A Novel Approach to Investigate Adsorption of Crystal Violet from Aqueous Solutions Using Peels of *Annona squamosa*


Department of Chemistry, Lady Doak College, Madurai, Tamilnadu, India

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**Abstract:** An effective and economical adsorbent was prepared from the peels of *Annona squamosa* for the removal of crystal violet from aqueous solutions. Adsorption studies were carried out using batch experiments. The dependence of initial dye concentration, pH, contact time, particle size and temperature on the adsorption process was studied. The crystal violet was found to be electroactive and hence electrochemical studies were also performed. The study showed that the equilibrium was achieved within 60 min for the different initial concentrations (10 to 30 mg.l\(^{-1}\)). The equilibrium adsorption data were analyzed using various isotherm models and they were found to fit Langmuir, Freundlich, Temkin and Harkins-Jura isotherm models in varying orders of magnitude. The maximum dye adsorption capacities for cyclic voltammetry and spectral studies at 303 K were found to be 5.6818 × 10\(^{-4}\) A.g\(^{-1}\) (in terms of current) and 5×10\(^{4}\) mg.g\(^{-1}\) (in terms of weight), respectively. The data suggested that the adsorption kinetics was best represented by pseudo-second order kinetic model. The thermodynamic parameters including \(\Delta G\), \(\Delta H\) and \(\Delta S\) for the adsorption process have also been evaluated using which it was concluded that the process of adsorption was spontaneous and endothermic. The cyclic voltammetric and spectral studies yielded similar results. Furthermore, statistical analysis also showed the absence of any significant difference between the two methods.

**Key words:** Adsorption • Crystal Violet • *Annona squamosa* • Cyclic voltammetry

**INTRODUCTION**

At present, most of the developing countries like India are facing a major problem viz. pollution. This may be due to the population outburst and industrial growth. Many industries use toxic and hazardous chemicals for manufacturing their finished products. The waste products (effluents) discharged by these industries contain toxic heavy metals, dyes, hazardous chemicals that may affect our environment even if they are present at low concentrations [1]. The use of various dyes has become popular among many industries such as paper, textile, leather, food, cosmetics and pharmaceuticals [2]. These industries generate coloured effluents which are directly discharged into the natural water sources like river, lakes etc. They cause adverse effects to the aquatic plants by reducing the light penetration through the water and thereby inhibiting photosynthetic process [3]. Crystal violet, a well known basic dye, belonging to triphenylmethane group, is used as biological stain, veterinary medicine, additive to poultry feed to inhibit propagation of mould, intestinal parasites and fungus, textile dying and paper printing [4]. It is harmful upon inhalation, ingestion and skin contact and also has been found to cause cancer and severe eye irritation [5]. Basic dyes have high brilliance, intense colours and are highly visible even in very low concentration [6]. Such dyes are poorly degraded by microbial enzyme and can persist in a variety of environment. The treatment of the dye effluents before being discharged into water sources is therefore a concern environmental protection. Among the various effluent treatment processes, adsorption is found to be the most economical and efficient process [7]. Several adsorbents have been used for the removal of crystal violet such as grapefruit peel [8], tamarind seed...
powder [9], coniferous pinus bark powder [10], treated ginger waste [11], spent tea leaves (STL) [12], male flowers of coconut tree [13], coconut bunch waste [14], pumpkinsseed hull [4], agricultural waste [16], citric acid modified rice straw [17], date palm fiber [18], leaf biomass of Calotropis procera [19], Ricinus Communis pericarp carbon [20], citrullus lanatus rind [21], bottom ash [22], pretreated walnut shell [23]. Watermelon shell [24], cassava peels [25], polyanilinenanocomposite coated on rice husk [26], chitosan [27], etc., had been evaluated as effective adsorbent for the removal of metal ions. Annonas squamosa peels have been evaluated as a low cost adsorbent for the removal of lead and cadmium ions from water [28]. However, it has not been used for the removal of crystal violet dye. Moreover, electrochemical studies on the adsorption of crystal violet dye from aqueous solutions have not yet been reported. Our studies were aimed at the removal of crystal violet dye from aqueous solutions under different experimental conditions using Annonas squamosa peels along with the exploration of adsorption kinetics and isotherms using both electrochemical and spectral studies. Fig. 1 shows aromatic structure of crystal violet.

