



Efficient Removal of Toxic Textile Dye using Petiole Part (Stem) of *Nymphaea alba*

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Received: 24 January 2021, Revised: 11 May 2021, Accepted: 01 July 2021
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ABSTRACT

The removal of toxic textile dye, Congo red (CR) an azo based textile dye, was investigated from aqueous solution by low cost, eco-friendly available adsorbents such as petiole part (stem) of water lily (*Nymphaea alba*) under various experimental conditions. Batch experiment was carried out at varying pH, dye concentration, contact time and particle size as well as doses of the adsorbent. CR was analyzed by a UV-visible spectrophotometer. Optimum pH was found at pH 2 and 6. A relative study was done using sodium chlorite and formaldehyde treated water lily. The maximum removal of CR was obtained 94.68% using untreated water lily (UT-WL). Adsorption increased with the increase of the particle size of the adsorbent. The highest removal of CR was found at a lower dose (62.5 g/g) of the adsorbent. The Freundlich isotherm model was best fitted to equilibrium data obtained from the experiment. The adsorption kinetics successfully fitted to the pseudo-second-order kinetic model.

KEYWORDS: Congo red, Petiole part(stem), Adsorption isotherm, Adsorption kinetics, Removal efficiency.

INTRODUCTION

Bangladesh is profoundly involved in the textile production and export. A large number of textile mills, mostly around the Dhaka city, impart in the development of this sector. But these mills generate toxic dye content in wastewater without treatment. The frequent discharge of effluents, bearing dyes, surfactants, etc. from industries to the surface water causes contamination. It was reported by various organizations and monitoring authorities that the pollution of the rivers and canals caused by the dye in and around Dhaka is well above their acceptable level (Rahman *et al.*, 2013). Toxic effluents containing azo dyes are discharged from various industries and they adversely affect water resources, soil fertility, aquatic organisms and ecosystem integrity. Disodium-4-amino-3-[4-[4-(1-amino-4-sulfonato-naphthalen-2-yl) diazenylphenyl] phenyl] diazenyl-naphthalene-1-sulfonate ($C_{32}H_{22}N_6Na_2O_6S_2$) commercially known as Congo red is one of the toxic dyes. It is a synthetic reactive water soluble dye used as in medicine, indicator, color in textiles (initially cotton) (Chatterjee *et al.*, 2007). This type of azo dye adversely affects the central nervous system and is highly carcinogenic and mutagenic for mammalian somatic cells (Mittal *et al.*, 2010; Liu *et al.*, 2012). Congo red causes platelet aggregation and is hazardous, particularly in hypoalbuminetic patients (Rocha *et al.*, 2009).

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Several techniques like oxidation (Elahmadi *et al.*, 2009), radiation (Ma *et al.*, 2007), photolytic process (Erdemoğlu *et al.*, 2008), adsorption (Raghuvanshi *et al.*, 2008) and microbial electrochemical technologies (Das S. *et al.*, 2020; Gupta *et al.* 2020) are well known for removing CR dye from waste water. Among these techniques adsorption is a cost-effective technology for the treatment of wastewater containing different types of dye. Many investigations have been carried out regarding the removal of dyes from wastewater by using suitable adsorbent. Arafath *et al.*, (2013) have investigated the adsorption efficiency of Neem leaf and Mehagoni leaf powder for the removal of dyes from textile effluents. They found that the rate of adsorption was fast in the first 1.2 hours then gradually increased and then slowed down as equilibrium reached. Raghuvanshi *et al.*, (2008) have found 81% removal of congo red dye from aqueous solution using Neem leaves as an adsorbent by using batch system adsorption. Orange and Banana peel have been used by Mane and Bhusari in 2012 as adsorbent for the removal of colour dyes originated from textile effluent and reported equilibrium time 55 minutes and 45 minutes, respectively. Zuurro *et al.*, have studied the removal of two azo dyes in 2013. They experimented Reactive green -19 (RG19) and Reactive violet 5 (RV 5) using spent tea leaves (STL) as adsorbent. After thermal exposure of STL to 300°C for 1 hour, removal efficiencies of 98.8% and 72.8% were observed for RG19 and RV5, respectively. El Maghraby *et al.*, have studied both treated and untreated rice hulls for methylene blue adsorption in 2011. The adsorption capacity increased from 72 to 94% with increasing the pH from 3 to 10. The pretreatment of rice hulls with citric acid did not reveal any beneficial effect. A comparative study has been done by Mohammed *et al.*, in 2007. They found that the adsorption process using activated carbon insured a good degree of color reduction reaching 99.7% and found better than activated bauxite which reached 95%. Jeyanthi and Dhinakaran (2012) have used treated coconut coir pith to adsorb methylene blue. Sorption data revealed that this adsorbent has a greater affinity to methylene blue. Reddy *et al.*, (2013) have found that tannery sludge derived activated carbon exhibits dye removal efficiency of about 80–90% which was also observed with commercial coal-based activated carbon. Using rice husk charcoal as dye adsorbent, Janveja *et al.*, have found in 2014 that adsorption increased from 0.2 g/L to 1.2 g/L doses and then it became constant. They also found, with the change of contact time from 30 minutes to 210 minutes, the adsorption increased and then became constant. Liu *et al.*, have experimented in 2012 on the adsorption of methylene blue by kapok fiber treated by sodium chlorite that optimized with response surface methodology. The predicted value (105.48 mg/g) of the model was excellent agreement with experimental value (110.13 mg/g). Many other low-cost adsorbents have been used for the removal of dye from the wastewater such as coconut coir dust, (Macedo *et al.*, 2006) wheat shells, (Bulut *et al.*, 2007) sugarcane bagasse ash, (Kanawade and Gaikwad 2011) papaya seeds (Hameed 2009), etc.

