ISSN: 1609-1620 (Print); ISSN: 2674-5224 (Online)
PAHTEI
REFERRED & REVIEWED JOURNAL
152 - 165
VOLUME 27 ISSUE 05 2025

Cu(II) ADSORPTION FROM AQUEOUS SOLUTION BY MAGNETIC CELLULOSE/Fe_3O_4/SiO_2/4-AMINOANTIPYRINE ADSORBENT

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ABSTRACT

This study focuses on the adsorption of Cu(II) ions using a novel magnetic adsorbent, which was synthesized by modifying a cellulose/Fe_3O_4/SiO_2 nanocomposite with 4-aminoantipyrine. The influence of pH, contact time and initial metal ion concentration on the adsorption capacity of the product was systematically investigated. Maximum adsorption efficiency was observed at pH 5. Equilibrium concentrations of Cu(II) ions in solution was set by using 1-phenyl-2- [2-hydroxy-3-sulfo-5-nitrophenylazo] 1,3-butadione (R) as reagent. During the study, several kinetic models parameters were evaluated. The equilibrium data were found to fit well with the pseudo-second-order model, indicating that this model effectively describes the adsorption process. To analyze the adsorption behavior, several isotherm models including Langmuir, Freundlich, Temkin, and Redlich–Peterson were employed. Among them, the Langmuir model provided the best fit to the experimental data, indicating monolayer adsorption. The maximum adsorption capacity of the adsorbent for Cu^{2+} ions was calculated to be 138,9 mg/g. The present study also encompassed desorption experiments, revealing that a 0.5 $mol \cdot L^{-1}$ HCl solution exhibited the highest efficiency for desorbing Cu (II) ions.

Keywords: adsorption, Cu(II), isotherms, nanocomposite, maximum adsorption capacity

Introduction

The removal of heavy metals from wastewater represents a critical environmental concern due to the significant adverse effects these metals have on both human health and the ecosystem [1]. Traditional methods for treating wastewater contaminated with metal ions include chemical precipitation, ion exchange, electrolysis, reverse osmosis, and adsorption. Among these approaches, adsorption is widely regarded as one of the most cost-effective, efficient, and promising techniques for addressing heavy metal contamination [2].

In recent years, the development of adsorbents for heavy metal ion removal has predominantly focused on the interaction between metal ions and the functional groups present on the surfaces of the adsorbents. These functional groups are crucial in influencing several key parameters, such as the adsorbent's efficiency, adsorption capacity, selectivity, and potential for reusability [3-5]. Consequently, the nature and concentration of functional groups on adsorbent materials play a vital role in optimizing their performance for metal ion removal in wastewater treatment.

In contrast to conventional adsorbents, magnetic bioadsorbents have garnered significant attention due to their superior separation efficiency, cost-effectiveness, and ease of operation [6] Among the various biopolymers, cellulose stands out as the most abundant, affordable, and environmentally sustainable renewable natural biopolymer, offering additional benefits such as biocompatibility and biodegradability [7]. Cellulose possesses unique mechanical and physical properties that make it highly advantageous for numerous applications, leading to its widespread use in a range of fields [8-10]. The chemical modification of cellulose, particularly through reactions involving its hydroxyl groups, facilitates the introduction of novel chelating functional groups, which significantly enhance its capacity to remove pollutants from environments [11,12].

Among the heavy metals, Cu(II) is one of the most prevalent toxic metals found in environmental pollution, primarily resulting from various industrial activities such as smelting, electroplating, and mining. The discharge of aqueous effluents containing high concentrations of copper ions from these processes poses significant risks to both environmental ecosystems and human health. The presence of Cu(II) in industrial wastewaters is a major concern due to its potential for bioaccumulation and toxicity. When individuals are exposed to elevated levels of Cu(II), either through ingestion, inhalation, or dermal contact, they may suffer from a wide range of health issues. Chronic exposure to copper can lead to severe conditions such as mortality, neurological damage, hypoglycemia, gastrointestinal disturbances, and muscle cramps. This underlines the importance of addressing copper contamination in industrial effluents to mitigate its harmful impact on human health and the environment [13].

