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Removing the Carcinogenic Reactive Black 5 Dye By Using Fly Ash As A Low-cost Contaminant

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Abstract

This research Aims to remove carcinogenic dye Reactive Black 5 (RB5) from aqueous solution using fly ash, the optimum conditions used to remove the reactive black 5 dye by means of fly ash temperature 25C and an initial concentration of dye 50mg/L after 60 min, pH3. experimental data were analyzed using Microsoft excel 2010, scanning electron microscopy (SEM) techniques, and XRD, EDX measurements were used to characterize sorbents. the Results showed that the Adsorption of the reactive black 5 dye corresponds to the Freundlich isotherm, Langmuir isotherm model, which indicates that the adsorption process is the monomolecular adsorption. It has also been shown that fly ash is regeneration for repeated use in the adsorption process.

Keywords : Adsorption , Fly ash , Reactive black 5 dye, Regeneration

Introduction

Azo dyes are organic synthetic compounds commonly used in Textile dyeing, the printing of paper, and other industrial methods, for example, The manufacturing of prescription products, toys, and foodstuffs The existence of at least one azo bond (-N = N-) The worldwide dyestuff market dominates the aromatic rings. With a share of about 70% [1], The textile industries depend heavily on water and consequently the fo rmation of large quantities of liquid wastes. These liquid wastes contain large quantities of biological dye. About 50% of the dyes used in the textile industries are Azo dyes. Studies indicate that about 15% of Azo dyes are dispersed into the environment [2,3].

The Rivers and lakes, in turn, limit the transfer of oxygen into the water and cause an increase in toxicity, which causes cancer for both aquatic animals and humans, so removing dye from wastewater is of great importance [4]. There are many effective ways to treat water contaminated with dyes, including advanced oxidation and oxidation, but it is expensive due to the high energy required [5,6]. The process of increasing molecules where two phases meet is known as adsorption. This approach is one of the most efficient and cost-effective methods for removing pollutants and dyes from aqueous solutions [7]. Adsorption has also been hailed as among the most commonly used treatment strategies due to the ease, efficiency, durability, and willingness to use available locally bio-materials. Carbon is widely used as an adsorbent in a variety of industries due to its high efficiency. The use is restricted, due to high cost and loss through regeneration [8]. The researchers have also been searching for alternative adsorbent materials that are environmentally safe, cost-effective, and pea shells activated carbon that is based on flamboyant pods (Delonix regia) [9], activated carbon [10], Eichhornia crassipes roots [11], spirogyra [12], sawdust [13], cactus [14], affordable palm kernel fiber [15], and Barbados shells [16]. have been extensively studied. (RB5) dye, ($C_{26}H_{21}N_5Na_4O_{19}S_6$) (figure. 1), is a tetra sulphonated disazo dye that is commonly used in the textile industry to dye cotton fibers and cellulose. The release of RB5 dye into the atmosphere posed a significant danger to public health, as the dye causes a variety of health problems, including respiratory problems, skin irritations, acute bronchitis, bladder cancer, and mutations, among other things. [17,18].As a result, it's important to clean wastewaters containing RB5 before releasing them into the environment. Various low-cost agricultural waste products, such as spent tea leaves [19], banana peel powder [20], eggshells, pumpkin seed hulls [21], RB5 dye elimination from wastewater have been tested with varying degrees of effectiveness. The aim of this study is to see how effective fly ash is at treating RB5 dyes in textile wastewater.[22]

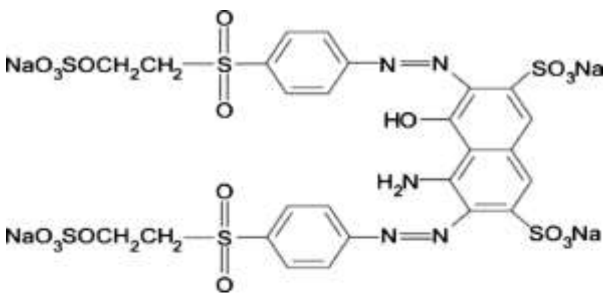


FIGURE 1. Molecular structure of Reactive Black 5 dye

TABLE 1. Characteristics of the dye Reactive Black 5 dye

Colour index name	Reactive Black 5
Chemical structure	$NaO_3SO(CH_2)_2O_2S$
Chemical class	Anionic, diazo
Molecular formula	$C_{26}H_{21}Na_4N_5O_{19}S_6$
Colour index number	20505
λ_{max} (nm)	597
Mw (g/mol)	991.8
Reactive group	Sulfatoethylsulfone
Natural pH	5.8

The characteristics of Reactive Black 5 dye are shown in table 1[2,5].

Reactive Black 5 dye applied in different industrial fields including textile industries food.[23] the Reactive Black 5 dye known by different commercial names such as Celmazol Black B, Cavalite Black B, and Diamira Black B use in textile production [24].

Materials and Methods

Materials

Preparation of Adsorbent

Fly ash(F A) was collected light smoke resulting from the combustion of liquid fuel in the baking oven and used directly without washing or activating.

Preparation of the Reactive Black 5 dye solution

Reactive Black 5 dye was obtained from Babylon textile factory Iraq. solubility in water at 25 °C (purity = 99%) A stock solution of 100 mg/L of RB5 dye was prepared by dissolving 0.05 g of dye in 500 ml distilled water and By diluting the concentration, it is used for further studies required.

Adsorbent characterization

The results of the examination of the fly ash sample show that the particle sizes are homogeneous at a very high rate as well as the homogeneous shape is spherical particle size is 33.03 nm. (figure 2) shows an electron microscopy image at different magnifications.

