

BALANCE, ISOTHERMS AND KINETICS OF REACTIVE YELLOW 86 COMMENCING SOLUTION BY BALSAMODENDRON CAUDATUM WOOD WASTE ACTIVATED NANO PERMEABLE CARBON MATERIAL

B. Sivakumar^{1,*}, M.Vijayalakshmi² and A. Babu Rajendran³

¹Department of Chemistry, Angel College of Engineering and Technology, Tirupur, 641665, TamilNadu, India.

²Department of Chemistry, Nandha Engineering College, Erode, 638052, TamilNadu, India.

³P.G. Assistant in Chemistry, Govt. HR. Sec. School, Dhalavoipatnam, Tirupur, 638672, TamilNadu, India.

*E-mail: bbsivakumarbb@gmail.com

ABSTRACT

The adsorption capacity of *Balsamodendroncaudatum* wood waste virtual to Reactive yellow 86 was tested in fabric wastewater organization. *Balsamodendroncaudatum* wood waste activated nano porous carbon material (BANCM) was treated by sulphuric acid to pick and choose up adsorption competence for the elimination of Reactive yellow 86 (C.I. No 70865-29-1) from aqueous solution. The treated (BANCM) with sulphuric acid was analyzed by SEM, XRD, FT-IR and TGA-DTA Analysis. Present study deals with the use of BANCM waste as an adsorbent for the removal of Reactive yellow 86 dye from its aqueous solutions. The studies show that sorption is powered by initial dye concentration, dye solution pH and adsorption temperature have been investigated in the present study. Isotherms for the sorption of Reactive yellow 86 on (BANCM) were tested by the Freundlich and Langmuir isotherm equations. A Kinetic study of dye followed the pseudo-first-order, pseudo second-order and Elovich models respectively. Equilibrium isotherms for the adsorption of Reactive yellow 86 on (BANCM) were analyzed by the Langmuir isotherm. Up shot indicate that the pseudo-first-order kinetic model was found to compare the investigational statistics fit.

Keywords: adsorption, reactive yellow 86, kinetics, low-cost adsorbents, aqueous solution

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INTRODUCTION

Water is essential to all forms of life. It acts as a medium, catalyst and applicant in various chemical reactions occurring in our environment. In natural history, a no of dictatorial mechanisms plays and vital role in controlling the physic-chemical properties of important as well as the number and types of its biological populations. Irrespective of basis, it constantly contains a complex mixture of organic and inorganic substances main of which are of natural origin resulting from complex contact between water, soil and underlying environmental status.

The biological and microbiological process taking place in soil and water. Balanced and colloidal mineral matter, plant detritus, algae and protozoa are also commonly established and reported¹. There has been proof of a connection between arsenic levels in water and frequency of skin cancer².

Activated nano porous carbon is costly and its recovery and use gain create it more costly³. However, in observation of the high cost and related problems of regeneration, there is a regular search for alternate low-cost adsorbents. Such types of adsorbents comprise pine tree leaves⁴, bagasse fly ash⁵, rice husk ash⁶, (*Arundo donax*) reeds⁷, red mud⁸, TiO₂ nanocomposites⁹ agricultural waste and timber industry waste carbons for the exclusion of various dyes from wastewaters¹⁰. Significant review of low-cost adsorbents for wastewater treatment has been offered by earlier researchers¹¹.

$$\frac{dq_t}{dt} = k_1(q_e - q_t) \quad (1)$$

Where, q_e and q_t are the adsorption capacity at equilibrium and at time t , respectively (mg g^{-1}), k_1 is the rate constant of pseudo-first order adsorption (l min^{-1}).