Versatile methods for cleaning wastewater have been developed in recent years, but still, there is scope to find a new cost-effective way of the removal of toxic dye like Congo red using cheap, easily available, and efficient adsorbent. *Nymphaea Alba*, commonly known as water Lily is available in our country and could be used as adsorbent. It is rich in nitrogen-free extract (53.09% - 56.57%) in all of its parts. Potassium (1.56% - 4.63%) and sodium (1.97% - 4.21%) were the dominant minerals with calcium, zinc, iron and copper equally present in *Nymphaea Alba* (Abarike *et al.*, 2015). Therefore, the adsorption and removal of Congo red from aqueous solution using water lily is the interest of the present research.

MATERIALS AND METHODS

Untreated and chemically treated water lily powder were used as adsorbent for the removal of

Congo red ($C_{32}H_{22}N_6Na_2O_6S_2$) purchased from Nova Chemicals, India. Sodium hydroxide (Merck, India), sodium chlorite (80% $NaClO_2$) (BDH Laboratory, England), concentrated hydrochloric acid (BDH Laboratory, England), glacial acetic acid (Merck, Germany), 1% formaldehyde (Merck, India) were used in the experiment. All the chemicals were analytical grade and were used without further purification. Instruments such as pH meter (Yangzhong SHI YIBIAO QJIAN CHANG) with a combination electrode with precession of ± 0.01 pH units and UV-visible Spectrometer (OPTIZEN, Korea) were employed for measurement of pH and concentration of dye solution, respectively.

Grey colored water lily was collected from the local pond and its petiole was separated and washed. The petiole was cut into small pieces and further washed with double distilled water followed by drying in the sunlight. These small pieces of water lily were then kept in an oven at $80^\circ C$ and then grinded. The crushed water lily was separated to the desired sizes accomplished using sieves of various mesh sizes and stored. The processing of untreated water lily is shown in the Flow chart 1.



Flow chart 1. Processing of untreated water lily.

To make better quality adsorbents, water lily powder was treated with sodium chlorite ($NaClO_2$) according to the matrix designed by Box-Benken experimental design (Liu *et al.*, 2012). At first, $NaClO_2$ of 6.20 g was dissolved in required volume (to dissolve $NaClO_2$) of double distilled water while 9.5 mL of acetic acid was added to it and stirred for homogeneous mixing. Afterward, 10.0 g grinded untreated water lily powder was added and stirred for about 60 minutes at 150 rpm at $90^\circ C$. The treated water lily powder was washed with distilled water until the filtrate reached pH 6–7. The washed powder was then dried at $80^\circ C$ to a constant weight and screened through a sieve to obtain the desired (75, 150 & 300 μm) mesh size. Similar process was executed in treating water lily by 1% formaldehyde. The water lily thus obtained by using sodium chlorite is termed as sodium chlorite treated water lily (SCT-WL) whereas FT-WL stands for formaldehyde treated water lily.

The batch adsorption studies were carried out with UT-WL (62.5 g/g of $\leq 75 \mu m$ mesh size) and 40.0 mL of 100 mg/L CR solution upon shaking at speed of 225 rpm at room temperature ($28.0 \pm 0.5^\circ C$) for 4 hours. Under these experimental conditions optimization of pH (within pH range from 2.0 to 11.0) and estimation of equilibrium time (the data was collected at different time intervals) at pH 2.0 and 6.0 were investigated. Effect of particle size (keeping dose 62.5 g/g and particle size of $\leq 75 \mu m$, $\leq 150 \mu m$, $\leq 300 \mu m$; at pH 2.0 and 6.0) and

effect of dose (dose 62.5, 125 and 187.5 g/g; keeping particle size of $\leq 300 \mu\text{m}$ only at pH 6.0; since, the colour of the solution changed red to deep blue and sedimentation occurred at pH 2, that is why the data on the adsorption at pH 2.0 was omitted) of UT-WL on the adsorption of CR of similar concentration were also studied by batch experiment. Adsorption isotherm of CR having concentration within the range of 10 to 100 mg/L was studied on UT-WL as well as SCT-WL at the dose level of 62.5 g/g (particle size $\leq 300 \mu\text{m}$) at pH 6.0 at room temperature ($28.0 \pm 0.5^\circ\text{C}$). Adsorption kinetics of CR (100 mg/L) on UT-WL and SCT-WL was compared under similar conditions as mentioned in the case of studying adsorption isotherm. All through these adsorption studies mentioned above DDW (double distilled water) was used as blank and after the adsorption the solutions were centrifuged and then the supernatant as well as the initial concentration of CR was analyzed by UV-visible spectrophotometer.