This study aims to synthesize an innovative magnetic adsorbent by modifying a cellulose/Fe_3O_4/SiO_2 nanocomposite with 4-aminoantipyrine for the removal of Cu(II) ions. The adsorption performance was systematically examined by evaluating the influence of key parameters, including pH, contact time, and initial metal ion concentration. Additionally, the desorption process was examined, and the optimal eluent for metal ion recovery was determined. To gain a deeper understanding of the adsorption behavior, several adsorption isotherms and kinetic models were evaluated.

Objective

All chemicals used were of analytical grade: ferrous chloride tetrahydrate ($FeCl_2 \cdot 4H_2O$), ammonium hydroxide (NH_4OH,25%), ethanol (95%), tetraethyl orthosilicate (TEOS), microcrystalline cellulose, 4-aminoantipyrine were purchased from Sigma-Aldrich. Copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) was used as the source of Cu(II) ions. Deionized water was used throughout the experiments.

The optical densities of the solutions were determined using a KFK-3 spectrophotometer, employing 1 cm path length quartz cuvettes. The pH levels of the solutions were monitored using a pH meter, calibrated with a standard pH-121 solution and a glass electrode. Distilled water was obtained through a-10 distillation unit. The sorbent was dried in a Zymark Turbo Vap LV drying oven to ensure optimal conditions for subsequent analysis.

Methods

Preparation of Solutions. Copper standard solution ($1x10^{-3}$).

All reagents used in this study were of high purity. A 1×10^{-3} M solution of $CuSO_4 \cdot 5H_2O$ was prepared by dissolving an accurately weighed 0.024968 g of the salt in distilled water and making up the volume to 100 mL in a volumetric flask. Working solutions with varying concentrations of Cu(II) were obtained by appropriate dilutions of this stock solution.

Preparation of buffer solutions

The buffer solutions with pH values ranging from 2 to 7, used in the experiment, were prepared by mixing appropriate amounts of 0.1 M acetic acid (CH_3COOH) and ammonium hydroxide ($NH_3 \cdot H_2O$). To adjust the pH to 2, hydrochloric acid (HCl) was added.

Preparation of reagent

1-phenyl-2- [2-hydroxy-3-sulfo-5-nitrophenylazo] 1,3-butadione (PHSNPAB). PHSNPAB synthesized as a result of azocoupling reaction of diazotized 2-amino-4-nitro-6-sulphophenol-1 with benzoylacetone in a weakly alkaline medium, and its composition and structure were established by IR and NMR- spectroscopy.

Synthesis of magnetic adsorbents

In this study, a magnetic cellulose-based adsorbent was employed. The sorbent was synthesized by modifying the cellulose/Fe_3O_4/SiO_2 nanocomposite with 4-aminoantipyrine using a previously established method [14].

Adsorption experiments

Adsorption experiments for the removal of Cu(II) ions were performed at ambient temperature. In each trial, 2 mL of a Cu(II) ion solution was introduced into 50 mL conical flasks, followed by the addition of 30 mg of the prepared sorbent. The pH of the solutions was then adjusted to the desired value, and the pH was monitored throughout the experiment using a pH-121 pH meter. The flasks containing the metal ion solution and sorbent mixture were allowed to equilibrate for 24 hours. Following this incubation period, the liquid phase was separated from the solid phase by filtration using filter paper.

To analyze the remaining concentration of Cu(II) ions, 1 mL of the supernatant from each flask was carefully removed and diluted with a buffer solution at pH 5. This dilution ensured the stabilization of the pH for subsequent analysis. The final concentration of Cu(II) ions was determined using the reagent 1-phenyl-2- [2-hydroxy-3-sulfo-5-nitrophenylazo] 1,3-butadione (PHSNPAB) (R). The measurements were carried out with a KFK-3.The removal of metal ions from the solution, as well as the metal uptake in the solid phase or surface loading q_e ($mg \cdot g^{-1}$), were calculated using the equations provided below:

$$R, \% = \frac{C_0 - C_e}{C_e} x100 \qquad (1),$$

here R is a percentage of metal ion removal.

$$q_e = \frac{(C_0 - C_e)V}{m} \qquad (2),$$

here, C_0 represents the initial concentration of metal ions ($mg \cdot L^{-1}$), C_e is the equilibrium concentration ($mg \cdot L^{-1}$), V denotes the volume of the solution (L), and m is the amount of adsorbent used (mg).

