Journal of Advanced Scientific Research

Available online through https://sciensage.info

ISSN

0976-9595

Research Article

ADSORPTIVE REMOVAL OF TETRACYCLINE ANTIBIOTIC FROM AQUEOUS SOLUTION USING MAGNETIC NANOCOMPOSITES AS ADSORBENT

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Received: 23-09-2021; Revised: 17-02-2022; Accepted: 23-02-2022; Published: 31-03-2022

 https://doi.org/10.55218/JASR.202213207

ABSTRACT

The gradual increase of antibiotics in aquatic environments poses a serious threat to human health and ecosystems, and removal technology for antibiotics has attracted great interest in recent years. An adsorption method using an adsorbent MNC was designed for the rapid removal of tetracycline (TC) antibiotics from water. The results showed that TCs sorption on adsorbent was highly pH-dependent, and the optimal pH was found to be 4.5-5.6 for tetracycline (TC). The adsorption efficiency could reach 99.8%, suggesting that MNC is an excellent adsorbent for TC removal from water. The adsorption kinetics fitted the pseudo-second-order model perfectly. The adsorption isotherms study showed the maximum sorption capacity. The differences in the removal trends of the three TCs may be attributed to their different pKa values. Moreover, the thermodynamic parameters for the adsorption were estimated, and the $\Delta H°$ and $\Delta G°$ values indicated the endothermic and spontaneous nature of the sorption process.

Keywords: Tetracycline, Wastewater, Adsorbent, Adsorption, Drug.

1. INTRODUCTION

The disaster of freshwater in lots of growing international locations has been in addition irritated through pollution from chemical and organic species that have severe results on human health [1]. Pharmaceutical antibiotics, one of the maximum closely used lessons of medication in clinical remedy and the farming industry, have often been detected in soil, floor water, groundwater, and ingesting water. Most antibiotics cannot be completely absorbed and metabolized through human beings and animals [2-4]. Some of the antibiotics that are used excessively have low biodegradability and might probably cause a range of adverse effects as well as acute and chronic toxicity, disruption of aquatic photosynthetic organisms, impact on native microbic populations, and harm to antibiotic-resistant genes in microorganisms [5, 6]. The presence of low levels of antibiotics and their transformation products in the environment could provide conditions for the transfer and spread of antibiotic-resistant determinants among microorganisms, an emerging issue in public health. There is an increased interest in improving the removal efficiency of micro contaminants, such as antibiotics and other pharmaceuticals, in wastewater treatment plants. While existing treatment technologies produce water that satisfies current regulatory standards, it has been demonstrated that the removal of many emerging contaminants, including antibiotics, personal care products, and hormones, is incomplete. Because of the need to provide sustainable water supplies to meet the escalating water consumption associated with population growth and increased agriculture and industrialization, the ability to recover water from wastewater for reuse is critical. In this regard, it is crucial to understand the fate of currently unregulated chemicals introduced into the wastewater. Thus, the presence of antibiotic residues in water poses serious risks to humans and ecology and could be a major concern [7]. Antibiotics discharged from wastewater treatment plants to the environment have received increasing attention due to the propagation of antibiotic resistance in microorganisms.

Tetracycline (TC) is one of the most widely used antibiotics worldwide and is difficult to be metabolized in animals. Consequently, a large fraction of TC has been ending up in the wastewater system. Due to its inability to be treated in wastewater treatment plants, TC has been widely detected in soils, surface waters, groundwater, coastal environment, and even drinking water due to discharge into the environment. Tetracycline (TCs), a large cluster of broad-spectrum antibiotics, are of 3 varieties that supported the preparation techniques like natural, semi-synthetic, and synthetic TCs. The natural TCs like tetracycline, oxytetracycline, and chlortetracycline were obtained by fermentation of a particular form of microorganism (Streptomyces sp.), whereas the semi-synthetically produced TCs embrace demeclocycline, rolitetra-cycline, and methacycline, and the artificially prepared TCs are doxycycline and minocycline.

TC is poorly absorbed by humans and animals once ingested, regarding 50-80% eventually excreted as nonmetabolised parent compound into the domestic waste matter [8]. In recent years, TC has been reportedly found in surface water, and even groundwater [9, 10]. The presence of TC and alternative antibiotics in natural environments will cause the bacterium to accumulate and transmit antibiotic-resistant genes, which probably threatens ecosystem functions and human health [11, 12]. Therefore, it is of great importance to develop economical and cost-effective treatment technologies for the removal of TC from contaminated waters to reduce its ecological risks. Various techniques like ozonation [13], photo-Fenton method [14], electro photocatalytic degradation [15, 16], and adsorption [17-22] are used for the removal of tetracycline from water. Among these available strategies, adsorption could be a widely used effective technology for the treatment of low concentration antibiotics.

