



Evaluation of the Adsorption Kinetics and Equilibrium for the Potential Removal of Congo Red Dye From Aqueous Medium by Using a Biosorbent

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Activated *Mangifera indica* Saw Dust (AMSD) has been investigated as low cost and eco-friendly biosorbent prepared for the removal of Congo red (CR) in aqueous solution. Various adsorption parameters such as effect of contact time, adsorbent dose, effect of pH and initial concentration of Congo red on the adsorption capacity of the adsorbent were studied. The adsorbent was also characterized by FTIR, XRD and SEM Analysis. The equilibrium data followed both Langmuir and freundlich isotherm. The kinetic parameters of adsorption such as Lagergren Pseudo first order, Pseudo second order have also been studied. These studies suggest that the AMSD Could be used as a low cost alternative for waste water treatment for dye removal.

Keywords: Adsorption; kinetics; Isotherm; congo red; XRD; SEM; AMSD.

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1. INTRODUCTION

Water pollution with toxic compounds is of major concern for human health as well as for the environmental quality [1]. The wide use of synthetic dyes in textile dyeing, paper and pulp and other industrial application has caused large scale development of dye industries and consequently has produced large volume of dye waste water [2]. Due to ever growing demands in textile, synthetic organic dyes are widely used for dyeing textile fibers such as cotton and polyester, Approximately 10,000 different dyes and pigments are used for textile industries and over 7 X 10⁵ tons of waste produced annually. Considering volumes discharged and effluent composition, water from textile industry was declared as one of the major source of wastewater in Asian Countries. Discharge of such effluents impacts color to receiving streams and affect its aesthetic value [3]. The Textile dyeing industry consumes large quantities of water at its different steps of dyeing, finishing etc. Processes, due to large volume of water consumption, the Production of hung Volume of wastewater is inevitable. Generally, the wastewater from Printing and dyeing unit in a textile plant is rich in color, containing residues of dyes and chemicals. Dye wastewater is characteristically high in organic content, high salt content and low in biodegradation [4]. Many pollutants in wastewater from dye manufacturing, printing and textile industries are color left by dyes.

The discharge of dye bearing waste water into natural streams or on land has created significant concern as the dye impact toxicity and impedes light penetration and thus upsets the biological activity [5]. Color is one of the most important hazards in industrial effluents because the presence of dyes in water reduced light penetration, precluding the photosynthesis of aqueous flora. Besides that some dyes may cause allergy, dermatitis, skin irritation and cancer to human in addition to being mutagenic [6]. The industrial effluents discharge from dyeing and printing industries are highly colored with a large amount of suspended organic solid. These effluents are discharge into rivers make water unfit for domestic, agricultural and industrial purposes. Many dyes and their break down Product may be toxic for living organism; therefore removals of dyes are most important aspects of waste water treatment before discharge [7].

Traditionally, biological, physical and chemical method has been tested for dye removal. Biological Process is probably the most in expensive one but many dyes are poorly biodegradable due to their complex structure and xenobiotic properties moreover many dyes are toxic to microorganism, causing direct destruction of their catalytic capabilities. Reverse osmosis and electrochemical coagulation is complex and generally not feasible on a large scale due to economic consideration advanced oxidation processes (CH₂O₂/UV, O₃) have the potential to eliminate organic carbon of dye wastewater; however, they are too expensive. Chemical coagulation needs loading of chemical coagulant and optimal Operation condition such as pH and coagulant dose [8]. Adsorption is an effective and simple method for dye removal.

In adsorption Process activated carbon is the most popular and widely used dye adsorbent due to their high specific Surface area and high removal efficiency for most of dyes. In spite of this it suffers from few disadvantages such as activated carbon is quite expensive and its regeneration Produced additional effluent and results considerable loss of the adsorbent [9]. Thus use of several low cost adsorbents has been studied by many researchers. They have studied the feasibility of using low cost material such as waste orange peel, [10] banana pith, [11] neem leaf powder, [12] bagasse fly ash, [13] yellow passion fruit peel, [14] oil palm fire-based activated carbon, [15] corncob activated carbon [16] teak leaf, maize corn and babool tree bark carbon, [17] pumpkin seed hull, [18] and ground egg shell waste, [19] as adsorbent for removal of dyes in aqueous solutions.

The objective of the present communication is to evaluate the adsorption kinetics and equilibrium for the removal of Congo red (CR) dye using Activated *Mangifera indica* saw dust (AMSD). Mango tree is a plant belongs to the family anacardiace (*Mangifera indica*) is an ever green plant, which is extensively cultured in India [20].

2. EXPERIMENTAL DETAILS

2.1 Materials and Methods

2.1.1 Preparation of adsorbent

The *Mangifera indica* saw dust was collected from the local saw mill. *Mangifera indica* saw dust was cleaned, thoroughly washed with distilled water and then dried in an oven. Now it was further treated with hydrogen peroxide (100

volumes) for about 24 hours to remove all adhering organic particle and dried at 110°C for one hour in an oven. Finally, granules of activated saw dust thus obtained were stored in vacuum desiccators until required.

2.1.2 Preparation of stock solution

Congo red (CR) (Direct Red 28, C.I.22120, azo dye) supplied by Loba Chemical Ltd., (India) were used as adsorbate without further purification. The stock solution (1000 mg/L) was prepared by dissolving accurately weighed quantity of dye (CR) in double distilled water. Experimental solutions of the desired concentration were obtained by successive dilutions. For present study the CR is selected because CR is convenient for detection by spectroscopic method.

2.2 Point of Zero Charge

The pH at zero charge (pH_{PZC}) of AMSD was determined by the solid addition method [21]. To the series of 100 ml conical flasks, 45 ml of KNO_3 solution of known concentration was transferred. The pH_i values of the solution were roughly adjusted from pH 2 to 9 by adding either 0.1 HCl or NaOH. The total volume of the solution in each flask was made up to 50 ml by adding the KNO_3 solution of same strength. The pH_i of the solution was accurately noted, and 0.1gm of AMSD was added to the flask, which was securely capped immediately. The suspensions were then manually shaken and allowed to equilibrate for 48 h with intermittent manual shaking. The pH values of the supernatant liquids were noted. The difference between the initial and final pH values ($\Delta pH = pH_f - pH_i$) was plotted against the pH_i . The point of intersection of the resulting curve at which $\Delta pH = 0$ gave the pH_{PZC} .

2.3 Distribution Coefficient

A distribution coefficient of adsorbent is a ratio of quantity of the adsorbate adsorbed per unit of solid to the amount of adsorbate remaining in solution at equilibrium. The distribution coefficient is calculated by following equation [22].

$$K_d = \frac{(C_0 - C_e) \times V}{C \times m} \quad (\text{Eq. 1.})$$

Where:

C_0 is the initial concentration of adsorbate (mg/L).

