiments.

References

1. Onishchenko, G. G. (2015). Actual tasks of hygienic science and practice in maintaining public health. *Hygiene and sanitation*, (3), 7–11.
2. Kulikova, D. V., & Pavlychenko, A. V. (2016). Estimation of ecological state of surface water bodies in coal mining region as based on the complex of hydrochemical indicators. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (4), 62–70.
3. Klymenko, I., Yelatontsev, D., Ivanchenko, A., Dupenko, O., & Voloshyn, N. (2016). Developing of effective treatment technology of the phenolic wastewater. *Eastern-European Journal of Enterprise Technologies*, 3(10(81)), 29–34. https://doi.org/10.15587/1729-4061.2016.72410.
4. Alexandros Stefanakis, I., Seegera, E., Dorerb, C., Sinkec, A., & Thullnera, M. (2016). Performance of pilot-scale horizontal subsurface flow constructed wetlands treating groundwater contaminated with phenols and petroleum derivatives. *Ecological Engineering*, 95, 514–526. https://doi.org/10.1016/j.ecoleng.2016.06.015.
5. Polymeric materials: products, equipment, technologies (2019). Moscow: The concept of communication of the XXI century, 1999, (10), 68. Retrieved from https://ruscont.ru/efd/667858.
6. Ivanchenko, A. V., Yelatontsev, D. O., Voloshin, M. D., & Dupenko, O. O. (2015). Study of the technology of extracting resinous substances from wastewater from coke-chemical enterprises by the method of reagent flotation. *Bulletin of Odessa Polytechnical University*, (45), 158–163.
7. Kolesnyk, V. Ye., Kulikova, D. V., & Pavlychenko, A. V. (2016). Substantiation of rational parameters of perforated area of partitions in an improved mine water settling basin. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (6), 120–127.
8. Ivanchenko, A. V., & Khavikova, K. Ye. (2019). Complex purification of industrial phenolic wastewater from virgin adsorbents from natural raw material. *Bulletin of Vinitsa Polytechnic Institute*, (2), 27–34. https://doi.org/10.31649/1997-9266-2019-143-2-27-34.
9. Kharkina, O. V. (2015). Effective operation and calculation of biological wastewater treatment facilities. Volgograd: Panorama. ISBN 978-5-9666-0172-0.
10. Farberova, E. A., Tingaeva, E. A., & Kobeleva, A. R. (2015). Sludge treatment using charcoal activated carbon waste. *All-Russian scientific and practical journal. Water: chemistry and ecology*, (6), 51–54.
11. Feofanov, Ryakhovsky, M. S. (2015). Comparative assessment of sorption capacities of homogeneous and complex loads during water treatment. *All-Russian scientific and practical journal. Water: chemistry and ecology*, (7), 85–90.
12. Somin, Betts S. A., & Komanova, L. F. (2016). The use of crop waste in the purification of water from phenol. *All-Russian scientific and practical journal. Water: chemistry and ecology*, (4), 50–55.
13. Ganzhiuk, A. Ya., Karvan, S. A., & Deychuk, G. M. (2016). Application of mineral adsorbents in the processes of purification, separation and conditioning of gas and liquid media. *Bulletin of Khmelnytsky National University*, (2), 266–269.
14. Fatima Zolna Choumane, Belkacem Benguella, Maachou, B., & Saadi, N. (2017). Valorisation of a bioflocculant and hydroxyapatites as coagulation–flocculation adjuvants in wastewater treatment of the steppe in the wilaya of Saïda (Algeria). *Ecological Engineering*, 107, 152–159. https://doi.org/10.1016/j.ecoleng.2017.07.013.

Математичне моделювання процесів очищення стічних вод від фенолів і роданідів із використанням глауконіту

A. V. Ivanchenko, K. Є. Хавікова, A. I. Триклю

Дніпровський державний технічний університет, м. Кам’янське, Україна, e-mail: karina.havikova@gmail.com
Мета. Підбрати оптимальну дозу природного мінералу глауконіту в поєднанні з катіонним флокулянтом для вилучення фенолів і роданідів із промислових стоків. Обґрунтувати переваги використання природного глауконіту як адсорбенту з розширеною катіонною здатністю до поглинання токсичних речовин. Розробити математичну модель адсорбційного очищення фенольних стічних вод на флотаційній установці.

Методика. Хімічні дослідження здійснювали згідно з методиками В. М. Кагасова, Є. К. Дербишевої. При проведенні експериментів із визначення концентрації фенолів у промислових стоках застосовували фотометричний метод, заснований на зastosуванні забарвлених у червоний колір з'єднуваних фенолів із 4-аминоантипірином в присутність гексацианоферрату калію. Для встановлення концентрації роданідів у фенольній стічній воді використовували фотометричний метод, заснований на взаємодії роданід-іона в кислому середовищі з іонами заліза (III) хлориду. Визначення оптичної щільності розчинів проводили на фотоколориметрі концентраційному КФК-2 з подальшим застосуванням калібрувальних графіків.

