Removal of Azo Dye (Dispersed Red 17) Using Activated Carbon and Studying the Influencing and Kinetic Factors

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Abstract: One of the main environmental challenges nowadays is the removal of dyes from colored effluents, especially those from textile companies. Current techniques for color removal from wastewater are expensive and ineffective for treating a variety of such wastewater. In this work, the effective adsorbent material activated carbon produced from palm fibers is used to remove the dye. To measure the adsorption capacity, aqueous solutions with various basic Dispersed Red Dye 17 (DR17) concentrations (20-150 mg l-1, respectively) were shaken with specific amounts of adsorbents. On dye removal, the effects of adsorbent dosage, starting pH, starting dye concentration, agitation speed, and contact time have been investigated. Within 60 to 90 minutes of the start of each experiment, the majority of the dye was eliminated from the solution. As the dye removal rate reaches 82%.

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1.1 Introduction

Dyes are one of the most important chemical industrial wastes of water, and among the multiple organic substances that pollute water systems, due to their importance and wide use in many industrial sectors, many materials were found such as the paper industry, textiles, leather and in the food industry[1,2] , Where it has effects on The raw materials used in the preparation of dyes are considered toxic to human, animal, and plant life[2]. Thus, the disposal of such compounds from aqueous solutions of the operations[3]. Dyes are organic chemical compounds with complex structures that can absorb and reflect light at wavelengths within the visible field of the electromagnetic spectrum[4,5,6]. donor has color. Dyes have two defining properties: color and the ability to be fixed on rigid supports such as textiles, using dyeing or printing techniques[7].

Adsorption is the widely used and recommended technique for the treatment of effluents such as dyes. Adsorption on the adsorbent is the most promising and technical method. However, the high cost of some diesel is often an obstacle to applying this process. However, the adsorption phenomenon on activated carbon has a high ability to remove organic and inorganic compounds in addition to The possibility of renewing this porous adsorbent material, as it is suitable and well suited to combating water pollution, from through the upgrading of natural waste [1,8].

With its large specific surface area, microporous structure, high adsorption capacity, and strong surface reactivity, activated carbon is a distinct and flexible adsorbent. The benefits of large specific surface area, microporous structure, high adsorption capacity, and strong surface reactivity make activated carbon an extremely popular and flexible adsorbent. Their key uses include the purification of indoor air in populated areas like restaurants and food-processing establishments, and chemical plants, as well as several gas-phase applications[9]. They are also used to eliminate undesired organic pollutants from drinkable water, including color, odor, taste, and others. The goal of the current study was to assess and contrast the effectiveness of activated carbon in removing the basic dye dispersed red dye 17 (DR17) from aqueous solutions. The effectiveness of removal was assessed by looking at the impacts of contact duration, pH, starting dye solution concentration, adsorbent dose, and agitation rate.[10]

1.2 Materials and Methods

1.2.1 Materials

Dispersed red dye 17 (DR17). Analytical-grade reagents were used throughout. The experiment employed ionic water only. The UV-VIS Spectrophotometer Spectro UV-2550 double beam recording spectrophotometer was used to measure the dye concentrations using (1) cm Carystall cells. To change the pH, a digital pH meter, model number(720)WTW (82362), was employed.

1.2.2 Preparation of adsorbent

In this work, activated carbon was made from palm fiber using a physicochemical activation technique that included chemical processing and pyrolysis. The fibers are first washed before being dried for 24 hours at 100°C in an oven. The fibers were then burned for two hours at 600°C [11].

The resultant primary activated carbon was then submerged for two hours at room temperature in a 1 (mol/L) sulfuric acid solution. The primary fiber was removed from the acid solution after the allotted amount of time, completely cleaned with distilled water, then dried for 24 hours at 100°C[12].

1.4 Preparation of dye solution

A specific volume of the stock solution was diluted to achieve the necessary concentration of 100 mg L for the experimental solution. Activated carbon was filtered before the sample, and a UV-VIS light-scanning computer spectrophotometer was used to quantify absorbance. Dispersed red dye 17 (DR17) measured at wavelength of 492 nm, and concentrations were calculated using a reference calibration curve.