The Pseudo Second – Order Equation

The pseudo second-order adsorption kinetic rate equation is expressed as¹³

$$\frac{dq_t}{dt} = k_2(q_e - q_t)^2 \quad (2)$$

Where, k_2 is the rate constant of pseudo-second order adsorption ($\text{g. mg}^{-1}. \text{min}^{-1}$). where, k_2 is the rate constant of pseudo-second order sorption ($\text{g. mg}^{-1}. \text{min}^{-1}$). If the first sorption rate h ($\text{mg g}^{-1} \text{min}^{-1}$) is

$$h = k_2 q_e^2 \quad (3)$$

The Elovich Equation

The Elovich model equation is normally expressed¹⁴ as:

$$\frac{dq_t}{dt} = \alpha \exp(-\beta q_t) \quad (4)$$

Where, α is the initial adsorption rate ($\text{mg.g}^{-1} \text{min}^{-1}$), β is the sorption constant (g. mg^{-1}) during any one conduct test.

RESULTS AND DISCUSSION

Characterization of sorbent

The exterior area of the BANCM was designed throughout N_2 sorption at 77K using a NOVA1000, Quanta chrome company. The pH of BANCM was measured by a PHS-3C pH meter. pH of zero charges (pHpzc) of the samples was definite using pH drift method¹⁵. The surface area of the BANCM obtained from the N_2 equilibrium sorption isotherms was found to be $760 \text{ m}^2/\text{g}$. The outcome of “pH drift” test, from which the pHpzc of BANCM studied in this test was found to be the 4. The better color removal of the dye, Reactive yellow 86, was notified at pH of 6.

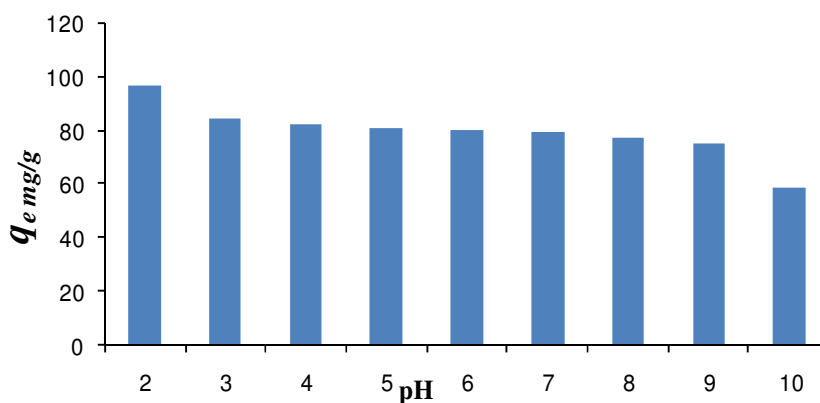


Fig.-2: Effect of pH on % of elimination of Reactive yellow 86 by BANCM

Influence of pH

The arrangement of experiments conducted to find the effect of pH on sorption. It was observed that pH influences BANCM surface dye essential sites and the dye chemistry in water. Fig.-2 show the measure of dye removed, using acid activated sorbent at initial pH value. In this testing, the initial dye concentration was fixed at 20 ppm. From the quaver flask experiments, improved color removal of the dye, Reactive yellow 86, was observed at pH of 6. The uptake of Reactive yellow 86 was established to be best at pH 6 with the maximum dye uptake of 89%. As the external charge density decreases with an increase in the

solution pH, the electrostatic repulsion between the positively charged dye and the surfaces of sorbent is reduced, this causes more sorption¹⁶.

Influence of concentration

The group sorption experiments were carried out by using three diverse concentrations of dye viz. 20mg/L, 40mg/L and 60mg/L at pH 6. The reaction temperature of 30 °C was chosen for sorbent. The rate of confrontation was maintained constant at 200 rpm. The colorful profiles were obtained using the absorbent BANCM.

