Biosorption of Toxic Reactive Blue Textile Dye from Effluent Water Using Immobilized Biomass Based Adsorbent

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ABSTRACT

The present research employed immobilized *Canna indica* beads (CIBs) to obtain maximum degradation of highly toxic Reactive Blue Dye (RBD), predominantly used in textile industry. The CIBs were characterized using FTIR and SEM-EDX analysis. A batch adsorption study was conducted to measure the removal of harmful RBD dye. Different factors were examined in the biosorption technique to achieve the maximum level of toxic dye elimination, such as adsorbent-solute interaction time (5-120 min), solution pH (2-10), adsorbent dose (25 to 250 mg/100 mL), RBD concentration (50-250 mg/L), and temperature (30-60°C). Removal of 99.96% of RBD was successfully achieved at the optimum pH 7, RBD concentration of 50 mg/L, adsorbent dosage of 150 mg/100 mL, a temperature of 303 K, and 60 min of interaction time. The Langmuir isotherm and pseudo-second-order (PSO) kinetic model data have been found to be an ideal match compared to the Freundlich isotherm and pseudo-first-order (PFO) kinetic model. The maximum adsorption capacity onto CIBs biosorbent was found to be 70.49 mg/g. It was noticed that the chemical reaction occurred naturally and released heat during the process which denoted an exothermic reaction. These results shown that the adsorption of RBD removal is efficient using prepared adsorbent from *Canna indica* root tubers. Therefore, these CIBs could be used for other toxic dyes and heavy metals from industrial wastewater.

1. INTRODUCTION

Water is a precious resource that supports human progress and all living microorganisms life on Earth. Aquatic organisms are depend on water bodies for survival. Textile industry dyes are incredibly poisonous to aquatic environments, which prevent light and oxygen from reaching the water and it can reduce photosynthesis (Sivalingam et al., 2019; Sivalingam and Sen, 2019). The textile business is massive, employing around 35 million people throughout the globe, and earns almost $1 trillion in sales annually (Desore and Narula, 2018). Discharging untreated effluents from textile industries into water bodies is one example of anthropogenic activities that pollute and make water unusable (Bhatia et al., 2017). Fabric, paint, and pigment dyes have been used over millennia in the textile industries, and they have many more uses outside just coloring the fabric (Kosaiyakanon et al., 2020). Around one million distinct varieties of dyes are available in the market, and they are crucial in the production of textiles, paints, and pigments (Ali, 2010). Dyes are partially or entirely saturated chemical substances that absorb light to generate color. As much as 50% of the colors used never make it onto the fiber and act as contaminants in the liquid phase (Rehman et al., 2020; Yuan et al., 2020). Hence need to purify the dye-colored industry water that can be used as treated water for industry and humans' day-to-day activities.

Several methods for removing pollutants from effluents are available including adsorption, cementation, ion exchange, membrane filtration, precipitation, solvent extraction, evaporation, chemical oxidation, and electrochemical processes and so on. From these methods, adsorption is highly effective one for effective wastewater treatment since

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adsorbents are inexpensive and available easily (Kyzas and Kostoglou, 2014; Midha and Dey, 2008). Adsorption is used for a large-scale method of separation, purification, and detoxification process which has been increasing significantly last few decades; and also it removes impurities from gasses and liquids with their color, odor, and isolation (Wang et al., 2018). The interaction force of affinity between adsorbent and adsorbate in the adsorption is most significant in this ternary system (Gunarathne et al., 2018; Sivalingam and Sen, 2019). Biosorbents can refer to either living or non-living biomass, including plants, algae (cyanobacteria, unicellular and multicellular microalgae), bacteria, and fungi. A few examples of dead biomass are forest by-products, fibers, peat, rice hulls, chitosan polymer, and agro-food waste. Most places have access to biosorbents, inexpensive filter materials with excellent binding capacity and selectivity (Gupta et al., 2015).

Commercial activated carbons (CAC) are generated from agro-industry waste and by products from different industry, whereas commercial ion-exchange resins are made from natural substances such as clays and red mud. These commercial substances are the traditional preferable adsorbents for pollutant degradation, but their cost-effectiveness limits to use huge amount in industry level. Commercial carbons manufactured from more expensive feedstocks that are often not worth to expense, even though they could be effective in specific pollution control and environmental applications. Because of their low-cost and incredible efficiency, developing the green adsorbents from waste sources like industrial, agricultural, and forest product (Bhatia et al., 2017; Rehman et al., 2020).

Sodium alginate is a brown algal polymer that occurs naturally, and it is unique because of its high biocompatibility, biodegradability, and renewability. High adsorption affinity is another feature since it has numerous hydroxyl and carboxyl groups. It has been demonstrated that sodium alginate's carboxyl and pyranose oxygen atoms may form stable five-membered chelates rings, which could be exploited as requisite sites in adsorption process (Paudyal et al., 2013). Sodium alginate has weak mechanical power, poor thermal stability, and short shelf life (Wang et al., 2018). Plants can aid in the breakdown of human and animal wastewater and removal of disease-causing germs and contaminants. Their potent to adsorb various contaminants has been acknowledged globally in water treatment sector (Ansari et al., 2020). *Canna indica*, also known as Indian shot, is a native of America and a member of the Cannaceae family. *Canna indica* is widely used as an adsorbent, food, and medicine and is available in abundance. When it is grown on a microscopic scale, this plant can absorb heavy metals, including lead, chromium, zinc, nickel, and cadmium (Dixit et al., 2014).