C_e is the concentration of adsorbate at equilibrium (mg/L).

V is the total volume of adsorbate (L)

m is the weight of adsorbent (gm)

2.4 Adsorption Studies

The adsorption experiment were carried out in a batch process by using aqueous solution of Congo red CR with AMSD the experiments were conducted to observe the effect of contact time, adsorbent dose, pH and initial concentration of Congo red at equilibrium condition for the concentration of dye over range 10 mg/L to 90 mg/L at a fixed pH. In each experiment an accurately weighed amount of AMSD was added to 50 ml of Congo red solution in 100 ml stopper bottle and the mixture were agitated in mechanical shaker for a given length of time at constant temperature 27°C.

The adsorbent was separated from solution by centrifugation. The absorbance of the supernatant solution was estimated to determine the residual concentration. Residual dye concentration was determined using absorbance values measured before and after the treatment at $\lambda_{max} = 500$ nm by spectrophotometer (Systronic model-2206) with a quartz cell of 1 cm path length. The experiments were carried out at initial pH values ranging from 2 to 10. The initial pH of solution was controlled by addition of 0.1 M HCl and 0.1 M NaOH solutions. Kinetics of adsorption was determined by analyzing adsorptive uptake of the dye from aqueous solution at different time intervals. Two main system variables, initial dye concentration and contact time, were varied to investigate their effect on adsorption kinetics.

The FTIR, X-ray diffraction (XRD), Scanning Electron Microscope (SEM) studies of the adsorbent were carried out at SICART, V.V Nagar (Gujarat).

3. RESULTS AND DISCUSSION

3.1 Adsorbent Characterization

For structural and morphological characteristics F.T.I.R., X.R.D., and SEM of adsorbent AMSD were carried out.

3.1.1 F.T.I.R. analysis

FTIR spectra were obtained for AMSD before and after the adsorption process shown in

Figs. 1 and 2 respectively. The I.R. absorption band and corresponding possible groups are shown in Table 1. The Main functional groups involved in adsorption process were found to be =C=O, -COOH, R-OH and Ar-NH₂, R-NH₂ groups. The broad intense absorption peaks

detected at 3422 cm⁻¹ and 3421.cm⁻¹ of AMSD before and after CR adsorption could be assigned to O-H stretching vibration of hydroxyl group. The bands observed at about 2923 and 898 cm⁻¹ could be assigned to the -CH group stretching.

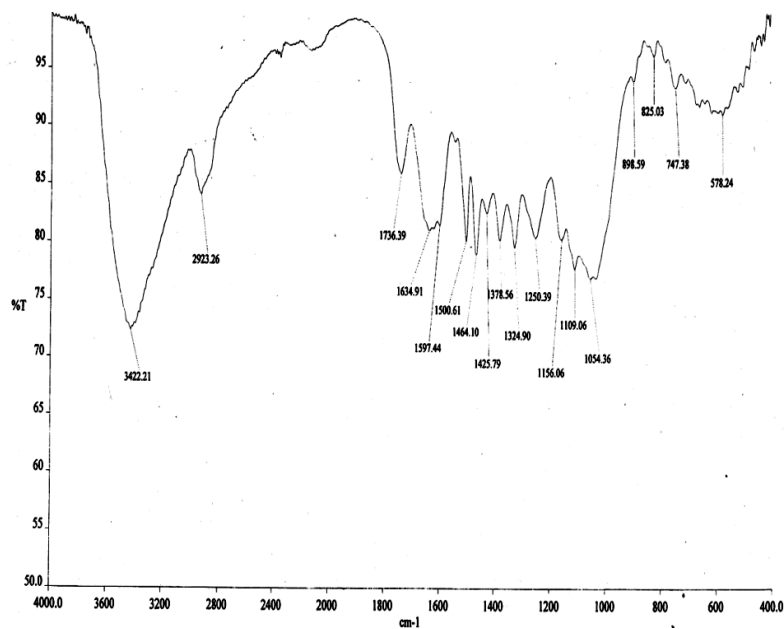


Fig. 1. FTIR spectra of AMSD before adsorption of Congo red

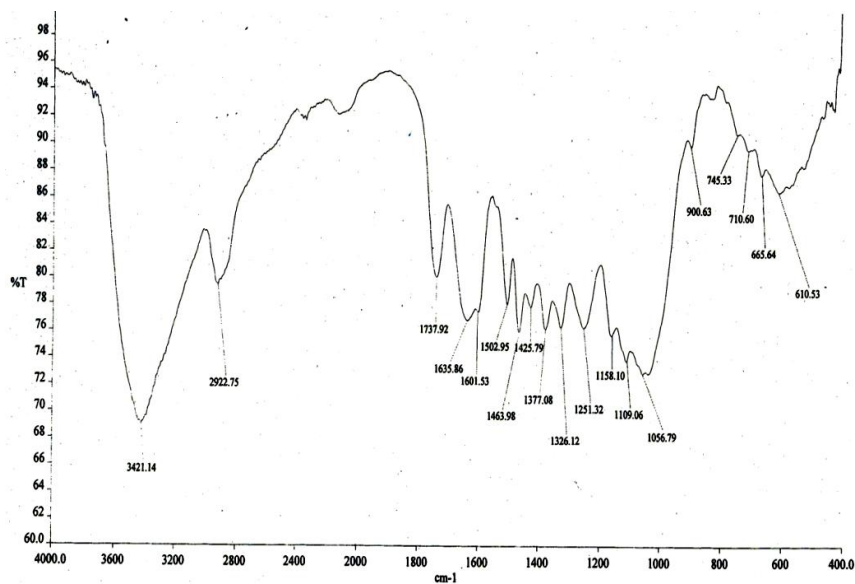


Fig. 2. FTIR spectra of AMSD after adsorption of Congo red

The peak located at 1634 and 1736 cm^{-1} is characteristic of carbonyl group stretching from aldehyde and ketones. The band appears at 1054-1109 cm^{-1} is due to C-O or C-N group stretching. The absorption peak at 1250 cm^{-1} indicates presence of C-O stretching in alcoholic or ester group. While the absorption peaks at 1464, 1500 and 1597 cm^{-1} and bending vibration band at 747-898 cm^{-1} are mainly due to the C=C bond ring stretching (Phenyl ring). The involvement of these functional groups in dye adsorption process can be judged from change in frequency of absorbing groups (Figs. 1 and 2).

Figs. 1 and 2 show presence of several functional groups for binding CR on AMSD surface.

3.1.2 XRD analysis

The XRD diagrams of AMSD before and after the adsorption process are shown in Figs. 3 and 4 and Tables 2 and 3 respectively. The XRD pattern of the adsorbent shows typical spectrum of cellulose material having main and secondary

peaks. The main peak is taken as indicative of the presence of highly organized crystalline cellulose, while secondary peak is a measure of polysaccharide structure [23].

