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RESEARCH ARTICLE - CHEMICAL ENGINEERING

Adsorption of Reactive Blue Dye from Aqueous Solutions Using Sawdust as Adsorbent: Optimization, Kinetic, and Equilibrium Studies

G. M. Ratnamala[1] · U. B. Deshannavar[1] · Sunil Munyal[1] · Kushal Tashildar[1] · Suraj Patil[1] · Amar Shinde[1]

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Abstract Adsorption using sawdust from Malaysian teak wood as adsorbent has been studied in order to remove reactive blue dye from aqueous solutions (AS). The dye removal study comprised of investigation of parameters such as concentration of dye, pH, agitation time, and temperature. Optimization was performed using response surface methodology. Kinetics of adsorption of reactive blue dye with activated sawdust was analyzed using Lagergren's kinetic models, and it was found that the dye reduction efficiency by activated sawdust followed pseudo-second-order kinetic model. Langmuir and Freundlich's isotherm models were used for the fitment of batch adsorption experimental data, and it was observed that Langmuir model was found to agree with the values obtained by experimentation based on regression analysis and RMSD values. The study showed that activated sawdust as a promising adsorbent for the reduction of reactive blue dye from AS.

Keywords Reactive blue dye · Sawdust · Adsorption · Isotherm · Kinetic models

List of symbols

Q_o	Adsorption capacity (mg/g)
k_f	Adsorption capacity (mg/g)
t	Agitation time (min)
q	Amount of adsorbate adsorbed (mg/g)
q_e	Amount adsorbed at equilibrium (mg/g)
b	Constant (L/mg)
n	Constant (–)
R_L	Dimensionless constant (–)
c_e	Equilibrium concentration of adsorbate (mg/L)
K_1	Lagergren's pseudo-first-order rate constant (min^{-1})
K_2	Lagergren's pseudo-second-order rate constant ($\text{g mg}^{-1}\,\text{min}^{-1}$)

✉ U. B. Deshannavar
deshannavar@gmail.com

[1] Department of Chemical Engineering, KLE DR. M.S. Sheshgiri College of Engineering and Technology, Udyambag, Belgaum 590008, Karnataka, India

1 Introduction

Freshwater—prominent utility of textile, paper, food, pharmaceutical, tannery and printing industries—finds it way as effluent into water bodies. This wastewater mainly contains unexhausted dyestuffs which are regarded as major water pollutants [1,2]. The unexhausted dyestuffs are non-biodegradable, stable, and toxic in nature and affect the aquatic life, food chain, and human beings [2–5]. The treatment of wastewater containing unexhausted dyestuffs hence gains utmost priority prior to its discharge into water streams. Among various treatment methods for the treatment of effluents containing unexhausted dyestuffs and other organic/inorganic pollutants, adsorption has got highest priority as the process is simple in operation and inexpensive [6]. Activated carbon is proved to be an effective adsorbent in effluent treatment process. However, there is a scope to find readily available inexpensive adsorbents from agro-industrial origin. Several researchers have used these wastes as adsorbent materials and reported them as effectual adsorbents. Bhatti et al. [7], Lim et al. [8], and Khan et al. [9] tried *Citrus sinensis* (mosambi) bagasse, *Lemna minor* (duckweed), and pine needles biochar as adsorbent for the removal of methylene blue, methyl violet 2B, and reactive black-5 dyes, respectively, from synthetic samples and reported them as potential low-cost adsorbents. Sawdust also has been used as adsorbent for the treatment of effluents containing dyes, organic/inorganic pollutants. However, a limited study has been conducted for the reduction of reactive blue dye from AS.

In this investigation, sawdust from Malaysian teak wood was used in the modified form (activated) to reduce reactive blue dye from AS. The adsorption capacity of activated sawdust was investigated by using Langmuir and Freundlich isotherms. Kinetics of adsorption of reactive blue dye onto activated sawdust and amount adsorbed at equilibrium were analyzed by using Lagergren's kinetic models. Central composite design (CCD) method was used to investigate the effects of different factors on reduction of dye using activated sawdust. These are discussed in detail in the following sections.

1.1 Isotherms and Kinetic Models

The adsorption isotherms are used to estimate the capacity of adsorbents and to explain the interaction of adsorbent with adsorbate. Various isotherm models are proposed in the literature and Langmuir and Freundlich models have got the highest priority among all [10].

Langmuir isotherm is based on physical adsorption model and assumes that each active site on the adsorbent adsorbs one molecule only (monolayer adsorption). The Langmuir adsorption is written as [11]:

$$q_e = \frac{Q_o b c_e}{1 + b c_e} \tag{1}$$

Equation (1) can be expressed as:

$$\frac{c_e}{q_e} = \frac{c_e}{Q_o} + \frac{1}{b Q_o} \tag{2}$$

The separation factor, R_L (used to decide the type of adsorption), can be determined as:

$$R_L = \frac{1}{1 + b c_o} \tag{3}$$

Freundlich isotherm is an empirical model which assumes that the amount adsorbed at equilibrium has power law dependence on the adsorbate concentration at equilibrium and can be expressed as [12]:

$$q_e = k_f c_e^{1/n} \tag{4}$$

The linear form of Eq. (4) is:

$$\log q_e = \log k_f + \frac{1}{n} \log c_e \tag{5}$$

Kinetics of adsorption of adsorbate onto adsorbent can be analyzed by using Lagergren's pseudo-first-order and pseudo-second-order kinetic models.

Lagergren's pseudo-first-order equation in its linear form is [13]:

$$\log (q_e - q) = \log q_e - \frac{K_1 t}{2.303} \tag{6}$$

Lagergren's pseudo-second-order equation in its linear form is [14]:

$$\frac{t}{q} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e} \tag{7}$$

2 Materials and Methods

2.1 Adsorbent

Sawdust from local saw mill was obtained, water washed, and then dried in sun for a day. The sawdust having size 150/75 µm was used for the present study. Sawdust was acid-treated by soaking it in 2N sulfuric acid for 3 h. The acid- treated sawdust was cleaned thoroughly with distilled water and dried at 100 ± 4 °C in oven and incinerated in oxygen-deficient atmosphere in the furnace at 600 °C for 2 h. The activated sawdust carbon was stored in airtight container. Morphology of the activated sawdust analyzed using SEM is as shown in Fig. 1. The surface area and pore size of activated sawdust carbon were determined by BET surface area analyzer (ASAP 2020 V3.04 H, Micromeritics, USA). The surface area and pore size of activated sample were 900 m^2/g and 10 nm, respectively.

