Removal of Congo red from aqueous solution using saw dust as a low cost adsorbent

Muhammad Nawaz, Sharjeel Waqas, Muhammad Usman Tahir, Waqar Ali Khan, Muhammad Jamil

Abstract: In this study the use of low cost adsorbent has been studied as an alternate of activated carbon for the adsorption of Congo red from aqueous solution. Saw dust was used to remove Congo red from aqueous solution by batch adsorption techniques. Effect of contact time, amount of adsorbent, initial concentration of dye, temperature of the solution and pH of the solution were studied. It was seen that maximum dye removal was reached at 90 min. Amount of dye adsorbed per unit mass of adsorbent increased with increasing initial dye concentration (25 to 100mg/l) and solution temperature (25 to 70 °C) while it decreased with increasing adsorbent dosages (0.25 to 1.0 g/50 ml) and pH of the solution (5.7 to 10). The equilibrium adsorption isotherms have been analyzed by Freundlich and Langmuir models at different initial concentrations of 25, 50, 75 and 100 mg/l, and the results were discussed in detail. The results showed that saw dust could be used as an effective and low cost adsorbent for the removal of dyes from aqueous solution.

Keywords: Adsorption, Adsorption isotherms, Congo red, Dye removal, Saw dust

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1   Introduction

Large quantities of synthetic dyes are extensively used in different industries such as textile, tannery, paint, cosmetic, food and pharmaceutical. These industries produced huge volume of wastewater every year [1]. Dyes containing wastewater without proper treatment cause damage to aquatic environment [2]. They also cause serious health problems to human and animals because they are toxic, mutagenic or carcinogenic [3]. Therefore, the riddance of dyes from wastewater is of significant environmental importance [4]. Dyes are very difficult to biodegrade because of their complex molecular structure [5]. Therefore, conventional treatment processes for the treatment of wastewater are not effectual [1].

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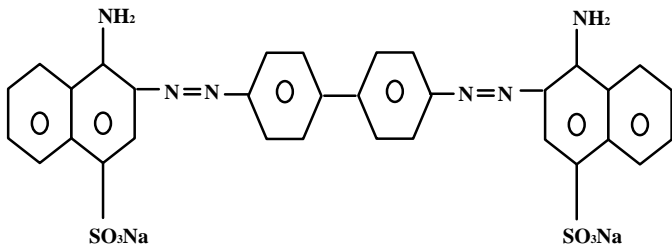 *PH-+923004382693   Email: professor_jamil@yahoo.com*

Physical and chemical technologies such as coagulation and flocculation [6], electrochemical removal [7], photochemical degradation [8], membrane separation [9] and adsorption [10] are used to treat dyes containing wastewater. Among these treatment methods, adsorption process is an efficient treatment process especially when the adsorbent is easily available and inexpensive [11]. Adsorption is a promising alternative wastewater treatment process because of simplicity of operation, easy handling of materials, sludge free process and regeneration capacity [12,13].

Activated carbon (AC) has been used by different researchers with great success in adsorption process for the treatment of dyes containing wastewater [14,15]. AC is expensive and its regeneration also increases the cost of the process [16]. So, there is a need to find alternative low cost adsorbents for the process. Many researchers had used various low cost adsorbents such as rice husk [17], cattail root [18], calcium rich fly ash [19], cashew nut shell [20], orange peel [21], sugarcane bagasse [22] and bentonite [23] for the treatment of dyes containing wasterwater.

In this study, we use saw dust (SD) as an adsorbent for the adsorption Conge red (CR) from its aqueous solution. CR is an anionic dye and it has been extensively used in rubber, plastic, paper and textile industries [1]. The structure of CR is presented in Fig.1. SD is the by-product of the wood industry and easily available at a very low price.

Fig. 1. Structure of Congo red

2   Materials

2.1   Saw dust

Saw dust was collected from a local saw mill at Mongi Bungalow, Toba Tek Singh, Pakistan. For the removal of muddy materials, the saw dust was washed with distilled water and then dried in the sunlight. After that the material was grounded and sieved to desired particle size. Particles between 177-250 microns were selected for experiments. The dried saw dust was activated at 110 °C for 2 hours in a hot air oven and then stored in an air tight container for further use.

2.2   Congo Red

The adsorbate Congo red dye was supplied by New Central Chemicals, Lahore, Pakistan. The dye was of analytical grade and 99.8 % pure. It was used as received without further purification. Stock solution of CR was prepared with double distilled water. Experimental solutions were then obtained from the stock solution by dilutions with distilled water.