Desorption process

Desorption studies were performed using different acidic solutions—HNO_3, HCl, H_2SO_4, and CH_3COOH—each prepared at a concentration of 0.5 $mol\cdot L^{-1}$.

For each experimental setup, approximately 30 mg of the modified adsorbent was accurately weighed and transferred into separate conical flasks. Subsequently, 2 mL of the metal ion solution was introduced into each flask, followed by the addition of 18 mL of solution adjusted to the optimal pH previously determined for adsorption. The mixtures were then maintained under static conditions for duration of 24 hours to ensure equilibrium. After the desorption process was completed, the mixtures in each flask were filtered to separate the liquid phase from the solid adsorbent. The recovered solid adsorbent was subsequently dried for further analysis.

Results and discussion

Effect of pH on the sorption of Cu (II)

The initial pH of the solution plays a crucial role in the adsorption efficiency of Cu(II) ions from aqueous media. This is attributed to its impact on key factors such as the surface charge of the adsorbent, the degree of ionization, and the chemical speciation of Cu(II) ions in the solution [15,16].

In this experiment, 30 mg of the sorbent was accurately weighed and transferred into individual containers. Then, 2 mL of a 10^{-3} M Cu(II) solution and 18 mL of buffer solution at the desired pH were added. The mixtures were allowed to stand for 24 hours to reach equilibrium. After this period, the suspensions were filtered using filter paper to separate the solid phase, and the remaining Cu(II) concentration in the filtrate was determined using a KFK-3 spectrophotometer. The influence of solution pH on copper adsorption is illustrated in Figure 1.

Cu(II) adsorption was strongly pH-dependent, increasing from 15% at pH 2 to 95% at pH 5. At low pH, high H^+ concentration protonated the adsorbent's functional groups ($-NH_2$, -OH) and competed with Cu^{2+} for binding sites. As pH increased, deprotonation enhanced electrostatic attraction between negatively charged adsorbent and positively charged copper species (Cu^{2+}, $Cu(OH)^+$). Above pH 6, precipitation of $Cu(OH)_2$ became significant.

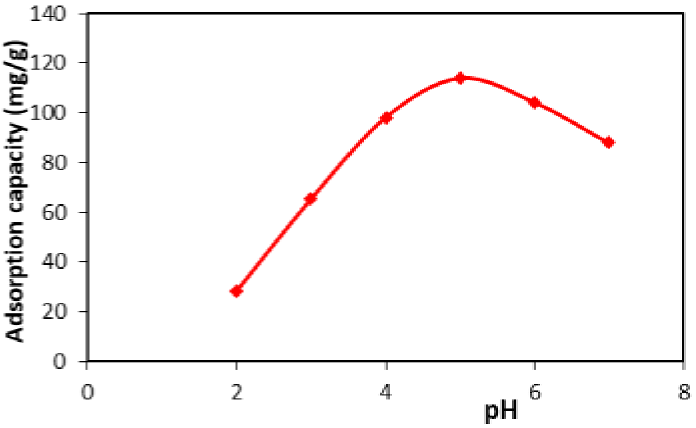

Figure 1. Effect of pH on adsorption of Cu(II).

The findings indicated that the highest adsorption of Cu(II) ions was achieved at pH 5.0. As a result, all further experiments were conducted at this pH to investigate the adsorption behavior in more detail.

Effect of Contact Time on the Adsorption Capacity of Cu(II) Ions

The effect of the time required to reach the maximum adsorption capacity is illustrated in Figure 2. To assess this, the time was systematically varied between 0 and 240 minutes. At each specified time interval, the equilibrium concentrations of metal ions in the sample were measured using the KFK-3 instrument.

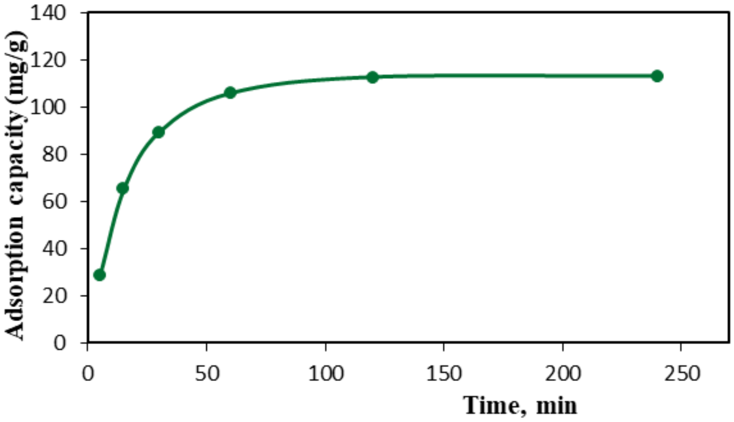

Figure 2. Effect of time on adsorption of Cu(II).