2.2 Chemicals

Analytical reagent (AR)-grade chemicals (KNO_3, H_2SO_4, HCl, and NaOH)—products of Merck, India, and dye obtained from Forbes Campbell Knitwear, Belagavi, were used. Stock solution was prepared in double-distilled water.

2.3 Experimental Procedure

All adsorption experiments were conducted in batch mode in Borosil® conical flasks. pH was adjusted using NaOH/HCl. Measured amount of activated sawdust was added. Contents were agitated in LABLINE rotary shaker. At regular intervals of time, samples were drawn and centrifuged using REMI laboratory centrifuge, and dye concentration was analyzed by spectro-photometric analysis [15] using UV–Vis ELICO-BL 198 spectrophotometer at 600 nm. In the current study, the dye concentration, quantity of adsorbent, pH, and tem-

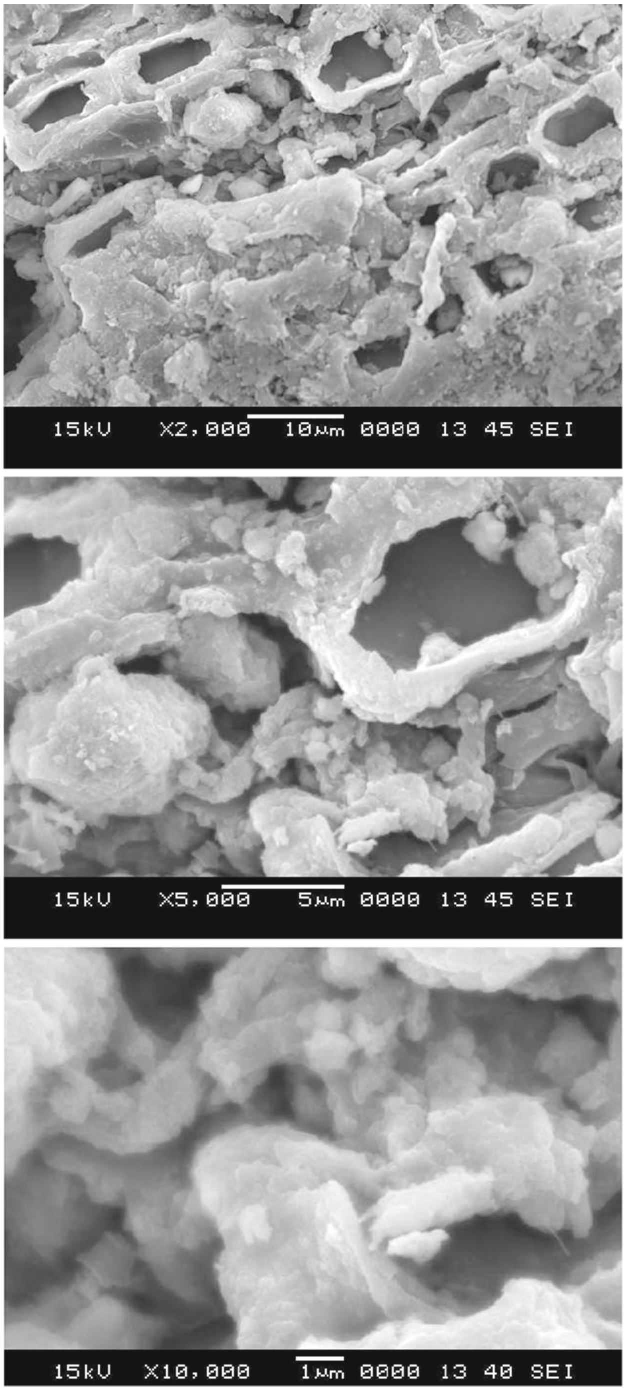

Fig. 1 SEM micrographs of the activated sawdust

perature were varied in the range of 50–130 mg/L, 1–3 g/L, and 2–12, and 20–40 °C, respectively.

2.4 Design of Experiments for Optimization of Parameters

Optimization was carried out using CCD for batch adsorption experiments. CCD for efficient dye reduction from AS had four factors at five levels. Summary of CCD and experiments is shown in Tables 1 and 2. The response variable is dye reduction efficiency at equilibrium conditions.

Table 1 Factors and levels used in the central composite design study

Parameters	−2	−1	0	+1	+2
pH	2	3	4	5	6
Dosage (g/L)	1	1.5	2	2.5	3
Concentration (mg/L)	50	70	90	110	130
Temperature (°C)	20	25	30	35	40

Table 2 Batch adsorption experiments as per CCD

Sl. no	pH	Concentration (mg/L)	Dosage (g/L)	Temperature (°C)
1	4	130	2.0	30
2	4	90	2.0	30
3	6	90	2.0	30
4	4	90	2.0	30
5	2	90	2.0	30
6	3	70	2.5	35
7	5	70	1.5	35
8	4	90	2.0	40
9	4	90	2.0	30
10	5	110	1.5	35
11	4	90	2.0	30
12	4	90	1.0	30
13	4	90	2.0	30
14	3	70	1.5	25
15	3	110	2.5	35
16	4	90	3.0	30
17	5	70	2.5	25
18	5	110	2.5	25
19	4	90	2.0	30
20	5	110	2.5	35
21	5	70	1.5	25
22	3	110	1.5	25
23	3	70	2.5	25
24	3	110	1.5	35
25	5	70	2.5	35
26	4	90	2.0	20
27	3	70	1.5	35
28	5	110	1.5	25
29	4	50	2.0	30
30	3	110	2.5	25
31	4	90	2.0	30

2.5 Analysis and Optimization

RSM analyzes parameters affecting the experiment as individuals and in combination. Minitab 14 was used to correlate