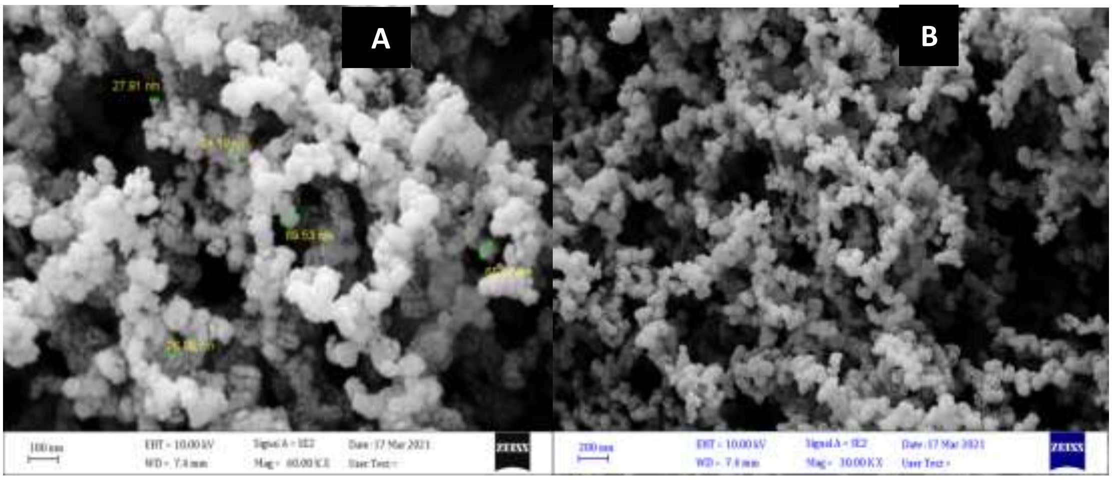


FIGURE 2. FE-SEM images of FA (A), (B) before adsorption at different magnification

To get more information about the composition of the surface before adsorption Energy Dispersive X-ray analysis is recorded (EDX) (figure 3)b and XRD (figure 3)a

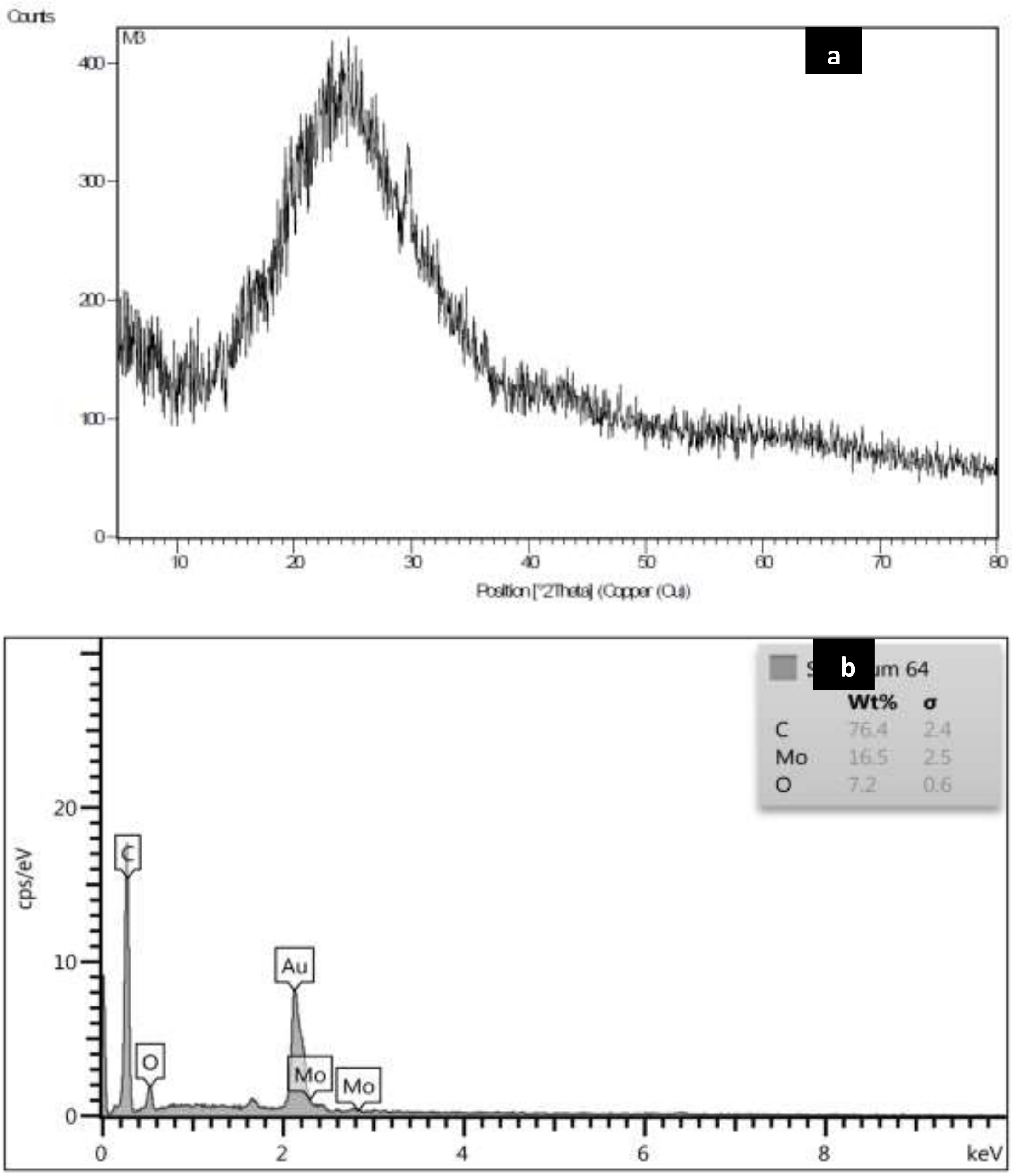


FIGURE 3. a XRD and b EDX result of FA surface before adsorption

Batch Sorption Studies

Using the equation: Qe (mg/g), the sum of RB5 dye adsorbed at equilibrium on to FA was determined.

$$\% \text{ dye removal } = \frac{C_o - C_e}{C_o} \times 100 \quad (1)$$

Where C_o :is the dyes initial concentration and C_e :is the dye concentration at equilibrium.