The effect of contact time on the adsorption capacity of Cu(II) ions shows that equilibrium is reached after 120 minutes. During this period, the adsorption capacity increases as the contact time progresses, and a steady state is achieved by 120 minutes. Beyond this time, no significant increase in adsorption occurs, indicating that the system has reached its adsorption equilibrium.

Effect of initial concentration of Cu (II) ions on adsorption capacity

The influence of the initial Cu(II) ion concentration on the adsorption capacity of the sorbents was systematically examined.The experiment was conducted with concentrations ranging from 10 mg/L to 200 mg/L at a pH of 5. For this, 30 mg of sorbent was measured, and the appropriate concentrations of the metal ion solution with pH 5 were added to flasks, which were then left for 24 hours. After this period, the optical densities of the resulting homogeneous solutions were recorded using a KFK-3 spectrophotometer. The results of the experiment are presented in the figure below (Figure 3).

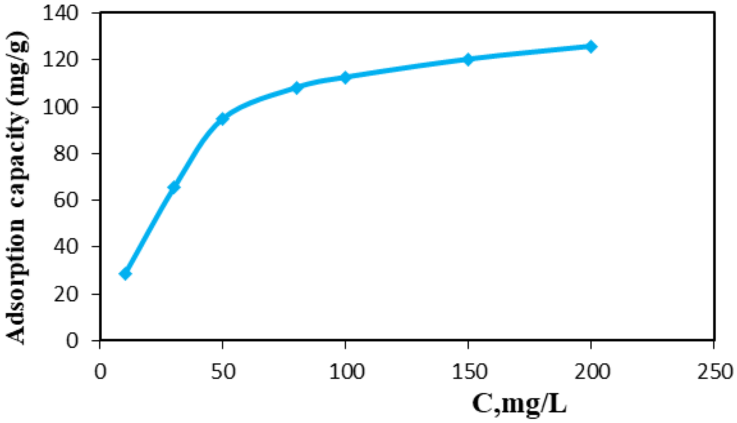

Figure 3. Effect of initial concentration on adsorption of Cu(II).

As the initial concentration of Cu(II) ions increases, the adsorption capacity (q_e) also increases. However, at higher concentrations (C_0 > 200 mg/L), the rate of increase slows down due to the saturation of active sites. The system reaches equilibrium as it approaches the maximum adsorption capacity ($q_{max} \approx 138$ mg/g). At lower concentrations (10–50 mg/L), the adsorption efficiency is 90–98%, while at higher concentrations (>200 mg/L), the effectiveness decreases. These results are consistent with the Langmuir model and help determine the optimal concentration range for the adsorbent application (50–150 mg/L).

Desorption process.

The desorption process was examined to assess the potential for reusability of the sorbent material. In this investigation, desorption was performed using various inorganic acid solutions, each at an equal concentration of 0.5 mol·L^{-1}, including HNO_3, HCl, H_2SO_4 and CH_3COOH. Among the tested eluents, the 0.5 mol·L^{-1} HCl solution demonstrated the highest efficiency in desorbing Cu(II) ions from the sorbent, indicating its superior desorption capacity.

Adsorption Kinetic Studies

The investigation of adsorption kinetics is essential for elucidating the rate at which adsorbate molecules interact with and adhere to the surface of adsorbent particles. This analysis provides critical insights into how various operational parameters influence the dynamics of the adsorption process. By employing appropriate kinetic models, researchers can not only characterize the temporal progression of adsorption but also deduce the underlying mechanisms governing the interaction between metal ions and the adsorbent material.

The kinetic data of Cu(II) ions were modeled using two distinct kinetic models: pseudo-first-order, pseudo-second-order models.

