

Biosorption of Anionic and Cationic Dyes from their Aqueous Solutions Using Iraqi Sawdust

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Abstract— The ability of Iraqi sawdust (SD) to remove Bromothymol Blue (anionic) and Malachite Green Oxalate (cationic) dyes from their aqueous solutions were investigated by Batch adsorption technique. The adsorbent (SD) was characterized by using SEM, FTIR and UV-VIS. Spectrometry instruments. The pHs of the solutions have a strong effect on the adsorption capacity of both dyes. The suitable pH for decolorization of BTB and MGO was 3 and 5, respectively. The adsorption isotherm studies show that BTB dye has high adsorption capacity through Freundlich isotherm, meanwhile Langmuir isotherm was more suitable for MGO dye. The thermodynamic parameters (ΔH , ΔS and ΔG) indicate that the type of adsorption of BTB dye on SD surfaces is physisorption but for MGO dye is chemisorption. The adsorption process in both dyes are endothermic, spontaneous and increased randomly.

Keywords— Biosorption, Bromothymol Blue, Dyes, Malachite Green Oxalate, Iraqi Sawdust.

I. INTRODUCTION

Dyes are synthetic aromatic organic compounds which have various applications as colorants for dyeing and printing in different industries. Throw dyes in the environment is a matter of concern for both toxicological and aesthetic reasons because these dyes damages the quality of receiving streams and is toxic to food chain organisms [1]. Bromothymol blue (BTB, $\lambda_{max}=591\text{nm}$) dye is a pH indicator is used in physiological tissue to follow the interaction of lipid with protein and in biomedical, biological and chemical engineering applications [2]. Malachite green oxalate (MGO, $\lambda_{max}=621\text{nm}$) dye has been found widely used in the fish farming industry as a fungicide, ectoparasiticide and disinfectant, also it was used for coloring leather and silk, distilleries, and it is very hazardous and severe carcinogenic to mammalian cells and accelerates the generation of tumor in liver [3,4]. The structure of both dyes is shown in Figure (1). Color removal from industrial wastewater by adsorption techniques has been increasingly important because of the chemical and biological stability of dyes to conventional water treatment methods and increased need for high quality treatment [5]. The adsorption is an equilibrium phenomenon including the adsorbent being in contact with the bulk phase and the so-called interface layer.

This layer consists of two zones: the part of gas in the force field of the solid surface and the surface layer of the solid. The term 'adsorption' deals with the process in which molecules collects in the interfacial layer, but desorption indicate the converse process [6]. The word adsorbate refers to the substance that was adsorbed and adsorbent refers to the surface that adsorbs.

The aim of this study is to examine the efficiency of natural Iraqi sawdust (SD) for biosorption of BTB and MGO dyes from their aqueous solutions. The effect of various parameters such as initial dye concentration, contact time, dose of adsorbent, pH and temperature were then evaluated and correlated to the amounts of equilibrium adsorption obtained.

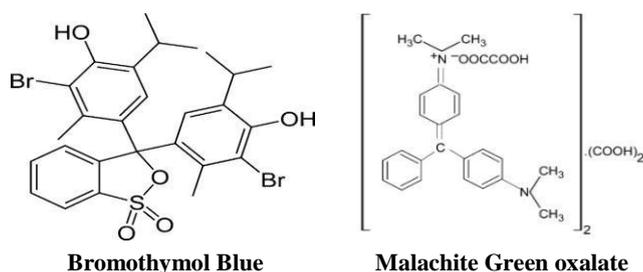


Figure 1. The chemical structures of dyes.

II. EXPERIMENTAL

A. Preparation of Sawdust

Sawdust was obtained from Iraqi Carpentry Factories, washed several times with normal tap water followed by distilled water to remove adhered dust particles. The cleaned material was kept in an oven for 24 hours at 110°C [7]. The dried mass was then crushed and sieved. The size of the particles was equal to or less than $75\ \mu\text{m}$, then it was used in the adsorption experiments without any further modification.

B. Characterization of Sawdust

The Morphology of Sawdust obtained was investigated via Scanning Electron Microscope (SEM) (Inspect S 50 FEI Company) instrument. The organic functional groups present in the sawdust were determined using Fourier transform Infrared Spectroscopy (FTIR) (Shimadzu IR Prestige 21). Atomic Force Microscope device (AFM) (SPM-AA 3000, advanced Angstrom Inc.) was used to measure nano average particle size of the adsorbent.

C. Characteristics and Analysis of Dyes

Malachite green-oxalate (MGO) and bromothymol blue (BTB) were supplied from Sigma Aldrich and used as received without further purification. UV-Visible spectrophotometer (Shimadzu.PC 1650 Double beam) was used to measure the concentration of both dyes before and after adsorption at specific wavelength of them.

