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Research Article

ADSORPTION OF ALIZARIN RED DYE FROM AQUEOUS SOLUTION ON AN ACTIVATED CHARCOAL

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ABSTRACT

The activated charcoal was used for the removal of alizarin red dye from aqueous solution. Different parameters such as effect of contact time, initial dye concentration and pH were investigated. It was observed from the concentration study that the amount of dye adsorbed per unit mass of the adsorbent increased with increase in dye concentration. The pH study presented that the adsorption of dye on to activated charcoal was high at pH 2, which was decreased by further increase in pH. For the determination of mechanism of adsorption, pseudo-first order and pseudo-second order kinetic model were studies. It was found that the adsorption kinetic is best described by pseudo-second order equation. The experimental data was best filled to Langmuir isotherm which illustrated the adsorption of dye on the surface of charcoal was monolayer adsorption. The maximum sorption capacity was 8.97 mg/g.

Keywords: Alizarin red, Activated charcoal, Adsorption, Longmuir Isotherm.

INTRODUCTION

Dyes and pigments are colored substances, which have affinity to the substrate to which it has been applied. Various industries such as paper and pulp, tanneries, cosmetic, coffee pulping, pharmaceutical, food processing, electroplating and dye manufacturing discharge colored and toxic effluent to water [1,2]. Many industries use dyes and pigments to color their products and the waste effluent (contain colored materials) are discharge into water bodies. The release of untreated colored wastewater to the environment is very dangerous to living organisms. The untreated wastewater containing colored compounds, which have complex structures and difficult to biodegrade. Some dyes used in the textile industries are toxic and carcinogenic, which present eco-toxic hazard and introduce the potential danger of bioaccumulation and also affect human through the food chain [3]. The synthetic dyes are severe environmental hazard which disturb water quality and causing allergic reactions and various types of poisoning [4]. Because of their toxicity, it is necessary to treat waste water coming from dying and printing units. Various treatment methods have been employed for the removal of dyes from waste water, such as coagulation, filtration, sedimentation, cation exchange membrane, electrochemical degradation, advanced oxidative process and adsorption [5-8]. Among these techniques adsorption has been found to be the most effective process for the removal of contaminants from waste water due to its efficiency, higher adsorption capacity and low operational coast [9]. Several adsorbents have been used for the removal of dye from waste water such as natural adsorbent like clay, cellulosic materials, chitosan and chitin. Agricultural waste such as fruits peel, have also been reported for the removal of these organic waste materials [10]. Activated carbon is the most widely used adsorbents for waste and portable water treatment, solvent recovery and decolorizing, and for domestic applications such as odor and smell removal [11]. Activated carbon is used due to its higher adsorption capacity, higher surface area and micro porous structure [12]. Activated carbon can be prepared from a large number of feed stocks such as anthracite and bituminous coal, lignite, peat, wood and coconut shells etc. Recently the production of low cost activated carbon from agricultural residues (corn cob, palm shell, rice husk and apricot stone) has been reported [13,14].

In the present study, we used activated charcoal as an adsorbent for the removal of alizarin red from aqueous solution. The aim of this work is to study the effect of time, pH, and the initial concentration of dye on the removal of alizarin red from aqueous medium. The obtained data was also fitted to Langmuir isotherm and calculated the corresponding adsorption parameters.

EXPERIMENTAL

Preparation of charcoal sample:

The granular activated charcoal is purchased from Haq Chemical Industry. The activated charcoal sample was crushed, ground, sieved through 300 μm mesh screener and then stored for further use.

Adsorption kinetics and equilibrium isotherm of Alizarin red onto activated charcoal:

50 mL Alizarin red solution (20ppm) and 0.2 g of activated charcoal was taken in six different titrations flasks and shaken using a mechanical shaker for time duration of 10, 20, 30, 40, 50 and 60 min at 25 ^oC. The concentration of alizarin red in solution was determined by using Spectronic-20. The Equilibrium isotherm was also studied as a function of the concentration (10-90 ppm) of alizarin red in solution at equilibrium time (80 min) and temperature was 25 ^oC.