Removal of antibiotics by sorption is one of the cheap ways with small technical difficulties. Several adsorbents are widely used to take away tetracycline from waste matter like carbon nanotubes [23], graphene oxide [24], activated carbon [25, 26], zeolites [27-28], and metal oxides [29]. Magnetic nano composite could be a common adsorbent that's used to take away tetracycline from an aqueous solution. The uniform pore structure and high surface area make it a perfect sorbent. The cation exchange capability is comparatively high, which enhances the impact of surface modificatin on the adsorbent capacity of the sorbent [30, 31]. Iron oxides are widely spread in ecosystems, and iron-modified adsorbent is used for organic and heavy metal removal from wastewaters [32-35]. They show a high affinity to TC compounds due to the surface complexation method [36, 37]. Iron ion may form a bridge between the adsorbent and tetracycline molecule and enhance the adsorption [38-40]. The purpose of this work is to study the removal of tetracycline using MNC adsorbent. The adsorbent has been changed with trivalent iron. In this work, we chose TC as a common representative of antibiotics and heavy metals, respectively. The ultimate goal of the present study was to simultaneously remove TC from water. To achieve this objective, the influences of several operating parameters such as contact time, initial contaminant concentration, and pH on the removal of TC were investigated. Fourier transforms infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS) of adsorbent and after adsorption was also performed to identify the possible adsorption mechanisms. The improved performance of adsorbent in up taking TC and the adsorption and co adsorption mechanisms can provide more insights into complex pollution treatment in aquatic systems. The results of various operational parameters like hydrogen ion concentration, contact time, adsorbent dosage, etc. have been investigated.

2. EXPERIMENTAL

2.1. Target compound and chemicals

The adsorbent was purchased from Fuchen Chemical Reagent Factory (Tianjin, China). Potassium permanganate was obtained from the Economic & Technological Development Zone Fine Chemical Plant (Laiyang, China). Calcium chloride, hydrogen peroxide, sodium nitrate, hydrochloric acid (37%), and concentrated sulfuric acid were bought from Shanghai Sinopharm Chemical Reagent Co. Ltd. Millipore water (18 MΩ) was used in all the experiments. All chemicals were of reagent grade and used as received. The tetracycline (Molecular weight: 444.4, Molecular formula: $C_{22}H_{24}N_2O_8$) was purchased from Sigma-Aldrich, USA. The chemical structure of Tetracycline is presented in Fig. 1. The distilled water was used to prepare the stock solution of tetracycline. Other chemicals used in this study were prepared from Merck, Germany.

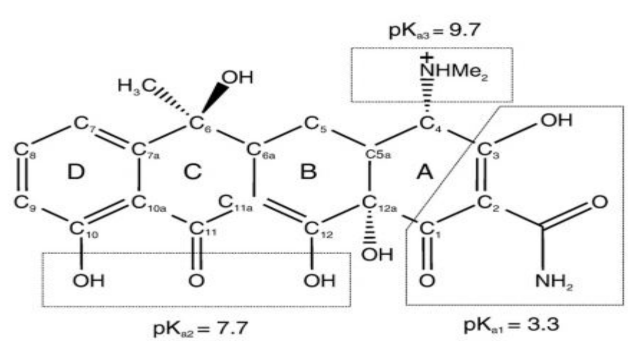

Fig. 1: Chemical structure of tetracycline

Table 1: Properties of tetracycline

Molecular Formula	$C_{22}H_{24}N_2O_8$
Synonyms	Tetracyclinum, Achromycin, Tetracyclin
Molecular Weight	444.4 g/mol
IUPAC name	2-Naphthacenecarboxamide, 4-(dimethylamino)-1,4,4a,5,5a,6,11,12a-octahydro-3,6,10,12,12a-pentahydroxy-6-methyl-1,11-dioxo-, [4S-(4a,4aa,5aa,6b,12aa)]-
Melting Point	170-173°C (with decomposition)
Specific Rotation	[a]25/D -239° (MeOH)
MERCK Number	9310
Solubility	231 mg/L (at 25°C)
pH	3.0-7.0

2.2. Apparatus

Adsorption measurements were recorded on a Systronics spectrophotometer 166 (India) over the wavelength range 325 to 990 nm. Measurements of pH of the solutions were carried out on a digital pH meter fitted with a glass electrode (DB 1011 India), which was previously standardized with buffers of known pH in acidic and alkaline medium. Sartorius CP224S analytical balance (Gottingen, Germany) and ultrasonic cleaner (Frontline FS 4, Mumbai, India) were used during the study.

2.3. Experimental Design

The impact of operational and method parameters, such as pH scale result, adsorbent dose, tetracycline drug concentration, temperature, pH scale, and contact time, was investigated on the surface assimilation of tetracycline drug. However, because a significant number of experiments and extensive data analysis are required, it's difficult to maintain an associate degree experimental style as well as of these elements. As a result, the most important factors were chosen. According to the findings, the parameters of drug concentration, pH, temperature, and adsorbent dose have the most significant impact on tetracycline drug adsorption rate.

2.4. Preparation of analytical solutions

The standard solution of the drug was prepared in an aqueous solution. The standard solution was utilized for the preparation of various solutions of the wanted concentration. Sodium hydroxide was used for essential dilutions. All reagents used in the present work were of analytical grade. Adsorbent UPR were obtained from M/s Naphtha Resins, Bangalore, India, and were used without any purification. In this experiment, the stock solution of TC was prepared by dissolving 100 mg of TC in 1L of water. Depending on the concentration of TC needed for the experiment, it was diluted. Batch studies were conducted to research the result of pH scale, initial TC concentration, temperature, and initial MNC dose on adsorption efficiency for TC. Temperature and pH scale were controlled using HCl and/or NaOH solution and from 10°C to 30°C using the electrical thermostat, severally, to result from adsorption of TC onto MNC.