D. Batch Adsorption Studies of Dyes

Batch adsorption of MGO and BTB dyes on sawdust adsorbent was studied using thermostated shaker at various temperatures in the range (298-318K). The effect of various parameters like the pH, contact time, initial dye Malachite green oxalate (MGO) and Bromothymol blue (BTB) dyes were evaluated. For each experimental run, 30 ml of either MGO or BTB solutions at specified optimum concentration and pH were mixed completely with adsorbent over a fixed time. The working solutions were prepared daily and their pH was adjusted by addition of 0.1M HCL and/or NaOH solutions. The concentrations of MGO and BTB dyes were measured at 621nm and 591nm, respectively by using UV-Vis. Spectrophotometer and the following relation was used for calculation of dyes removal (%):

$$\% \text{ Dyes removal} = ((C_o - C_t) / C_o) \times 100$$

Where C_o and C_t (mg.L^{-1}) are the initial dye concentration and concentration at time t , respectively. The equilibrium adsorption capacity of MGO and BTB was calculated according to the following equation [8]:

$$Q_e = (C_o - C_e) V / W$$

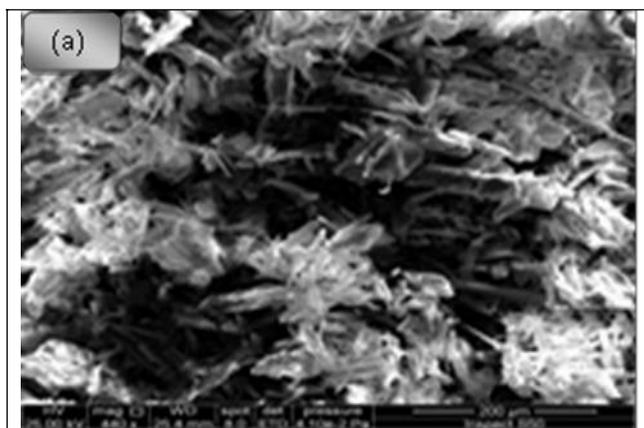
Where Q_e (mg.g^{-1}) is the equilibrium adsorption capacity, C_e is the dye concentration at equilibrium, V (L) is the volume of solution and W (gm) is the weight of adsorbent.

The effect of contact time, amount of sawdust and the pH of the dyes solutions were evaluated. A stock solution of malachite green-oxalate (MGO) (150 mg.L^{-1}) and bromothymol blue (BTB) (50 mg.L^{-1}) dyes were prepared by dissolving respectively, 0.15 gm of MGO dye and 0.05 gm of BTB dye in 1000 ml bidistilled water. After that, a subsequent dilution was applied for a working solution. The pH measurements were done using pH-meter (model BP3001 JiTrans) instrument.

III. RESULTS AND DISCUSSIONS

A. Characterization of Sawdust.

Figure (2) represents the SEM image of sawdust before and after adsorption of dyes that showed a complete change in surface morphology. Before adsorption, it is shown that the sawdust surface is coarse and very crispy (Figure (2a)). While after adsorption of both BTB and MGO dyes, the surface of sawdust seems smother (Figures (2b) and (2c)). Sawdust is a heterogeneous material consisting of particles of irregular shapes having considerable layers with pores of varying size and provides a fair possibility for the dye to be adsorbed. On the other hand, Sawdust is basically composed of cellulose as well as lignin, and all these components contribute as active sites for the adsorption of dye molecules. The chemical components of raw sawdust in the absence and presence of BTB and MGO dyes are presented in Table (1). Figures (3), (4) and (5) shows the FT-IR spectra of sawdust in its natural form and dyes loaded forms. Figure (3) shows several peaks referring to the presence of various functional groups that suggest the binding possibly of SD with dyes molecules. Consequently, the medium stretching bands show that sawdust containing vinyl and methyl groups. A strong peaks on 1060.85 and 1037.70 corresponds to stretching C-OH and C-O-C bands. After the adsorption of BTB dye, a strong bands between (500-600) were appears refer to C-X group, 1627.92, 1597.06 cm^{-1} corresponds to C=C stretching. Meanwhile for MGO dye adsorption, the FT-IR spectrum show many peaks mainly at 1615 and 1586 cm^{-1} that corresponds to C=C stretching, 1373 corresponds to C-C aromatic stretching and 1172 corresponds to C-N stretching. The prominent IR bands for sawdust before adsorption of BTB and MGO dyes are tabulated in Table (II).



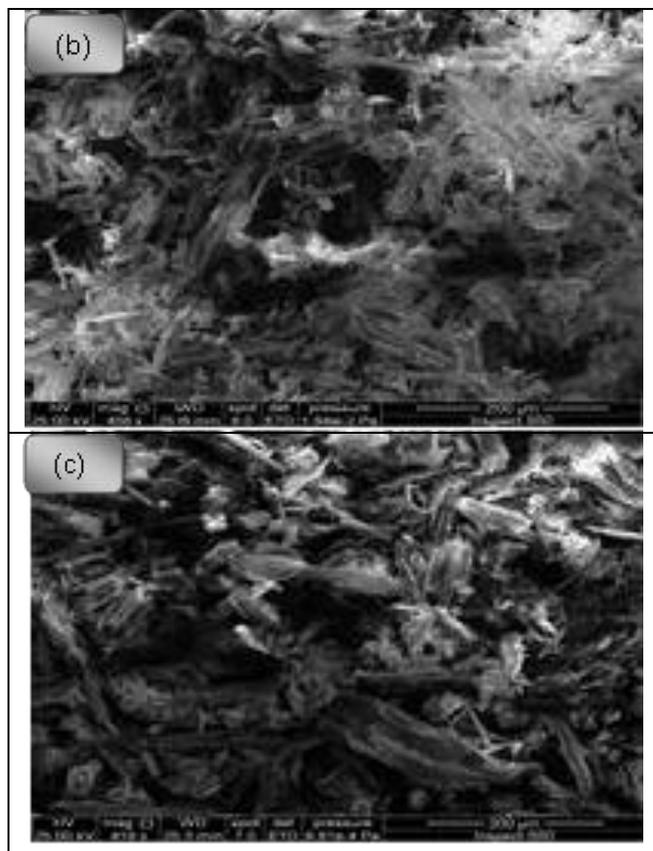


Figure 2. (a)SEM image of raw sawdust before and after adsorption of (b)BTB and (c) MGO dyes.

