материалов, чтобы иметь предоставление о фактической скорости процесса ЭПО, что требуется для составления технологических карт в условиях реальных производств и оптимизации сопутствующих процессов.

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D.K. Khandamova, PhD assistent;
Sh.P. Nurullaev, Proffessor;
Z.S. Alixonova, Accosiate professor;
O.O.Babaev, doctoral student
(Tashkent Institute of Chemical Technology, Uzbekistan)

ISOTHERMAL MODELS OF ADSORPTION OF IRON IONS BY ORGANOBENTONITES IN

Introduction. The contamination of water resources with iron (Fe^{2+}) ions is a significant environmental problem due to its negative impact on human health and aquatic ecosystems. Traditional water treatment methods often fail to effectively remove Fe^{2+} ions [1, 2]. In recent years, researchers have investigated the use of bentonite-based adsorbents as a promising

method for removing Fe^{+2}. Consequently, it has been determined that utilizing activated bentonites for purifying Fe^{+2} ions in wastewater (including sewage) offers several advantages due to its unique properties [3,4].

Research methods. The object of the study is Navbakhor bentonite (PBG brand), which is considered a local raw material, modified with organic substances such as trimethylammonium (TMAB) and triethylammonium (TEAB), and the adsorption properties of iron ions in aqueous solutions were studied.

Analysis of the obtained results. Adsorbents were weighed on analytical scales in an amount of 5 grams, placed in a solution prepared in the presence of 500 ml of iron sulfate at various concentrations, mixed, settled for 1 hour, and filtered. The total iron concentration was determined by the spectrophotometric method. The essence of the method lies in the fact that iron (III) oxide is quickly reduced to iron (II) oxide in an alkaline environment. This determines the total amount of iron (II) and iron (III) ions (λ=420 nm) in an alkaline medium. [5]. The adsorption isotherms of iron ions in solution using synthesized adsorbents were studied using the Freundlich, Langmuyer, Dubinin-Radishkovich, and Temkin isotherm models. Using these models, the adsorption data was analyzed and the main parameters of the adsorption process were determined (Fig.1). According to the obtained results, the adsorption of Fe^{+2} ions on the adsorbents was 0,111 mg/g in PBG bentonite, 0,164 mg/g in TMAB and 0,198 mg/g in TEAB, respectively. Analysis using the Freundlich model. The Freundlich equation, or Freundlich adsorption isotherm, is an adsorption isotherm that represents the empirical relationship between the amount of gas adsorbed on a solid surface and the gas pressure. The same relationship holds for the concen-tration of solute adsorbed on the surface of a solid and for the concentration of solute in the liquid phase. In 1909, Herbert Freundlich gave an expression describing the isothermal change in the adsorption of the amount of adsorbed gas per unit mass of a solid adsorbent with gas pressure[6]. The results of adsorption of Fe^{2+} ions on modified adsorbents using the Freundlich model are presented in Figure 2.

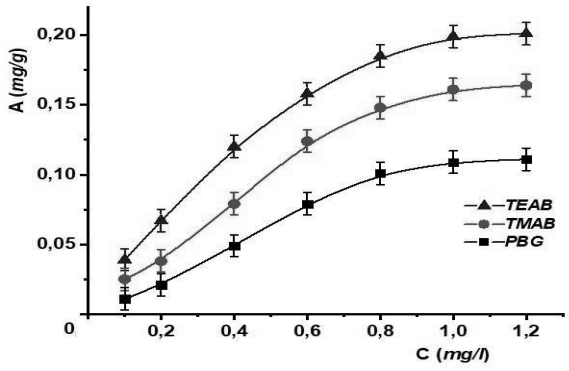

Figure 1 – Isotherms of adsorption of iron ions on adsorbents at 303K

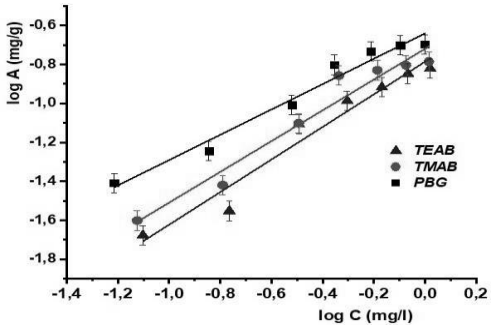

Figure 2 – Isotherms of adsorption of iron ions on adsorbents at a temperature of 303°C according to the Freundlich model

The Freundlich isotherm model indicates good adsorption at $0<1/n<1$. In this case, the degree of adsorption decreases with increasing concentration. The values of 1/n in PBG, TMAB, and TEAB adsorbents are 0.836, 0.789, and 0.65, respectively, and the values of n are greater than 1 (PBG = 1.19, TMAB = 1.53, TEAB = 1.26). When n > 1, it means that adsorption is strong, in this case, adsorption efficiency decreases with increasing concentration. The parameters of the Freundlich model isotherms are given in Table 1.