The FTIR spectroscopic studies of WL before and after adsorption were done to realize the effect of the adsorption of Congo red on the surface of WL. For this purpose, KBr was used as a reference. The pellet of WL (before and after adsorption) and KBr was made at 1:200 weight ratio, exposed to the mid IR radiation and recorded the data at 2 cm^{-1} resolution for 30 times scanning.

RESULTS AND DISCUSSION

The initial pH of dye solution plays an important role particularly on the adsorption capacity by influencing the chemistry of both dye molecule and adsorbents in aqueous solution (Virlan *et al.*, 2013). When the pH of the solution is lower than the pH at zero point charge (pH_{zpc}) value, the system is said to be "below the pH_{zpc} ". Below the pH_{zpc} , the acidic water donates more protons than hydroxide groups, and the adsorbent surface is positively charged (Mohamad *et al.*, 2017). Conversely, above pH_{zpc} , the surface is negatively charged. Very low pH change was observed at pH 2 and pH 6. Therefore, adsorption experiments were carried out maintaining optimized pH (2 and 6) value. The data are plotted in Fig. 1.

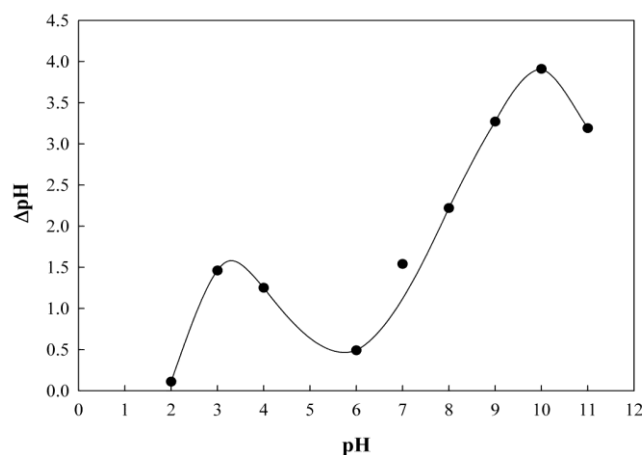


Fig. 1. Optimization of pH for the adsorption of Congo red (CR) on water lily (WL).

The estimation of equilibrium time for the adsorption of Congo red on UT-WL was studied at pH 2 and pH 6 which is shown graphically in Fig. 2. The equilibrium attains more quickly at pH 6 (within 2.0 hours) than that at pH 2 (within 3.5 hours). The finding for the equilibrium time in the case at pH 2 is quite similar to the result obtained by Arafath *et al.* 2008 with different types of dyes.

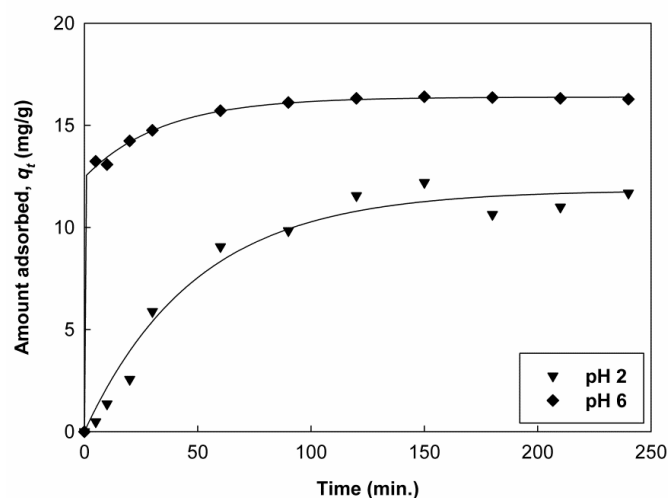


Fig. 2. Variation of the amount of Congo Red adsorbed (q_t) per gram of UT-WL (mesh size $\leq 75 \mu\text{m}$) at pH 6 and pH 2 with time.

The pH of the solution has an influence on the uptake of dye by the adsorbent. The effect of pH on the percent removal of CR from the aqueous solution is illustrated in Fig. 3. The highest removal of CR was observed at pH 2 and 6.

The molecular form of Congo red in solution could change significantly at pH 3. At pH 2, the dye solution changed its color from red to dark blue and the precipitated dye can be efficiently removed by filtration. CR exists as an anionic form at basic pH and as a cationic form at acid pH. At pH 2 significantly high electrostatic attraction exists between the positively charged surface of the adsorbent and the anionic dye. As the pH of the system is increased, the number of negatively charged surface increases and the number of positively charged site decreases. The adsorption of Congo red at alkaline pH is due to the presence of excess OH^- ion competing with the dye anions for the adsorption sites (Virilan *et al.*, 2013). This result was found to contrast with the research findings by Namasivayam and Kavitha in 2002, where the highest removal of Congo red was observed at pH 2.0 by using activated carbon from coir pith.