**MATERIALS AND METHODS**

**Adsorbent:** Peels of *Annonas squamosa* (*PAS*) collected were thoroughly washed with distilled water to remove the dirt adhering to the surface. It was then dried, powdered and sieved to a size of 250-300 µm and stored in an air tight container till further use. No other physical or chemical treatment was done prior to adsorption experiment.

**Adsorbate Solution:** Crystal violet (CV) used for this study was received from Sigma Aldrich (CI-42555, molecular formula – C_{25}H_{26}N_{8}Cl, molecular weight – 408 gmol⁻¹, λ max – 584 nm) and used without further purification. A stock of 1000 mg l⁻¹ dye solution was prepared using deionized water. Different concentrations of dye solution were prepared by appropriate dilution from the stock solution.

**Instruments Used:** The absorbance of dye solutions at the desired wavelength was determined using Thermo Scientific Helios Alpha UV-Visible spectrophotometer. Cyclic voltammetric studies were carried out using CHI 6063C – Electrochemical analyzer. The FT-IR spectra of PAS before and after adsorption were recorded using FT-IR spectrophotometer (Thermofisher) using KBr pellet method.

**Electrochemical Measurements:** All voltammetric experiments were performed in the single compartment cell with a volume of 5 ml at 30°C. The working electrode was glassy carbon. Ag/AgCl electrode was used as a reference electrode and a platinum wire served as the counter electrode.

**Batch Adsorption Studies:** Adsorption of CV dye solution was carried out using batch experiments and the effect of various parameters like contact time (10-60 min), pH (2-12), initial dye concentration (10-30 mg l⁻¹), particle size (150 µm, 250 µm and 300 µm) and temperature (30-50°C) on the removal of CV were studied.

The adsorption studies were carried out by adding varying amounts of adsorbent to 50 ml of dye solution of known concentrations. The solutions were agitated at 160 rpm using shaker to attain equilibrium at predetermined time intervals. The samples were taken and the supernatant solution was separated from the adsorbent by centrifugation for 5 minutes. The supernatant solutions were used to obtain reduction peak current (iₚ) values as a function of the concentration of CV dye remaining after adsorption, using electrochemical analyzer. The same solutions were used to measure the absorbance of the solutions, using UV-Visible spectrophotometer.

For cyclic voltammetric studies, amount adsorbed at equilibrium calculated as:

\[ q_e = \frac{(i_p e - i_p s)V}{W} \]  

where \( i_p e \) is the initial reduction peak current of the dye solution (µA), and \( i_p s \) is the reduction peak current of the dye solution at equilibrium (µA).

**Fig. 1: Structure of crystal violet**
The percentage dye removal was calculated using

\[
\% \text{ removal} = \left( \frac{I_{po} - I_{pe}}{I_{po}} \right) \times 100
\]  

(2)

For spectral studies, amount of dye adsorbed at equilibrium was given by,

\[
q_e = \frac{(C_o - C_e)V}{W}
\]  

(3)

where \(C_o\) is the initial concentration of the dye (mg.l\(^{-1}\)), \(C_e\) is the concentration of dye at equilibrium (mg.l\(^{-1}\)), \(V\) is the volume of the solution (l), \(W\) is the weight of adsorbent (g).

The percentage dye removal was calculated using

\[
\% \text{ removal} = \left( \frac{C_o - C_e}{C_o} \right) \times 100
\]  

(4)

**RESULTS AND DISCUSSION**

**Spectral Characterization of the Adsorbent:** The FTIR spectra of \(PAS\) before and after adsorption were studiedin order to explore the surface porosity of the adsorbent in the range of 400-4000 cm\(^{-1}\). The FTIR spectrum of \(PAS\) shows peaks at 614.8 cm\(^{-1}\), 771.1 cm\(^{-1}\), 823.8 cm\(^{-1}\), 1059.0 cm\(^{-1}\), 1446.3 cm\(^{-1}\), 1618.7 cm\(^{-1}\), 3418.3 cm\(^{-1}\). Since the adsorbent shows a large number of peaks, it is evident that the adsorbent is complex in nature. Comparing Figs. 2a and 2b, it can be noted that some of the above mentioned peaks are shifted (1446.3 cm\(^{-1}\) and 1618.7 cm\(^{-1}\)) or disappeared (614.8 cm\(^{-1}\) and 771.1 cm\(^{-1}\)) and some new peaks (456.7 cm\(^{-1}\) and 466.6 cm\(^{-1}\)) are also formed. Hence

from the spectrum it is obvious that there is possible involvement of those functional groups on the surface of \(PAS\) in the adsorption process [21].