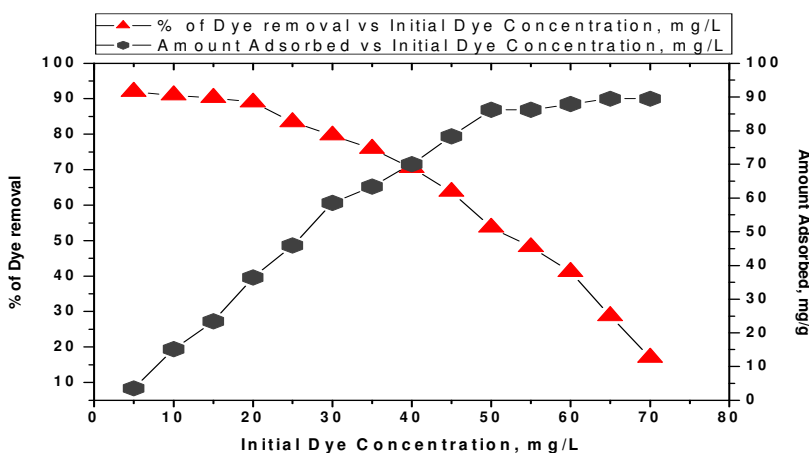


Fig.-3: Effect of concentration on adsorption of Reactive yellow 86 on BANCM at pH 6.

SEM investigation

The SEM of the sorbent revealed in Fig.-4 open to the elements that, it is exceedingly permeable in nature. From the SEM consequences, it was found that there are matching holes and cave category openings on the facade of the sample that would completely have greater than previous to the surface area¹⁷.

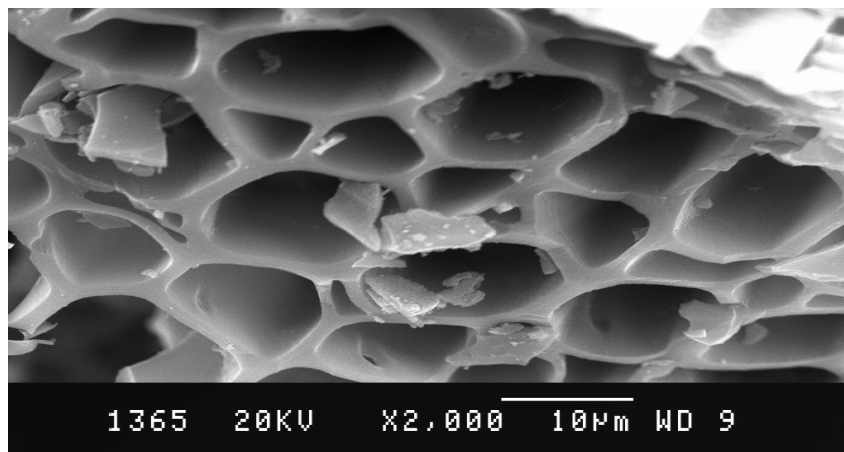


Fig. -4: SEM investigation for BANCM

XRD investigation

Figure- 5 shows the extensive angle XRD prototype for nanoporous carbon sample. The XRD study of nanoporous carbon proved that the carbon equipped by acid behavior shows the X-ray diffraction angle $2\theta = 23$ it is similar to the reported graphitization timbersquander¹⁸.

FT-IR investigation

The FT-IR spectrum of the *Balsamo dendron caudatum* wood squander activated nano porous carbon prepared by a range of treatment processes shown in Fig.-6 revealed that the carbons evaluated contain four classes of surface groups: carboxyls, lactones, phenols and carbonyls.. Shifts in sorption location may be caused by factors such as intramolecular and intermolecular hydrogen bonding, steric consequence and number of-conjugation^{19,20}.

TGA-DTA investigation

The Thermal stability of the carbon materials prepared by sulphuric acid was analyzed by the TG&DTA are shown in Figure 7. The curve obviously exemplifies that the carbon samples begin to drop weight at about 60° C due to the volatilization of tiny molecules and it started to lose weight intensively above 600° C could be due to the decomposition of polymeric molecules formed through the carbonization process.