2.5. Simple colorimetric method for tetracycline drug

The color formation when it was dissolved in alkaline environment is the basis for this procedure. A colored chromogen was generated when tetracycline drug was dissolved in aqueous solution at pH 10.1, and it gave the adsorption maximum at 700 nm. The commercially available F-C reagent was diluted with water in a ratio 1:1. Working concentration of drug solution was prepared by dilution of the above stock solution with 1.4 M Na_2CO_3 and F-C reagent (1:1). Pure TC solution equivalent to 0.55 mg mL^{-1} was mixed with 3 mL of 1.4 mol L^{-1} Na_2CO_3 and 2mL of F-C reagent (1:1) in a 50-mL volumetric flask. After 20 min, the volume was made up to the mark with water and the contents were mixed thoroughly. A blank solution was prepared in the same way in the absence of drug. The blank was measured against water.

2.6. Adsorption experiments

The adsorption experiments were conducted using the batch equilibration techniques during a temperature-controlled water bath shaker. For the adsorption equilibrium experiments, a fixed adsorbent dose (1 g/l) was weighed into 100 ml conical flasks containing 50 ml of different initial concentrations. The mixture was agitated for 1 h at 25°C until the equilibrium was obtained. The adsorbent was then separated from the solution by centrifugation at 10 000 revolutions per minute for 60 min. The concentration of tetracycline within the solution was measured using a UV-visible spectrophotometer (TU-1810, Bingjing Puxi Co. Ltd.) at a wavelength of 700 nm. The adsorption capability was calculated exploitation the following equation:

$$q_e = \{(C_0\text{-}C_e)/W\} \times V \quad (1)$$

Where C_0 and C_e are the initial and equilibrium concentrations of tetracycline (mgL^{-1}), respectively, m is the mass of the adsorbent (g), and V is the volume of the solution (L).

To study the impact of the pH scale of the tetracycline solution on the sorption capability, 10 mg adsorbent was placed in 20 milliliters of a 50 mg L^{-1} tetracycline solution, whose pH scale was adjusted from 6.5 to 12 with an acceptable quantity of HCl and NaOH. Moreover, once the impact of the adsorption dose was investigated, completely different amounts of adsorbent (0.16 to 1.5g/l) were added to 20 ml of a 50 mg L^{-1} solution. Furthermore, when the dynamic adsorption tests were conducted, 200 mg of the adsorbent was put into 400ml of a 50 mg L^{-1} tetracycline solution, and the concentration of tetracycline was measured at certain time intervals.

2.7. Isotherm studies

The experimental records from the batch experiment were analyzed victimisation two-parameter (Langmuir, Freundlich and Tempkin) models to determine whether the theoretical models fit the experimental information better or worse. In these models, linear regression analysis was used to determine whether the theoretical models fit the experimental information better or worse.

2.8. Quality assurance/quality control

In order to ensure the correctness, reliability, and reproducibility of the gathered data, all of the batch isotherm tests were reproduced thrice. Blanks were run in several tests, and corrections were made as needed. All of the glasswares used in the study were prepared by soaking for three days in a 5 percent HNO_3 solution before being rinsed twice with distilled, demonised water and oven dried.

3. RESULTS AND DISCUSSION

3.1. Characterization of adsorbents

Surface elemental compositions of the adsorbent were measured by an X-ray photoelectron spectroscopy (XPS) (Thermo Fisher Scientific, K-alpha 1063, UK). Scanning electron microscopy (SEM) was used to document surface morphologies with H-7500 (JEM-1230 HC, JPN). The crystal forms of the materials were measured with X-ray diffraction (Shimadzu X-ray JPN). The IR-spectrum of the products was carried with Perkin Elmer Spectrum 65 (USA). The adsorbent Magnetic Nano Composite was analyzed by Scanning electron microscope (SEM) as shown in Fig.2. SEM method is commonly used to find out the surface characteristics and morphological features of the developed materials. In the present study, SEM photograph of MNC reveals that developed compound have surface texture and porosity. The measured surface area of Magnetic Nano Composite adsorbent (MNC) was 740m^2/g.

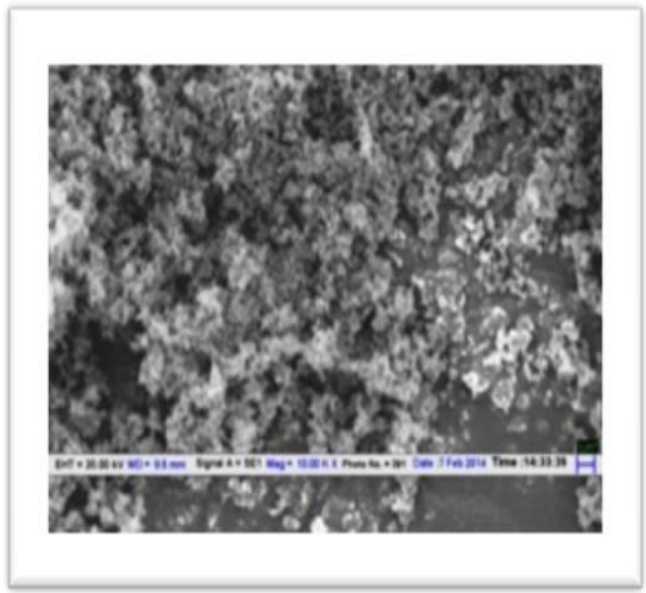

Fig. 2: Scanning Electron Microscope of MNC

3.2. Effect of adsorbent dosage

Logically, at an identical initial concentration of tetracycline, the rise within the amount of adsorbent can improve the removal potency. This can be as a result of a lot of adsorbents offer a lot of active sites for the adsorbate. Thus, we have a tendency to additionally examine the impact of the adsorption dose on the tetracycline adsorption efficiency. The optimum adsorbent dose resolves using varied amounts of MNC, from 0.16 to 1.5 g/l. totally different amounts of MNC were mixed with 0.4 mg/ml tetracycline solution and agitated at 25°C for 60 min to permit tetracycline to be sufficiently adsorbable. As shown in Fig. 4, the optimum dose of MNC was 1g/l, and also the removal efficiency might reach 90% once mixed with 0.4 mg/ml tetracycline resolution for 60 hours.