1.5 Result and Discussion

1.5.1 X-ray diffraction (XRD)

Activated carbon mixed with sulfide acid, as it is clear from the figure (1) that the process of homogenization between acid and activated carbon molecules is clear, and this indicates that the process of placing active carbon fibers in the sulfide solution was effective, as the activated carbon appeared with two peaks, so the highest intensity appeared at an angle (25.4781)o and Miller's coefficient (002), and also hydrogen appeared at the angle (14.7549)o and Miller's coefficient (001) and did not show any other undesirable elements, and this indicates that the material is homogeneous with each other and pure from Impurities did not show other compounds such as sulfur compounds or carbon and hydrogen compounds and this explains that the study is able to remove the dye of azo from water through activated carbon and mixed with acid such asM sulfide acid and through Table (1), which shows the results of X-ray diffraction shows that the granular size and crystal size in a state of decrease and this is a clear indication of the disappearance of pigments and unwanted particles, the lower the granular size and crystal size decreases the presence of matter. We conclude from this that after the process of immersing the activated carbon fiber with sulfide acid, hydrogen appeared at the angle (14.7549) and this indicates that the acid began to affect the active carbon fiber[13,14].

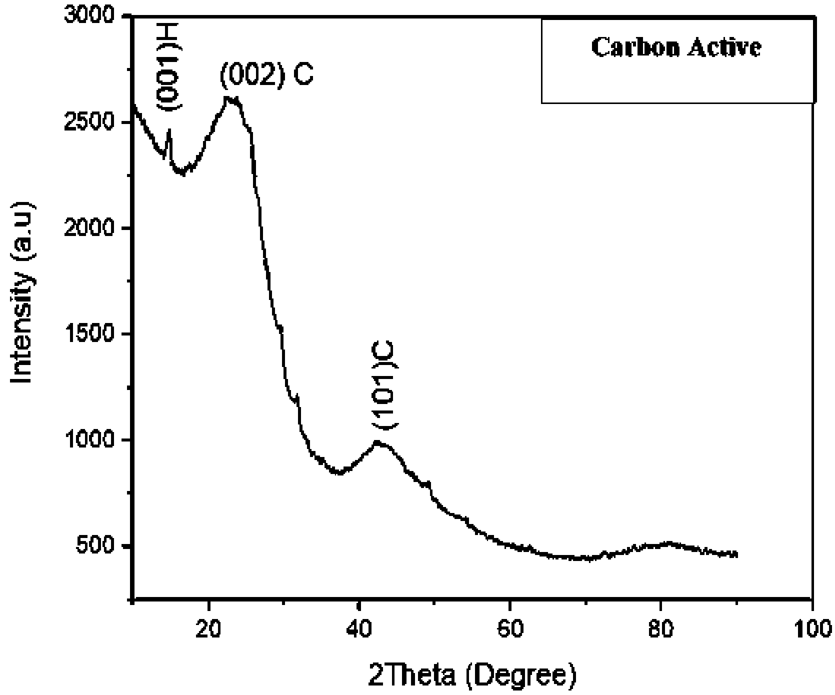


Figure 1 shows the XRD results of active carbon .

Table (1) X-ray diffraction results

Pos. [°2θ]	d-spacing [Å]	Height [cts]	Rel. Int. [%]	FWHM Left [°2θ]	Area [cts*°2θ]	Matched by	Crystallite Size only [Å]	MicroStrain only [%]
14.7549	5.99895	190.72	27.69	0.2598	48.87		359	0.83602
25.478	3.49324	688.81	100	0.6927	470.7	96-720-6195	133	1.31338
29.568	3.01865	207.41	30.11	0.3464	70.87	96-720-6195	272	0.5553

31.785	**2.81302**	**116.08**	**16.85**	**0.2598**	**29.75**	**96-720-6195**	**370**	**0.3808**
49.1701	**1.85149**	**57.18**	**8.3**	**0.5196**	**29.31**		**191**	**0.4851**

