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ADSORPTION STUDIES OF Ni (II) ION REMOVAL FROM AQUEOUS SOLUTIONS BY NOVEL MODIFIED SYNTHETIC COPOLYMER: ADSORPTION ISOTHERMS

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This work is dedicated to adsorption study of Ni(II) ions by synthetic adsorbent based on maleic anhydride styrene copolymer and 4-Amino-N-2-thiazolylbenzenesulfonamide modified with thiourea. During work different parameters affecting adsorption process were investigated such as influence of pH, contact time, ionic strength and initial metal ion concentration. It was found that maximum adsorption capacity is observed at pH=3 and is equal to 18 mg/g. In order to describe adsorption process different adsorption isotherm models were studied and the results were found to be consistent with the Langmuir model. Dubinin-Raduskhevich model was investigated to show that physical adsorption takes place in the system adsorbent-adsorbate. The present work also includes desorption studies and 0.5 mol/l solution of HNO₃ has shown the highest desorption capacity over Ni(II) ions.

Keywords: adsorption, Ni (II), copolymer, isotherm

INTRODUCTION

It is known that water is a very valuable natural resource for both humans and other living creatures but currently, water pollution is considered a dangerous problem and is a serious global problem [47, 29]. Among these pollutants, inorganic pollutants, especially heavy metals, differ from others [44]. Thus, the high toxicity of these pollutants and inability to be broken down and eliminated biologically, this group of inorganic pollutants is always in the spotlight [48]. Heavy metals are mainly transition elements (Pb, As, Hg, Cd, Zn, Ag, Cu, Fe, Cr, Ni, Pd, etc.) [34, 27]. The main features of this group of elements are that they are extremely toxic even at the ppm level. The main cause of environmental pollution with heavy metals is mankind's own responsibility. The rapid development of industry has resulted in the same rapid increase in the amount of harmful substances released into the environment [9, 15, 38]. Wide use of these metals in various fields of agriculture and industry has led to the pollution of the environment with these metals. This group of metals also includes nickel also. Nickel is the 24th most common element on earth and makes up 3% of all compounds [40, 22]. Nickel is mainly used for mixing with other metals during the purchase of alloys, so that the obtained product has high corrosion resistance against air, water and alkalis [11]. For this reason, nickel is regularly used in various industrial processes such as electroplating, painting of ceramic products, mineral processing and stainless steel production, batteries, non-ferrous metal coins, metal alloys and so on [30, 38]. Such widespread use of nickel leads its massive release into the aquatic environment through industrial waste and nickel-containing products in wastewater [24].

Nickel is one of the most important trace element for protein metabolism and hormone regulation in the human body [31]. However, exposure to high amounts of it causes various types of chronic and acute diseases [41], as well as genotoxicity [10, 21], neurotoxicity [37], hepatotoxicity [1], nephrotoxicity [43], kidney and lung damage [17], shortness of breath [8, 18], skin dermatitis [49], gastrointestinal tract disorders [36], vomiting [16], diarrhea in the human body so resulting in inhibition of oxidants and increased risk of cancer [13, 20, 12, 35]. Therefore, the World Health Organi-



zation, the permissible concentration of nickel in water should not exceed 0.02 mg/l. This proves how dangerous even a very small amount of nickel is [42].

One of the most important problem of our time is finding novel method for the removal of nickel from aqueous medium. Among the various separation methods, adsorption is one of the most efficient, cost-effective and effective methods used to remove heavy metals from solution. Adsorption has shown high efficiency in the separation of metal ions, including nickel. Thus, adsorption is already used in several industrial processes, including the separation of nickel from wastewater, due to its low cost, rapidity, ease of application, efficiency even for low concentrations [39].

In recent years, significant progress has been made in the purification of nickel ions from water using the adsorption process. However, there is still a need for the synthesis of new sorbents that are more effective in a short time with the ability to effectively separate nickel from the solution at a low or high concentration [32, 26].

The purpose of the presented work is to study the sorption of Ni(II) ions from its aqueous solutions by a polymer chelating sorbent based on a copolymer of maleic anhydride and 2-(4-aminobenzenesulfamido)-thiazole with styrene and modify this sorbent by novel thiourea derivative for the increasing its sorption capacity. The characteristics of sorption, especially pH, time, ionic strength, initial concentration of metal ion were studied. The desorption process was also investigated and the optimal eluent was determined. Several adsorption isotherms have been studied.

