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# Kinetics and Equilibrium Isotherm for adsorption of Basic Blue 9 Dye onto Activated Charcoal prepared from Bhagar Seed Husk

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## Abstract

The aim of this investigation was to determine the adsorption behaviour and kinetics of Basic blue 9 dyes in aqueous solution on activated carbons prepared from husk of Bhagar seeds by ZnCl2 activation method in self-generated atmosphere using an oven. FTIR spectra indicated high surface functional groups present on the surface of activated charcoal. The specific surface coverage on activated charcoal was found to be 344.77 $m^2$ per gram of activated charcoal. The adsorption equilibrium and kinetics of Basic blue 9 dyes on prepared activated charcoal were then examined at 298 K. The adsorption isotherms of the Basic blue 9 on activated adsorbent was determined and correlated with common Langmuir, Freundlich and Temkin isotherm models. The Freundlich isotherm showing a better fit for the adsorption data than the Langmuir and Temkin isotherm. The maximum monolayer adsorption capacity obtained from Langmuir isotherm was 666.7 mg of dye Basic blue 9 per gram of activated charcoal. The kinetics of dye adsorption on the activated charcoal has also been studied by fitting the data in the Lagergren's pseudo-first order and the Ho-McKay's pseudo second order kinetic models. It was observed that the adsorption of Basic blue 9 dyes over the prepared activated charcoal undergoes the Pseudo-second order processes at all the concentrations of the dye.

*Keywords:* Kinetic, equilibrium, isotherm activated carbon, Bhagar seed husk.

## 1. Introduction

Dyes are synthetic chemical compounds having complex aromatic structures, which make them more stable and difficult to biodegradable. Dyes are extensively used to colour the products in the textile, cosmetic, plastic, food, and pharmaceutical industries. The major problem in the recent years concerning in the dyes and textile industry wastewaters is colored effluent. The colored wastewater contains number of toxic and organic compounds, which are destructive to all aquatic organisms [1]. Most of the dyestuffs are designed to be resistant to environmental conditions like light, effects of pH and microbial attack [2]. The presence of these dyes is a great threat to animal health and desirable to remove colouring material from effluents before their discharge in environment not only for aesthetic reasons, but it is important to regions where water resources are scarce or sensitive. The dye containing wastewater discharged from the industries can affect photosynthetic activity in aquatic life by impeding light penetration. Moreover, most of the dyes are toxic, carcinogenic and harmful to human health. Even at low concentration (1 mg $L^{-1}$), dyes could be highly noticeable, and could cause an aesthetic pollution and disturbance to the ecosystem and water sources [3]. Therefore, there is an increasing demand of efficient and economical technologies for removing dyes from water environment in the world. Activated carbon is the most popular adsorbent and has been used with great successes for many years in potable water treatments, in the pre treatment of water for its use in industry and in the safe disposal of different industrial effluents [4]. Attention is being laid on the use of this commodity as pollution controlled media particularly in the removal of organics from liquid phase [5].

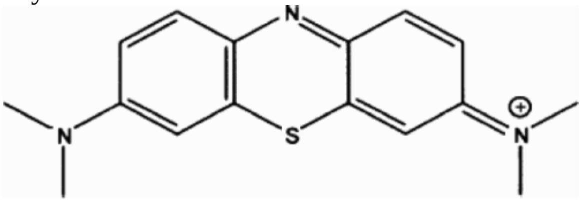
The uses of activated charcoals are widely used to remove pollutants from wastewaters by adsorption processes. Conversely, commercially available activated charcoal is expensive. In the past years, special attention on the preparation of activated carbon from several agricultural by-products has been given due to the growing interest in low cost activated charcoal from renewable agricultural resources. Many researchers have produced activated Charcoal from natural resource such as, bagasse [6], cassava peel [7], date pits [8], coir pith [9], wood apple shell [10], jute fiber [11], palm-tree cobs [12], plum kernels [13], rice husks [14], olive stones [15]. The advantage of using inexpensive natural resource as raw materials for manufacturing activated carbon is that these raw materials are renewable and potentially less expensive to manufacture. Adsorption of dyes on activated charcoal was found as a superior technique for water reuse from industrial wastewater in terms of initial cost and not affected by toxic substances. The achievement of an activated charcoal treatment process depends on the type of charcoal and the characteristics of the industrial wastewater in addition to the operating conditions. Activated charcoal is relatively modern form of porous carbon materials with a number of significant advantages over the more traditional powder materials. These include high surface area and adsorption capacity as well as adsorption power from the gas and liquid phase [16].

The present study aims to evaluate the efficiency of activated charcoal produced from bhagar seed husk in the removal of Basic Blue 9 dye. One of food is known here in local language Marathi as Vari Tandul, Bhagar also commonly known as Varyache Tandul or Samo or Kodri. Bhagar or Vari Tandul is primarily harvested in the southern region and Nasik district of Maharashtra, India. It is a grass (*Echinochloa Colonum*) which normally grows along with the rice paddy as it requires humid, or even spongy, soil. In India traditionally seeds of Bhagar are eaten during fasts.

## 2. Materials and methods

### 2.1. Basic Blue 9

Basic Blue 9 was obtained from CDH New Delhi, was used as an adsorbate and not purified prior to use. Double distilled water was used for preparing all the solutions and reagents. Chemical structure of the dye is shown as Chemical structure of Dye: Basic Blue 9



Basic Blue 9 [3, 9- bis dimethylaminophenazo thionium chloride]
Methylene Blue, λmax = 668 nm.