3   Methods

Batch experiments were carried out by stirring 250 mg of saw dust with 50 ml of aqueous solution of CR of known concentration in 250 ml round bottom flask placed in a temperature controlled rotamentle. The experiments were conducted at different concentrations (betwwen 25-100 mg/l), temperatures (between 25-75 °C, sorbent doses (between 250-1000 mg) and pH (between 5-10) at a constant stirring rate. After the desired contact time, the samples were removed from round bottom flask and centrifuged at 3000 rpm for 2-3 min. after that UV-spectophotometer (set at a wavelength of 500 nm, maximum absorbance) was used to determine the final concentration of CR.

4   Results & Discussions

4.1   Effect of contact time

Different experiments were performed for the removal of CR from the aqueous solution using SD as an adsorbent at different contact times, keeping initial dye concentration, pH and temperature constant. The results are shown in Fig.2. It is clear from the Fig.2. that the removal of CR increase with an increase in contact time. When contact time increase from 45 to 90 min, the dye removal increases from 18.2% to 34.5%. There was a slight change observed in the removal of CR after 90 min. So, this time was considered as an equilibrium time.
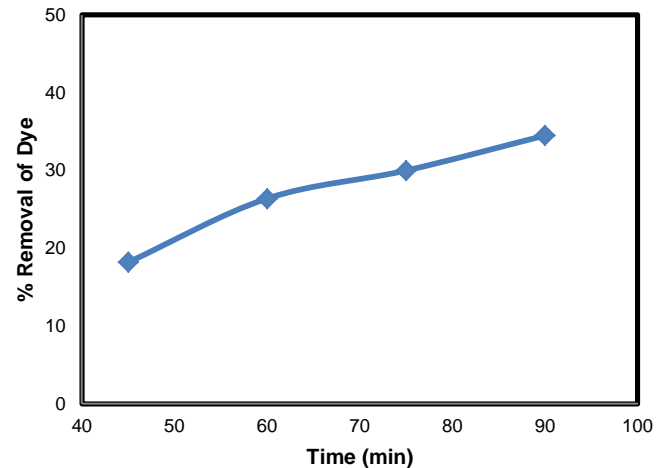

Fig. 2. Effect of contact time on the removal of CR by saw dust (Conditions: T=25°C; pH= 7.1; W/V = 0.25 g/50ml)

