Available online at www.ewijst.org

ISSN: 0975-7112 (Print)
ISSN: 0975-7120 (Online)

Environ. We Int. J. Sci. Tech. 14 (2019) 49-64

Environment & We
An International
Journal of Science
& Technology

Removal of Acid Violet 19 dye from aqueous solution using sawdust of Indian Rosewood (*Dalbergia sissoo*) as adsorbent

Seema Sharma[1], Savita Rani[2*], Kirandeep Kaur[1], Shubham Jindal[1], Samriti Garg[1]
[1]Department of Applied Chemistry,
Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab, India.
[2]Department of Yadavindra College of Engineering,
Punjabi University Guru Kashi Campus, Talwandi Sabo, Punjab, India.
*Email: gargsavita25@yahoo.com

Article history:
Received 13 October 2018
Received in revised form
7 February 2019
Accepted 17 February 2019
Available online
31 March 2019

Keywords:

Adsorption isotherms;
Water contamination;
Batch adsorption study;
Kinetic study

Abstract

With the aim of finding a cost effective adsorbent for the removal of Acid Violet 19 (AV 19) dye from polluted water, the batch adsorption studies were carried out for removing the dye from the aqueous solutions under various process conditions using processed sawdust of Indian Rosewood as adsorbent. The adsorbent was characterized by FT-IR and SEM techniques. The effect of variation of various parameters that is pH, shaking speed, contact time, dosage of adsorbent, initial concentration of dye in solution and temperature was investigated. Maximum percentage adsorption was observed at pH 5 and maintaining this pH the aforesaid procedural key parameters were varied. The adsorption initially increases with the increase in dosage of adsorbent, shaking speed and contact time attains maxima and eventually decreases. On the other hand opposite behavior was noticed for the variation in initial concentration of the dye and temperature. The adsorption process was found to corroborate well with Freundlich isotherm and the maximum monolayer adsorption capacity of sawdust was found to be 50.0 mg/g. Pseudo-first-order and pseudo-second-order kinetic models studied the rate of adsorption and the data fits to pseudo-first-order kinetic model.

Introduction

Water, a natural resource, essential for the survival of life on earth is being polluted day by day due to industrial and anthropogenic activities (Kaur and Pratibha, 2012). Polluted water, generally come from domestic usage, commercial establishments, industries and public institutions where water is used for various activities (Adams *et al.*, 1995). The release of pollutants from industries in water bodies is one of the most important cause of water pollution. The contaminants such as heavy metals, cyanides (Cervantes *et al*., 2000), toxic organic waste, phenols, suspended solids, inorganic waste, colour and turbidity have become a matter of great concern for the environment and public health (Aisen *et al*., 2000). There are so many qualitative and quantitative parameters of polluted water but colour is the first noticeable indication of contamination in water. The colour impurity arises mainly due to discharge of dye containing waste water by textile industry into water bodies (Garg *et al.,* 2004). Many industries such as textile, leather, paper and plastic use dyes to colour their end products. The textile industry is the major user of dyes for colouring of various fiber types (Smelcerovic *et al*., 2010) and alone accounts for two-third of the total dye stuff contaminants in polluted water bodies (Lata *et al.,* 2007). It has been found that industries discharge approximately 800,000 tons of synthetic dyes in water bodies annually (Banerjee and Chattopadhyaya, 2013). The presence of even low concentration of dyes in effluent is easily visible and is highly undesirable. The effluents from textile and other dye consuming industries have high values of biological and chemical oxygen demand, indicating the deteriorated quality of water. The level of contamination, in effluent water of textile industry due to dyes, depends upon the binding capability of dye molecules to different types of fibres. Higher is the binding capacity of dye molecules, lesser is the level of contamination of dye in water or vice-versa (Kini *et al*., 2013).

Consequences of presence of dyes in water can easily be observed by occurrence of various diseases and abnormalities in biotic community. Dyes cause severe health hazards to human beings such as dysfunctioning of kidneys, reproductive system, liver, brain and central nervous system. Some of the dyes may also cause cancer as they decompose into carcinogenic aromatic amines (Santhi *et al*., 2011). Complexity of molecular structure of dyes causes difficulty in their degradation and makes them vulnerable to chelate with metal ions producing micro toxicity in aquatic life. Most of the dyes are stable to photo-degradation and bio-degradation (Garg *et al*., 2004). In order to address the problem of removing dyes from water, several physical, chemical and biological treatment approaches have been tried by different research groups (Kini *et al*., 2013) which include wide range of methods such as coagulation, chemical oxidation, membrane separation process, electrochemical process, aerobic and anaerobic microbial degradation. But these methods are very expensive, thus, devising economical methods to treat dye laden waste water has attracted wide interest in recent years. Among all the known methods, the adsorption method has been found to be better for waste water treatment in terms of initial cost, simplicity of design and ease of operation. The process of adsorption involves use of adsorbents from various origins including plants, animals, and microorganisms, industrial and agricultural waste as well as synthetic adsorbents.

Activated carbon (granular or powder) is a favorable adsorbent because of its large surface area, micro porous structure and high adsorption capacity. But the high cost of activated carbon limits its use at wider level (Khan *et al*., 2004). Therefore, the need of low cost adsorbents becomes imperative. The porous nature of waste materials from vegetation makes them suitable for adsorption of dye molecules hence, these waste materials have been extensively investigated for adsorption of dyes from aqueous solution and are cost-effective as they are waste from abundantly available vegetation.

Present study addresses the application of sawdust as a low cost adsorbent for the removal of Acid Violet 19 (AV 19) dye (for physico chemical properties refer Table 1) from its aqueous solution. The domain of applications of the dye under study is extensively vast. It is widely used as staining agent for finding the stains for bacteria, proteins, tumor cells, fungi etc. Its biological utility includes detection of enzyme activity, protein activity and tumor cell activity. It is also immensely utilized in various industries where it is used in colour filters, photographic film, recording materials, inks, highlighters, explosives, leather and textile. These industries contribute the AV-19 dye as water contaminant into water bodies causing threat to biotic communities due to genotoxicity, neurotoxicity and oral toxicity of the dye. So, the removal of the dye from water bodies is a challenging task for the research community. The method and agent used for the removal of contaminant gets wider acceptability at industrial level if it is abundantly available and cost efficient, in spite of its nominal efficiency. The adsorption method taking sawdust as biosorbent meets the above mentioned expectations.