### 2.2 Preparation and characterization of activated carbon

Precursor (Bhagar seed husk) used for preparation of activated carbon was procured locally, washed with de-ionized water, dried, crushed and grinded in food processor to the smaller particle size (1-2 mm). The powdered husk material was then impregnated with $ZnCl_2$ (1:1, by weight) by constant stirring for 48 hours. The mixture was dehydrated in an oven overnight at 105 °C; then carbonized in a same oven at temperature of 150 °C and activated for 12 h. The activated product was then cooled to room temperature and washed with distilled water to remove the remaining chloride until the washed water gives negative test of chloride by silver nitrate. The prepared activated charcoal was characterized by FTIR analysis, $pH_{pzc}$ was determined by batch equilibrium method [17]. Initial pH values ($pH_i$) of 25 mL of $KNO_3$ solutions (0.1 M) were adjusted in pH range of 2–8 using 0.1M HCl or NaOH. Then, 0.1 g of prepared activated charcoal was added to each sample. Equilibration was carried out by shaking, in a thermo-stated magnetic shaker for 4 h (greater than equilibrium contact time) at 298 K. The dispersions were then filtered and the final pH of the solutions ($pH_f$) was determined, point of zero charge was found from a plot of ($pH_i - pH_f$) versus $pH_i$. The surface coverage of prepared activated charcoal from Bhagar seed husk were determined, based on maximum monolayer adsorption capacity ($q_{max}$) of Basic blue 9 calculated from Langmuir isotherm model and projected area of adsorbate molecule [18]. The surface coverage ($S_c$) per unit gram of prepared activated charcoal ($m^2\ g^{-1}$) can be calculated by the equation:

$$S_c = \frac{6.023x10^{23}\ x\ A_m\ x\ q_{max}}{1000} \tag{1}$$

The value of projected area $A_m$ of Basic blue 9 dye is 0.244 $nm^2$ [19]. The surface morphology of prepared activated charcoal was examined by Jeol JST-6360A scanning electron microscopy. The powder X-ray diffraction pattern of prepared activated charcoal was examined by using a diffractometer (Bruker, AXS D-8 Advance).

*2.3 Batch equilibrium studies*

Adsorption isotherms were performed in a series of titration flasks (250 ml) where solutions of Basic Blue 9 dye (50 ml) with different initial concentrations (100-500 mg $l^{-1}$) were placed in these flasks. 0.1 g of activated carbon prepared from Bhagar seed husk was added to dye solutions and kept in an isothermal shaker (magnetic) at 25±1 °C for 2 h to reach equilibrium of the solid-solution mixture. The pH was adjusted to 7 by adding either few drops of diluted hydrochloric acid or sodium hydroxide (0.1 M). The titration flasks were then removed from the magnetic thermo-stated shaker and the final concentration of dye Basic blue 9 in the solution was analyzed. The concentration of Basic Blue 9 in the supernatant solution after and before adsorption was determined using colorimeter (Elico, Japan) at 660 nm. The samples were centrifuge prior to analysis in order to minimize interference of the carbon fines with the analysis. Removal efficiency of Basic Blue 9 was determined as:

$$\%\,\text{Basic blue 9 removal} = \frac{C_o - C_e}{C_o} \times 100 \tag{2}$$

Where $C_o$ (mg $L^{-1}$) and $C_e$ (mg $L^{-1}$) are initial and equilibrium concentrations of Basic Blue 9 in the liquid-phase respectively.

The amount of adsorption at equilibrium, $q_e$ (mg $g^{-1}$), was calculated by equation:

$$q_e = \frac{C_o - C_e}{M} \times V \tag{3}$$

Where, $C_o$ and $C_e$ (mg $L^{-1}$) are the liquid-phase concentrations of dye at initial and equilibrium, respectively. V is the volume of the solution (L), and W is the mass of dry adsorbent activated charcoal used (g). Adsorption isotherm data were analyzed as;

*2.4 Batch kinetic studies*

The experimental procedures of kinetic studies were basically similar to those of equilibrium experiments. The aqueous samples were taken at definite time intervals, and the concentrations of dye were similarly measured. The amount of adsorption at time t, $q_t$ (mg $g^{-1}$) was calculated by:

$$q_t = \frac{C_o - C_t}{M} \times V \tag{4}$$

Where, $C_o$ and $C_t$ (mg $L^{-1}$) are the liquid-phase concentrations of dye at initial and at time t, respectively. V is the volume of the solution (L), and W is the mass of dry adsorbent activated charcoal used (g).

## 3. Results and discussion

*3.1 Characteristics of the prepared activated carbon*

The prepared activated Charcoal from bhagar seed husk shows functional groups are shown in table 1, which reveals that the most abundant functional groups included aromatic (C-H), carboxylic acid (C-O, C=O and O-H), carbonyl (C=O), alkane (C-H) and amine (N-H, C – N) were found. This suggest to adsorb Basic blue 9 on activated charcoal these functional groups are responsible. It was found that the pH at point of zero charge ($pH_{pzc}$) of the activated carbon were 4.1 (Fig.1).