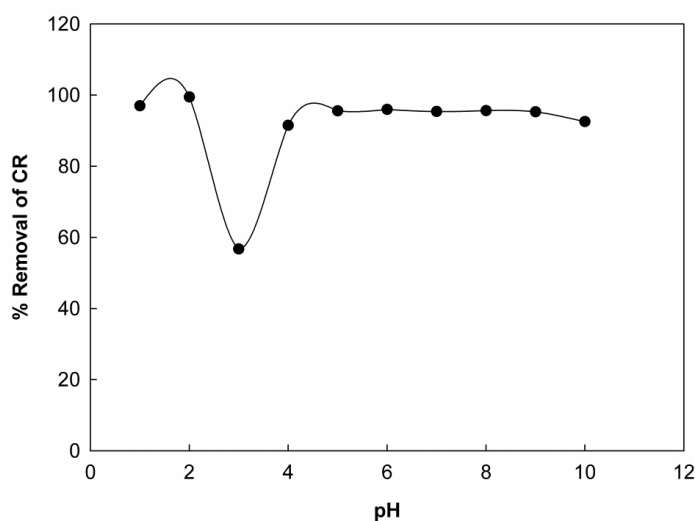


Fig. 3. Variation of the removal of Congo Red at different pH.

The effect of particle size of UT-WL for the adsorption of CR was investigated at pH 2 and pH 6. The particle size of UT-WL was found to have a profound effect on the percent removal of CR with varying pH. The percent removal of CR adsorbed onto UT-WL increased with the increase of particle size (for particle size $\leq 75 \mu\text{m}$ removal 90.67%, $\leq 150 \mu\text{m}$ removal 95.96% and $\leq 300 \mu\text{m}$ removal 97.50%) of the adsorbent at pH 2 which is shown in Fig. 4. On the other hand, at pH 6 the percent removal found to be comparable 93.67% and 94.68% for particle size of $\leq 75 \mu\text{m}$ and $\leq 300 \mu\text{m}$, respectively, whereas the particle size of $150 \mu\text{m}$ exhibited comparatively lower removal 88.22%, shown in Fig. 5.

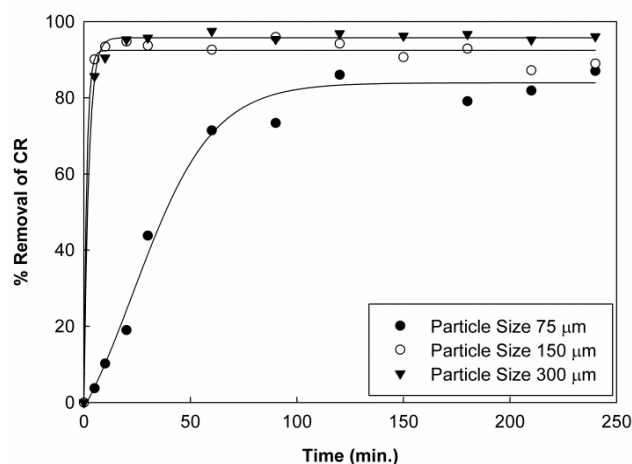


Fig. 4. Variation of the percent removal of Congo Red onto UT-WL with different particle sizes ($\leq 75 \mu\text{m}$, $\leq 150 \mu\text{m}$, $\leq 300 \mu\text{m}$) at pH 2 (dose level = 62.5 g/g).

The internal diffusion to mass transfer increases with the increase in particle size (Raghuvanshi *et al.*, 2005). For smaller particle size ($\leq 75 \mu\text{m}$), adsorption occur quickly and saturation attain rapidly. At pH 6 the finding is almost similar to that obtained by using the root of *Eichhornia crassipes* (Wanyonyi *et al.*, 2014) but differ at pH 2. These results also differ from what was obtained by using water hyacinth petiole at pH 6 (Rahman *et al.*, 2019).

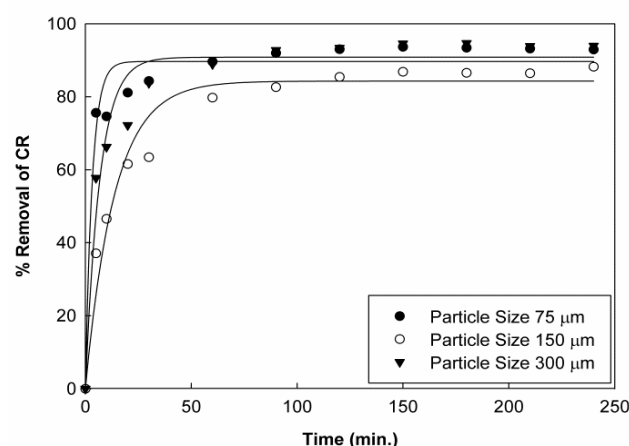


Fig. 5. Variation of the percent removal of Congo Red onto UT-WL with different particle sizes ($\leq 75 \mu\text{m}$, $\leq 150 \mu\text{m}$, $\leq 300 \mu\text{m}$) at pH 6 (dose level = 62.5 g/g).