Considering the repercussions of the presence of AV-19 dye in water bodies and the unexplored potential of raw sawdust as adsorbent, the sawdust from Indian Rosewood (Dalbergia sissoo) is explored for its adsorption efficiency toward the AV-19 dye in aqueous solution. The nature of adsorption mechanism is studied by isotherm models (Freundlich and Langmuir isotherm), kinetic studies (pseudo-first-order and pseudo-second-order kinetic models) and by the variation of various process conditions (pH, shaking speed, contact time, dosage of adsorbent, initial concentration of dye in solution and temperature).

Table 1 Description of physico chemical properties of Acid Violet -19 dye

S. No	Property	Description
1.	Dye Class	Triphenylmethane
2.	Molecular Formula	$C_{20}H_{17}N_3Na_2O_9S_3$
3.	Molecular weight	585.54
4.	Physical form	Olive to dark green crystals or powder
5.	Solubility	Soluble in water, slightly soluble in ethanol and insoluble in xylene
6.	Melting point	>250^0C
7.	pH range	12.0 to 14.0
8.	Colour change at pH	Red (12.0) to colorless (14.0)
9.	Adsorption maxima	546 nm
10.	Emission maxima	630 nm

Experimental details

Materials and reagents

All the chemicals used in the study were of analytical grade and were used without further purification. HCl and NaOH solutions were used for adjusting the pH of dye solutions. The solutions were prepared in deionized water. The dye Acid Violet 19 was procured from Central Drug House (P) Ltd and was used as such.

Processing of Adsorbent: Indian Rosewood sawdust was collected from a local sawmill of Bathinda city. Sawdust was further converted into fine powder by grinding in a mixer grinder. It was then washed with demineralized water and boiled for 7−8 hours to remove watersoluble impurities. After boiling, the sawdust was washed several times with demineralized water till the filtrate is colorless. It was dried in hot air oven at 90°C for about 6 hours. Then it was sieved to a particle size of 300 micron and stored in air tight container.

Preparation of stock solution of AV 19 Dye: Acid Violet 19 (analytical grade), also known as Acid Fuchsin, an acidic dye has molecular formula and molecular mass as$C_{20}H_{17}N_3Na_2O_9S_3$and 585.54g/mol respectively. AV 19 dye belongs to class of triarylmethane dyes. Stock solution of strength 1000 ppm of dye was prepared by dissolving 1 g of dye per 1000 ml of solution. Working solutions of desired dye concentration were prepared by diluting the stock solution.

Adsorbent characterization: FT-IR spectra of raw sawdust and dye loaded sawdust were recorded using attenuated total reflectance (ATR) mode on Spectrum Two spectrophotometer of Perkin Elmer make. This mode does not require KBr pellet formation for recording the spectrum. SEM pictures were taken on JEOL−JSM6510LV scanning electron microscope at SAI Labs, Thapar University, Patiala. Samples were mounted on stubs using double sided conducting tapes of carbon. Gold coating of the samples was done using sputtering coater.

Batch Adsorption studies: The adsorption of AV 19 dye on sawdust was investigated by batch mode technique. The experiments were carried out in triplicates. Experiments were performed by shaking 50 ml of dye solution of known initial concentration containing 0.05g of sawdust at particular pH and at 25°C for 2 hrs. Adsorption isotherms were constructed by measuring the concentration of adsorbate (dye) in the aqueous medium before and after adsorption, at a fixed temperature. The effect of pH on dye removal was studied by varying pH of dye solutions from 2.0 to 5.0. The influence of initial dye concentration was studied by changing the concentration between 10−75 mg/L. The effect of temperature on dye removal was carried out by agitating 50 ml of dye solutions of concentration 30 mg/L at temperatures ranging from 25 to 50°C for 2 hrs. The effect of contact time on adsorption was investigated by varying the contact time such as 30, 60, 90, 120, 150, 180 minutes, keeping other parameters constant. Similarly, the influence of variation of shaking speed (50−250 rpm) and adsorbent dose (0.02−1.5 g per 50 ml) on the process of dye removal was measured. The residual concentration of AV 19 was determined using Genesys 10S UV−Vis Thermo Scientific spectrophotometer at 545 nm. The percentage removal of dye from solution was calculated by the following equation:

$$\text{Percentage removal of dye} = \left(\frac{C_o - C_e}{C_o}\right) \times 100 \qquad (1)$$

Where C_o and C_e are the initial and final dye concentration (mg/L), respectively.

The adsorption capacity (q) was calculated as follows:

$$\text{Adsorption capacity } (q) = V\left(\frac{C_o - C_e}{m}\right) \qquad (2)$$

Where q is the amount of dye adsorbed per unit mass of adsorbent (mg/g), m is the mass of adsorbent (g) and V is the volume of solution in litres.

Determination of pH of Point of zero charge (pH_{zpc}): The point of zero charge pH (pH_{zpc}) of sawdust was evaluated by the solid addition method using 0.01 M KNO_3 solution. The experiments were carried out in a series of 100 ml conical flasks containing 50 ml of 0.01 M KNO_3 solution. The initial pH in each flask was adjusted with the increase of interval of 1 unit covering the range of 2−10, by adding 0.1 M NaOH or 0.1 M HCl solution. 0.5 g of sawdust was added to each flask and kept for 48 hours with intermittent manual shaking to attain the equilibrium. After the given time period, final pH was determined. The difference of final and initial pH values was plotted against the initial pH. The point of intersection of the resulting curve with abscissa, at which change in pH is zero, gave the value of pH_{zpc} (Babić *et al*., 1999).