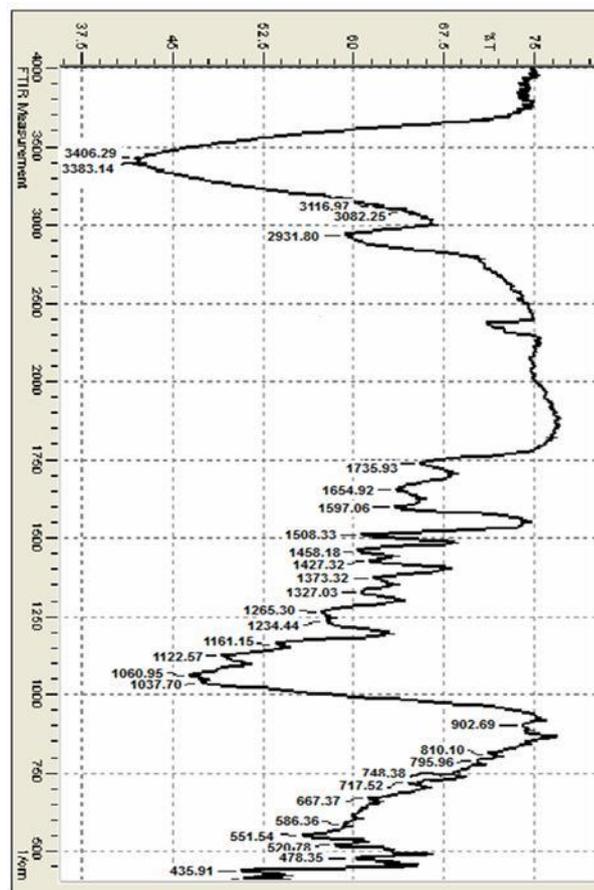


Figure 3. The Transform Infrared Spectrum (FTIR) of adsorbent raw sawdust.

Table I

The chemical components of raw SD in the absence and presence of both dyes.

Adsorbent	Component	Percentage %
SD	Carbon	68.89
	Oxygen	10.09
	Calcium	6.75
	Aluminium	3.04
	Antimony	11.23
SD+BTB.	Carbon	89.60
	Oxygen	9.69
	Aluminium	0.70
SD+MGO.	Carbon	96.69
	Silicon	0.91
	Aluminium	0.72
	Antimony	1.68

Table II

The prominent IR bands for Sawdust before adsorption.

Bond position (cm ⁻¹)	Assignment
3406.29	O-H stretch
2931.80	C-H stretch
1654.92	C=C stretch
1597.06	C=O stretch
1508.33	Aromatic region
1037.70	Si-O stretch
478.35	Si-O bend

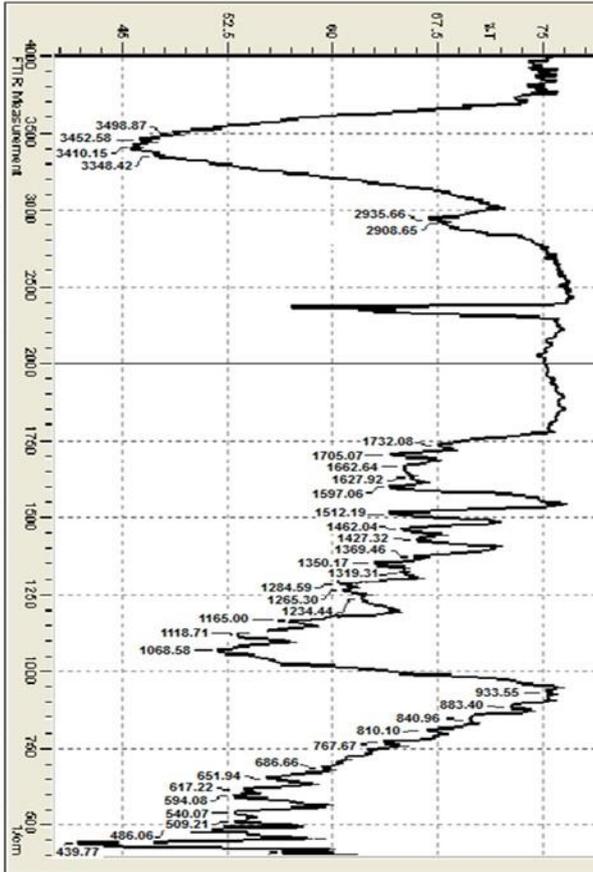


Figure 4. The Transform Infrared Spectrum (FTIR) of adsorbent raw sawdust with BTB.