The adsorbent dose is an important parameter in adsorption studies because it determines the capacity of adsorbent for a given initial concentration of dye solution. Different doses of adsorbent (62.5, 125 and 187.5 g/g) were used with keeping particle size of $\leq 300 \mu\text{m}$. After

equilibrium, the samples were allowed to settle for some time and then the supernatant solutions were analyzed. Fig. 6 shows the effect of adsorbent doses on the percent removal of CR by UT-WL at pH 6. It observes that initially, the percentage of removal of dye is higher for 125 g/g UT-WL than the other two dose levels. With the proceeding of time, the percent removal of CR seems to be higher for a lower dose of the adsorbent. The percent removal of CR onto UT-WL obtains the maximum 94.68% at dose level 62.5 g/g whereas removal of CR obtains 92.05% and 88.65% for 125 and 187.5 g/g, respectively. The comparison of the effect of the dose level of UT-WL on the adsorption of CR indicates that the adsorption decreases as the dose level of adsorbent increases. This is due to the over-lapping of adsorption sites resulting in a decrease of total surface area available (Singh *et al.*, 2001; Boskey and Camacho 2007). This finding is quite similar to previous research work (Rahman *et al.*, 2019).

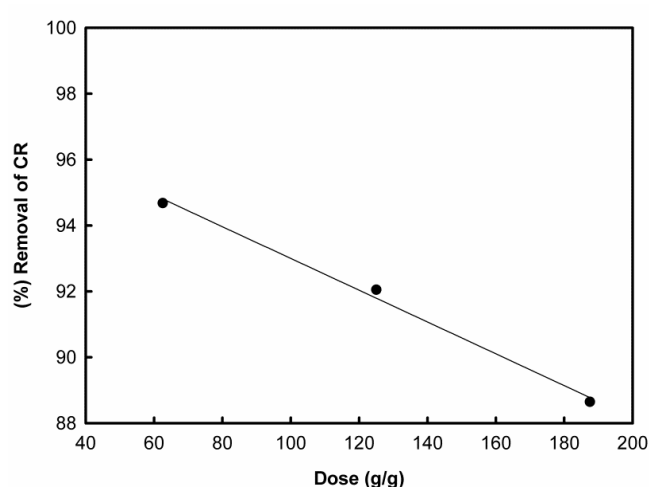


Fig. 6. Variation of the percent removal of CR onto UT-WL with varying dose at pH 6 with particle size: $\leq 300 \mu\text{m}$.

Due to low removal in the case of FT-WL, the adsorption isotherms of CR were studied on UT-WL and SCT-WL at pH 6 and shown in Fig. 7. The figure illustrates that the UT-WL appeared to be more conducive to adsorbing CR rather than SCT-WL. The active sites in UT-WL were found to be occupied more readily by CR molecules rather than those in SCT-WL. The nature of adsorption was studied by comparing these isotherms with Langmuir and Freundlich isotherm model.

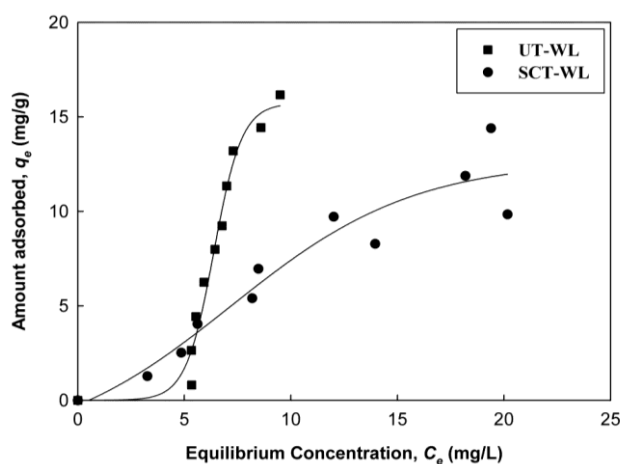


Fig. 7. Adsorption isotherm of CR on UT-WL and SCT-WL at pH 6.

Monolayer coverage of dye molecules on the adsorbent with all adsorption sites of equivalent energy is elucidated by the Langmuir adsorption Isotherm as follows -

The Langmuir Isotherm equation (Gupta *et al.*, 2017)

$$\frac{x}{m} = \frac{aC_e}{1 + bC_e} \quad (1)$$

[Where, x/m = amount adsorbed; C_e = Equilibrium concentration, a , b = Langmuir Constants]

$$\therefore \frac{C_e}{x/m} = \frac{1}{kK_{eq}} + \frac{C_e}{k} \quad \text{or,} \quad \frac{C_e}{q_e} = \frac{1}{q_m K_{eq}} + \frac{C_e}{q_m} \quad (2)$$

[Where, q_e = amount of adsorbed at equilibrium; q_m = amount adsorbed while monolayer is formed]

The Freundlich model (Gupta *et al.*, 2017) is applied to calculate the adsorption data of CR, as per the given relation:

$$\frac{x}{m} = K_F C_e^{1/n} \quad (3)$$

$$\log\left(\frac{x}{m}\right) = \log K_F + \frac{1}{n} \log C_e \quad (4)$$

[Where, K_F = Freundlich Constant; n = constant and $n > 1$]

The adsorption isotherm at pH 6 obtained to be fitted relatively more precisely with Freundlich than to Langmuir isotherm. The plot of fitting isotherm for the adsorption of CR on UT-WL and SCT-WL with Langmuir and Freundlich isotherm at pH 6 is shown in Fig. 8 and 9, respectively. Here, the value of correlation coefficient, R^2 , for the adsorption of CR on UT-WL is found 0.427 shown in Fig. 8 for fitting with Langmuir isotherm whereas in Fig. 9 the value is only 0.814 for fitting with Freundlich isotherm. On the other hand, in the case of SCT-WL, R^2 value is obtained to be 0.000 (Fig. 8) and 0.862 (Fig. 9) for fitting with Langmuir and Freundlich isotherm, respectively. Langmuir and Freundlich coefficients for the adsorption of Congo red on UT-WL and SCT-WL at pH 6 are shown in Table 1. These results contrasted with the previous research work (Chatterjee *et al.*, 2007) where the isotherm data were better fitted with Langmuir model rather than Freundlich model for the adsorptive removal of congo red by chitosan hydrobeads.