Results and discussion

Characterization of adsorbent

FT-IR analysis: The adsorbent before and after dye adsorption was characterized by FT−IR spectroscopy. The spectra were taken in the range of 4000−400 cm^{-1}. Figures 1 (a&b) represent the spectra of saw dust and dye loaded saw dust. A broad peak at 3334.9 $cm^{-1}$was assigned to O−H stretching vibrational mode. The peak observed at 2922.5 cm^{-1}correspondsto C−H stretching vibrations of methyl and methylene groups, the peak at 1745.9 cm^{-1} was assigned to C=O stretching mode. A peak at 1600.3 $cm^{-1}$was attributed to the presence of carboxylic group in the biosorbent. The signal at 1031.97 cm^{-1} was assigned to C−O stretching modes of vibration. The interaction between dye molecules and functional groups on saw dust was indicated by slight shift in position of peaks. The band at 3334.9 was shifted to 3326.8 and the peak at 1600.3 shifted to 1588.2 cm^{-1}. These results indicated the involvement of some functional groups in adsorption of dye molecules through weak electrostatic forces of interaction or Van der Waals forces.

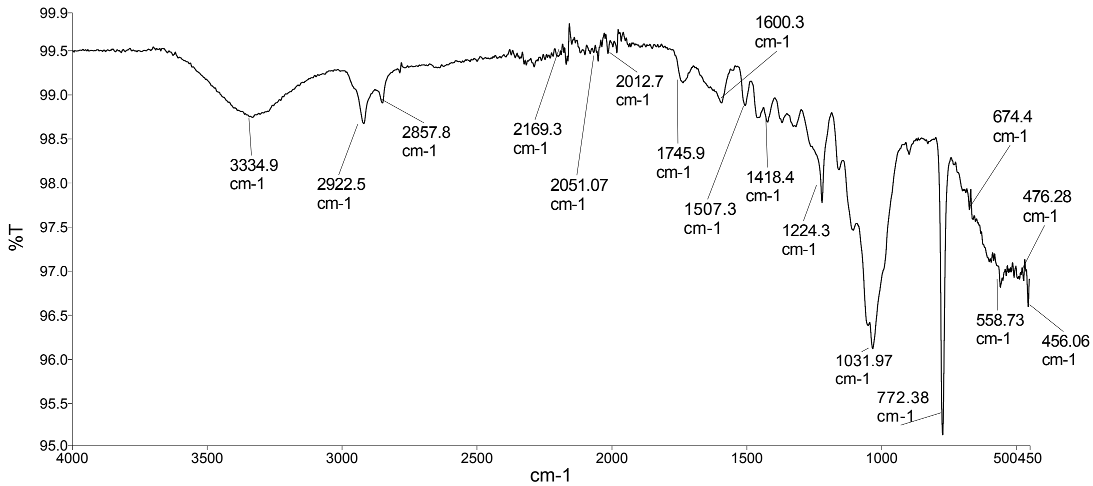

Figure 1 (a) FTIR spectrum of Saw dust

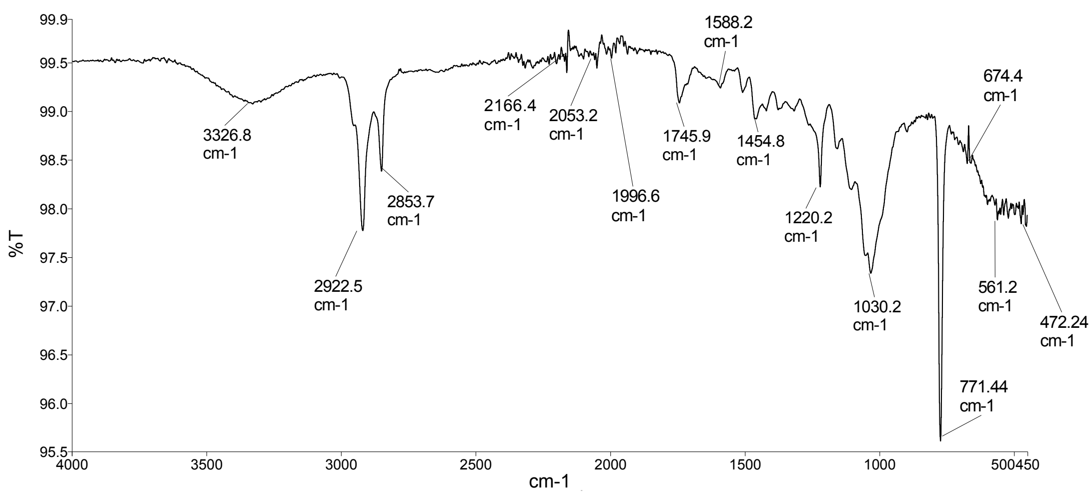

Figure 1 (b) FTIR spectrum of Dye loaded Saw dust

Scanning electron micrograph analysis: The scanning electron microscopic (SEM) photograph indicates surface texture and porosity of material. This photograph helps to observe changes in microstructure of surface of adsorbent due to adsorption of dye molecules. The SEM image of sawdust before dye adsorption, indicates the presence of deep pores of different sizes providing high internal surface area to sawdust (Figure 2a). After the dye adsorption, the presence of dye molecules in pores of adsorbent, causes more dense and closed pores, thus resulting into disruption in the shape and size of pores (Figure 2b).

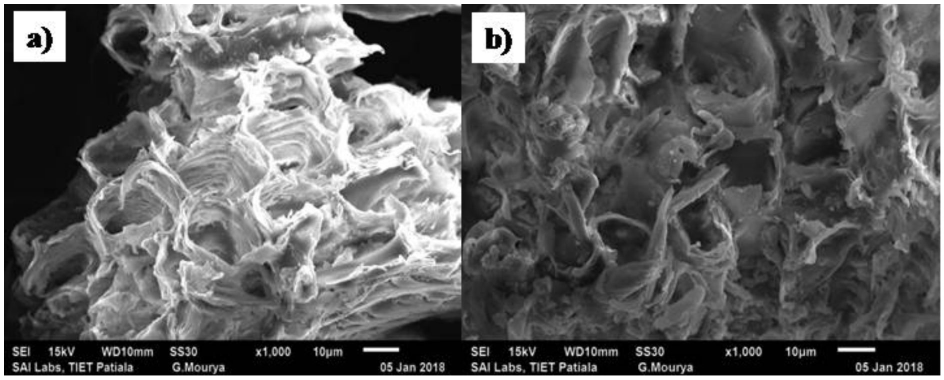

Figure 2 Scanning electron microscopic photograph of Sawdust (a) before adsorption (b) after adsorption of AV 19 dye

pH of Point of zero charge (pH_{zpc}): The influence of pH on the dye removal can be explained on the basis of isoelectric point of the adsorbent surface. Figure 3 represents the graph for difference of final and initial pH values versus the initial pH of KNO_3 solutions. The point of zero charge pH (pH_{zpc}) was found at a value of 6.32. At pH_{zpc}, the acidic and basic functional groups do not contribute towards the pH of the solution. At pH of the solution below pH_{zpc}, the surface of adsorbent is positively charged and can attract anions from the solution. When the pH of solution is greater than pH_{zpc} the surface of adsorbent is negatively charged and it attracts cations (Banerjee and Chattopadhyaya, 2013). In the present case, a lower pH is favorable for dye removal as at low pH, the number of positively charged sites is increased which favor the adsorption of negatively charged dye ions by electrostatic forces of attraction.