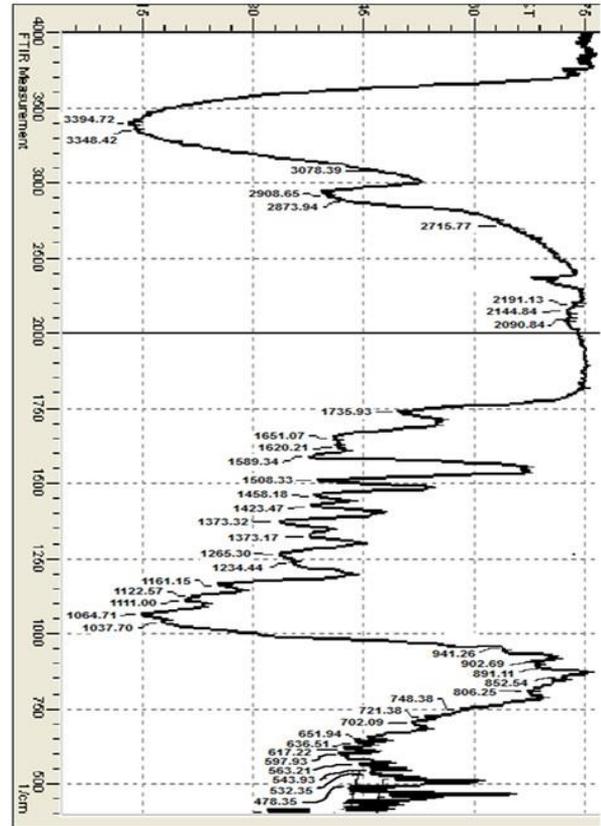


Figure 5. The transform infrared spectrum (ftir) of adsorbent raw sawdust with MGO.

Atomic force microscopy (AFM) instrument was used to evaluate the average particle size of sawdust and its distribution. Figure (6) represents the AFM image and granularity cumulating distribution Chart of sawdust adsorbent. The data obtained indicates that the average particle size is 80nm.

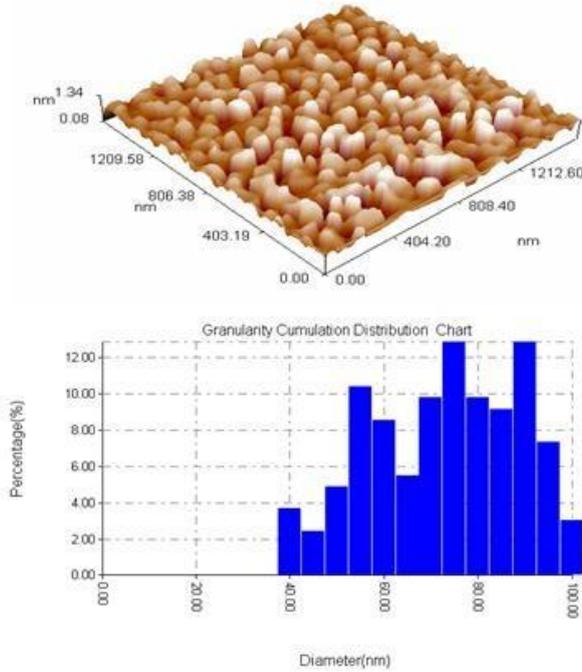


Figure 6. Atomic Force Microscopy (AFM) images and the Granularity Cumulating Distribution Chart for SD adsorbent.

B. Effect of contact time on adsorption.

The time variation plot indicates that the removal of both dyes was rapid in the initial stages until it reaches equilibrium, then it is slow down gradually, as shown in Figure (7). To implement this experiment, 0.03g adsorbent (SD) was treated with 30 ml of 30 mg.L⁻¹ MGO and BTB dye solution for different time periods (5-35) min with stirring at 298K. The results indicated that the percentage removal of both dyes were 49% for BTB and 87% for MGO obtained within 15 and 20 min, respectively. Such a difference in the adsorption behavior of the two classes of dyes may be ascribed to the various effects of several factors including the nature and presence of active groups on dyes molecules.

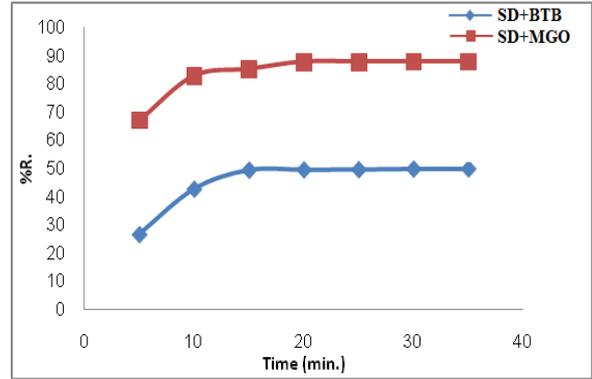


Figure 7. Effect of contact time.

C. Effect of Adsorbent dose.

In this study, different weights of sawdust (0.005-0.04) g were collected with 30mL of MGO and/or BTB dyes solutions of 30 mg.L⁻¹ concentration at dyes pH values. The adsorption data were plotted as presented in Figure (8). The data obtained reveal that the percentage removal of both dyes under study were increased with increasing the adsorbent dose until they reach equilibrium, after that, the percentage removal attains constant. It is readily understood that the number of available adsorption sites and the surface area increase by increasing the adsorbent dose, it therefore, results in the increase of amount of adsorbed dye. After formation of equilibrium, it was observed a decrease in amount of adsorption. This may be attributed to overlapping or aggregation of adsorption sites resulting in a decrease in total adsorbent surface area available to BTB and MGO dyes and as an increase diffusion path length [9].