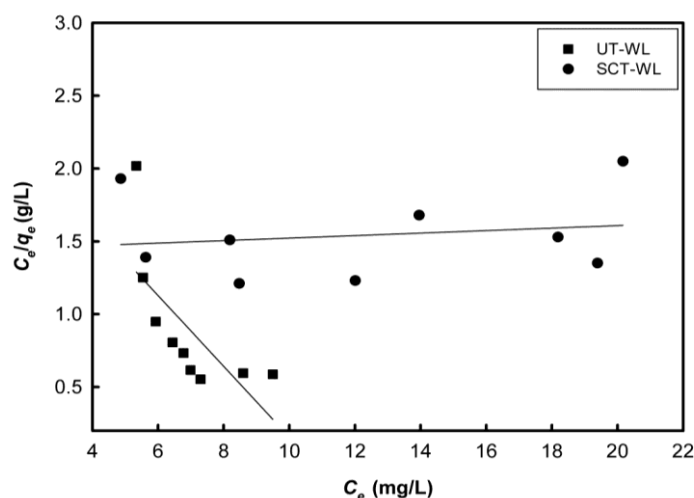


Fig. 8. A plot of C_e/q_e vs. C_e for fitting with the Langmuir isotherm for the adsorption of Congo Red on UT-WL ($R^2 = 0.427$) and SCT-WL ($R^2 = 0.000$) at pH 6.

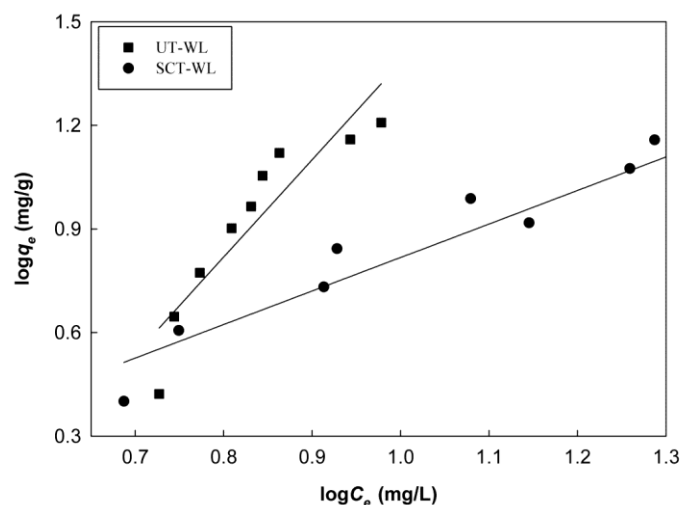


Fig. 9. Plot of $\log q_e$ vs. C_e for fitting with the Freundlich isotherm for the adsorption of CR on UT-WL ($R^2 = 0.814$) and SCT-WL ($R^2 = 0.862$) at pH 6.

Table 1. Langmuir and Freundlich coefficients for the adsorption of Congo red on UT-WL and SCT-WL at pH 6.

Adsorbents	Langmuir Coefficients			Freundlich Coefficients		
	q_m (mg/g)	K_{eq} (L/mg)	R^2	K_F (L/g)	n	R^2
UT-WL	4.12	1.59	0.427	0.037	0.35	0.814
SCT-WL	116.28	80.95	0.000	0.702	1.03	0.862

[N.B.: q_m = amount of CR adsorbed in monolayer; K_{eq} = Equilibrium constant; R^2 = correlation coefficient; K_F = Freundlich constant; n = number of layer formed.]

The adsorption kinetics of CR on UT-WL and SCT-WL was studied at pH 6 by fitting the data with different kinetic models.

Lagergren first order kinetic equation (Gupta *et al.*, 2017)

$$\ln(q_e - q_t) = \ln q_e - k_1 t \tag{5}$$

and

Ho's pseudo-second order kinetic equation (Gupta *et al.*, 2017)

$$t / q_t = 1 / k_2 q_e^2 + t / q_e \tag{6}$$

where, q_e = the amounts adsorbed at equilibrium

q_t = the amounts adsorbed at any time t

k_1 and k_2 are the first order and second-order rate constants, respectively.

The adsorption kinetics of CR on UT-WL and SCT-WL were investigated from the data obtained in determining the equilibrium time for the adsorption. These kinetic data are fitted with the Lagergren pseudo-first order (Fig. 10) and Ho's pseudo second-order (Fig. 11) kinetics. The data are incorporated in the Table 2.

