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Using of modified-bentonite as low-cost sorbent for removal of methylene blue dye from aqueous solution

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Abstract— Batch experiments have been studied to remove methylene blue dye (MB) from aqueous solution using modified bentonite. The modified bentonite was synthesized by replacing exchangeable calcium cations in natural bentonite with cationic surfactant cetyl trimethyl ammonium bromide (CTAB). The characteristics of modified bentonite were studied using different analysis such as Scanning electronic microscopy (SEM), Fourier transform infrared spectrometry (FTIR) and surface area. Where SEM shows the natural bentonite has a porous structure, a rough and uneven appearance with scattered and different block structure sizes, while the modified bentonite surface morphology was smooth and supplemented by a limited number of holes. On other hand, (FTIR) analysis that proved NH group aliphatic and aromatic group of MB and silanol group are responsible for the sorption of contaminate. The organic matter peaks at 2848 and 2930 cm^{-1} in the spectra of modified bentonite which are sharper than those of the natural bentonite were assigned to the CH_2 scissor vibration band and the symmetrical CH_3 stretching absorption band, respectively, also the 2930 cm^{-1} peak is assigned to CH stretching band. The batch study was provided the maximum removal efficiency (99.99 % MB) with a sorption capacity of 129.87 mg/g at specified conditions (100 mg/L, 25°C, pH 11 and 250rpm). The sorption isotherm data fitted well with the Freundlich isotherm model. The kinetic studies were revealed that the sorption follows a pseudo-second-order kinetic model which indicates chemisorption between sorbent and sorbate molecules.

Keywords— methylene blue dye; organo-bentonite; sorption; isotherm; kinetic.

1. Introduction

There are many pollutant materials resulting from industrial activities that affect the integrity of the environment, for example, organics and non-organic pollutants, one of the main organic pollutants are dyes. Dyes, are commonly Used in several industries such as food, cosmetics, textiles, paint, clothing, plastics, etc. Dye wastewater was one of the most significant industrial wastewater problems [19]. Dyes can be divided into synthetic and natural, even further sorting the synthetic dye into three general categories: cationic (basic dyes) anionic (direct, acid and reactive dyes) and non-ionic (disperse dyes) [11]. Cationic dyes are extensively used in the coloration of silk, nylon, acrylic, leather and wool. Basic dyes, such as methylene blue dye (MB), with cationic properties from positively charged sulfur or nitrogen centers and the brightest class of soluble dyes with very high tectorial values; less than 1 ppm of the dye creates an evident coloration. Most of these chemicals, even at low concentrations, are probable and known human carcinogens and are of significant health concern It include a wide range of different chemical structures based primarily on the substituted aromatic groups [15]. Typical treatment methods for dye wastewater are coagulation / flocculation, adsorption and oxidation in conjunction with different biological treatment methods [2]. Combined adsorption, biodegradation (aerobic and anaerobic) and advanced oxidation also have been proposed for dye wastewater treatment [2]. The wastewater treatment technology is constantly undergoing renovations, such as biological, oxidation methods, etc. The major disadvantage of using oxidation methods is that it can create hazardous by-products in wastewater even from biodegradable dyes, that are not contributory to the thorough removal of pollutants [9]. Compared to other methods, the adsorption technique provides an feasible and economical technique for the dye wastewater treatment due to inexpensive adsorbents and effective process [10]. Activated carbon is widely used as an adsorption sorbent, however is limited in use due to its high cost. Therefore, the researchers sought to find alternatives. another such alternate is natural clay mineral surface modification (e.g. silica, bentonite, zeolite, sepiolite, montmorillonite, clinoptilolite, etc.). Through exchanging ions for inorganic metal cations on natural clay with a quaternary ammonium cation has long hydrocarbon chains, the natural clay which are naturally hydrophilic change to organophilic. Organically modified clays (organoclays) have a high capacity to sorb organic pollutants [15]. Based on the above, this study aims to modify the natural bentonite by trimethylammonium bromide (CTAB) and use it as an available and cheap material in the removal of MB from aqueous solution. Several experiments were performed to study the effect of many factors on the solution's removal efficiency such as adsorbent dosage, contact time, agitation speed, and initial pH. In addition, the adsorption isotherms and adsorption kinetics also achieved.

2. Materials and Methods

2.1 *Materials*

The bentonite used in this study was local Iraqi bentonite in natural form calcium type, with particles size of 0.354 mm. It has been provided by the State Company of Geological Survey and Mining (Baghdad). The characteristics of the bentonite are presented in **Table 1**. The cationic dye methylene blue dye (MB) [C.I. Basic Blue 9, C16H18N3SCl, M.W= 319.86 g. g.mol^{-1}, and λmax:665 nm] supplied by Thomas baker company (India) was used for this study without any further purification.