1.5.2 Scanning Electron Microscope SEM Results

Activated carbon dipped in sulphide acid at microscopic approximation (500 nm, 5 µm, 20 µm) as shown in Figure 2. Microscopic images of it .as it is noted that the material is in a stable state and a good interference process between active carbon and acid and there is no breakage of molecules and grains or cracks, as well as the distance between the gaps, is very close, which indicates that the process of dipping active carbon with acid was successful and influential, the absence of cracks or fractures of the material is a clear indication that it is free of defects, foreign particles, and unwanted distortions This suggests that the goose dye can be removed by active carbon obtained from palm fibers and dipped in sulfide acid to remove the pigments in water[15,16,17,18].

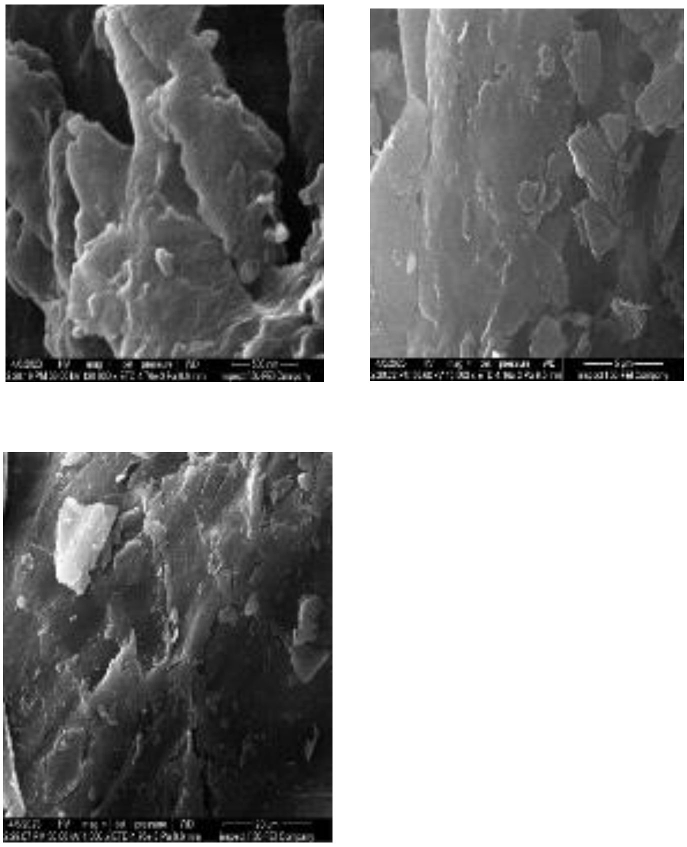


Figure 2: Scanning electron microscopy.

1.5.3 Effect of pH

An essential component of the adsorption process is the pH of the solution, and the beginning pH of the solution has a bigger impact than the end pH. Experiments were conducted at (26 1 °C) with a concentration of 100 mg L-1 of the main dye and a dose of 1 g of adsorbent to examine the impact of pH on the adsorption of DR17. Absorption can often increase or decrease depending on the original pH. This results from the sorbent's surface charge fluctuating in response to pH. The link between pH and DR17 clearance rate is seen in the graph.

Regarding the removal rate of DR17, it can be observed in Figure 3 that the rate of removal reduces as the pH of the solution rises. The amount of hydroxyl groups decreases as the pH of the solution rises, lowering the amount of negatively charged sites and raising the DR17 dye's affinity for the adsorption surface. As the dye removal rate reaches 73% when the pH is 2 .