4.2   Effect of initial dye concentration

Removal of CR by SD using different initial concentration was studied at 25°C and the results are presented in Fig.3. It is clear from the Fig.3(a), percent removal of CR decreased with the increase in initial concentration but the actual amount of dye adsorbed (mg/g) increased with the increase in initial concentration as shown in Fig.3 (b). When initial concentration of CR increase from 25 to 100 mg/l, the amount of dye adsorbed increases from 2.2 (44.00%) to 5.3 mg/g (26.50%). The removal of CR increased because with the increase in CR concentration, the resistance to up-take of CR from the solution decreased [11]. Rate of adsorption also increases with the increase in initial concentration due to increase in the driving force [11]. Similar results were observed of CR removal on cattail root [18] and calcium rich fly ash [19].
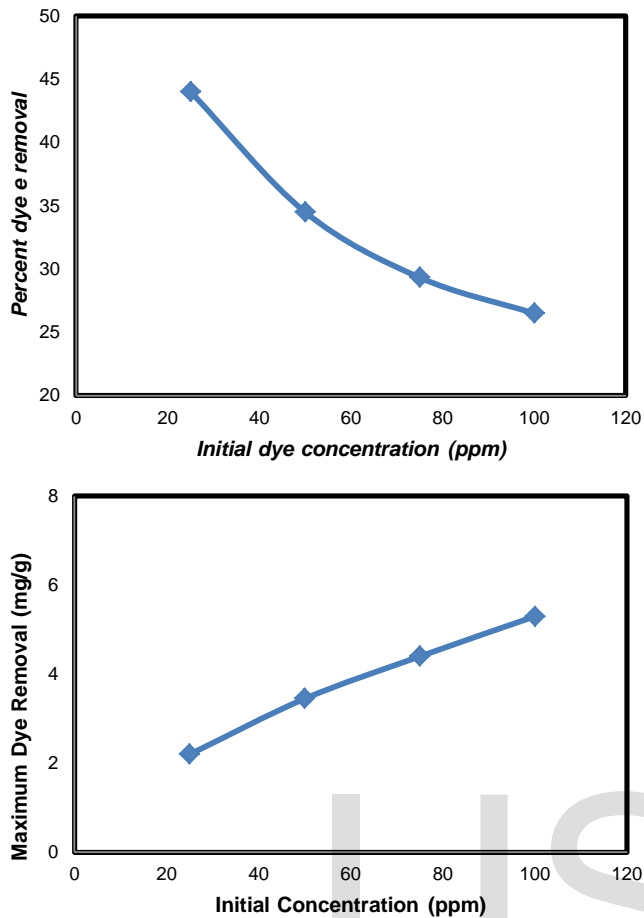
Fig. 3. Effect of initial dye concentration on adsorption of CR by saw dust. (a) Percent dye removal (b). Maximum dye removal (Conditions: T=25°C; pH= 7.1; sorbent dosage = 250 mg, t= 90 min)
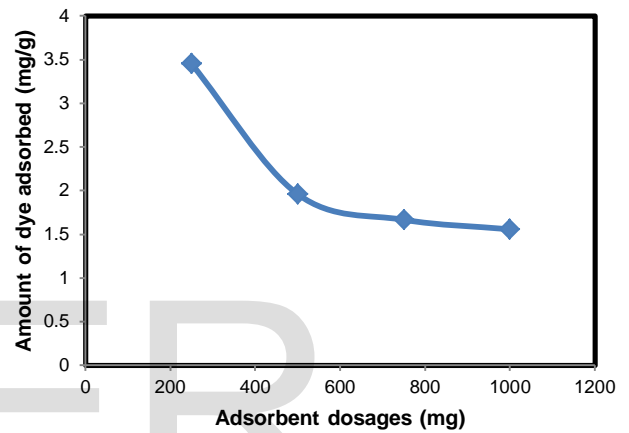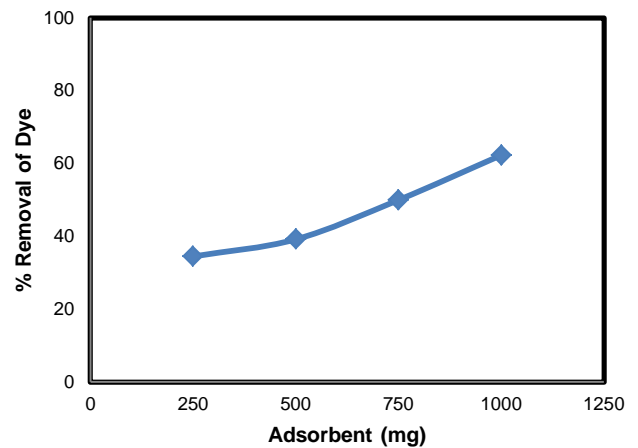

Fig. 4. Effect of sorbent dosage on the removal of CR by saw dust. (a). Percent removal of dye (b). Amount of dye adsorbed (Conditions: T=25°C; pH= 7.1; C_o = 50 mg/l, t= 90 min)

4.3 Effect of Adsorbent dosages

Removal of CR by using different quantities of SD as an adsorbent was studied for 50 mg/l of aqueous solution at 25 °C and pH 7.1. Fig. 4(a) shows that as the quantity of adsorbent increase the removal of CR also increases. When the quantity of SD increases from 0.25 to 1.0 g, the percent dye removal increase from 34.5 % to 62.3 %. CR removal increases because adsorbent surface area and adsorbent sites increases with the increase in the amount of the adsorbent [18]. On the other hand, Fig. 4 (b) shows that amount of dye adsorbed per unit adsorbent decreases with an increase in adsorbent dose. The amount of dye adsorbed (mg/g) decreases from 3.45 to 1.56 as the adsorbent dosage increases from 0.25 to 1.0 g. similar results were obtained by different investigators for the adsorption of CR [14,22].