Table1: Characteristics of Iraqi Bentonite. (State Company of Geological Survey and Mining, Baghdad)

Characteristics	Value
Physical	Pass
Particle size, mm	0.35
Moisture content, %	4.57
Bulk density, kg/m^3	845
Specific surface area, m^2/g	63.5
CEC, meq/100g	65
Composition (wt%)	
Silica (SiO_2)	57
Aluminum (Al_2O_3)	13.5
Ferric oxide (Fe_2O_3)	4.5
Magnesium oxide (MgO)	2.35
Calcium oxide (CaO)	8
Sodium oxide (Na_2O)	0.7
Potassium oxide(K_2O)	0.4
Titanium oxide (TiO_2)	0.75
Loss on ignition (L.O.I)	12.8

The aqueous solution of dye was prepared by dissolving a specific amount of dye in distilled water in order to obtain a concentration of 1000 mg/L. The surfactant cetyl trimethyl ammonium bromide (CTAB) [C19H42Br, M.W.= 364.45 g.mol-1] supplied by Interchimiques SA company (France) used to modify bentonite from hydrophilic to organophilic nature. The deionized water was used in all experiment, also, for adjusting the pH different the 0.2 mol/L of NaOH and HCl was used.

2.2 *Preparation of CTAB-bentonite*

The organobentonite was prepared by adding 10 g of Ca-bentonite with 100 mL of distilled water in the beaker and stirred at 250 rpm for 2 hr to Swell and achieve homogeneity [13]. a different amount of modified surfactant (CTAB) then added (0.05, 0.1, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45 and 0.5g amine/1g natural bentonite) to determine the best ratio of “amine/bentonite” that gives the highest removal efficiency. The mixture was stirred for 2 hr, the resulting Organobentonite was filtered and washed with distilled water several times to remove excess salts and afterwards dried at 80 ° C in the oven. The product was crushed and sieved [14].

2.3 *Characterization of organobentonite*

The characteristics of the natural and modified bentonite were examined through several analyses as follows:

Scanning electron microscopy (SEM): The surface morphology of bentonite was tested by SEM (NOVASEM, FEL450L) analysis under 10 KV voltage and a 6-mA flux. This taste clarifies the changes in bentonite structural properties before and after CTAB modification.

Fourier transform infrared spectroscopy (FTIR): Study of FTIR enables spectrophotometric observation and provides means to identify functional groups on the sorbent surface. The spectrum analysis was carried out within the range 400–4000 cm^{-1} using Bruker Tensor 27 spectrophotometer with KBr pellet technique. It is achieved at the University of Baghdad, College of Science

Surface area: Surface area is an important factor in determining the active sites that will be occupied with the contaminants. Specific surface area was determined by surface area analyzer the BET method from the nitrogen adsorption at 77 K, using an automatic Micrometrics ASTM D 3663, USA. It performed at the Ministry of Oil (Institute of Oil Training and Development).

2.4 *Adsorption experiments*

The adsorption of methylene blue dye by modified bentonite was studied using batch experiments under different conditions, the removal experiments were carried out by adding the modified bentonite to 100 mL of synthetic solution of MB with initial concentration of 100 mg/L, then the mixture was shaken using thermostatic shaker (Type LSI-3016A, Korea). Batch tests were implemented with different contact time (0 - 180 min), initial pH of the solution (2 - 12), agitation speed (0 - 300 rpm), sorbent dosage (0.05 - 0.7 g/100mL). A fixed amount (25 mL) of the solution was taken from each flask, and filtered to separate the adsorbent from the aqueous solution using filter paper type (Wattmann No. 40), then the filtered solution was analyses using double beam UV-visible spectrophotometer (PG Instruments, Model UV T80, Japan) at λmax = 665 nm to determine the remain MB concentration. The amount of pollutant (MB) adsorbed on CTAB-bentonite, qe (mg/g), was calculated from the mass balance Eq.1 [18]:

$$q_e = \frac{(C_o - C_e)V}{m} \tag{1}$$

Where qe is the amount of MB adsorbed per unit adsorbent mass (mg/g), (L) is the volume of MB solution, C0 and Ce (mg/L) is the initial and equilibrium concentration of dyes, V and m (g) is the adsorbent mass. The removal efficiency (*R%*) of MB onto CTAB-bentonite at time t was calculated by:

$$R\% = \frac{(C_o - C_e)}{C_o} \times 100 \tag{2}$$

Table 2: summry of Batch experiments

Batch experiments				
Bentonite modification (0.05-0.5g CTAB/g NB)	Time effect (0-180 min)	PH effect (2-12)	Agitation speed effect (0-300 rpm)	dosage effect (0.05-0.7 g/100 mL)