The naturally occurring bioplastics, and chitin are nearly equal to the cellulose characteristics. It has several valuable properties for modification during derivative synthesis because of its lengthy polymeric chain as a polysaccharide. N-acetyl-D-glucosamine is associated by b-1, 4 units that share many chemical characteristics with cellulose, exception of the acetamido group at carbon-2 in cellulose (Karthikeyan et al., 2005). Crustacean exoskeletons, especially those of shrimp and crabs, are rich in chitin (Gonzalez et al., 2018). It has several eco-friendly qualities, such as biodegradable, biocompatible, non-toxic, porous, and light respectively. Shrimp shells are considered large-scale waste worldwide, and many developing countries dump them directly into the sea. Chitin can be extracted directly from these shells in large quantities using a simple and cost-effective process (Elieh-Ali-Komi and Hamblin, 2016). However, the inability of chitin to dissolve in water limits their use on a large scale (Hamed et al., 2016). This study aims to prepare CIBs from *Canna indica* root tuber as an adsorbent and analyse with FTIR and SEM techniques. The prepared adsorbent will use to produce clean water from RBD dye contained wastewater.

2. METHODOLOGY

2.1 Chemicals and materials used

Reactive Blue Dye was procured from Sigma-Aldrich. All other essential chemicals used in this study, including HCl and NaOH, were procured from HiMedia Laboratories Pvt. Ltd., Mumbai, India. To produce immobilized beads, *Canna indica* plant saplings were sourced from the Kaivalya Garden Center located in Anna Nagar, Chennai, Tamil Nadu, India. *Canna indica* is a frequently employed plant for the remediation of industrial wastewater.

2.2 RBD aqueous solution preparation

RBD is one of the toxic dye present in textile industry, with a 637.43 g/mol molecular weight and $C_{23}H_{14}Cl_2N_6O_8S_2$ molecular formula. The RBD stock solution of 1.0 L was set by dissolving 1.0 g of dye in of double-distilled water. The stock solution was diluted to the appropriate working solution concentration (between 10 and 100 mg/L) in double-distilled water for the batch adsorption experiment. 0.1 N HCl and 0.1 M NaOH were used to modify the pH of the working solutions.

2.3 Adsorbent preparation

The tubers of the *canna indica* plant were dried for three hours at 80°C after peeling. It was grounded using a mortar and pestle to make a fine powder and stored under sterile conditions for later use. 1.0 g to 4.0 g powder was combined with 3% sodium alginate and chitin, respectively, dissolved in acetic acid. The required 2-3 mm size of the immobilized *Canna indica* root tuber beads was achieved by slowly infusing sodium alginate and chitin in a 4% (w/v) of calcium chloride solution. To enhance the mechanical stability, CIBs were applied in curing process with 4% of calcium chloride solution for 4 h. The beads were continuously washed in double distilled water and filtered using Whatman 42 size filter paper up to reaching pH 7. Later, the characterization and adsorption process was carried out with prepared immobilized beads.

2.4 Adsorbent characterization

The different analysis methods are used to identify the properties of prepared CIBs adsorbent. FTIR (Fourier Transform Infrared) spectroscopy techniques are used to find the availability of various functional groups present in the adsorbent and using SEM (Scanning Electron Microscopy) techniques the surface morphology of the immobilized beads were investigated.

2.5 Batch adsorption

The adsorption process of RBD was performed in a batch experiments. The several parameters are influencing adsorption technique, including pH, RBD concentration, CIBs dose, contact time, adsorbent dose, and temperature were examined in a series of adsorption trials. This adsorption was performed with varying one parameter to evaluate and rest of the parameter has been fixed. Numerous experimental conditions were used to check the optimum results as follows: initial RBD dye concentration: 50 to 250 mg/L, adsorbent dosage: 25 to 250 mg/100 mL, the solution pH: 2 to 10, temperature: 303 to 333 K, contact time: 5 to 120 min. The required amount of immobilized beads were added in 100 mL of RBD solution which placed in the incubator shaker at the speed of 120 rpm. Supernatant solution was collected using Whatman 42 filter paper after the stipulated time, and dye removal was calculated by measuring the absorbance value of 580 nm (Shimadzu: UV-1900i double-beam spectrophotometer). The percentage of RBD removal was calculated using the following Equation (1),

$$\% \text{ Removal} = \frac{C_o - C_e}{C_o} \times 100 \qquad (1)$$

Where; C_0 and C_e are RBD's initial and final solution (mg/L), respectively.

2.6 Equilibrium adsorption isotherm

The batch adsorption experiment was conducted between 50 to 250 mg/L RBD concentration. 100 mg/100 mL of immobilized beads were placed in each flask, then incubated in the shaker incubator at 303 K temperature for 60 min. Following the specified incubation period, the supernatant solution was collected from filteration process and measured UV Vis-spectroscopy by 580 nm absorbance. The equilibrium adsorption of RBD onto the immobilized beads can be calculated using Equation (2) (Gonzalez et al., 2018):

$$q_e = (C_i - C_e)\ V/m \qquad (2)$$

Where; q_e is the capacity of adsorption (mg/g), C_i and C_e are initial and equilibrium RBD concentrations (mg/L), V is volume of RBD solution (L), and M is the weight of CIBs used (g) (Assimeddine et al., 2021). Equilibrium isotherms are commonly employed for assessing an adsorbent's capacity, surface characteristics, and binding affinity. Langmuir and Freundlich isotherm models were utilized to know monolayer (homogeneious) and multilayer (heterogeneous) sites on the immobilized beads. The adsorption isotherm parameters, adsorption capacity (mg/g) and correlation coefficient [R^2], were calculated using a non-regression analysis in ORIGINPRO 9.0 software.

