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Adsorption of Biebrich Scarlet Dye into Remains Chromium and Vegetable Tanned Leather as Adsorbents

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Abstract

Chromium tanned leather wastes (CTLW) and vegetable tanned leather wastes (VTLW) were used as adsorbent materials to remove the Biebrich scarlet dye (BS), as an anionic dye from wastewater, using an adsorption method. The effects of various factors, such as weight of leather waste, time of shaking, and the starting concentration of Biebrich scarlet dye, temperature and pH were studied. It described the adsorption process using Langmuir and Freundlich isotherm models. The obtained results agreed well with the Langmuir model, and the maximum adsorption capacities of CTLW and VTLW were 73.5294 and 78.1250 mg.g^{-1}, respectively, suggesting a monolayer adsorption process. The adsorption kinetic was found to follow a pseudo-second-order kinetic model with correlation coefficients $R^2 >$ 0.9982 and 0.9900 for CTLW and VTLW, respectively. The results predicted that chromium leather wastes were more suitable adsorbents for the removal of BS dye from wastewater than vegetable tanned leather wastes, and the adsorption process is endothermic, according to the study of the effect of temperature.

Keywords: Adsorption, Biebrich scarlet, leather waste, Adsorption method, Kinetic.

امتزاز صبغة البيبريش القرمزية على بقايا الجلود المدبوغة بالكروم ونباتيا كمواد مازة

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الخلاصة

تم استخدام بقايا الجلود المدبوغة بالكروم (CTLW) والمدبوغة نباتيا (VTLW) كمواد مازة لازالة صبغة البيبريش القرمزية (BS) كصبغة انيونية من مياه الصرف الصحي باستخدام طريقة الامتزاز. تمت دراسة تأثير عوامل مختلفة مثل: وزن بقايا الجلود، زمن الرج، التركيز الابتدائي لصبغة البيبريش القرمزية، درجة الحرارة و الاس الهيدروجيني. تم وصف عملية الامتزاز باستخدام أنموذجي متساوي درجة حرارة الامتزازلنكماير وفيرندليش. النتائج المستحصلة جيدة التطابق مع أنموذج لنكماير، وكانت سعة طبقة امتزاز العظمى لكل من CTLW و VTLW 73.5294 و 78.1250 ملي غرام/غرام على التوالي، مشيرا إلى عملية امتزاز أحادي الطبقة. وجد أن حركية الامتزاز تتبع الأنموذج الحركي لتفاعل المرتبة الثانية المنتحلة مع معاملات الارتباط $R^2>0.9900$ و0.9982 لCTLW و VTLW على التوالي . اظهرت النتائج ان بقايا الجلد المدبوغ بالكروم اكثر ملائمة كمادة مازة لازالة صبغة BS من مياه الصرف الصحي من بقايا الجلد المدبوغة نباتيا, وكذلك عمليه الامتزاز ماصة للحرارة طبقا لدراسة تأثير درجة الحرارة.

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1. Introduction

The treatment of wastewater produced by pollutants and textile dyes is one of the most important environmental issues that must be resolved today. In the leather industry, it used large quantities of water in the dyeing process, which led to the production of liquid waste contaminated with dyes. Therefore, the colored wastewater resulting from industries is unsafe for the environment, especially aquatic organisms, because of the dye molecules that impede the penetration of light, so it is necessary to drain it from the water. Various methods and technologies exist for wastewater treatment, including chemical oxidation, membrane filtration, microbiological decomposition and adsorption [1]. The adsorption process is one of the most common methods in the process of removing pollutants and colorants from wastewater because it has advantages, the most important of which are reducing energy use and increasing efficiency, low initial investment requirements, and ease of operation and operation compared to traditional and unconventional methods [2]. Alternative low-cost adsorbent materials with high adsorption capacity are used to remove effluents, for example, plants (cane waste, wood and plant husks), fish scales [3], clay [4], mineral carbon [5], and leather waste. The residues of hard leather resulting from leather tanning factories are interesting adsorbents to provide profitable use of these materials and eliminate their harmful impact on the environment [6], so they are considered good adsorbents.

In this study, two types of leather waste (chromium tanned leather waste and vegetable tanned leather waste) were used as low-cost adsorbents to treat solutions containing Biebrich scarlet (BS) dye. To evaluate the characteristics of the adsorption process in batch experiments, Langmuir and Freundlich isotherm adsorption models, as well as various kinetic models including pseudo first-order model and pseudo second-order model kinetics were used to estimate the kinetics data for the adsorption of Biebrich scarlet (BS) dye.

2. Materials and Methods

2.1. Materials

Adsorbents: The waste leather samples were obtained from a local tannery (supplied by AL Wafaa-company for leather tanning in Baghdad City). The chromium leather waste samples were cut into small pieces, then the pieces were washed with distilled water several times and dried in an oven at 99-105 °C for 6 hours for the chrome-tanned leather waste because their shrinkage temperatures are above 100 ºC in a dry state, while vegetable-tanned leather was dried in an oven at 50 ºC. In a wet state, the shrinkage temperature of vegetable-tanned leather ranges from 75 to 85 °C. Considering the possibility of absorbent interference in the UV spectrophotometer, the leather waste was initially stirred and kept in water for two hours to remove excess tannin [7]. It continued the drying process for the leather sample until it reached a constant weight. The waste leather pieces were ground into granules using a laboratory mill into 7-14 mesh-sized particles. The grand samples are stored in a desiccator to keep them dry. We use samples as adsorbents in our experiments after the characterization of these samples using different techniques to study their surface properties. Figure 1 shows the preparation steps for the waste leather samples CTLW and VTLW as adsorbents.

Figure 1 - The preparation procedure of the (CTLW and VTLW) powders as adsorbents.