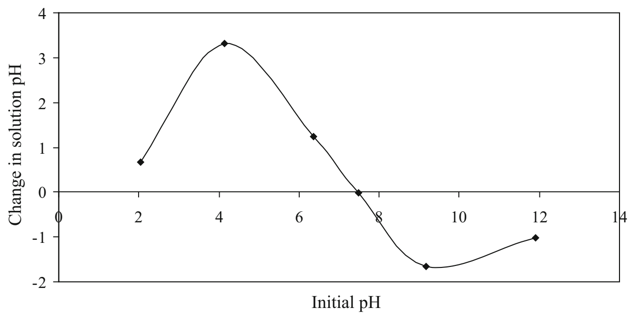

Fig. 2 Change in solution pH versus initial pH

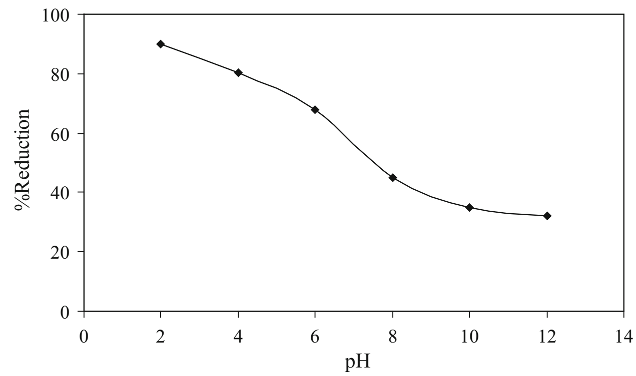

Fig. 3 Effect of solution pH on reactive blue dye reduction efficiency by activated sawdust (conditions: dye concentration = 50 mg/L; adsorbent quantity = 1 g/L; agitation time = 60 min; temperature = 30 °C)

data. ANOVA based on the F test with unequal variance ($P < 0.05$) was used for the evaluation of the importance of the terms in the model. Response optimizer of Minitab 14 was used to get the optimal values.

3 Results and Discussion

3.1 Point of Zero Charge (PZC)

Point of zero charge of the adsorbent plays a vital role in the adsorbent characterization and indicates affinity of the adsorbate to adsorbent surface [16]. The PZC of activated sawdust was estimated and as described by Ofomaja and Ho [17]. Figure 2 shows change in pH vs. pH of solution. The activated sawdust has pH_{PZC} at 7.5. The activated sawdust will possess positive charge and adsorb anionic dye when the pH is less than PZC ($pH < pH_{PZC}$). The adsorbent will possess negative charge and adsorb cationic dye when pH is more than PZC [5,18].

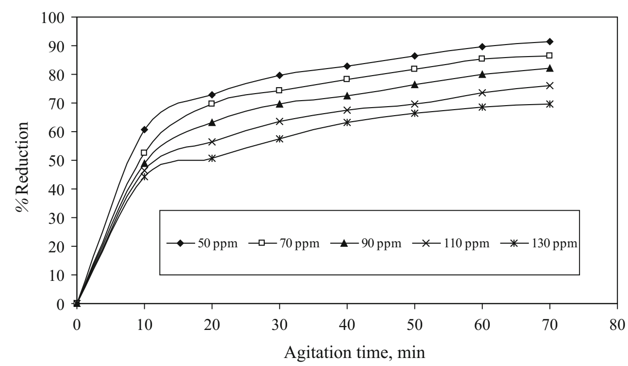

Fig. 4 Effect of dye concentrations and agitation time on reactive blue dye reduction efficiency by activated sawdust (conditions: solution pH = 2; adsorbent quantity = 1 g/L; temperature = 30 °C)

3.2 Efficiency of Activated Sawdust

A series of experiments was conducted to study the efficiency of raw sawdust and activated sawdust at initial dye concentration, 50 mg/L, adsorbent dosage, 1 g/L, solution pH, 2, and the contents were agitated for a period of 60 min. It was found that the dye reduction efficiency of raw sawdust was 20 %, whereas for activated sawdust 88 %. The increase in percentage reduction is mainly due to activation which resulted in higher surface area of sawdust.

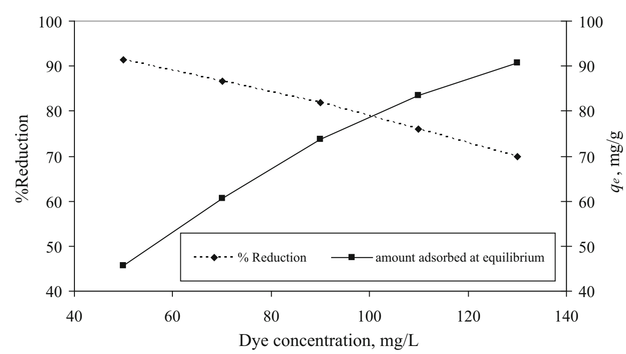

Fig. 5 Effect of dye concentrations on reactive blue dye reduction efficiency by activated sawdust (conditions: solution pH = 2; adsorbent quantity = 1 g/L; agitation time = 70 min; temperature = 30 °C)

3.3 Effect of Solution pH

Adsorption depends on initial pH. The effect of initial pH of solution on capacity of activated sawdust was investigated by varying solution initial pH from 2 to 12. Figure 3 shows the effect of solution pH on dye reduction efficiency. It can be seen that dye reduction efficiency decreases with increase in solution pH. The dye reduction efficiency was 90 % when the solution pH was 2, and it decreased drastically to 32 % when pH was 12. Similar observations were also made by Ratnamala et al. [19] and Mehdi et al. [20] for the adsorption of Remazol Brilliant Blue R and Reactive Black 5, respectively, by red mud. Reactive blue dye is anionic in nature, and favorable adsorption, therefore, occurred at $pH < pH_{PZC}$.