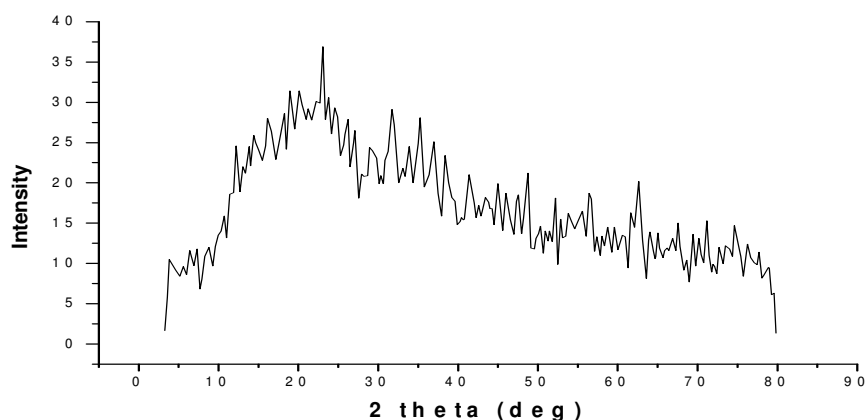


Fig. -5:XRD pattern for BANCM

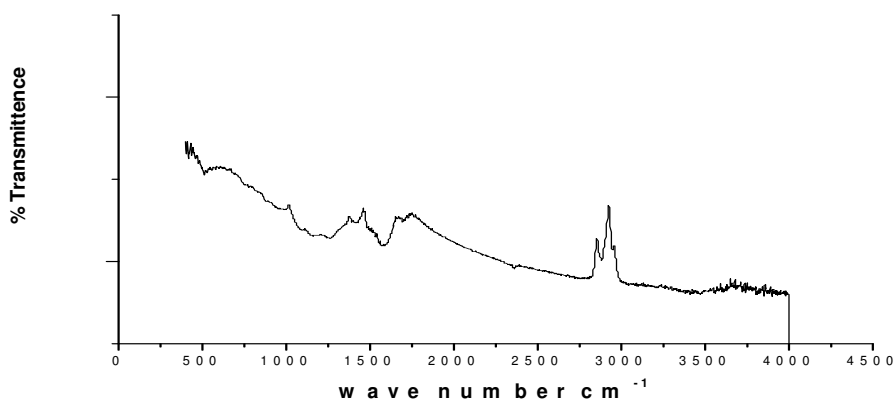


Fig.-6:FTIR Spectra for BANCM

Influence of the Temperature on Kinetic Rate Constant and Rate Parameters

Adsorption test was conducted with fixed initial dye concentration (20mg/L) at pH 6 and at a variety of temperature viz. 30 °C, 45 °C and 60 °C. The examination of the data in (Table-1) reveals that the influence of the temperature of the dye has very little control on the pseudo second-order rate constants. The Table-2 also reveals that the influence of the temperature of dye on Elovich and pseudo first order

rate constant is neither substantial nor little. It is apparent that the sorption of dye on the BANCM waste activated carbon is best described by first-order rate equation with regression coefficient value is greater than 0.99.