Adsorbate: Biebrich scarlet (BS) is one of the common anionic azo days, or acidic dyes. It is known by several names: acid red 66, Ponceau BS, Biebrich scarlet sodium salt. IUPAC name is 2-[(2-hydroxy-1-naphthalenyl)azo]-5-[(4-sulfophenyl)azo]benzenesulfonic acid disodium salt. It is soluble in water and alcohol, C.I. number 26905, its chemical formula $C_{22}H_{14}N_4Na_2O_7S_2$, molar mass is 556 g/mol and λmax: 505 nm [8]. As it is used to dye cotton, wool, silk and paper, a glossy shade of the fluorescent effect is required [9]. Figure 2 shows the chemical structure of BS. A stock solution related to (BS) of 1000 mg/L was prepared by the dissolution of dye (1 g) into distilled water (1000 mL). The stock solution was diluted to prepare different concentrations of BS dye (10, 20, 30, 40 and 50) mg/L.

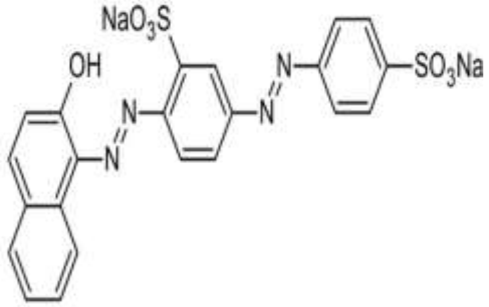


Figure 2 - Chemical structure of Biebrich scarlet dye

2.2. Adsorption Experimental: Adsorption experiments were conducted to study the optimum case for the adsorption of (BS) dye onto both the leather waste (CTLW and VTLW) as adsorbents at a temperature of 298 K using an electrostatic shaker at a speed of 150 rpm. The effect of the leather waste dose was studied by changing the amount of (CTLW and VTLW) from 0.01 to 0.1 g with a dye concentration of 50 mg/L, volume of a solution of 25 mL, for 45 minutes. The effect of the adsorption period was studied by taking different times from 5 to 90 minutes with the adsorbent weight of 0.05g/50mL dye solution and a concentration of 50mg/L. To study the effect of the BS dye concentrations, different concentrations from 10mg/L to 50mg/L were prepared, with a weight of 0.025g/25mL of BS dye for 20 minutes. The residual BS dye concentration was determined by a UV-Vis Spectrophotometer (Shimadzu UV 1800, Japan). The amount of adsorbed dye at equilibrium q_e (mg/g) and removal efficiency (R%) for the leather waste were calculated using the following equation [10].

$$q_e = \frac{c_i - c_e}{m} \times \mathrm{v} \tag{1}$$

$$\text{Removal R\%} = \frac{c_i - c_e}{c_i} \times 100 \tag{2}$$

Where c_i and c_e are the concentrations of dye at the initial and at equilibrium (mg/L), m is the weight of leather waste (g) and V is the volume of the solution (L).

2.3. Isotherm Models

2.3.1. Langmuir Adsorption Isotherm: In aqueous solution, the Langmuir equation is written as: [11]

$$\frac{C_e}{Q_e} = \frac{1}{K_L\, Q_m} + \frac{1}{Q_m} \,.\, C_e \tag{3}$$

Where C_e is adsorbate's equilibrium concentration (mg/L), Q_e is the amount of material adsorbed per gram of the adsorbent at equilibrium ($mg.g^{-1}$), Q_m is the maximum capacity of the monolayer coverage (mg/g) and K_L is the Langmuir isotherm constant ($L.mg^{-1}$).The values of Q_m and K_L are calculated from the slope as well as the intercept of the line obtained when drawing C_e/Q_e versus C_e. The fundamental property can also be expressed by Langmuir's equation in terms of a dimensionless constant or separation factor R_s, using the following equation:

$$R_s = 1/\,(1 + K_L\, C_i) \tag{4}$$

Where C_i is the starting concentration ($mg.\, L^{-1}$), and K_L is Langmuir constant (L/mg).

The values R_s between 0 and 1 indicate that the adsorption is adequate, linear ($R_s = 1$), favorable ($0 < R_s < 1$), irreversible ($R_s = 0$) and unfavorable ($R_s > 1$).

2.3.2. Freundlich Adsorption Isotherm: The basic empirical equation proposed by Freundlich can be expressed as [12]:

$$q_e = K_{Fr} \,.\, [C_e]^{1/n_f} \tag{5}$$

While the Freundlich isotherm linear equation is expressed as [13]:

$$\ln q_e = \ln K_{Fr} + \left(\frac{1}{n_f}\right) \ln C_e \tag{6}$$

Where C_e is the concentration at equilibrium (mg/L), K_{Fr} is the Freundlich constant in ($mg.g^{-1}(mg.\, L^{-1})^{-1/n}$) related to adsorption capacity and n_f is indicates the constant depends on the temperature and nature of the adsorbate. The values of K_{Fr} and $1/n_f$ are calculated from the intercept and the slope of the linear relationship between $\ln q_e$ against ln C_e. The adsorption curve is linear when it ($1/n_f = 1$) indicates that there is no interaction between the adsorbed species and the adsorption sites are of the homogeneous type. While($1/n_f < 1$), the adsorption is favorable and therefore the adsorption capacity increases, when the value of ($1/n_f > 1$), the adsorption is unfavorable, the adsorption capacity decreases and the adsorption bonds become weak [14].

2.4. The Kinetic Study

Pseudo-First Order: pseudo-first-order kinetic model, also called the Lagergren equation, which is the first kinetic equation for liquid/solid adsorption systems based on solid capacitance and has been widely used to describe adsorption kinetics [15,16]. It was expressed as: [17]

$$\ln\,(q_e - q_t) = \ln q_e - k_1 . t \tag{7}$$

The kinetics of pseudo-second-order adsorption are described and expressed as [18]:

$$\frac{t}{q_t} = \frac{1}{k_2\, q_e^2} + \frac{t}{q_e} \tag{8}$$

Where q_e is equilibrium adsorption capacity ($mg.g^{-1}$), q_t is adsorbed amount of adsorbate onto adsorbent at time t ($mg.g^{-1}$) and k_1 is rate constant for the adsorption process per min (min^{-1}) for the pseudo-first-order model. k_2 is the equilibrium rate constant for a pseudo-second-order model (g/mg.min). The slop and intercept of linear plots of ln $(q_e - q_t)$ against t and $t/\, q_t$ against t were applied to estimate the values of k_1 , q_e for the pseudo- first -order and k_2 and q_e for pseudo-second-order.