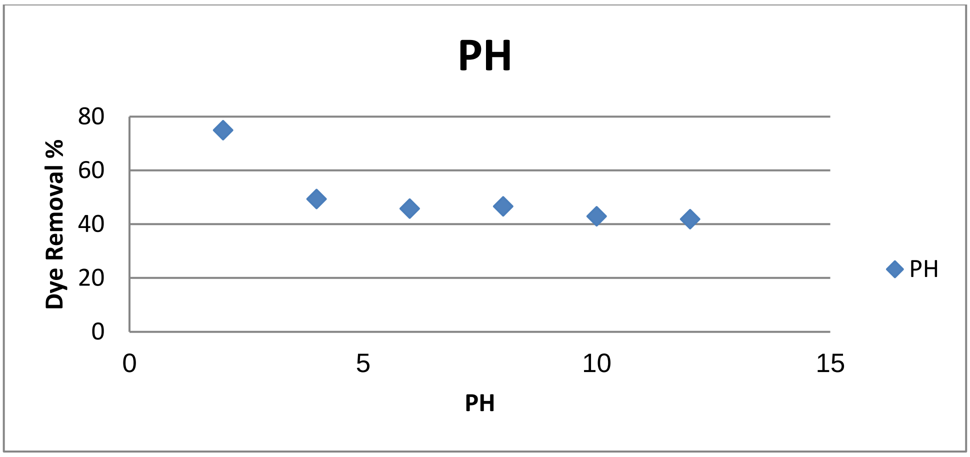


Fig 3: Effect of pH on the percent of dye removal on AC

1.5.4 Effect of Stirring Rate

The thickness of the liquid film around the particles in liquid adsorption systems influences the rate of solute mass transfer to the particles, which in turn depends on the stirring rate[10]. The outcomes demonstrated that when agitation speed rose from 100 rpm to 800 rpm, the intensity of agitation had an impact on the removal efficiency. As can be observed from Fig. 4, when the stirring speed is greater than 600 rpm, the removal efficiency increases only little in comparison to the DR17 adsorption, suggesting that the stirring speed has minimal bearing on the film thickness. Consequently, 600 rpm was used as the stimulation rate for all studies. As the dye removal rate reaches 80 % .

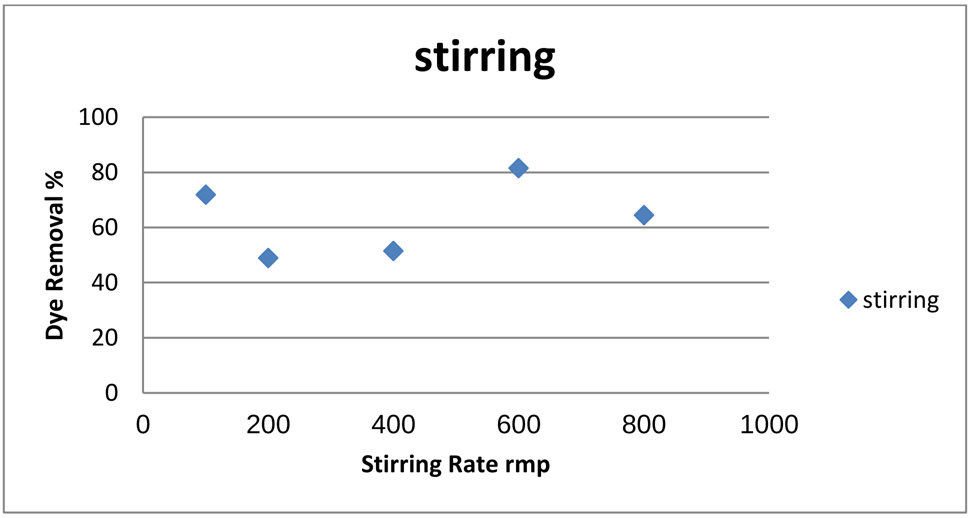


Fig 4: Effect of stirring rate on the percent of dye removal on AC

1.5.5 Effect of contact time

Through batch studies, the effect of contact duration on the ability of dyes to bind to activated carbon was investigated to reach the equilibrium depicted in Figure 5 depicts the movement of the dye molecule from the solvent to the adsorbent particle as it diffuses across the surface can be used to explain the mechanism of color removal. According to the findings, activated carbon achieved equilibrium after operating for 90 minutes. The adsorption capacity remained unchanged after that for both of the observed adsorbates. As the dye removal rate reaches 82% when the time is 90 min . The adsorption rate initially increased significantly before progressively decreasing as a result of saturation. The physical adsorption's passive uptake or the ion exchange of the adsorbent surface may be used to define the fast-phase sorption.[23]