3. Description of sorption data

Sorption isotherms are mathematical models that demonstrate the dissemination of the sorbate species between sorbent and liquid based on a set of presumptions mainly related to the homogeneity / heterogeneity of sorbents. The degree of coverage and the possibility of interaction among the sorbate species. These isotherms related to the absorption of pollutants per unit mass of sorbent, q_e, to the equilibrium concentration of sorbate in the bulk solution phase, C_e [7] [18] [21]. The sorption data for MB is fitted with isotherm models a linearized form of Langmuir and Freundlich as follows:

$$\frac{C_e}{q_e} = \frac{1}{q_{max}\, k_L} + \frac{1}{q_{max}} C_e \tag{3}$$

$$ln q_e = ln K_F + \frac{1}{n} ln C_e \tag{4}$$

where *qe* is the amount of MB adsorbed on the adsorbent (mg/g) at equilibrium, *qmax* is the maximum adsorption amount for the adsorbent (mg/g), *Ce* the equilibrium MB concentration in solution (mg/L). K_F (L/g) is the Freundlich sorption coefficient .While *KL* is the Langmuir adsorption constant (L/mg) and *n* is an empirical coefficient related to the intensity of the sorption[5].

3.1 *Sorption Kinetic Study*

Kinetic sorption models are helpful to understand the mechanism of the sorption process of MB onto CTAB-bentonite. These models include pseudo-first-order; pseudo-second-order as follows:

Pseudo-first-order rate equation: is quantified by [1]:

$$\left(\frac{dq_t}{dt}\right) = K_1(q_e - q_t) \tag{5}$$

Where q_e is the amount of contaminant sorbed at equilibrium (mg/g), K_1 is the rate constant of pseudo first order adsorption (min^{-1}), and q_t is the quantity of contaminant sorbed at time t (mg/g). Eq.5 is integrated for the boundary conditions t = 0 to t=t and q_t=0 to q_t=q_e and transferred it to linear form as shown in Eq.6:

$$log(q_e - q_t) = log q_e - (k_1/2.303)t \tag{6}$$

Pseudo-second-order rate equation: is based on adsorption equilibrium capacity can be expressed as :[17]

$$\left(\frac{dq_t}{d_t}\right) = K_2(q_e - q_t)(q_e - q_t)^2 \tag{7}$$

Where K_2 is the rate constant of pseudo second order adsorption (g mg^{-1} min^{-1}). Taking into account, the boundary conditions t=0 to t=t and q_t=0 to q_t=q_e . The integrated form of Eq.7 can be rearranged to obtain a linear form of this equation as shown in Eq.8:

$$\frac{t}{q_t} = \left(\frac{1}{k_2 {q_e}^2}\right) + \left(\frac{t}{q_e}\right) \tag{8}$$

4. Result and discussion

4.1 *Characterization of bentonite*

SEM analysis: The surface morphology and microstructure of natural bentonite before and after modification by CTAB were displayed using SEM analysis as shown in Figure (1). This figure showed significant changes in natural bentonite surface morphology after modification with CTAB [27]. Figure (1a), can be clearly seen that the natural bentonite has a porous structure, a rough and uneven appearance with scattered and different block structure sizes, while the modified bentonite surface morphology was smooth and supplemented by a limited number of holes as shown in the figure. (1b) [11].

FTIR analysis: The FTIR spectra of natural and modified bentonite before and after sorption of MB were shown in Figure (2). FTIR spectrum of natural bentonite showed characteristic smectite bentonite mineral peaks at 464, 530, 792, 1643, 2330, 3630, 3793 and 3907 cm^{-1}. The organic matter peaks at 2848 and 2930 cm^{-1} in the spectra of modified bentonite which are sharper than those of the natural bentonite were assigned to the CH_2 scissor vibration band and the symmetrical CH_3 stretching absorption band, respectively, also the 2930 cm^{-1} peak is assigned to CH stretching band. FTIR curve showed the groups CH_3, CH_2, and CH, indicating that the CTAB molecules were intercalated between the bentonite mineral layers, and the higher intensity of the characteristic of modified bentonite peaks compared with that in natural bentonite, indicate the organophilic nature of the modified bentonite. Results of the FTIR clearly indicated that CTAB has achieved surface modification of natural bentonite. By associating FTIR spectra of modified bentonite before and after MB sorption, further peaks at 3450 cm^{-1} indicate aliphatic and aromatic NH group of MB, 1384 cm^{-1} showed CH_3 group presence [4]. The shift in peaks from 3630 cm^{-1} to 3657 cm^{-1} indicates the adsorption of dyes on silanol group [16]. The peak at 1633 cm^{-1} is caused by vibrations of the C–N bond [16].