MATERIAL AND METHODS

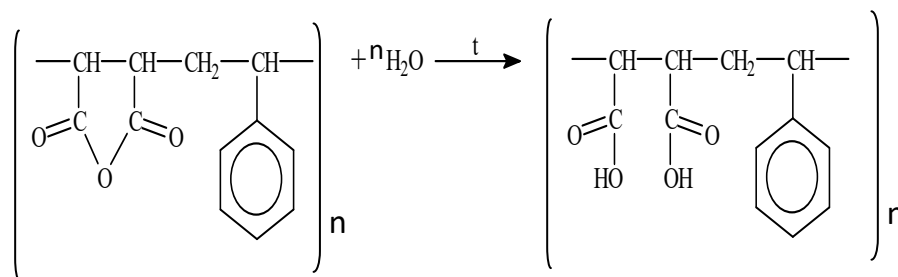
Devices

The optical densities of the solutions were measured with a KFK-3 spectrophotometer using 1 cm thick quartz cuvettes. The pH values of the solutions were measured using a pH-meter equipped with a pH-121 standard solution with a glass electrode. Distilled water was obtained through a-10 device.

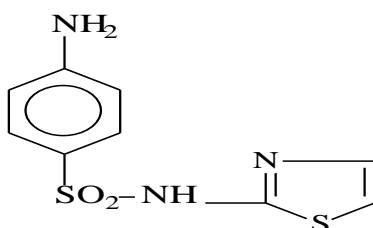
Preparation of solution

Nickel standard solution (1×10^{-2})

All the reagents used are of high purity. The 10^{-2} M solution of nickel was obtained by dissolving 0.2628 g of $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ in 100 ml of distilled water. Different concentrations of Ni(II) solution was prepared by diluting 10^{-2} stock solution.



Scheme 1. Hydrolysis of the anhydride groups contained in the copolymer



Scheme 2. Structure of 4-Amino-N-2-thiazolylbenzenesulfonamide

Buffer Solution

The buffer solutions (pH=3-8) used during the experiment were obtained by mixing appropriate amounts of 0.1 M CH_3COOH and $\text{NH}_3\text{xH}_2\text{O}$ and for pH 2 HCl was used.

Synthesis and identification of sorbent

Radical copolymerization of maleic anhydride with styrene in a benzene solution in a water bath (75-80 C) for during 140 min conducted. As an initiator azobiisobutyronitrile recrystallized in ethanol were used.

The obtained copolymer was washed with benzene and dried to constant weight in a drying cabinet at 50°C. The yield of the copolymer is 95-97%. It is known from the literature [33] that maleic anhydride forms a 1:1 (mole ratio) alternating copolymer with styrene. Calculated amounts of formaldehyde and the corresponding amine are added to the obtained copolymer. The reaction is carried out in a sand bath with continuous stirring. Since the reaction is carried out in an aqueous environment, the anhydride groups contained in the copolymer are hydrolyzed (Scheme 1).

In the system, unstable carbonyl-amine is obtained from the interaction of formaldehyde and amine groups. The removed carbonylamine interacts with the carboxyl groups in macromolecules, and the removed amine fragment enters the macromolecule (Scheme 2).

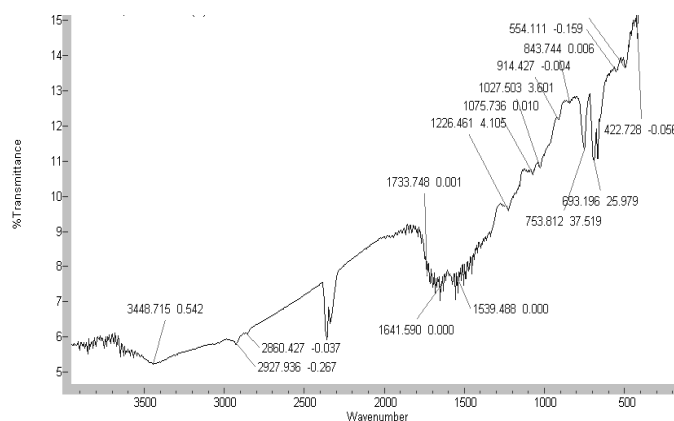


Fig.1. IR spectrum of the sorbent

In the IR spectrum (Figure 1) of the sorbent, 3668-3111 cm^{-1} [valence vibrations of the $-\text{OH}$ group in the carboxyl group, as well as valence vibrations of the $-\text{NH}$ group (3361 cm^{-1})], 1733-1745 cm^{-1} (valence vibrations of the $-\text{C}=\text{O}$ group in the carboxyl group), absorption bands are observed at frequencies 1585-1565 cm^{-1} (C-N valence oscillations and N-H deformation oscillations), 1605-1457 cm^{-1} (valence oscillations in the benzene ring), 730-695 cm^{-1} (deformation oscillations in the benzene ring)