Pseudo-first-order model. The kinetic data of adsorption in this model are estimated using the pseudo-first-order equation (Lagergren equation). It helps to estimate the degree of adsorption by the adsorption capacity. The equation is as follows:

$$\ln(q_e - q_t) = lnq_e - k_1 t \qquad (3)$$

where q_e and q_t represent the adsorption capacities at equilibrium and at time t (min), respectively (mg·g⁻¹), while k_1 is the rate constant for pseudo-first-order adsorption (min⁻¹). A plot of $\ln(q_e–q_t)$ versus time t is constructed. The values of k_1 and q_e were determined from the slope and intercept of the $\ln(q_e–q_t)$ versus time t plot.

The graph showing the relationship between $\ln(q_e–q_t)$ and t is presented in Figure 4. A significant discrepancy between the experimental q_e and the calculated q_e (denoted as $q_{e(exp)}$) suggests that the pseudo-first-order kinetic model does not adequately describe the adsorption process of Cu(II) onto the magnetic adsorbent.

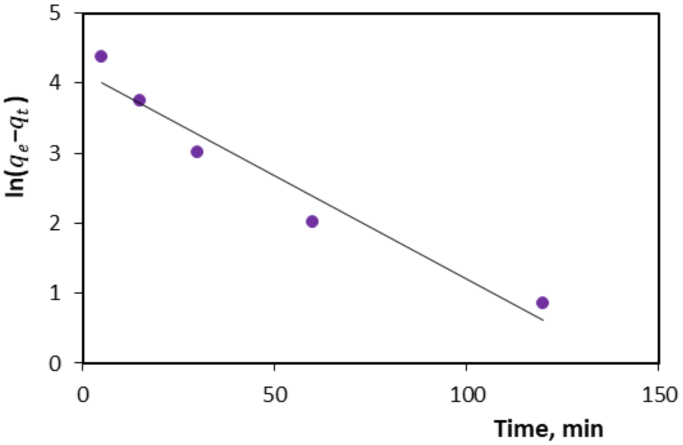

Figure 4. Pseudo-first order kinetics plot for the removal of Cu(II).

Pseudo-second-order model. The adsorption kinetics were also analyzed using the pseudo-second-order model, which is represented by the following equation:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \qquad (4)$$

where, k_2 - is the rate constant of the pseudo-second-order model (g·mg⁻¹·min⁻¹), and kq_e^2— represents the initial adsorption rate (mg·g⁻¹·min⁻¹).

The plot of t/q_t versus t is presented in Figure 5. The values of k_2 and q_e were obtained from the slope and intercept of this linear plot. The close agreement between the experimental $q_{e(exp)}$ and the calculated $q_{e(cal)}$ values indicates that the adsorption of Cu(II) ions onto the synthesized magnetic adsorbent follows the pseudo-second-order kinetic model.

A summary of the kinetic parameters is provided in Table 1.

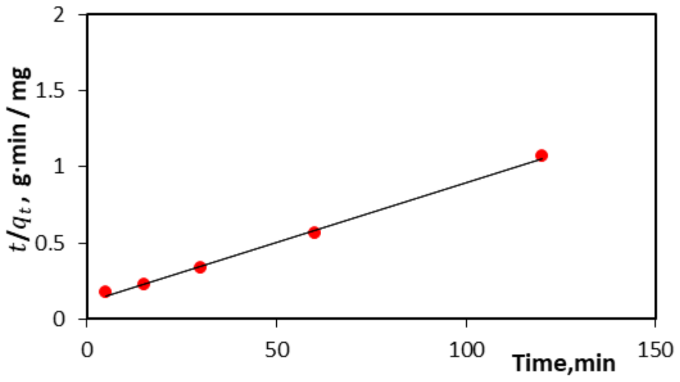

Figure 5. Pseudo-second-order kinetics plot for the removal of Cu(II).

