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Study of Adsorption Isotherms of Congo red dye Using Biosorbent (*Polyalthia longifolia* Seeds)

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Abstract : Study of removal of Congo red from aqueous solution at 500 nm wavelength has been investigated through a batch study. The adsorption process was found to be dependent on adsorbent dose, contact time, pH, initial concentration and temperature of Congo red solution. Solutions of Congo red having concentrations 10, 20, 30 & 40 ppm were used. It was found that maximum removal of dye was 91% for 10 ppm solution, in 120 min with 6.5 pH, 200 mg/50 ml as dose and 40°C temperature. The equilibrium data were described by Freundlich, Langmuir & Tempkin isotherm model. Langmuir isotherm considers monolayer adsorption while Freundlich isotherm considers multilayer adsorption. Adsorption isotherm obtained fitted well into both Freundlich and Langmuir equation but Tempkin isotherm provides a reasonable model for the adsorption of Congo red onto CPPL because of its high value of R^2. Result suggests that it is a non conventional and efficient biosorbent for the removal of Congo red from aqueous solution and can be used for the development of clean and cheap technology for effluent treatment.
Key words: Adsorption Isotherms, Congo red dye, Biosorbent, *Polyalthia longifolia.*

Introduction:

In various industries such as textiles, paper, paints, leather, rubber, plastics, cosmetics, food, and drug dyes are used. More than 70% dyes are consumed in industries[21]. It is observed that during the process in industries large amount of dyes get release in to the industrial effluent. Due to their chemical structures, dyes are resistant to fading on exposure to light, water and many chemicals and, therefore are difficult to be decolorized once released into the aquatic environment. Many of the organic dyes are hazardous and may affect aquatic life and even the food chain. Therefore, it is very important to develop new systems that can be used for removing dyes from industrial effluent. Activated carbon is the most used material owing to its adsorption capacity, but it is very expensive and its regeneration is difficult. Research has been directed towards developing more effective and economical solutions, investigating the use of various low cost adsorbents. These materials should be low cost, easily available and disposable without regeneration. The agricultural and plant wastes could be a good way to reduce cost problems. There are various conventional methods of removing dyes including coagulation and flocculation, oxidation or ozonation and membrane separation[13]. However, these methods are not widely used due to their high cost and economic disadvantage. Activated carbon is widely used as an adsorbent due to its high adsorption capacity, high surface area, micro porous structure, and high degree of surface respectively.

The adsorption process provides an attractive alternative especially if the adsorbent is inexpensive and readily available. By far, activated carbon has been the most favoured material for adsorption of various materials like dyes, heavy metal ion etc. A seed of Polyalthia longifolia is one of the readily available agricultural material which can be used as a good adsorbent

Experimental

For experimental work of adsorption all the chemicals were used of analytical grade. The instruments which are used, Digital colorimeter (Make: Equiptronics) Model EQ-650-A and Digital pH Meter (Make: Equiptronics) Model EQ-610 were used.

Preparation of Carbonized Powder of Polyalthia longifolia Seeds (CPPL)

Seeds of Polyalthia longifolia were collected from the local areas Hadapsar Pune district, India. The seeds were washed with water and dried at 110 to 120^{o} C in the oven. Then they are crushed into small pieces then carbonized in the muffle furnace at temperature 600^{o}C in presence of inert medium of nitrogen gas for 6-7 hrs. Carbonized material was grinded into fine powder with the help of mortar and pestle. Then it was passed through a 63 mesh sieve to get particles of uniform size and stored in air tight container.

Preparation of dye solutions

Congo red solutions of different concentrations (10 to 40 mg/L) were prepared by using the stock solution (1000 mg/L) with distilled water. The pH adjustment was carried out using 0.1 N HCl or NaOH solutions.

Batch adsorption studies

Batch adsorption study were carried out for 50 ml of dye solution using 200 mg of adsorbent for different time interval at room temperature by using colorimeter at λmax = 500 nm.

