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# Sustainable Optimization of Crystal Violet Dye Removal Using Potato Peel DerivedActivated Carbon: Kinetics and Isotherm Studies

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**Abstract**

Batch conditions are used to remove crystal violet dye from activated carbon made from potato peels in an aqueous solution. Investigations were conducted into the effects of several parameters, including temperature, adsorbent dose, pH, contact duration, and starting dye concentration, on the adsorption of CV onto PP. The properties of the substance were determined
using FTIR studies. Using the Langmuir, Freundlich method, the isotherm findings were examined. To fit the experimental data, linear regression was used. It was discovered that the Freundlich isotherm and the PP adsorption capacity (qe) effectively capture the equilibrium data. After using pseudo-first-order models to examine the kinetics of CV dye adsorption, it was discovered that the model adequately explained the CV dye's behavior.

KEYWORDS: Potato peel, Activated carbon, crystal violet, Adsorption, Isotherm, Kinetics

## INTRODUCTION

Life is not possible without water [1,2]. Currently, water degradation is one of the most pressing global concerns, as it is essential for the development of life. Toxic pollutants are discharged into the atmosphere as a result of rapid industrialization, anthropogenic activities, unplanned urban migration, unsustainable water resource utilization, and rapid population growth [3-6]. Typically, synthetic dyes and pigments are employed to color the products of numerous industries, including the textile and paper and fiber industries [7]. As a result, 40,000–50,000 tons of dyes are discharged into the water systems annually [8,9]. The aquatic ecology is harmed as a result of the interference with light penetration and the reduction in aesthetic value of water bodies [10]. Certain dyes and their derivatives have the potential to cause cancer and have mutagenic, toxic effects. In humans, these dyes also cause malfunctions in the neurological, liver, and kidney systems. Their decolorization is difficult due to their intricate structure. Therefore, the eradication of pigment from effluent is a critical concern for environmentalists and researchers. A variety of technologies were developed to remove synthetic pigments from effluent in order to mitigate their environmental impact. A few of the techniques employed to remove colored dyes include chemical coagulation, oxidation, ozonation, flocculation, membrane-based separation techniques, biological processes, sono chemical processes, photocatalytic processes, and adsorption electrochemical processes [11-15]. Electrochemical coagulation and adsorption are the most frequently employed and significant of these physical-chemical techniques [16]. The adsorption techniques have garnered significant attention due to their flexibility and ease of use. It is a straightforward and efficient approach that enables the measurement of equilibrium and kinetics without the necessity of highly intricate apparatus [17]. Despite the extensive research

on the use of activated carbon as an adsorbent for the adsorption of basic dyes, its high cost precludes its commercial application. Many studies have been carried out in the last few years to find new inexpensive adsorbents. Numerous industrial and agricultural wastes, such as waste apricots, sewage sludge, teak leaves, rice husk, pine wood sawdust, hardwood sawdust, coir pith, waste materials, orange peel, waste tires, hen feathers, deoiled soya, and bottom ash, have been utilized to remove dyes from wastewater [1-2].

An untreated form of absorbent peel powder (potato peel) was utilized in this investigation to eliminate crystal violet (CV) dye. CV dye, a member of the triphenylmethane group, is primarily used in veterinary and animal medicine as a biological stain to identify bleeding fingerprints and in a variety of industrial textile processes [18]. CV is a dye that is resistant to microbial degradation and is stable. Consequently, it is imperative that it be eliminated from wastewaters prior to their discharge in order to guarantee environmental safety [19]. The adsorption process is influenced by temperature, ionic strength, adsorbent dosage, pH, and the properties of the adsorbate [20-21]. Consequently, we optimized the reaction conditions to ensure the adsorbent's optimal performance. Additionally, the adsorbent's performance was evaluated in saline water, river water, and potable water, and it demonstrated exceptional adsorption efficiency for the removal of CV dye. The primary advantage of an adsorbent is its direct use without any treatment, which reduces the cost of the procedure and makes it convenient for large-scale use. Consequently, potato peel powder has the potential to be employed on a large scale as a useful adsorbent to remove the hazardous pigments from effluent, thereby protecting natural water bodies from contamination.

## Materials and methods

**Materials:** All materials were employed without additional purification. In this work, the adsorbent used was *potato peel* powder, while adsorbates were a cationic dyes CV, obtained from SD-Fine chemicals, Mumbai and used without further purification, All the chemicals used in this study were of analytical grade.