2.7 Adsorption kinetics study

The adsorption kinetic study reports the uptake of RBD from aqueous solutions with constant concentration. Adsorption kinetics were carried out in RB flasks containing 100 mL of 100 mg/L RBD concentration along with 100 mg/100 mL of immobilized CIB at 303 K in a shaking incubator for

60 min. After 60 min, the solution was filtered, and a colorimeter was used to measure the absorbance of the dye on the immobilized beads at 580 nm. The quantity of RBD adsorbed on the immobilized beads was determined using Equation 2 (Katheresan et al., 2018). The adsorption rate can be expressed as PFO, PSO and mixed adsorption kinetic models.

2.8 Thermodynamic study

The adsorption of RBD onto immobilized CIBs was subjected to thermodynamic investigation. At 303 to 333 K temperatures, the thermodynamic study was conducted with 100 mL of 100 mg/L RBD concentration and immobilized CIBs. Gibbs free energy (ΔG°), change in enthalpy (ΔH°), and change in entropy (ΔS°) are the crucial thermodynamic factors could be calculated using the given equation in Table 3.

3. RESULTS AND DISCUSSION

3.1 Immobilized CIBs characterization

The CIBs adsorbent analysis of before and after adsorption process is important to get the changes occurred on the prepared adsorbent. The FTIR analysis was conducted with wavenumber from 400 to 4,000 1/cm region, as shown in Figure 1. Figure 1(a) can be seen that there are four significant peaks formed at different wavenumbers (1,087, 1,621, 3,102, and 3,840 1/cm). The C-O stretching in ether is formed at 1,087 and 1,032 1/cm peaks. Because of C=O stretching vibration, the peaks at 1,621 are produced (Amide I). Figure 1(b) shows distinct significant peaks at various wavenumbers: 1,032, 1,612, and 3,514 1/cm. The vibration mode of the strong hydrogen-bonded O-H stretching of the alcohol is seen at 3,514 1/cm, similar spectra has been reported by Venkatesh and Arutchelvan (2020).

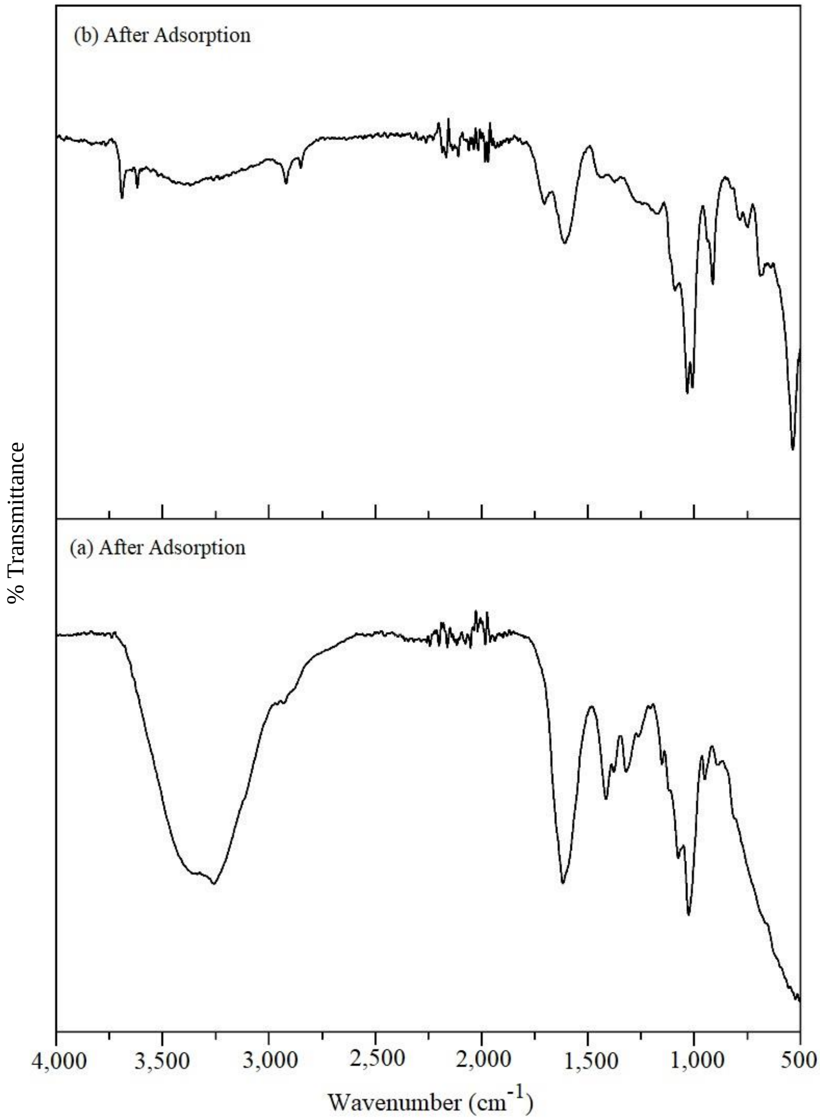

Figure 1. FTIR spectra of CIBs (a) before adsorption, (b) after adsorption

As adsorption process takes place at the surface of an adsorbent, its very sensitive to surface features, such as the pore size distribution. Figure 2(a-b) displays the morphology images of SEM analysis for immobilized CIBs taken prior to adsorption. Figure 2(c-d) shows the morphology images of the SEM study of immobilized CIBs after adsorption. The SEM images captured the both before and after adsorption process to find the changes in the CIBs surfaces clearly and distinctly (Wang et al., 2018). When the surface smoothness is examined, can be seen from Figure 2(a-b) possessing more pores, bigger cavities, and nonporous solid material. During the adsorption process the RBD molecules were fills out in fewer pores and reduces pore size, as demonstrated in Figure 2(c-d). These results are accepted that the immobilized CIBs have prevalent adsorption limits concerning the adsorption of RBD molecules. Elemental analysis also obtained from SEM where can be found the weight and atomic % of various elements. Figure 2 clearly depicting the Ca, Cl, and Na percentage changes after the adsorption process which has confirming the RBD dye molecule interaction and CIBs particle.