In present study XRD Pattern of adsorbent before treatment showed spectrum having main peak at 2θ of 72.2877, while the XRD spectrum of adsorbent after treatment show three main peaks of 2θ of 44.539, 72.3548, 87.9629, respectively.

3.1.3 SEM analysis

Scanning electron microscopy (SEM) has been a primary tool for characterizing the surface morphology and fundamental physical properties of the adsorbent surface. It is useful for determining the particle, shape, porosity and appropriate size distribution of adsorbent, scanning electron micrographs of adsorbent before and after treatment are shown in Figs. 5 and 6, respectively.

Table 1. IR Adsorption bands and corresponding possible groups

Adsorption band (cm^{-1}) before adsorption	Adsorption band(cm^{-1}) after adsorption	Functional groups
3422	3421	-OH, -NH ₂
2923,	2922	-CH
1736	1737	-C=O
1054-1109	1056-1109	-C-O or-C-N
1634	1635	-COO ⁻ , -C=O
1500-1597	1502-1601	=C=C=
747-898	747-898	=C=C= (ring structure)
1250	1251	-C-O

Table 2. XRD peak position of AMSD before adsorption of Congo red

No.	Visible	Dataset name	Start position 2θ	End position 2θ	Step 2θ	Measured date time
1	True	1502 sample before treatment	3.025	99.975	0.05	
No.	Position 2θ	d-spacing	significance	Rel. Int. [%]	Height	FWHM
1	72.28	1.306	6.3488	100	376.09	0.72

Table 3. XRD peak position of AMSD after adsorption of Congo red

No.	Visible	Dataset name	Start position 2θ	End position 2θ	Step 2θ	Measured date time
1	True	1502 sample after treatment	3.025	99.975	0.05	
No.	Position 2θ	d-spacing	significance	Rel.Int. [%]	Height	FWHM
1	44.58	2.032	1.2161	15.65	143.19	0.246
2	72.35	1.30	3.49	100	571.75	0.3936
3	87.96	1.10	0.846	51.8	89.83	0.96

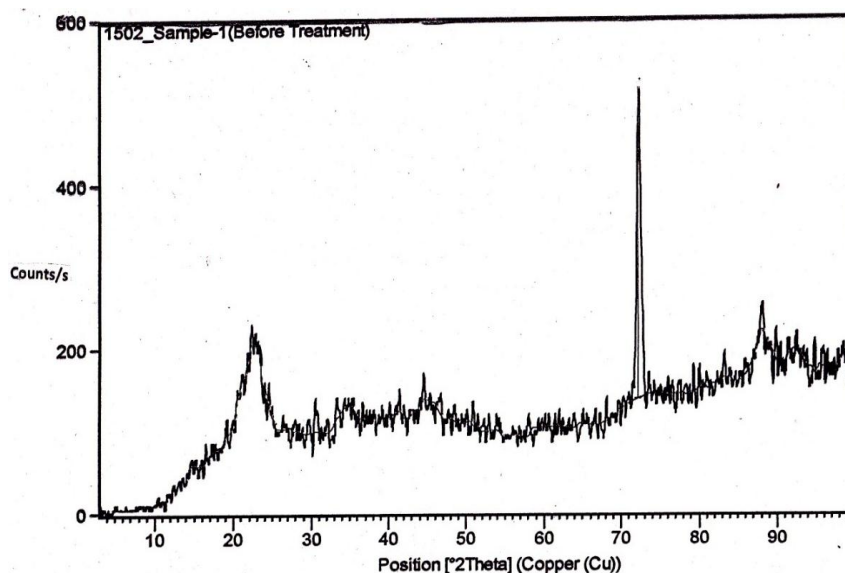


Fig. 3. XRD diagram of AMSD before adsorption of Congo red

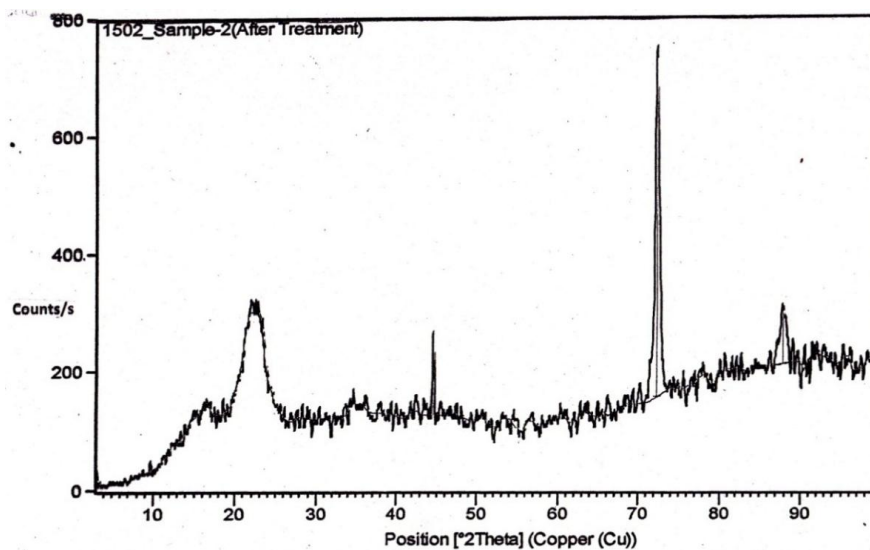


Fig. 4. XRD diagram of AMSD after adsorption of Congo red

Fig. 5 shows AMSD has considerable numbers of pores before treatment where there is a good possibility for dye to be trapped and adsorbed into these pores. while Fig. 6 shows very distinguished dark spots which can be taken as a sign of effective adsorption of dye molecule in the cavities and pores of AMSD.

3.2 Point of Zero Charge

Point of zero charge determination of biosorbent is important in elucidating biosorption

mechanism. Biosorption of cations is favour at $pH > pH_{PZC}$. While anion biosorption is favoured at $pH < pH_{PZC}$. The specific biosorption of cations shifts pH_{PZC} towards lower values whereas the specific biosorption of anion shifts pH_{PZC} towards higher values. The plot of change in solution pH (ΔpH) vs initial pH (pH_i) showed that with increasing initial pH, the pH change became more negative and the zero value of ΔpH was reached at value of 3.62 (Fig. 7) which is considered as the pH_{PZC} of AMSD.