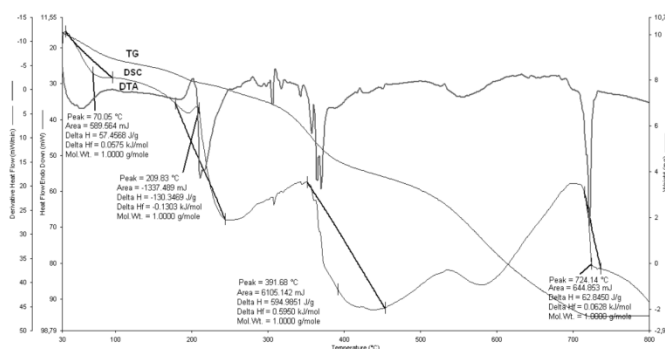


Fig.2. Thermogram of 4-Amino-N-2-thiazolybenzenesulfonamide fragment containing sorbent



The resistance of the sorbent to temperature was determined by the thermogravimetric method (Figure 2). From the thermogram of the sorbent, it is known that the breakup of water and other mixtures observed with an endothermic effect at 150°C (mass reduction-17.04%). Destruction of the macromolecule and oxidation or burning of destroyed fragments observed with a weak endothermic effect in the temperature range of 70-209°C the mass decreases (mass reduction-42.67%). In the temperature range of 391-724°C, complete combustion of the polymer observed with a strong exothermic effect occurs (mass reduction-35%).

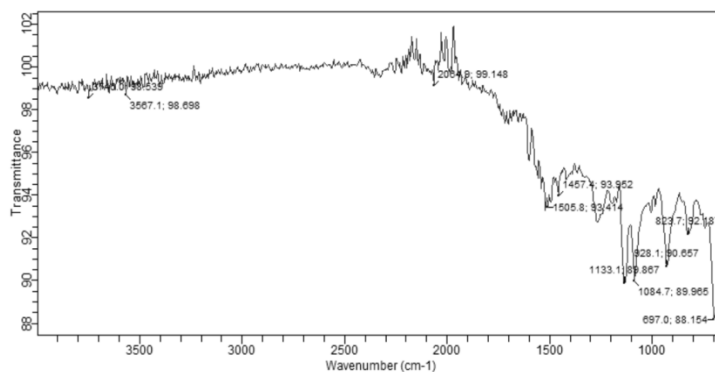
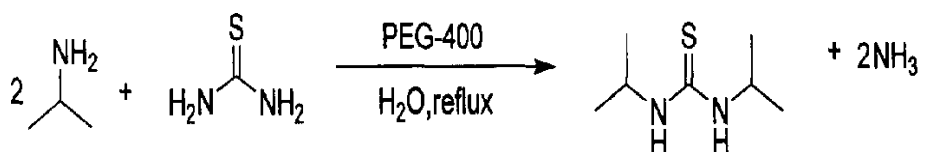


Fig.3. FTIR spectrum of the functionalized sorbent

According to the analysis of the FT-IR spectrum of diisopropylthiocarbamide (Figure 3), N–H vibrations at 3567 cm^{-1} are visible in the spectrum of the ligand in the region of 3450–3100 cm^{-1} . The band at about 1457 cm^{-1} in the compound shows some change in the spectrum after the conversion of that compound. The new band shifts to about 1486–1524 cm^{-1} . These shifts can be attributed to the increase in the double bond character of the C–N bond. The spectrum of the compound confirms that C=S as the main functional group exhibits a peak at a wavelength of 1190-2140 cm^{-1} . Conversion through the exocyclic sulfur atom is associated with a decrease in the π -electron density of the thiourea exocyclic C=S bond. In addition, the ν (C=S) bond of the free ligand is red-shifted to lower frequencies upon conversion.

Synthesis of N,N'-diisopropyl thiourea

The synthesis of N, N'-diisopropyl thiourea was carried out according to the literature [45, 3] (using PEG-400 catalyst) in a 2:1 ratio of thiourea and diisopropylamine, and the reaction was carried out for 36 hours at normal atmospheric pressure. Then the obtained solid mass was washed, filtered and dried. The scheme of the reaction is as follows is in the scheme below (Scheme 3).



Scheme 3. Formation reaction of N,N'-diisopropyl thiourea

Sorption experiments

Sorption studies of Ni (II) ions were carried out at room temperature. For each experiment, 2 ml of metal ion solution of known concentration ($5 \cdot 10^{-3}$ mol/L) was added to 50 ml conical flasks. 30 mg of sorbent and appropriate pH were added to each flask. The pH level of the solutions was monitored using a pH-121 pH-meter. After keeping the obtained mixture for 24 hours, the liquid phase was separated from the solid phase by filter paper.