3. Results and Discussions

3.1. The Effect of Adsorbent Amount

The influence of adsorbent amount on BS dye removal by functionalized CTLW and VTLW is shown in Figure 3. By taking amounts of the adsorbent ranging from 10 to 10 mg/25 mL from the dye solution at a concentration of 50 mg/L, and for 45 minutes, the removal percentage R% increases for all types of adsorbents; (80.7 to 97.9 %) from (34.6 to 94.5 %) for CTLW and VTLW, respectively. This increase in the removal ratio was due to the increase in the surface area and adsorption sites in the adsorbent material available for adsorption [19]. According to this result, 25 mg was selected as the optimum weight for further experiments. This figure also reveals that the removal efficiency for CTLW was higher than that for VTLW.

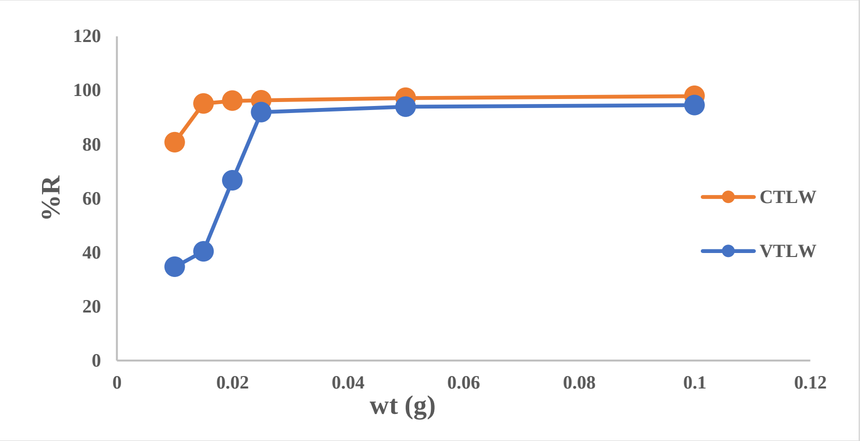


Figure 3 - The effect of the leather waste weight on the removal percentage of BS dye using CTLW and VTLW as adsorbents. Conditions: 50 mg/L / 25 mL, 45 minutes, 298 K.

3.2. The Effect of Contact Time

The effect of contact time on the removal ratio of 50 mg/L of BS dye was determined by changing the adsorption time from 5 to 90 minutes at a constant temperature of 298 K, and the weight of the adsorbent is 0.05 g/50mL. Figure 4 shows the effect of adsorption time on the adsorption of the BS dye. It is clear from this Figure that the percentage of removal R% increases at a time of 5 minutes and then reaches a steady state at a time of 20 minutes and remains stable. Therefore, the time profile is a smooth continuous curve and individual leads to the saturation of the adsorbent and refers to a single-layer coating of the dye on the surface of the adsorbent material [20]. Thus, the optimum time chosen was 20 minutes.

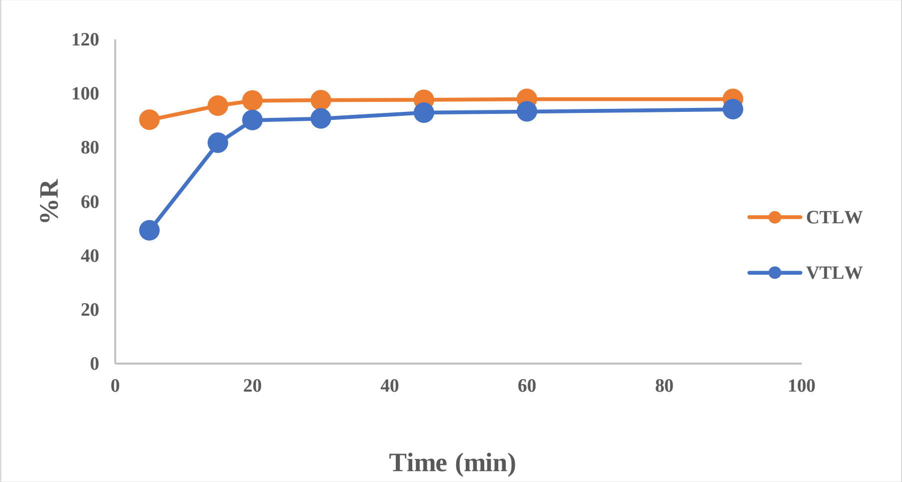


Figure 4 - Effect of adsorption time on the adsorption of BS dye onto CTLW and VTLW. Conditions: 0.05 g/ 50 ml, 50 mg/L, 298 K.

3.3. The Effect of initial Concentration on Adsorption of BS Dye

To determine the effect of the initial concentration of BS dye, variable concentrations ranging from (10, 20, 30, 40 and 50 mg/L) at 298 K, weight of the adsorbent (0.025 g/25 ml), and time 20 minutes. From Figure 5a, when the initial concentration of BS dye is increased from 10 to 50 mg/L, the removal efficiency decreases with the change of R (%) from 98.7 to 93.2% for CTLW and from 83.3 to 56.7% for VTLW. These results are due to the fact that the higher the dye concentration in the surface area of the adsorbent material, the less adsorption there would be. Also, Figure 5b shows that the adsorption capacity depends on the initial concentration, and the maximum capacities of 37.99 mg/g and 23.84 mg/g were achieved for CTLW and VTLW, respectively, at a high concentration of 50 mg/L and a minimum of 8.12 mg/g and 5.0 mg/g at a lower concentration, of 10 mg/L. This is because the higher the initial concentration, the greater the equilibrium concentration will be, so the capacity will increase from the 10 mg/L concentration to 50 mg/L. The optimum concentration was selected as 30 mg/L