3.2 Optimization of adsorption process

In adsorption process, the contact time is a crucial parameter since it provides insights on the kinetics required to complete interaction with the CIBs surface. All other factors were held constant while the impact of contact time was examined by varying the intervals from 5 to 120 min at room temperature with a pH of 7 in a rotary shaker at 120 rpm and 150 mg/100 mL adsorbent dose, can be seen in Figure 3(a). Figure 3(a) illustrates the removal percent of RBD dye at various contact time. The adsorption increased to a more significant proportion as the interating duration has been monitored between 5 to 120 min, and observed that after 60 min there was no changes occured. At 60 min of treatment the RBD removal from an aqueous solution was adsorbed 99.20%. This is caused by the early presence of highly active sites and the destabilization of the driving force. As the duration rises, the dye's ability to bind to the active sites becomes less and less until it reaches the equilibrium (Venkatesh and Arutchelvan, 2020; Sun et al., 2013).

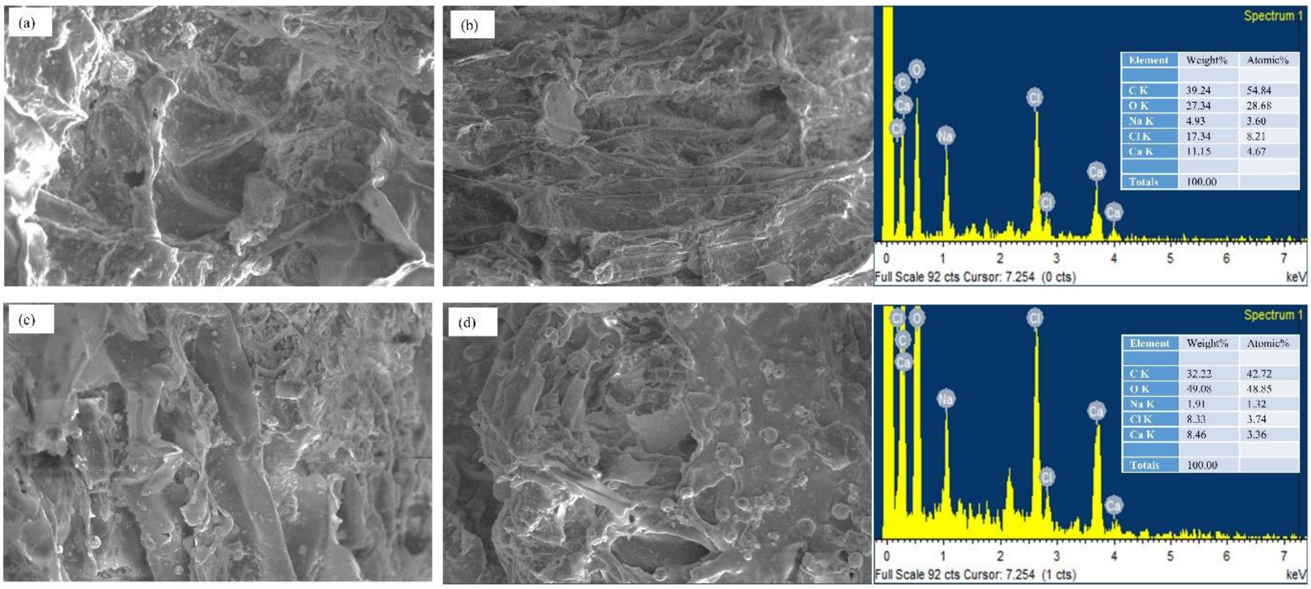

Figure 2. Surface morphology results of immobilized CIBs (a-b) before adsorption, (c-d) after adsorption

The removal of RBD varies dosages of suspended CIBs is shown in Figure 3(b).The amount of the adsorbent used has a significant impact on the method used to calculate an adsorbent capacity for a certain amount of adsorbent. The working experiment is done at room temperature at pH 7 in a rotary shaker operating at 120 rpm. This condition is ideal for the thorough distribution of particles and molecules in an aqueous solution. For the analysis, various adsorbent dosages ranging from 25 to 250 mg/100 mL. The adsorbent dosage with a 150 mg/100 ml yielded of 99.96% RBD dye adsorption because of availability of vast pores, adsorbent's capacity, and surface characteristics (Sivalingam and Sen, 2019). The % removal of dye that is adsorbed onto immobilized CIBs is significantly influenced by the RBD's initial concentration, as shown in Figure 3(c). Optimal results were obtained when the process was performed at standard working settings of 303 K, pH 7, 120 rpm agitation, and 60 min of contact time. From 25 to 250 mg/L RBD concentrations were accounted to conduct the experiment with an intervals 50 mg/L. As shown in Figure 3(c) RBD removal has achieved of 99.04% at 50 mg/L solution. Additionally, it was noted that the original dye concentration increases the rate of RBD removal from an aqueous solution got reduced (Venkatesh and Arutchelvan, 2020).