The mass balance relationship equation was used to calculate the adsorption capacity Q_e (mg/g) after equilibrium:

$$Q_e = \frac{C_o - C_e}{W} \times V \quad (2)$$

Where V: is the volume of the solution (L) and W: is the mass of adsorbate (g)

Results and discussion

Calibration Curve of Reactive Black 5 Dye

Different solutions of RB5 dye with concentrations (0.08,0.1,0.3,0.5, 1,3, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50) mg/L. The absorbances at λ_{max}= 597 nm of RB5 dye solutions are plotted against the solutions concentrations to get the calibration curve presented in(figure 4)

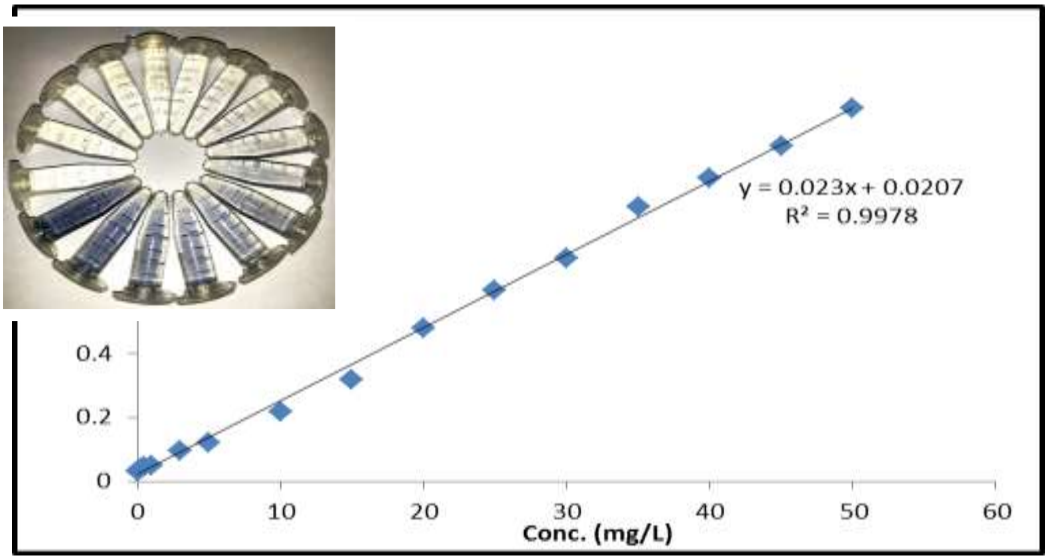


FIGURE 4. Calibration Curve of Reactive black 5 dye

Effect of adsorbent dose

The adsorbent dosage is a critical factor in determining adsorption capability [25] and the effect of adsorbent quantity on optimization of quantity plays an important role in the adsorption process of RB5 dye employing FA. The adsorption of RB5 dye onto fly ash findings is illustrated in (figure 5). The results show that increasing the amount of adsorbent in the range (0.2 to 1.5) g increases the percentage of adsorption. At 1.5 g, the greatest removal level for RB5 dye is found..

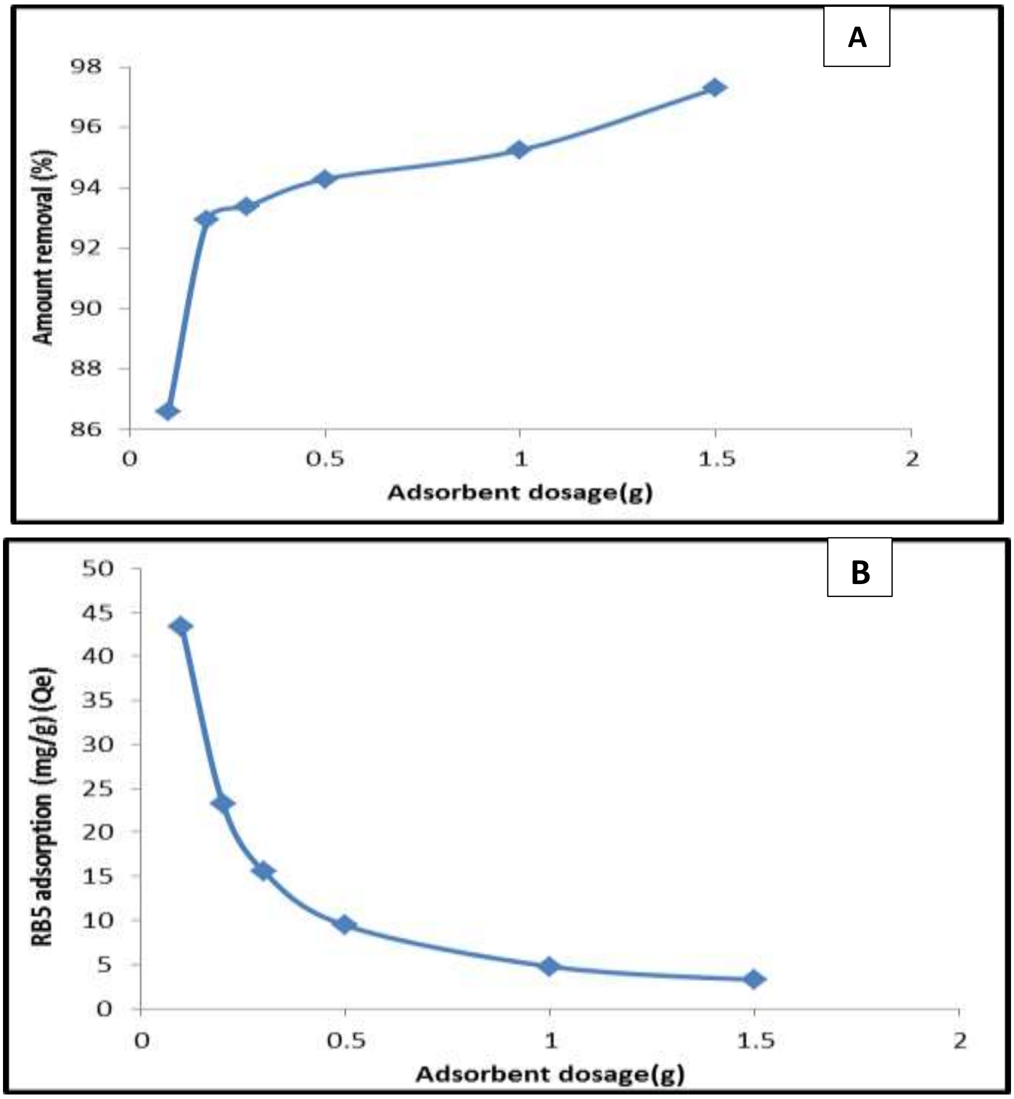


FIGURE 5. Effect of adsorbent dosage on adsorption of RB5 dye on FA surface

(A) percentage removal (B) amount of RB5 dye adsorbed(mg/g)