The amount of dye adsorbed on activated charcoal was calculated from the difference between the initial and final solution concentration using the equation 1:

$$q = \frac{(C_o - C)V}{m} \qquad 1$$

Where q is adsorption capacity (mg/g), C_o = initial dye concentration (mg/L), C is final dye concentration in (mg/L), V is volume of solution (L) and m is weight of activated charcoal (g).

Effect of pH on the removal of alizarin red:

50 mL alizarin red (20 ppm) and 0.2g of activated charcoal were taken in four separate titration flasks and then arranged in order of pH 4, 6, 8 and 10. The solutions were shaken for 65 min using mechanical shaker at 25 ^oC at equilibrium time (60 min) and then the concentration of alizarin red in solution was determined by using Spectronic-20.

RESULTS AND DISCUSSION

Effect of contact time on adsorption of alizarin red onto the activated charcoal:

Figure 1 show the adsorption of alizarin red onto activated charcoal at different contact time. The adsorption capacity of alizarin red increased as increased the adsorption time and then equilibrium was reach after 50 min. The adsorption of dye molecules onto the adsorbent was rapid initially, which might be due to the easily available active site on the adsorbent surface for the alizarin red molecules. The results showed that the activated carbon removed about 90 % of alizarin red within one hour.

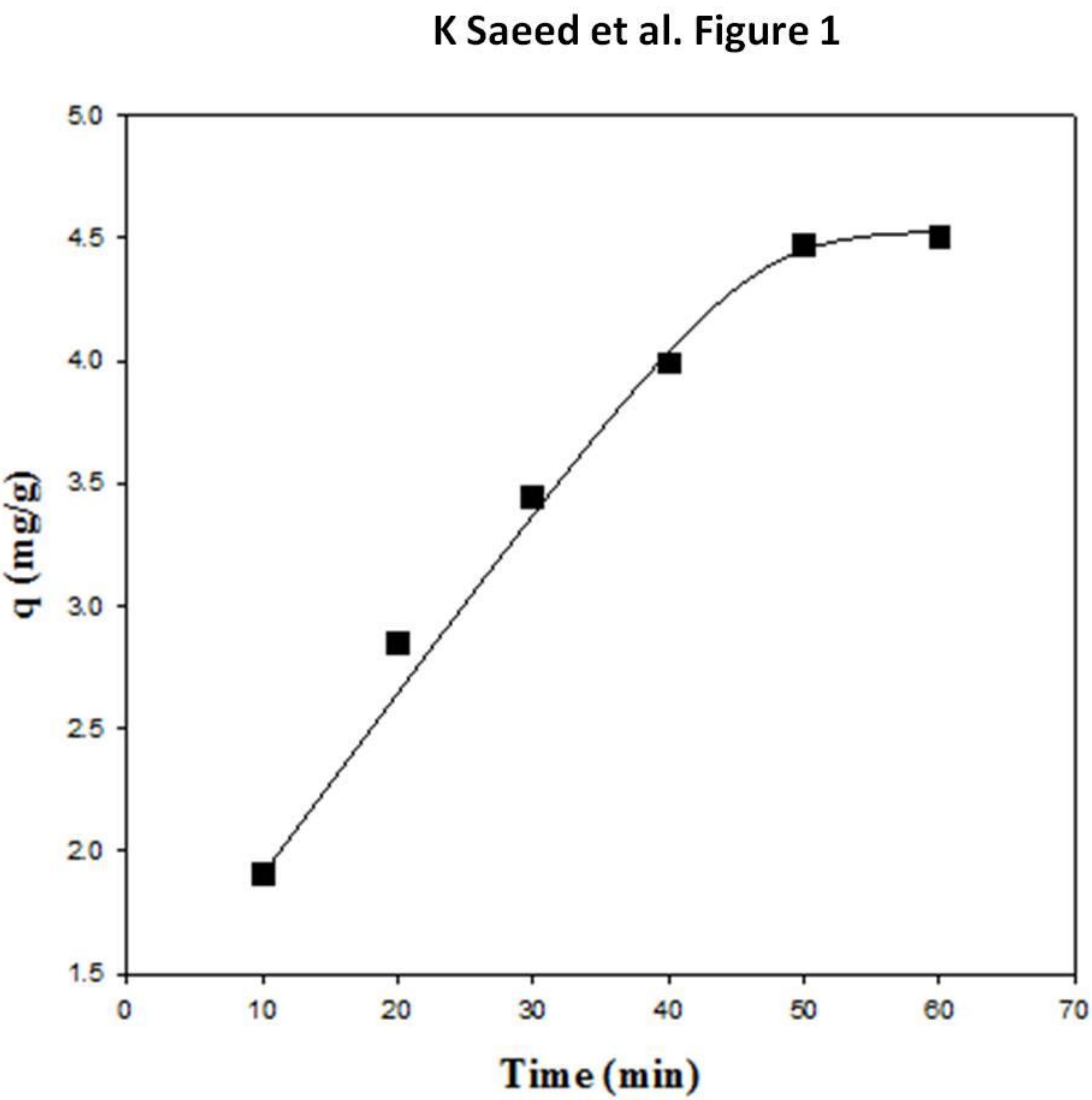

Figure 1: Effect of contact time on the removal of dye.

Effect of initial dye concentration on dye removal:

The effect of initial alizarin red concentration on the efficiency of its adsorption onto activated charcoal was investigated in the initial concentration range of 10-90 mg/g. Figure 2 show the effect of initial dye concentration on the removal of alizarin red. The result showed that the percentage of dye removal was decreased as increased the initial dye concentration. At a constant activated charcoal amount, the decrease in the adsorption percentage is probably due to the saturation of active binding site on the activated charcoal surface at higher dye concentration. On the other hand, by increasing the initial dye concentration the actual amount of dye adsorbed per unit mass of the activated charcoal increased as show in figure 3. It is generally observed that the amount of dye adsorbed per unit mass of the adsorbent increased with increase in dye concentration. Similar trend has been reported in literature [15,16].