The pH at point of zero charge ($pH_{pzc}$) of activated carbon prepared from Bhagar seed husk shows that there exhibits a relationship between $pH_{pzc}$ and adsorption capacity of the adsorbent used. The result shows that cations adsorption will be favorable at pH value higher than point of zero charge. While anion adsorption will be favored at pH values lower than point of zero charge [20]. This investigate that the pH greater than 4.1 adsorption of Basic Blue 9 (cationic dye) is more favourable, due to strong electrostatic attraction between cationic dyes and negatively charged adsorbent surface. The specific surface coverage area of prepared activated charcoal was found to be 344.77 $m^2$ $g^{-1}$. Further, prepared activated charcoal were characterised by scanning electron microscopy (fig. 2) and powdered x-ray diffraction spectroscopy (fig.3). From figure 2 and 3 clearly showed that the prepared activated charcoal is porous structure with large internal surface area and amorphous material, respectively.

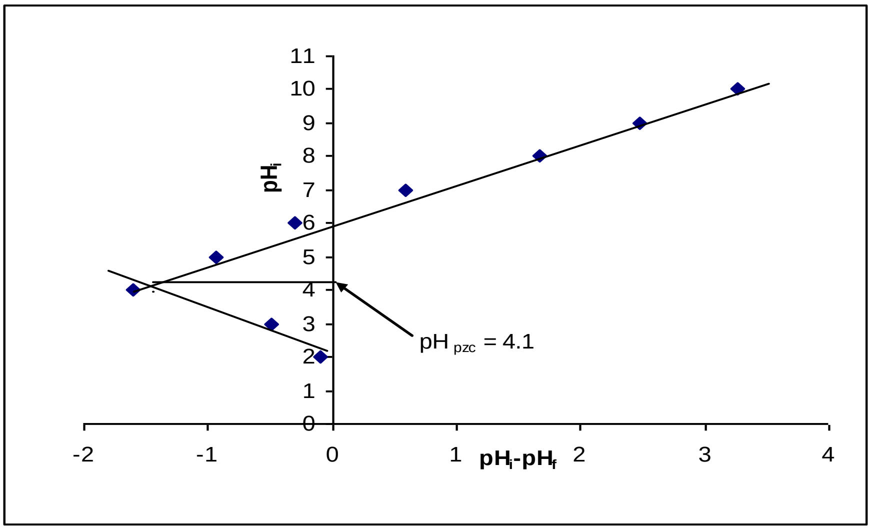


**Fig. 1** $pH_{pzc}$ of activated charcoal prepared from husk of bhagar seed

**Table 1** Functional groups in AC prepared from bhagar husk by FTIR analysis.

| IR Frequency ($cm^{-1}$) | bond | Functional group |
|---|---|---|
| 3626.29 | O-H stretching vibrations | Alcohol, phenol |
| 3338.89 | N-H stretching vibrations | Amines, amides |
| 3153.72 | C-H stretching vibrations | Aromatic |
| 2683.63 | C-H stretching | Alkanes |
| 2779.52 | C-H stretching | Aldehyde |
| 1770.71 | C=O stretching | Carbonyl |
| 1693.56 | C=O stretching | Carboxylic acid |
| 1616.40 | N-H bending | Primary amine |
| 1560.46 | C-C stretching | Aromatic |
| 1500.67 | C-C stretching | Aromatic |
| 1429.30 | C-C stretching | Aromatic |
| 1396.51 | C-H bending | Alkanes |
| 1334.78 | C-N stretching | Aromatic amine |
| 1303.92 | C-O stretching | Carboxylic acid, ester, ether |
| 1213.27 | C-N stretching | Aromatic amine |
| 1109.11 | C-O stretching | Carboxylic acid, ester, ether |
| 745.08 | O-H bending | Carboxylic acid |
| 804.34, 684.75 | C-H bending | Aromatic |
| 630.74, 555.52 | C-Cl stretching | Alkyl halide |