Conditions: (pH 6, C_o: 50 mg/L, T: 298 K, Contact time: 60 min)

Effect of Contact Time

The effect of contact time on the adsorption of RB5 dye from an aqueous phase onto FA was studied at various time intervals ranging from 15 to 240 minutes. The results (figure 6) show that the elimination of RB5 dye by FA rises with time and reaches a maximum value at about 60 minutes for 50 mg/L after which it remains constant (plateau). At equilibrium, the amount of dye adsorbed is found to be 23.25 mg/g (93.03 %). The results are derived from the significant quick adsorption of RB5 dye and the time in the crucial parameter for dye adsorption from the aqueous phase.

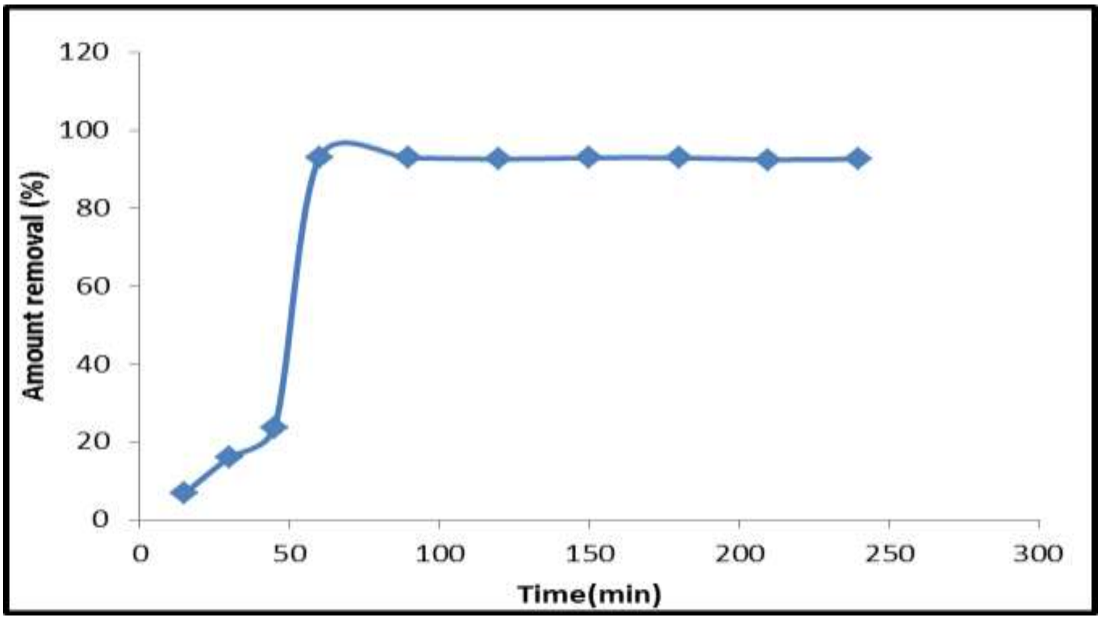
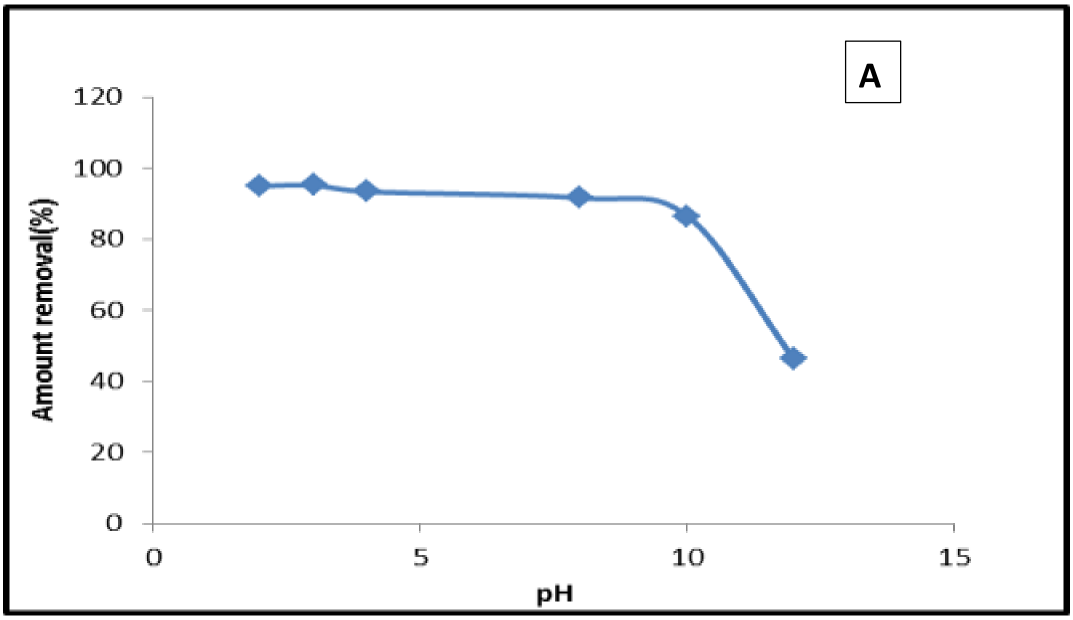


FIGURE 6. Effect of contact time on adsorption of RB5 dye on FA surface

Conditions: (pH 6, C_o: 50 mg/L, T: 298 K, FA dose:0.2 g)

Effect of pH Solution

One of the most critical elements influencing dye adsorption onto suspended particles is pH [26]. The effect of pH on the adsorption of RB5 dye using FA is being investigated by varying the initial solution pH values from 2 to 12. The outcomes are shown in (figure 7). As the pH climbs from 2 to 12, the adsorption effectiveness reduces from 95.05 percent to 46.27 percent.