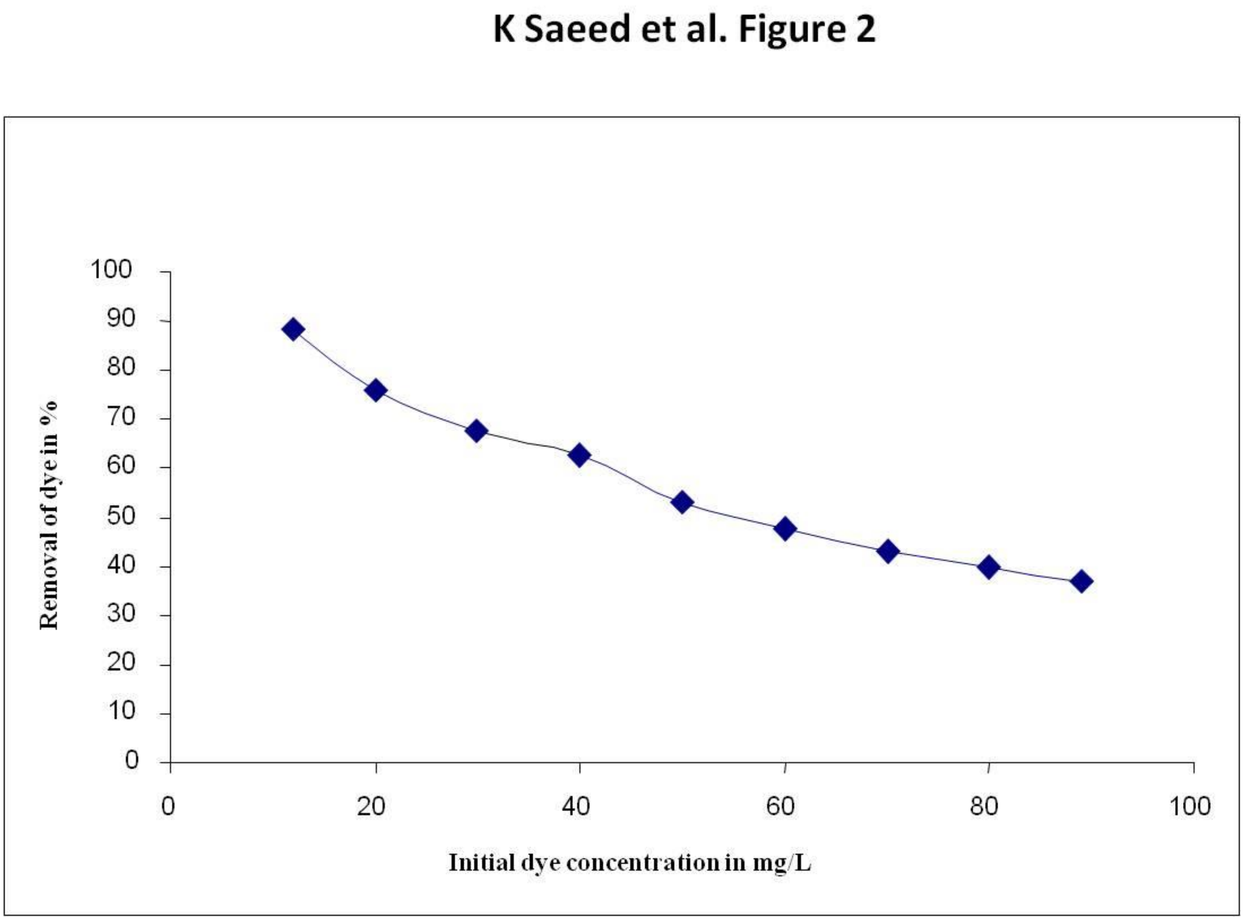

Figure 2: Effect of initial dye concentration on the dye removal in %.

K Saeed et al. Figure 3