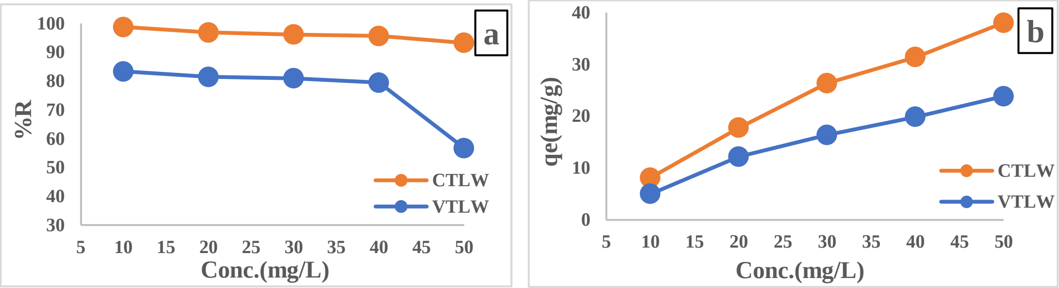


Figure 5 - Effect of initial concentration on the adsorption of BS dye onto CTLW and VTLW. (a) Removal efficiency R (%). (b) Adsorption capacity (mg/g). Conditions: 20 minutes, 0.025 g/25 ml, 298 K.

3.4. The Effect of temperature on the adsorption of the BS Dye: The temperature effect of the BS dye was studied at temperatures ranging from 288 to 328 K, at the optimum conditions for each dye concentration (30 mg/L), the weight of the leather waste (0.025g/25ml), and at 20 minutes. Figure 6 shows the effect of temperature on the adsorption of the BS dye on the surfaces of the adsorbents CTLW and VTLW. The results showed that the removal efficiency increases with increasing temperature, so the adsorption process can be classified as an endothermic process [21].

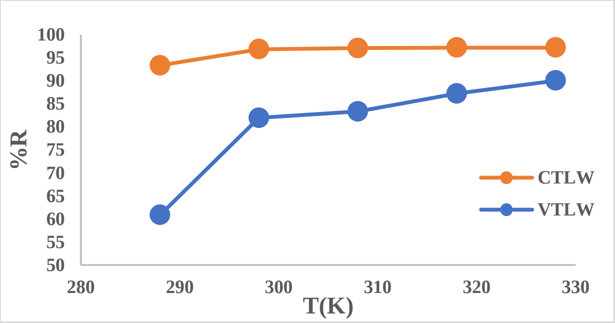


Figure 6 - Effect of temperature on the adsorption of BS dye onto CTLW and VTLW. Conditions: 20 minutes, 0.025 g/ 25 ml.conc.30 mg/L.

3.5. Influence of Initial pH: The effect of pH on the adsorption of BS dye was studied by contrasting it between 2.5 and 10.2, at 298 K, where the dye concentration was 30 mg/L, the weight of the leather was (0.025g/25ml), and the shaking time was 20 minutes. The pH of the solution was adjusted with HCl (0.1M) and NaOH (0.1M). Figure 7 shows the effect of pH on the removal efficiency ratio for BS dye using leather waste CTLW and VTLW. The adsorbents showed the high adsorption efficiency of BS dye in the range of pH (2.5-6.3), and then it decreased significantly at pH greater than 8. More protons are available at relatively lower pH, and as a result, more amino groups are available in the leather and Cr(III) in the chrome-tanned leather remains is positively charged, increasing the adsorption sites of the anionic surfacing, thus increasing the BS removal rate on the other hand, we find that the percentage of removal efficiency at alkaline pH is lower due to the lack or scarcity of positively charged sites on the surface of the adsorbents and the competition between OH^- and anionic surfactants for adsorption sites [19].

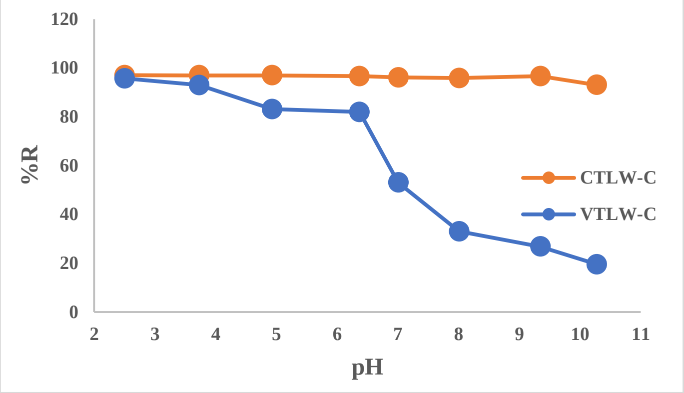


Figure 7 - Influence of initial pH on the adsorption of BS dye onto CTLW and VTLW. Conditions: 20 minutes, 0.025 g/ 25 ml. conc.30 mg/L, 298 K.

3.6. Adsorption Isotherm

3.6.1. Langmuir Isotherm: The isotherm of adsorption of the BS dye on CTLW and VTLW at various temperatures is illustrated in Figure 8, and the dimensionless equilibrium parameter at C_i equals 50 mg/L. The results obtained from the Langmuir isotherm model for the removal of BS dye on CTLW and VTLW as adsorbents, are shown in Table 1. Isotherm data was plotted linearly using Langmuir's equation and plotted between C_e/Q_e versus C_e as shown in Equation 3. The correlation coefficients R_S (Table 1) show a strong positive evidence for dye adsorption on CTLW and VTLW following Langmuir isotherms. The applicability of the linear model of the Langmuir's model to CTLW and VTLW were demonstrated by the high correlation coefficients, and by calculating the separation factor, Rs, which is a measure of adsorption preference (0 < Rs < 1), that the adsorption was appropriate [22].