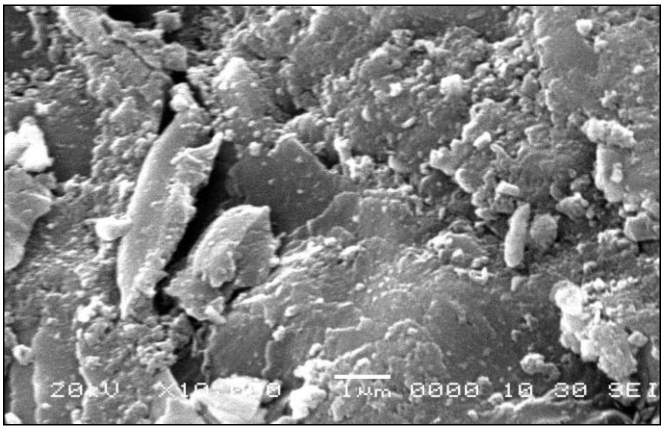


**Fig. 2** Scanning Electron Micrograph of Activated Carbon produced from bhagar seed husk

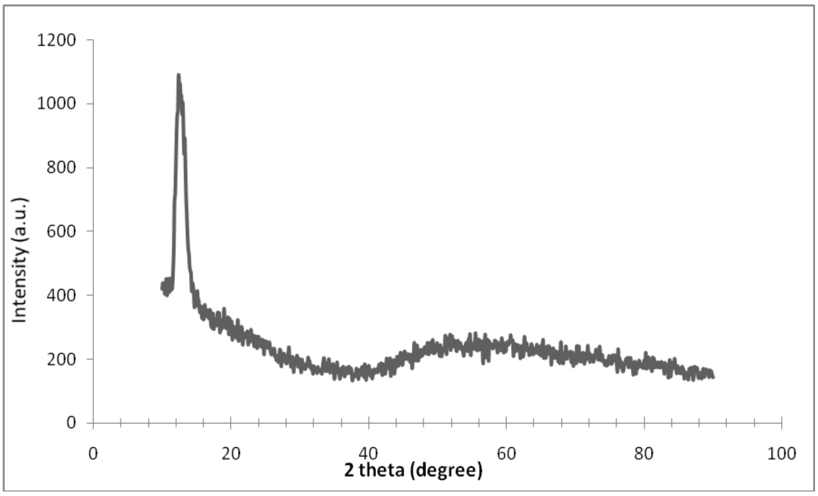


**Fig. 3** XRD Pattern of Activated Carbon produced from bhagar seed husk

*3.2 Effect of contact time on adsorption*

Contact time experiments for Basic Blue 9 dye have been carried out at initial concentration of 100 mg L$^{-1}$ and at temperatures 298 K. Figure 4 shows the contact time necessary for adsorption of Basic blue 9 dye on activated charcoal to reach equilibrium is about 100 -110 min. It can be also seen from fig. 4, that the amount of the adsorbed dye onto activated charcoal increases with time and, at after some time, reaches a constant value beyond which no more is removed from solution. At equilibrium time 110 min, the amount of the dye desorbed from the adsorbent is in equilibrium with the amount of the dye adsorbed onto the activated charcoal. The adsorption capacity at equilibrium is 49.3 mg g$^{-1}$ with an initial dye concentration of 100 mg L$^{-1}$. It is evident that the activated charcoal prepared from Bhagar seed husk is efficient to adsorb Basic Blue 9 dye from aqueous solution.

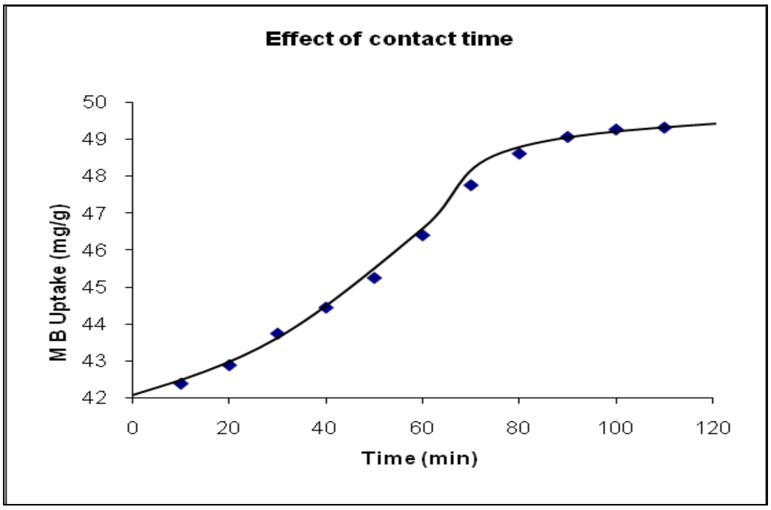


**Fig. 4** The variation of adsorption capacity with adsorption time at initial Basic Blue 9 dye concentration of 100 mg L$^{-1}$ at 298 K

*3.3 Adsorption isotherms*

The adsorption isotherm investigates when the adsorption process reaches an equilibrium state, how the adsorption molecules distribute between the liquid phase and the solid phase. The analysis of equilibrium adsorption data by fitting them to different isotherm models is an important step in finding a suitable model that can be used for design purposes. Adsorption isotherm study was carried out well-known isotherms, Langmuir, Freundlich and temkin. The Langmuir isotherm is based on assumption that the monolayer adsorption onto a surface containing a finite number of adsorption sites with uniform forces of adsorption with no migration of adsorbate in the plane of surface. The Freundlich isotherm model assumes heterogeneous adsorption, in which the energy term in Langmuir equation varies as a function of the surface coverage. Temkin isotherm is based on the heat of adsorption, which is due to the adsorbate and adsorbent interations. The applicability of the isotherm models is correlated by judging the correlation coefficients, $R^2$. Fig.5 shows the typical equilibrium adsorption of Basic Blue 9 on prepared activated charcoal at 298 K, the adsorption isotherm curve rises steeply at low concentrations and gradually approach to a plateau at higher concentration.

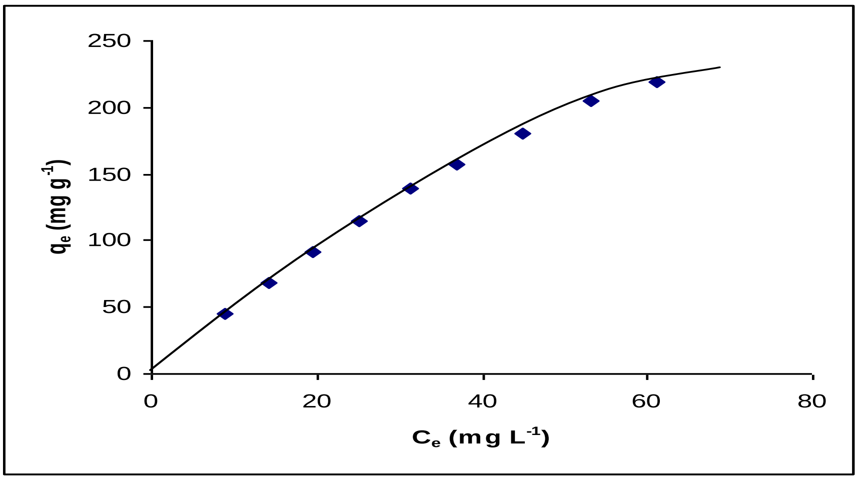


**Fig. 5** Adsorption isotherm of Basic Blue 9 on prepared activated charcoal at 298 K

*Langmuir isotherm*

The Langmuir isotherm model is given by the following linear form by the equation [21]:

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

Where $C_e$ is the equilibrium concentration of Basic blue 9 (mg/L), $q_e$, the amount of adsorbate adsorbed per unit mass of adsorbent (mg $g^{-1}$), $q_m$ and $K_L$ are Langmuir constants related to monolayer adsorption capacity and affinity of adsorbent towards adsorbate, respectively. When $C_e/q_e$ was plotted against $C_e$, straight line with slope $1/q_m$ was obtained (Fig. 6), indicating that the adsorption of Basic Blue 9 on activated carbon produced from Bhagar seed husk follow the Langmuir isotherm. The Langmuir constants $q_m$ and $K_L$ were calculated from this isotherm and their values are given in Table 2.

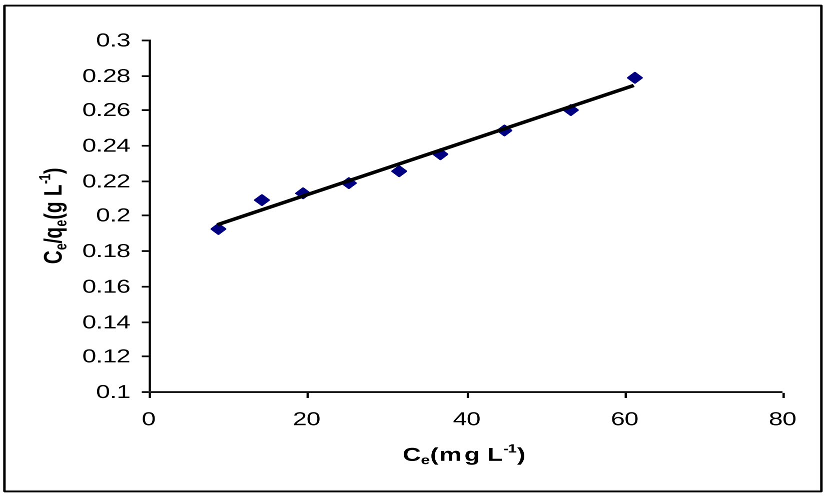


**Fig. 6** Langmuir adsorption isotherm of Basic Blue 9 on prepared activated carbon at 298 K

Confirmation of the experimental data into Langmuir isotherm model indicates the homogeneous nature of bhagar husk carbon surface, i.e. each Basic Blue 9 dye molecule-bhagar husk carbon adsorption has equal adsorption activation energy. The results also demonstrate the formation of monolayer coverage of Basic Blue 9 dye molecule at the outer surface of bhagar husk carbon. Similar observation was reported by the adsorption of acid orange 10 dyes onto activated carbon prepared from agricultural waste bagasse [6], by the adsorption of direct dyes on activated carbon prepared from sawdust [22] and adsorption of Congo red dye on activated carbon from coir pith [23]. Table 3 lists the comparison of maximum monolayer adsorption capacity of some dyes on various adsorbents. Compared with literature, Table 3 shows that the activated charcoal prepared in this work has very high monolayer adsorption capacity. This work has shown that utilization of activated charcoal produced from husk will be useful in the treatment of Basic Blue 9 dyes from industrial waste effluents.

**Table 2** Adsorption isotherm constants for Basic Blue 9 at 298 K

| Langmuir isotherm | |
|---|---|
| $q_{max}$(mg $g^{-1}$) | 666.7 |
| $K_L$(L $mg^{-1}$) | 8.25x $10^{-3}$ |
| $R^2$ | 0.9845 |
| $R_L$ | 0.5477 to 0.1951 |
| Freundlich isotherm | |
| 1/n | 0.826 |
| $K_F$ [(mg$g^{-1}$)($mg^{-1}$)$^{1/n}$] | 7.764 |
| $R^2$ | 0.9963 |
| Temkin isotherm | |
| B (J $mol^{-1}$) | 214.61 |
| B | 11.54 |
| $K_T$ (L $mg^{-1}$) | 0.1534 |
| $R^2$ | 0.9719 |

The crucial features of this model can be expressed in terms of a dimensionless separation constant ($R_L$) [28], which is defined by:

$$R_L = \frac{1}{1 + K_L C_0} \qquad (6)$$

Where $K_L$ is the Langmuir constant and $C_0$ the initial dye concentration (mg $l^{-1}$). The value of $R_L$ indicates the type of the isotherm to be either unfavorable ($R_L$>1), linear ($R_L$=1), favorable (0<$R_L$<1) or irreversible ($R_L$=0). Value of $R_L$ was found in the range of 0.5477 to 0.1951 and confirmed that the activated carbon is favorable for adsorption of Basic Blue 9 dye under conditions used in this investigation.