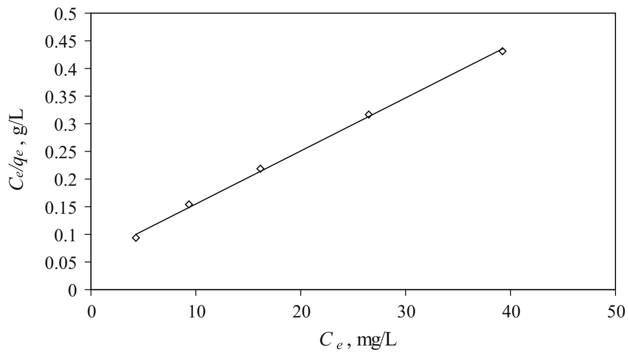

Fig. 6 Plot of Langmuir adsorption isotherm

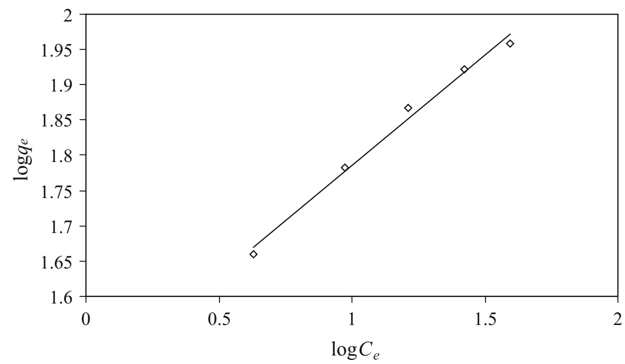

Fig. 7 Plot of Freundlich adsorption isotherm

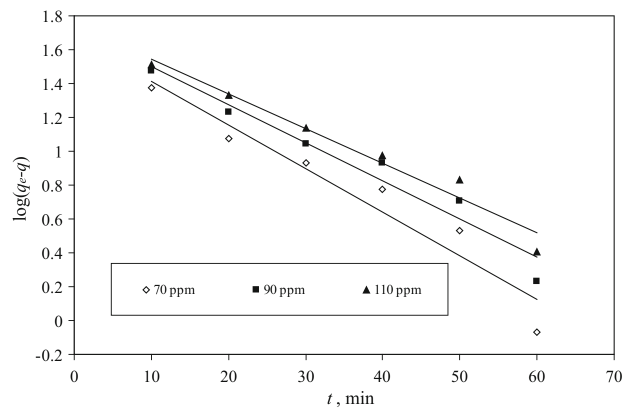

Fig. 8 Plot of pseudo-first-order kinetics for adsorption of reactive blue dye onto activated sawdust

3.4 Effect of Dye Concentration and Contact Time

Figure 4 describes the dye reduction efficiency at different dye concentrations and contact time. Dye reduction efficiency of 72, 69.5, 63, 57, and 51 % was achieved for dye concentrations of 50, 70, 90, 110, and 130 mg/L, respectively, at 20 min of adsorbate—adsorbent agitation. Contact time between adsorbate and adsorbent was increased, and dye reduction efficiency of 92, 87, 82, 76, and 70 % was achieved at 70 min of agitation for 50, 70, 90, 110, and 130 mg/L of dye concentration, respectively. It was also noticed that the dye reduction efficiency decreased with increase in dye concentration (Figs. 4, 5). However, the amount of dye adsorbed per unit mass of adsorbent increased with increase in dye concentration (Fig. 5). Earlier researchers have reported similar results in adsorption of reactive blue [21] by activated carbon prepared from sugarcane bagasse pith and adsorption of Reactive Yellow 2 by low-cost adsorbent [22]. The increase in amount of dye adsorbed per unit mass of adsorbent with increase in dye concentration is due to the accessibility of adequate adsorbent sites on the activated sawdust surface, and the increased dye concentration caused a driving force which resulted in decreased mass transfer resistance.

The data obtained from the experimentations of the investigation of dye concentration are used for the establishment of isotherms. Adsorption isotherms, Langmuir and Freundlich, were used to investigate the adsorption capacity of dye by activated sawdust. Figure 6 shows the linear plot of c_e/q_e versus c_e (Langmuir) for dye adsorption onto activated sawdust. Table 3 summarizes the Langmuir constants. Figure 7 depicts the plot of log q_e versus log c_e (Freundlich) for dye adsorption onto activated sawdust. Table 3 also summarizes the Freundlich constants along with R^2 values. Even though, R^2 values for both the models, i.e., Langmuir and Freundlich

Table 3 Langmuir and Freundlich isotherm constants

Dye concentration (mg/L)	R_L	*Langmuir constants*			
		Q_o (mg/g)	b (L/mg)	R^2	RMSD
50	0.12	111.11	0.15	0.998	0.15
70	0.09				
90	0.07				
110	0.06				
130	0.05				

Freundlich constants			
k_f (mg/g)	n	R^2	RMSD
29.72	3.19	0.989	22.16

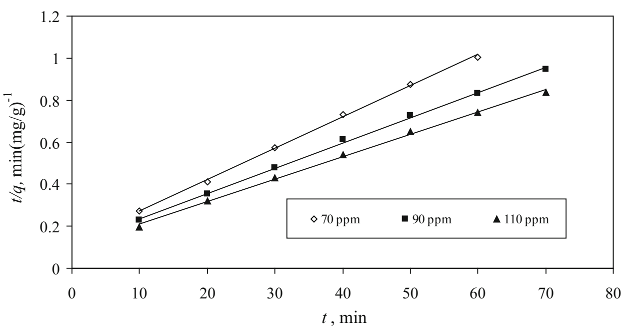

Fig. 9 Plot of pseudo-second-order kinetics for adsorption of reactive blue dye onto activated sawdust

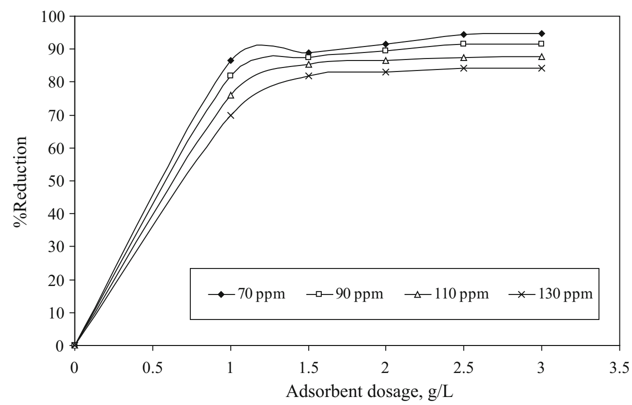

Fig. 10 Effect of quantity of adsorbent on reactive blue dye reduction efficiency by activated sawdust (conditions: solution pH = 2; agitation time = 70 min; temperature = 30°C)