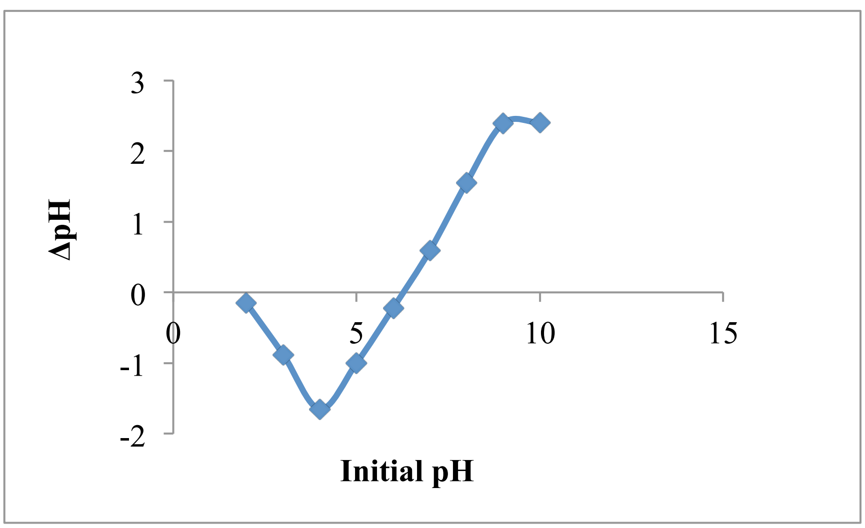

Figure 3 Graph for determination of pH of point of zero charge

Batch adsorption studies

Effect of pH: The percentage adsorption of dye from aqueous solution changes by variation in pH of the solution because pH affects the degree of ionization of the dye and the surface properties of the sorbents (Li and Wang, 2009).Figure 4 shows the effect of change in pH (2.0−5.0) on the percentage removal of AV 19 dye from 50 ml of 30 ppm aqueous solutions of dye containing 0.05 g of sawdust adsorbent maintaining temperature 25°C, the flasks were agitated for 2 hours at 200 rpm. From the graph, it is observed that percentage removal of dye increases with increase in pH. Maximum percentage (50.07%) of dye was adsorbed at pH 5. Above pH 5, adsorption studies for dye removal were not carried out, due to the reason that colour of dye starts fading above pH 5.

Effect of adsorbent dose: To study the effect of adsorbent dose, 50 mL of dye solutions of concentration 30 ppm at pH 5.0 containing adsorbent dose between 0.02−1.5 g were agitated for 2 hours at 200 rpm and 25°C. The results indicated that the percentage removal of dye increased by raising the adsorbent dose up to 0.05 g due to increase in surface area and greater availability of adsorption sites (Reddy *et al*., 2010) (Figure 5). However, the percentage of dye adsorption decreased after 0.05 g of dose of adsorbent. This may be attributed to the formation of aggregates of sawdust particles resulting in decreased effective adsorption area and active sites of adsorbent at higher dosage (Ekmekyapar *et al*., 2006)

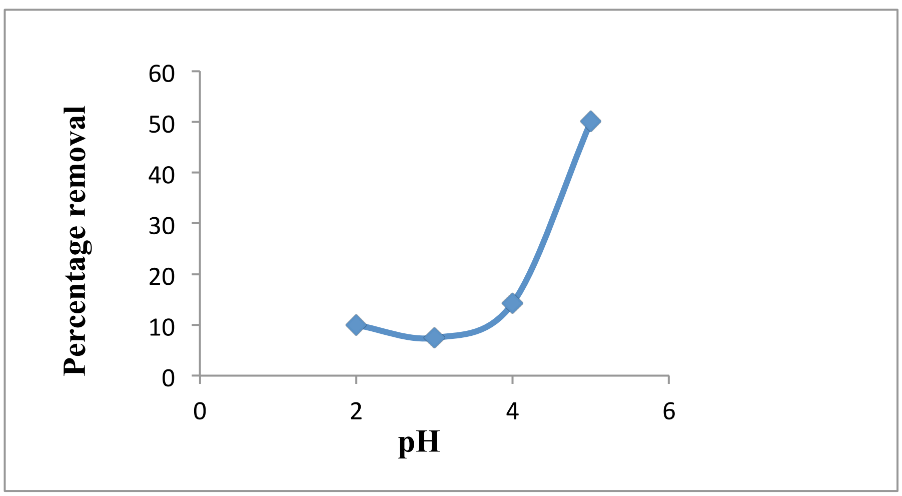

Figure 4 Graph showing effect of pH on percentage adsorption of AV 19 dye

Effect of contact time: The adsorption data for percentage removal of colour contaminant under investigation with change in contact time in the range 30−180 min. is presented in Figure 6. It was observed that adsorption increases with the increase of contact time, reached maxima at 120 minutes and beyond this adsorption decreases. It is because most of the active sites are occupied by that time. The adsorption of dye increased gradually as the time approaches 90 minutes. After 90 minutes, the percentage removal showed sudden increase but at the end of 120 minutes, it started to decrease and became almost constant later than 150 minutes. The dye retention behaviour of adsorbent after 150 minutes may be attributed to the saturation of adsorption sites.