**Table 3** Comparison of the maximum monolayer adsorption of some dyes on various adsorbents

| Dyes | Adsorbents | Maximum monolayer adsorption capacity (mg $g^{-1}$) | Temp. (K) | Reference |
|---|---|---|---|---|
| Basic Blue 9 | Bhagar seed husk AC | 666.7 | 298 | This work |
| Methylene blue | Periwinkle shell based AC | 500.00 | 298 | [24] |
| Methylene blue | waste bagasse AC | 472.10 | 298 | [6] |
| Methylene blue | Rice husk AC | 343.50 | 303 | [25] |
| Methylene blue | Coconut shell AC | 277.90 | 303 | [25] |
| Methylene blue | Jute fiber AC | 225.64 | 298 | [26] |
| Basic red 46 | Sludge-based AC | 188.00 | 298 | [26] |
| Methylene blue | Groundnut shell AC | 164.90 | 303 | [25] |
| Methylene blue | Bamboo dust AC | 143.20 | 303 | [25] |
| Basic red 46 | Chemviron GW AC | 106.00 | 298 | [26] |
| Congo red | Coir pith-based AC | 6.72 | 301 | [27] |

*Freundlich isotherm*

The well-known linear logarithmic form of Freundlich model is given by the following equation [29]:

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \qquad (7)$$

Where $q_e$ is the amount adsorbed at equilibrium (mg $g^{-1}$), $C_e$ the equilibrium concentration of the adsorbate (Basic Blue 9) and $K_F$ and n are Freundlich constants, n giving an indication of how favourable the adsorption process and $K_F$ (mg $g^{-1}(mg^{-1})^{1/n}$) is the adsorption capacity of the adsorbent. $K_F$ is the adsorption coefficient and represents the quantity of dye adsorbed onto activated carbon adsorbent for a unit equilibrium concentration. The value of 1/n lies between 0 and 1 is a degree of adsorption intensity or surface heterogeneity, becoming more heterogeneous as its value gets closer to zero. A value for 1/*n* below one indicates a normal Freundlich isotherm while 1/*n* above one is indicative of collective adsorption [30]. The plot of log $q_e$ versus log $C_e$ gives straight lines with slope '1/n' is 0.8506 (Figure 7), which shows that the adsorption of Basic Blue 9 also follows the Freundlich isotherm. Accordingly, Freundlich constants ($K_F$ and 1/n) were calculated and recorded in Table 2. The Freundlich model yields a somewhat better fit ($R^2$=0.996) than the Langmuir model ($R^2$ = 0.9845).

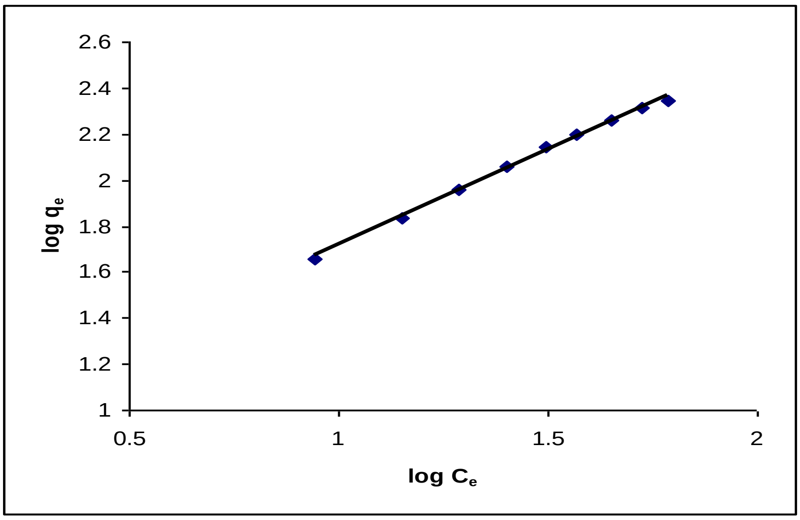


**Fig. 7** Freundlich adsorption isotherm of Basic Blue 9 on prepared activated carbon at 298 K

*Temkin isotherm*

The linear form of Temkin isotherm is given by the equation [31]:

$$q_e = B \log K_t + B \log C_e \quad (8)$$

Where B =RT/b represent the heat of adsorption, T is the absolute temperature (K), R is the universal gas constant (J $K^{-1}$ $mol^{-1}$), 1/b indicates the adsorption potential of the adsorbent and $K_t$ (L $mg^{-1}$) is the equilibrium binding constant corresponding to the maximum binding energy. The plot of $q_e$ versus log $C_e$ (fig.8) allows the determination of isotherm constants B (J $mol^{-1}$) and $K_t$ (L $mg^{-1}$) (Table 2). The calculated value of heat of adsorption from the slope illustrated in Table 2, indicates that the adsorption of Basic Blue 9 on prepared activated carbon from Bhagar seed husk follows mechanism of chemisorption.

*3.4 Adsorption kinetics*

In order to further reveal the adsorption mechanism of Basic Blue 9 onto activated charcoal prepared from bhagar seed husk and rate-controlling steps, a kinetic investigation was conducted. Pseudo-first and pseudo-second order model have been used for testing experimental data. The effects of contact time on the uptake of Basic Blue 9 onto activated charcoal are shown in fig. 4. The figure shows that the adsorption process can be divided into two steps, the rapid 80 % uptake of Basic Blue 9 onto activated charcoal was observed within first 60 minutes, and slow uptake of Basic Blue 9 onto activated charcoal observed until equilibrium was reached.