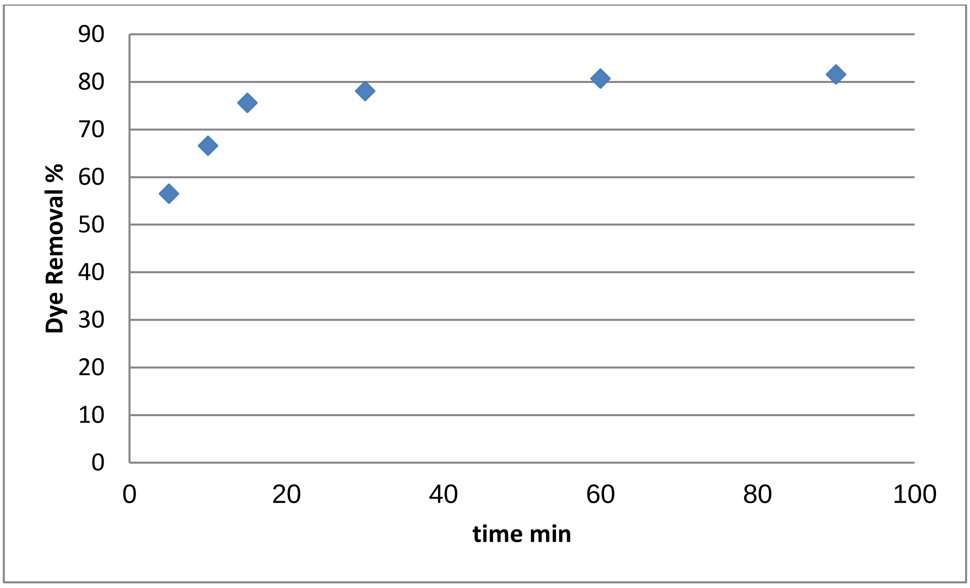


Fig 5:Efect Impact of contact time on AC's dye removal percentage

1.5.6 Effect of adsorbent mass

At a dye concentration of 100 mg l-1 DR17, various shaking durations (5-90 min), and various AC concentrations (0.5.1, 1.5, 2 and 3) at pH = 2, room temperature (2.5 and 3 g recorded at 25 1 °C), the impact of the quantity of activated carbon (AC) on the dye absorption was studied. The outcome is displayed in Figure 6. The amount of adsorbent utilized was generally found to improve the rate of adsorption. This rise became more noticeable when the adsorbent concentration was raised from (0.5-3 g). Within 60 to 90 minutes, the majority of the dye is removed; thereafter, the dye concentration barely changes. Advertising to Increase the Rates of Dye Removal. When the concentration of activated carbon is 3 g , the dye removal rate is 77%. Increase in dye removal percentage with adsorbent dose can be attributed to increased adsorbent surface area and availability of more adsorption sites[10]