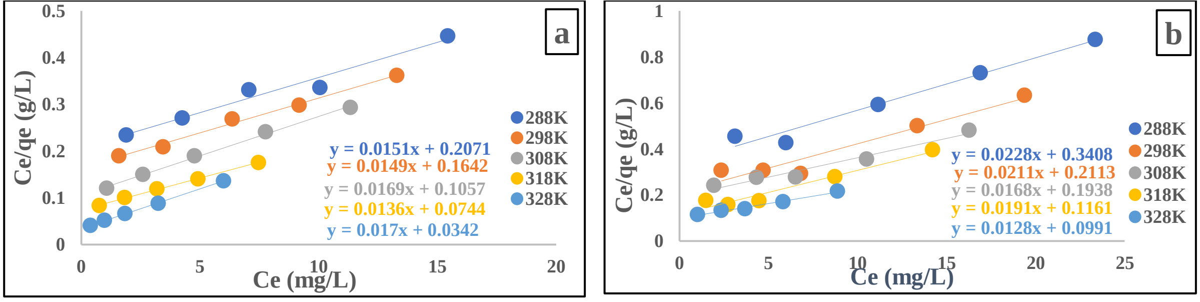


Figure 8 - Langmuir isotherms of BS dye onto (a) CTLW (b) VTLW at different temperatures.

Table 1 - Langmuir constants for adsorption of BS dye onto CTLW and VTLW at different temperatures and the dimensionless equilibrium parameter at C_i equal 50 mg/L.

Adsorbents	**Temperature (K)**	**Q_m (mg.g^{-1})**	**K_L (L/mg)**	**R^2**	**R_S**
CTLW	288	66.2251	0.0729	0.9664	0.2153
	298	67.1140	0.0907	0.9920	0.1806
	308	59.1716	0.1598	0.9971	0.1112
	318	73.5294	0.1827	0.9984	0.0986
	328	58.8235	0.4970	09997	0.0386

VTLW	288	43.8596	0.0669	0.9692	0.2301
	298	47.3933	0.0998	0.9340	0.1668
	308	59.5238	0.0866	0.9624	0.1874
	318	52.3560	0.1645	0.9540	0.1083
	328	78.1250	0.1291	0.9877	0.1340

3.6.2. Freundlich isotherm: The adsorption isotherm of the BS dye on to CTLW and VTLW at various temperatures is illustrated in Figure 9. The same equilibrium data for dye adsorption and the applicability of Freundlich isotherms were analyzed. The Freundlich constants are obtained by plotting the graph $\ln q_e$ against $\ln C_e$ as shown in Equation 6. The obtained results are shown in Table 2. The regression correlation coefficient obtained for the Freundlich isotherm model was lower than that of the Langmuir isotherm model. Hence, the relevance of Freundlich isotherms has not been demonstrated.

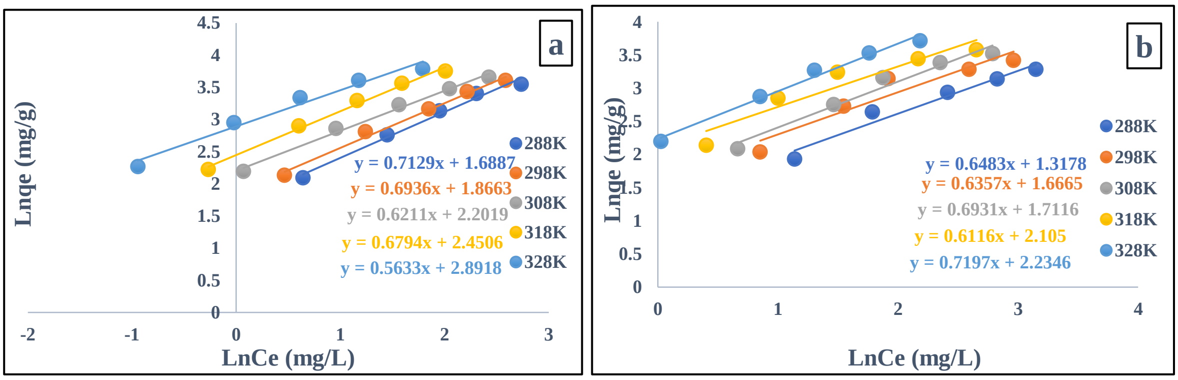


Figure 9 - Freundlich isotherms of the BS dye onto (a) CTLW (b) VTLW at different temperatures.

Table 2 - Freundlich constants for adsorption of BS dye onto CTLW and VTLW at different temperatures.

Adsorbents	**Temperature (K)**	**Slope** $\left(\frac{1}{n_f}\right)$	$\mathbf{n_f}$	**Intercept** $\mathbf{lnK_{Fr}}$	$\mathbf{K_{Fr}}$ $(\mathbf{mg.g^{-1}(mg.L^{-1})^{-1/n}})$	**R²**
CTLW	288	0.7129	1.4027	1.6887	5.4124	0.9851
	298	0.6936	1.4417	1.8663	6.4643	0.9898
	308	0.6211	1.6100	2.2019	9.0421	0.9906
	318	0.6794	1.4718	2.4506	11.595	0.9924
	328	0.5633	1.7752	2.8918	18.025	0.9729
VTLW	288	0.6483	1.5424	1.3178	3.7351	0.9547
	298	0.6357	1.5730	1.6665	5.2936	0.9039
	308	0.6931	1.4427	1.7116	5.5378	0.9650
	318	0.6116	1.6350	2.1050	8.2071	0.9005
	328	0.7197	1.3894	2.2346	9.3427	0.9850

The correlation factor analysis for data of both isotherms predicted that the applicability of these data was nearly explained by the Langmuir model, and that the adsorption of BS dye onto both adsorbents follows the mono-layer adsorption [23]

3.7. The Kinetics Study

The straight line graphs $\ln(q_e - q_t)$ against t for the adsorption of BS dye onto CTLW and VTLW as adsorbents at different temperatures are shown in Figure 10 using Equation 7; Table 3 summarizes the pseudo first order parameters. This model shows that the rate of the sorption process is proportional to the number of vacant sites that are available on the adsorbent surfaces and is usually used in the liquid-solid phase [24]. From the results listed in Table 3, we can observe that there is no agreement between the values of q_e experimental (q_e exp) and q_e calculated (q_e cal), which suggests the pseudo first order model, is unsuitable to describe the adsorption process.