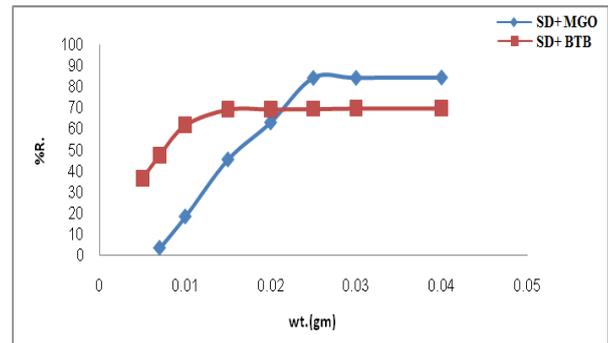


Figure 8. Effect of adsorbent dose (C₀ = 30 ppm).

D. Effect of pH.

The pH is one of the most important parameters that affect the adsorption capacity of dyes. It was found that increasing the pH of the BTB dye solution from 3 to 11 leads to decrease the percentage removal from 81.54 % to 36.41 % due to the protonation of different functional groups of SD at acidic media they have a positive surface charge. Therefore an electrostatic attraction between negatively charge BTB dye and positively charged surface leads to increase in adsorption and percentage removal of dye molecules. On the other hand, in alkaline media, low protonation of the SD surface have been obtained leading to decrease the percentage removal of dye [2]. For MGO dye, maximum removal percentage was achieved at pH = 5 (99.69 %). The mechanism and extent of dye adsorption will be different with pH because of the presence of different functional groups and atoms on dye and adsorbent surface. The percentage removal increased from 39.192 to 99.69 mg/g for 25 mg.L⁻¹ initial MGO concentration. At lower pH all reactive site adsorbent and dye molecule got positively charged due to increase of proton in aqueous media. In this case the repulsive force between all groups leads to decrease in dye removal. The gradual rise to pH 5 leads to deprotonation of groups causing electrostatic interaction, hydrogen bonding. This increases the magnitude of dye migration and diffusion to the sawdust surface. On the contrary, the percentage removal of MGO dye significantly decreased at pH up to 5 because the negative charge of both adsorbent and dye molecules leads to causing repulsion [4].

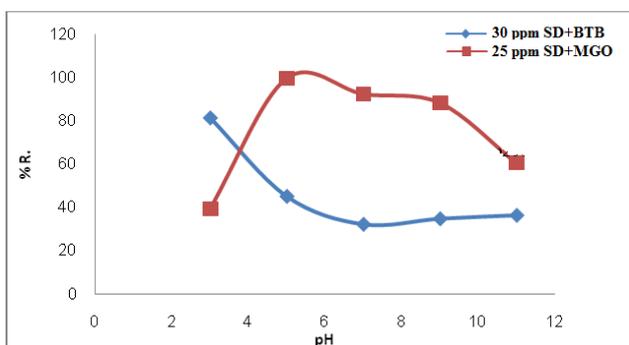


Figure 9. Effect of pH on the BTB &MGO on SD.

E. Adsorption Isotherm.

Adsorption isotherm is universally adopted as the relationship between the amount of adsorbate adsorbed at a given temperature and its concentration in the equilibrium solution. Isotherm is important for determining the maximum amount of adsorbate adsorbed by a given amount of adsorbent [10].

Several isotherm equations used to for analyzing adsorption equilibrium data are Langmuir, Freundlich and Dubinin-Radushkevich isotherms. The Langmuir adsorption isotherm refers that when the adsorbate occupies a site further adsorption cannot take place at that site. All sites are strongly equivalent and there is no interaction between molecules adsorbed on neighboring sites [11]. Langmuir isotherm to homogeneous adsorption that adsorption can occur at a constant number of definite localized sites with no transmigration of the adsorbate in the plane of the surface. The Freundlich isotherm model to heterogeneous surface of adsorption capacity and adsorption intensity with irregular distribution of heat of adsorption [12]. Langmuir model can be given as:

$$C_e/q_e = 1/q_{max} K_L + (1/q_{max})C_e.$$

Where q_e is the amount of adsorbate in the adsorbent at equilibrium (mg.g⁻¹), C_e is the equilibrium concentration (mg.L⁻¹), and q_{max} (mg.g⁻¹) and K_L are the Langmuir isotherm constants related to free energy.

Freundlich model can be given as:

$$\log q_e = \log K_F + (1/n) \log C_e.$$

Where K_F and $1/n$ are Freundlich isotherm constant (mg.g⁻¹) (dm³.g⁻¹)ⁿ related to adsorption capacity.

Dubinin-Radushkevich isotherm model for the adsorption process following a pore packing mechanism. This model used to explain the adsorption process occurred onto homogeneous and heterogeneous surfaces [13]. The D-R formula can be given as:

$$\ln q_e = \ln q_{max} - \beta \varepsilon^2$$

$$\varepsilon = RT \ln(1 + 1/C_e)$$

Where q_{max} (mg.g⁻¹) is a constant in the Dubinin-Radushkevich isotherm model which is refers to adsorption capacity; β (mol².kJ⁻²) is a constant refers to the mean free energy of adsorption; R (J.mol⁻¹.K⁻¹) is the gas constant; ε is Polanyi potential and T (K) is the absolute temperature. The calculations given in Tables (III).