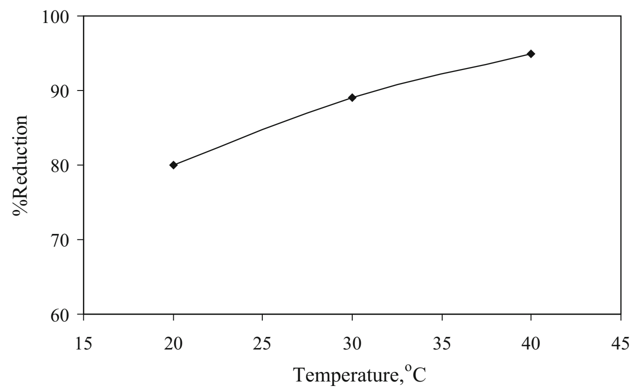

Fig. 11 Effect of temperature on reactive blue dye reduction efficiency by activated sawdust (conditions: solution pH = 2; agitation time = 70 min; dye concentration = 70 mg/L; and adsorbent quantity = 1.5 g/L)

were above 0.9, Langmuir model was found to be in a good agreement with the experimental values based on RMSD values.

The dye reduction efficiencies at different adsorbent–adsorbate agitation time for various dye concentrations were used for the kinetic studies. Lagergren's pseudo-first-order and pseudo-second-order kinetics were selected for the analysis of kinetics of dye reduction by activated sawdust. Figure 8 shows the plot of log $(q_e - q)$ versus t (Lagergren's pseudo-first-order kinetics) at various dye concentrations, and Fig. 9 depicts t/q versus t (Lagergren's pseudo-second-order kinetics) at various dye concentrations. Table 4 tabulates the Lagergren's kinetic constants obtained along with R^2 and RMSD values. It can be seen that R^2 values for both the model are above 0.9. However, the q_e experiment and q_e predicted from Lagergren's pseudo-second-order kinetic model showed good agreement, indicating that dye adsorption onto activated sawdust follow Lagergren's pseudo-second-order kinetic model as compared with Lagergren's pseudo-first-order model.

3.5 Effect of Quantity of Adsorbent

Adsorption strongly depends upon the quantity of the adsorbent. Determination of optimum adsorbent quantity plays a vital role in adsorption process. In order to determine the optimum adsorbent quantity, batch experiments were conducted at various adsorbent quantities varying from 1 to 3 g/L. Figure 10 depicts the effect of adsorbent quantity on dye reduction efficiency at various dye concentrations. Dye reduction efficiency of 86, 82, 76, and 70 % (amount adsorbed at equilibrium: 60.62, 73.79, 83.56, and 90.85 mg/g) was achieved at an adsorbent quantity of 1 g/L for 70, 90, 110, and 130 mg/L of dye concentrations, respectively, whereas, the dye reduction efficiency increased to 95, 92, 87, and 84 % (amount adsorbed at equilibrium: 26.46, 32.93, 38.47, and 43.74 mg/g) for dye concentrations of 70, 90, 110, and 130 mg/L, respectively, when the adsorbent quantity was 2.5 g/L. This increase in dye reduction efficiency is mainly due to the accessibility to adequate adsorption sites and enhanced

Table 4 Pseudo-first-order and pseudo-second-order kinetic model parameters

Dye concentration (mg/L)	q_e, experiment (mg/g)	Pseudo-first-order kinetic model parameters				Pseudo-second-order kinetic model parameters			
		K_1 (min^{-1})	q_e (mg/g)	R^2	RMSD	K_2 (g/mg) min^{-1}	q_e (mg/g)	R^2	RMSD
70	65.1	0.059	47.1	0.93	18	0.0024	67.1	0.99	2
90	79.5	0.052	53.3	0.95		0.0025	83.3	0.99	
110	90.4	0.047	55.9	0.96		0.0026	93.5	0.99	

Table 5 Experimental design matrix and results for the dye removal percentage

Sl. No.	pH	Dye concentration (mg/L)	Adsorbent quantity (g/L)	Temperature (°C)	Dye reduction (%)	
					Actual	Predicted
1	4	130	2.0	30	72	69.708
2	4	90	2.0	30	81	81
3	6	90	2.0	30	70	70.37
4	4	90	2.0	30	81	81
5	2	90	2.0	30	86	82.20
6	3	70	2.5	35	89	89.5
7	5	70	1.5	35	80	79.66
8	4	90	2.0	40	83	83.04
9	4	90	2.0	30	81	81
10	5	110	1.5	35	74	74.45
11	4	90	2.0	30	81	81
12	4	90	1.0	30	78	77.37
13	4	90	2.0	30	81	81
14	3	70	1.5	25	81	81.33
15	3	110	2.5	35	80	80.79
16	4	90	3.0	30	82	81.20
17	5	70	2.5	25	75	74.33
18	5	110	2.5	25	68	69.62
19	4	90	2.0	30	81	81
20	5	110	2.5	35	76	76
21	5	70	1.5	25	74	74.29
22	3	110	1.5	25	68	69.62
23	3	70	2.5	25	83	83.62
24	3	110	1.5	35	76	77
25	5	70	2.5	35	80	79.45
26	4	90	2.0	20	72	70.54
27	3	70	1.5	35	88	87.45
28	5	110	1.5	25	68	67.83
29	4	50	2.0	30	84	84.87
30	3	110	2.5	25	73	73.66
31	4	90	2.0	30	81	81

Table 6 Analysis of variance for % reduction of dye using sawdust

Source	DF	Seq SS	Adj SS	Adj MS	*F*	*P*
Regression	14	929.30	929.33	66.38	48.10	0.000
Linear	4	811.50	39.83	9.95	7.22	0.002
Square	4	79.96	79.96	19.99	14.48	0.000
Interaction	6	37.87	37.87	6.31	4.57	0.007
Residual error	16	22.083	22.08	1.38	–	–
Lack of fit	10	22.083	22.08	2.20	–	–
Pure error	6	0.000	0.000	0.000	–	–

surface area with increase in adsorbent quantity. When the adsorbent quantity was 3 g/L, the increase in dye reduction efficiency was almost negligible as compared with that at an adsorbent quantity, 2.5 g/L (Fig. 10) which is possibly due to overlapping of active sites of the adsorbent particles [23]. Based on the experimental observations, it can be concluded that maximum dye reduction efficiency can be obtained at an adsorbent quantity of 2.5 g/L (optimum dosage).