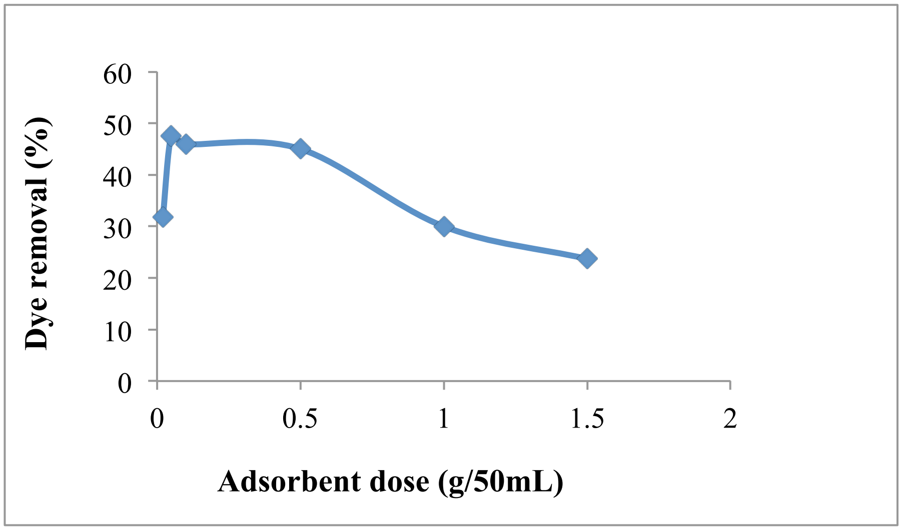

Figure 5 Graph showing effect of adsorbent dose on percentage adsorption of AV 19 dye

Effect of shaking speed: The effect of change in shaking speed on percentage removal of AV 19 colourant was investigated by taking 50 ml of dye solution of concentration 30 ppm containing 0.05 g of adsorbent at 25°C and keeping the contact time 120 minutes. The shaking speed was varied from 50 to 250 rpm in the installments of 50 rpm. The percentage removal of dye initially increases with increase in the shaking speed. This behaviour is observed up to 200 rpm and afterwards the downfall was noted (Figure 7). When mixture is shaken, the movement of solid particles is brisk in the solution. Thus, the concentration of dye molecules near the surface of solid adsorbent particles increases, possibly to a level near that of bulk concentration. Diffusion of dye molecules to the boundary layer of adsorbent particles and surrounding solution increases with increase in shaking speed. The decrease in adsorption beyond shaking speed of 200 rpm probably is due to decrease in diffusion of dye molecules. This is probably due to breaking of the newly formed bonds between dye molecules and adsorbent surface, caused by sufficient additional energy attained as a result of high speed (Ghasemi *et al*., 2007).

Effect of temperature: To investigate the effect of temperature on percentage removal of dye, five samples containing 50 ml of 30 ppm dye solution with pH 5.0 each, were shaken at 200 rpm for 120 minutes and temperature was maintained at 25, 30, 35, 40 and

50°C. It is observed that at the initial stage, percentage adsorption of AV 19 dye decreases sharply up to 35°C. After 35°C, the rate of removal of dye slows down (Figure 8). This changed trend of adsorption indicates towards characteristics for exothermic adsorption process. (Nimkar *et al*., 2014)