Table 1. Adsorption kinetic parameters

Pseudo-first-order				Pseudo-second-order		
q_e, (exp), mg·g^{-1}	k_1, (min^{-1})	q_e (cal), mg·g^{-1}	(R^2)	k_2, (g·mg^{-1}·min^{-1})	q_e (cal), mg·g^{-1}	(R^2)
112,6	0.025	98,3	0.942	0,0018	115,2	0,998

Adsorption isotherms

Adsorption isotherms offer valuable insight into the equilibrium distribution of adsorbate molecules between the solid and liquid phases, revealing the degree and characteristics of their interaction at equilibrium. Evaluating experimental isotherm data through the application of various mathematical isotherm models is a fundamental approach to identify the most appropriate model for describing the adsorption system. This is particularly important for optimizing and designing adsorption processes at both laboratory and industrial scales [17, 18]. In this study, equilibrium adsorption data were analyzed using three widely recognized isotherm models: Langmuir, Freundlich, and Temkin.

Langmuir Isotherm model

The Langmuir adsorption model assumes that adsorption occurs through the formation of a monolayer of adsorbate molecules on a homogeneous surface of the adsorbent, with no further adsorption once the surface is fully covered. It further assumes that the energy of adsorption remains uniform across all sites and that there is no lateral movement of adsorbed molecules on the surface [19]. All adsorption sites are considered to have equal energy, and the strength of intermolecular interactions diminishes with increasing distance from the adsorbent surface [20]. The Langmuir equation is mathematically represented as follows:

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \qquad (5)$$

here q_m is the maximum adsorption capacity (mg·g^{-1}) and K_L is the Langmuir constant (L·mg^{-1}) The linear form of the Langmuir model is:

$$\frac{C_e}{q_e} = \frac{1}{q_m} C_e + \frac{1}{q_m K_L} \qquad (6)$$

The constants q_m and K_L are obtained from the slope and intercept of the linear plot of C_e/q_e versus C_e. A key feature of the Langmuir isotherm is the dimensionless constant known as the Separation Factor or Equilibrium Parameter (R_L), which is calculated using the following equation:

$$R_L = \frac{1}{(1+(K_L \times C_i))} \qquad (7)$$

Here, R_L represents the equilibrium parameter (dimensionless), and C_i is the initial adsorbate concentration (mg·L^{-1}). The value of R_L provides insight into the nature of the adsorption process: $R_L > 1$ indicates unfavorable adsorption, $R_L = 1$ suggests a linear adsorption isotherm, $R_L = 0$

corresponds to irreversible adsorption, and values of $0 < R_L < 1$ imply that the adsorption is favorable.

Freundlich isotherm model

The Freundlich isotherm model considers the heterogeneous nature of the adsorbent surface, assuming that the active sites possess varying energies and are exponentially distributed. This model is represented by the following equation:

$$\ln q_e = \ln K_F + \frac{1}{n}\ln C_e \qquad (8)$$

The constants K_F and n can be obtained from the intercept and slope of the linear plot of $\ln q_e$ versus $\ln C_e$, respectively. The constants KFK_FKF and nnn are determined from the intercept and slope, respectively, of the linear plot of lnqe\ln q_elnqe against lnCe\ln C_elnCe

The value of 1/n typically ranges between 0 and 1, reflecting the extent of nonlinearity between solute concentration and adsorption. When 1/n equals 1, the adsorption process is linear. A higher n value suggests a more homogeneous adsorbent surface, while lower n values indicate greater adsorption capacity at low solute concentrations. Moreover, a low n value points to the presence of a significant number of high-energy adsorption sites [21].

Temkin Isotherm model

The Temkin isotherm model includes a parameter that explicitly considers the interactions occurring between the adsorbent and the adsorbate. [22, 23]. This model is represented by the following equation:

$$q_e = BLn(K_T \cdot C_e) \qquad (9)$$

In this model, B = RT/b, where b represents the Temkin constant, K_T is the equilibrium binding constant ($L \cdot g^{-1}$), and B corresponds to the heat of adsorption ($J \cdot mol^{-1}$)[24]. The Temkin isotherm is typically expressed in its linearized form using the following equation:

$$q_e = B \ln K_T + B \ln C_e \qquad (10)$$

The values of constants B and K_T can be determined from the slope and intercept of the linear plot, where q_e is plotted on the ordinate and $\ln C_e$ on the abscissa.