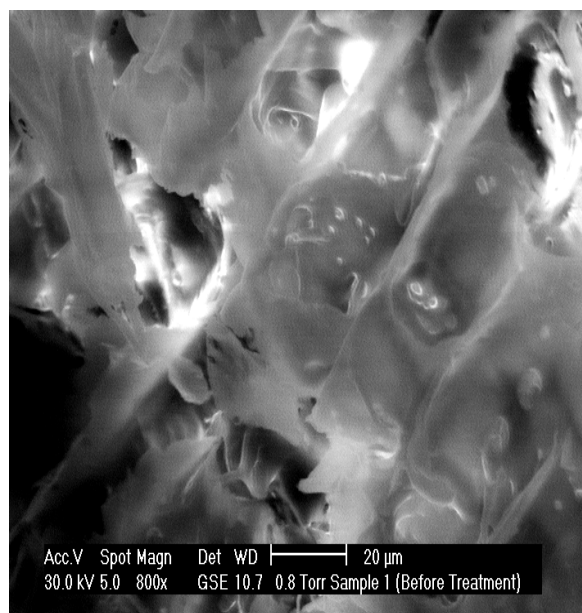


Fig. 5. SEM micrograph of AMSD before adsorption of Congo red

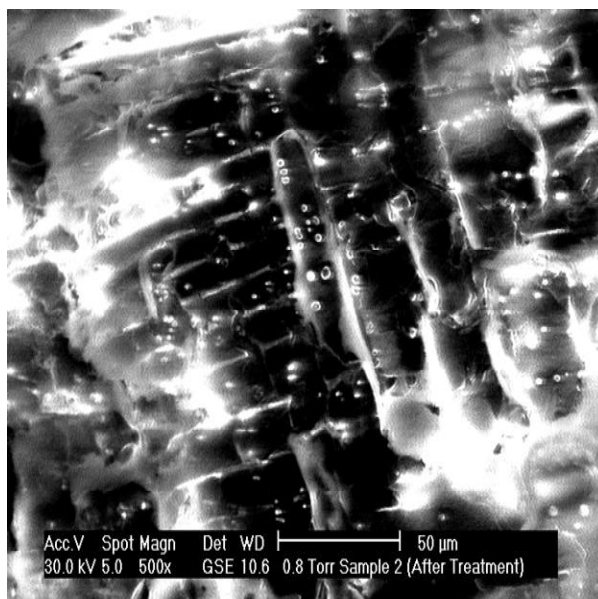


Fig. 6. SEM Photo graph of AMSD after adsorption of Congo red

3.3 Adsorption Studies

3.3.1 Effect of operational parameters

3.3.1.1 Effect of contact time

The effect of contact time on the removal of CR was investigated using 70 mg/L initial concentration of CR solution with 2 gm/L AMSD at pH 6. The extent of removal of CR by AMSD

was found to increase with increase in contact time. The maximum (82.38%) Removal of CR occurs at 30 min. as shown in Fig. 8. The value of distribution coefficient (K_D) was found to vary from 21.17 to 41.19 L/g. The maximum value (41.19 L/g) of distribution coefficient was observed at 30 min. based on these results, 30 min for AMSD was taken as the equilibrium time in adsorption experiments.

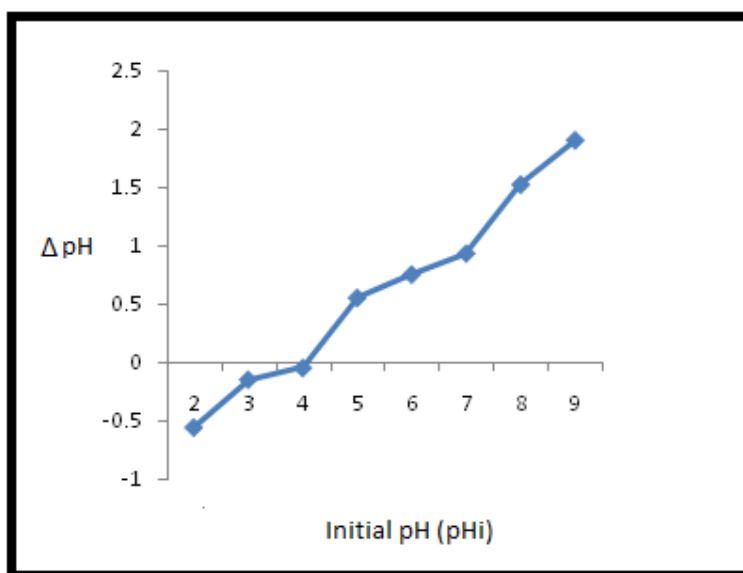


Fig. 7. Point of zero charge (pH_{PZC}) of adsorbent (AMSD) using KNO₃

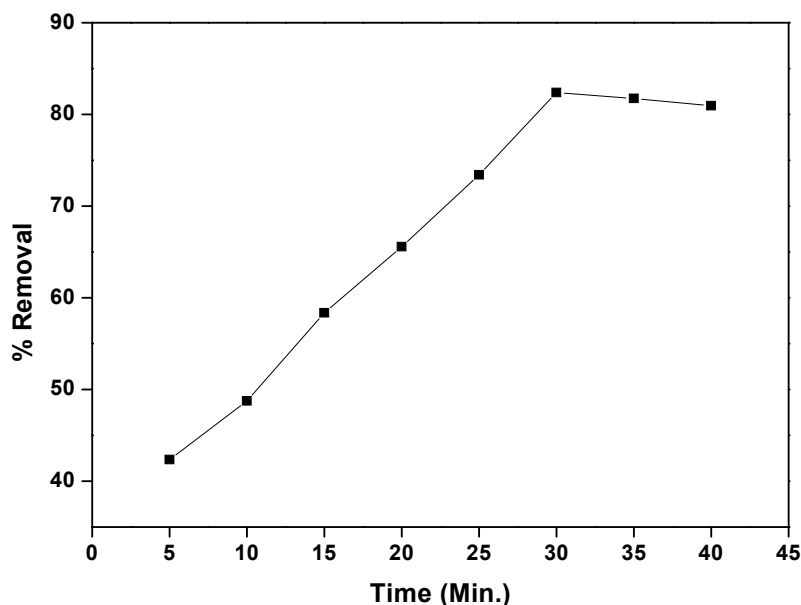


Fig. 8. Effect of Contact time on % removal of Congo red (Initial Conc. of Congo red 70 mg/ L, adsorption dose 2 gm/L and pH 6.)

3.3.1.2 Effect adsorbent dose

The effect of adsorbent dose on the removal of CR was studied using 70 mg/L initial concentration of CR solution. With varying adsorbent dose of AMSD from 0.5 to 4 gm/L. at PH 6 and contact time 30 min. The % removal of CR increases as the adsorbent dose increases due to increase in total number of exchange sites as shown in Fig. 9. When adsorbent dose increases up to 2gm/L, % removal reach to a

maximum value (88.46%). The value of distribution coefficient (K_D) was found to varies from 38.43 to 44.23 L/g. The maximum value (44.23 L/g) of distribution coefficient was occurs at 2gm/L. Based on these results 2 gm/L dose of AMSD was taken as the equilibrium dose.