Analysis using the Lengmuer model. Langmuir's adsorption model explains adsorption by assuming that the adsorbate behaves as an ideal gas under isothermal conditions. According to the model, adsorption and desorption are reversible processes. His theory began when he put forward the idea that gaseous molecules do not return from the surface elastically, but are held up similarly to the groups of molecules in solids. The Langmuir isotherm model describes the main characteristics of adsorption isotherms, namely monolayer adsorption and the proximity of the adsorbent to the adsorbate.

The correlation coefficients (R^2) according to the Langmuir model were 0,921 for PBG, 0,964 for TMAB, and 0947 for TEAB. In the Langmuir model, R (L) (or separation coefficient, separation factor) is an important parameter representing the ease of adsorption. It describes how adsorption occurs depending on the initial adsorbate concentration according to the adsorption isotherms. The value of R (L) is interpreted as follows: R (L)>1: The adsorption process is unfavorable, R (L)=1: The adsorption process is linear (ideal state), 0<R(L)<1: The adsorption process is favorable, which indicates good adsorption, R (L) = 0: The adsorption process is irreversibly strong. The study found that the isotherm of the Langmuir model has a separation coefficient (R (L)) of 0.26, 0.197, and 0.104, respectively. The results of the Langmuir model isotherm are presented in Table 1. Analysis using the Dubinin-Radishkovich model. The Dubinin-Radushkevich model is often used to estimate characteristic porosity and the visible free energy of adsorption. The Dubinin-

Radushkevich (D-R) adsorption isotherm model is based on the potential theory of adsorption developed by Polanyi. Due to its basic thermodynamic basis, it is fundamentally strong and highly valued compared to other isothermal models. In the Dubinin-Radushkevich isotherm model, the E value is stated to fall within the energy range of 8-16 kJ/mol for ion exchange adsorption.

The values of the constants are determined by the intersection of the linear model (q_{max} = exp (intercept)) and the slope of the tangent of the angle (KD-R=-slope). In the literature, the value of E is emphasized as a criterion for evaluating the type of adsorption process. If the value of E is greater than 16 kJ/mol, the adsorption is chemisorption. If the value of E is less than 8 kJ/mol, it corresponds to a physical adsorption process. If it falls within the range of 8-16 kJ/mol, it indicates that ion exchange adsorption is occurring. The values of the Dubinin-Radushkevich model constants for Fe^{+2} ion adsorption isotherms on PBG, TMAB and TEAB are presented in Table 1.

Table 1 – Indicators of Fe^{2+} ion adsorption on adsorbents based on Freundlich, Langmuir, Dubinin-Radushkevich, and Temkin isotherm models

Adsorbtion Izotherm Models	Parameters	Adsorbents		
		PBG	TMAB	TEAB
Lengmyur	q_{max} (mg/g)	0.206	0.235	0.239
	K_L (L/mg)	0.056	0.081	0.171
	R_L	0.261	0.197	0.104
	R^2	0.997	0.998	0.999
Freyndlix	K_F (1/mg)	0,163	0.191	0.229
	1/n	0,836	0.789	0.650
	n	1,196	1.267	1.538
	R^2	0.917	0.964	0.947
Temkin	B_T (J/mol)	13.354	19.541	26.052
	K_T (L/mg)	0.055	0.056	0.063
	R^2	0.969	0.989	0.961
Dubinin-Radushkevich	q_m (mg/g)	4.362	4.636	5.214
	β_d (mol^2/kJ^2)	$1.23 \cdot 10^{-4}$	$1.86 \cdot 10^{-5}$	$3.09 \cdot 10^{-6}$
	E (kj/mol)	34.4	56.9	65.4
	R^2	0.834	0.881	0.865

The Temkin isotherm model considers the influence of the indirect adsorbate-adsorbent interaction on the adsorption process. It is based on the assumption that the heat of adsorption of all molecules in the layer decreases linearly due to an increase in the surface coverage of the adsorbent. The decrease in the heat of adsorption is linear, not logarithmic, as in the Freundlich isotherm. According to the results, the correlation coefficient for this isotherm was 0.989 for TMAB. The adsorption isotherms of Fe^{2+}ions on PBG, TMAB and TEAB adsorbents are presented in the table below. Based on the conducted research, the correlation coefficients in the

Langmuir model were more accurately described than in the Freundlich, Temkin, and Dubinin-Radiushkevich models.

According to Langmuir's model, the adsorption capacity (q_{max}) of adsorbents in PBG is 0.206; 0.235 - in TMAB; 0.239 mg/g – in TEAB.

Conclusion. Based on the conducted studies, the Langmuir model provided a more accurate description of Fe^{2+} ion adsorption compared to the Freundlich, Temkin, and DubininRadushkevich models. The adsorption capacities (qmax) of the synthesized adsorbents were determined to be 0.206 mg/g for PBG, 0.235 mg/g for TMAB, and 0.239 mg/g for TEAB. Fe^{2+} ion adsorption values were found to be 0.151 mg/g for PBG, 0.164 mg/g for TMAB, and 0.168 mg/g for TEAB.

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