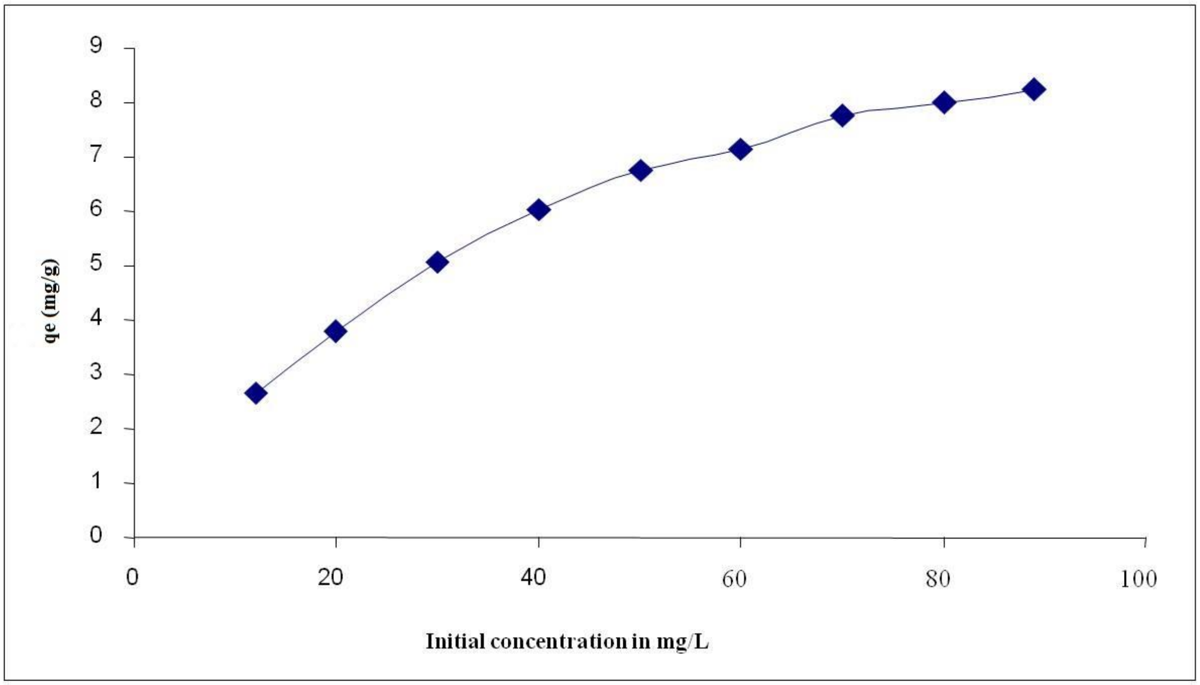

Figure 3: Effect of initial dye concentration on the dye removal in mg/L.