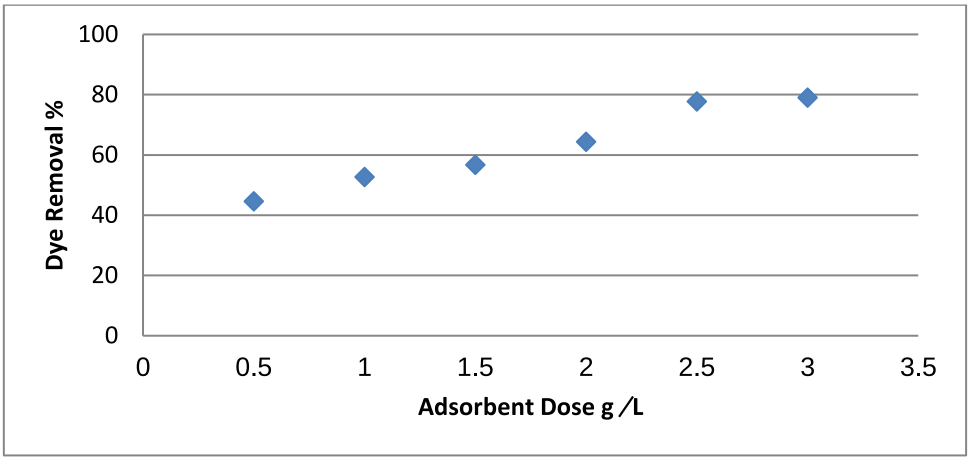


Fig 6: Effect of adsorbent dose on the percent of dye removal on AC

1.5.7 Effect of intial concentration

Effects of the DR17's starting concentration (25 150 mg l-1) on the charcoal removal efficiency are shown in Fig 4. A fixed dose of adsorbent (3 g) was used in experiments, which were conducted at room temperature (25 1 °C), a pH of 2.0, and a swirling speed of 600 rpm. The direct correlation between initial dye concentration and accessible binding sites on the sorbent surface determines the impact of initial dye concentration. The impact of the initial dye concentration is seen in Figure7. The saturation of adsorption sites on the adsorbent surface may be the reason why the % dye removal generally decreased with increasing starting dye concentration. The adsorbent surface[20] had open active sites at low concentrations, but when the initial dye concentration rose[21], the active sites needed to adsorb dye molecules vanished. Raising the initial dye concentration causes an increase in the adsorbent's loading capacity, which may be due to the high driving force on mass at a high initial dye concentration. In other words, at higher initial dye concentrations[22], the residual concentration of dye molecules will be higher. At lower concentrations, there are fewer dye molecules than there are available adsorption sites, therefore the adsorption percentage becomes independent of the original concentration. as the removal rate reaches 90% when con. 25mg/l ,while removal rate reaches 82% when con. 150 mg/l .

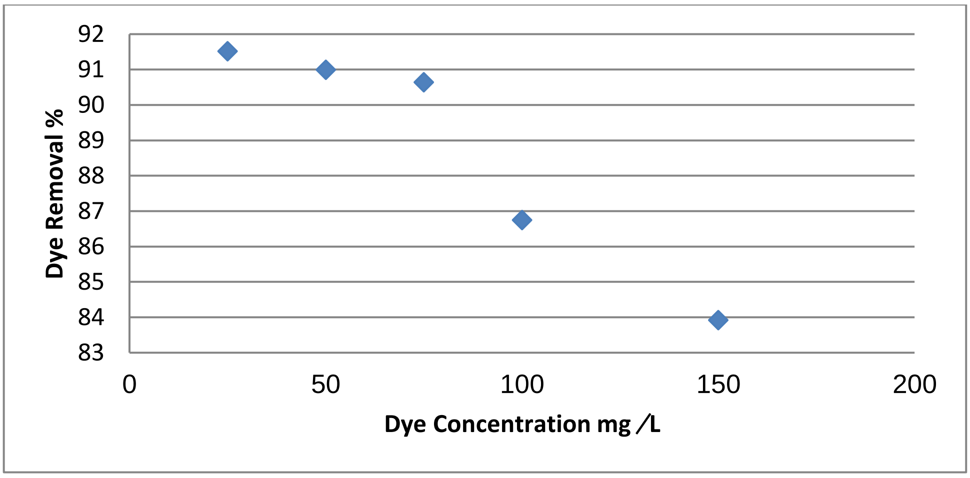


Fig 7: Relation between initial dye concentration on percent removal for different dyes on AC