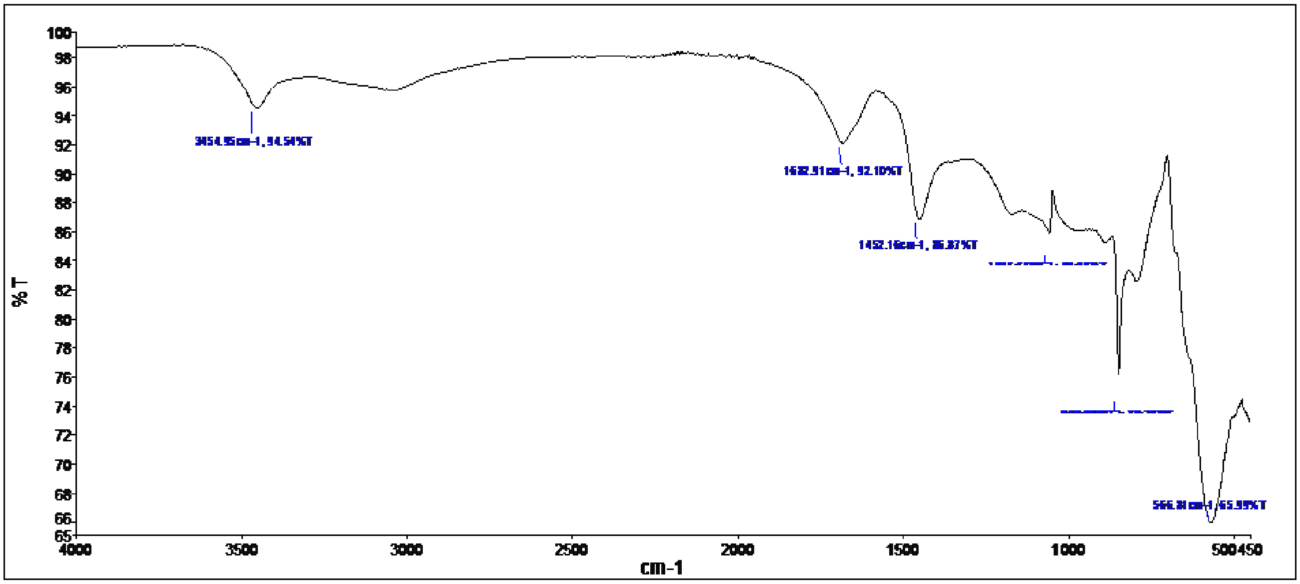

Fig. 3: X-Ray diffraction pattern of MNC

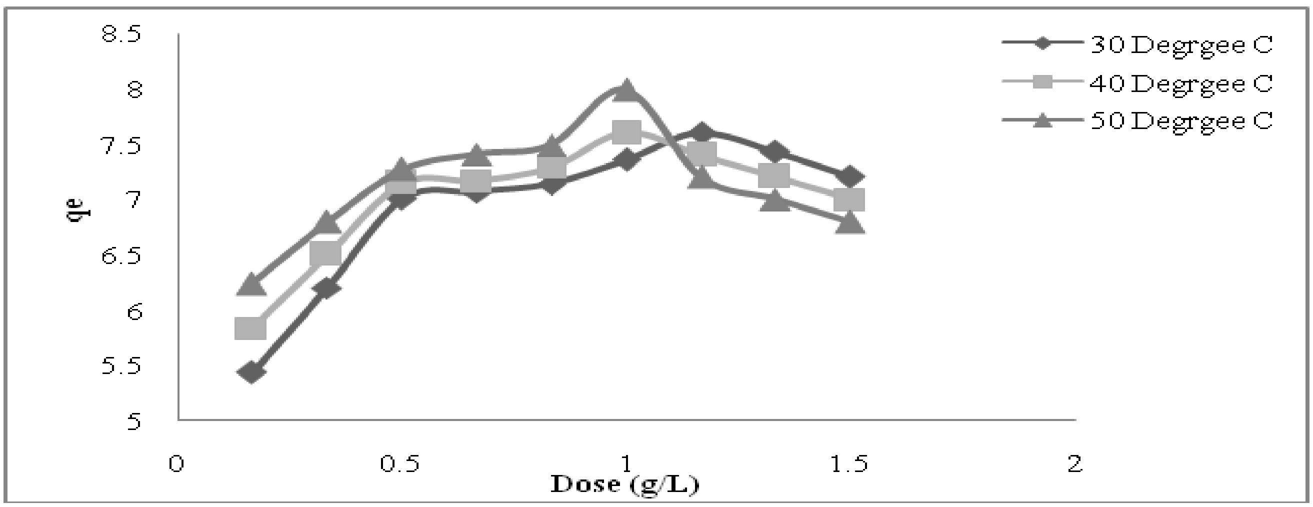

Fig. 4: Effect of amount of adsorbent for the removal of tetracycline by MNC-1g/L at pH 10.1 and different temperatures

3.3. Effect of initial concentration of tetracycline

Fig. 5 describes the effect of TC initial concentrations on the removal percentage by adsorbent MNC. The TC removal percentage via adsorbent MNC was found to decrease with an increase in initial concentrations. This may be due to the vacant sites are filled up and no further adsorption occurs due to saturation of vacant sites of adsorbent.