For Langmuir isotherm, values of RL that shown in Table (3) indicates the type of the adsorption isotherm. The RL values refer to the kind of isotherm to be irreversible (RL=0), favorable (0 < RL < 1), linear (RL=1) or unfavorable (RL>1) [14]. The values of RL are 0.324, 0.304 and 0.267 for BTB and 0.340, 0.581 and 0.743 for MGO dyes adsorption indicating that the adsorption of both dyes are favorable.

For Freundlich isotherm, n is constant refer to the intensity of adsorption, so when $n=1$ this indicates that the division between the two phases are independent of the concentration, while when the value of $(1/n)$ is less than one it refers to a normal adsorption. From the other side, for $(1/n)$ be greater than one that refers to cooperative adsorption [15]. Higher values of q_{max} indicate higher adsorption capacity. The q_{max} value of MGO is higher than BTB dye, this indicate that MGO dye molecules have higher adsorption capacity than BTB dye molecules [16]. For Dubinin-raushkevich isotherm, when the values of energy (E) are between 8 and 16 $\text{kJ}\cdot\text{mol}^{-1}$ this implies that the adsorption process is chemical ion-exchange, while when E value is less than 8 $\text{kJ}\cdot\text{mol}^{-1}$ then the process is physisorption, meanwhile, when the energy value is greater than 16 $\text{kJ}\cdot\text{mol}^{-1}$ it refers to chemisorption process [17]. The data that presented in Table (III) indicate that the type of adsorption in BTB dye is physisorption but for MGO dye is chemisorption process. The values of coefficient of regression (R^2) for both dyes of Table (III) indicate that there are a better fitting to Freundlich isotherm model for BTB and to Langmuir isotherm for MGO dyes adsorption.

These results suggest that the adsorption is physisorption for BTB dye and chemisorption for MGO dye adsorbed on sawdust surface.

F. Thermodynamic studies.

The thermodynamic studies consist of several parameters such as standard Gibbs free energy change ΔG° ($\text{kJ}\cdot\text{mol}^{-1}$), standard enthalpy change ΔH° ($\text{kJ}\cdot\text{mol}^{-1}$), and standard entropy change ΔS° ($\text{kJ}\cdot\text{mol}^{-1}$).

The standard Gibbs free energy of activation for adsorption of BTB and MGO dyes in SD calculated from the relations [18]:

$$\Delta G^* = \Delta H^* - T\Delta S^*$$

The ΔG° , ΔH° and ΔS° values were calculated at three different temperatures (298, 308, 318)K and at various pH values (3,5,7,9,11).

The thermodynamic constants are calculated by the following formula:

$$\Delta G^\circ = -RT \ln K_o$$

Table III
Adsorption Isotherm Constant of Bromothymol Blue and Malachite green oxalate Dyes on the Sawdust at Temperatures.

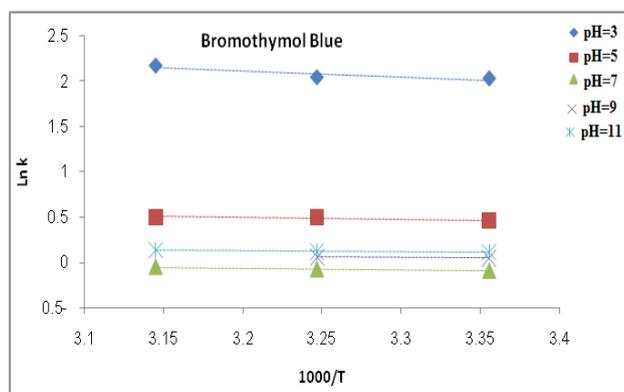
pH	T (K)	Langmuir constants				Freundlich constants			Dubinin and Radushkevich constants			
		q_{max}	K_L	R_L	R^2	n	K_F	R^2	B ($\text{mol}^2\cdot\text{kJ}^{-2}$)	q_{max}	E (kJ/mol)	R^2
Bromothymol Blue Dye												
3	298	11.467	0.058	0.324	0.784	0.318	0.171	0.958	8×10^{-3}	156.35	7.937	0.988
	308	11.428	0.043	0.304	0.781	0.315	0.167	0.956	8×10^{-3}	159.86	7.937	0.988
	318	9.398	0.031	0.267	0.851	0.272	0.101	0.976	2×10^{-3}	52.404	15.823	0.810
Malachite green oxalate Dye												
5	298	42.373	0.074	0.340	0.990	5.959	27.990	0.958	1×10^{-4}	37.382	70.922	0.811
	308	43.103	0.062	0.581	0.999	7.018	33.220	0.875	5×10^{-5}	41.364	223.714	0.981
	318	45.045	0.040	0.743	0.991	9.823	38.159	0.945	6×10^{-6}	40.459	289.017	0.767