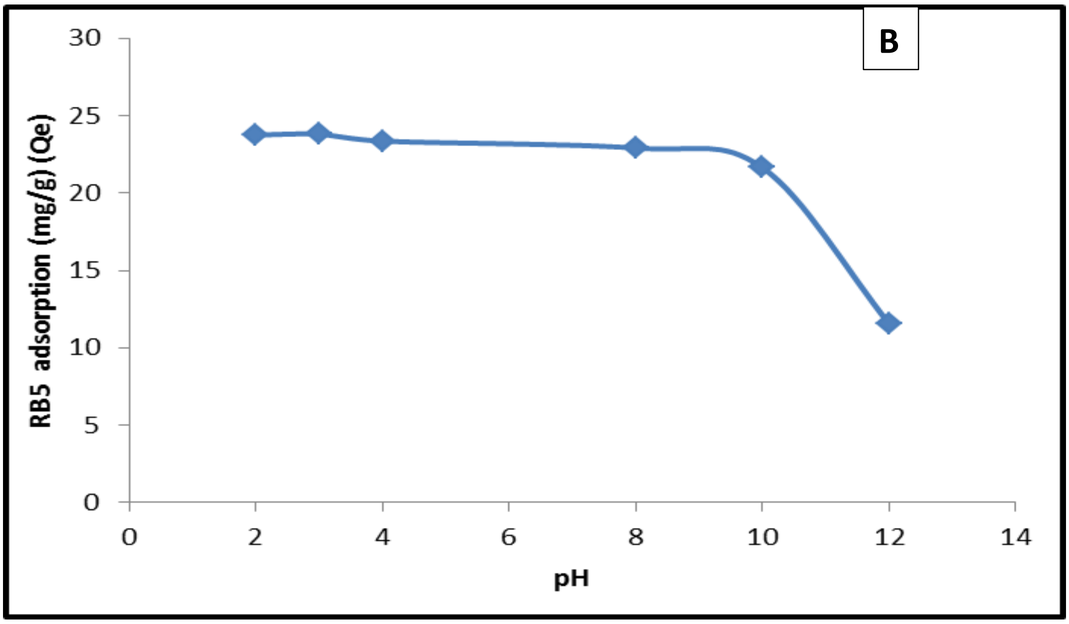


FIGURE 7. Effect of pH on adsorption of RB5 dye on FA surface

(A) adsorption percentage and (B) amount of RB5 adsorbed(mg/g)

Conditions:(Contact time:60min, C_o: 50 mg/L, T: 298 K, FA dose:0.2 g)

Effect of Temperature

Temperatures ranging from 25°C to 55°C were used to investigate the influence of temperature on dye removal. The efficiency of dye adsorption as a function of temperature is depicted in (figure 8). As the temperature rises from 25 to 55 degrees Celsius, the adsorption capacity falls somewhat from 23.82 to 20.50 mg/g.

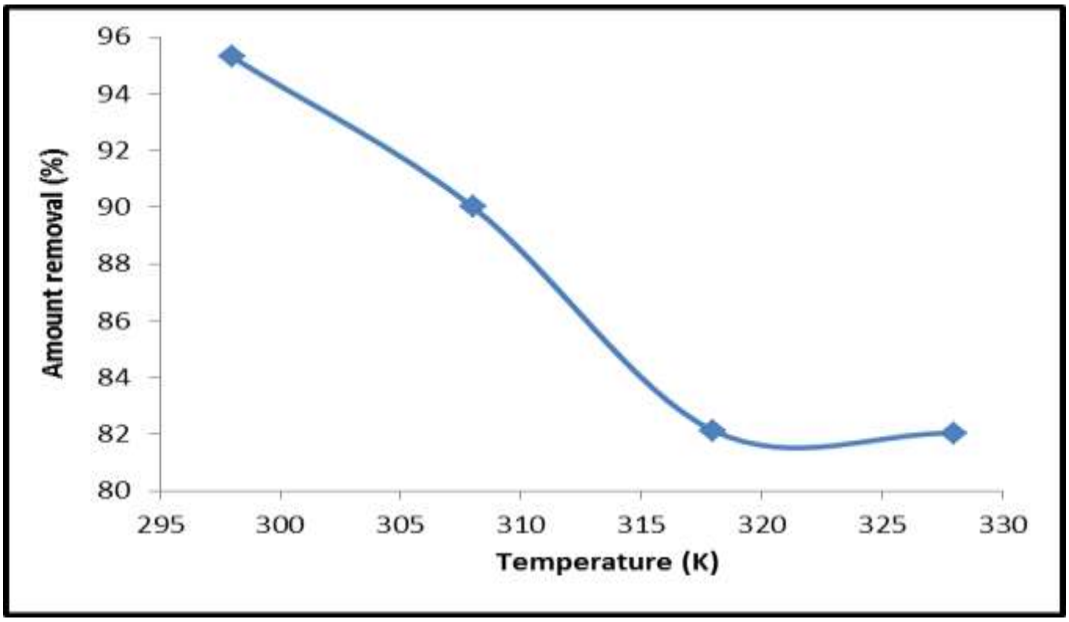


FIGURE 8. Effect of temperature on adsorption of RB5 dye on FA surface

Conditions: (pH 3, C_o: 50 mg/L, Contact time: 60 min, FA dose:0.2 g)

effect of initial concentration

The effect of various RB5 dye concentrations on RB5 dye adsorption capacity is depicted in (figure 9). As expected, the results for the adsorption capacity at equilibrium increased from 4.82 to 40.44 mg/g. with a 10 to 100 mg/L rise in the initial dye concentration. Following maximum adsorption, the adsorbent's sites are filled with dye molecules (RB5), and there are no binding sites available [27]. The adsorption of MB on fly ash[28] and sulfonic acid group modified MIL-101[29] exhibits a similar pattern.