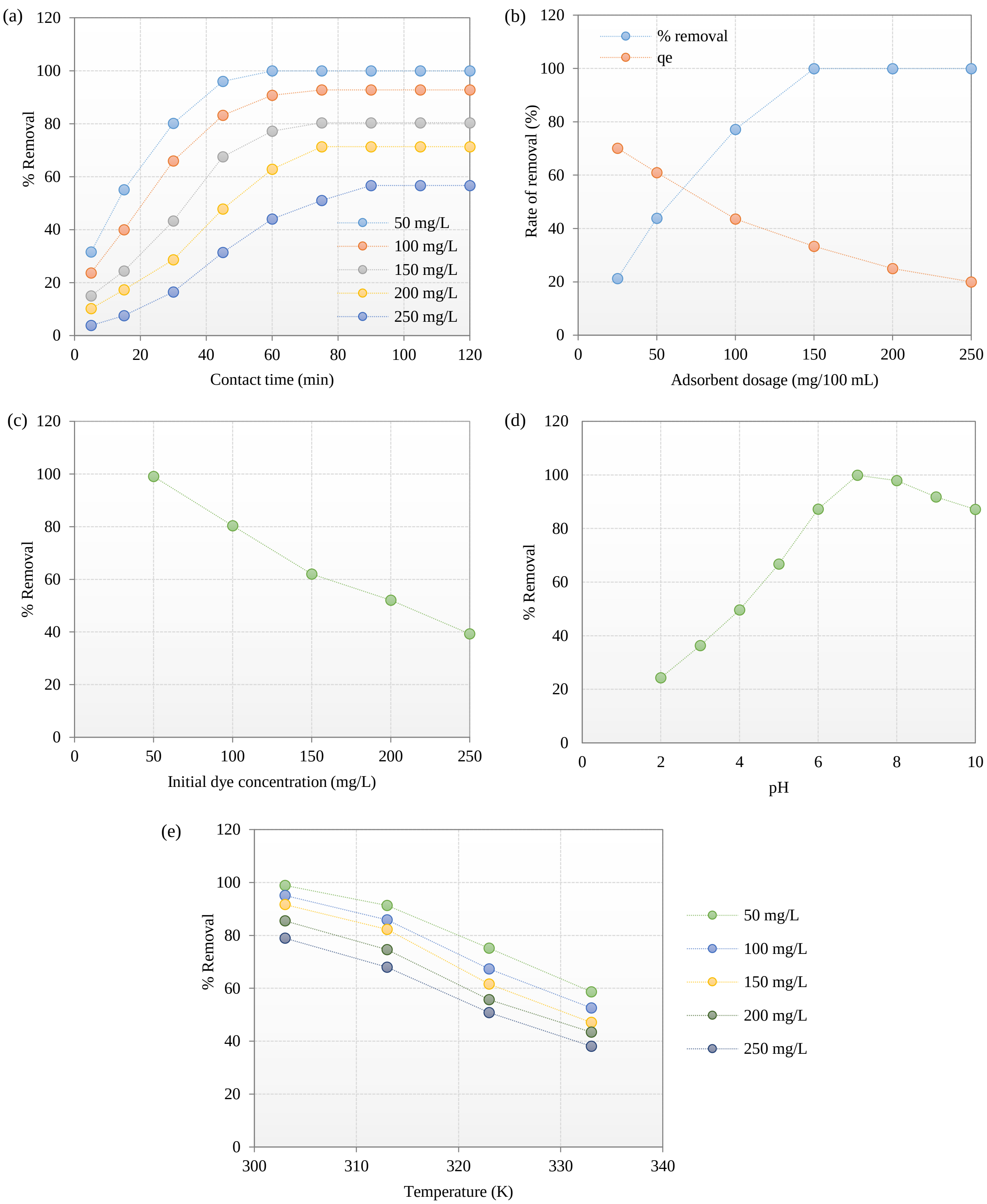

Figure 3. Removal of RBD, (a) contact time, (b) biosorbent dosage, (c) dye concentration, (d) pH, (e) temperature

Figure 3(d) shows the study of pH optimization for dye removal. The RBD concentration in the aqueous solution was studied by varying the pH from 2 to 10 at 303 K, 120 rpm, with the optimized dosage of adsorbent and contact time. As the pH of the solution increased from 2 to 7, the proportion of adsorbed dye increased, and the final removal was 98.88% at the optimum pH of 7. The CIB-stabilized RBD adsorption temperature dependence is shown in Figure 3(e). Varying temperatures such as 303, 313, 323, and 333 K were used for the analysis. As shown in Figure 3(e), a minimum quantity of the RBD was adsorbed by the immobilized CIBs as the temperature increased. This is due to the fading attraction between the dye and the immobilized beads, and the process suggests that it is exothermic nature (Kosaiyakanon et al., 2020).

3.3 Adsorption isotherm

The isotherm study giving better clarity as interaction occurs between the immobilized CIBs and the RBD in the liquid medium. Adsorption isotherms, often expressed as the ratio of the amount adsorbed to the amount still in solution, describe the equilibrium connection between an adsorbent and an adsorbate at a specific temperature. Two different models were used to examine the equilibrium adsorption isotherm, namely Langmuir and Freundlich which often called the two-parameter adsorption isotherms (Venkatesh and Arutchelvan, 2020). The correlation coefficient (R^2), extreme monolayer ability of adsorption (q_m), and error values like SSE and RMSE were assessed using the ORIGINPRO 9.0 software utilizing the experimental data and non-linear equation (Table 1).