3.4. Effect of pH

The impact of pH on tetracycline absorption ability is determined by the tetracycline structure and the functional groups on the adsorbent composite surface. The results indicate that tetracycline removal is highly influenced by the pH of the solution. This is due to the fact that tetracycline charges considerably change with pH as shown in Fig.6 for pH below 3.3 the dimethylammonium group is protonated, which results in tetracycline in +ve form. Between pH 6.5 and 7.7, it is in the form of zwitter ion. Above pH 7.7, it is present as a monovalent anion, or a divalent anion. On the other hand, deprotonation and protonation reactions of iron hydroxide coated on zeolite change the surface charge of the modified zeolite. Deprotonation and protonation reactions of iron hydroxide coated on zeolite, on the other hand, alter the modified zeolite's surface charge. The surface charge is more favorable in acidic conditions and becomes negatively charged in alkaline conditions. This is in line with the pH of the modified adsorbent, which was estimated at 10.1. So, at acidic and alkaline conditions, electrostatic repulsion between tetracycline molecules and modified adsorbent decreases the adsorption capacity. It seems that the best efficiency of modified adsorbent for tetracycline removal is at pH 10.1.

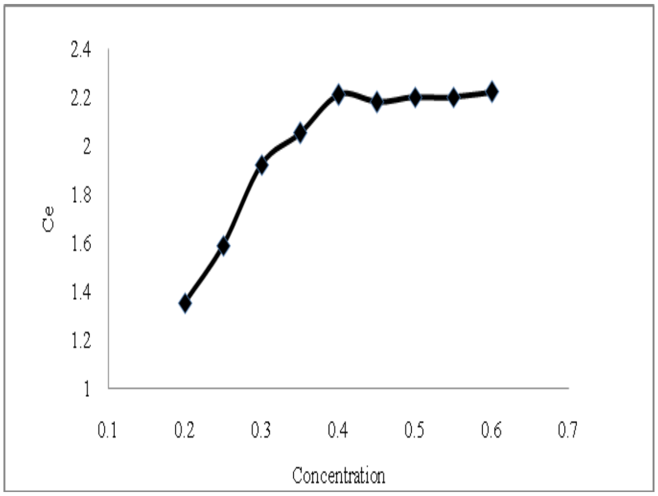

Fig. 5: Effect of concentration of the drug for the removal of tetracycline by MNC-1g/L at pH 10.1 and 30°C temperature

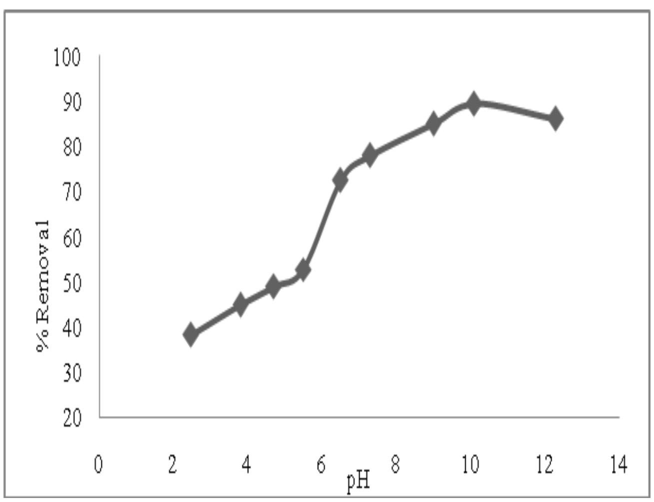

Fig. 6: Effect of pH for the Removal of tetracycline by MNC g/L at pH 10.1 and 30°C temperature

3.5. Effect of contact time

Fig. 7 represents the results of the adsorption uptake of tetracycline antibiotics for adsorbent versus contact time at different initial concentrations (0.2 to 0.6 mg/mL). The adsorption of tetracycline antibiotics was initially rapid, but it gradually slowed as equilibrium reached 60 minutes. Since the active sites were saturated early in the adsorption process, this result was obtained. Many adsorbent active sites are accessible, but as time passes, the adsorbent surface adsorption point is occupied, slowing the adsorption process. More than 60 minutes was determined to be adequate for tetracycline antibiotics to reach uptake equilibrium in subsequent experiments.