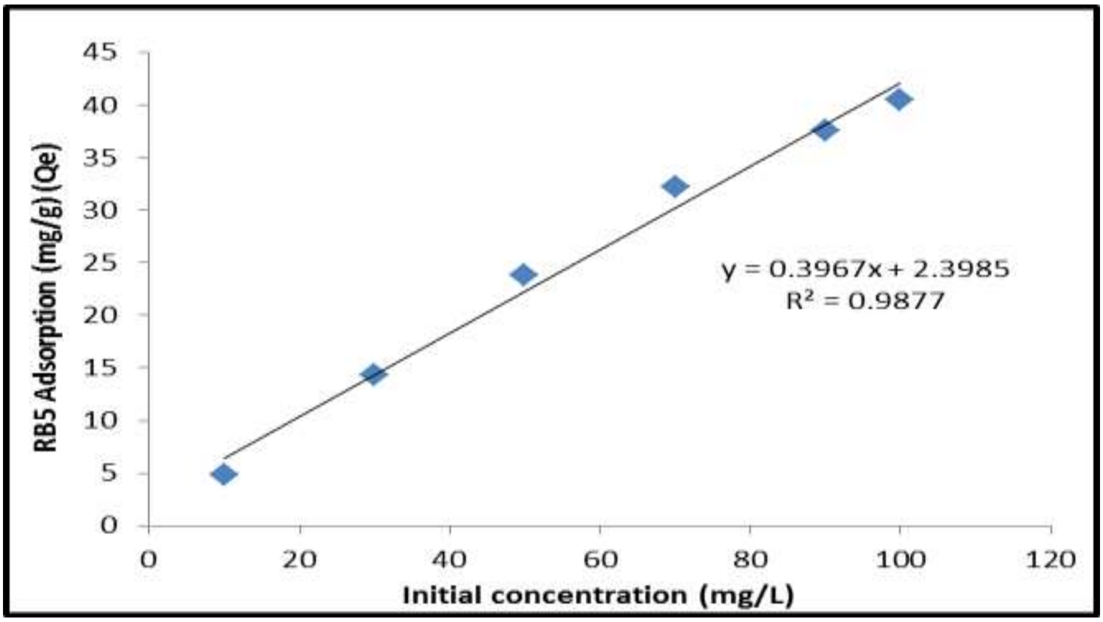


FIGURE 9. Effect of initial concentration on adsorption of RB5 dye on FA surface

Conditions: (pH 3, T:298 K, FA dose:0.2 g, Contact time: 60 min)

Adsorption isotherms

Adsorption isotherm models are commonly used to design and understand the mechanism of interaction that exists at equilibrium between the adsorbate and the adsorbent [30]. At constant temperature, to characterize the distribution of dye ions between the liquid and solid phases, two isotherm models (Langmuir and Freundlich) were used. The Langmuir model assumes monolayer adsorption on a structurally homogeneous adsorbent with energetically uniform adsorption sites. Is based on the assumption that each active site can only react with one dye molecule at a time, and that no further Adsorption can occur at that location [31]. The Freundlich model assumes that active sites have a heterogeneous energetic distribution. Interactions between adsorbed molecules are also present [32]. Eqs. (3) and (4) the linear version of the Langmuir and Freundlich isotherm models, respective.

Langmuir equation: $$\frac{1}{q_e} = \frac{1}{q_{max}} + \frac{1}{(K_L \times q_{max})} \times \frac{1}{C_e} \quad (3)$$

Freundlich equation: $$\text{Log}(q_e) = \log(K_F) + \frac{1}{\text{n}} \text{Log}C_e \quad (4)$$

Where q_e: is the concentration of the dye at equilibrium (mg/g), C_e: is the adsorption capacity (mg/L), q_m: is the maximum adsorption capacity (mg/g), K_L: is the Langmuir constant related to the free energy of adsorption. (L/mg), K_F: is the Freundlich isotherm constant indicative of the adsorption capacity (mg/g) $(L/mg)^{1/n}$, 1/n: is the adsorption intensity which should have a value between 0.1 and 1.0 for favourable adsorption.

(figure 10) shows a plot of log qe versus log C_e for the adsorption of RB5 dye on FA. K_F was discovered to be 11.0917. The value of n = 1.9778 was found to be optimal for favourable multilayer sorption (n >1). This suggested that physisorption and chemisorption were both present during the process. Since the Freundlich adsorption isotherm model had a higher coefficient of regression (R^2 = 0.9041), it was the best fit for explaining the equilibrium conditions for RB5 dye adsorption onto FA. Previous findings from Eichhornia crassipes Methylene blue dye adsorption was then followed the Freundlich model, implying multilayer adsorption [33].