The correlation coefficient, R^2 values are 0.975 (Fig. 10) and 0.990 (Fig. 11) for the pseudo first and pseudo second-order kinetics, respectively at pH 6 for the adsorption of CR on UT-WL. On the other hand, the R^2 value are 0.950 (Fig. 10) and 0.982 (Fig. 11) for the pseudo first and pseudo-second order kinetics, respectively at pH 6 for the adsorption of CR on SCT-WL. The experimental results revealed that the kinetics of adsorption of CR on UT-WL and SCT-WL best fitted to the Ho's pseudo second-order kinetic model. These kinetic data showed disagreement with the result found in removing congo red by using rice husk carbon

(Sharma and Janveja, 2008) where the adsorption kinetics was better explained by the Lagergren pseudo-first order model.

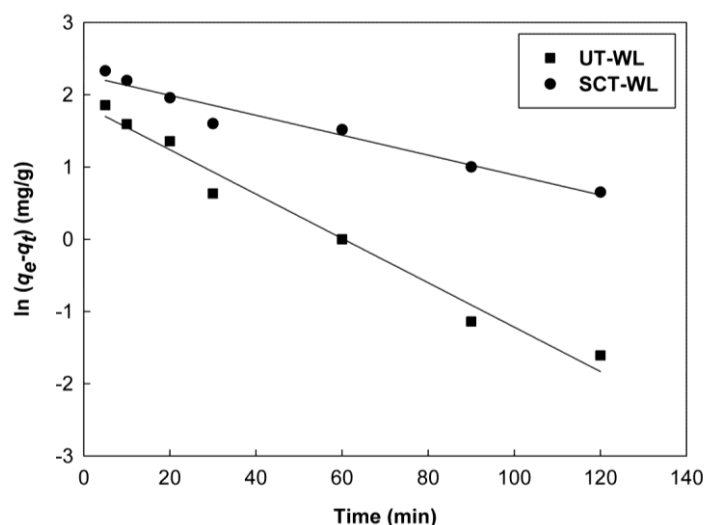


Fig. 10. A plot of $\ln (q_e - q_t)$ versus time for fitting with Lagergren equation of pseudo first order kinetics of adsorption of CR on UT-WL and SCT-WL at pH 6.

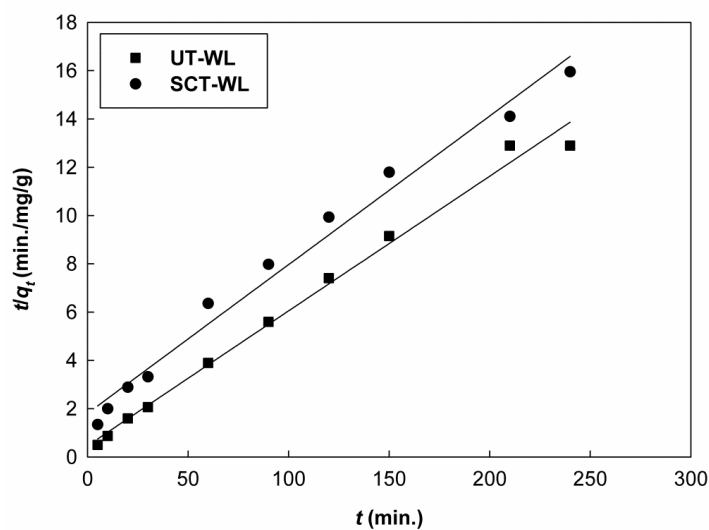


Fig. 11. A plot of t/q_t vs. time for fitting with Ho's equation of pseudo second-order kinetics for adsorption of CR on UT-WL and SCT-WL at pH 6.

Table 2. Pseudo first order and pseudo second order kinetic parameters for the adsorption of CR onto UT-WL and SCT-WL at pH 6.

Adsorbents	q_e (mg/g)	Pseudo-First-order kinetic model		Pseudo-Second-order kinetic model	
		k_1 (min^{-1})	R^2	k_2 ($\text{g}/(\text{mg min})$)	R^2
UT-WL	6.39	3.07×10^{-2}	0.975	6.65×10^{-3}	0.990
SCT-WL	9.66	1.38×10^{-2}	0.950	2.10×10^{-3}	0.982

[N.B.: q_e = amount of CR adsorbed at equilibrium; k_1 = first order rate constant; k_2 = second order rate constant; R^2 = Correlation coefficient]

Maximum removal was observed 94.68% for UT-WL, 84.08% for SCT-WL and 75.27% for FT-WL shown in Fig. 12. The study on the uptake of CR by UT-WL, SCT-WL and FT-WL (dose level 62.5 g/g and $\leq 300\mu\text{m}$ mesh size) at pH 6 reveals that percent removal of CR from aqueous solution influenced predominantly by surface modification. By observing the percent removal of CR on untreated and treated water lily it is clear enough that UT-WL has been found to be more conducive to adsorb CR rather than treated WL by sodium chlorite and formaldehyde. As CR is an anionic dye, due to the treatment of WL by sodium chlorite and formaldehyde negative charge arose on the surface of WL which had become reluctant to interact with the negative charge of CR. Therefore, UT-WL can be considered a handsome candidate for adsorption of CR under the present experimental conditions (pH, contact time, particle size and dose).