Effect of pH on dye removal:

The dye and adsorbent interaction depends upon the structure of the dye and the nature of adsorbent. Dyes are complex aromatic organic compounds with unsaturated bond and different functional groups. Therefore, they have different degree of ionization at different pH values, and this alters the net change on dye molecules. The net charge on the adsorbent is also pH dependent. Therefore, the pH of the medium is an important parameter for dye removal from aqueous solutions [17].

Figure 4 shows the adsorption of alizarin red at different pH value range from 2 to 10 at room temperature. The results showed that the high quality of alizarin red was adsorbed onto activated charcoal (6 mg/g) at low pH 2 and by further increase in pH, the adsorption of dye onto activated charcoal was decreased. It was reported that, in aqueous solution acidic dye is first dissolved and then dissociate and as a result anionic dye ions are formed. It was also reported that at low pH positive charge sites are created on the adsorbent surface in contact with water. It result a significantly high electrostatic attraction between positively charge surface of the adsorbent and anionic dye. As the pH of the system increased, the number of negatively charged sites increased and the number of positively charge sites decreased. A negatively charge surface sites on the adsorbent did not favor the adsorption of dye anion due to electrostatic repulsion [18].\

K Saeed et al. Figure 4

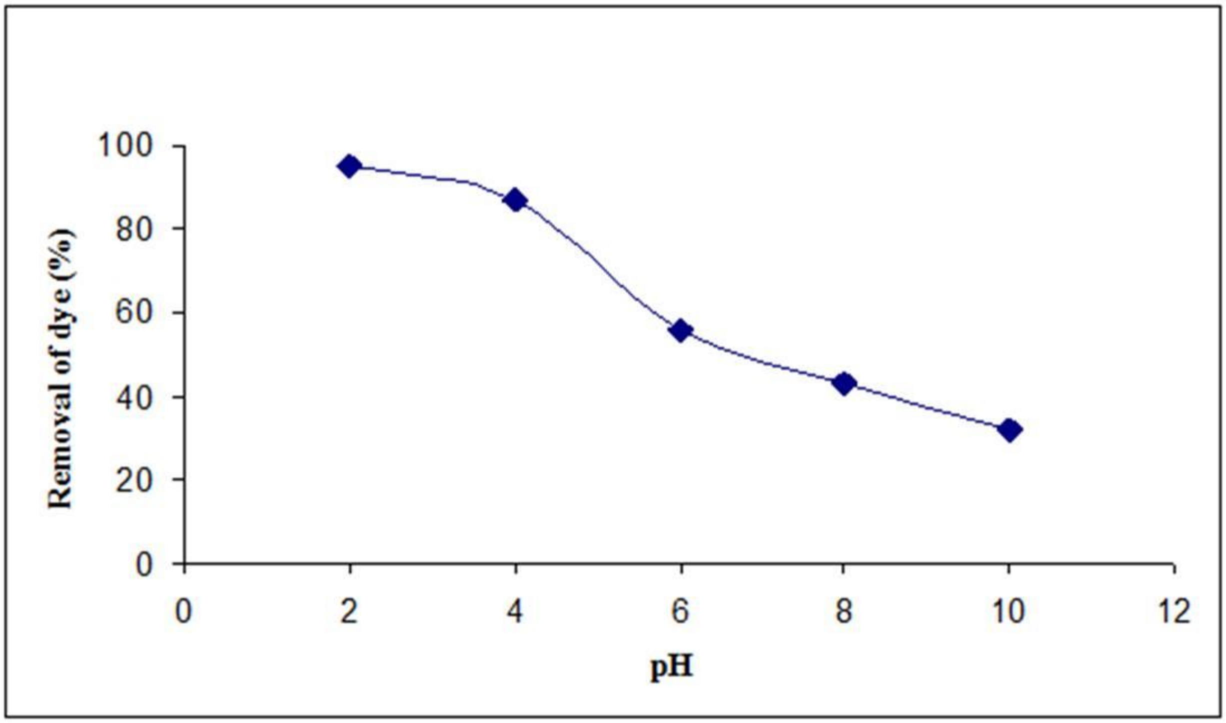

Figure 4: Effect of pH on dye removal in %.