3.3.1.3 Effect of pH

The pH is one of the most important factors controlling the adsorption of dye on to adsorbent.

It was reported that below pH 2 its solution change color from red to dark blue and its original red color was different above pH 10. Therefore, effect of solution pH was studied between 2 and 10. The studies were conducted at a fixed initial concentration of CR 70 mg/L, adsorbent dose 2 gm/L and contact time 30 min.

The maximum (84.2 %) Removal of CR occurs at pH 6 as shown in Fig. 10. The value of distribution coefficient (K_D) was found to varies from 23.13 to 42.07 L/g. The maximum value (42.07 L/g) of distribution coefficient was occurs at pH 6, therefore all the succeeding investigation was performed at pH 6.

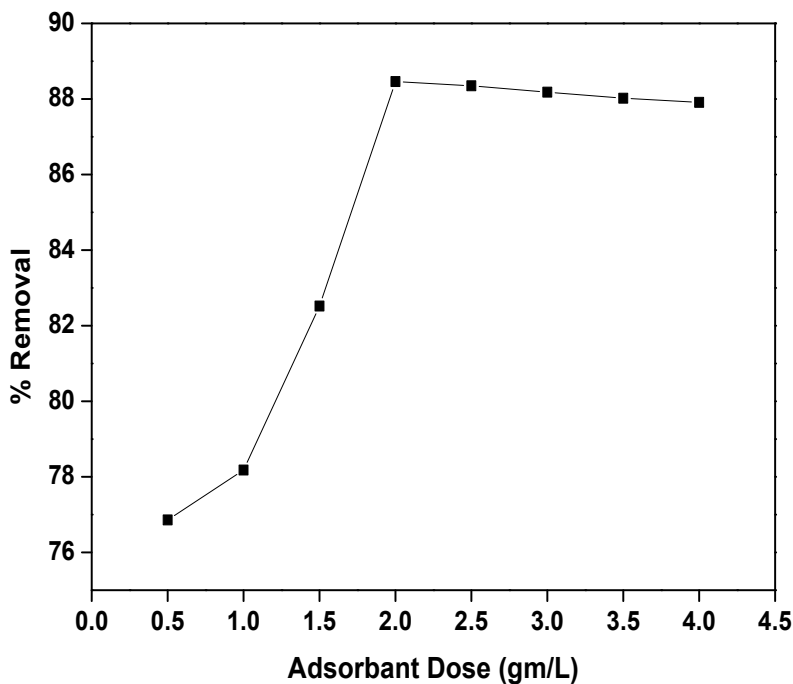


Fig. 9. Effect of adsorbent dose on % Removal of Congo red (Initial conc. of Congo red 70 mg/L, contact time 30 Min. and pH 6.)

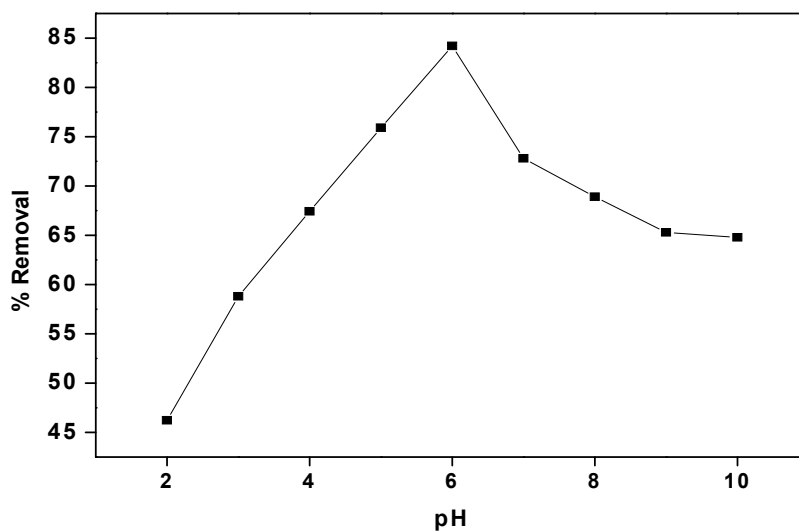


Fig. 10. Effect of pH on % Removal of Congo red (Initial conc. of Congo red 70 mg/L, adsorption dose 2 gm/L and contact time 30 min.)

3.3.1.4 Effect of initial adsorbate concentration

The effect of initial concentration of adsorbate (CR) on the amount adsorbed (q) is shown in Fig. 10. While the effect of initial concentration of adsorbate (CR) on Removal of Congo red is shown in Fig. 11. The initial concentration of CR were changed in order to determine proper CR adsorption keeping the adsorbent dose 2 gm/L, contact time 30 min and pH 6. Fig. 11 show that the as the dye concentration increases amount of adsorbed dyes also increases. While Fig. 12 showed that % removal decreases with an

increase in the dye concentration. It is also note that the rate of removal of dye is faster at lower concentration and decreases with increasing concentration. It is apparent from the Fig. 12 that with increasing concentration of CR (adsorbate) from 10 mg/L to 90 mg/L the % removal decreases from 86.02 to 43.94%. The value of distribution coefficient (K_D) was found to decreases with an increase in the dye concentration from 43.01 to 21.97 L/g. were as, the value of distribution coefficient (K_D) was found to decreases from 43.01 to 21.97 L/g with increase in amount of adsorbed dye.

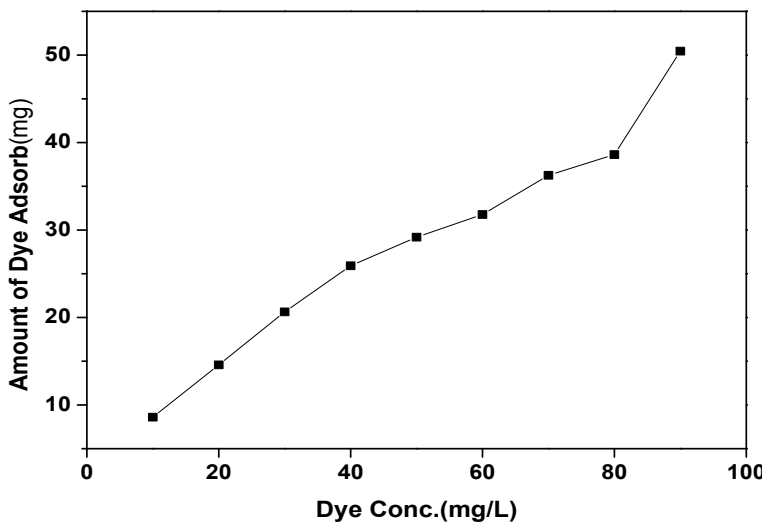


Fig. 11. Effect of initial dye concentration on adsorption of dye (adsorption dose 2 gm/L. contact time 30 min. and pH 6.)