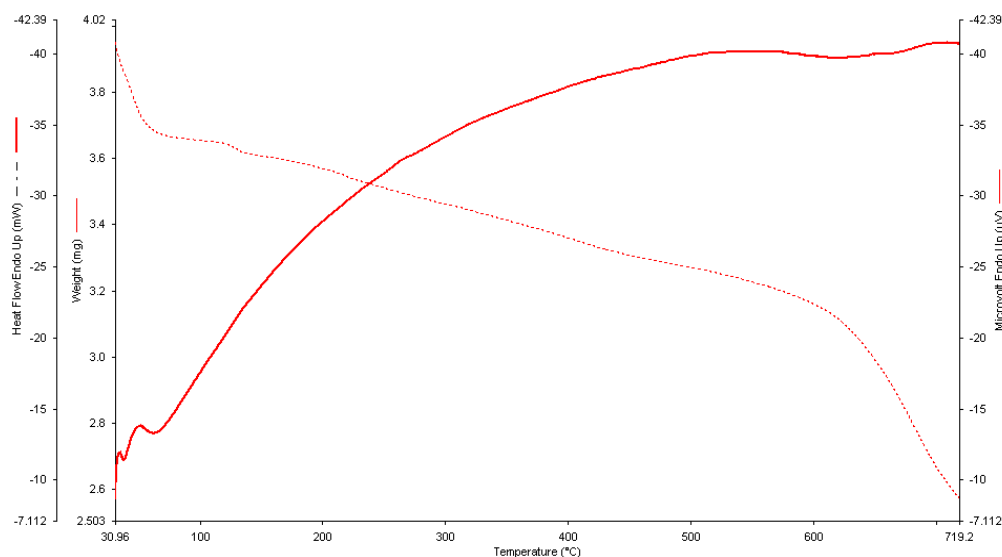


Fig.-7: TGA Curve for BANCM

Table- 2: The sorption kinetic model rate constants for BANCM various temperature

Sorbent	Initial Temperature	Pseudo first order		Pseudo Second order			Elorich Model		
		k_1 $l\text{min}^{-1}$	r^2	k_2 $g\text{ mg}^{-1}\text{ min}^{-1}$	h $mg\text{ g}^{-1}\text{ min}^{-1}$	r^2	β $g\text{ min}^{-1}$	α $mg\text{ g}^{-1}\text{ min}^{-1}$	r^2
BANCM	30°C	0.0124	0.9268	0.00787	0.4237	0.9237	0.1678	0.5345	0.9887
	45°C	0.0075	0.8258	0.0286	5.4469	0.4563	0.1928	0.62467	0.93567
	60°C	0.0344	0.6689	0.0344	0.1157	0.6367	0.4956	0.4359	0.9789

Isotherms

The Langmuir, Freundlich isotherms are the most commonly used two-factor models in the literature connecting the non-linear balance between the amount of dye adsorbed on the acid treated (BANCM)(q_e) and the equilibrium concentration of the solution (C_e) at a constant temperature (30°C).

Langmuir Model

Langmuir model was developed based on the suggestion of the arrangement of a monolayer of the adsorbate class onto the surface of the element of the adsorbent. It has also been assumed that the surface sites are totally actively homogeneous. But in the true sense, the sorbent surface is actively heterogeneous²¹. This model is the most widely used two-parameter equation, normally expressed in the form by the subsequent equation:

$$\frac{1}{q_e} = \frac{1}{Q_o K_L} + \frac{C_e}{Q_o} \tag{5}$$

Where,

- q_e = the quantity of dye removed at equilibrium (mg/g)
- C_e = the equilibrium concentration of dye (mg/L)
- Q_0 = the Langmuir constant, related to the adsorption capability (mg/g)
- b = the Langmuir constant, related to the energy of sorption (L/mg)
- K_L = direct measure of the intensity of the adsorption (L / mg)

C_e/q_e was plotted against C_e using linear deterioration examination, as shown in Fig.-7. The constants Q_0 and K_L were resolute from the intercept and slope of the linear plots, correspondingly. As shown in Table-4, the Q_0 from the Langmuir isotherm were 149.15mg/g for Reactive yellow 86. The values of K_L it could be concluded that sorptions of acid dye ($K_L = 0.08838$). The necessary feature of Langmuir equation can be expressed in terms of a dimensionless division factor R_L ²². The essential uniqueness of Langmuir isotherm can be uttered in terms of a dimensionless parameter, R_L , which is defined by $R_L = 1/1 + bC_0$, where, C_0 is the initial dye concentration (mg/L) and b is the Langmuir constant (L/mg). The parameter indicates the form of isotherm as given in Table-3.