Table 1. The adsorption results of isotherm models, kinetic models, and thermodynamic study

Isotherm models	Formula	Parameters	Values
Langmuir isotherm	$q_e = \frac{q_m\ K_L\ C_e}{1\ +\ K_L\ C_e}$	Q_m (mg/g)	70.49
		K_L (L/mg)	2.104
		R^2	0.988
Freundlich isotherm	$q_e = K_F\ C_e^{1/n}$	K_F ((mg/g (L/mg)$^{1/n}$)	6.328
		n	0.476
		R_L	0.0094
		R^2	0.939

The isotherm study demonstrates the adsorbate adsorbed by CIBs adsorbent is directly proportional to the equilibrium RBD adsorbate in the solution. The effectiveness of adsorption isotherm was analyzed by calculating the dimensionless constant RL. The known linear growth of the Langmuir isotherm (Figure 4) is obtained by the values for the (Langmuir constant: L/mg) k_L, (maximum sorption capacity: mg/g) q_m, and (equilibrium concentration of RBD solution: mg/L) C_e. Freundlich isotherm graph of adsorption capacity vs. adsorption intensity is shown in Figure 4. K_F and n are determined from the q_e vs. C_e plot (intercept and slope). The separation factor (R_L) is calculated, for 50 mg/L (0.0094), 100 mg/L (0.0047), 150 mg/L (0.0031), 200 mg/L (0.0023), and 250 mg/L (0.0018). The R_L value gives feasibility, which can be either R_L>1 shows unfavorable condition, R_L=1 means linear, 0 < R_L <1 ensure favorable situation, or R_L=0 confirms the process is favourable, these all condition indicates the form of the isotherm (Venkatesh and Arutchelvan, 2020). *Canna indica* has a linear Laungmuir isotherm with a high value of R^2 (R^2=0.988), indicating the adsorption of RBD (Table 1).

3.4 Adsorption kinetics

The various parameters such as changing the contact period from 5 to 120 min, RBD solution from 25 to 250 mg/L, temperature (303K), and the number of immobilized CIBs respectively, were studied. The removal rate of RBD from prepared solution was calculated using adsorption kinetic models, including a PFO model and a PSO model (Kosaiyakanon et al., 2020). The values of numerous adsorption kinetic model parameters like rate constant (k), correlation coefficient (R^2), and equilibrium adsorption capacity (q_e) etc were calculated using ORIGINPRO 9.0 software.

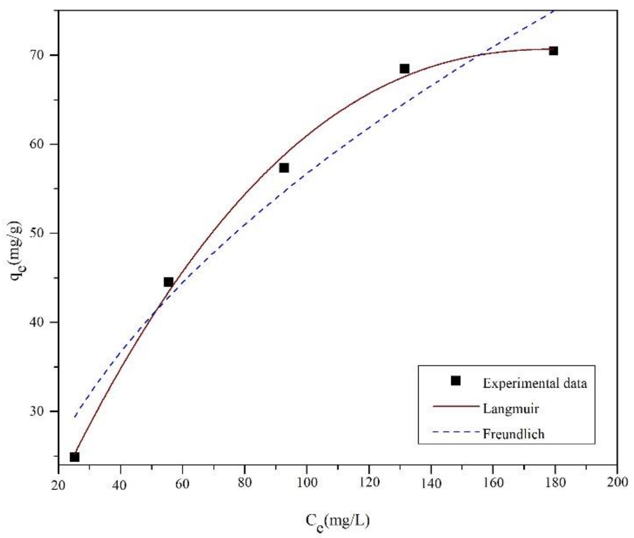

Figure 4. RBD adsorption isotherm model of Langmuir, and Freundlich model

The value of first-order rate constant is 0.1006 1/min (Figure 5(a) and Table 2) and second-order rate constant value of 0.0056 1/min (Figure 5(b) and Table 2) are determined onto immobilized CIB adsorbent. According to the rate constant values, the RBD varied for more active positions on the surface of the immobilized CIBs as the initial RBD concentration and contact duration grew (Riyanti et al., 2023). The equilibrium adsorption capacity (q_e(exp)) of CIBs used to eliminate RBD from the prepared solution was related with the estimated adsorption capacity (q_e(cal)) values using the ORIGINPRO 9.0 software. The type of adsorption kinetic model was best explained by evaluating the q_e and the correlation coefficient (Yuan et al., 2020). Adsorption capacity (q_e) values derived from experiments at equilibrium (q_e(exp)) are more closely correlated with values obtained from the PSO model (q_e). The findings showed that the PSO model provided the best match compared to the PFO model when CIBs were used to remove RBD from an aqueous environment. The physisorption process has described using both the kinetic models (Venkatesh and Arutchelvan, 2020). RBD was adsorbed onto immobilized CIBs, and the more significant correlation coefficient (R^2) value between the PFO and PSO models proved that physisorption takes place in the reaction.

3.5 Thermodynamic study

In a study of the spontaneousness, unpredictability, feasibility, and nature of the adsorption of RBD onto immobilized CIBs, thermodynamic metrics, including ΔG° (Gibbs free energy), ΔS° (change in entropy), and ΔH°(change in enthalpy) are used to characterize the process. Immobilized CIB thermodynamic data for RBD removal are shown in Figure 6.