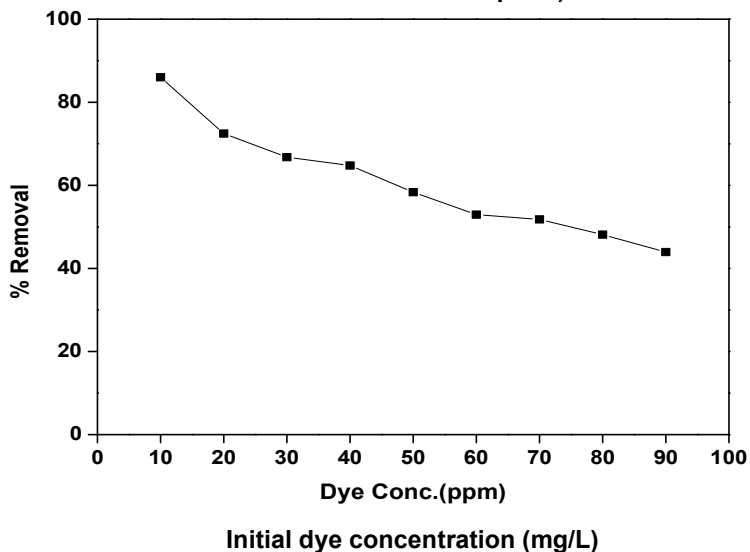


Fig. 12. Effect of Initial dye Concentration on % Removal of Congo red (Initial conc. of Congo red 70 mg/L, adsorption dose 2 gm/L and pH 6.)

3.4 Adsorption Isotherms

The distribution of dye between the liquid phase and the adsorbent is a measure of the position of equilibrium in adsorption process and can be generally expressed by Langmuir and freundlich isotherms.

The adsorption studies were conducted at a fixed initial concentration of Congo red with varying temperature. The adsorption isotherm were studied at 300°K and 310°K. The equilibrium data were analyzed by Langmuir and freundlich isotherms.

3.4.1 Langmuir isotherm

The Langmuir model [24] assumes uniform energies of adsorption on to the surface and no transmigration of adsorbate in the plane of the surface. The Langmuir isotherm is represented by the following equation.

$$\frac{C_e}{q_e} = \frac{1}{a b} + \frac{C_e}{b} \quad \text{--- (Eq. 2)}$$

Where as C_e is concentration of dye solution (mg/L) at equilibrium and q_e is the amount of CR adsorbed per unit mass of adsorbent (mg/g). a and b are Langmuir constant the constant 'a' signifies the adsorption capacity (mg/g) and b is related to the energy of adsorption (L/mg).

The linear plot of C_e / q_e vs C_e shows that adsorption follows Langmuir isotherm (Figs. 13a and 13b) at temperature 300°K and 310°K respectively. The values of a and b were calculated from the slope and intercept of linear plots respectively and presented in Table 4.

In present investigation the value of adsorption capacity (a) was 40 and 45.5 mg per gram of AMSD for CR at 300°K and 310°K, respectively. The applicability of the Langmuir isotherm suggested monolayer coverage of CR on the surface of AMSD.

The essential characteristics of the Langmuir isotherm can be expressed by dimension less constant called equilibrium parameter R_L define by equation

$$R_L = \frac{1}{(1 + b C_i)} \quad \text{--- (Eq. 3)}$$

Where b is Langmuir constant and C_i is the initial dye concentration (mg/L). R_L values obtained using equation (3) for 70 mg/L CR concentration was 0.069 and 0.054 at 300°K and 310°K respectively.

According to the value of R_L the isotherms shape and whether it is favorable or not may be interpreted as, the value of $R_L > 1$, indicated unfavorable adsorption and the value of $R_L < 1$ and greater than zero indicated favorable adsorption. Also if $R_L = 0$, indicates Irreversible adsorption.

In present study the value of R_L is less than 1 and greater than zero show that adsorption of CR on AMSD is favorable.

3.4.2 Freundlich isotherm

The freundlich isotherm [25] is an empirical equation assuming that the adsorption process take place on heterogeneous surface and adsorption capacity is related to the concentration of adsorbate.

The linear form of the freundlich equation is as follows.

$$\log q_e = \log K + \frac{1}{n} \log C_e \quad \text{Eq. 4}$$

Where $\log k$ is a measure of the adsorption capacity and n is an indicator of adsorption intensity. The freundlich coefficient $1/n$ which should have values in the range of 0 to 1 for favorable adsorption. A plot of $\log q_e$ vs $\log C_e$ gives a slope of $1/n$ and intercept of $\log K$ shown in Figs. 14a and 14b at 300°K and 310°K respectively. The value of $1/n$ and K were calculated from slope and intercept respectively and are given in Table 5. In present investigation the value of $1/n$ are 0.55 and 0.40 at 300°K and 310°K, respectively and the values of K are 3.981 and 6.607 at 300°K and 310°K, respectively.

Table 4. Langmuir isotherm constants

Temperature (°K)	Concentration of solution (mg/L)	Langmuir constant		
		a (mg/gm)	b (L/gm)	R ²
300	70	40	0.275	0.9690
310	70	45.5	0.450	0.9836

Table 5. Freundlich isotherm Constant

Temperature (⁰ K)	Concentration of solution (mg/L)	Freundlich constant		
		k	1/n	R ²
300	70	3.981	0.55	0.9727
310	70	6.607	0.40	0.9938

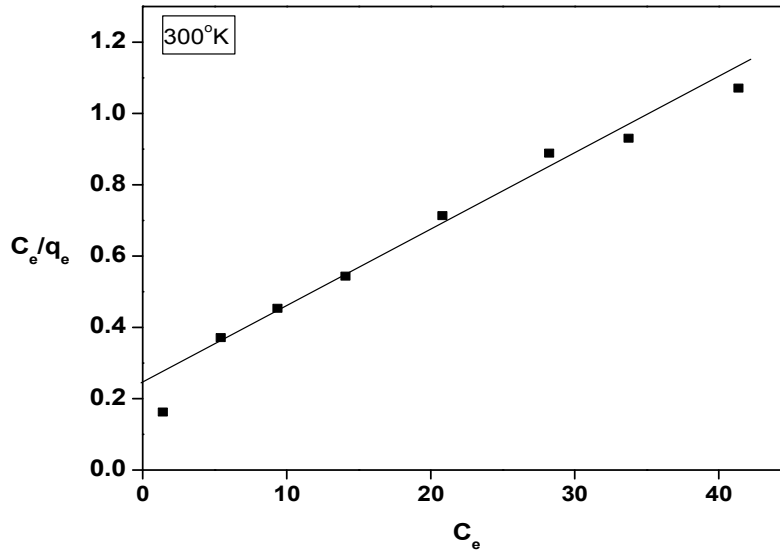


Fig. 13a. Langmuir plot for adsorption of Congo red by AMSD (adsorption dose 2gm/L. contact time 30 min. and pH 6, temp. 300⁰ C)