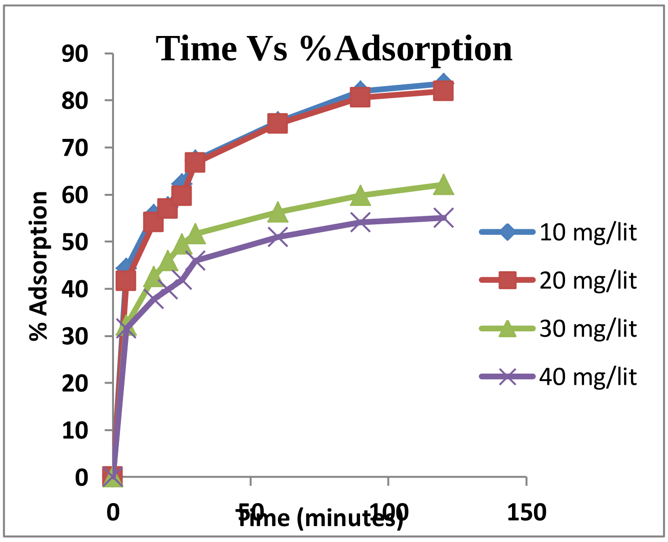

Figure 1. Effect of contact time on %adsorption of Congo red

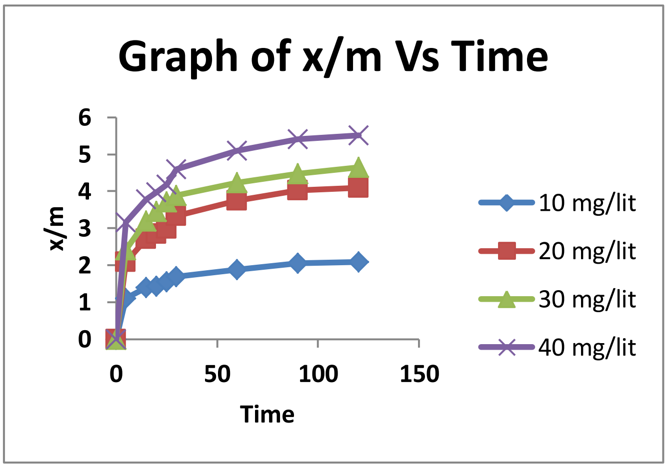

Figure 2. Effect of contact time on adsorption capacity

Results And Discussion

Effect of contact time

Adsorption of Congo red was carried out with 10, 20, 30 & 40 mg/lit of Congo red solution by using 200 mg of adsorbent for 5 to 120 min at different pH (3 to 6.5). In the initial stage it shows greater rate of adsorption with adsorption capacity (1.1 to 2.0 mg/gm) and percentage removal 83% at equilibrium time 120 min.

Effect of pH

At room temperature as the pH increases from 3.5 to 6.5 the value of q_e increases from 1.23 to 2.13 mg/gm and percentage removal (49.18% to 85.25%) adsorption capacity and %removal also goes on increasing 1.35 to 2.30 mg/gm (54.10% to 91.80%).

Effect of Adsorbent dose

Increase in amount of adsorbent (25 mg to 200 mg) adsorption rate increases but adsorption capacity goes on decreasing. For 10 mg/lit solution of Congo red adsorption capacity decreases from 2.62 to 1.68 mg/gm and %adsorption increases 13.11 to 67.21%. Maximum %removal was observed for dye 10 mg/lit.

Effect of Initial concentrations and temperature

During the experimentation work it was observed that as the concentration of Congo red solution increases %removal decreases (44.26 to 83.61%) to (31.63 to 55.10%) at 25^{o}C because less sites are available for adsorption, while at 40^{o}C it changes from (50.82 to 91.80%) to (37.76 to 62.24%).