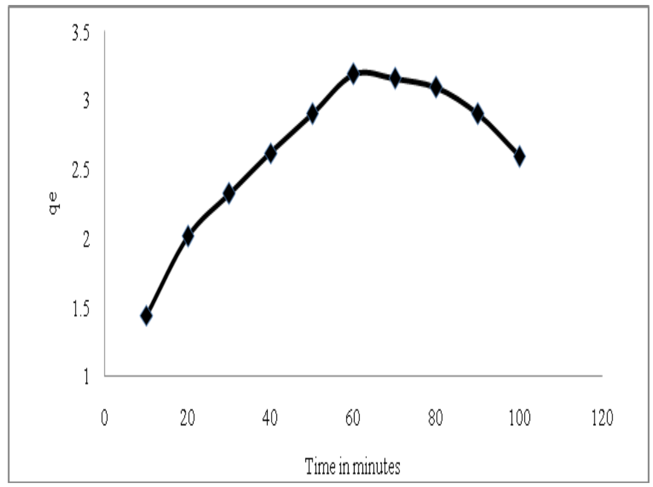

Fig. 7: Effect of time for the removal of tetracycline by MNC-1g/L at pH 10.1 and 30°C temperature.

3.6. Effect of Temperature

Temperature is also a significant factor in the removal method's major uses of the adsorbent. The sorption of methylene blue by UPR at various temperatures is depicted in Fig. 8.

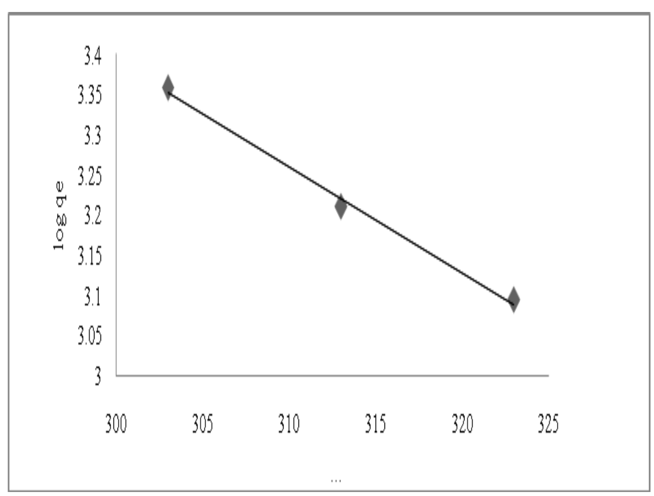

Fig. 8: Effect of temperature for the removal of tetracycline onto MNC-1g/L at pH 10.1 and different temperatures

Temperature has a positive effect on adsorption efficiency, implying that as the temperature of the system rises, the amount of removed decreases. This trend can be explained by the fact that the chemical interactions between the methylene blue and the adsorbent are endothermic in nature. The computations of thermodynamic parameters frequently show this as well.

3.7. Adsorption Isotherm Analysis

Adsorption isotherms, which are typically the ratio between the quantity adsorbed and that remained in solution at equilibrium at different temperatures, are used to characterize equilibrium studies that provide the potential of the adsorbent and adsorbate. The earliest and simplest known relationships explaining the adsorption equation are the Freundlich, Langmuir, and Temkin isotherms.

3.7.1. Langmuir Isotherm

The Langmuir isotherm is derived on the assumption of mono-layer adsorption on a homogenous surface. It is expressed by [41]:

$$\frac{Ce}{qe} = \frac{1}{qmKL} + \frac{Ce}{qm} \qquad (2)$$

Where Ce is the equilibrium concentration (mg/L), qe is the amount of TC adsorbed (mg/g), qm is qe for complete monolayer adsorption capacity (mg/g), and KL is the equilibrium adsorption constant (L/mg). The essential characteristic of a Langmuir isotherm can be expressed in terms of a dimensionless separation factor, RL [42]:

$$R_L = \frac{1}{1+KLCo} \qquad (3)$$

Where KL is the Langmuir constant and C_0 is the lowest initial TC concentration (mg/L).

Table 2: Langmuir constants for tetracycline over MNC

Temp.(°C)	b($molg^{-1}$)	Q°($Lmol^{-1}$)	bQ°	R^2	%RSD#
30	0.928	0.018	83.42	0.989	0.916
40	2.146	0.020	90.16	0.957	0.883
50	2.299	0.022	95.19	0.941	0.828

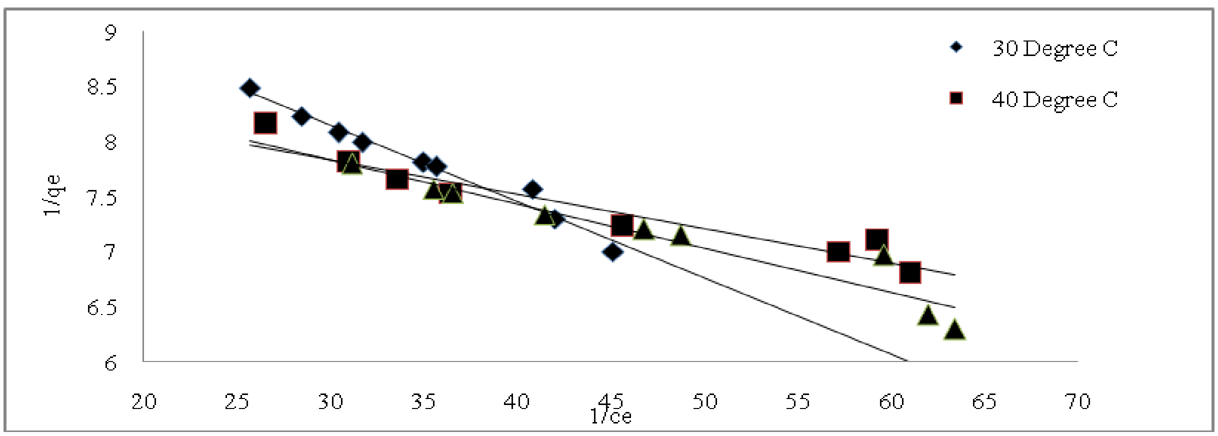

Fig. 9: Langmuir adsorption isotherms for adsorption of tetracycline over MNC at pH 10.1