In the pseudo-second order kinetic model, the rate of sorption is assumed to be linearly correlated with the square of the number of vacant-sites available on the surface of the leather waste. A plot t/q_t against t will give a straight line as this model is applicable to the sorption process in Figure 11. Table 4 shows the values of pseudo-second order rate constant data for the adsorption of BS dye onto leather waste samples. As shown in Tables 3 and 4, the average values of regression coefficients R² for the pseudo 2nd model was higher than for the pseudo-first order model. Additionally, there is a good accordance between the values q_e exp and q_e cal for the pseudo 2nd model, so we can predict that the pseudo-second order kinetic model provides the best fit to the experimental equilibrium.

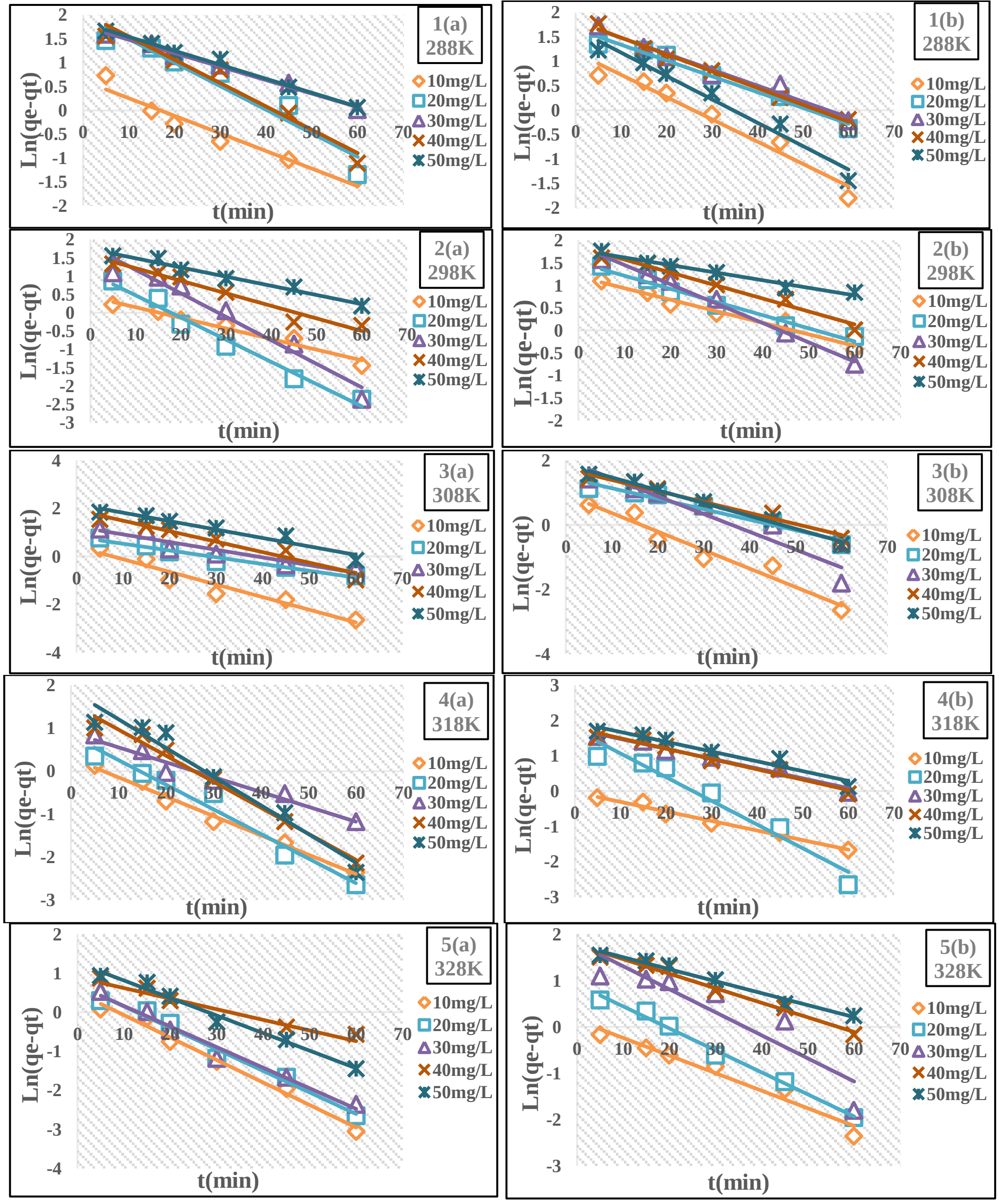
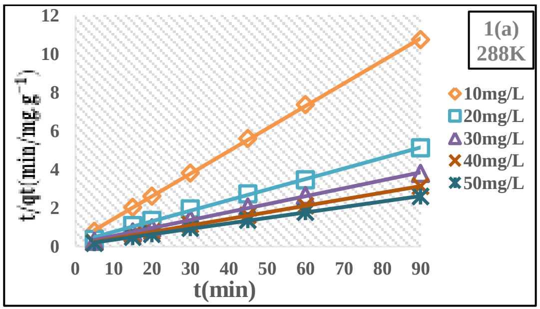
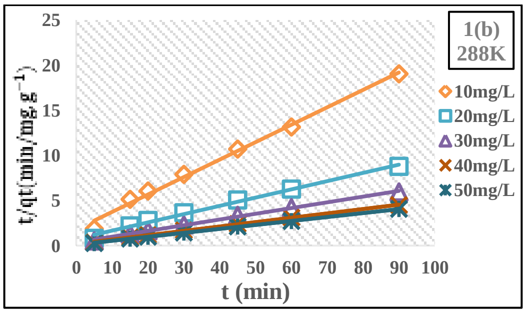


