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Adsorption of Remazol Brilliant Violet-5R from Aqueous Solution Using Sugarcane Bagasse as Biosorbent: Kinetic and Thermodynamic Studies

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Abstract: Sugarcane bagasse is an inexpensive and eco-friendly natural biosorbent for the removal of various organic pollutants. The adsorption of Remazol Brilliant Violet-5R (RBV-5R) dye on sugarcane bagasse (SCB) was studied. Biosorbent was characterized using EDX and FTIR. The effect of various experimental parameters, such as pH, biosorbent dosage, initial dye concentration, contact time, adsorption with shaking and without shaking, and the temperature, was optimized. At pH 6, maximum biosorption of 92.22% was achieved using 0.15 g of SCB. The equilibrium was attained within 30–40 min for the removal of RBV-5R. The initial dye concentration of 10 µg/mL was determined as an optimum concentration for maximum removal of RBV-5R at 30 °C. Langmuir and Freundlich adsorption isotherms were applied, and it was found that the biosorption of RBV-5R follows Freundlich adsorption isotherms. Kinetic studies were also carried out and it was found that the proposed method followed the pseudo-second-order kinetic model (R^2 = 0.98). From desorption study, it was found that maximum desorption in the increasing order was obtained using ethanol, methanol, and 0.2 M sodium hydroxide (NaOH). The biosorption study was applied to actual textile waste effluent to pave way for the practical usage of this technology on a larger scale and the results were found effective.

Keywords: sugarcane bagasse; azo dye; remazol brilliant Violet-5R; biosorption; desorption

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1. Introduction

One of the biggest problems affecting the majority of developing and third-world countries in the twenty-first century is water quality [1,2]. Water bodies can becomecontaminated in a variety of ways, including through the addition of radioactive materials, insecticides, pesticides, dyes, nitrites, phosphates, and heavy metals [3]. One of the main classes of organic compounds that pose an increasing environmental risk is textile dyes and other industrial dyestuffs [4,5]. According to recent studies, significant amounts of dyes are lost during production and processing operations and end up in the environment as effluents from industrial wastewater [6]. Azo dyes are frequently used in textile manufacturing as well as in the leather, paper, ink, pharmaceutical, and cosmetic industries [7,8]. When these dyes are dumped in industrial effluent, it seriously harms people, plants, and animals. Azo dyes are found in wastewater and are highly mutagenic, causing defects in genes and inhibiting the growth of biota [9]. For the treatment of wastewater, a number of biological, physical, and chemical methods have been proposed [10–12]. These methods include

membrane separation, ozonation [13–15], chemical oxidation [16], photodegradation [17], coagulation, flocculation, electrochemical methods, and adsorption [18–20]. Of all of these approaches, adsorption is one of the most effective ways to remove colours from wastewater because it is inexpensive, environmentally friendly, and biodegradable [21]. Heavy metals and non-biodegradable dyes are removed from wastewater using the biosorption process. Natural biosorbents are mainly used in biosorption, which contains pores and cellular structures. Biosorption is a physiochemical binding of contaminants with selected biosorbents [22].

Sugarcane bagasse (SCB) is the fibrous waste produced after sugarcane has been crushed to extract its juice. It is one of the most common types of biomass waste on earth [23,24]. A readily available and inexpensive waste of the sugar industry called bagasse can be used to prepare adsorbents. A qualitative analysis of SCB revealed that its main constituents include cellulose, hemicellulose, lignin, ash, and wax [9,25]. Begasse is made up of 50% cellulose, while 25% of it is hemicellulose, 25% is lignin, and 2.4% is ash. In comparison to other agricultural waste products, such as rice straw and wheat straw, which have ash concentrations of 17.5% and 11.0%, respectively, bagasse has many advantages. The macromolecules with humic and fulvic compounds, lignin, cellulose, hemicelluloses, and proteins that have adsorptive sites, such as carbonyl, carboxylic, amine, and hydroxyl groups, are the main components of the sugarcane bagasse-based biosorbent. These sites enable it to adsorb the dyes by the ion exchange phenomena or by complexation [26].

In the current study, SCB has been used to examine the biosorption of the selected azo dye, RBV-5R. The optimal conditions for maximum adsorption were identified. Similar to this, kinetic models and various isotherms were used to determine the mechanism of the adsorption process and the capacity of the sugarcane bagasse for adsorption. The ability of the biosorbent to remove dye from actual textile waste effluent was also examined. The biosorbent used in this study is reasonably priced, widely accessible, and environmentally friendly. As a result, the best alternative for getting rid of RBV-5R is SCB, which can also be used to reduce water pollution, protect the environment and aquatic life, and eventually shield humans from the harmful impacts of water pollution.

2. Material and Methods

2.1. Chemicals

The dye and all of the compounds were of analytical grade and were used without further purification. The dye RBV-5R (Sigma-Aldrich, Burlington, MA, USA), which has colour index numbers of 18,097 and a maximum wavelength of 559 nm, was bought from Boss Chemical China.

2.2. Instrumentation

All spectrophotometric measurements were performed using a UV/Vis Spectrophotometer (721, FAITHFUL, Cangzhou, China), which had matched 1 cm glass cells. To shake, an orbital shaker (KJ-201BD, China) was employed. The elemental content of the biosorbent was determined using the energy dispersive X-ray (EDX) JSM-IT-100 (JEOL, Tokyo, Japan). The functional group(s) responsible for biosorption was identified using Fourier Transform Infrared Spectroscopy (FTIR) Pres-tigye (Shimazu, Kyoto, Japan). The pH of the solution was checked using a pH metre (Hanna, Woonsocket, RI, USA).