K Saeed et al. Figure 5

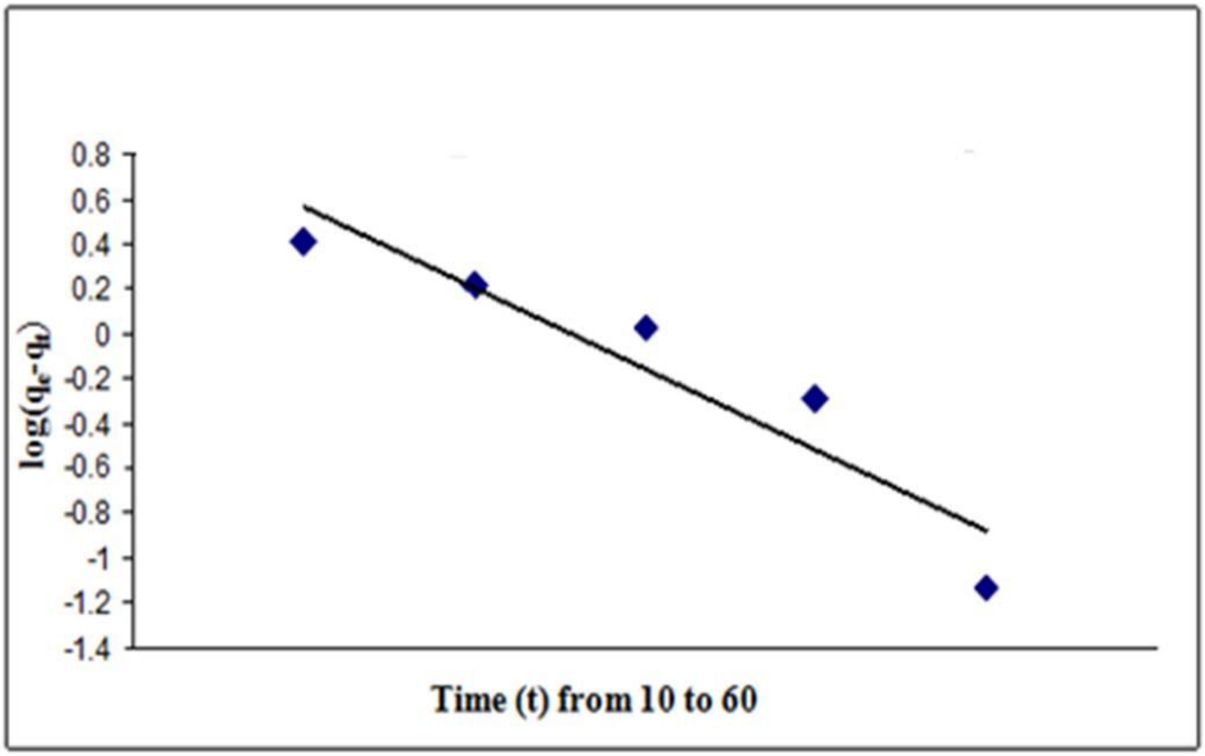

Figure 5: Kinetics of alizarin red dye removal according toPseudo-first order model.