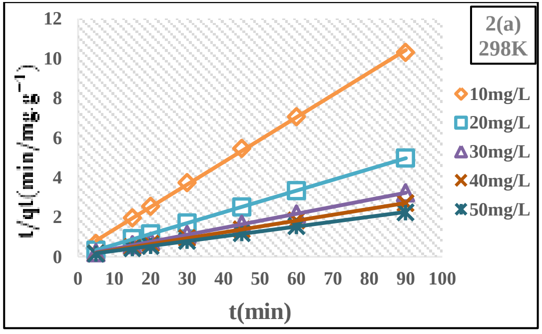
Figure 10 - Pseudo-first order kinetic plots on the adsorption of BS dye onto (1a) CTLW (1b) VTLW, (2a) CTLW (2b) VTLW, (3a) CTLW (3b) VTLW, (4a) CTLW (4b) VTLW and (5a) CTLW (5b) VTLW at different temperatures.

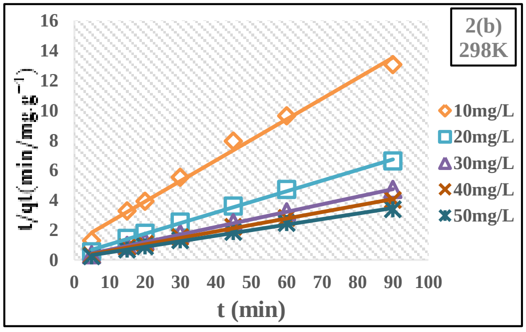
Table 3 - Pseudo-first order rate constants on the adsorption of BS dye onto CTLW and VTLW at different temperatures.

CTLW					**VTLW**			
C_i (mg/L)	**q_e exp (mg/g)**	**q_e cal (mg/g)**	**k_1 (min^{-1})**	**R^2**	**q_e exp (mg/g)**	**q_e cal (mg/g)**	**k_1 (min^{-1})**	**R^2**
288K								
10	8.3844	1.8719	0.0369	0.9432	4.7287	3.2576	0.0457	0.9575
20	17.5589	7.3448	0.0495	0.9257	10.2476	5.2593	0.0323	0.9761
30	23.7146	5.8591	0.0283	0.9901	15.1061	6.1055	0.0327	0.9723
40	28.7853	7.6990	0.0489	0.9618	20.0589	6.2320	0.0344	0.9892
50	34.6108	6.2921	0.0294	0.9905	22.2523	5.2315	0.0478	0.9686
298K								
10	8.7382	1.5565	0.029	0.9651	6.8985	3.3005	0.0256	0.9678
20	18.125	2.9567	0.0607	0.9764	13.643	4.5194	0.0292	0.9791
30	28.007	6.1300	0.0643	0.9554	19.139	6.5936	0.0430	0.9932
40	33.478	4.7645	0.0343	0.9559	22.464	6.4333	0.0288	0.9743
50	40.436	5.7064	0.0251	0.9728	26.662	5.9727	0.0168	0.9702
308K								
10	9.3042	1.5057	0.0526	0.9353	7.98349	2.5602	0.0574	0.9468
20	18.903	2.2476	0.0282	0.9671	15.860	4.3119	0.0325	0.9677
30	28.620	3.4435	0.0320	0.8807	23.077	7.3661	0.0553	0.9096
40	37.629	6.8716	0.0437	0.9485	29.728	5.6751	0.0341	0.9672
50	45.837	8.7626	0.0350	0.9422	34.044	6.4908	0.0398	0.9899
318K								
10	9.6344	1.3578	0.0450	0.9881	8.4316	0.9658	0.0270	0.9788
20	18.974	2.2853	0.0573	0.9682	18.030	5.7081	0.0672	0.9505
30	28.856	2.4591	0.0346	0.9603	27.275	5.8095	0.0279	0.9712
40	38.077	4.8037	0.0605	0.9828	32.299	6.0164	0.0294	0.9650
50	48.148	6.5247	0.0668	0.9602	38.408	7.0540	0.0277	0.9450
328K								
10	9.8466	1.6505	0.0576	0.9845	8.6674	1.1570	0.0381	0.9581
20	19.6344	2.0135	0.0551	0.9806	18.4316	2.5150	0.0476	0.9906
30	28.9740	1.9792	0.0527	0.9781	28.0306	6.1135	0.0498	0.8232
40	38.8325	2.4246	0.0271	0.8998	36.9221	5.9126	0.0314	0.9783
50	48.4316	3.5356	0.0449	0.9826	41.9929	5.8526	0.0259	0.9804