**Effect of pH on Adsorption of CV:** The pH of dye solution is an important parameter in adsorption process which affects the surface binding sites of the adsorbent and the degree of ionization of the dye in solution. In order to understand the effect of pH, the equilibrium adsorption studies were carried out at a concentration of 10mg.l\(^{-1}\) dye solutions at pH ranging from 2 to 12. The percentage removal of dye was found to be marginally greater at pH 8 (Fig. 3), which is indeed the pH of the dye solution itself. Hence further studies were carried out without adjusting the pH of the dye solution.

**Cyclic Voltammetric Studies on CV:** The electrochemical behaviour of CV dye was examined over a potential range from -1.5V to +1.5V (vs. Ag/AgCl) with a scan rate of 100 mVs\(^{-1}\). The cyclic voltammogram of CV dye was shown in Fig. 4. A reduction peak was observed at -0.756V which indicated that the CV dye was electroactive [28].

**Effect of Contact Time and Initial Dye Concentration:** The effect of initial dye concentration onto adsorption of CV by \(PAS\) was studied at different initial concentrations (10 - 30 mg.l\(^{-1}\)) at 303 K and the results were shown in Fig. 5.

The reduction peak current (\(i_p\)) values at various time intervals for different initial concentrations of CV dye solutions were noted. It was found that the \(i_p\) values decreased as the time of contact between the CV dye solution and \(PAS\) increased and reached a constant value indicating an increase in the percentage removal of CV.
Fig. 3: Effect of pH on adsorption of CV onto PAS (Concentration of CV: 10mg.l\(^{-1}\), adsorbent dose: 0.2g; particle size: 200-250 µm; agitation speed: 160 rpm; temperature: 30°C)

Adsorption Kinetics: The mechanism of adsorption and the potential rate controlling steps involved in the process of adsorption had been investigated using kinetic models such as pseudo-first-order, pseudo-second-order and intraparticle diffusion model [19]. The linear form of these models is given by equations (5), (6) and (7), respectively.

\[
\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303}
\]  
\[
\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t
\]  
\[
q_t = k_i t^{1/2} + C
\]

The \(\Delta i = (i_{p-i_m})\) values were found to increase as the initial concentrations of CV increased. This indicated that the percentage removal of dye also increased (from 92 to 98 %) with increasing concentrations. Similar results were also observed in spectral studies.

As the initial concentration of CV increased, the percentage removal increased from 92 to 98 %. This is due to the fact that increase in concentration enhances the interaction between the dye and the adsorbent despite the necessary driving force to overcome the resistance to mass transfer of dye [19]. The uptake of CV increased rapidly during initial stages and reached a constant value beyond 40 min for all the initial concentrations studied.

Fig. 4: Cyclic voltammogram of CV dye.

Fig. 5: Effect of contact time on adsorption of CV onto PAS at different initial concentrations (adsorbent dose: 0.2 g; particle size: 200-250 µm; agitation speed: 160 rpm; temperature: 30°C) (a) and (c) Spectral studies (b) & (d) Cyclic Voltammetric studies
Fig. 6: Pseudo-first order kinetic plot for adsorption of CV onto PAS at different initial concentrations (particle size: 200-250 µm, agitation speed: 160 rpm, temperature: 30°C) (a) Spectral studies (b) Cyclic Voltammetric studies

Fig. 7: Pseudo-second-order kinetic plots for adsorption of CV onto PAS at different initial concentrations (particle size: 200-250 µm, agitation speed: 160 rpm, temperature: 30°C) (a) Spectral studies (b) Cyclic Voltammetric studies

where \( q_t \) and \( q_e \) (mg.g\(^{-1}\)) are the adsorption capacities at time \( t \) and at equilibrium, respectively \( k_1 \) (min\(^{-1}\)) and \( k_2 \) (mg. (g.min\(^{-1}\))) are pseudo-first and pseudo-second order rate constants; \( k_d \) is the intraparticle diffusion rate constants (mg.g\(^{-1}\).min\(^{0.5}\)) and \( C \) is the intercept which gives an idea about the boundary layer thickness. The pseudo second-order model was developed based on the assumption that the rate-controlling step is chemisorption involving valence force due to sharing or exchange of electrons between adsorbent and adsorbate molecules [5]. Fig. 6 presents the pseudo-first order kinetic plot for adsorption of CV onto PAS at different initial concentrations. The higher \( R^2 \) (>0.98) for the pseudo-second order kinetics (Fig. 7), indicated the fitness of this model and it was suggested that chemisorption might be a rate-controlling step[5]. Moreover the \( q_t \) values calculated using pseudo second-order equation agreed well with the experimental \( q_t \) indicating that the adsorption of CV onto PAS could be well represented using the pseudo second order kinetic model. These results were in accordance with those obtained using cyclic voltammetric studies.