Table -3: Parameters for types of Isotherm

R_L	Type of isotherm
$R_L > 1$	Unfavourable
$R_L = 1$	Linear
$0 < R_L < 1$	Favourable
$R_L = 0$	Irreversible

In the current research work, the researcher aims at shaping how well the Langmuir model can be applied to the chosen adsorbate –sorbent structure.

$$R_L = (1/1+K_L C_0) \quad (6)$$

Where,

C_0 = (mg /L) is the first dye concentration.

R_L = the nature of the adsorption process.

Table- 4: Equilibrium isotherm constants at 30°C

Freundlich isotherm			Langmuir isotherm		
K_f (mg/g)	$1/n$	R^2	K_L /mg	q_0 mg/g	R^2
6.0455	0.5312	0.9989	0.08838	149.15	0.9989

The intended R_L values of acid dye are found to be between 0.3857, 0.3286 and 0.3351 for dye concentrations viz. 20 mg/L, 40 mg/L and 60 mg/L, respectively (data not shown). The extent of the R_L values, i.e., $0 < R_L < 1$, indicated the good sorption of each of the dye.

Freundlich Model

At Equilibrium conditions, the adsorbed amount, q_e can also be predicted by using the Freundlich equation²³:

$$q_e = k_f C_e^{1/n} \quad (7)$$

Where,

q_e = dye concentration in solid at balance (mg/g)

C_e = dye concentration in solution at balance (mg/L)

k_f = measure of adsorption capacity

n = adsorption intensity

A logarithmic form of the above equation is

$$\log q_e = \log k_f + (1/n) \log C_e \quad (8)$$

The ideals of n and k_f were stubborn from the plot $\log C_e$ vs $\log q_e$. Where, k_f is the idea of the sorbent capacity and $1/n$ is a compute of surface heterogeneity, ranging between 0 and 1, attractive more various as its value gets nearer to zero. The Freundlich equation predicts that the dye concentration on the sorbent will hoist so long as there is an expansion in the dye concentration in the liquid. The investigational evidence indicates that an isotherm is reached at a limiting value of the solid phase concentration. The equation itself does not have any real physical significance. Freundlich isotherm fitted well to the data with correlation coefficient value 0.9871. The designed Freundlich isotherm constants at 30°C are as shown in Table 4. The value of Freundlich model $n = 1.7227$ lying in the array of 1 - 10, designate sympathetic sorption.

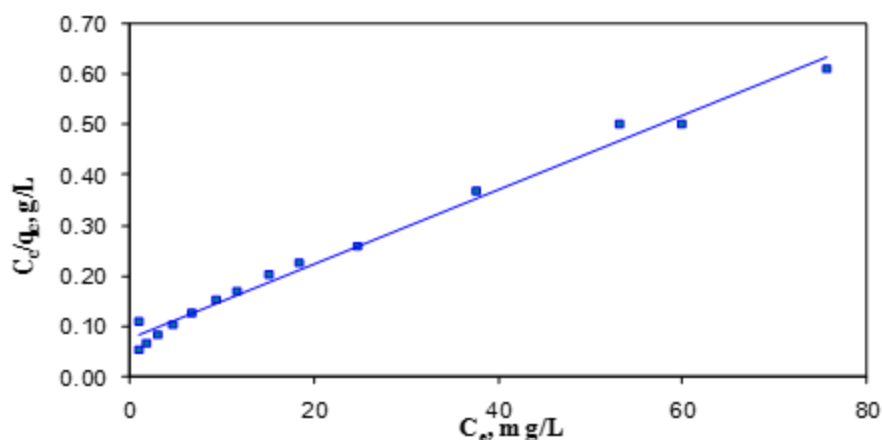


Fig.-8: Langmuir plot for Reactive yellow 86 adsorption onto BANCM. M, 100 mg; V, 50 ml; C_0 , 20 mg/L; pH, 6.5; temperature, 30°C)