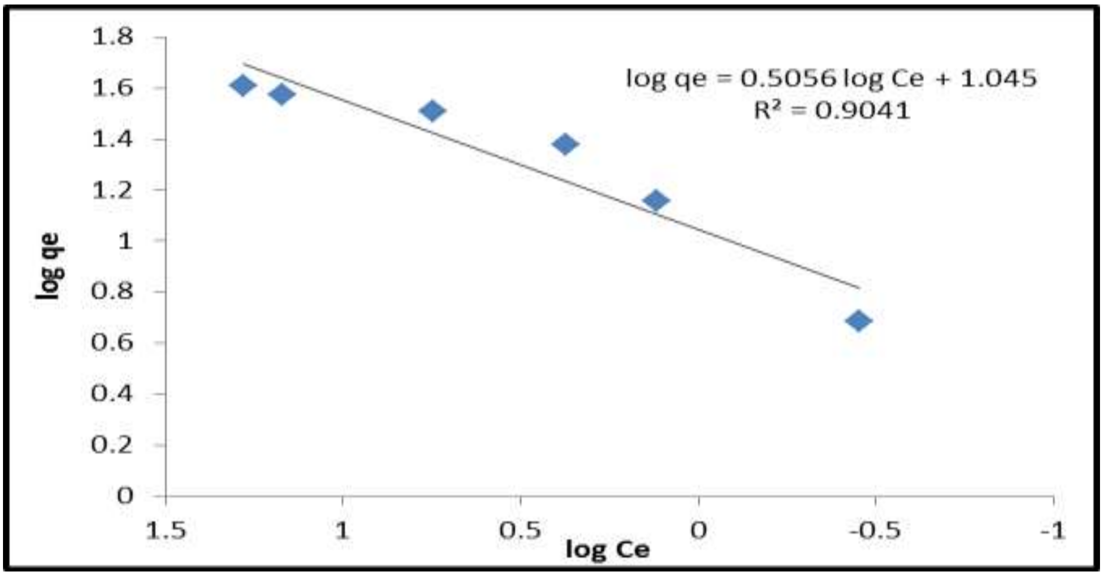


FIGURE 10. Freundlich model plots of RB5 dye adsorption

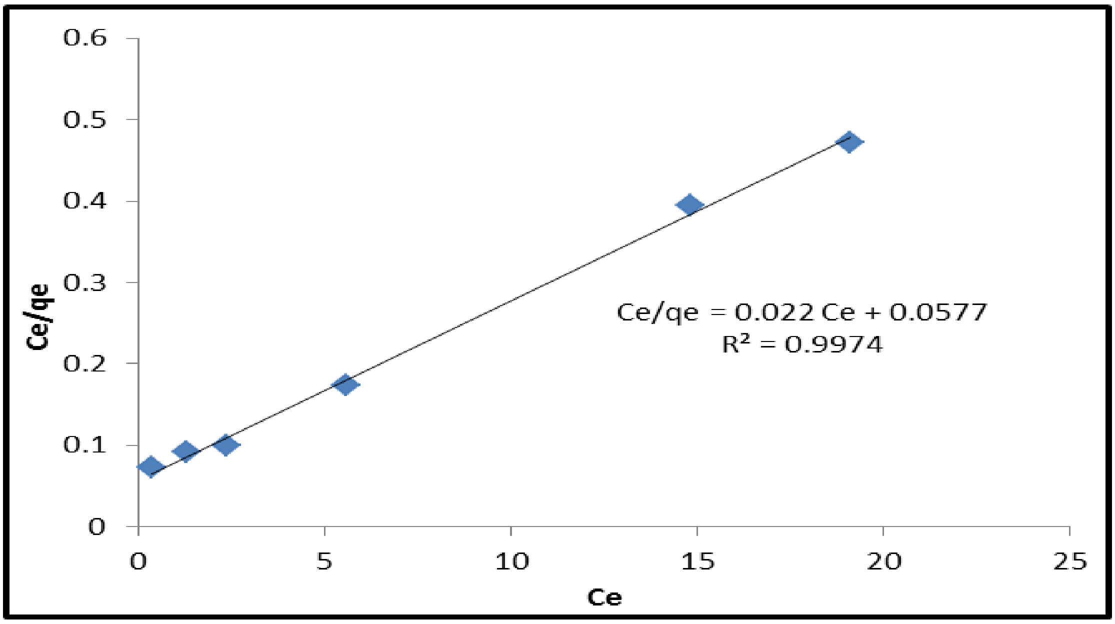


FIGURE 11. Langmuir model plots of RB5 dye adsorption

A dimensionless constant separation factor or equilibrium parameter may be used to express critical characteristics of the Langmuir isotherm. [34] is the concept of R_L:

$$R_L = \frac{1}{1 + K_L C_o} \qquad (5)$$

TABLE 2. The parameter R_L indicates the shape of isotherm.

R_L value	Type of isotherm
$R_L > 1$	Unfavorable
$R_L = 1$	Linear
$0 < R_L < 1$	Favorable
$R_L = 0$	Irreversible

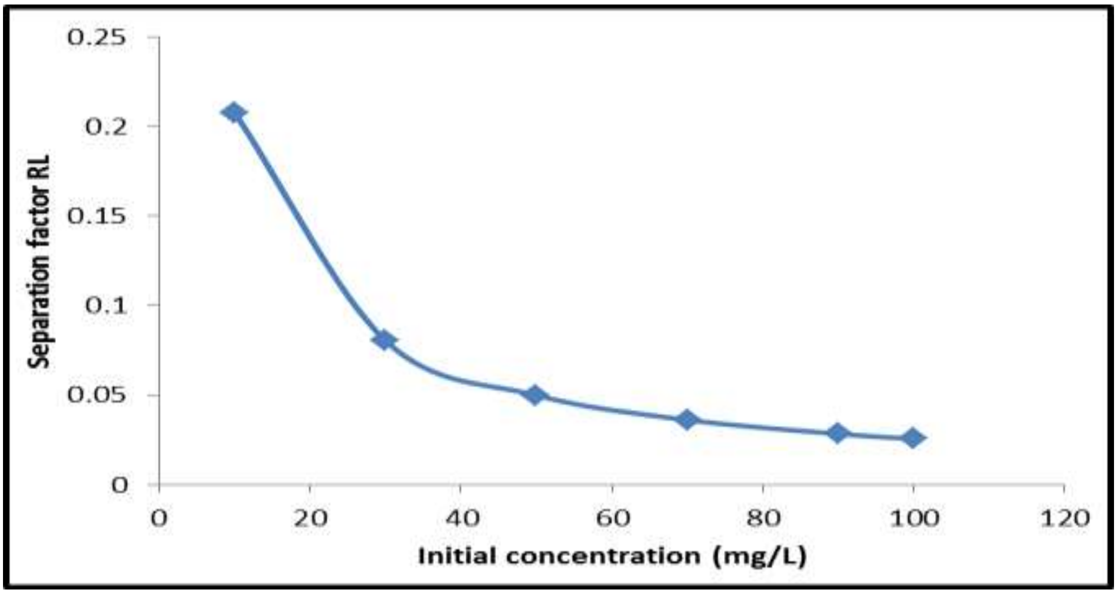


FIGURE 12. Separation factor, R_L for the adsorption of RB5 dye on FA surface

TABLE 3. Constants of adsorption isotherms for RB5 dye adsorption on FA surface

Langmuir isotherm parameters			Freundlich isotherm parameters		
qm (mg/g)	KL (L/mg)	R^2	KF (mg/g)	n	R^2
45.454	0.3813	0.9974	11.0917	1.9778	0.9041