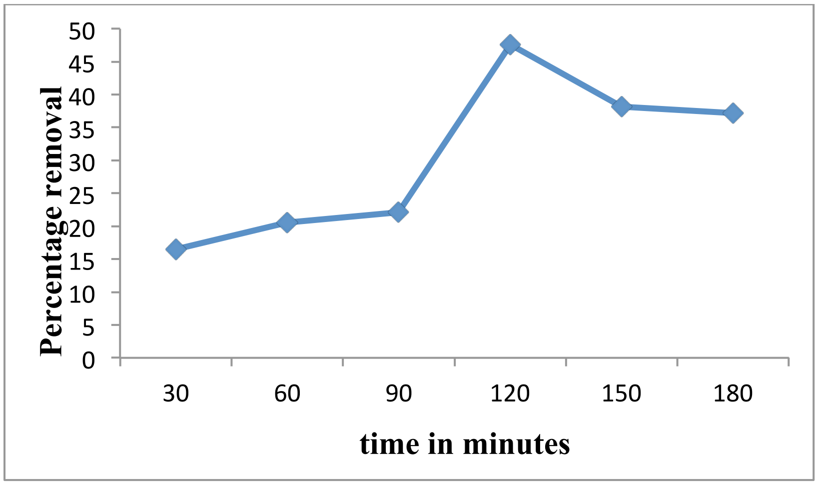

Figure 6 Effect of contact time on percentage adsorption of Acid Violet 19 dye

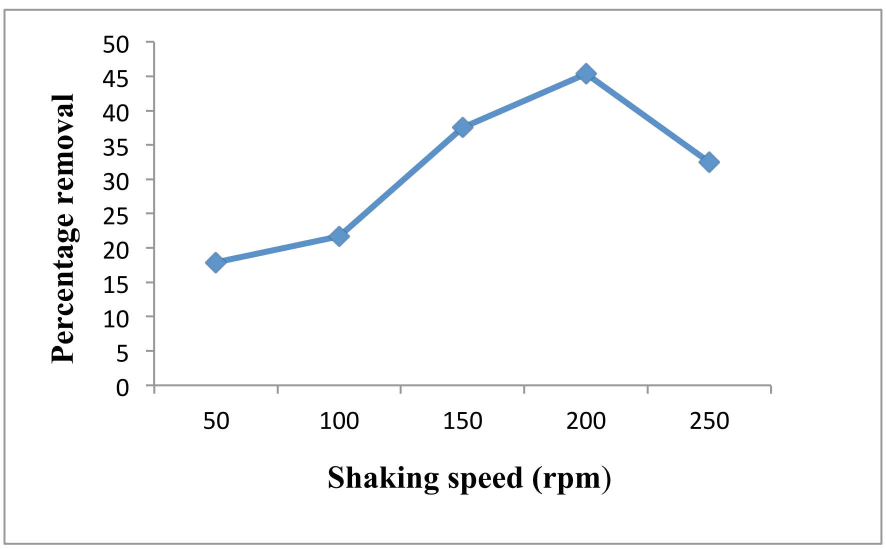

Figure 7 Effect of variation of shaking speed on adsorption of AV 19 dye

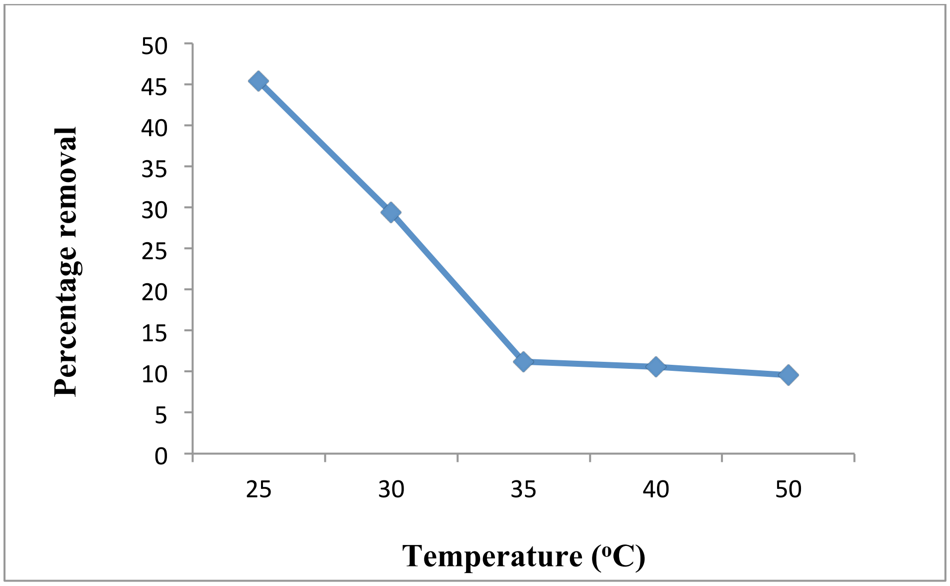

Figure 8 Graph showing effect of temperature on adsorption of AV 19 dye

Effect of initial concentration of dye: Figure 9 depicts the effect of change in initial concentration of dye on its percentage removal from aqueous solution. The initial concentration of dye was varied in the range 10−75 mg/L. The plot indicated that with the increase of initial concentration of dye, the percentage removal decreases. This behaviour of dye can be explained on the basis of the fact that percentage removal of dye decreases gradually when the process of adsorption approaches equilibrium. For lower initial concentrations, there is availability of more number of active sites on the surface of adsorbent, so the percentage removal is higher. As the concentration of dye increases, the vacant sites on the adsorbent surface get saturated resulting in decreased adsorption. (Kumar *et al*., 2011)

Adsorption isotherms: The adsorption isotherm describes the distribution of adsorbate molecules between the liquid and solid phase at equilibrium. Adsorption isotherm studies were carried out using Langmuir and Freundlich isotherm models. The Langmuir isotherm equation (Langmuir, 1918) is given as:

$$q_e = \frac{q_m K_L C_e}{1+K_L C_e} \tag{3}$$

The linear form of equation may be expressed as:

$$\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{q_m K_L} \tag{4}$$

where, C_e is the liquid-phase equilibrium concentration (mg/L) of the adsorbate, q_e is the amount of dye adsorbed at equilibrium (mg/g), q_m is the maximum monolayer adsorption capacity (mg/g) and K_L is the Langmuir constant (L/mg). Values of q_m and K_L can be calculated from the plot of C_e/q_e versus C_e.

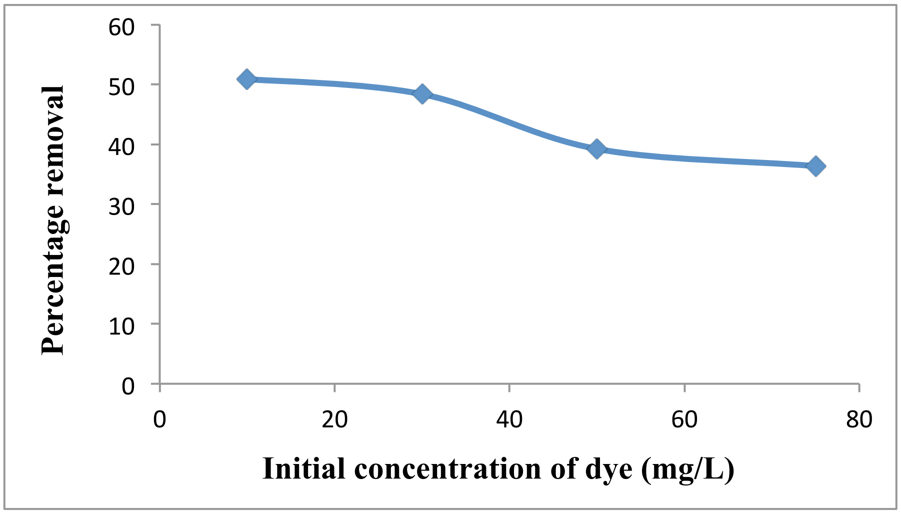

Figure 9 Effect of initial concentration of dye on adsorption of AV 19 dye

The linear plot of adsorption of AV 19 dye onto sawdust is depicted in Figure 10a. The values of constants q_m and K_L are given in Table 2. The essential features of the Langmuir isotherm can be expressed in terms of a dimensionless constant known as separation factor (R_L) and is expressed as

$$R_L = \frac{1}{1+K_L C_o} \tag{5}$$

The value of R_L indicates the isotherm to be either unfavourable (R_L>1), linear (R_L=1), favourable (0<R_L< 1) or irreversible (R_L=0) (Yao *et al*., 2010). The values of R_L for different initial concentrations of dye came out in the range 0−1 indicating the process to be favourable.

The Freundlich isotherm (Freundlich, 1906) is expressed by the following empirical equation:

$$\log q_e = \log K_f + \frac{1}{n} \log C_e \tag{6}$$

where, q_e is the solid phase equilibrium concentration (mg/g), C_e is the liquid-phase equilibrium concentration (mg/L), K_f and 1/n are Freundlich constants. K_f and n are obtained from intercept and slope of the linear plot of log q_e versus logC_e (Figure 10b).

Table 2 represents the data including correlation coefficients (R^2) of both isotherms. The comparison of values of R^2 indicates that the Freundlich model gives a better fit to the experimental adsorption data than the Langmuir model. Also, the values of R^2 for two isotherms under study are very close indicating the applicability of both Freundlich and Langmuir isotherms to the AV 19 dye adsorption on sawdust. It reveals that both monolayer adsorption and heterogeneous conditions exist, thus highlighting that adsorption is a complex process involving more than one mechanisms. Maximum value of adsorption capacity is 50.0 mg/g as determined from Langmuir model.