2.3. Collection of Biosorbent (Sugarcane Bagasse)

Sugarcane bagasse from the Peshawar, Pakistan, region was collected and washed repeatedly with distilled water to remove dust particles. Following washing, it was dried completely for a few days in the shade. Dry bagasse was ground into a fine powder, passed through a 600 micron mesh screen, and then deposited in an airtight container for future usage.

2.4. Biosorption Study

The biosorption process was conducted under optimized pH, biosorbent dosage, dye concentration, shaking time, and temperature. In a conical flask, a known volume of the RBV-5R dye solution was mixed with 0.15 g of biosorbent. The sample was placed on an orbital shaker at 100 rpm for 60 min after the pH was brought down to pH 6. The sample was then filtered, and the dye's initial concentration was 20 µg/mL after it had been diluted with 25 mL of distilled water. Absorbance was measured using UV–Vis double beam spectrophotometer at a maximum wavelength of RBV-5R at λ = 559 nm. The percent of adsorption was calculated using the following Equation (1).

$$\% \text{ adsorption} = C_i - C_e/C_i \times 100 \quad (1)$$

where C_i is the initial concentration of dye solution and C_e is the equilibrium concentration after time t. While the adsorption capacity was calculated using Equation (2) [27].

$$Qe = (Ci - Ce)\ V/m \quad (2)$$

The value of Qe (mg/g), represents the amount of dye adsorbed on the surface of adsorbent. Where Ci (ppm) is the initial concentration of dye solution before adsorption, Ce (ppm) is the equilibrium concentration of dye solution, V (L) is the volume of solution, and m (g) represents the mass of adsorbent.

2.5. Preparation of Buffer

0.4 M CH_3COOH, H_3BO_3, and H_3PO_4 acids were dissolved in known volume of distilled water. The solution was then heated and diluted to 500 mL. The pH of the prepared buffer solution was adjusted using 0.1 M NaOH.

3. Results and Discussion

3.1. Characterization of Biosorbent

The surface morphology of SCB was analyzed through SEM (Figure 1a,b). SEM analysis revealed that SCB has a heterogeneous structure and is composed of two parts in general, i.e., fibrous and irregular. The fibrous part is covered under the irregular part. The fibrous particles are present in a linear fold's shape with numerous pores/holes on their surfaces [28]. These small pores/holes and fibres accumulate the dye.

The EDX spectrum showed the elemental composition of SCB (Figure 1c). The fibrous part is mainly composed of some nonmetallic elements, i.e., C, O, Cl, and Si, along with metallic elements, such K, Cu, and Zn. The irregular part is siliceous and contains oxygen. The oxides formation between Si and oxygen results in the solidification of irregular particles [24].

The FTIR spectrum of SCB showed peaks at 3623 and 3757 cm^{-1}, suggesting the presence of (OH) group while the peak at 1710 cm^{-1} indicated a C=O bond of carboxylic acid, normally found in fibrous materials. The peak at 1620 cm^{-1} corresponds to the presence of a conjugated hydrocarbon's carbonyl group (Figure 1d). The carbonyl group plays a vital role in the adsorption of dye as reported in previous studies [24].

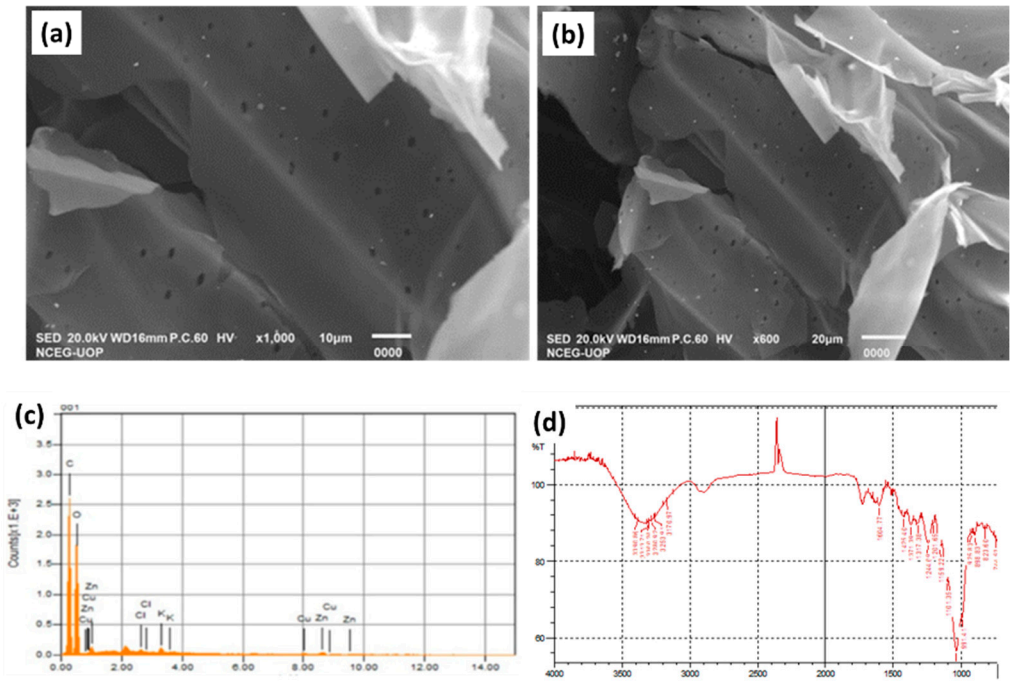

Figure 1. (**a**,**b**) SEM (**c**) EDX (**d**) FTIR spectrum of sugarcane bagasse (SCB).