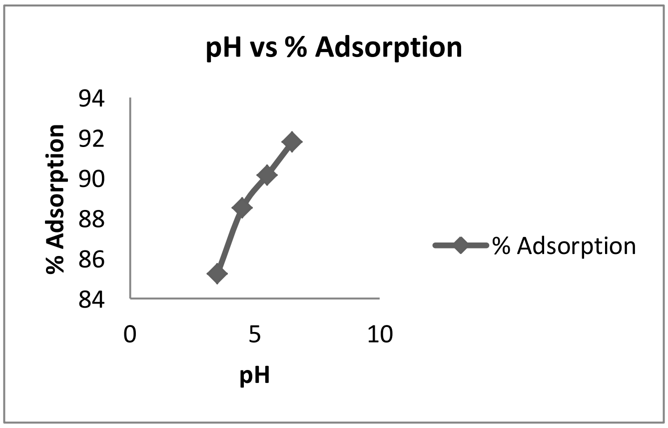

Figure 3. Effect of pH on % adsorption

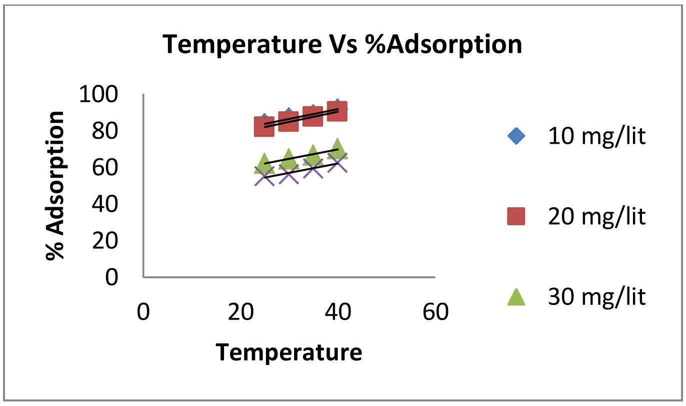

Figure 4. Effect of temperature on %adsorption

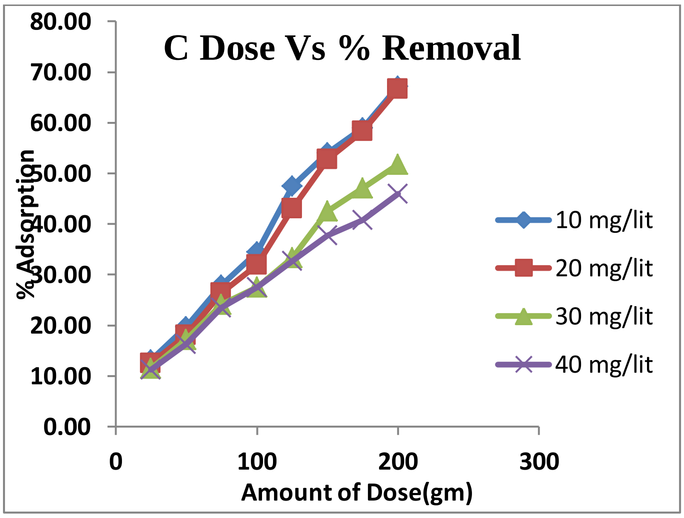

Figure 5. Effect of amount of adsorbent on % adsorption

Adsorption isotherms

In the experimentation of adsorption, isotherms play an important role in describing the adsorbate-adsorbent interaction. The isotherm data were analyzed by fitting them into Langmuir, Freundlich and Tempkin isotherm models.