1.5.8 Kinetic study

Kinetic processes have been the primary focus of the majority of adsorption research. The adsorption process benefits from the kinetic data analysis since it provides evidence of the adsorbate absorption rate, which regulates the resident time in the adsorbent [24]. Adsorption kinetics refers to the rate at which contaminants are removed from the aqueous solution. Additionally, the kinetics analysis is crucial for assessing the effectiveness of adsorption, explaining the process by which the phenomenon occurs, and providing dynamic evidence for the amount of time needed to reach equilibrium, the rate of adsorption, and the adsorption rate's limiting step. A high adsorption rate is a necessary quality in addition to the adsorbent's adsorption capacity and removal effectiveness if it is intended for use in wastewater treatment plants [25]. Using experimental data at different elemental concentrations, pseudo-first-order, pseudo-second-order and intraparticle diffusion models were used to analyze the dye kinetics study on the adsorbents. Table (2) lists the calculated parameter values that were derived using these models in line with equations (1–5). Accuracy is compared between computed and observed qe and R2 values for each applied model to determine the most appropriate model. Figure 8 in Microsoft Excel 2016 was used to do linear regression to determine these kinetic model parameters. The largest values of R2 f a second-order model is considered to fit the adsorption behavior, according to the values of qe. In addition, the C values were above zero, which indicated that the boundary layer diffusion resulted from the rate limitations of the adsorption process rather than internal diffusion [26].

using the pseudo-first order Lagrange model:

$$\frac{dqt}{dt} = K(qe - qt) \qquad (1)$$

The essential formula of this equation is given by:

$$\log(qe - qt) = \log qe - \frac{k1}{2.303}\, t \qquad (2)$$

The following is an expression for the pseudo-second-order model:

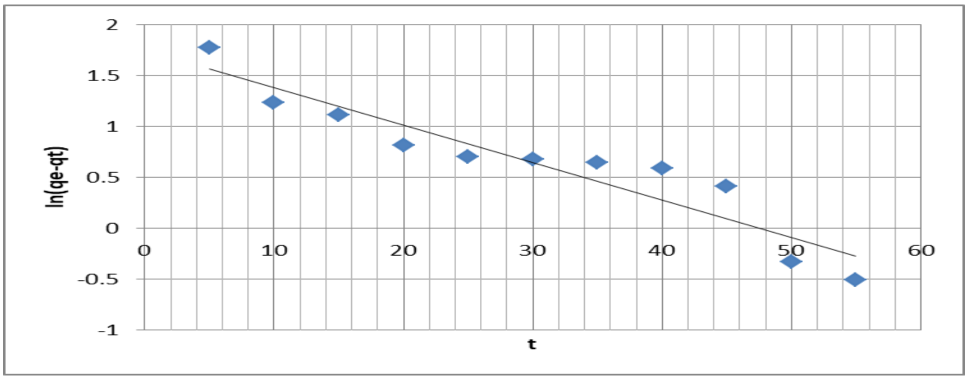
$$\frac{dqt}{dt} = k_2(qe - qt)^2 \qquad (3)$$

The essential formula of this equation is given by:

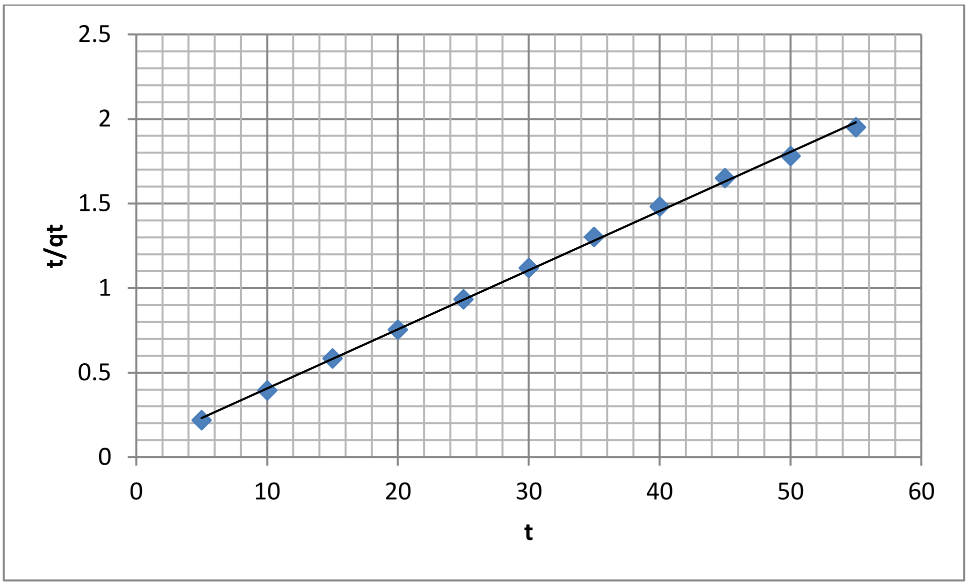
$$\frac{t}{qt} = \frac{1}{k2\ qe2} + \frac{1}{qe}t \qquad (4)$$