Redlich–Peterson Isotherm model

This model integrates both the Langmuir and Freundlich isotherms, providing a comprehensive description of adsorption processes on homogeneous as well as heterogeneous surfaces. It is often employed to compare and evaluate the performance of these two isotherm models [25].The isotherm is represented by the following equation:

$$q_e = \frac{K_R C_e}{(1 + \alpha R C_e{}^{\beta})} \qquad (11)$$

The parameters of the Redlich–Peterson isotherm include: K_R, the Redlich–Peterson constant ($L \cdot g^{-1}$); α_R, another Redlich–Peterson constant ($L \cdot mg^{-1}$); and β, a dimensionless constant. The value of β typically ranges between 0 and 1. At low adsorbate concentrations, the model approximates Henry's law. When β approaches 1, the equation simplifies to the Langmuir isotherm, whereas at higher concentrations and lower β values (approaching zero), the model behavior becomes similar to that of the Freundlich isotherm.

Table 1. Constants and coefficients of adsorption isotherm models for the Cu^{2+}

Model	Parameter			
Langmuir isotherm	q_{max} (mg·g^{-1})	K_L (L·mg^{-1})		R^2
	138,9	0,042		0,998
Freundlich isotherm	K_F (mg^{1-n} ·L^n ·g^{-1})	n		R^2
	12,37	0,56		0,956
Temkin isotherm	B (kJ ·mol^{-1})	K_T (L·mg^{-1})		R^2
	87,4	1,24		0,923
Redlich-Patterson isotherm	K_{RP} (L·mg^{-1})	RPα (L·mg^{-1})	Rβ	R^2
	1,85	0,032	0,91	0,978

Table 1 presents the adsorption isotherm constants, which highlight the surface characteristics and adsorption affinity. The maximum adsorption capacity (q_{max}) and Langmuir constant (K_L) were obtained through nonlinear fitting, yielding an R^2 value of 0.998, indicating an excellent fit for the Langmuir model. This suggests a uniform distribution of adsorption sites, as assumed by the model. For Cu, the q_{max} was 138,9. While the Langmuir model provided a good description of the adsorption data, other models were also assessed. The Freundlich isotherm revealed that the concentration of metal ions on the adsorbent increased with solution concentration, with an R^2 of 0.956 for Cu, which was lower than the Langmuir model's fit. The Freundlich constant (K_F) was 12.37, and the power (n) fell within the optimal range of 0–10. The Temkin model, which accounts for the distribution of adsorption energy, showed that lower K_T values corresponded to weaker bonds between the adsorbate and adsorbent. The Redlich–Peterson model, which combines aspects of both the Langmuir and Freundlich models, yielded an R^2 of 0.978. Overall, the Langmuir isotherm provided the best fit for the adsorption data, supporting the idea of a uniform distribution of active sites and consistent adsorption energy.

Conclusion

The findings of the study clearly indicate that the magnetic cellulose/Fe_3O_4/SiO_2/4-aminoantipyrine composite is highly effective for the adsorption of Cu(II) ions from aqueous media. Key factors such as solution pH, contact duration, and initial metal ion concentration were found to significantly impact the adsorption efficiency. Among the various isotherm models applied to interpret the adsorption data, the Langmuir model exhibited the best correlation with the experimental results. The high correlation coefficient ($R^2 = 0.998$) of the Langmuir model confirmed its strong agreement with the experimental data. The maximum adsorption capacity for Ni was found to be 138,9. With its combination of high efficiency, easy separation, cost-effective regeneration, and environmental friendliness, this advanced adsorbent presents a sustainable solution for industrial wastewater treatment, particularly for heavy metal remediation.

Декларации

Рукопись не была представлена в какой-либо другой журнал или на конференцию.

Ограничения исследования

Ограничений, которые могли бы повлиять на результаты исследования, нет.

Подтверждение

Автор хотел бы выразить благодарность работникам службы поддержки и пожилым людям, которые приняли участие в этом исследовании, поделившись своими бесценными знаниями и опытом. Их сотрудничество и открытость в значительной степени способствовали глубине и богатству результатов исследований.

Источник финансирования

Нет.

Конфликт интересов

Авторы не сообщили о потенциальном конфликте интересов.