Then 1 ml of sample was taken from each flask and diluted with a buffer solution of pH-5. The final concentration of Ni (II) ions was 2,2',2'',2'''-{(1,1-Dioxo-2,1λ6-benzoxathiole -3,3(1H)-



diyl)bis[(6-hydroxy-5-methyl-3,1-phenylene)methylenenitrilo]}tetraacetic acid reagent (R) was measured using KFK-3 photoelectrocolorimeter at wavelength $\lambda=580$ nm. The degree of removal of metal ions is calculated by the following formulas:

$$R_{\%} = \frac{C_0 - C_e}{C_e} 100 \quad (I)$$

$$q_e = \frac{(C_0 - C_e)V}{m} \quad (II)$$

Here, C_0 is the initial concentration of the metal ion ($\text{mol}\cdot\text{L}^{-1}$), C_e is the equilibrium concentration of the metal ion ($\text{mol}\cdot\text{L}^{-1}$), V is the volume of the solution (L), and m is the mass of the sorbent (mg).

Desorption process

The preparation of adsorbent is usually a complex process that requires a certain amount of time and energy. At the same time, the substances used for synthesis are often very expensive and difficult to obtain. Therefore, it is very important to investigate the reusability of the investigated sorbent. A number of methods are used for the regeneration of adsorbents, such as biological method (with the help of microorganisms), thermal method (through oxidation) and chemical method, which is the most commonly used method, where the absorbate is expelled with a suitable solvent [28]. In this research, we have studied the effect of different acids and its concentration on the desorption process.

The desorption study was carried out using $0.5 \text{ mol}\cdot\text{L}^{-1}$ solutions of different inorganic acids with the same concentration, that is, HNO_3 , HCl , H_2SO_4 and CH_3COOH acids. To carry out the experiment, 30 mg of sorbent was poured into 4 flasks, 2 ml of 10^{-2} M Ni (II) solution and 18 ml of pH 3 were added and kept for 24 hours. Then, the solid part of the solution was separated from the liquid by filtration. 20 ml of 0.5 M HNO_3 , HCl , H_2SO_4 and CH_3COOH acid solutions were added to the filtered part.

Each was kept by tightly closed for 24 hours. A day later, the liquid part of the solution separated from the solid again. Then 1 ml of the homogeneous solution was taken, 1-2 ml of 2 mol/l KOH solution was added, diluted with pH 6.0 buffersolution, and the final concentration of Ni (II) ions was determined using the KFK-3 device.

RESULTS AND DISCUSSION

Effect of pH on the sorption of Ni (II)

The pH of the solution is an important factor affecting the sorption capacity of Ni(II), because it affects the stability of nickel in the solution and can change its forms in the solution, for example, at different pH values, nickel in solution Ni^{2+} , $\text{Ni}(\text{OH})^+$, $\text{Ni}(\text{OH})_2$, $\text{Ni}(\text{OH})^{3-}$ forms [19]. Besides, it can change the electrical properties of the sorbent surface. At pH values above 8, Ni^{2+} is the major form of nickel found. The pH of the initial solution was chosen between 2.0 and 8.0 to prevent the formation of hydroxides during sorption .

To conduct the experiment, 30 mg of sorbent was weighed and collected in separate containers, then 2 ml of 10^{-2} M metal ion solution and 18 ml of appropriate pH were added to it and kept for 24 hours.

After 24 hours , the solution was filtered through a filter paper to separate solid particles and measured at a wavelength of $\lambda=580$ nm using a KFK-3 spectrophotometer. The effect of the pH of the solution on the sorption of nickel is shown in the figure below (Figure 4).

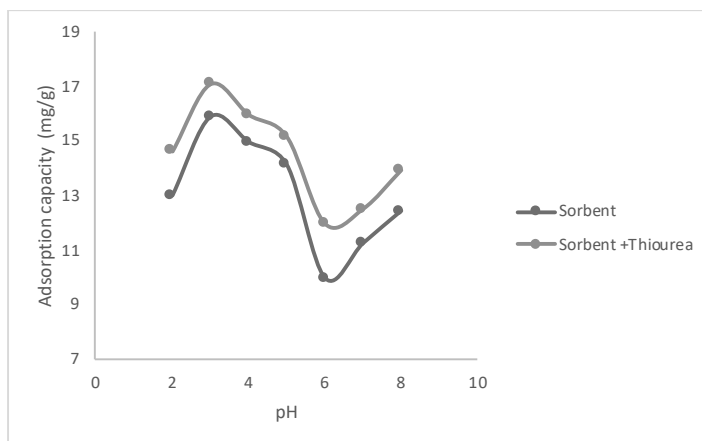


Fig.4. Effect of pH on the sorption of nickel

As a result of the measurement, it was found that the capture of Ni (II) ions with the highest percentage from the solution was at pH 3. Therefore, this value of pH was used in all subsequent experiments. A graphical representation of the result of the experiment is given in the figure below.