K Saeed et al. Figure 6

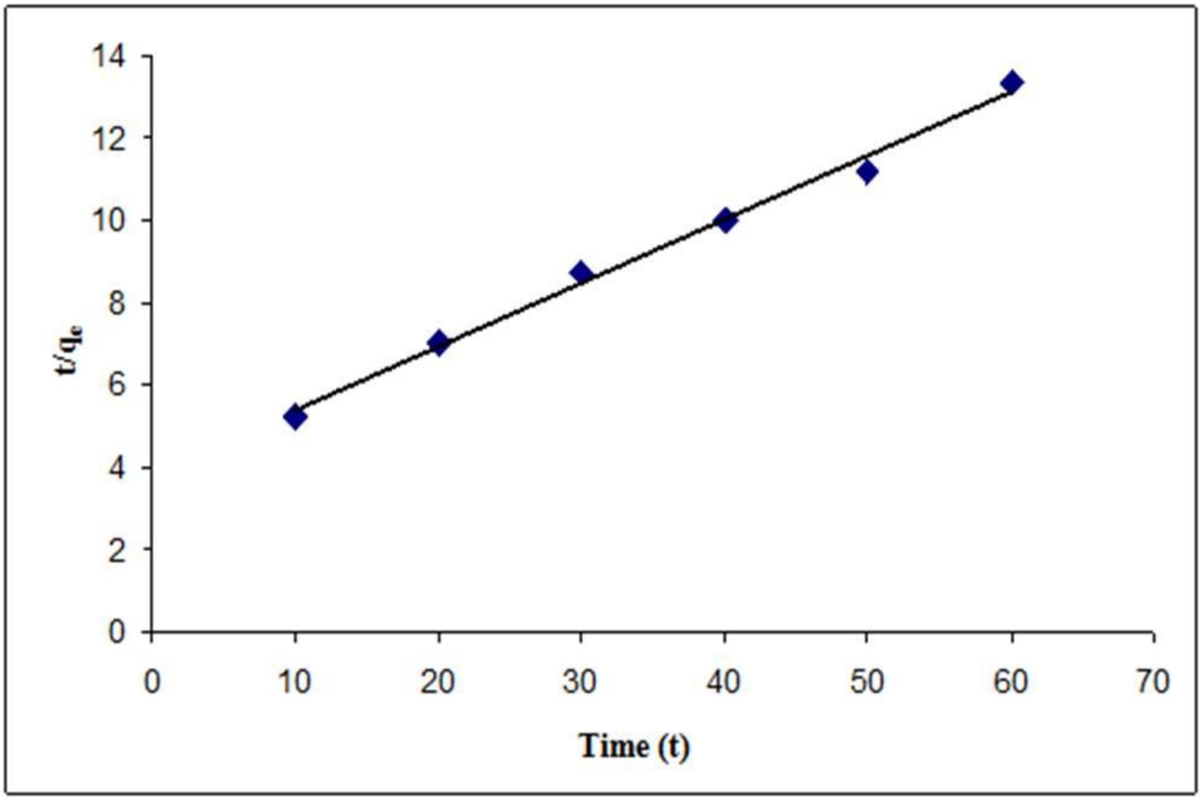

Figure 6: Kinetics of alizarin red dye removal according toPseudo-second order model.

Kinetic studies:

For the determination of mechanism of adsorption such as mass transfer and chemical reaction, the pseudo first-order and the pseudo-order kinetic models were used to test the experimental data of alizarin red adsorption on activated charcoal. The first order rate equation of the lagergren is represented as [19]:

$$\log (q_e\text{-}q_t) = \log (q_e) - \frac{R_1}{2.303} t \qquad 2$$

Where qe (mg/g) is the amount of dye adsorbed at equilibrium, qt (mg/g) is the amount of dye adsorbed at time t and k is the rate constant of pseudo first order. A straight line is obtained by plotting log (q_e-q_t) versus t indicates the application of pseudo first order kinetic model whereas in true first order log q should be equal to the intercept [20].

The pseudo second order equation based on adsorption equilibrium capacity may be represented as [21]:

$$\left[\frac{t}{qt}\right] = \frac{1}{kq q_e^2} + \frac{1}{qe}(t) \qquad 3$$

By plotting (t/qt) verses "t" give a linear relationship from which q_e and k_2 can be determined from the slope and intercept of the plot.

The best fit kinetic model is mainly selected on the linear regression correlation coefficient (R^2).

The results of the kinetic parameters are listed in table 1. The correlation coefficients (R^2) of pseudo second order adsorption model are higher than that of pseudo first order model. Also the experimental data of the amount of alizarin red adsorbed on activated charcoal at equilibrium time are much closer to that of the calculated data. It is thus concluded that the adsorption of alizarin red is best described by the pseudo second order equation, it is also concluded that the rate limiting step may be the chemical reaction but not the mass transport [22,23].

	Pseudo first order	**Pseudo second order**
q_e (exp.)	4.47	4.47
q_e (calc.)	1.08	4.12
R^2	0.881	0.9932

Table 1: Parameters of Pseudo-second order model.