### Preparation of adsorbent

The *Solanum tuberosum* peels was collected and rinsed repeatedly with water to eliminate soluble impurities and particles. Then, it was divided into small sections, dried in the sun for 10 days, and then desiccated in a hot air furnace at 80℃ for 24 hours. The mechanical grinder was

used to thoroughly pulverize the completely desiccated material, which was then chemically activated by treating it with concentrated sulphuric acid while maintaining constant agitation for 24 hours at room temperature. After that, it was heated in the hot air oven at 110℃ for 12 hours to activate it. The surplus acid was removed from the carbonized material by washing it thoroughly with ample water on multiple occasions. Subsequently, it was desiccated in a hot air oven at 550℃ for 12 hours and in a muffle furnace at the same temperature for one hour. The adsorbent acquired in this manner was thoroughly ground and sieved through a 125-250 mesh before being stored in airtight containers for future use (Umadevi and Renuga devi, 2015; Theivarasu et al., 2012; Sivakumar et al., 2014).

**Preparation of dye solution**

The stock solutions were prepared by dissolving 100 mg of CV dye in 1000ml of distilled water. The pH of working solution was adjusted by adding 0.1 mol/L of an HCl and NaOH to the solution.

**Determination of the batch adsorption experiment of *Solanum tuberosum* peels**

The adsorption capacity of the adsorbents *Solanum tuberosum* peel was investigated through batch adsorption studies. These assays are highly effective and simplified for the evaluation of the basic characteristics that influence the adsorption process.

**Effect of Variation of Initial Concentration of the CV Dye on Adsorption**

We conducted batch mode experiments with potato peel adsorbent, modulating the initial dye concentration at room temperature (32±2℃) and a pH of 6.8±0.2. In a conical flask containing 100 milligrams of PP (potato peel) adsorbent, dye solutions (100 ml) were started at varying concentrations (30, 50, 70, and 100 mg/l). Following this, the adsorbent and adsorbate mixture was agitated on a horizontal electrical bench shaker at a speed of 120 rpm for a variety of time intervals, including 10, 20, 30, 40, 50, 60, 80, 100, 120, and 180 minutes. By centrifugation, the adsorbate was separated from the adsorbent, and the residual dye concentrations for Crystal Violet dye were determined using a spectrophotometer at 590 nm.

**Effect of Variation of pH on the Adsorption of Dye**

The pH was adjusted from 2 to 10 to investigate the impact of pH on dye adsorption. In order to investigate the impact of pH, 100ml of dye solution with an initial concentration of 100mg/l was placed in conical flask that contained 100mg of PP adsorber. The dye solutions' pH was adjusted

by adding 0.1N $H_2SO_4$ or 0.1N NaOH. The solutions were left to agitate for a period of 120 minutes. By centrifugation, the adsorbate was separated from the adsorbent, and the residual dye concentration was determined with a spectrophotometer.

**Effect of Variation of Adsorbent Dosage on the Adsorption of Dye**

The removal of dyes (CV) was investigated in relation to the adsorbent dosage at a temperature of 32 ± 2℃ and a pH of 6.8±0.2. In beaker that contained 50, 100, 150, and 200 milligrams of PP adsorbent, the dye solution (100ml) was taken at an initial concentration of 100 mg/l. The contact time was varied from 10 to 150 minutes while the adsorbent and adsorbate mixture was agitated at room temperature using a horizontal electrical bench shaker. After centrifugation separated the adsorbate from the adsorbent, the concentration of residual dye was measured using a spectrophotometer.

**Effect of Variation of Temperature on the Adsorption of Dye**

In order to examine the impact of temperature on the adsorption of the dyes utilized in this study, 100ml of dye solution with an initial concentration of 100mg/l was poured into Pyrex vessels that contained 100mg of PP adsorbent at a pH of 6.8±0.2. The contact time was varied from 10 to 120 minutes in a temperature-controlled water reservoir cum rotary agitator at diverse temperatures (27°C, 37°C, and 47℃) to agitate these solutions. Centrifugation was employed to separate the adsorbate from the adsorbent, and a spectrophotometer was employed to determine the residual dye concentration.

**Kinetic, Thermodynamic and Adsorption Isotherm Studies for the Removal of Dyes**

Using the Lagergren rate equation, Intraparticle diffusion rate equation, and Elovich rate equation, the rate constants for the adsorption of the dyes from aqueous solution were determined. Langmuir and Freundlich adsorption isotherms were evaluated for the adsorption of CV dyes using the low-cost adsorbent that was prepared and employed in this investigation.