Surface area: As mentioned previously the analysis of the surface area is important in determining the active sites. The results showed that the surface area of the modified bentonite (43.31 m^2/g) was lower than natural bentonite (63.32 m^2/g) [11]. This is due to the surfactant CTAB covered the bentonite surface and organic molecules penetrated and overlapped this surface, the specifice surface area and pores volume decreased because of the channel between the layers have been blocked [25].

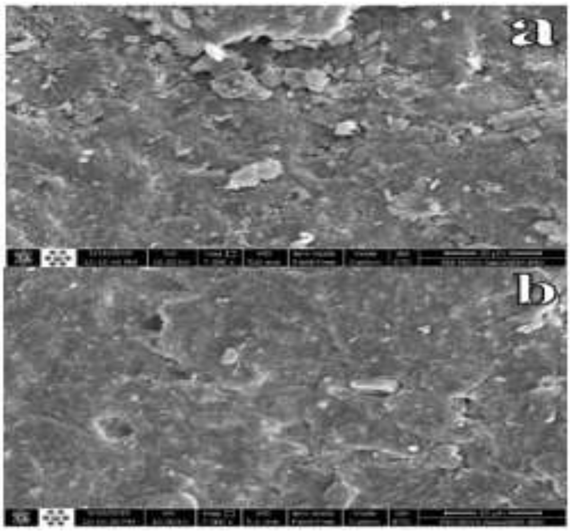


Figure 1: SEM images of (a) Natural bentonite and (b) CTAB-bentonite.

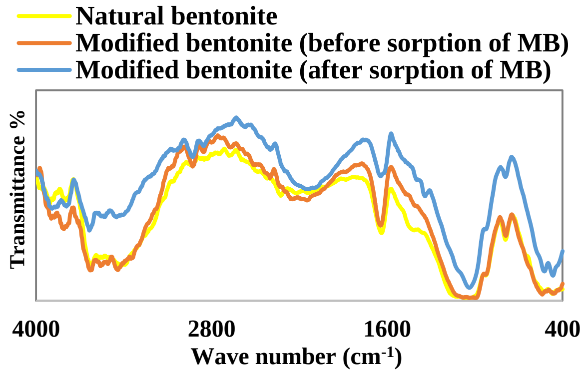


Figure 2: FTIR of natural bentonite and modified bentonite before and after sorption of MB

4.2 *Influence of batch operating parameters on the adsorption of MB*

4.2.1 modification Effect of bentonite surface

Batch experiments were conducted to investigate the impact of surface modification on MB removal efficiency. Modified bentonite was prepared by adding different ratios of surfactant (g CTAB / 1g of natural bentonite). Figure (3) showed the remove percentage of MB from aqueous solutions as an adsorbent function at different ratios of surfactant (CTAB) for specific conditions (Co=100 mg/L, time=180 min, pH=7, agitation speed=200 rpm, CTAB-bentonite dosage=0.2g) at 25 °C. The removal of MB was decreases with an increases the amount of surfactant (CTAB) which was because the cations of CTAB-bentonite and cations of MB generated electrostatic repulsion force [8]. The ratio (0.05 g CTAB /1g natural bentonite) showed the higher removal efficiency of MB, so it was chosen as the best ratio for modification of bentonite. However, the removal efficiency of MB using natural bentonite from aqueous solutions under the same above conditions was 45.6%. It was seen that the modified bentonite has 2.03-times adsorption capacity than natural bentonite for the removal of MB.This was due to the fact that the spacing of the bentonite layer increased after modification and Bentonite hydrophilic surface converted to hydrophobic to increase adsorptive properties [11]**[10].**

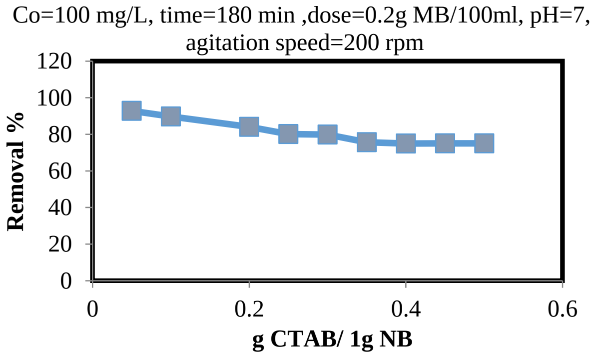


Figure 3: Effect of the ratio of CTAB/bentonite for the adsorption of MB.