Table 7 Optimization results

Parameters	Value
pH	2
Concentration (mg/L)	50
Dosage (g/L)	2.6
Temperature (°C)	36.9

3.6 Effect of Temperature

The effect of temperature on dye reduction efficiency was studied by varying temperatures as 20, 30, and 40 °C. Dye reduction efficiency with temperature is shown in Fig. 11. Dye reduction efficiency increased with an increase in temperature, indicating that adsorption of dye is an endothermic process in this system. But as the adsorption process was found to be endothermic from temperature effect studies, it can be concluded that chemisorption may be the dominant phenomena [24]. Increase in temperature results in the formation of new active sites on the adsorbent and results in the penetration of reactive dye [25].

3.7 Response Surface Optimization

A set of 31 experiments was designed as per CCD matrix and are summarized in Table 5. The experiments were carried

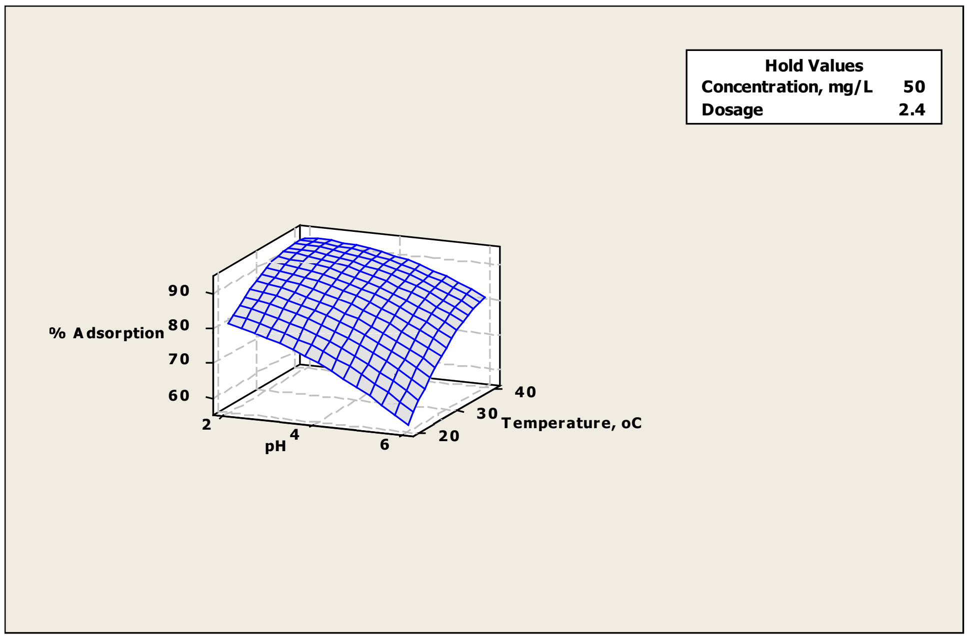

Fig. 12 Surface plot for effect of temperature and pH on adsorption of dye

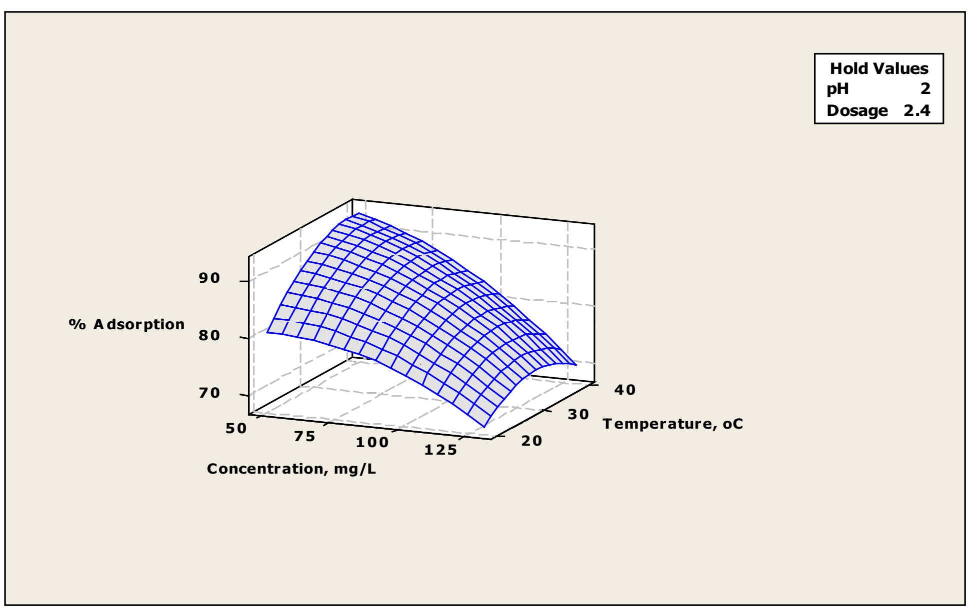

Fig. 13 Surface plot for effect of temperature and concentration on adsorption of dye