Adsorption isotherms:

Adsorption isotherms describe how adsorbates interact with adsorbent. The adsorption data was also fitted to Langmuir isotherms. The langmuir isotherm model assumes monolayer adsorption on a surface with a finite number of identical sites that all the sites are energetically equivalent and there is no interaction between the adsorbed molecule [24, 25]. The langmuir isotherm may be expressed as:

$$\frac{Ce}{qe} = \frac{1}{b.q_m} + \frac{Ce}{q_m} \qquad 4$$

Where q_e is the maximum amount of adsorption (mg/g), C_e is the equilibrium concentration of dye in the solution (mg L^{-1}), b and q_m is the adsorption equilibrium constant, which related to saturation adsorption capacity and binding energy, respectively. The values of q_m and b were calculated from the slope and intercept of the plot (figure7) and are shown table 2.

K Saeed et al. Figure 7

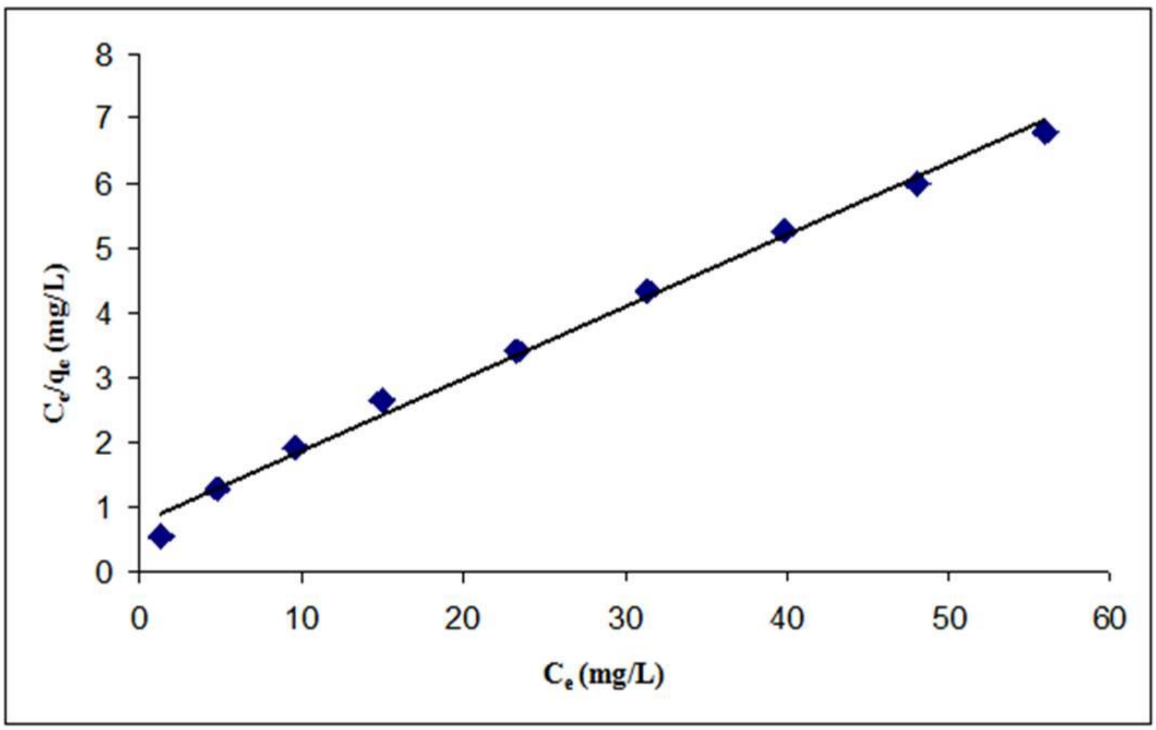

Figure 7: Langmuir adsorption isotherm of Alizarin red dye on activated charcoal.

q_m	b	R^2
8.97 mg g^{-1}	1.36	0.9934

Table 2: Langmuir constant of Alizarin red dye on activated charcoal.

CONCLUSION

The activated charcoal was used as adsorbent for the removal of Alizarin red dye from aqueous solution. The adsorption of the dye molecules increased as increased the adsorption time and then nearly constant after 50 min. The pH study presented that the adsorption of dye on to activated charcoal was high at pH 2, which was decreased by further increase in pH. It was also found that the adsorption kinetic followed more pseudo-second order equation than pseudo- first order equation. The equilibrium adsorption was fitted to Langmuir isotherm, which presented that the adsorption of dye on the surface of charcoal was monolayer adsorption.

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