Intraparticle diffusion is a transport process involving movement of species from the bulk of the solution to the solid phase. In a well stirred batch adsorption system, the intraparticle diffusion model has been used to describe the adsorption process occurring on a porous adsorbent. According to intraparticle diffusion model, a plot of \( q_t \) versus \( \frac{\sqrt{t}}{t} \) should give a straight line with a slope \( k_d \) and an intercept of zero if the adsorption limited by an internal diffusion process. The relationship between \( q_t \) and \( \sqrt{t} \) at different concentrations was studied (Figs. 8a and 8b).

The plot in this analysis revealed a linear step, corresponding to fast uptake of sorbate. The line in the initial stage does not pass through the origin. This revealed that the uptake is dominated by film diffusion than it does for the intraparticle diffusion process. Tables 1 and 2 summarized adsorption kinetic model parameters using spectral and cyclic voltammetric studies, respectively.

**Adsorption Isotherms:** The adsorption isotherm establishes a relationship between the amount of dye molecules adsorbed onto the adsorbent and the
equilibrium concentration of the dye molecules in solution at a given temperature. The fitness of the equilibrium data obtained for the adsorption of CV onto PAS was analyzed using various models viz., Freundlich, Langmuir, Temkin and Harkins-Jura adsorption isotherm models.

**Freundlich Isotherm:** The Freundlich isotherm is suitable for heterogeneous surface [16] and its logarithmic form can be expressed as

\[
\log q_e = \log k + \frac{1}{n} \log C_e
\]

where \( k \) and \( n \) are Freundlich constants related to adsorption capacity and adsorption intensity, respectively.

Freundlich plots for the adsorption of CV onto PAS using spectral and cyclic voltammetric studies were shown in Fig. 9 (a) and Fig. 10 (a), respectively. The constants \( k \) and \( n \) values were determined from the intercept and slope of the plots, respectively. If \( n \) value was found to be 1, it indicates that the partition between the two phases were independent of the concentration of the dye [29]. The \( R^2 \) values were found to be 1 indicating the fitness of the Freundlich model with the equilibrium data.

**Langmuir Isotherm:** The Langmuir isotherm assumes monolayer adsorption process. The linear form of it can be expressed as

\[
\frac{1}{X/M} = \frac{1}{q_{\text{max}}} + \frac{1}{q_{\text{max}} b C_e}
\]

where \( q_{\text{max}} \) is the maximum monolayer dye concentration in the solid phase (mg.g\(^{-1}\)), \( C_e \) is the equilibrium dye concentration in the aqueous phase (mg.l\(^{-1}\)).
Fig 9: (a) Freundlich (b) Langmuir (c) Temkin (d) Harkin-Jura adsorption isotherm plots for the adsorption of CV by PAS (Concentration of CV: 20 mg.l$^{-1}$; adsorbent dose: 0.2 g; particle size: 200-250 µm; agitation speed: 160 rpm; temperature: 30°C) using Spectral studies.

Fig 10: (a) Freundlich (b) Langmuir (c) Temkin (d) Harkin-Jura adsorption isotherm plots for the adsorption of CV by PAS (Concentration of CV: 20 mg.l$^{-1}$; adsorbent dose: 0.2 g; particle size: 200-250 µm; agitation speed: 160 rpm; temperature: 30°C) using cyclic voltammetric studies.
the equilibrium dye concentration in the solid phase (mg·g⁻¹) and b is the Langmuir equilibrium constant (L·mg⁻¹).

Langmuir plots for the adsorption of CV onto PAS using spectral and cyclic voltammetric studies were shown in Fig. 9(b) and Fig. 10 (b), respectively. The constants qmax and b obtained from spectral and cyclic voltammetric studies for three different concentrations (10-30 ppm) were presented in Tables 3 and 4, respectively. The dimensionless constant separation factor (R_L) which indicates whether the adsorption process is unfavourable (R_L > 1), linear (R_L = 1), favourable (0 < R_L < 1) or irreversible (R_L = 0) can be calculated as

\[ R_L = \frac{1}{1 + bC_0} \]  

(10)

The R_L values were found to be less than 1 indicating that the adsorption process was favourable [21]. The R² values were to be 1 indicating the fitness of the Langmuir model with the equilibrium data.