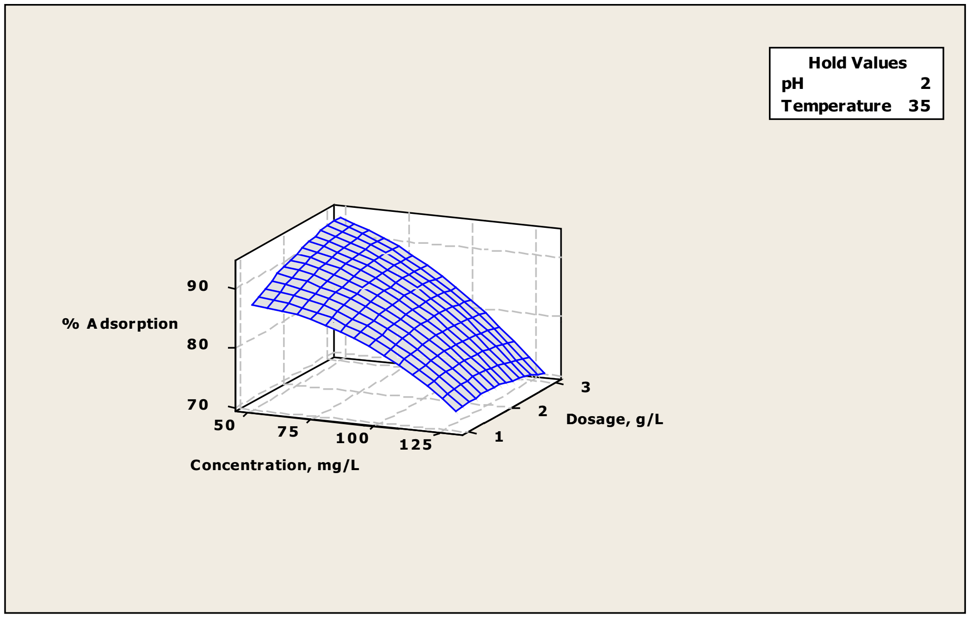

Fig. 14 Surface plot for effect of concentration and dosage on adsorption of dye

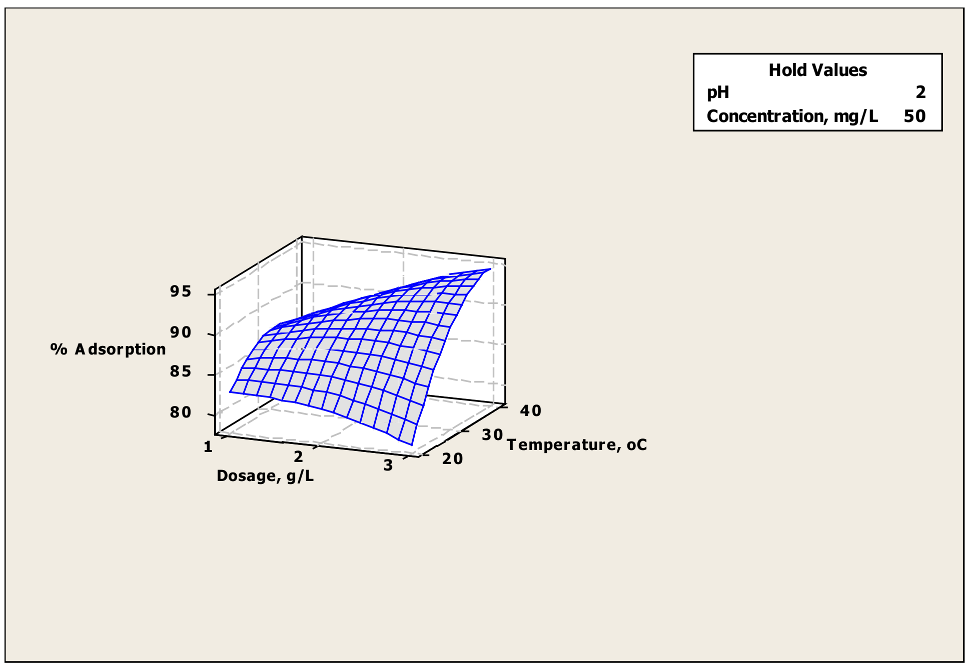

Fig. 15 Surface plot for effect of temperature and dosage on adsorption of dye

out to study the effect of four factors influencing the dye reduction efficiency by activated sawdust as an individual and on interaction with each other to optimize the process using RSM. Four variables affecting the dye reduction efficiency such as solution pH, dye concentration, adsorbent quantity, and temperature were varied at five levels (−2, −1, 0, +1, and +2). The higher level of variable was referred as '+' and the lower level as '−'. The percentage reduction efficiency of dye obtained from the experiments at the end of 70 min of dye-activated sawdust contact for each of the experiments is presented in Table 5.

A model relating the four factors in uncoded form to the response was developed with the regression coefficients by using multiple regression analysis (MRA) (Eq. 8).

$$\begin{aligned}\%\text{ removal efficeincy of dye } &= 29.93 - 3.92X_1\\ &-0.21X_2 + 10.06X_3 + 3.068X_4\\ &-1.17X_1^2 - 0.0023X_2^2 - 1.70X_3^2 - 0.042X_4^2\\ &+0.065X_1X_2 - 1.125X_1X_3\\ &-0.037X_1X_4 + 0.043X_2X_3\\ &+0.0031X_2X_4 - 0.025X_4X_3 \end{aligned} \tag{8}$$