After soaking of the sorbent with N, N'-diisopropyl thiourea, the effect of the pH value of the environment on the sorption process was studied and in this case it was determined that the maximum absorption was at the value of pH 3.

Effect of time on the sorption of metal ions

The results of kinetic studies show that the degree of adsorption of Ni(II) ions to adsorbents can be extremely variable and difficult to predict. Thus, it is known in the literature that the equilibrium time of Ni(II) sorption is reached within 15 minutes [7], and another one is completed in 7 days [46]. It is clear that this change depends on the type of sorbent used. Basically, synthetic sorbents reach equilibrium faster than natural sorbents, which in most cases is explained by the fact that they have more sorption centers, have a high surface area, and have more and wider pores.

In order to study the dependence of sorption on time, 30 mg of sorbent was taken and 2 ml of 10^{-2} M metal solution was added to it, and then 18 ml of pH 3 was added and the rate of sorption of metal ions in the solution was studied for 30-270 minutes. The result of the experiment is given in the graph below.

As can be seen from the figure (Figure 5), after 60 min, the sorption has already stabilized and reached the equilibrium state. It can be said that after this time, the metal ion was no longer captured from the solution. The same situation was observed when N, N'-diisopropyl thiourea was absorbed into the sorbent. That is, the sorption after 60 min reached the plateau price. A graphical representation of the result of the experiment is given in the figure below.

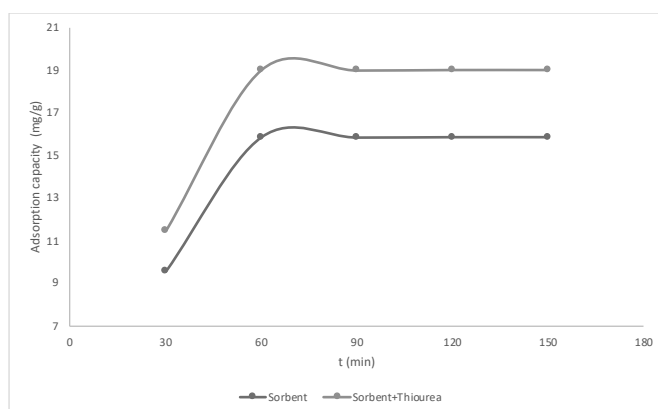


Fig.5. Effect of time to sorption process



In the course of this work, the effect of ionic strength on the capture rate of Ni(II) ion was studied. For these purposes, 2 mol/L potassium chloride KCl solution was used.

Studies have shown that the presence of K^+ and Cl^- ions in the range $\mu = (0.2-1.4)$ mol/L has a negligible effect on metal ion sorption.

Effect of initial concentration of Ni(III) ions on adsorption capacity

The initial concentration of the metal ion is very important in the study of the adsorption process. Because the concentration of metal ions is one of the main factors that ensures its movement towards the surface of the adsorbent [4].

During the experiment, the effect of the concentration of primary metal ions on the degree of adsorption by the synthesized sorbent was studied. For this purpose, the concentration range of Ni (II) ions from 2×10^{-4} mol/L to 8×10^{-3} mol/L was used. For this purpose, 30 mg of sorbent was weighed, and an appropriate volume of metal ion solution and pH 3.0 was added. After 60 minutes, optical densities of homogenous solutions in KFK-3 were measured at $\lambda = 590$ nm with pH 6.0 buffer solution. The result of the experiment is given in the figure below (Figure 6).

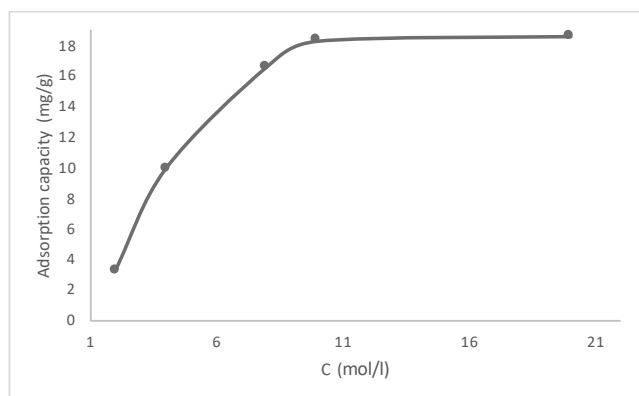


Fig.6. Effect of initial concentration adsorption capacity

Desorption process

This work also includes the study of the opposite process - desorption. It is an important task to have the necessary eluents to adsorb the metal ion. In our article, this process is carried out using different inorganic acids of the same concentration, in particular, 0.5 mol/L solutions of HNO_3 , HCl , H_2SO_4 and CH_3COOH acids. The research results showed that the maximum desorption capacity on Ni(II) ions is 0.5 mol/L HNO_3 solution.