Kinetic Studies

The kinetic data of the adsorption of AV 19 was evaluated using pseudo first order and second order kinetic models.

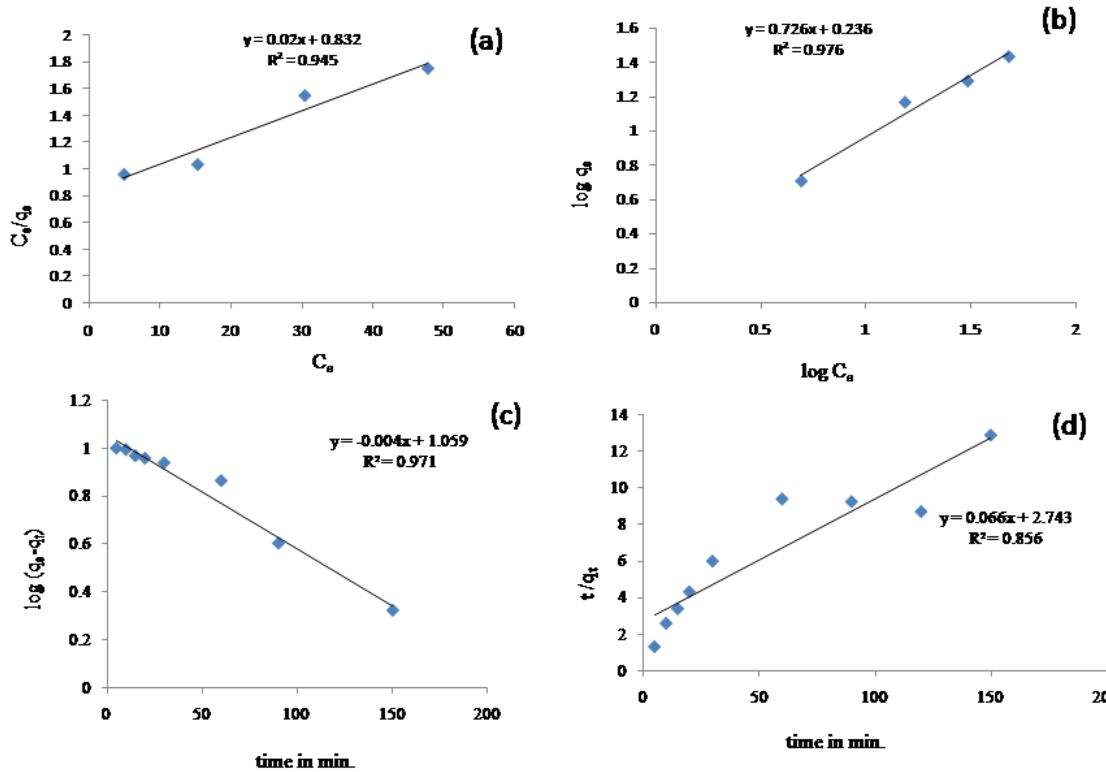

Figure 10 (a) Langmuir Adsorption Isotherm (b) Freundlich Adsorption Isotherm (c) Pseudo first order kinetics (d) Pseudo second order kinetics for adsorption of Acid Violet 19 dye

Table 2 Isotherm parameters for adsorption of AV 19 dye on sawdust at 298 K

Langmuir Isotherm model				Freundlich Isotherm model		
q_m (mg/g)	K_L	R^2	R_L	K_f	1/n	R^2
50.0	0.024	0.945	0.581 for 30 mg/L	1.721	0.726	0.976

Table 3 Kinetic studies for adsorption of AV 19 dye on sawdust

$q_{e, exp}$ (mg/g)	Pseudo first-order			Pseudo second-order		
13.73	k_1 (1/min)	R^2	$q_{e, cal}$ (mg/g)	k_2 (g/mg.min)	R^2	$q_{e, cal}$ (mg/g)
	9.2×10^{-3}	0.971	11.45	1.58×10^{-3}	0.856	15.15

The Pseudo first order model: This model assumes that the rate of change of solute uptake with time is directly proportional to the difference in saturation concentration and the amount of solute uptake.

The rate constant of adsorption is determined from the following first order rate expression (Lagergren, 1898):

$$\log (q_e - q_t) = \log q_e - \left(\frac{k_1}{2.303}\right) t \tag{7}$$

where, q_e and q_t are the amount of dye adsorbed (mg/g) at equilibrium and time t, respectively, k_1 is the rate constant of adsorption of pseudo first order. The values of the rate constant (k_1)and amount of dye adsorbed at equilibrium (q_e), as determined from the graph of log ($q_e - q_t$) versus t (Figure 10c) are given in Table 1.

The Pseudo second order model

The pseudo second order adsorption kinetic rate equation (Ho and McKay, 1999) is expressed as follows:

$$\frac{t}{q_t} = \frac{1}{k_2 {q_e}^2} + \frac{1}{q_e} t \tag{8}$$

where q_e is equilibrium adsorption capacity, q_t is amount of dye adsorbed at time t and$k_2$is rate constant of pseudo second order adsorption ($gmg^{-1}min^{-1}$). Values of q_e and k_2(Table 3) are determined from the slope and intercept of plot of $\frac{t}{q_t}$versus t (Figure 10d).

From the values of R^2, it is observed that adsorption of AV 19 dye on sawdust follows pseudo first-order kinetic model. Also the calculated value of q_e is closer to experimental value for pseudo first-order model. Therefore, pseudo-first order model is best suitable for AV 19 dye adsorption on saw dust.

Conclusion

Saw dust of Indian rosewood has been explored for its adsorption capacity towards the acid violet 19 dye from aqueous solution. Isotherm studies, kinetic studies and variation of various procedural parameters in batch mode revealed that the process is physical monolayer adsorption following first order kinetics. Most of the industries dealing with dyes are small scale industries, where the owner is unwilling to invest money on effluent treatment process. Here, the raw sawdust offers a convenient economical choice for the dye removal from the effluent. The mere contact of the dye laden water and sawdust removes 50% dye as per the results of present study. The use of raw sawdust in the form of bioreactors will definitely improve the adsorption efficiency, especially if these bioreactors are used in a series of two or three, which involves megre monetary investment. Its low cost, abundant availability and eco-friendly nature convinced the authors to rate it as a competent adsorbent. The adsorbent has a great unexplored potential, so in further studies the adsorption capability of sawdust can be modified by converting it into nanocomposites.