3.2. Effect of pH on the Adsorption of RBV-5R by SCB with and without Shaking

One of the extensive parameters that affects the biosorption process is pH. The effect of pH on the biosorption of RBV-5R on sugarcane bagasse was studied in the range of 2–10 with and without shaking. Shaking allowed for an 84.40% dye removal at pH 6, but at pH 10, the removal rate was just 74.97%. The amount of dye removed at the same pH without shaking was 68.10%, while under optimized conditions, the amount of dye removed while shaking was 84.40% (Figure 2). An acidic medium has a higher biosorption rate than an alkaline one. The reason for this may be that SCB, which has a positive charge in an acidic medium, is more suited for an anionic adsorbate, such as RBV-5R. The pH 7, or the point at which sugarcane bagasse has a net zero charge, was found to be the point of zero charge for this material [23]. Bagasse has a positive charge in an acidic medium, but RBV-5R is an anionic dye, which results in more biosorption when the adsorbent has a high positive charge, and the adsorbate has a negative charge. However, the reduction in adsorption process in pH more than 7 is caused by the negative charges carried by the SBC and the adsorbate.

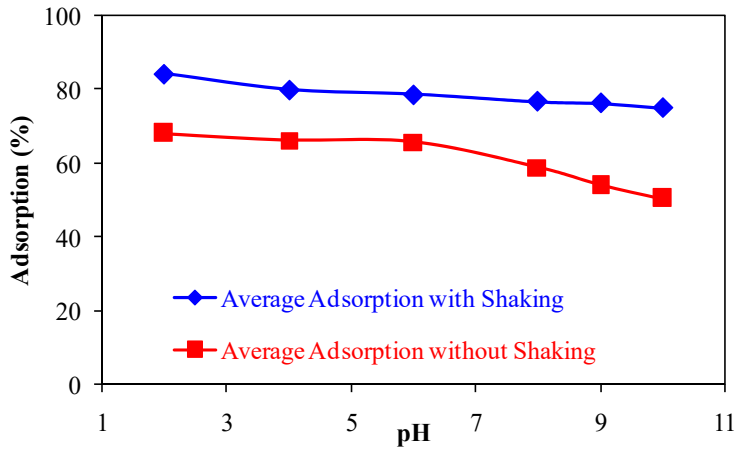

Figure 2. Effect of pH on the adsorption of RBV-5R by SCB at 20 µg/mL RBV-5R, 0.1 g SCB, and 60 min of contact time.

3.3. Effect of Biosorbent Dosage on Adsorption of RBV-5R by SCB

The effect of changing the dose of the adsorbent, from 0.01–0.30 g with shaking, on the elimination of RBV-5R was examined. Figure 3 demonstrates that dye removal increased with the addition of 0.01 g of adsorbent up to 0.15 g, and that desorption occurred when the amount of adsorbent was raised from 0.15 g to 3 g. 43.66% of the dye was eliminated with 0.01 g of biosorbent, while 87.46% was eliminated with 0.15 g. The adsorption capacity (Qe) of SCB was 2.92 mg/g for the initial dose of 20 ppm dye in 25 mL for the 0.15 g adsorbent. Figure 3 depicts the decrease in dye adsorption at a high SCB dose (>0.15 g). RBV-5R was 84.91% absorbed at 0.20 g SCB and 78.29% absorbed at 0.3 g of SCB. The aggregation of the biosorbent, which reduces the number of active sites available for adsorption, may be the cause of this decline in biosorption [29,30]. Initially, the increase in biosorption was caused by the presence of more active sites, since the biosorbent had a larger surface area.

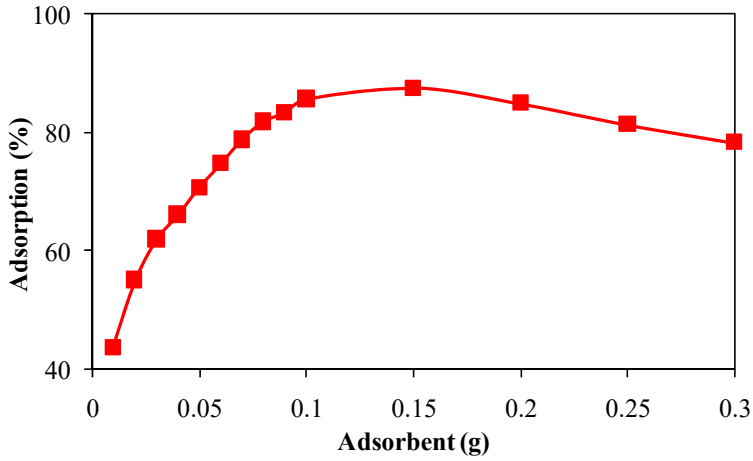

Figure 3. Effect of biosorbent dosage on the biosorption of RBV-5R using SCB at 20 µg/mL RBV-5R, pH set at 6, and 60 min of contact time with shaking.

3.4. Effect of Contact Time on Adsorption of RBV-5R by SCB with and without Shaking

The investigation was conducted for up to 60 min in order to assess the effect of contact time on the adsorption process. In each example, whether there is shaking or not, Figure 4 demonstrates that as the contact duration grows, the adsorption increases and becomes constant at about 60 min. Figure 4 also shows that the dye initially disappears quickly before progressively slowing down. At 10 min, the dye elimination was 44.96% with shaking and 26.86% without shaking, respectively. Similar to this, after 60 min of contact time, the dye removal was 83.89% with shaking and 73.71% without shaking, respectively. For 83.89% RBV-5R adsorption on SCB, the adsorption capacity at equilibrium (Qe) was found to be 2.46 mg/g. The rate of biosorption was fast in the beginning, whichmay be because of the larger surface area of SCB exposure to RBV-5R. After some time, the rate was reduced because of the transportation of dye particles from the exterior to the interior surface of the SCB. Maximum adsorption with shaking is because shaking keeps the biosorbent active and no aggregation takes place; hence, maximum surface area exposure was possible [31].