4.4 Effect of temperature

Removal of CR by SD was studied in the range of temperatures between 25 to 75°C for initial concentration 50 mg/l at pH 7.1 and the results presented in Fig. 5. Results shows that amount of dye adsorbed are slightly increased as temperature increases from 25 to 75°C. When temperature increases from 25-75°C, the amount of dye adsorbed increases from 3.45 to 4.86 mg/g as shown in Fig.5. Adsorption capacity may be affected by the diffusion process and chemisorption. If diffusion process is the rate controlling step, then adsorption capacity increases with the increase in temperature due to endothermicity of the diffusion process. With the increase in temperature, mobility of the adsorbate increases and retarding forces acting on the adsorbate decreases [11]. This results in the increase in adsorption capacity. On the other hand, because of sufficient contact time if resistances involved in the diffusion of adsorbate are ignored, chemisorption may involve in the increase in adsorption capacity of SD [11]. Different other researchers has been reported the results similar to the current study [11,15].
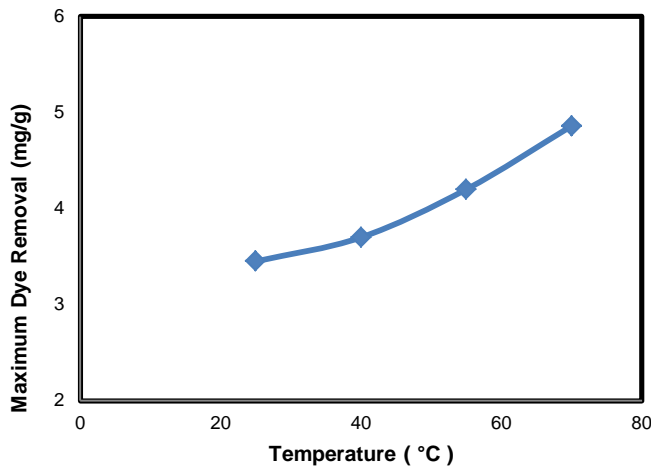
Fig. 5. Effect temperature on the removal of CR by saw dust (Conditions: pH= 7.1; C_o = 50 mg/l, W/V = 0.25g/50 50 ml mg, t= 90 min)

4.5   Effect of pH

The effect of pH on dye removal by SD was studied at 25°C with 50 mg/l aqueous solution and 0.25 g of SD as an adsorbent. Experiments were performed over a pH range of 5.7-10 and the results obtained are shown in the Fig.6. it can be seen that percent dye removal has inverse relation with pH. 47.5% CR was adsorbed over SD at pH 5.7, while it drops to 25.6% at pH 10. Adsorbent surface charge, speciation of the dye and degree of ionization are affected by the pH of the solution [15]. Electrostatic attraction between CR and SD might be decreased, therefore with the increase in pH of the solution, removal of CR decreased [22]. Similar result has also been observed for activated carbon [15], rice husk [24], kaolin and zeolite [25], however, pH of the solution had negligible effects on CR removal by cattail root and neem leaf powder [18,26].
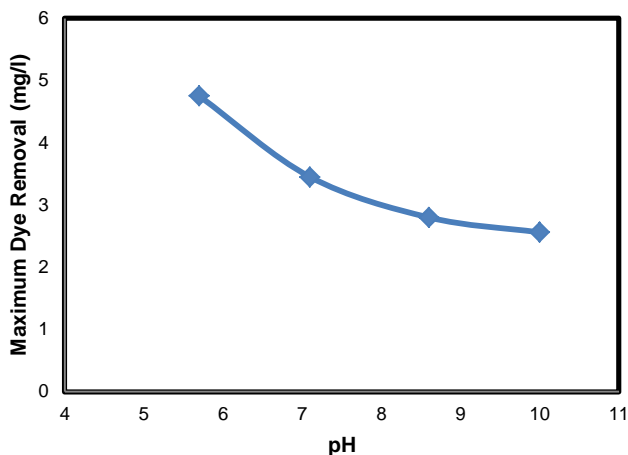

Fig. 6. Effect initial solution pH on the removal of CR by saw dust (Conditions: T=25°C; C_o = 50 mg/l, W/V = 0.25g/50 50 ml, t= 90 min)

4.6   Adsorption isotherms

Langmuir and Freundlich isotherms were used to analyze the data obtained.

The Langmuir isotherm is

$$q_e = \frac{q_m k_L C_e}{1 + k_L C_e}$$

It can be written in linear form as

$$\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{q_m b}$$

Where

C_e is the concentration of the dye at equilibrium stage (mg/l), q_e is the amount of dye adsorbed per unit mass of adsorbent (mg/g), q_m and b are Langmuir constants. Fig.7. establish a plot between $\frac{C_e}{q_e}$ verses C_e for the adsorption of CR on SD. The values of q_m and b were calculated from the slop and intercept of plot between $\frac{C_e}{q_e}$ versesC_e and listed in Table.1. The adsorption capacity calculated in this study under used conditions was 7.82 mg/g, which is near the value if compared with the calculated adsorption capacities of other researchers [11,14,24].