Результати. Експериментально показано, що при застосуванні інтервалу доз глауконіту 2–6 г/дм³ досягається найефективніше очищення рідких відходів від фенолів і зменшення концентрації вихідної фенольної води з 510 до 330–390 мг/дм³ упродовж 110–140 хв на механічній стадії. Досліджено зниження гранічно допустимої концентрації (ГДК) фенолов і роданидів з підбором оптимальної дози адсорбенту за допомогою математичної обробки експериментальних даних, яка склав 2–3,5 г/дм³ за тривалість флотації 120 хв. Отримане зниження вихідної концентрації роданидів від 475,2 до 328–348 мг/дм³. Досягнуто зниження гранично допустимої концентрації роданидів із 475,2 до 328–348 мг/дм³. Досягнуто зниження дози адсорбенту у промислових стоках до норми не більше 400 мг/дм³ перед біологічним очищенням.

Наукова новизна. Досліджено процес сорбційного вилучення фенолів і роданидів з рідких відходів з використанням глауконіту для оцінки математичної моделі адсорбційного процесу. Уперше встановлено, що глауконіт може бути використаний як адсорбент для фенольних стічних вод, що дозволяє прогнозувати оптимальну дозу адсорбенту, вивчити процес інтенсивності знищення загрязнених агентів до екологічно безпечних показників. Практична значимість. Надано математичний опис процесу очищення фенольних стічних вод із використанням глауконіту. У результаті зміни концентрації (ПДК) фенолов в стічних водах коксохімічного предприєття, регламентованого – не більше 415 мг/дм³, зменшення концентрації фенолов і роданидів до екологично безпечних показників.

Ключові слова: коксохімічні стоки, адсорбція, феноли, роданиди, природний глауконіт, катіонний флокулянт

Математичне моделювання процесів очистки стічних вод від фенолів і роданидів з використанням глауконіту

А. В. Иванченко, К. Е. Хавикова, А. И. Трикило

Дніпропетровский государственный технический университет, г. Каменское, Украина, e-mail: karina.havikova@gmail.com

Цель. Подобрать оптимальную дозу природного минерала глауконита в сочетании с катонным флокулянтом для извлечения фенолов и роданидів из промышленных стоков. Обосновать преимущества использования природного глауконита как адсорбента с развитой катионной способностью к поглощению токсичных веществ. Разработать математическую модель адсорбционной очистки фенольных сточных вод на флотационной установке.

Методика. Химические исследования осуществляли согласно методикам В. М. Кагасова, Е. К. Дербишевой. При проведении экспериментов по определению концентрации фенолов в промышленных стоках применяли фотометрический метод, основанный на образовании окрашенных в красный цвет соединений фенолов с 4-аминоантипирином в присутствии гексацианоферрата калия. Для установления концентрации роданидів в фенольной сточной воде использовали фотометрический метод, основанный на взаємодії роданід-іона в кислому середовищі з іонами заліза (ІІІ) хлориду. Определе- ние оптической плотности растворов проводили на фо- токолориметре концентрационном КФК-2 с последую- щим применением калибровочных графиков.

Результаты. Экспериментально показано, что при при- менении интервала доз глауконита 2–6 г/дм³ достигается эффективная очистка жидких отходов от фенолов и уменьшение концентрации исходной фенольной воды с 510 до 330–390 мг/дм³ в течение 110–140 мин на механической стадии. Достигнуто снижение предельно допустимой концентрации (ПДК) фенолов в исходных сточных водах 328–348 мг/дм³. Исследован процесс очистки промышленных стоков от роданидів с подбором оптимальной дозы адсорбента с помощью математической обработки экспериментальных данных, который составил 2–3,5 г/дм³ с продолжительностью флотации 120 мин. Получено снижение ис- ходной концентрации роданидів с 475,2 до 328–348 мг/дм³. Досягнуто ПДК роданидів при норме – не более 400 мг/дм³ перед біологічним очищенням.

Научная новизна. Исследован процесс сорбционного удаления фенолов и роданидів из жидких отходов с различными дозами глауконита для описания математической модели адсорбционного процесса. Впервые установлены кинетические закономерности процесса извлечения фенолов из сточных вод глауконитом в количестве 2–8 г/дм³ у поєднанні з катіонним флокулянтом об'ємом 5 ml/dm³ в інтервалі часу 20–120 хв, що дає можливість прогнозувати оптимальну дозу адсорбенту, вивчити процес інтенсивності знищення загрязнених агентів до екологічно безпечних показників.

Практическая значимость. Дано математическое описание процесса очистки фенольных сточных вод с использованием глауконита. Исходя из описания математической модели для промышленного внедрения предложено использовать природный адсорбент глауконит в интервале оптимальных доз 2–6 г/дм³ в сочетании с катионным флокулянтом об'ємом 5 ml/dm³ в інтервале времени 20–120 мин. Получена возможность прогнозировать оптимальную дозу адсорбента, влияя на время сорбционного процесса и снизить содержание загрязняющих агентов до экологически безопасных показателей.

Ключевые слова: коксохимические стоки, адсорбция, фенолы, роданиди, природный глауконит, катионный флокулянт

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