Authors' contribution: *Seema Sharma (Associate Proferssor and project leader), Kirandeep Kaur (Assistant Professor) and Savita Rani (Assistant Professor) are responsible for experimental; project design and wrote the manuscript. Shubham Jindal (Project Student) and Samriti Garg (Project Student) performed the experiments. Savita Rani (Assistant Professor) is also done final editing and corresponding author of Manuscript.*

References

Adams, C.D., Fusco, W., Kanzelmeyer, T., 1995. Ozone, hydrogen peroxide/ozone and UV/ozone treatment of chromium and copper complex dyes: decolorization and metal release. *Ozone: Science & Engineering* 17(2), 149-162.

Aisen, P., Enns, C., Wessling-Resnick, M., 2001. Chemistry and Biology of eukaryotic iron metabolism. *TheInternational Journal of Biochemistry & Cell Biology* 33(10), 940-959.

Babić, B.M., Milonjić, S.K., Polovina, M.J., Kaludierović, B.V., 1999. Point of zero charge and intrinsic equilibrium constants of activated carbon cloth. *Carbon* 37 (3), 477-481.

Banerjee, S., Chattopadhyaya, M.C., 2017. Adsorption characteristics for the removal of a toxic dye, tartrazine from aqueous solutions by a low cost agricultural by-product. *Arabian Journal of Chemistry* 10, S1629-S1638.

Cervantes, F. J., vander Velde, S., Lettinga, G., Field, J. A., 2000. Competition between methanogenesis and quinone respiration for ecologically important substrates in anaerobic consortia. *FEMS Microbiology Ecology* 34(2), 161-171.

Ekmekyapar, F., Aslan, A., Bayhan, Y. K., Cakici, A., 2006. Biosorption of copper (II) by nonliving lichen biomass of *Cladonia rangiformis* hoffm. *Journal of Hazardous Materials* 137 (1), 293-298.

Freundlich, H.M.F., 1906. Over the adsorption in solution. *The Journal of Physical Chemistry* 57, 385-471.

Garg, V.K., Amita, M., Kumar, R., Gupta, R., 2004. Basic dye (methylene blue) removal from simulated wastewater by adsorption using Indian Rosewood sawdust: A timber industry waste. *Dyes and Pigments*63, 243-250.

Ghasemi, M., Naushad, Mu., Ghasemi, N., Khosravi-fard, Y., 2014. A novel agricultural waste based adsorbent for the removal of Pb(II) from aqueous solution: Kinetics, Equilibrium and thermodynamic studies. *Journal of Industrial and Engineering Chemistry*20, 454-461.

Ho, Y.S., McKay, G., 1999. Pseudo-second order model for sorption processes. *Process Biochemistry* 34, 451-465.

Kaur, I., Pratibha., 2012. Acid treated Indian Rosewood Sawdust (*Dalbergia Sissoo*): An Efficient Adsorbent for Methylene blue. *Journal of Industrial Research & Technology* 2(2), 58-66.

Khan, T.A., Singh, V.V., Kumar, D.,2004. Removal of some basic dyes from artificial textile wastewater by adsorption on Akash Kinari coal. *Journal of Scientific and Industrial Research* 63, 355-364.

Kini, S.M., Saidutta, M.B., Murty, V.R.C., Kadoli, S.V., 2013. Adsorption of basic dye from aqueous solution using HCl treated sawdust. *International Research Journal of Environment Sciences*2 (8), 6-16.

Kumar, P.S., Ramalingam, S., Kirupha, S.D., Murugesan, A., Vidhyadevi, T., Sivanesan, S., 2011. Adsorption behaviour of nickel (II) onto cashew nut shell: Equilibrium, thermodynamics, kinetics, mechanism and process design. *Chemical Engineering Journal* 167, 122-131.

Lagergren, S., 1898. About the theory of so-called adsorption of soluble substances. *Kungliga Svenska Vetenskapsakademiens Handlinger* 24, 1-39.

Langmuir, I., 1918. The adsorption of gases on plane surfaces of glass, mica and platinum. *Journal of the American Chemical Society* 40 (9), 1361-1403.

Lata, H., Garg, V.K., Gupta, R.K., 2007. Removal of a basic dye from aqueous solution by adsorption using *Parthenium hysterophorus*: An agricultural waste. *Dyes and Pigments* 74 (3), 653-658.

Li, K., Wang, X., 2009. Adsorptive removal of Pb (II) by activated carbon prepared from *Spartina alterniflora*: Equilibrium, kinetics and thermodynamics. *Bioresource Technology* 100 (11), 2810-2815.

Nimkar, D.A., Chavan, S.K., 2014. Removal of Methylene Blue (Basic Dye) from Aqueous Solution using Sawdust as an Adsorbent. *International Journal of Engineering Researchand Technology* 3 (4), 1579-1583.

Reddy, D.H.K., Seshaiah, K., Reddy, A.V.R., Rao, M.M., Wang, M.C., 2010. Biosorption of Pb^{2+} from aqueous solutions by *Moringa oleifera*: Equilibrium and kinetic studies. *Journal of Hazardous Materials* 174 (1-3), 831-838.

Santhi, T., Manonmani, S., Vasantha, V.S., Chang, Y.T., 2011. A new alternative adsorbent for the removal of cationic dyes from aqueous solution. *Arabian Journal of Chemistry* 9, S466-S474.

Smelcerovic, M., Dordevic, D., Novakovic, M., Mizdrakovic, M., 2010. Decolorization of a textile vat dye by adsorption on waste ash. *Journal of the Serbian Chemical Society*75 (6), 855-872.

Yao, Z.-Y., Qi, J.-H., Wang, L.-H., 2010. Equilibrium, kinetic and thermodynamic studies on the biosorption of Cu(II) onto chestnut shell. *Journal of Hazardous Materials* 174 , 137-143.