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SELLÜLOZA/FE_3O_4/SIO_2/4-AMINOANTIPIRIN ƏSASLI MAQNETIK ADSORBENTI ILƏ SULU MƏHLULDAN CU(II) IONLARININ ADSORBSIYASI

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XÜLASƏ

Bu tədqiqat selüloza/Fe_3O_4/SiO_2 nanokompozitinin 4-aminoantipirinlə modifikasiyası yolu ilə sintez edilmiş yeni maqnetik adsorbentdən istifadə edərək Cu(II) ionlarının adsorbsiyasına yönəlmişdir. Məhsulun adsorbsiya qabiliyyətinə pH, təmas müddəti və ilkin metal ionlarının konsentrasiyasının təsiri sistemli şəkildə araşdırılmışdır. Maksimum adsorbsiya səmərəliliyi pH 5-də müşahidə edilmişdir. Məhlulda Cu(II) ionlarının tarazlıq konsentrasiyası reagent kimi 1-fenil-2- [2-hidroksi-3-sulfo-5-nitrofenilazo] 1,3-butadion (R) istifadə etməklə müəyyən edilmişdir. Tədqiqat zamanı bir neçə kinetik model parametrləri qiymətləndirilmişdir. Tarazlıq məlumatlarının psevdo-ikinci dərəcəli modellə yaxşı uyğunlaşdığı aşkar edilmişdir ki, bu da bu modelin adsorbsiya prosesini effektiv şəkildə təsvir etdiyini göstərir. Adsorbsiya davranışını şərh etmək üçün müxtəlif izoterm modelləri, məsələn, Langmuir, Freundlich, Temkin və Redlich-Peterson tətbiq edilmişdir. Onların arasında Langmuir modeli tək qatlı adsorbsiyanı göstərən eksperimental məlumatlara ən yaxşı uyğunluğu təmin etdi. Cu^{2+} ionları üçün adsorbentin maksimum adsorbsiya qabiliyyəti 138,9 mq/q hesablanmışdır. Bu tədqiqat həmçinin desorbsiya təcrübələrini əhatə etdi və 0,5 mol•L^{-1} HCl məhlulunun Cu (II) ionlarının desorbsiyasında ən yüksək səmərəliliyi nümayiş etdirdiyini aşkar etdi.

Açar sözlər: adsorbsiya, Cu(II), izotermlər, nanokompozit, maksimum adsorbsiya qabiliyyəti

АДСОРБЦИЯ CU(II) ИЗ ВОДНОГО РАСТВОРА С ИСПОЛЬЗОВАНИЕМ МАГНИТНОГО АДСОРБЕНТА НА ОСНОВЕ ЦЕЛЛЮЛОЗЫ/FE_3O_4/SIO_2/4-АМИНОАНТИПИРИНА

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РЕЗЮМЕ

В этом исследовании основное внимание уделяется адсорбции ионов Cu(II) с использованием нового магнитного адсорбента, который был синтезирован путем модификации нанокомпозита целлюлоза/Fe_3O_4/SiO_2 с 4-аминоантипирином. Систематически исследовалось влияние pH, времени контакта и начальной концентрации ионов металла на адсорбционную способность продукта. Максимальная эффективность адсорбции наблюдалась при pH 5. Равновесные концентрации ионов Cu(II) в растворе устанавливались с использованием 1-фенил-2-[2-гидрокси-3-сульфо-5-нитрофенилазо] 1,3-бутадиона (R) в качестве реагента. Поглощение растворов измерялось на KFK-3 с l=1 см. В ходе исследования оценивались несколько параметров кинетических моделей. Было обнаружено, что данные о равновесии хорошо соответствуют модели псевдовторого порядка, что указывает на то, что эта модель эффективно описывает процесс адсорбции. Для интерпретации поведения адсорбции применялись различные изотермические модели, такие как Ленгмюра, Фрейндлиха, Темкина и Редлиха–Петерсона. Среди них модель Ленгмюра лучше всего соответствовала экспериментальным данным, указывая на монослойную адсорбцию. Максимальная адсорбционная емкость адсорбента для ионов Cu^{2+} была рассчитана как 138,9 мг/г. Настоящее исследование также включало эксперименты по десорбции, показывающие, что раствор HCl 0,5 моль•л-1 продемонстрировал наибольшую эффективность для десорбции ионов Cu (II).

Ключевые слова: адсорбция, Cu(II), изотермы, нанокомпозит, максимальная адсорбционная емкость

Publication history

Article received: 02.04.2025;
Article accepted: 15.04.2025
Article published online: 30.04.2025
DOI: https://doi.org/10.32010/FNNR1483