Where ΔG° is the free energy change ($\text{kJ}\cdot\text{mol}^{-1}$), R is the gas constant ($8.315 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$), K_o is the thermodynamic equilibrium constant and T refers to temperature (K). The K_o value was calculated from the relation given below:

$$K_o = Q_e / C_e$$

Where Q_e refers to the amount of dyes adsorbed on the SD surface at equilibrium ($\text{mg}\cdot\text{L}^{-1}$), C_e the equilibrium concentration of dyes in solution ($\text{mg}\cdot\text{L}^{-1}$). From Van't Hoff equation standard enthalpy change and standard entropy change ΔS° of adsorption was calculated from the following formula [11]:

$$\ln K_o = -\Delta H_o / RT + \Delta S_o / R$$



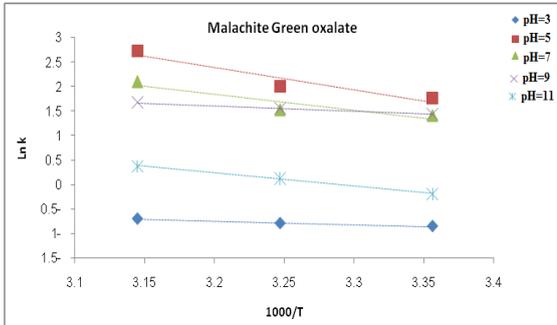


Figure 10. Plot of $\ln k$ versus $1000/T$ for the thermodynamic parameters for the adsorption of BTB and MGO onto SD.

Table (IV) presents the calculated values of the standard thermodynamic quantities for the dyes adsorption. The results of the change in the thermodynamic functions indicated that the adsorption of both dyes is endothermic in nature because of the positive values of ΔH° suggest that adsorption was favorable at higher temperature (318K). The values of enthalpy change within the range 2.1–20.9 kJ.mol^{-1} indicates that the type of adsorption is physisorption but when the values within the range 20.9–418.4 kJ.mol^{-1} , this suggest that the type of it chemisorption [19]. The results presented in table (IV) indicates that the type of adsorption is physisorption for BTB dye while for MGO dye the type of adsorption is chemisorption. This conclusion is consistent with that obtained from the studies of the theoretical isotherms.

The negative values of the Gibbs free energy change (ΔG°) refers that the adsorption process was spontaneous. The positive values of the entropy (ΔS°) refers that the increased randomness at the solid-solute during the adsorption process [18] and it may also indicate that ion exchange reactions take place and create steric hindrances [19].

G. Adsorption kinetics

Kinetic modeling gives information about adsorption mechanisms and possible rate controlling steps such as mass transport or chemical reaction processes [20].

Several kinetic models as pseudo-first and pseudo-second order, Weber–Moris, and Elovich are available. The most prevalent are the pseudo-first and the pseudo-second order kinetic equations. Pseudo-first-order rate equation is obtained under the ideal assumption of a totally homogenous adsorption surface which considers the rate of occupation of adsorption sites to be proportional to the number of unoccupied sites and is given as follows [21]:

$$\log (q_e - q_t) = \log q_e - k_1 t / 2.303$$

Where k_1 (min^{-1}) is the pseudo-first order rate constant, q_t (mg.g^{-1}) and q_e (mg.g^{-1}) are adsorption capacities at a given time t (min) and the equilibrium condition, respectively.

The pseudo-second-order model is based on adsorption equilibrium capacity defined by this equation [22]:

$$t/q_t = 1/(k_2 \cdot q_e^2) + t/q_e$$

Where k_2 ($\text{g.mg}^{-1}.\text{min}^{-1}$) is the pseudo-second-order rate constant.

Table IV

Thermodynamics Parameters for Adsorption Bromothymol Blue and Malachite Green oxalate Dyes on the Sawdust at Different Temperatures.

pH	T (K)	Bromothymol Blue				Malachite Green oxalate			
		ΔH kJ.mol^{-1}	ΔS $\text{J.mol}^{-1}.\text{K}^{-1}$	R^2	ΔG kJ.mol^{-1}	ΔH kJ.mol^{-1}	ΔS $\text{J.mol}^{-1}.\text{K}^{-1}$	R^2	ΔG kJ.mol^{-1}
3	298	5.660	35.733	0.802	-4.988	6.092	13.391	0.980	2.101
	308				-5.346				1.968
	318				-5.703				1.834
5	298	1.508	8.944	0.878	-1.157	37.564	140.091	0.909	-4.183
	308				-1.247				-5.584
	318				-1.336				-6.985

As in Table (V), The kinetic studies for the adsorption process demonstrate that the pseudo-second-order model is better describes the biosorption process of BTB and MGO dyes on the SD surface as indicated from the values of the coefficient R^2