**Temkin Isotherm:** Temkin isotherm suggests that sorption energy decreases as the degree of completion of the sorptional centers of an adsorbent is increased [21].

\[ q_e = B_T (\ln A_T + \ln C_0) \]  

(11)

where, \( B_T = RT/b \) is the absolute temperature (K), R is the gas constant (8.314J·mol⁻¹·K⁻¹), \( A_T \) is the equilibrium binding constants (L·mg⁻¹) and \( B_T \) is related to the heat of adsorption (J·mol⁻¹).

Temkin plots for the adsorption of CV onto PAS using spectral and cyclic voltammetric studies were shown in Fig. 9(c) and Fig. 10(c), respectively. The constants A_T and B_T values were determined from the intercept and slope of the plots, respectively. The R² values were in the range 0.999 to 1.0 indicating the fitness of the model with the equilibrium data.

**Harkins-Jura Isotherm:** Harkins-Jura adsorption isotherm accounts for multilayer adsorption and can be explained with the existence of heterogeneous pore distribution. It can be expressed as

\[ \frac{1}{q_e} = \frac{1}{A} - \frac{1}{A} \log C_e \]  

(12)

where B and A are the isotherm constants.

Harkins-Jura plots for the adsorption of CV onto PAS using spectral and cyclic voltammetric studies were shown in Fig. 9(d) and Fig. 10 (d), respectively. The constants A and B values were determined from the slope and intercept of the plots, respectively. The R² values were in the range 0.999 to 1.0 indicating the fitness of the model with the equilibrium data. Hence there could be a possibility of multilayer adsorption to occur [21].

**Effect of Particle Size:** Adsorption of CV onto PAS of three different particle sizes (200-250, 250-300, 300-500 µm) was studied by keeping all other parameters constant. The variation of particle size on the adsorption process monitored by spectral technique was shown in Fig. 11. As particle size was decreased, the adsorption efficiency of PAS increased. This could be due to increase in the total surface area with decrease in particle size leading to increase in the adsorption efficiency of the adsorbent [21].

In Cyclic voltammetric studies, a drastic change in the peak potential was observed on changing the mesh size of the adsorbent. This may be due to the involvement of H⁺ ions during the electro-oxidation process. Negative shift in the peak potential which may be due to intercalative mode of interaction between the adsorbent and the dye was observed.

**Effect of Temperature:** Temperature has a significant effect on the process of adsorption. Adsorption of CV onto PAS was studied at three different temperatures (303 K, 313 K and 323 K) for 10 mg·l⁻¹ initial concentration

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**Table 3: Adsorption isotherm model parameters based on spectral studies**

<table>
<thead>
<tr>
<th>T (K)</th>
<th>Langmuir isotherm</th>
<th>Freundlich isotherm</th>
<th>Temkin isotherm Model</th>
<th>Harkins-Jura isotherm model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>qmax (mg·g⁻¹)</td>
<td>b (L·mg⁻¹)</td>
<td>k (mg·g⁻¹) n</td>
<td>A</td>
</tr>
<tr>
<td>303</td>
<td>5×10⁴</td>
<td>2×10⁴</td>
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**Table 4: Adsorption isotherm model parameters based on cyclic voltammetric studies**

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<th>T (K)</th>
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<th>Temkin isotherm Model</th>
<th>Harkins-Jura isotherm model</th>
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<tr>
<td></td>
<td>qmax (µA/m)</td>
<td>b (µA/m)</td>
<td>k (µA/m) n</td>
<td>A</td>
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<tr>
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</table>
Fig. 11: Effect of particle size on adsorption of CV onto PAS (adsorbent dose: 0.2 g; contact time: 60 min; agitation speed: 160 rpm; temperature: 30°C) (a) spectral studies (b) cyclic voltammetric studies.

Fig. 12: Van’t Hoff plot for effect of temperature on the adsorption of CV (a) Spectral studies (b) Cyclic Voltammetric studies

Table 5: Thermodynamic parameters for the adsorption of CV.