3.5. Influence of Initial Dye Concentration on the Adsorption Process

Dye concentration also affects the adsorption process. The effect of initial dye concentration on the adsorption of RBV-5R by SCB was studied at varying concentrations of RBV-5R from 10 µg/mL to 100 µg/mL with shaking. Figure 5 displays that the efficiency of biosorbent decreased with an increase in the initial dye concentration. It was observed that 92.22% biosorption of RBV-5R with Qe value of 1.55 mg/g was achieved in 60 min at 10 µg/mL of initial concentration of RBV-5R using 0.15 g of SCB at pH 6 and 5 mL of Robinson–Britton buffer. The Robinson–Britten Buffer contains CH_3COOH, H_3BO_3, and H_3PO_4 acids. Acetate ion, dihydrogen borate, and dihydrogen phosphate ions are the conjugate bases of the selected acids [32]. However, 100 µg/mL RBV-5R was 82.83%

adsorbed by 0.15 g of SCB in 60 min at pH 6. An increase in the initial concentration of dye leads to the saturation of the biosorbent and as a result a decrease in the adsorption was observed (Figure 5). The initial dye concentration increases the mass transfer of dye onto the surface of the adsorbent, and the pores on the surface of the biosorbent are completely occupied by the dye molecules, preventing further accumulation and causing a reduction in biosorption [33].

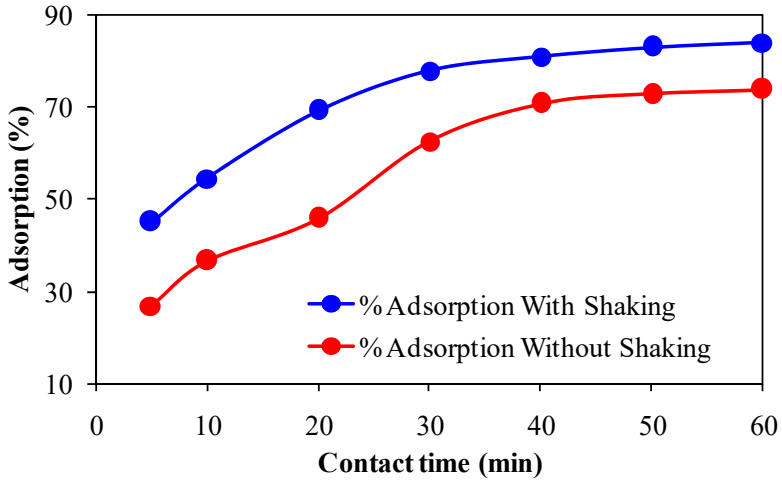

Figure 4. Effect of contact time on the biosorption of RBV-5R using SCB at 20 µg/mL RBV-5R, pH 6, 0.15 g SCB.

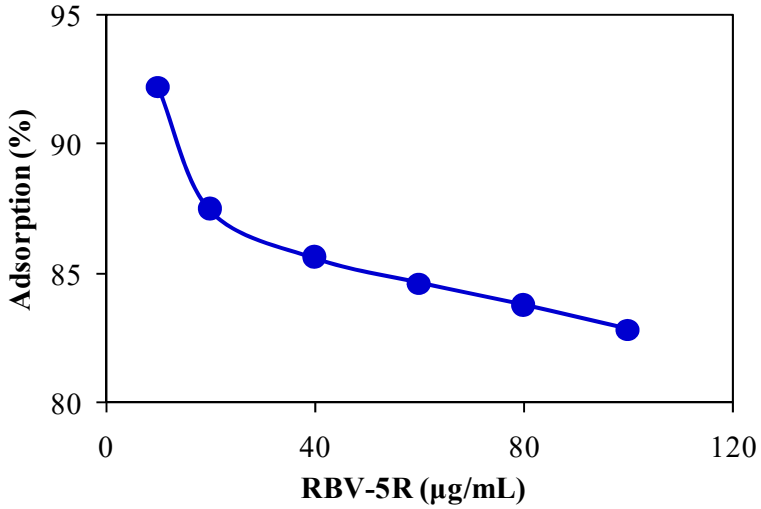

Figure 5. Effect of initial dye concentration on the biosorption of RBV-5R by SCB at pH 6, 0.15 g SCB, and 60 min of contact time with shaking.

3.6. Desorption of RBV-5R from SCB

To investigate the desorption of RBV-5R, the post-filtered biosorbent, i.e., SCB loaded with RBV-5R under optimized conditions was treated with desorbents, such as HCl, NaOH, ethanol, and methanol. The experiments were conducted in triplicate and the percent desorption (%D) for each experiment was calculated by the following Equation (3). The average value of the percent desorption was drawn for comparative analysis (Figure 6).

$$D = \frac{\text{desorbed } \mu g}{\text{adsorbed } \mu g} \times 100 \quad (3)$$

Since RBV-5R is an anionic dye, there are strong electrostatic forces between the adsorbent and adsorbate that has positive charge in acidic medium, which results in the

least amount of desorption in acidic solution and the most in alkali. However, in alkali, the desorption is increased due to the comparable charges of the adsorbent and adsorbate. Since RBV-5R is an organic polar dye, it is stable in ethanol and methanol for extraction, hence treating the biosorbent with these solvents produced the highest percentage of desorption.