3.7.2. Freundlich isotherm

For non-ideal adsorption on heterogeneous surfaces, the Freundlich isotherm is appropriate. The existence of various functional groups on the surface as well as many adsorbent-adsorbate interactions, contribute to the heterogeneity [43, 44]. The Freundlich isotherm is expressed by the empirical equation:

$$\text{Log } q_e = \frac{1}{n}\log C_e + \log K_F \qquad (4)$$

Where qe is the equilibrium TC concentration on the adsorbent ($mg\ g^{-1}$); Ce, the equilibrium TC concentration in solution ($mg\ L^{-1}$); and KF is the Freundlich constant.

3.7.3. Temkin isotherm

The Temkin equation suggests a linear decrease of sorption energy as the degree of completion of the sorption centers of an adsorbent is increased. The heat of adsorption of all the molecules in the layer would decrease linearly with coverage due to adsorbent interactions. The adsorption is characterized by a uniform distribution of binding energies. The Temkin isotherm has been generally applied in the following form [45, 46]:

$$q_e = RT/b \ln(AC_e) \qquad (5)$$

And it is linearised as:

$q_e = B \ln A + B \ln C_e$ (6)

Where B = RT/b, b is the Temkin constant related to heat of sorption (J/mol), A is the Temkin isotherm constant (L/g), R is the gas constant (8.314 J/(mol K)) and T is the absolute temperature (K).

Table 3: Freundlich constants for tetracycline over MNC

Temp.(°C)	K_f	N	R^2	%RSD#
30	1.336	0.840	0.985	0.810
40	1.559	1.261	0.975	0.909
50	1.4891	1.121	0.984	0.920

Table 4: Temkin constants for tetracycline over MNC

Temp.(°C)	B ($Jmol^{-1}$)	A (Lg^{-1})	B	R^2
30	2.548	4.516	8615.20	0.928

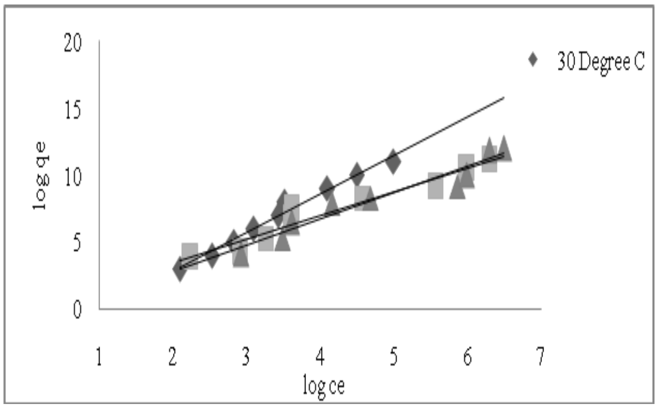

Fig. 10: Freundlich adsorption isotherms for adsorption of tetracycline over MNC at pH 10.1

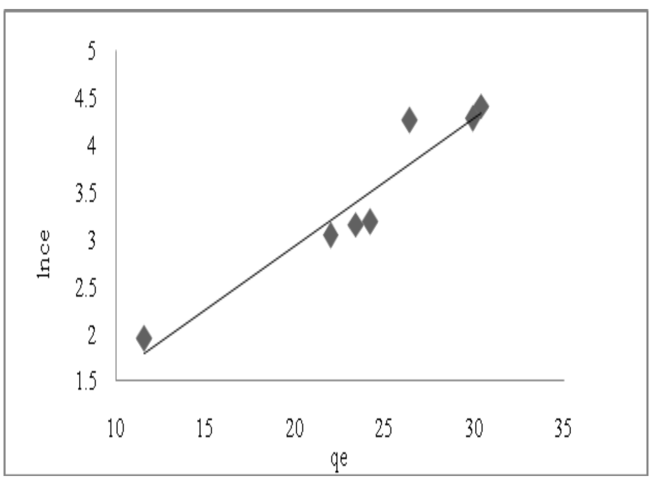

Fig. 11: Tempkin adsorption isotherms for adsorption of tetracycline over a MNC at 30°C

3.8. Adsorption thermodynamics

The effect of different temperatures was assessed for adsorption experiments. As shown in Table 6, with the increase of temperature, the adsorption rate of adsorbent MNC increased obviously but the temperature had a slight effect on the equilibrium adsorption capacity of adsorbent MNC. To better evaluate the effect of temperature, the thermodynamic parameters of enthalpy change (ΔH), Gibbs free energy (ΔG), and entropy change (ΔS) could be calculated according to the following equations

$\ln C_e = \Delta H/RT + K$ (7)

$\Delta G = -RT \ln K\alpha$ (8)

$K\alpha = 10^6 K_L$ (9)

$\Delta S = \Delta H - \Delta G / T$ (10)