Table 1. Langmuir and Freundlich isotherm constants for adsorption of Congo red on SD at 25°C

Langmuir constant			Freundlich constant		
q_m(mg/g)	b (L/mg)	R^2	n	k(mg/g)	R^2
7.82	0.0266	0.9882	2.9788	1.1218	0.9621

R_L, a dimensionless constant, used to determine whether the adsorption is favorable or not and it was calculated by:

$$R_L = \frac{1}{1 + bC_o}$$

Where, C_o is the intial concentration of adsorbate and b is the Langmuir constant. The value of R_L shows the isotherm type such that linear $(R_L = 1)$, favourable $(0 > R_L > 1)$, unfavourable $(R_L > 1)$ and irreversible $(R_L = 0)$ [27]. Values of R_L were calculated and listed in the Table.2. From the Table.2. it can be seen that value of R_L was in the range of 0 to 1, which means that Langmuir isotherm was favourable for the adsorption of CR on SD under the conditions used in this research work.

Table 2. Values of dimensionless constant R_L

Initial dye concentration (mg/g)	b(L/mg)	R_L
25		0.601
50	0.0266	0.429
75		0.334
100		0.273

The Freundlich isotherm is

$$q_e = K_F C_e^{1/n}$$

It can be written in linear form as

$$\ln q_e = \frac{1}{n} \ln C_e + \ln K_F$$

Where

K_F is the adsorption capacity and $1/n$ is the adsorption intensity. For favorable adsorption conditions, value of n must be in the range of 1-10 [24]. Fig.8. indicates a plot of $\ln q_e$ verses $\ln C_e$, gives a straight line with values of slop and intercept shown in the Table.1. The value of n calculted in this study under used conditions was 2.9788 which mean that Freundlich isotherm was favourable for the adsorption of CR on SD [28].
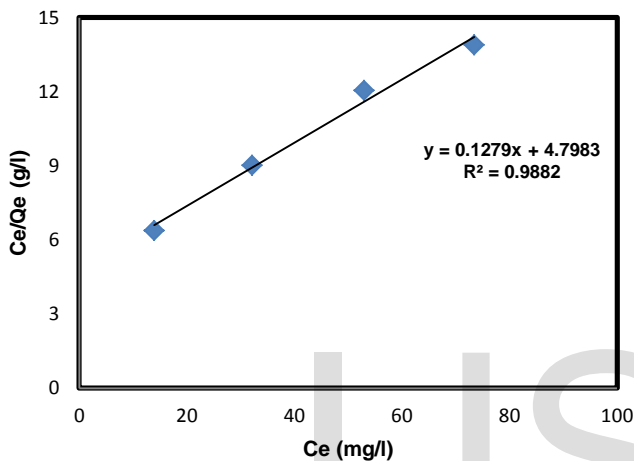

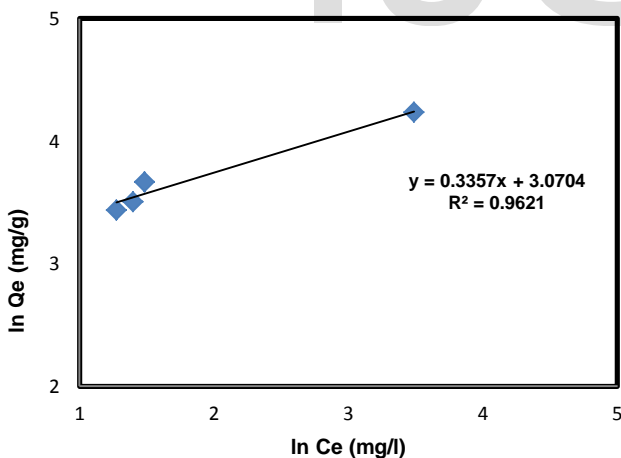**Fig. 7.** Langmiur isotherm for adsorption of CR on saw dust

Fig. 8. Freundlich isotherm for adsorption of CR on saw dust

5   Conclusions

From the present research work, it was found that Saw Dust could be effectively used as an adsorbent for the removal of Congo red from aqueous solution. Effect of initial dye concentration, adsorbent dosage, temperature and pH was studied for the adsorption of CR. Amount of dye adsorbed per unit mass of adsorbent increased with the increase of initial dye concentration, adsorbent dosage and temperature while it decreased when we increase the pH of the solution. The experimental data obtained is analyzed against Langmuir and Freundlich isotherm equations. The results shows that the data obtained for the adsorption of CR on SD followed Langmuir and Freundlich isotherms. The adsorption capacity was found to be 7.82 mg/g. The value of R_L calculated from the experimental data are 0.601, 0.429, 0.334 and 0.273 at initial dye concentration of 25, 50, 75 and 100 mg/L respectively which means that adsorption of CR on SW is favourable. Adsorption intensity calculated from Freundlich isotherm shows that SD could be used for the removal of CR.

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