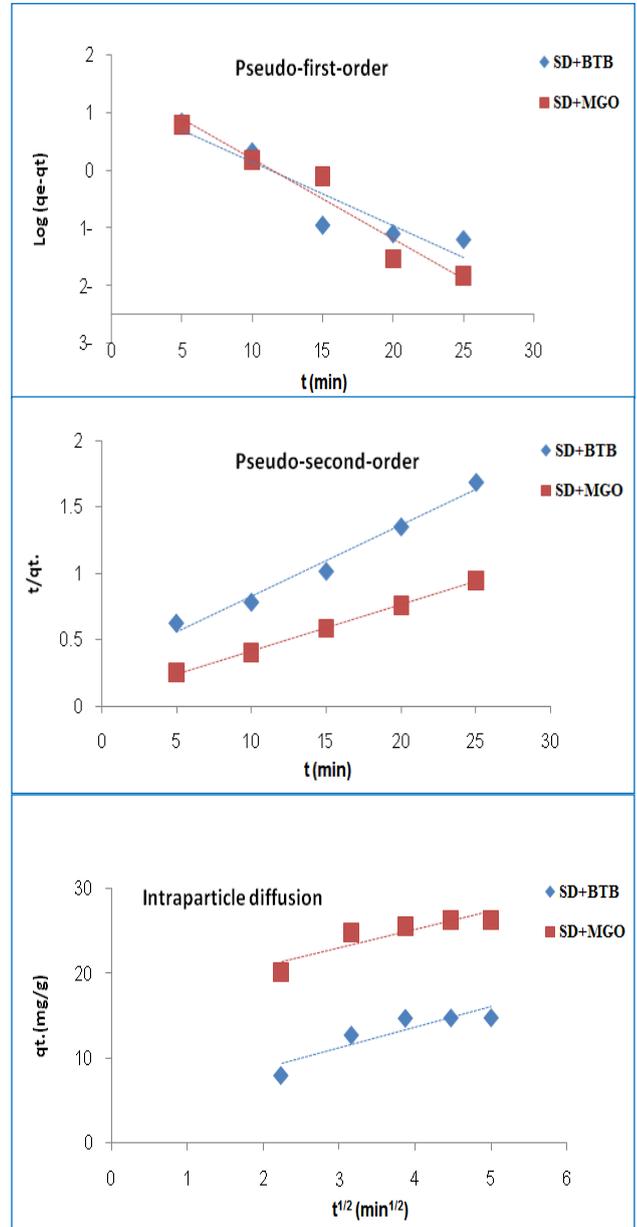
The best fit of the second-order expression suggests that the chemisorptions mechanisms involved in the adsorption [23]. As shown the correlation coefficient value of MGO is greater than BTB this agreed with thermodynamics studies that the adsorption of MGO is chemisorption.

The linear form of intra-particle diffusion model can be expressed as follows equation [24]:

$$q_t = k_D t^{1/2} + C$$

Where C and k_D are the constant parameters refers to the thickness of the boundary layer (mg.g^{-1}) and intra-particle diffusion rate constant ($\text{mg.g}^{-1}.\text{min}^{-1/2}$), respectively.

The plot of intraparticle diffusion was linear, but didn't pass within the origin this suggest that the intraparticle diffusion is not the only rate determining step, but also other processes may control the rate of adsorption. Surface adsorption and intraparticle diffusion were likely to take place simultaneously, both the processes controlling the kinetics of dyes-adsorbent interaction [25]. The evidence for such conclusion is the rate constants of second-order and intraparticle diffusion, where their values are the highest among other kinetic models as shown in Table 6. Large values of rate constants are related to an improved bonding between dyes and adsorbent particles [26]. Figure (11) shows that the intercept in the case of MGO is greater than BTB this mean the greater boundary layer effect [27].



The kinetic study of BTB and MGO dyes.

Table V
The kinetic parameters for the adsorption of BTB & MGO. dyes onto sawdust.

System	Pseudo-first order			Pseudo-second order			Intraparticle diffusion		
	K_1 $L.\text{min}^{-1}$	q_e mg.g^{-1}	R^2	K_2 $\text{g.mg}^{-1}.\text{min}^{-1}$	q_e mg.g^{-1}	R^2	k_D $\text{mg.g}^{-1}.\text{min}^{-1/2}$	C	R^2
SD+BTB	-0.252	17.026	0.867	0.010	18.622	0.979	2.4379	3.902	0.803
SD+MGO.	-0.320	39.093	0.945	0.020	28.490	0.999	2.161	16.569	0.809

IV. CONCLUSIONS

Iraqi sawdust, a carpenter factories waste, was successfully used as a low cost adsorbent for the removal of dangerous dyes BTB and MGO. The biosorption process of BTB and MGO dyes on sawdust surface are depending on several parameters such as contact time, adsorbent dose, concentration of dyes, temperature and pH. The percentage removal of BTB dye molecules was found to be 81.54% with initial concentration 30 mg/L at pH 3 in 15 min at 298 K. On the other hand, percentage removal for MGO dye was 99.69 % with initial concentration 25 mg/L at pH 5 in 20 min at 298 K. The shifting of peaks in FTIR spectrum emphasizes the BTB and MGO dyes adsorption onto sawdust. The SEM study also made support to it by observing difference in surface morphology of adsorbent before and after adsorption of both dyes. The adsorption equilibrium data for BTB dye showed good fit to the Freundlich isotherm model, while Langmuir isotherm model is perfect for MGO dye adsorption.

The kinetic study confirms that the best model in the adsorption of both dyes on SD is pseudo-second-order model. Thermodynamic study demonstrates that the adsorption process is endothermic, spontaneous and increasing randomness due to the negative values of free energy change, positive value of enthalpy change and positive value of entropy change, respectively. Finally it is concluded that, the Iraqi sawdust could be considered as an effective and eco-friendly adsorbent for the removal of BTB and MGO dyes from their aqueous solutions.

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International Journal of Emerging Technology and Advanced Engineering

Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 7, Issue 8, August 2017)

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