Adsorption isotherm

For a better understanding of the adsorption process, the relevant adsorption equilibrium must be used in the study. The nature of the adsorbate-adsorbent interaction is described by adsorption equilibrium. In the present study the equilibrium data were analyzed using the Langmuir, Freundlich and Dubinin-Radushkevich isotherms.

Langmuir isotherm

The Langmuir equation is often used to give the sorption equilibrium. In the Langmuir isotherm, it is assumed that all areas of the surface of the sorbent are similar to each other, that is, homogeneous. In this model, the sorption of metal ions occurs on a homogeneous surface without any interaction between equally adsorbed ions. assumes and the ability of a molecule to adsorb at a given site does not depend on the occupancy of neighboring sites, adsorption is reversible and the adsorbed molecule is assumed to be unable to migrate along the surface or interact with its neighbor [6].

The Langmuir model is expressed by the following formula:



$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e}$$

Here, C_e (mmol/L) is the adsorbate concentration in the aqueous phase at equilibrium, q_e (mmol/g) is the equilibrium adsorption capacity, q_m is q_e for a complete monolayer, and K_L is the Langmuir isotherm constant (L/mmol⁻¹).

A linear graph of $1/q_e$ versus $1/C_e$ is shown in the figure below. The values of Q_{max} and K_L were calculated from the slope and intercept of the plot, respectively.

The main characteristic of the Langmuir isotherm can be represented by a separation factor called the equilibrium parameter (R) and has the following form:

$$R_L = \frac{1}{1 + b C_0}$$

Here, b is the Langmuir constant (L/mmol), C_0 is the initial adsorbate concentration (mmol/L). The R_L value indicates the type of isotherm. A value between 0 and 1 indicates a favorable adsorption process.

The results show that the R_L is between 0 and 1 and equal to 0.99 when only sorbent is used and after modification, which indicates that the adsorption is favorable under the experimental conditions determined by the Langmuir model. Also, the value of the regression coefficient is $R^2 = 0.4877$ and 0.6771 , respectively, indicating that this isotherm model is in good agreement with the experimental adsorption data (Figure 7).

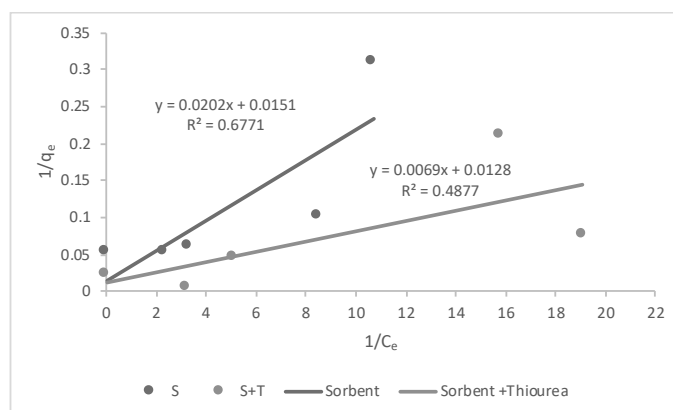


Fig.7. Langmuir isotherm model

Freundlich isotherm

The Freundlich isotherm model determines the degree of heterogeneity of the adsorbent surface. Adsorption sites consist of small heterogeneous adsorption sites, each of which is homogeneous [5].

The isotherm is described by the following equation

$$\ln q_e = \ln K_F + \frac{1}{n} \ln C_e$$

where C_e (mmol/L) is adsorbate concentration at equilibrium, q_e (mmol/g) is the equilibrium adsorption capacity, K_F is Freundlich constant and $1/n$ is the heterogeneity factor.

On average, the more favorable adsorption tends to have a Freundlich constant n between 1 and 10. A larger value of n (a small value of $1/n$) implies a stronger interaction between the adsorbent and the adsorbate, while $1/n$ equal to 1 indicates linear adsorption, which is characterized by the same adsorption energies for all points on the branch. Linear adsorption generally occurs at



very low solute concentration and low adsorbent loading. Our calculations show that $1/n = 0.5674$ and after functionalization case 1.602. So it indicates normal adsorption in both cases (Figure 8).

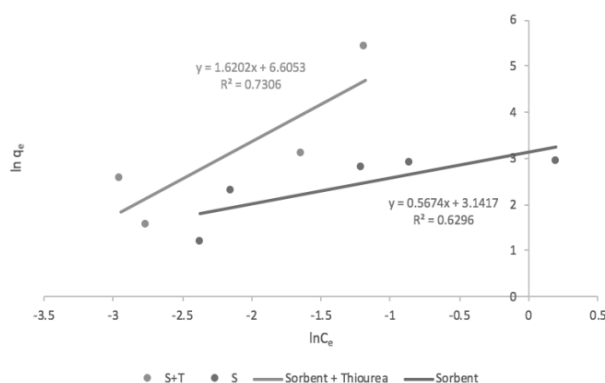


Fig.8. Freundlich isotherm model

Temkin isotherm

According to the Temkin isotherm equation, adsorption is characterized by a uniform distribution of binding energies up to a maximum binding energy, and the fall in the heat of adsorption of all the molecules in the layer decreases linearly with coverage because of adsorbent–adsorbate interactions [2].