4.2.2 Effect of equilibrium time

The equilibrium time should be determined to ensure achieving equilibrium concentrations. (4) shows the Contact time effect on removal of 100 mg / L MB using 0.1 g CTAB-bentonite added to 100 mL of contaminated batch testing solution. This figure shows that with an increase in contact time, the removal percentage of these pollutants increased significantly. At the initial stage, the sorption rate was rapid and progressively slowed down subsequently. The slower sorption rate was probably related to lower sites of sorption on the CTAB-bentonite surface. The kinetic data show that 75% of methylene blue was removed mainly at 120 min. After these equilibrium periods up to 180 min ,The residual concentrations have no changed significantly [22].

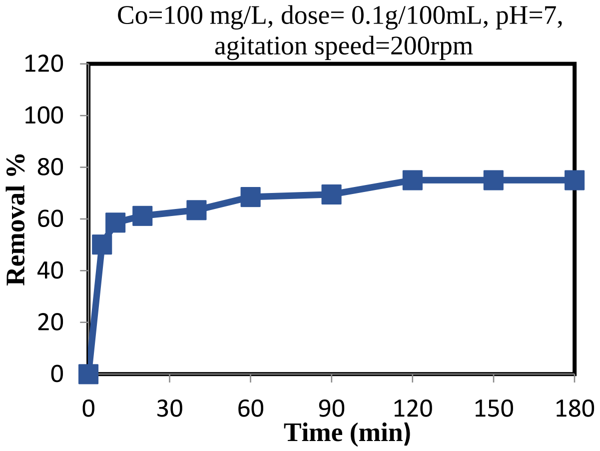


Figure 4: Removal efficiency of MB on CTAB-bentonite as a function of contact time.

4.2.3 Effect of initial pH of the Solution

The pH of aqueous solutions is a primary parameter that affects and regulates the sorption capacity of an aqueous solution ion sorbent due to its effect on the surface properties of the sorbent and the ionic forms of the contaminants in the solutions [6]. Figure (5) represents the effect of initial pH on the sorption of MB onto CTAB-bentonite under specific conditions (Co=100 mg/L, time=120 min, dose= 0.1g/100mL, agitation speed=200 rpm). The results showed that the removal percent for MB increased to reach the highest level (82%) with increasing of pH up to 11 and then decreased, this can be attributed to the electrostatic repulsion between the cationic dye species and the protonated adsorbent surface. While, after the modification of bentonite the surface of it becomes more positive [3]. The highest removal percent was occurred due to the electrostatic attraction between the negative surface of the adsorbent and cationic dye species [12].

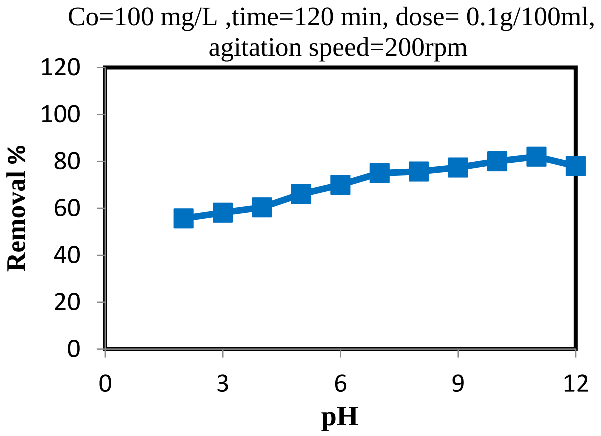


Figure 5: Removal efficiency of MB on CTAB-bentonite at different pH solution.

4.2.4 Effect of agitation Speed

The effect speed of agitation on the percentage of MB removal studied by changing the agitation speed from (0 to 250) rpm and maintaining all parameters equal to the best obtained in the previous steps.