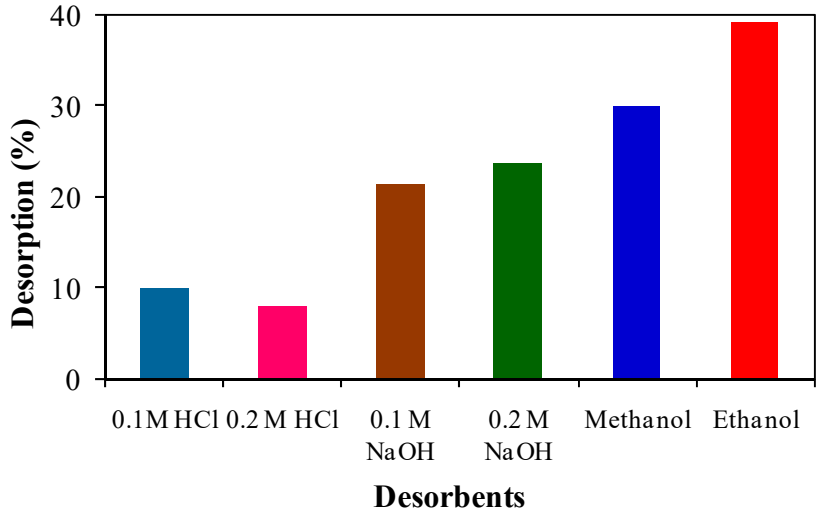

Figure 6. Desorption of RBV-5R from SCB using different reagents.

3.7. Application of SCB for Adsorption of Different Dye Samples

Two separate dye samples were exposed to the prepared biosorbent. The first sample was taken from the effluent of the textile industry, whereas the second was synthetic. Under optimal conditions, the SCB was employed for adsorption, and it was found that 95.78% of the synthetic dye sample and 94.55% of the industrial dye sample were removed in 60 min (Figure 7). As a result, this adsorbent may effectively treat industrial effluent.

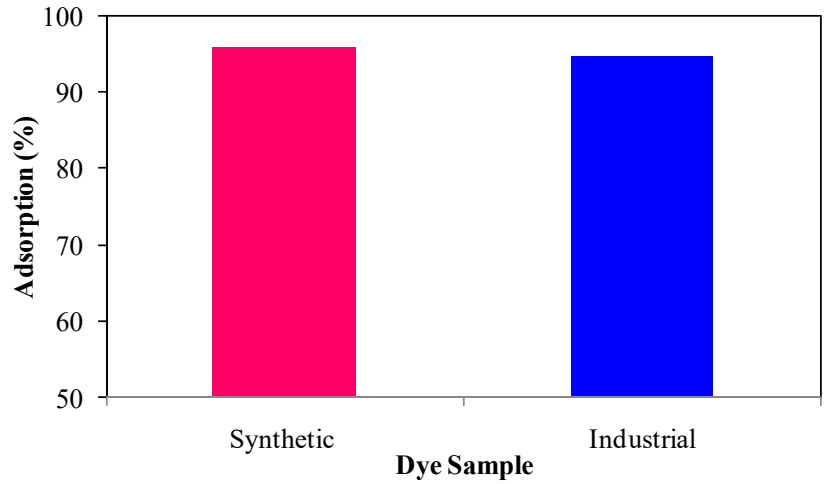

Figure 7. Percent adsorption of RBV-5R dye using sugarcane Bagasse biosorbent for synthetic and industrial dye samples.

3.8. Kinetic Study of the Adsorption of RBV-5R by SCB

The order of the adsorption of RBV-5R dye by SCB was identified by implementing the pseudo-first-order (PFO) and the pseudo-second-order (PSO) kinetic models (Equations (4) and (5)), respectively, and the respective kinetic parameters were determined (Figure 8, Table 1).

$$\ln (qe - qt) = \ln qe - k_1 t \quad (4)$$

$$t/q_t = t/q_e + 1/k_2 q_e^2 \quad (5)$$

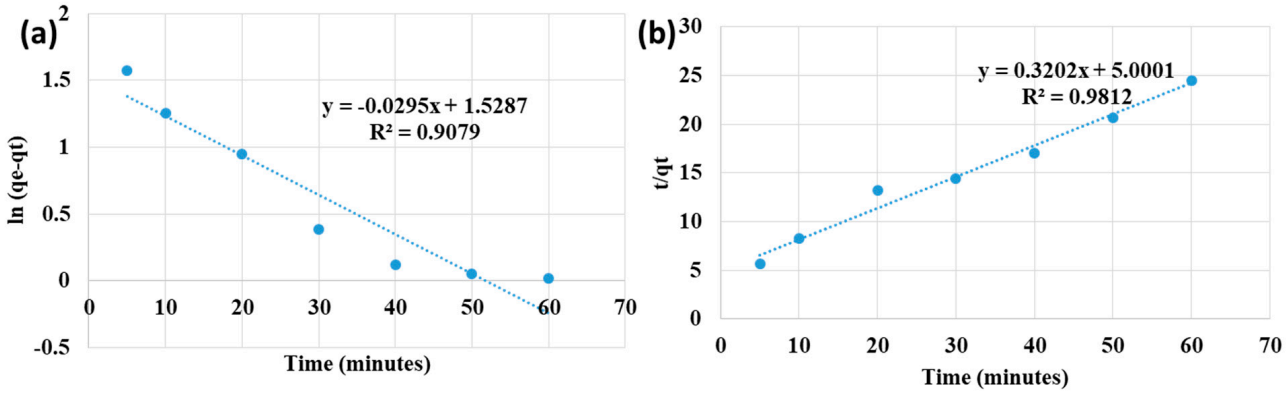

Figure 8. (**a**) Pseudo-first-order kinetic plot. (**b**) Pseudo-second-order kinetic plot.

Table 1. Kinetic parameters calculated for the biosorption of RBV-5R on SCB.