In equations (7)-(10), R is the gas constant (8.314 J $mol^{-1} K^{-1}$); T (K) is thermodynamic temperature; Kα is the thermodynamic equilibrium constant and KL (L mg^{-1}) is Langmuir equilibrium constant. The slope of fitted curves contrasted with ΔH/R and the thermodynamics parameters were obtained in Table 6. As shown in Table 6, the ΔG values of all adsorbents were negative which illustrated the TC adsorption over MNC was spontaneous and thermodynamically favorable. Furthermore, with the increase of temperature, the values of ΔG decreased which confirmed that the adsorption process at higher temperature might promote TC adsorption onto adsorbents. The ΔH values of the adsorbent were 1, 2, 3, 4 kJ mol^{-1}, respectively. It could be due to the TC adsorption over adsorbent MNC was a physicochemical adsorption process. Moreover, the positive ΔH values implied TC adsorption was a typical endothermic process, which was consistent with adsorption thermodynamics experiments. The positive ΔS values demonstrated that increased randomness occurred at the solid-liquid interface. In a word, the adsorption process was an endothermic and spontaneous process.

3.9. Kinetic experiments

Different kinetic models were used to investigate the rate of tetracycline adsorption on the modified zeolite (Lagergren, pseudo-second-order, Elovich, and diffusion model). The effect of contact time on adsorption efficiency is shown in Fig. 12. The kinetics of adsorption was analyzed using first and second-order equations. The following is the pseudo-first-order rate equation:

$$\frac{dq}{dt} = k_1 (q_e - q) \quad (11)$$

Integrating Eq. (3) results in:

$$\frac{\ln qe - q}{qe} = -k_1 t \quad (12)$$

The pseudo-second order equation can be expressed as:

$$\frac{dq}{dt} = k_2 (q_e - q)^2 \quad (13)$$

Integrating Eq. (5) gives:

$$\frac{t}{q} = \frac{1}{k2qe2} + \frac{1}{qe} t \quad (14)$$

By plotting ln qe -q/ qe for the first order and t/q for second order versus t, the lines with slopes of $-k_1$ and 1/qe are obtained.

The overall rate of adsorption in a solid-liquid system could be described by three steps in series:(1) transport of adsorbent from the bulk of liquid to the solid surface; (2) diffusion of adsorbate from the surface through the pores of adsorbent; (3) adsorption on the vacant sites of the adsorbent.

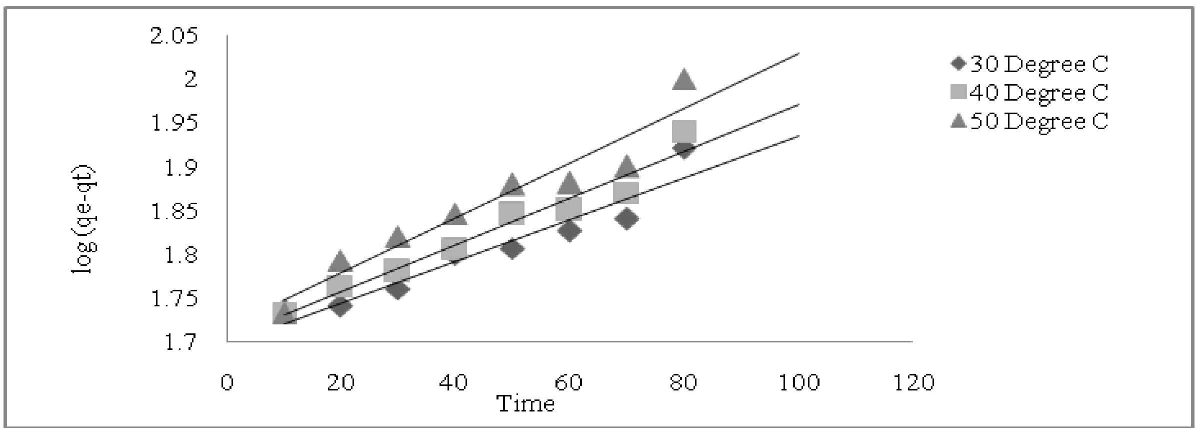

Fig. 12: Lagergren plots for adsorption of tetracycline of MNC at pH 10.1 at different temperatures.

Table 6: Thermodynamic parameters of tetracycline over MNC

Adsorbent	ΔG° (kJ mol^{-1})			ΔH° (kJ mol^{-1})	ΔS° (JK^{-1} mol^{-1})
	30°C	40°C	50°C	30°C	30°C
MNC	-20.52× 10^3	-32.32× 10^3	-35.31× 10^3	42.29× 10^2	52.15

Table 7: Rate constants k_{ad} for tetracycline over MNC

Temp.(°C)	k_{ad}	%RSD#
30	0.152	0.922
40	0.167	0.931
50	0.157	0.919

#average of three replicate measurements

4. CONCLUSION

The batch removal of TC from an aqueous solution was investigated using the adsorbent MNC. Temperature, initial TC concentration, adsorbent concentration, and contact time were all examined as factors in TC elimination. With a maximum adsorption capacity of tetracycline at room temperature, the Langmuir adsorption isotherms are found to provide the best match to the experimental results. The adsorption kinetics can be determined by pseudo-second-order kinetics. The results of the present investigation indicate that the MNC has the potential for use in removing TC antibiotics from aqueous solutions.

Conflict of interest

There is no conflict of interest.

Source of funding

There is no funding agency. All expenditure has been done by authors only.

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