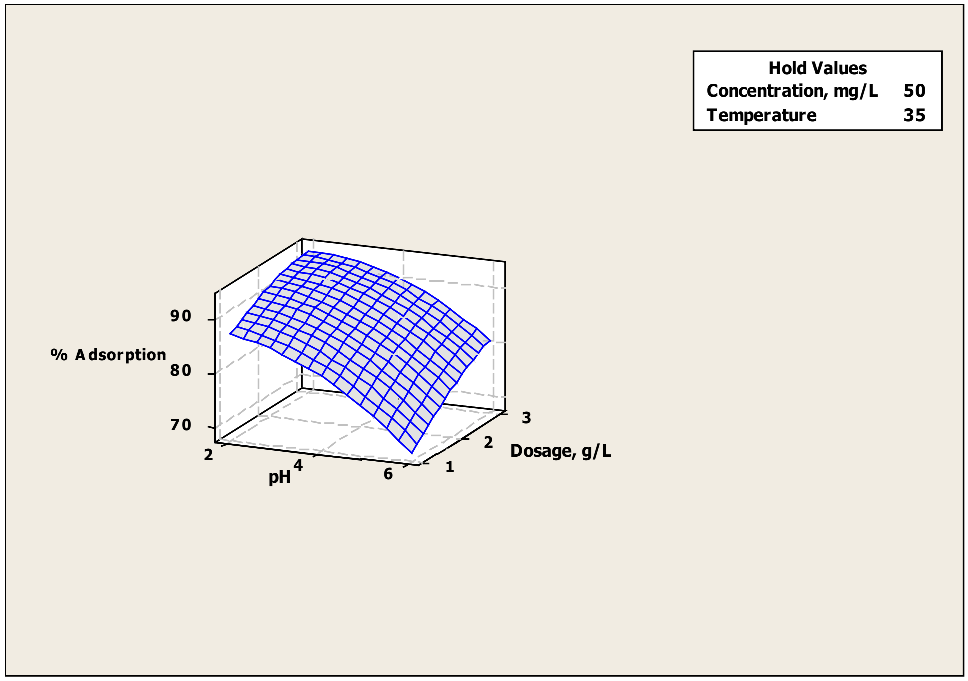

Fig. 16 Surface plot for effect of dosage and pH on adsorption of dye

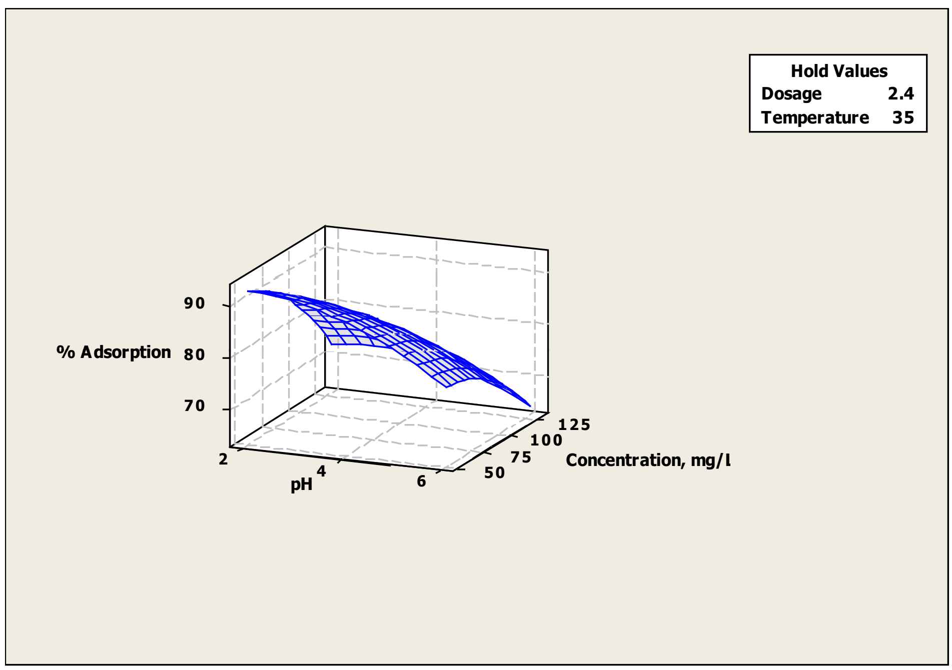

Fig. 17 Surface plot for effect of concentration and pH on adsorption of dye

Here, the coefficients of X_1 (pH) and X_2 (concentration) are negative terms indicating that with an increase in pH and dye concentration, the percentage reduction of dye decreases, whereas the positive coefficients of X_3 (dosage) and X_4 (temperature) indicate that the percentage reduction of dye increases with increase in adsorbent quantity and temperature. Statistical tools: Student's test, analysis of variance, F test, and lack of fit were used for the analysis of experimental results and are tabulated in Table 6.

Results depicted that the main and interaction terms of factors are significant ($P < 0.05$). The correlation coefficient 0.93 indicates good performance of statistical model. Percentage reduction of dye as predicted by model matches satisfactorily with the experimentally obtained values for all 31 experiments (Table 5). The analysis for adsorption of the dye using sawdust indicated that the second-order polynomial model Eq. (8) was significant. The optimum values for pH, dye concentration, sawdust quantity, and temperature were obtained using "Response optimizer" and are shown in Table 7.

The effect of pH and temperature on reduction of dye at activated sawdust quantity 2.4 g/L and concentration 50 mg/L is shown in the surface plot (Fig. 12). It can be observed from the figure that increasing the pH value decreases the percentage adsorption of the dye in the entire temperature range. Effect of temperature on percentage adsorption is very significant at low pH values.

Figure 13 shows the interactive effect of temperature and dye concentration on percentage reduction of dye using sawdust at constant activated sawdust quantity 2.4 g/L and pH 2. It shows that as the dye concentration increases, the percentage reduction of dye decreases.

The effect of dye concentration and adsorbent quantity on reduction of dye at constant pH 2 and temperature 35 °C is depicted in Fig. 14. It was observed that with an increase in dye concentration, reduction of dye decreases, and with an increase in quantity of adsorbent, reduction of dye increases. With higher adsorbent quantity and lower dye concentrations, the maximum reduction of dye occurs.

The surface plot of temperature and adsorbent quantity on the reduction of dye at pH 2 and dye concentration 50 mg/L is shown in Fig. 15. It can be observed that the reduction of dye increases with an increase in adsorbent quantity.

The effect of pH and adsorbent quantity on reduction of dye at constant temperature 35 °C and dye concentration 50 mg/L is shown in Fig. 16. Reduction of dye decreases with an increase in pH.

Figure 17 depicts the effect of pH and dye concentration on reduction of dye at adsorbent quantity 2.4 g/L and temperature 35 °C. The reduction of dye is more in the region of lower dye concentration and at lower pH, but the reduction of dye decreases with increase in dye concentration and pH.

4 Conclusions

Reduction of reactive blue dye from AS using activated sawdust from Malaysian teak wood was investigated, and the optimum parameters affecting the dye reduction efficiency were obtained. The maximum dye reduction occurred at pH 2, adsorbent quantity 2.6 g/L, agitation time 70 min, temperature 36.9 °C, and dye concentration 50 mg/L. The reduction of dye using activated sawdust as adsorbent was found to be an endothermic process. Langmuir isotherm was best-fitting model for the reduction of reactive blue dye by activated sawdust. The dye reduction kinetics is better explained by pseudo-second-order kinetic model.

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