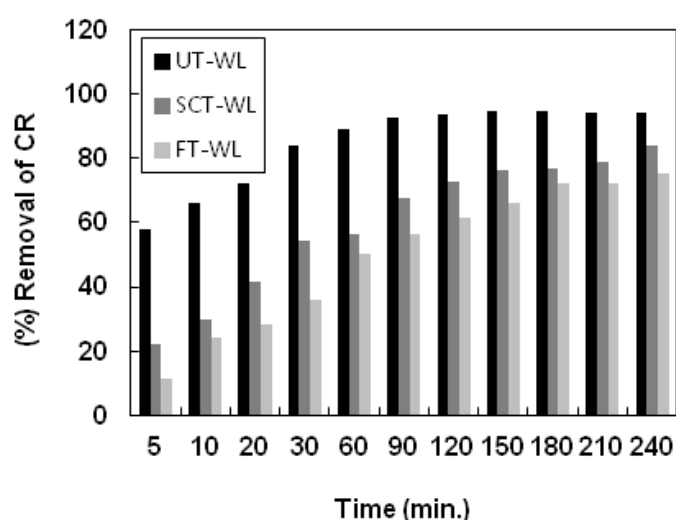


Fig. 12. Comparative study of the percent (%) removal of Congo Red (CR) by adsorption on UT-WL, SCT-WL and FT-WL at pH 6. (particle size $\leq 300\ \mu\text{m}$, dose 62.5 g/g).

The FT-IR spectroscopic study is supportive for explain the tentative effect of adsorption of Congo red on the vibrational frequencies of functional groups of UT-WL. Fig. 13 shows the FT-IR spectra of UT-WL before and after the adsorption of Congo Red.

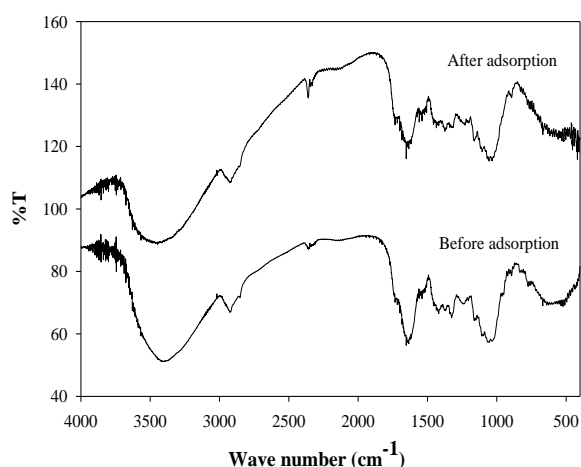


Fig. 13. FT-IR spectra of UT-WL before and after adsorption at pH 6.

In case of UT-WL before adsorption spectral study confirm the presence of H-bonded alcoholic group (-OH) at 3400.58 cm^{-1} broad peak (high concentration) (Pavia *et al.*, 2009), alkane C-H stretching at 2912 cm^{-1} (Braşoveanu *et al.*, 2013), -C = C- stretching at 1653 cm^{-1} , strong intensity adsorption band at 1060.99 cm^{-1} for alcohol (C-O) group (Camacho *et al.*, 2001) and for starch group at 1029 cm^{-1} (Pavia *et al.*, 2009). After adsorption, the spectral study confirm the presence of H-bonded alcohol (-OH) at 3400.58 cm^{-1} , C-H stretching at 2914 cm^{-1} (Pavia *et al.*, 2009), -C=C- group at 1653 cm^{-1} (Pavia *et al.*, 2009), N-H at 1539 cm^{-1} , S-O at 1374 cm^{-1} (Pavia *et al.*, 2009), the starch region is characterized by an absorption band around 1022 cm^{-1} (Pavia *et al.*, 2009), and their respective ratio indicates the degree of starch order. The bio-sorption of CR onto UT-WL may likely be due to electrostatic attraction between these groups and the anionic dye molecules. Moreover, at pH 6 partially charged hydronium can attract the negatively charged dye molecules and binding can occur through H-bonding.

CONCLUSIONS

The maximum removal of CR was 94.68% at pH 6 by using untreated water lily (UT-WL). A further experiment was done by the treatment of WL with sodium chlorite and formaldehyde. The maximum removal of CR by SCT-WL and FT-WL were 84.08% and 75.27%, respectively only at pH 6. The adsorption increased with the increase of particle size ($75\text{ }\mu\text{m}$ to $300\text{ }\mu\text{m}$), but the extent of adsorption varies inversely with the dose level of adsorbent. Adsorption parameter for the Langmuir and Freundlich isotherms were determined and the isotherm was best fitted to Freundlich isotherm. The adsorption kinetics was successfully fitted to pseudo-second-order kinetic model. FTIR study also supported the adsorption of Congo red on the untreated water lily. Between the treated and untreated adsorbents, the maximum removal was obtained for UT-WL. Therefore, the water lily is expected to be a cheap and useful adsorbent for the removal of CR dye from aqueous solution.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICTS OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

ACKNOWLEDGEMENT

We would like to acknowledge Centre for Advanced Research in Sciences (CARS), University of Dhaka, Dhaka, Bangladesh for giving support of FT-IR spectra.

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