The pseudo-first order reaction equation was widely used for the adsorption of liquid-solid system on the basis of solid capacity [32]. The linear form is generally expressed as the following:

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303} \text{ x } t \quad (9)$$

Where $q_e$ and $q_t$ are the amounts of Basic Blue 9 adsorbed (mg $g^{-1}$) at equilibrium and at time t (min), respectively, and $k_1$ the rate constant adsorption ($min^{-1}$).

Values of $k_1$ were calculated from the plots of log ($q_e$-$q_t$) versus t for different concentrations of Basic Blue 9. The correlation coefficient values at 100 and 300 mg $L^{-1}$ concentrations are lower than 0.90 as well as the experimental $q_e$ values do not agree with the calculated ones, obtained from the linear plots (Table 4). This shows that the adsorption of Basic Blue 9 onto activated carbon produced from bhagar seed husk does not follows first-order kinetics.

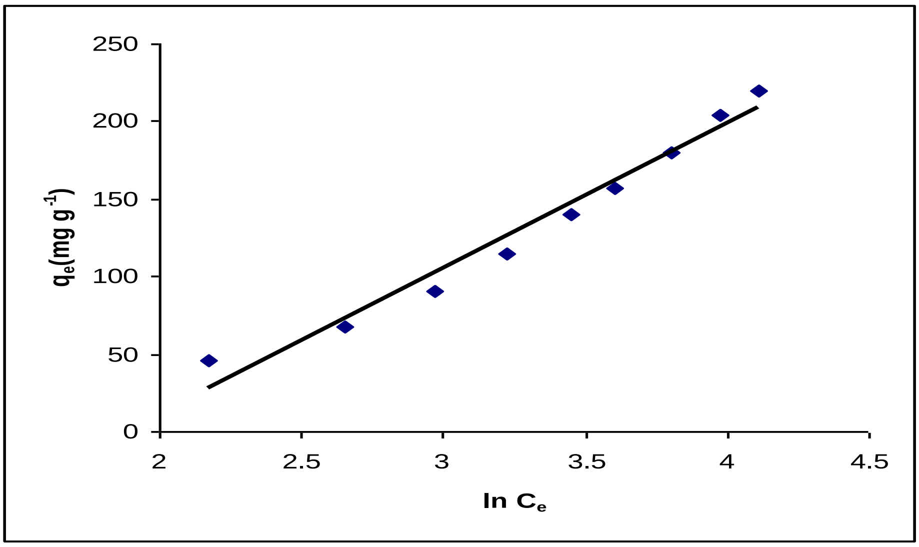


**Fig. 8** Temkin adsorption isotherm of Basic Blue 9 on prepared activated carbon at 298 K

On the other hand, the pseudo-second order model [33] is based on the assumption that the adsorption follows second order chemisorptions. The linear form of equation is written as follows:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} x\, t \qquad (10)$$

Where $k_2$ (g mg$^{-1}$ min$^{-1}$) is the rate constant of adsorption. By plotting a curve of $t/q_t$ against t, $q_e$ and $k_2$ can be evaluated. The initial adsorption rate, $h_o$ (mg g$^{-1}$ min$^{-1}$) is related as [34]:

$$h_o = k_2 q^2_e \qquad (11)$$

**Table 4** Comparison of the pseudo first- and second-order adsorption rate constants, and calculated and experimental $q_e$ values for different initial dye concentration

| Initial Conc. of Basic Blue 9 (mg L$^{-1}$) | $q_e$, exp (mg g$^{-1}$) | Pseudo-first order kinetic model | | | | Pseudo-second order kinetic model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $k_1$ (min$^{-1}$) | $q_e$, cal (mg g$^{-1}$) | $R^2$ | SSE (%) | $k_2$ (g mg$^{-1}$ min$^{-1}$) | $q_{e,, cal}$ (mg g$^{-1}$) | $h_o$ (mg g$^{-1}$ min$^{-1}$) | $R^2$ | SSE (%) |
| 100 | 49.3 | 0.04928 | 25.26 | 0.823 | 24.04 | 0.00448 | 51.02 | 11.68 | 0.998 | 1.72 |
| 300 | 132.4 | 0.00967 | 2.1473 | 0.886 | 130.25 | 0.00781 | 133.34 | 138.8 | 0.999 | 0.94 |

(11)

The values of $q_e$, $k_2$, $h_0$ and $R^2$ are listed in table 4. The dependence of $t/q_t$ versus t gives an excellent straight line relation for all the experimental concentrations and $R^2$ values are close to 1 (Table 4), confirming the applicability of the pseudo-second order equation. In addition, there is only a little difference between the $q_e$, exp. and $q_e$, cal. (Table 4), reinforcing the applicability of this model. It can also be seen in table 4 that with an increase in initial Basic Blue 9 concentrations, the initial adsorption rate ($h_o$) increases.

The sum or error squares (SSE, %) given by:

$$\mathrm{SSE}(\%) = \sqrt{\frac{\sum (q_{e,\exp} - q_{e,\mathrm{cal}})^2}{N}} \qquad (12)$$

Where *N* is the number of data points. The higher is the value of $R^2$ and the lower is the value of SSE; the better will be the goodness of fit, table 4 lists the calculated results. It is found that the adsorption of Basic Blue 9 on Activated charcoal can be best described by the second-order kinetic model. Similar phenomena have been observed in the adsorption of direct dyes on activated carbon prepared from sawdust [35] and adsorption of Congo red dye on activated carbon from coir pith [23].