Table 3 also displays the constant of the Freundlich isotherm "n," which defines the adsorption rate of the adsorbent. This value of 1.9778 suggests that RB5 dye adsorption by the FA adsorbent was favorable. The constant of the Freundlich isotherm “n” value between 1 and 10 suggests that the adsorption rate is favorable, according to Sarada et al. [35]. Furthermore, the adsorption potential of a multilayer device is related to the value of the Freundlich constant "K_F." The K_F value for the FA adsorbent was 11.0917 (mg/g) $(L/mg)^{1/n}$, indicating that the FA adsorbent's multilayer loading ability was limited

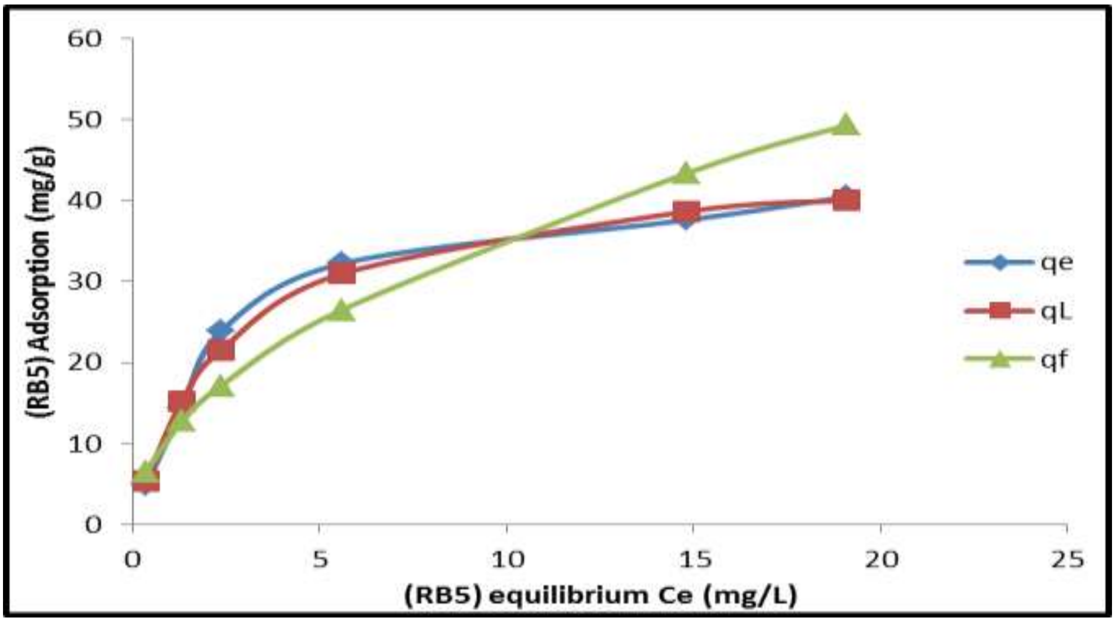


FIGURE 13. Langmuir and Freundlich equilibrium to compare experimental and calculated data. isotherms for RB5 dye on FA surface

Regeneration Study for FA surface

Deionized water was used to wash the dye-loaded fly ash many times. Finally, all of the fly ash were dried in the oven at 45 °C for 3 hours. It was used again to remove RB5 dye from the aqueous solution containing the dye (figure 14) shows the removal percentage before and after surface regeneration, and the removal percentage is in the first adsorption (95.3%) and the second adsorption after regeneration (98.47%).

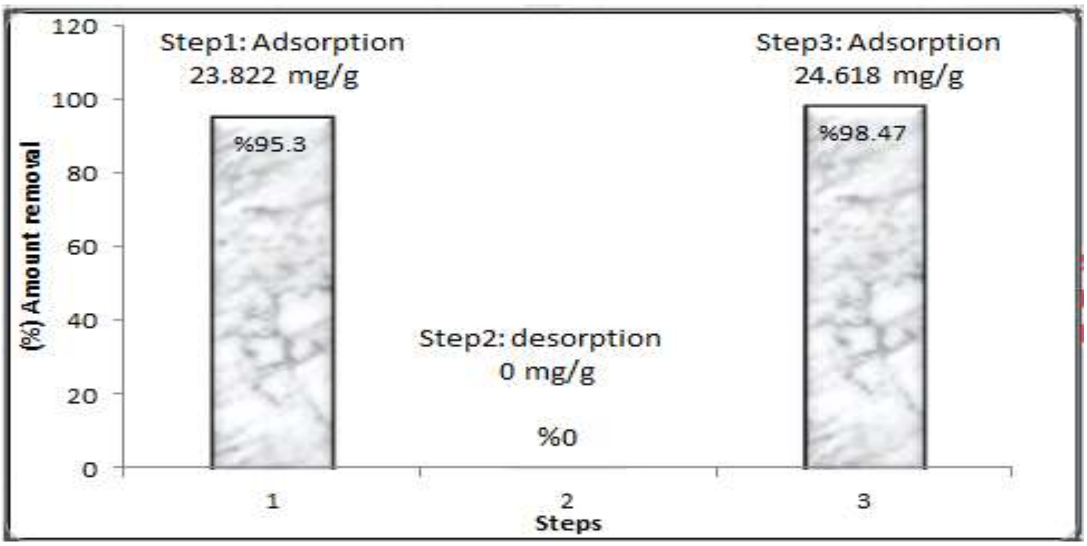


FIGURE 14. The surface response to the recycling process and the possibility of using it as an adsorbent surface with the same efficiency

Conclusion

Conducted in this study removal of RB5 dye from aqueous solution using FA to investigate the adsorption process of dangerous RB5 dye. The experimental results revealed that contact time, pH, FA dosage, and initial RB5 dye concentration all had a significant impact on the RB5 dye adsorption potential on the FA. With increasing initial dye concentration, time, and pH, the adsorption potential of RB5 dye (mg/g) increased, and the optimal pH for adsorption was 3. optimum contact time of 60 min indicated that the adsorbent was successful for RB5 dye removal from an aqueous system. According to the results, FA may be a promising low-cost adsorbent for extracting RB5 dye from wastewater. Overall, these experimental results shed light on a dye adsorption process in new ways.

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