<table>
<thead>
<tr>
<th>Studies</th>
<th>$\Delta G$ (kJ mol$^{-1}$)</th>
<th>$\Delta H$ (kJ mol$^{-1}$)</th>
<th>$\Delta S$ (kJ K$^{-1}$ mol$^{-1}$)</th>
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<td>Spectral</td>
<td>303 K 313 K 323 K</td>
<td>-30.7381 -37.1651 -43.5921</td>
<td>164 0.6427</td>
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<tr>
<td>Cyclic voltammetric</td>
<td>-3.4963 -4.7183 -5.9403</td>
<td>33.5303 0.1222</td>
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</table>

Evaluation of Thermodynamic Parameters:
Thermodynamic parameters such as change in free energy change ($\Delta G$), enthalpy change ($\Delta H$) and entropy change ($\Delta S$) were determined using the following equations

$$K_o = \frac{C_{\text{solid}}}{C_{\text{liquid}}}$$  

where $K_o$ is the equilibrium constant, $C_{\text{solid}}$ is the solid phase concentration (mg l$^{-1}$), and $C_{\text{liquid}}$ is the liquid phase concentration (mg l$^{-1}$).

$$\Delta G = -RT \ln K_o$$

$$\ln K_o = -\frac{\Delta G}{RT}$$  

$$\Delta G = \Delta H - T\Delta S$$  

$$\ln K_o = \frac{\Delta S}{R} - \frac{\Delta H}{RT}$$

A plot of $\ln K_o$ vs. $1/T$ gives a straight line with slope equal to $\Delta H/ R$ and intercept is equal to $\Delta S/ R$. Knowing the value of $R$, $\Delta H$ and $\Delta S$ can be evaluated. From the values of $\Delta H$ and $\Delta S$, $\Delta G$ can be determined using the equation (16). The results are presented in Table 5.

The negative values of $\Delta G$ indicated that the adsorption of CV onto PAS is a favourable and a spontaneous process. The positive values of $\Delta H$ indicated the endothermic nature of the adsorption process and positive values of $\Delta S$ indicated increased randomness of the CV at the solid solution interface. The increase in the capacity of the adsorbent to remove CV at higher temperatures may be due to activation of the adsorbent surface thereby enlarging the size of the pores [21, 30].

Statistical Analysis of the Two Methods: Statistical analysis of the respective sets of data obtained by spectral and voltammetric studies was carried out by
student’s t-test. The analysis indicated that the calculated t-value \( t = 2.571 \) < tabulated-value \( t = 3.365 \) at 99% confidence level and hence it could be concluded that there is no significant difference between the two methods.

CONCLUSION

The adsorption of CV onto PAS was found to be an efficient process. The parameters such as pH, initial dye concentration, contact time, particle size and temperature have shown significant effect on the removal of CV from aqueous solutions. The maximum uptake of CV by PAS occurred at pH 8 and the equilibrium adsorption was attained after 40 min. The equilibrium adsorption data were found to fit Freundlich, Langmuir, Temkin, Hankins-Jura isotherm models. The adsorption process followed pseudo second-order kinetics. Evaluation of thermodynamic parameters indicated that the adsorption process was endothermic and there occurs increased disorder at the solid-solution interface. The various results obtained indicated that the adsorbent chosen for the study was efficient and could be used for the removal of industrial dye effluents.

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REFERENCES


**Persian Abstract**

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چیده

برای جذب کریستال بیولو از آب آب آسیاب و آب آتشفشانی از Annona squamosal جدید پرداخته شده است. در اینجا تأثیرات مختلف الکتریکی ترکیبات آنالیز دانه ها و دندانههای انسان در سطح سطحی آنالیز دانه ها و دندانههای انسان در سطح سطحی آنالیز دانه ها و دندانههای انسان در سطح سطحی آنالیز دانه ها و دندانههای انسان در سطح سطحی آنالیز دانه ها و دندانههای انسان در سطح سطحی آنالیز دانه ها و دندانههای انسان در سطح سطحی آنالیز دانه ها و دندانههای انسان در سطح سطحی آنالیز دانه ها و Due to the importance of removing heavy metals from water, the use of organic waste materials such as walnut shells and rice straw has been studied. The study of the adsorption of crystal violet dye from aqueous solutions onto pretreated walnut shell in a packed column was conducted. The results showed that the adsorption capacity of the pretreated walnut shell was significantly higher than that of the untreated shell. The adsorption process was found to be well described by the Lagergren pseudo-first-order and the Langmuir isotherm models. The obtained results suggest that the pretreated walnut shell can be a promising adsorbent for the removal of crystal violet dye from aqueous solutions.