## Conclusion

The present investigation showed that bhagar seed husks can be effectively used as a raw material for the preparation of activated carbon for the removal of Basic Blue 9 dye from aqueous solution over a wide range of concentration. Basic Blue 9 is found to adsorb strongly on the surface of activated carbon. Adsorption behaviour is described by a monolayer Langmuir type isotherm. The value of the maximum adsorption capacity, $q_{max}$ (666.7 mg $g^{-1}$) is comparable with the values for commercial activated carbon reported in earlier studies. The Freundlich model yields a somewhat better fit ($R^2$=0.996) than the Langmuir model ($R^2$ = 0.9845) confirms the heterogeneous adsorption. Kinetic data investigates that adsorption of Basic blue 9 dyes on prepared activated charcoal follows pseudo second-order kinetic model.

## Acknowledgements

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## References

1. Ramakrishna, K.R., Viraraghavan, T., *Water Sci. Technol.*, 36 (1997) 189.
2. Albanis, T.A., Hela, D.G., Sakellarides, T.M., Danis, T.G., *Global Nest the Int. Journal*, 2 (2000) 237.
3. Vimonses, V., Jin, B., Chow, C.W.K., *J. Hazard. Mater.*, 177 (2010) 420.
4. Markovska, L., Meshko, V., Noveski, V., *Korean J. Chem. Eng.*, 18 (2001) 190.
5. Parkash, S., *Carbon*, 12 (1974) 37.
6. Tsai, W.T., Chang, C.Y., Lin, M.C., Chien, S.F., Sun, H.F., Hsieh, M.F., *Chemosphere*, 45 (2001) 51.
7. Rajeshwarisivaraj, S., Sivakumar, Senthilkumar, P., Subburam, V., *Bioresour. Technol*., 80 (2001) 233.
8. Girgis, B.S., El-Hendawy, A.A., *Micropor. Mesopor. Mater.*, 52 (2002) 105.
9. Kavita, D., Namasivayam, C., *Biores. Technol*,. 98 (2007) 14.
10. Doke, K.M., Khan, E.M., *Arabian J. Chem.* (2012), http://dx.doi.org /10.1016/j.arabjc.2012.07.031.
11. Senthilkumaar S., Varadarajan P.R., Porkodi K., Subbhuraam C.V., *J. Colloid Interf. Sci.*, 284 (2005) 78.
12. Avom, J., Mbadcam, J.K., Noubactep, C., Germain, P., *Carbon*, 35 (1997) 365.
13. Wu, F.C., Tseng, R.L., Juang, R.S., *J. Hazard. Mater.*, B69 (1999) 287.
14. Yalcin, N., Sevin, V., *Carbon*, 38 (2000) 1943.
15. El-Sheikh, A.H., Newman, A.P., *J. Anal. Appl. Pyrol.*, 71 (2004) 151.
16. Carrott, P.J.M., Nabais, J.M.V., Carrott, M.M.L.R., Pajares, J.A., *Carbon*, 39 (2001) 1543.
17. Lazarevic S., Jankovic-Castvan I., Jovanovic, D., Milonjic S., Jana´ckovic D., Petrovic R., *Appl. Clay Sci.*, 37 (2007) 47.
18. Tseng, R.L., Tseng, S.K., *J. Hazrd. Mater.*, 136 (2006) 671.
19. Wu, F.C., Tseng, R.L., Hu, C.C., *Micropor. Mesopor. Mater.*, 80 (2005) 95.
20. Nomanbhay, M.S., Palanisamy, K., *Electronic J. Biotechnol.*, 8 (2005) 43.
21. Langmuir, I., *J. Am. Chem. Soc.*, 40 (1918)1361.
22. Malik, P.K., *J. Hazard. Mater., B* 113 (2004) 81.
23. Namasivayam, C., Kavitha, D., *Dyes Pigments*, 54 (2002) 47.
24. Bello, O.S., Adeogun, I.A., Ajaelu, J.C., Fehintola, E.O., *Chem. Ecol.*, 24 (2008) 285.
25. Kannan, N., Sundaram, M.M., *Dyes Pigments*, 51 (2001) 25.
26. Martin, M.J., Artola, A., Balaguer, M.D., Rigola, M., *Chem. Eng. J.*, 94 (2003) 231.
27. Haghseresht, F., Lu, G., *Energy Fuels*, 12 (1998) 1100.
28. Hall, K.R., Eagleton, L.C., Acrivos, A., Vermeule, T., *Ind. Engin. Chem. Fund*., 5 (1966), 212.
29. Freundlich, H., *Zeitschrift für physikalische Chemie.*, 57 (1906) 385.
30. Fytianos, K., Voudrias, E., Kokkalis, E., *Chemosphere*, 40 (2000) 3.
31. Choy, K.K.H., McKay, G., Porter, J.F., *Resources Conser. Recycl.* , 27 (1999) 57.
32. Lagergren, S., K. Sven. *Vetenskapsakad. Handl.*, 24 (1898) 1.
33. Ho, Y.S., McKay, G., *Can. J. Chem. Eng.*, 76 (1998) 822.
34. Ho, Y.S., *Water Res.*, 37 (2003) 2323.
35. Weber, T.W., Chakkravorti, R.K., *AI. Ch. E. J.*, 20 (1974) 228