Figure (6) Shows that about 48.35 % of MB was absorbed Before agitation. It was noted that "the removal efficiency of dyes increased continuously when the agitation speeds increased. Furthermore, there was an improvement in MB uptake when shaking speed rise from zero to 250 rpm, at which approximately 85% of MB was removed. This is due to the fact that the increase in agitation rate enhances diffusion of contaminant to the surface reactive media. Thus, Proper contact is established between the sorbate solution and the attaching sites, promoting the efficient transfer of sorbate to the sites of sorbents [5][23]**.**

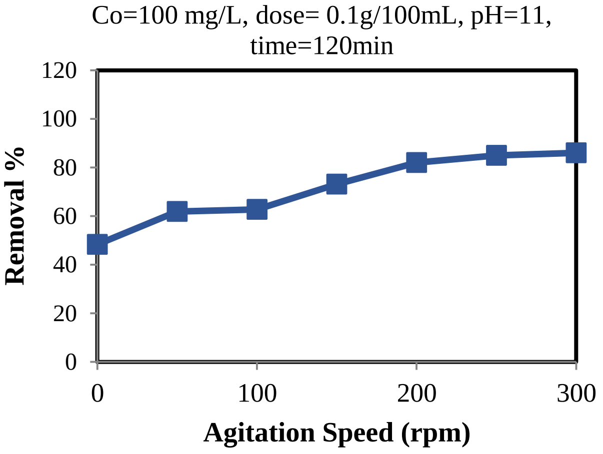


Figure 6: Effect of agitation speed on percentage removal of MB

4.2.5 Effect of CTAB-bentonite dose

The effect of CTAB-bentonite dose on the sorption process of MB was studied using various amounts of CTAB-bentonite range (0.05 to 0.7 g) which were added to 100mL of contaminated solution at 25 °C for batch tests with keeping other parameters as follows; C_o=100 mg/L, pH=11, agitation speed=250 rpm, and t= 120 min. Figure (7) presents MB removal percent as a function of various amounts of CTAB-bentonite. Obviously, this percentage improved with increased sorbent dosage up to 0.3 g and remains approximately constant. This was anticipated because the solution's higher dose of sorbent, the greater abundance of sorption sites. Also, this indicated that the optimal sorption is set in after a certain dose of sorbent and therefore the quantity of MB bound to the sorbent and the quantity of this contaminant remains constant in solution, even with the addition of the sorbent dose [24].

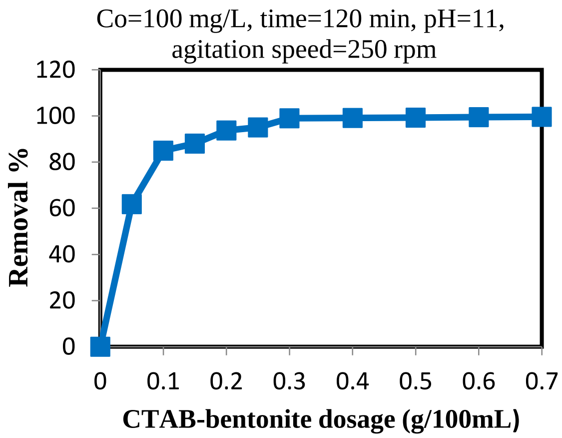


Figure 7: Effect of CTAB-bentonite dosage on removal efficiencies of MB

4.3 *Sorption Isotherms*

The experimental data were fitted with the Langmuir and the Freundlich models. Accordingly, the empirical coefficients for each model were determined from the slope and intercept of the linear plot using Microsoft Excel 2003 software as shown in Fig.8 and Table 3. Obviously that the Freundlich model provided the best coefficient of determination (R^2) compared to Langmuir model. Therefore, the Freundlich model was more appropriate for the representation of sorption data of MB onto CTAB-bentonite.

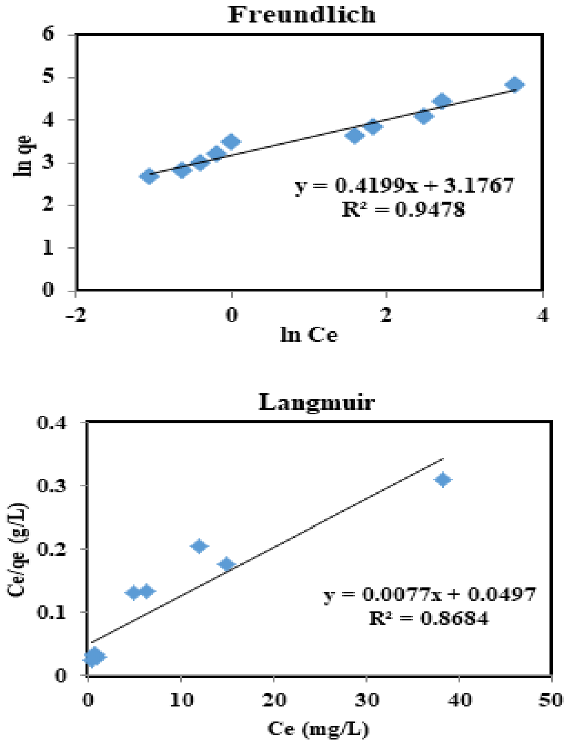


Figure 8: Linear form of isotherm models for sorption of MB onto CTAB-bentonite (Co=100 mg/L, dose=0.3g/100 ml, pH=11, agitation speed=250 rpm, contact time=2 h).