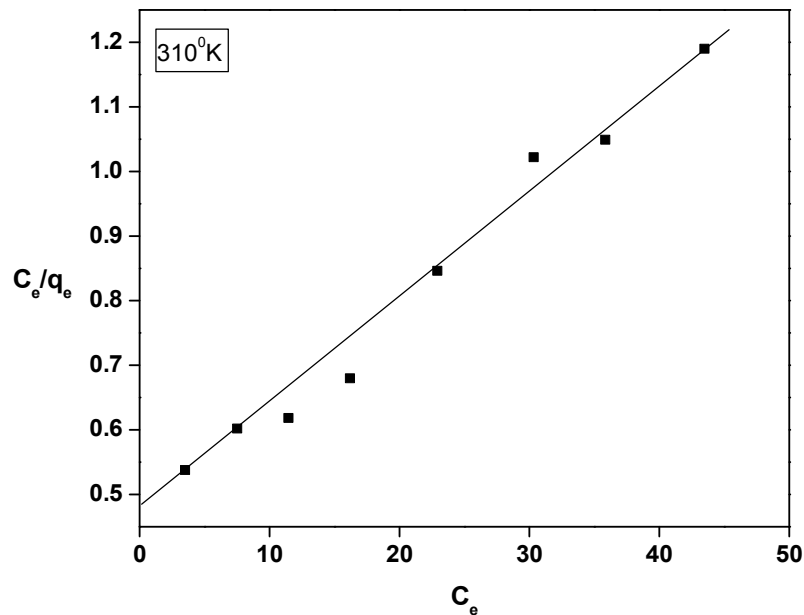


Fig. 13b. Langmuir plot for adsorption of Congo red by AMSD (adsorption dose 2gm/L. contact time 30 min. and pH 6, temp. 310⁰ C)

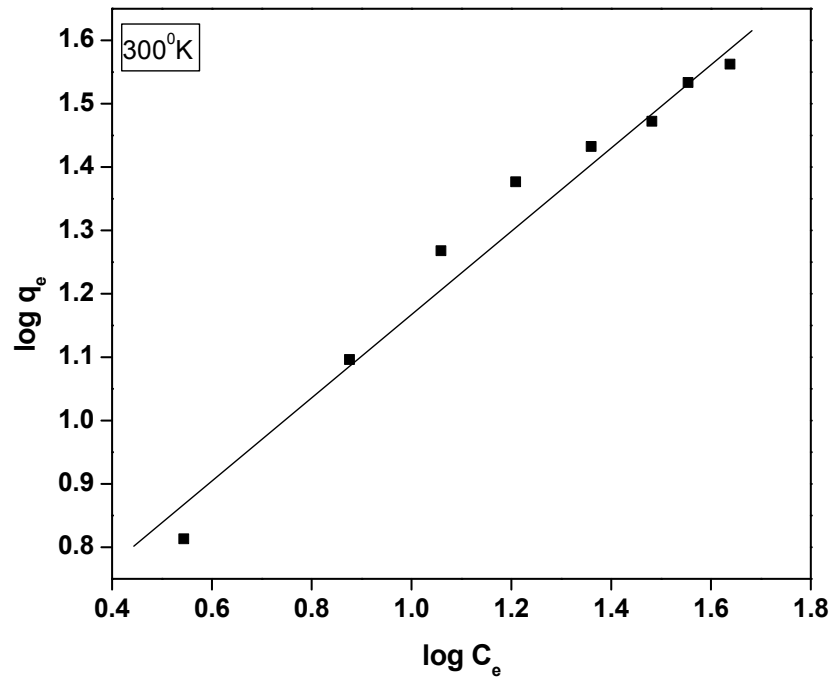


Fig. 14a. Freudilich plot for adsorption of Congo red by AMSD (adsorption dose 2gm/L. contact time 30 min. and pH 6, 300° K)

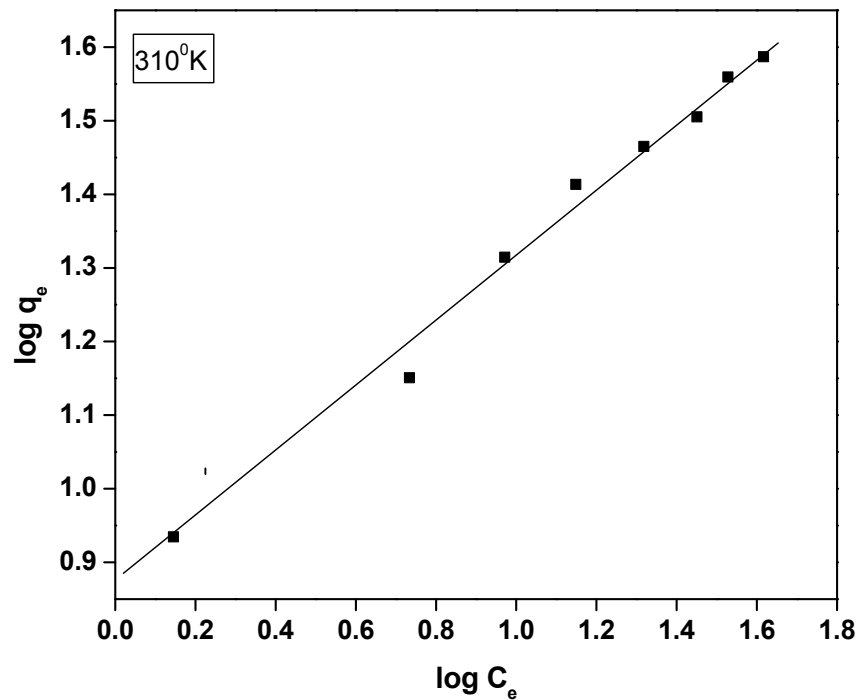


Fig. 14b. Freudilich plot for adsorption of Congo red by AMSD (adsorption dose 2gm/L. contact time 30 min. and pH 6, 310° K)

3.5 Adsorption Kinetics

In order to investigate the mechanism of sorption two kinetic models were tested: a pseudo first order and a pseudo second order model.

3.5.1 Pseudo first order model

Lagergren's rate equation is most widely used for the adsorption of adsorbate from a solution. The first order Lagergren's rate equation is expressed as follows :

$$\log(q_e - q_t) = \log q_e - K_1 t \quad \text{----- (Eq. 5)}$$

Where q_e and q_t (both in mg/gm) are the solute amounts adsorbed per unit mass of adsorbent at equilibrium and at time t (min), respectively K_1 (min^{-1}) is the first order rate constant.