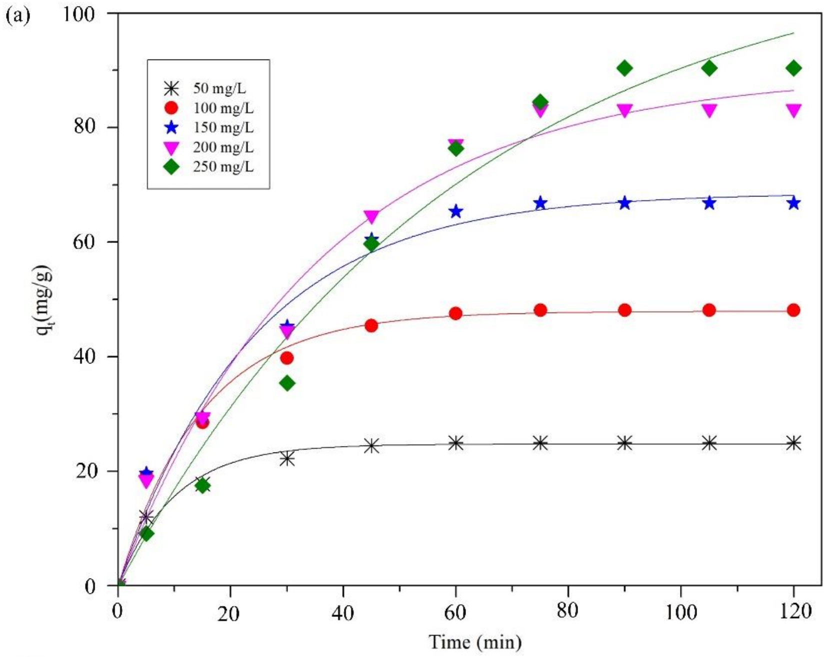

Figure 5. The toxic RBD adsorption kinetic study (a) PFO kinetics, (b) PSO kinetics

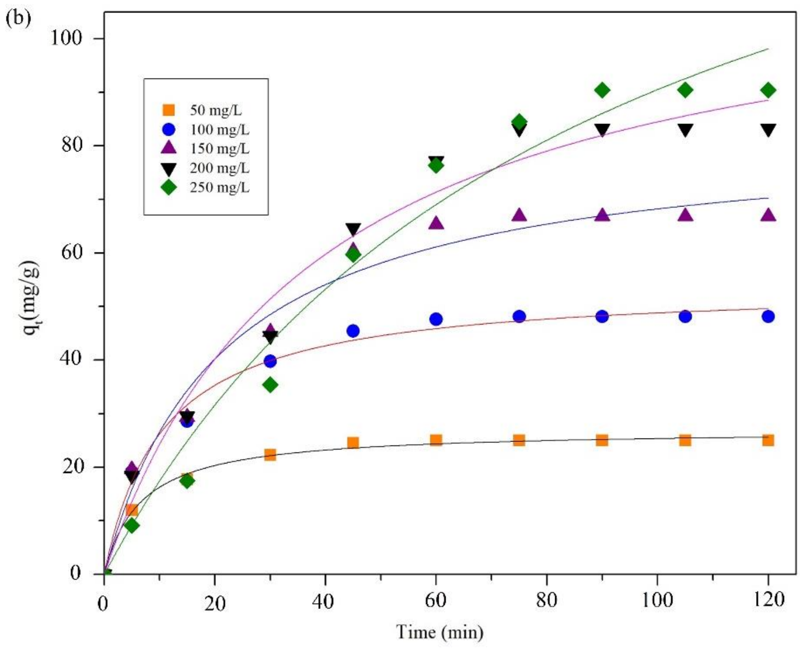

Figure 5. The toxic RBD adsorption kinetic study (a) PFO kinetics, (b) PSO kinetics (cont.)

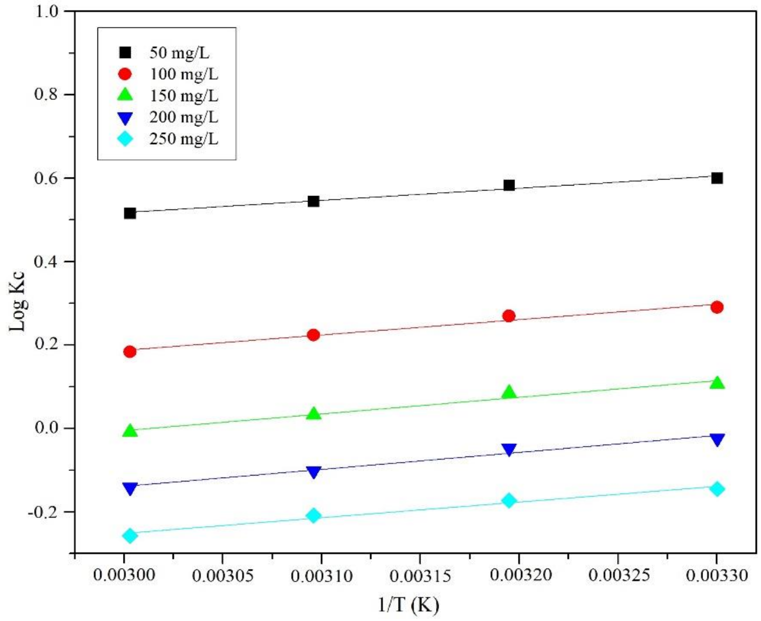

Figure 6. Thermodynamic analysis of Reactive Blue Dye removal from *Canna indica* bead entrapment

Table 2. Adsorption kinetic fit for the RBD onto CIBs

C_0 mg/L	q_e exp (mg/g)	Pseudo First Order [$q_t = q_e$ (1-exp(-k_1t))]			Pseudo Second order ($q_t = \frac{(q_e^2 k_2 t)}{(1+q_e k_2 t)}$)		
		q_e (mg/g)	k_1 (1/min)	R^2	qe (mg/g)	k_2 (1/min)	R^2
50	24.99	24.71	0.1006	0.9833	26.99	0.0056	0.9944
100	48.12	47.90	0.0682	0.9827	53.93	0.0017	0.9895
150	66.84	68.58	0.0420	0.9832	72.57	0.00057	0.9777
200	83.26	89.49	0.0282	0.9820	106.53	0.00022	0.9760
250	98.42	112.37	0.0163	0.9779	129.39	0.00067	0.9722

The other thermodynamic parameters were calculated using the graph of the logarithm of entropy (S°) versus the logarithm of enthalpy (H°) at constant temperature (1/T). Each temperature was given a calculated ΔG°. RBD adsorption onto immobilized CIBs from the aqueous solution resulted in an adverse ΔS° values, indicating that the process was enthalpy-driven. During dye adsorption, negative values of ΔG° and ΔH° were also noticed, demonstrating the feasibility, serendipity, and exotherms of the process can be seen in Table 3 (Venkatesh and Arutchelvan, 2020).