Table 3: Sorption isotherm constants with coefficients of determination for MB onto CTAB-bentonite.

Model	Parameters	M.B
Langmuir	q_{max} (mg/g)	129.87
	KL (l/mg)	0.155
	R^2	0.868
Freundlich	K_F (mg/g) $(l/mg)^{1/n}$	23.968
	n	2.382
	R^2	0.9478

In order to check the validity of the isotherm models, it is interesting and essential to recalculate the sorbet amounts using the equilibrium concentration values and two isotherm models parameters Figure (9). However, the Fitness between the predicted and experimental values was best for Freundlich in comparison with the Langmuir model. It is clear that the Freundlich isotherm model provided the best coefficient of determination compared to Langmuir model [14].

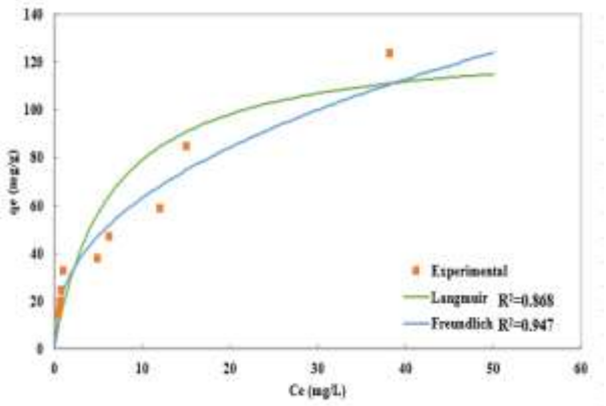
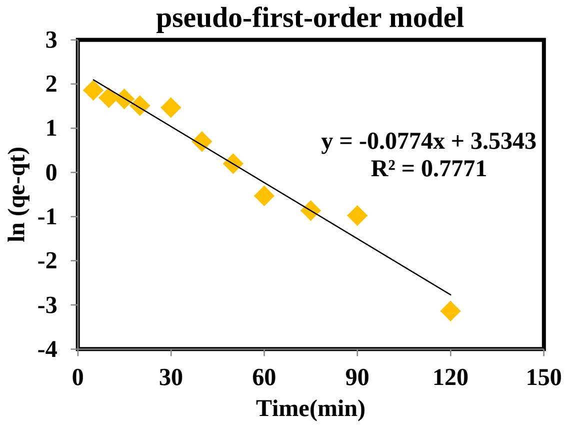


Figure 9: Comparison of the experimental results with the qe values obtained model for MB sorbed by CTAB-bentonite.

4.4 *Adsorption kinetics*

Adsorption kinetics is of vital importance when developing and accessing adsorbents to remove adsorbents from the aqueous solution. [26]. The pseudo first and second pseudo order models were employed to correlate the kinetics data. Plotting in (qe-qt) and t/qt versus t for the linear plot of the first and second pseudo order models as illustrated in Figure (10), a straight line is obtained and the constants of these models can be calculated according to the slop and the intercept.

The values of the constants of kinetic models with the coefficients of determination were listed in Table (4). Obviously that the reaction for CTAB-bentonite is being second-order because the value of the experimental qe is the closest to the calculated qe by the pseudo-second-order model compared to calculated by the pseudo-first-order model. Moreover, the coefficients of determination (R2) value for the pseudo-second-order was higher than that of the pseudo-first order model. So, the mechanism that governs this reaction will be chemisorption.