CONCLUSION

Sorption of Reactive yellow 86 dye on the BANCM was determined to be reliant on the pH, (The most favorable pH of Reactive yellow 86 was 6), temperature and concentration of sorbent. Adsorption equilibrium was reached within 220 min contact time for reactive yellow 86 dye used in this experiment. The entitlement saturation was found to be almost 99% for the BANCM correspondingly. The kinetics of Reactive yellow 86 sorption on adsorbent was found to follow a pseudo-first-order rate equation. The sorbent was employed to adsorb Reactive yellow 86 from aqueous solution explicitly and showed high removal capability at fitting conditions, indicating that the secondary sorption was an efficient and low-priced way for recycling of the used sorbents. A stability isotherm for the adsorption of Reactive yellow 86 on BANCM was analyzed by the Freundlich, and Langmuir isotherm equations. The absolute result showed that the Freundlich isotherm best-fit the Reactive yellow 86 sorption.

REFERENCES

1. E.A. Astolfi, A. Maccagn, J. C. Garcia-Fernandez, R. Vaccaro and R. Stimolo, *Biol. Trace Elem. Res.*, **3**, 133 (1981).
2. J. Yiamouyiannis and D. Burk, *Flouride*, **10**, 102 (1977).
3. A. Afkhami, M.S. Tehrani and H. Bagheri, *Desalination*, **263**, 240 (2010).
4. F. Deniz and S. Karaman, *Chem. Eng. J.*, **170**, 67 (2011), DOI: 10.1016/j.cej.2011.03.029.
5. V. S. Mane, I.D. Mall and V.C. Shrivastava, *Dyes Pigments*, **73**, 269 (2007).

6. V. S. Mane, I.D. Mall and V.C.Shrivastava, *J Environ Manage*, **84**, 390 (2007), DOI:10.1016/j.jenvman.2006.06.024.
7. Arwa Abdelhay, Abeer Al Bsoul, Amani Al-Othman, Nada M Al-Ananzeh, InshadJum'hAhmed A Al-Taani, *Adsorption Science and Technology*, **25**,46,(2017), DOI: 10.1177/0263617416684347.
8. Zhong-Pan Hu, Ze-Min Gao, Xinying Liu, Zhong-Yong Yuan, *Adsorption Science and Technology*, **27**,62,(2017), DOI: org/10.1177/0263617416684348.
9. Dayeon Choi Sooho Ham Du-Jeon Jang, *Journal Environmental Chemical Engineering*, **6**,1 (2018).
10. M. Bansal, D.Singh and V.K. Gargb, *J Hazard Mater*, **171**,83, (2009).
11. A. Demirbas, *J Hazard Mater*, **167**, 1(2009), DOI:10.1016/j.jhazmat.2009.01.081.
12. S. Lagergren, *Handlingar*, **24**,1 (1898).
13. Y.S. Ho, G.Mckay, D.A.J. Wase and C.F. Foster, *Adsorp. Sci .Technol*, **18**,639 (2000).
14. S .H.Chien and W. R.Clayton, *Soil. Sci. Soc. Am. J.*, **44** ,265 (1980).
15. P.C. C Fariaa, J. J. M. O.Rfao, M. F. R. Pereira, *Water Res.*, **38**, 2043 (2004).
16. R. J.Krupadam and R.Sarin, *Res. J. Chem. Environ.*, **7**,13(2003).
17. S. D. Khattri and M.K.Singh, *Water Air Soil Pollut.*, **120**, 283 (2000).
18. S.P.S.Syed, *Res. J. Chem. Sci.*, **1**, 89 (2011).
19. D.Kendall, *Applied Infrared Spectroscopy*, Reinhold Publishing Corp. Chapman & Hall, Ltd, London, 560 (1996).
20. J. Zawndski, *Carbon*, **19**, 19 (1981).
21. I. Langmuir, *J. Am. Chem. Soc.*, **40**, 1361 (1918).
22. S. Wang , Y. Boyjoo, A. Choueib and H. Zhu, *Water Res.*, **39** ,129 (2005).
23. H. Freundlich, *London.Methuen*, (1926), DOI:org/10.1002/jctb.5000454407.

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