Table 4 shows various adsorbents that has been used for removal of reactive blue dye. This result confirmed the capability of the prepared immobilized Canna indica beads to effectively remove reactive blue dye from the aqueous solution. This biosorbent also a potential candidature for elimination of organic and toxic contaminants from water.

Table 3. Thermodynamic parameters for the biosorption of RBD onto immobilized *Canna indica* beads

Thermodynamic parameter	C_0 (mg/L)	ΔH° (kJ/mol)	ΔS° (J/mol/K)	ΔG° (kJ/mol)			
				303 K	313 K	323 K	333 K
ΔG°= - RT ln Kc	50	-2.4301	-2.9830	-1.5105	-1.5163	-1.4623	-1.3885
$\text{LogK}_c = \frac{\Delta S°}{2.303R} - \frac{\Delta H°}{2.303RT}$	100	-3.040	-7.6131	-0.7311	-0.7003	-0.6004	-0.5080
$K_c = \frac{C_{Ae}}{C_e}$	150	-3.3203	-10.0075	-0.2680	-0.2204	-0.0867	0.0236
	200	-3.3854	-11.3095	0.0824	0.1532	0.2919	0.3999
	250	-3.1240	-11.4675	0.3659	0.4495	0.5898	0.7137

Table 4. Comparison of maximum adsorption of capacity of various adsorbent materials for RBD removal

S. No	Adsorbents for RBD removal	q_m (mg/g)	References
1	Activated carbon (*Enteromorpha prolifera*)	71.94	Sun et al. (2013)
2	Bagasse beads	3.17	Ngamsurach et al. (2022)
3	Chicken eggshell beads	24.10	Praipipat et al. (2022a)
4	Duck eggshell beads	12.63	Praipipat et al. (2022a)
5	Lemon peel beads-doped iron (III) oxide-hydroxide	3.23	Praipipat et al. (2022b)
6	Lemon peel beads-doped zinc oxide	2.59	Praipipat et al. (2022b)
7	Immobilized Canna indica beads	70.49	This study

3.7 Desorption study

To perform the desorption of immobilized CIBs beads that have adsorbed a RBD, was chosen three different desorbing solutions namely ethanol, acetic acid, and sodium hydroxide. From Figure 7 can be seen that acetic acid show better desorption capacity than ethanol, and sodium hydroxide. Up to 4 cycles the acitic acid treated CIBs has better desorption of 72% whereas ethanol, and sodium hydroxide could desorb of 39% and 46% only. Therefore acitic acid has chosen for other consecutive cycles.

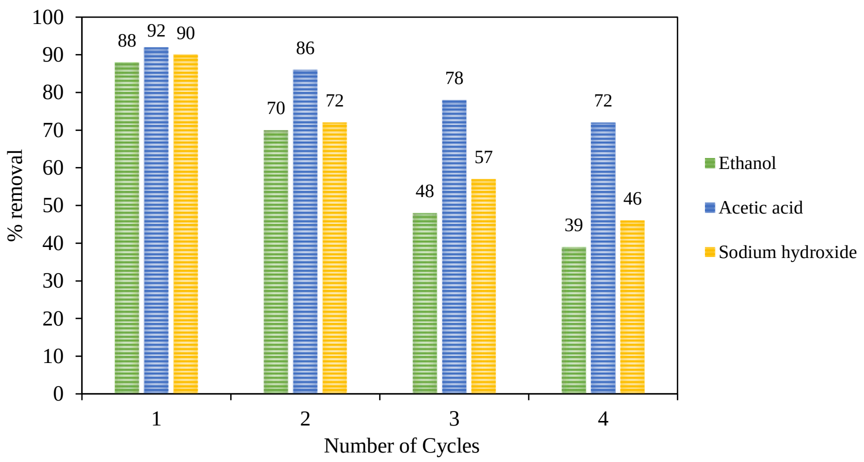

Figure 7. Desorption study of CIBs with different solutions

4. CONCLUSION

Canna indica root tubers were used to obtain the immobilized CIBs for adsorption of RBD from water. The biosorption test has beed carried out using several parameters, such as RBD concentration, pH, immobilized CIBs dose, contact period, and temperature. The maximum dye removal efficiency was found 99.20% at 303 K, 60 min, pH 7, with an adsorbent dosage of 150 mg/100 mL and 150 mg/L of RBD. The maximum adsorption capacity was found to be 70.49 mg/g. With various adsorption isotherm models, it is concluded that the Laungmuir model fitted well in this adsorption process. The adsorption kinetic data is consistent with a PSO kinetic model. The sorption of RBD onto the immobilized CIBs was feasible, spontaneous, exothermic, and enthalpy driven as confirmed by thermodynamic study. Based on the results, this experiment concluded that immobilized CIBs is proved to be a cost-effective and reusable adsorbent material for biosorption of RBD and also can be used for removal of other toxic dyes and heavy metal from real waters.

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