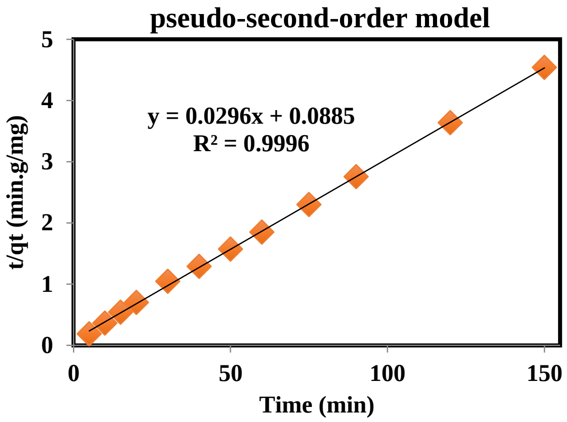


Figure 10: The kinetic models linear plot of sorption of MB onto CTAB-bentonite

Table 4: Kinetic models parameters with coefficients of determination

Model	Parameter	M.B
Pseudo-first-order	$k_1(min^{-1})$	0.0771
	q_e(experimental)(mg/g)	33.046
	q_e(calculated)(mg/g)	34.271
	R^2	0.7771
Pseudo-second-order	k_2(g/mg min)	0.0099
	q_e(experimental)(mg/g)	33.046
	q_e(calculated)(mg/g)	33.783
	R^2	0.999

5. Conclusions

CTAB-bentonite has been synthesized by replacing exchangeable calcium cations in natural-bentonite with cationic surfactant (CTAB). The characterization analysis of bentonite before and after modification proved that the CTAB created some improvement to the Bentonite surface properties and structure and convert it from hydrophilic to hydrophobic or organophilic. The experiments have shown that:

1. CTAB-bentonite was found to be effective for removing MB from aqueous solution with maximum sorption capacity of 129.87 mg/g.

2. The removal percent of MB was dependent on specific conditions such as contact time, initial pH of

the solution, agitation Speed, and CTAB-bentonite dose. The values of these conditions that provide the highest removal percent (99%) were 120 min, pH 11, 250rpm, and 0.3g/100mL, respectively.

3. The isotherm study refers that the sorption data correlated well with Freundlich in comparison with the Langmuir isotherm model.

4. The kinetic data showed that the pseudo-second-order was conformed better than pseudo-first-order confirming that that chemisorption has been predominant.

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NOMENCLATURE

MB = methylene blue

CTAB = cetyltrimethyl ammonium bromide.

SEM = Scanning electron microscopy.

FTIR = Fourier transform infrared spectroscopy.

C0 = the initial concentration of dye (mg/L).

Ce = the equilibrium concentration of,dye, (mg/L).

m = the adsorbent mass, (g).

V = the,volume,of dye,solution, (L).

qmax = the maximum adsorption amount for the adsorbent, (mg/g).

qe = the amount of dye adsorbed on the adsorbent (mg/g) at equilibrium.

qt = the quantity of contaminant sorbed at time = t (mg/g).

KF = the Freundlich sorption coefficient, (L/g).

KL = the Langmuir adsorption constant, (L/mg).

K_1 = the rate constant of pseudo first order adsorption (min-1)

K2 = the rate constant of pseudo second order adsorption, (g/mg.min)

n = an empirical coefficient related to the intensity of the sorption.

R2 = determination coefficient

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استخدام البنتونيت المعدل كمادة قليله التكلفة لإزالة الصبغة الزرقاء من الميثيلين من محلول مائي

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الخلاصة – تمت دراسة اختبارات الدُفعة لإزالة صبغة الميثيلين الزرقاء من المحلول المائي باستخدام البنتونيت المعدل. تم تصنيع البنتونيت المعدل عن طريق استبدال كاتيونات الكالسيوم القابلة للتبديل في البنتونيت الطبيعي مع منشط السطح بروميد الأمونيوم سيتيل ثلاثي ميثيل الكاتيوني (CTAB). تمت دراسة خصائص البنتونيت المعدلة باستخدام تحليلات مختلفة مثل المسح المجهري الإلكتروني(SEM) وقياس الطيف بالأشعة تحت الحمراء (FTIR) والمساحة السطحية. وتم الحصول على نتائج الدراسة بكفاءة إزالة (99.99٪) مع قدرة امتصاص تبلغ 129.87 ملغم / غم في ظروف محددة (100 ملغم / لتر ، 25 درجة مئوية ، درجة الحموضة 11 و 250 دورة في الدقيقة). البيانات isotherm للامتزاز تنطبق بشكل جيد مع نموذج Freundlich isotherm وقد كشفت الدراسات الحركية kinetic studies أن الامتصاص يتبع نموذجًا حركيًا من الدرجة الثانية pseudo-second-order kinetic model دلالة على الامتصاص الكيميائي بين جزيئات المادة المازة وملوث.

الكلمات الرئيسية – صبغة الميثيلين الزرقاء,. البنتونيت العضوي,. الامتصاص,. الأيسوثرم. حركي