The values of K_1 and q_e were calculated from the slope and the intercept of the plot of $\log(q_e - q_t)$ vs t respectively (Fig. 15) the calculated values of K_1 and q_e (cal) and q_e (exp) are summarized in Table 6.

In present investigation the value of K_1 , q_e (cal) and q_e (exp) was 0.2366 min^{-1} , 50.12 mg/g and 33.73 mg/g respectively. The experimental q_e

values is in agree with calculated ones, obtained from the linear plots. This shows that the adsorption of CR on AMSD is a Pseudo first order kinetics.

3.5.2 Pseudo second order model

Pseudo second order equation based on equilibrium adsorption is expressed as

$$\frac{t}{q_t} = \frac{1}{K_2 q_e} + \frac{t}{q_e} \quad \text{----- (Eq. 6)}$$

Where K_2 (g/mg.min) is the rate constant of second order adsorption If second order kinetics is applicable, the plot of t/q_t vs t should show a linear relationship q_e and K_2 can be determined from the slope and intercept of the plot. The Linear plots of t/q_t vs t (Fig. 16).

The calculated values of K_2 and q_e (cal) are summarized in Table 7.

In present investigation the values of K_2 and q_e was 0.0175 min^{-1} and 0.00128 respectively. The experimental q_e values do not agree with the calculated ones, obtained from the linear plots. This shows that the adsorption of CR on to AMSD is not a Pseudo second order kinetic.

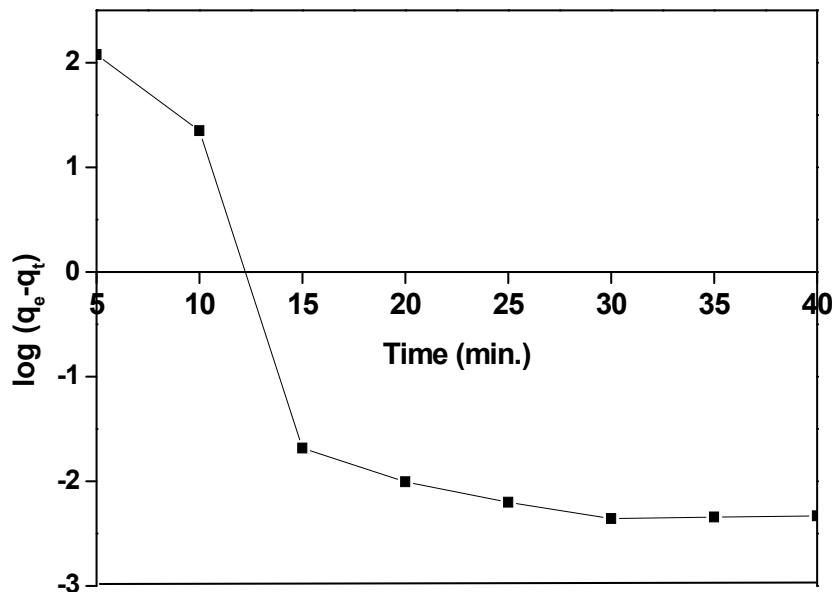


Fig. 15. Lagergren first order plot for adsorption of Congo red by AMSD (Initial conc. 70 /L mg, adsorption dose 2gm/L. contact time 30 min. and pH 6.)

Table 6. Kinetic model values for adsorption of Congo red on to AMSD

Concentration of Congo red (mg/L)	q_e (exp) (mg/g)	Pseudo first order constant		
		q_e (cal) (mg/g)	K_1	R^2
70	33.73	50.12	0.2366	0.8254

Table 7. Kinetic model values for adsorption of Congo red on to AMSD

Concentration of Congo red (mg/L)	q_e (exp)(mg/g)	Pseudo second order		
		q_e (cal)(mg/g)	K_2	R^2
70	33.73	0.00128	0.0175	0.9938

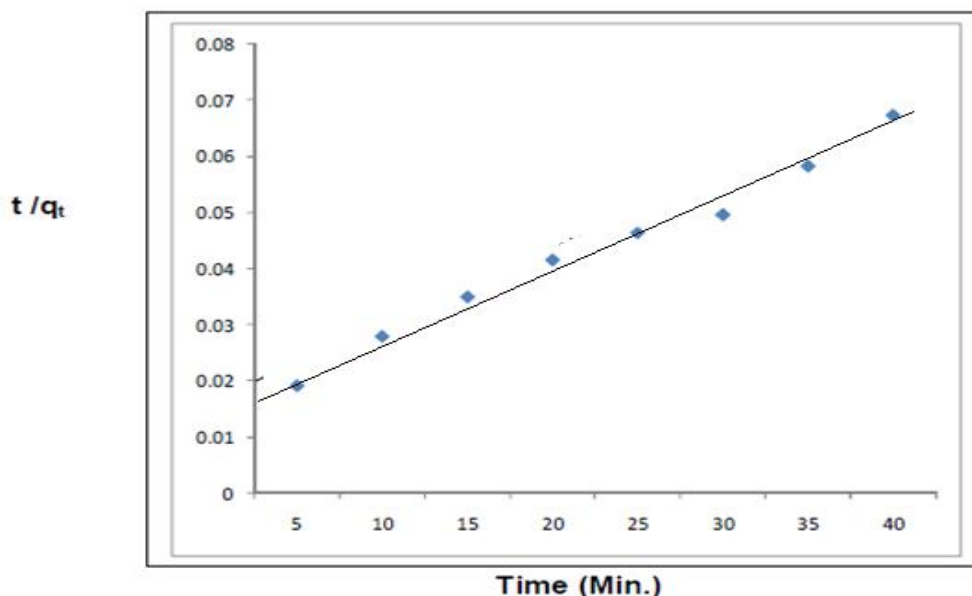


Fig. 16. Pseudo second order adsorption of Congo red on AMSD (Initial conc. 70 mg/L, adsorption dose 2 gm/L. contact time 30 min. and pH 6)

4. CONCLUSION

The adsorption of CR is depends on contact time, adsorbent dose, pH and initial concentration of dye solution. From the results it was concluded that maximum adsorption of CR from aqueous solution occurred at pH 6. Adsorption was increased with increasing adsorbent dose and decreases with increase in initial concentration of CR. Kinetics and isotherm studies revealed that AMSD can be effectively employed for the adsorption of CR. The experimental data are correlated reasonably well by the Langmuir and freundlich adsorption isotherm the value of $R_L < 1$ obtained indicates that applicability of Langmuir adsorption isotherm. The whole adsorption process was well described by Pseudo first order. The result of this study indicates that AMSD can be successfully

used for the adsorption of CR from aqueous solution.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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