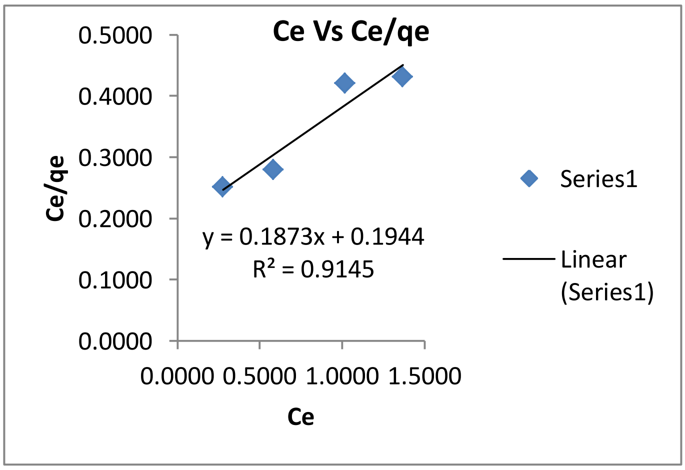

Figure 6. Langmuir isotherm

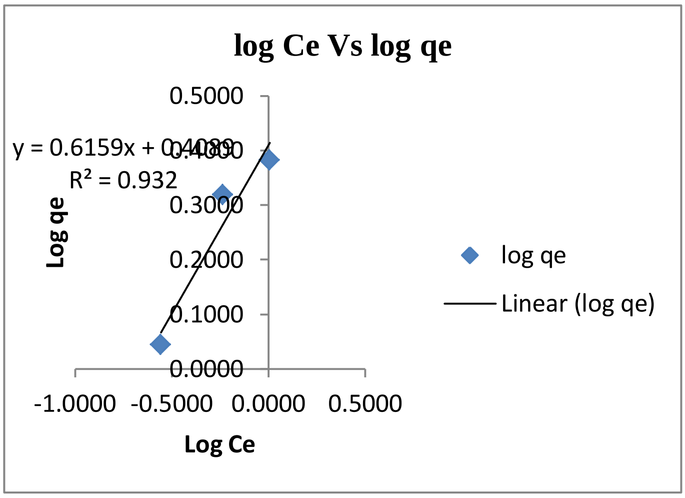

Figure 7. Freundlich isotherm

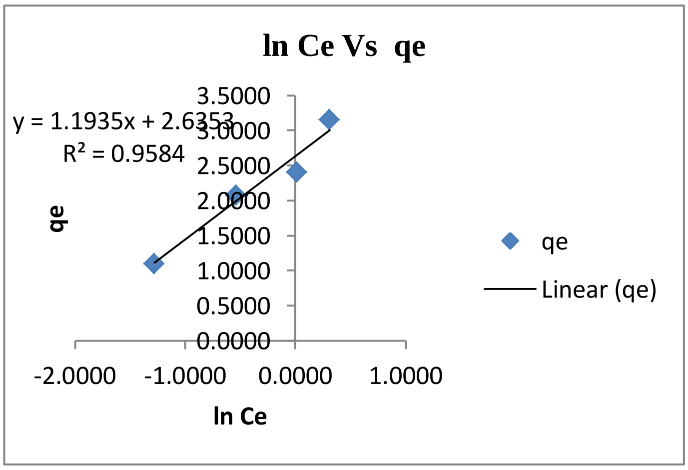

Figure 8. Temkin isotherm

Langmuir Isotherm

Langmuir isotherm considers monolayer adsorption. The linearized Langmuir isotherm equation (Equation 1) was used to obtain the maximum adsorption capacity of Congo red.

$$C_e / q_e = 1/ bQ_m + (1 / Q_m) C_e \qquad (1)$$

b : Adsorption equilibrium constant (L/mg)
Qm : Quantity of adsorbate required to form a single monolayer of adsorbent (mg/g)
qe : Amount adsorbed on unit mass of the adsorbent (mg/g) when the equilibrium concentration is Ce (mg/L).

The isotherm plots of Ce/qe vs. Ce for the adsorption of CR onto CPPL is as shown in Figure 6. The Langmuir constants Qo, and b, evaluated from the slope and intercepts of these plots Langmuir Isotherm in terms of dimensionless equilibrium parameter (Halls Separation Factor) RL

RL = 1/(1+bC0)
RL = 0.02528

Here the value of RL is 0 < RL < 1, It indicates that Langmuir isotherm is favourable.

Table: 1 Parameters in Langmuir isotherm

m	C	Q_0	b	R^2
0.187	0.194	5.3476	0.9639	0.914

Freundlich Isotherm

The Freundlich isotherm considers multilayer adsorption. Interactions between adsorbed molecules the linear Freundlich isotherm is expressed as:

$$\log q_e = \log K_f + 1/n \log C_e \quad (2)$$

Where qe = x / m
x : Mass of adsorbate
m : Mass of adsorbent
C_e : Eq. Concentration of adsorbate in solution.

The linear plots of log qe versus log C_e (Figure 7) shows that the adsorption of Congo red CPPL also follows Freundlich isotherm model. The Freundlich constants (Kf and n) and correlation coefficients are recorded.

Here, the value of
$0 < 1/n < 1$ also,
Value of R^2 for
Freundlich isotherm > Langmuir isotherm

This indicates that it also follows Freundlich adsorption isotherm.

Table: 2 Parameters in Freundlich isotherm

m	C	n	Kf	R^2
0.615	0.408	1.6260	2.5585	0.932

Temkin Isotherm

The linear form of Temkin isotherm model is given by the following Equation

$$q_e = RT/b \ln KT + RT/B \ln Ce \quad (3)$$

R = Gas Constant (8.314 J/mol K)
T = Absolute Temp (K)
KT = Tempkin constant (Lg-1)
B = Heat of sorption (J/mol)

Plot of qe versus ln Ce (Figure 10) gives a straight line, with slope representing B and intercept equal to K. The Tempkin constants along with the correlation coefficients are as follows. The R^2 values 0.958 confirm that Tempkin isotherm provides a reasonable model for the adsorption of Congo red onto CPPL.

Table: 3 Parameters in Temkin isotherm

m	C	b	B	kT	R^2
1.427	3.239	1.824	1.427	9.677	0.957

Table: 4 Tempkin isotherm at different temperature

Temp	25°C	30°C	35°C	40°C
m	1.193	1.304	1.319	1.427
C	2.635	2.837	3.024	3.239
b	2.077	1.932	1.941	1.824
B	1.193	1.304	1.319	1.427
kT	9.1	8.75	9.9	9.677
R^2	0.958	0.968	0.948	0.957

Conclusions

The removal of Congo red dye was 91% for 10 ppm solution, Percentage dye removal increases with increase in amount of adsorbent, temp, pH and time while it decreases with increase in concentration of dye. Tempkin isotherm provides a reasonable model for the adsorption of Congo red onto CPPL. Besides, the results indicated that the CPPL adsorbent is capable for the removal of Congo red with high affinity and capacity indicating its potential use as a low cost adsorbent in near future.

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