Kinetic Model	Parameters	Value
Pseudo-first-order	Q_e (mg/g) (exp)	2.46
	k_1 (min^{-1})	0.0295
	Q_e (mg/g) (cal)	4.61
	R^2	0.908
Pseudo-second-order	k_2 (g/mg min)	0.0205
	Q_e (mg/g) (cal)	3.12
	R^2	0.98

The time course data fits the pseudo-second-order kinetic model because, in comparison to other model (Figure 8a), the R^2 value of the linear regression line for the pseudo-second-order Equation (5) is approximately 1 (Figure 8b). The results demonstrate that the adsorption of RBV-5R on the surface of SCB is controlled by second-order kinetics rather than the first-order kinetics and yields a comparable value of the Qe, i.e., 3.12 mg/g, while the experimental value is 2.46 mg/g.

3.9. Effect of Temperature on the Adsorption of RBV-5R by SCB

The effect of temperature on the adsorption process of RBV-5R by SCB was studied in the range of 30–100 °C to determine the thermodynamic parameters of activation. Figure 9 demonstrates the dual effects of temperature on adsorption. At low temperatures, as the temperature rises from 30 to 60 °C, both Qe and the percent adsorption increase, but at higher temperatures, both Qe and the percent adsorption decrease in value. When temperature was high, between 60 and 100 °C, the Arrhenius and Eyring plots both showed that adsorption was an endothermic process, and when temperature was low, between 30 and 60 °C, it was an exothermic process [34]. Figure 10 depicts two RBV-5R adsorption phases in relation to temperature range. The reason why the percentage of adsorption and adsorption capacity are slightly less in value at low temperatures, such as 30 °C, is likely due to the fact that we used a fixed time period of 60 min to assess the dye's concentration, under the assumption that both adsorption and desorption were in equilibrium. However, in reality, the equilibrium time might have been reached sooner than 60 min and the desorption might have already begun, which would have resulted in a slightly lower percent adsorption and Qe. The exothermic adsorption process slowed down as the temperature rose, even though the equilibrium time increased to about ≥60 min. We consequently noticed a rise in Qe and percent adsorption up to 60 °C. That is the threshold temperature at which further temperature increases cause the rate of adsorption to increase, leading to the equilibrium between adsorption and desorption being reached in <60 min. As a result, the low values of the percent adsorption and Qe were seen with increasing temperature up to 100 °C, maintaining adsorbate and adsorbent shaking for up to 60 min

already led to start desorption. Figure 10 displays the activation energy, the enthalpy of activation, and the entropy of activation for 60 min of contact time between adsorbate and adsorbent when Qt is taken to be equal to Qe and RBV-5R adsorption–desorption on SCB is assumed in an equilibrium state. The activation parameters were calculated using the Arrhenius and Eyring Equations (6) and (7), and the pseudo-second-order rate constant was determined by using the pseudo-second-order kinetic model (Equation (5)) at each temperature. Maximum adsorption at ambient temperature may also be a result of the adsorbent swelling effect, which causes more dye molecules to penetrate the adsorbent surface because dye molecules are more mobile at high temperatures [35].

$$\ln k = \ln A - \frac{E_A}{R} \cdot \frac{1}{T} \quad (6)$$

$$\ln\left(\frac{k}{T}\right) = \ln\left(\frac{k_B}{h}\right) + \frac{\Delta S^{\#}}{R} - \frac{\Delta H^{\#}}{R} \cdot \frac{1}{T} \quad (7)$$

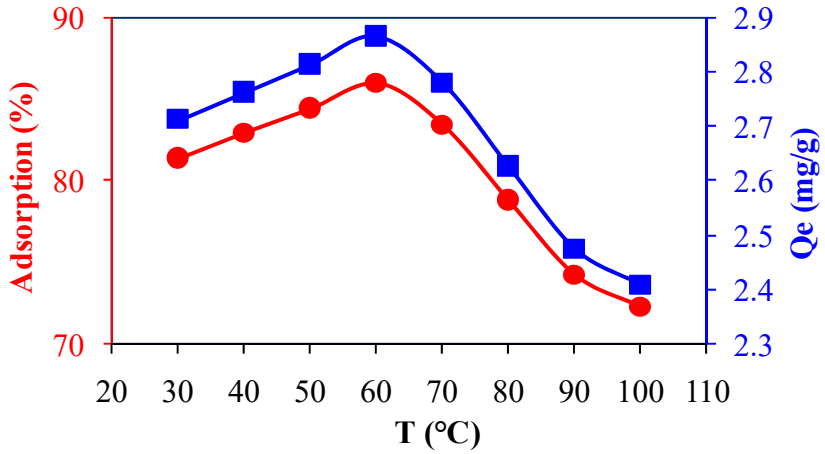

Figure 9. Effect of temperature on the biosorption of RBV-5R using SCB at 20 µg/mL RBV-5R, pH 6, 0.15 g SCB, and contact time of 60 min.