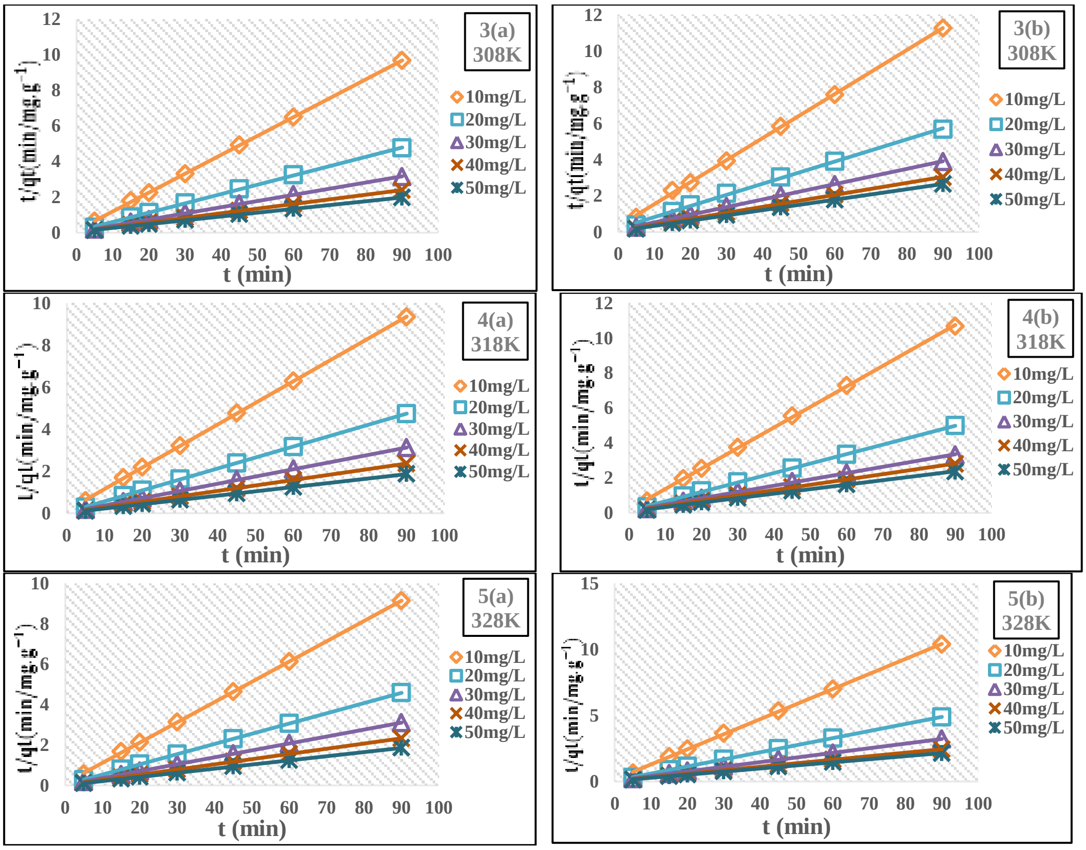


Figure 11 - Pseudo- second order kinetic plot for the adsorption of BS dye on a(1a) CTLW (1b) VTLW, (2a) CTLW (2b) VTLW, (3a) CTLW (3b) VTLW, (4a) CTLW (4b) VTLW and (5a) CTLW (5b) VTLW at different temperatures.

Table 4 - Pseudo-second order kinetic parameters of the adsorption of BS dye onto CTLW and VTLW at different temperatures.

	CTLW				VTLW			
C_i (mg/L)	q_e exp (mg/g)	q_e cal (mg/g)	k_2 (min^{-1})	R^2	q_e exp (mg/g)	q_e cal (mg/g)	k_2 (min^{-1})	R^2
288K								
10	8.3844	8.5470	0.0492	0.9997	4.7287	5.1786	0.0207	0.9932
20	17.558	18.281	0.0132	0.9982	10.247	10.952	0.0109	0.9926
30	23.714	24.213	0.0123	0.9983	15.106	15.748	0.0114	0.9973
40	28.785	29.498	0.0138	0.9994	20.058	20.661	0.0128	0.9989
50	34.610	35.087	0.0124	0.9992	22.252	22.675	0.0208	0.9996
298K								
10	8.7382	8.8652	0.0493	0.9991	6.8985	7.2833	0.0160	0.9900
20	18.125	18.348	0.0490	0.9999	13.643	14.084	0.0152	0.9977
30	28.007	28.490	0.0240	0.9998	19.139	19.801	0.0137	0.9990
40	33.478	33.898	0.0185	0.9997	22.464	23.094	0.0107	0.9975
50	40.436	40.816	0.0128	0.9993	26.662	26.954	0.0097	0.9953
308K								
10	9.3042	9.4339	0.0828	0.9999	7.9834	8.2101	0.0472	0.9995
20	18.903	19.047	0.0369	0.9997	15.860	16.286	0.0172	0.9982
30	28.620	28.901	0.0250	0.9997	23.077	23.696	0.0162	0.9993
40	37.629	38.167	0.0151	0.9997	29.728	30.211	0.0148	0.9994
50	45.837	46.511	0.0097	0.9993	34.044	34.602	0.0147	0.9996
318K								
10	9.6344	9.7465	0.0829	0.9999	8.4316	8.5034	0.0814	0.9996

20	18.974	19.157	0.0605	0.9999	18.030	18.450	0.0259	0.9996
30	28.856	29.069	0.0391	0.9999	27.275	27.777	0.0125	0.9986
40	38.077	38.461	0.0301	0.9999	32.299	32.786	0.0126	0.9991
50	48.148	48.543	0.0242	0.9999	38.408	39.062	0.0103	0.9988
328K								
10	9.8466	9.9800	0.0830	0.9999	8.6674	8.7642	0.0830	0.9997
20	19.634	19.801	0.0671	1.0000	18.431	18.656	0.0461	0.9999
30	28.974	29.154	0.0688	1.0000	28.030	28.571	0.0176	0.9993
40	38.832	38.910	0.0351	0.9999	36.922	37.453	0.0137	0.9995
50	48.431	48.780	0.0323	1.0000	41.992	42.372	0.0126	0.9994

4. Conclusion

The adsorption of Biebrich scarlet dye on leather waste was studied using adsorption methods that occur under different conditions such as weight of leather waste, contact time, initial concentration of dye, temperature and pH. Both the CTLW and VTLW adsorbent surfaces showed sufficient adsorption with respect to Biebrich scarlet dye. The experimental results were described by Langmuir and Freundlich, as well as the study of the kinetic model of the Pseudo first-order and Pseudo second-order models. The experimental results are compatible with the isotherm model Langmuir and the Pseudo second-order model kinetic. Chrome- tanned leather waste is a low-cost material and a more suitable adsorbent for the removal of BS dye from wastewater than vegetable tanned leather waste, and the adsorption is an endothermic process.

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