The intra-particle diffusion model can be expressed as follows:

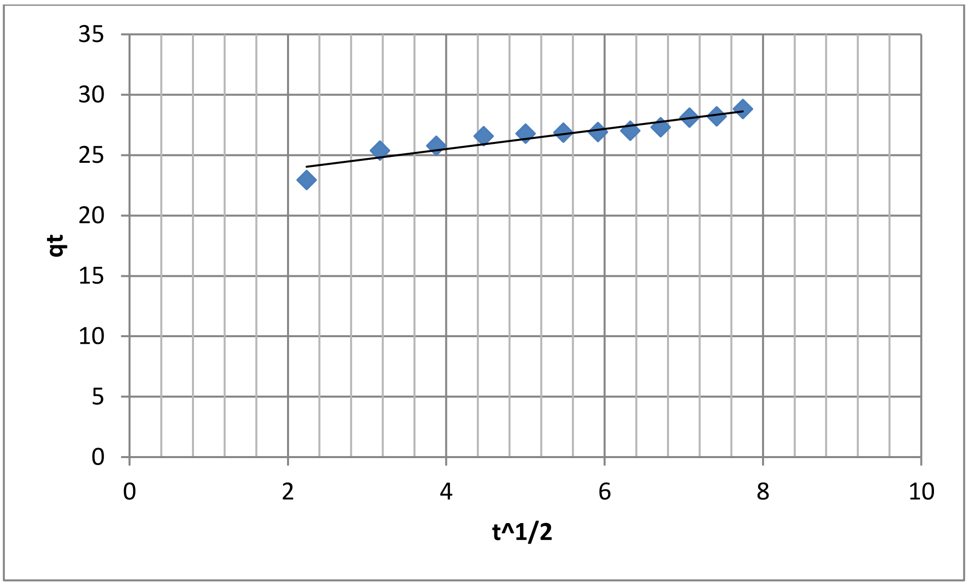
$$q_t = K_d\, t^{1/2} + C \qquad (5)$$



(a) Pseudo- first order



(b) Pseudo- second order



(c) Intraparticle diffusion

Fig 8: These kinetic models (a) pseudo-first order (b) semi-ordered (c) intraparticle diffusion

TABEL (2) : Kinetic parameters of various models fitted for the adsorption of Dye

Model	**Parameters**	
Pseudo- first order	Qe K_1 R^2	6 0.0368 0.8879
Pseudo- second order	Qe K_2 R^2	28.5 0.0216 0.999
Intraparticle diffusion	Ce K_P R^2	22.177 0.8319 0.891

1.6 Conclusion

A potential adsorbent for the filtration of azo and basic dyes is activated carbon. Under various experimental setups, In batch mode, the use of activated carbon to remove DR17 from wastewater was investigated. The amount of sorbent used, the rate of stirring, and the amount of dye present in the effluent all affect dye adsorption. The initial pH of the solution has an impact on the dye's ability to bind. The optimal pH for the elimination of dye DR17 from aqueous solutions under the experimental circumstances utilized in this study was 2, . The fastest dye removal was seen in the first 15 minutes at the beginning of each experiment and equilibrium was at 90 minutes The largest values of R2 (0.999) in a quadratic model are considered fit for the adsorption behavior .

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