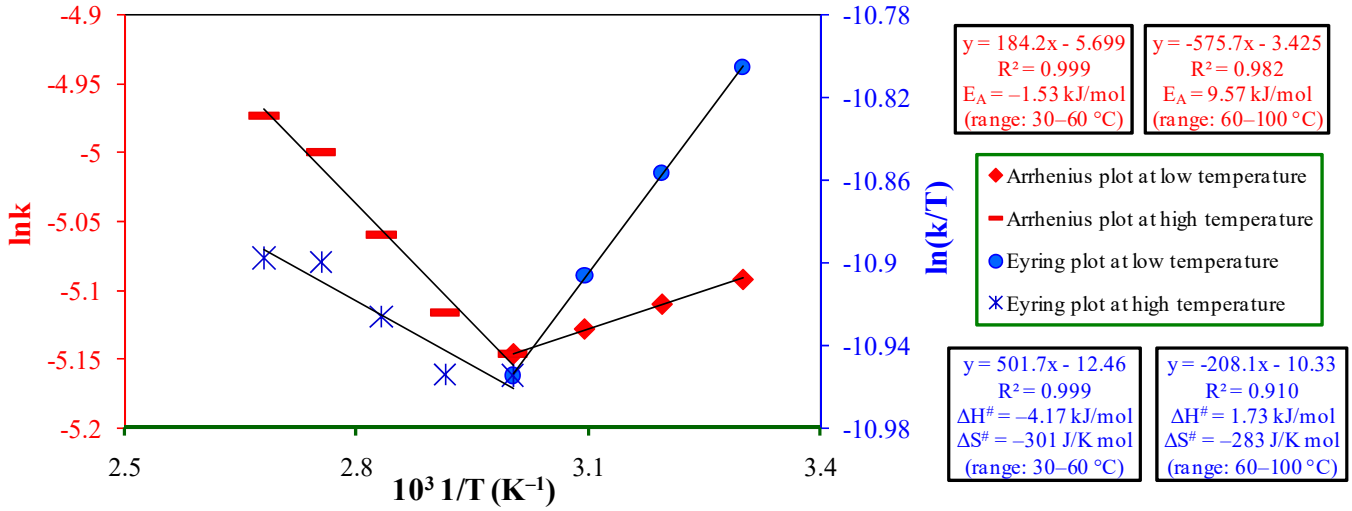

Figure 10. Thermodynamic parameters of activation for the adsorption of RBV-5R by SCB.

Equation (8) was used to obtain the values of Gibbs free energy of activation ($\Delta G^{\#}$) for the selected exothermic and endothermic temperatures. At 30 °C, the value of $\Delta G^{\#}$ was found to be 87.03 kJ/mol and at 80 °C, it is 101.63 kJ/mol, indicating that both processes are non-spontaneous, since we have to mix the adsorbent and adsorbate before the adsorption can begin. Processes that occur automatically and without external triggers are referred

to as spontaneous. The value of $\Delta G^{\#}$ at 30 °C exhibits the dye's affinity for adsorption at low temperatures, while $\Delta G^{\#}$ at 80 °C illustrates the substantial energy input required to continue the adsorption process.

$$\Delta G^{\#} = \Delta H^{\#} - T\Delta S^{\#} \quad (8)$$

3.10. Adsorption Isotherm for the Adsorption Process of RBV-5R by SCB

Freundlich and Langmuir adsorption isotherms were applied to identify the adsorption mechanism of the selected dye on the selected biosorbent in aqueous solution.

3.10.1. Freundlich Adsorption Isotherm

For non-ideal adsorption, the Freundlich isotherm model is used, and adsorption of heterogeneous surfaces is described by this isotherm using Equation (9)

$$\log q_e = \log K_F + 1/n \log C_e \quad (9)$$

The Freundlich adsorption isotherm was drawn for SCB by plotting log q_e versus log C_e (Figure 11a), where n and K_F are the constants that depend on the nature of the adsorbate and adsorbent. The value of n for the biosorption of RBV-5R on SCB was 1.38 and K_F = 1.69. It was found that the biosorption process is favorable and dye's multilayer formation takes place [36]. The value of R^2 is 0.99 for the Freundlich adsorption isotherm, which indicated the model is best fitted to the present study.

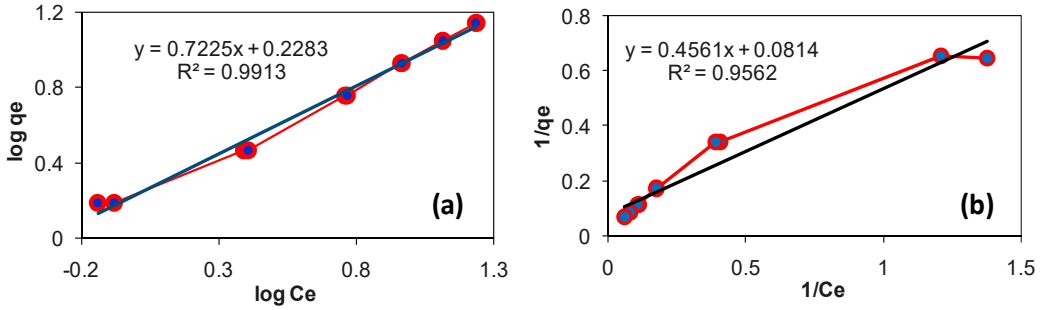

Figure 11. (**a**) Freundlich adsorption isotherm and (**b**) Langmuir adsorption isotherm for adsorption of RBV-5R on SCB.

3.10.2. Langmuir Adsorption Isotherm

The Langmuir adsorption isotherm is one of the widely used adsorption isotherms for the adsorption of a solute from the liquid solution. The Langmuir adsorption isotherm is suitable forsingle layer adsorption by the homogeneous surface of the adsorbent. The Langmuir isotherm is expressed by Equation (10).

$$\frac{1}{qe} = \frac{1}{K_L.qmax}.\frac{1}{Ce} + \frac{1}{qmax} \quad (10)$$

The value of K_L (Langmuir constant related to the energy of adsorption) was found to be 0.178 L/mg and maximum adsorption capacity (qmax) was determined to be 12.29 mg/g (Figure 11b). The R^2 value for Langmuir adsorption isotherm is 0.9562. The separation factor R_L or the equilibrium parameter was also determined by implementing Equation (11) and found to be 0.219. The value of R_L indicates the shape of the isotherm either linear, irreversible, unfavourable, or favourable, such that when $R_L > 1$ (unfavorable), $R_L = 1$ (linear), $0 < R_L < 1$ (favourable), and $R_L = 0$ (irreversible). In this instance, R_L is smaller than 1 and indicates that the RBV-5R's favourable adsorption on SCB. While being comparably well fitted, the Freundlich adsorption isotherm has the best R^2 value when we compare the two isotherms.

$$R_L = \frac{1}{1 + K_L Ci} \quad (11)$$

3.11. Mechanism of Adsorption of RBV-5R on SCB in Aqueous Medium

The SCB primarily contains carbonyl groups, which electrostatically interact with the selected dye's azo group (–N=N–), resulting in biosorption. Figure 12 shows a graphical representation of the biosorption process of RBV-5R.