The generalized (I) and linearized forms (II) of the model are given by the following equations:

$$q_e = \frac{RT}{b_T} \ln(K_T C_e) \quad (I)$$

$$q_e = \frac{RT}{b_T} \ln(K_T) + \frac{RT}{b_T} \ln(C_e) \quad (II)$$

Here K_T is Temkin isotherm constant (L/g), R - ideal gas constant (8.314 J/mol K), T - temperature (K), b_T constant related to the heat of sorption (J/mol)

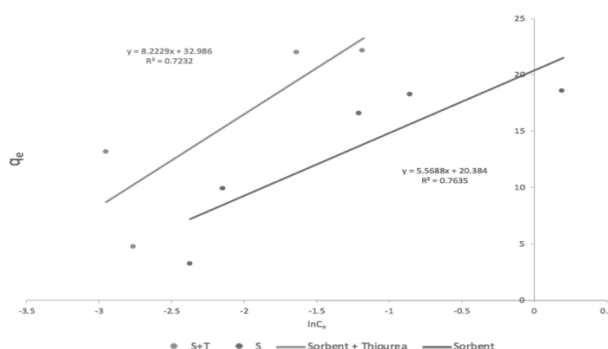


Fig.9. Temkin isotherm model

From the figure 9 the values for B_T is equal 5.5688 for just sorbent and after functionalization it becomes 8.2229. It shows there is physisorption occurs so if the $B_T < 8$ kJ/mol the adsorption process is physical adsorption and $B_T > 8$ kJ indicates chemical adsorption. The value of K_T is 38.8766425 and after functionalization 55.2285558.



Dubinin-Radushkevich (D-R) isotherm

The Dubinin-Radushkevich (D-R) isotherm model is applied to estimate porosity, free energy, and sorption characteristics. It is successfully applied for the adsorption of heterogeneous system including solid and liquid. This model is considered more general than the Langmuir model, because in its derivation a homogeneous surface and a constant sorption potential are not assumed [23]. The isotherm is obtained based on the following equation.

$$\ln q_e = \ln q_s - k_{D-R} \varepsilon^2$$

The Polanyi potential, which depends on temperature, gas constant and equilibrium density is expressed in the following equation:

$$\varepsilon = RT \ln \left(1 + \frac{1}{C_e} \right)$$

The Dubinin-Radushkevich isotherm has found many promising applications for determining whether the nature of sorption is physical or chemical. For this purpose, the k name obtained from the slope of the plot is used in the following equation:

$$E = \frac{1}{\sqrt{2k_{D-R}}}$$

The R^2 value is equal to 0.7993 and 0.5185. E is equal to 3.5 kJ/mol. If E is between 8 and 16 kJ/mol, it indicates a chemisorption process, and an E value below 8 kJ mol⁻¹ indicates a physical adsorption process. Thus, in our both case, the value of E is lower than 8 means that the physical adsorption (Figure 10).

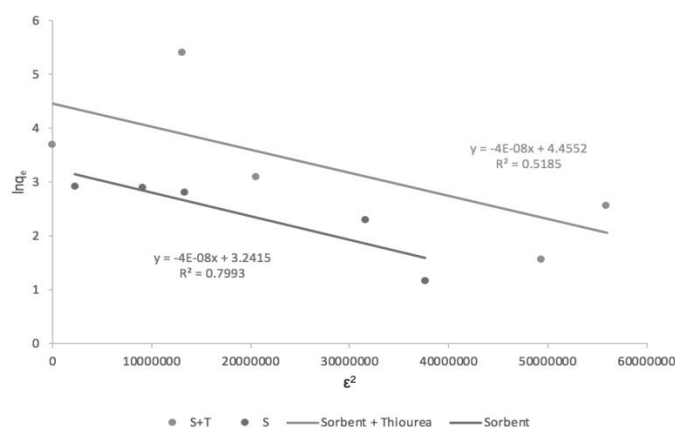


Fig.10. Dubinin-Radushkevich (D-R) isotherm

Application of adsorbent for determination of Ni (II) in waste water of oil field

For the analysis purposes water sample was taken from oil field of Pirallahi island. A sample of around 2 L of drinking water was left to distill for 1 day. An additional 1 L of filtrate was collected and acidified with 10 mL of HNO₃(1:1). The resultant mixture was then evaporated slowly till it reached 70-80 mL. The final solution was filtered, transferred to a 100 mL flask, and diluted with distilled water up to the mark. Resulting solution was passed through the microcolumn filled with adsorbent with 1.0 mL/min of speed. Ni(II) ions absorbed by adsorbent in microcolumn was desorbed by 1.5 M HNO₃ solution. Then eluent is passed into 25 mL flask. 2.5 mL of reactive is added into flask and diluted till mark with pH 5. Absorbances of the resulting solutions were measured at



$\lambda=580$ nm on KFK-3, $l=1$ cm on the background of R. The amount of Ni (II) ions in water samples were calculated on the basis of previously built calibration curve. Results were compared with AAS and are given in the table 1.

Table 1

Determination of Ni (II) in waste water of oil field

Analyzed object	Adsorbent	Reagent	$\bar{X} \pm \frac{t_{p.f.} \cdot S}{\sqrt{n}}, mg/L$	S_r
Water	S	R	$(0.357 \pm 0.015) \cdot 10^{-3}$	0.02
		AAS	$(0.364 \pm 0.016) \cdot 10^{-3}$	0.04

CONCLUSION

In conclusion, the outcomes of our investigations reveal promising and noteworthy results, that shows this novel functionalized sorbent can effectively be used for the removal of nickel from water. After modification of sorbent adsorption capacity approximately 20% increases. Adsorption isotherms were investigated by several models and it was found that results best fit the Langmuir model. Proposed method was applied for determination of Ni(II) ions in water samples taken from oil field of Pirallahi island.

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YENİ MODİFİKASIYA OLUNMUŞ SİNTETİK KOPOLİMER İLƏ SULU MƏHLULLARDAN Nİ (II) İONUNUN ADSORPSİYON TƏDQİQATLARI: ADSORPSIYA İZOTERMLERİ

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Bu iş Ni(II) ionlarının malein anhidrid stirokopolimeri və tiokarbamid ilə modifikasiya olunmuş 4-Amino-N-2-tiazolilbenzolsulfanilamid əsasında sintetik adsorbent vasitəsilə adsorbsiya tədqiqinə həsr edilmişdir. İş zamanı adsorbsiya prosesinə təsir edən müxtəlif parametrlər, o cümlədən pH-ın təsiri, təmas müddəti, ion qüvvəsi və ilkin metal ionlarının konsentrasiyası tədqiq edilmişdir. Müəyyən edilmişdir ki, maksimum adsorbsiya qabiliyyəti pH=3-də müşahidə olunur və 18 mq/q-a bərabərdir. Adsorbsiya prosesini təsvir etmək üçün müxtəlif adsorbsiya izoterm modelləri tədqiq edilmiş və nəticələrin Langmuir modelinə uyğun olduğu müəyyən edilmişdir. Fiziki adsorbsiyanın adsorbent-adsorbat sistemində baş verdiyini göstərmək üçün Dubinin-Raduskhevic modeli tədqiq edilmişdir. Bu iş həmçinin desorbsiya tədqiqatlarını əhatə edir və 0,5 mol/l HNO₃ məhlulu Ni(II) ionları üzərində ən yüksək desorbsiya qabiliyyətini göstərmişdir.

Açar sözlər: adsorbsiya, Ni (II), kopolimer, izoterm

АДСОРБЦИОННЫЕ ИССЛЕДОВАНИЯ УДАЛЕНИЯ ИОНОВ Ni(II) ИЗ ВОДНЫХ РАСТВОРОВ НОВЫМ МОДИФИЦИРОВАННЫМ СИНТЕТИЧЕСКИМ СОПОЛИМЕРОМ: ИЗОТЕРМЫ АДСОРБЦИИ

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Данная работа посвящена изучению адсорбции ионов Ni(II) синтетическим адсорбентом на основе сополимера малеинового ангидрида стирола и 4-амино-N-2-тиазолилбензолсульфонамида, модифицированного тиомочевинной. В ходе работы были исследованы различные параметры, влияющие на процесс адсорбции, такие как влияние pH, время контакта, ионная сила и начальная концентрация ионов металлов. Установлено, что максимальная адсорбционная емкость наблюдается при pH=3 и равна 18 мг/г. Для описания процесса адсорбции были изучены различные модели изотерм адсорбции, и было обнаружено, что результаты согласуются с моделью Ленгмюра. Модель Дубинина-Радушевича была исследована с целью показать, что физическая адсорбция происходит в системе адсорбент-адсорбат. Настоящая работа также включает исследования десорбции, и раствор HNO₃ с концентрацией 0,5 моль/л показал наибольшую десорбционную способность по ионам Ni(II).

Ключевые слова: адсорбция, Ni (II), сополимер, изотерма.