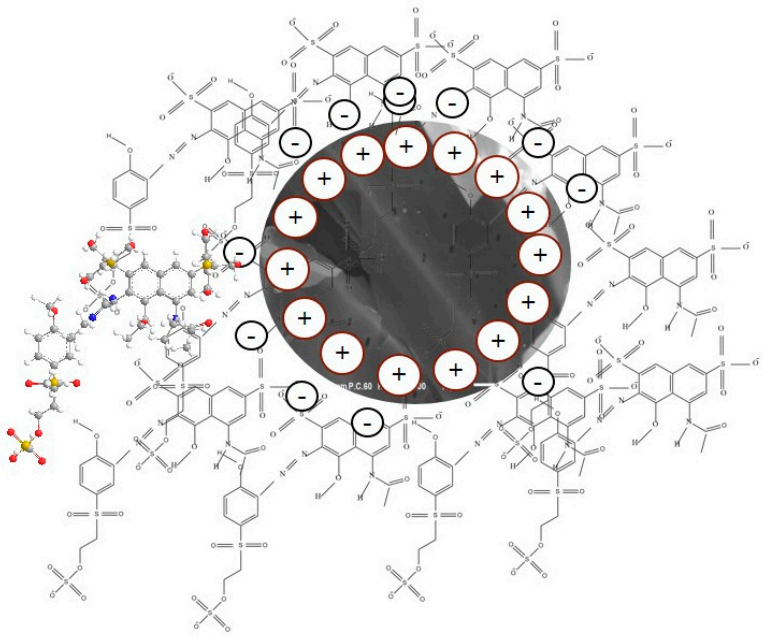

Figure 12. Mechanism of the adsorption of RBV-5R on SCB in aqueous medium.

3.12. Comparative Analysis of the Adsorption Efficiency of SCB with Other Adsorbents

It has been observed that a variety of adsorbents and biosorbents can remove RBV-5R. Table 2 includes a comparative data where the suggested biosorption techniques using SCB produce significant results in terms of time and selectivity toward the selected dye. Similar to this, Table 3 compares the SCB's adsorption capability for several contaminants, including RBV-5R.

Table 2. Comparative analysis of the RBV-5R removal by SCB and other adsorbents.

Dye	Technique	Adsorbent	Time	% Adsorption and Adsorption Capacity (mg/g)	References
RBV-5R	Adsorption	Rice Hulls	240 min	74% 21.73	[37]
RBV-5R	Adsorption	Egg Shell	120 min	95% 9.94	[7]
RBV-5R	Adsorption	SPS-200 (sawdust-based)	5 min	100% 453.3	[38]
RBV-5R	Adsorption	Cocoa Based Husk	300 min	81% 1250	[39]
RBV-5R	Biosorption	Sugarcane Bagasse	60 min	95% 2.46	Present work

Table 3. Comparative analysis of the adsorption capacity of SCB for different adsorbates.

Dye	Technique	Adsorbent	Time (min)	% Adsorption and Adsorption Capacity (mg/g)	References
Methyl Red	Adsorption	Treated Sugarcane Bagasse	120	78%	[2]
Basic Blue 3	Adsorption	Quartinised Sugarcane Bagasse	480	34.32% 37.59	[30]
Malanchite Green	Adsorption	Chemically Modified Sugarcane Bagasse	30	89% 34.48	[30]
Congo red	Adsorption	Sugarcane Bagasse	20	80% 4.43	[40]
Acid Balck-234	Adsorption	Polymeric biocomposites (Polyaniline/ Sugarcane Bagasse (Pan/SB)	60	52.6 62.5	[41]
Reactive Orange 16	Adsorption	Quartinised Sugarcane Bagasse	480	83.33%	[42]
Eurozol Navy Blue	Adsorption	Sugarcane Bagasse	30	70% 27.54	[43]
Methylene Blue	Adsorption	Sugarcane Bagasse biochar	60	95.47 30.13	[44]
Brilliant Red 2BE	Adsorption	Chemically Modified Sugarcane Bagasse	720 (12 h)	70.3% 73.6	[45]
Remzaol Brilliant Violet-5R	Biosorption	Sugarcane Bagasse	60	95% 2.46	Present work

4. Conclusions

SCB is recognized as a potential low-cost adsorbent for the removal of RBV-5R with an adsorption capacity of 2.46 mg/g. The biosorption of RBV-5R was influenced by a variety of variables, including pH, contact time, adsorbent dose, temperature, and initial dye concentration. The results showed that the RBV-5R biosorption process is pH-controlled, with the highest biosorption being observed at pH 6. The adsorption of RBV-5R increases with contact time and the equilibrium was established within 60 min. The adsorption is particularly temperature dependent, and it exhibits two phases in the low and high temperature ranges, according to the temperature effect. At low temperatures, adsorption is an exothermic process, whereas at high temperatures it is an endothermic one. Thermodynamic considerations demonstrate that rapid adsorption rates are more easily attained at lower temperatures. In the interim, the adsorption followed the Freundlich adsorption isotherm and a pseudo-second-order kinetics. Additionally, the adsorbent was tested for actual industrial wastewater and the outcomes were promising. As a result, SCB-based adsorbents may be an excellent option for wastewater treatment to efficiently preserve water resources.

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