## Results and discussion

**Influence of initial dye concentration and Contact Time on the Removal of Dyes from Aqueous Solution** In order to assess the adsorption capacity of the absorbents for the dye molecules, it is imperative to investigate the equilibrium distribution of the dyestuffs between the adsorbent and adsorbate [22]. The initial concentration of the dye solution (30, 50, 70, and 100mg/l) was varied in batch mode experiments at a temperature of 32±2°C and a pH of 6.8 ±

0.2. The adsorbents PP were used to achieve this at intervals of 10 to 160 minutes. Figures 1 illustrate the experimental outcomes that were achieved in the removal of CV pigments. The results indicated that the percentage of dye molecules adsorbing to the adsorbent PP from an aqueous dye solution decreased as the concentration of the dye solution increased and increased as the contact time increased. The percentage adsorption of dyes from aqueous solution exhibited a decreasing trend from 99.36% to 83.21% for CV dye , as the initial adsorbate concentrations were adjusted from 30 to 100 mg/l over a 160-minute contact time (Figures-1). This may be due to the fact that a fixed adsorbent dose comprises a fixed number of adsorption sites. Consequently, the adsorbents' dye removal percentage was reduced when a smaller number of surface-active adsorption sites were present on their surface at higher initial dye concentrations [23,56]. Moreover, the adsorbents' ability to adsorb (q) was enhanced with higher dye concentrations, since the initial concentration of the dye created a force that overcame the resistance of the dye molecules transferring between the liquid and solid phases [57]. The q values of adsorbent PP for CV dye increased from 29.81 to 83.21mg/g.

The adsorption rate was significant during the initial stages of adsorption as a result of the immediate uptake of dye molecules by the outer surface. Subsequently, the dye molecules migrate to the interior surface of the adsorbent, which is a relatively slow process [38]. Additionally, the development of subsequent layers of dye molecules is disrupted at higher initial dye concentrations as a result of repulsive interactions between the adsorbed dye molecules on the adsorbent surface and un adsorbed dye molecules in the solution [58]. The results obtained in this study are in good agreement with the results reported on the removal of Reactive Black dye on acid-treated potato peel waste [59], modified wheat straw [60], Congo Red dye removal using saw dust modified carbon [61], removal of Reactive Yellow dye on modified activated alumina [38] and removal of Malachite Green dye on wood apple shell [51] and paper industry waste sludge [62].

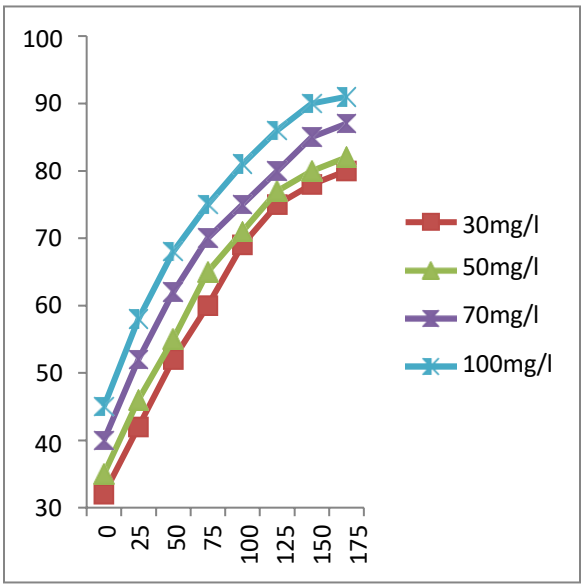



**Figure :1 Adsorption of CV Dye from Aqueous Solution with Variation of Initial Concentration of CV Dye Solution using PP**

**Effect of pH on Dye Removal:** According to [47-48], pH has an impact on the aqueous chemistry and surface adsorption sites of the adsorbents. In order to comprehend the adsorption mechanism, it is imperative that one observes the pH at which the surface charges coincide with zero, which is referred to as the zero point change (pHzpc) of the adsorbent. The adsorbent PP has a pH zero-point of 6.8. A positive charge is generated on the carbon surface below its zero point charge, while a negative charge is generated above it. The adsorption of cationic dyes is favored at pH values greater than pHzpc, whereas anionic dyes are favored at pH values lower than pHzpc [49]. Anionic dye ions are formed by the dissociation of the sulphonic acid group of anionic dye (D-SO3Na) in the aqueous solution [50]. The adsorbent's positively charged surface is subject to a significant electrostatic attraction with anionic dye ions, resulting in an increase in the removal of dyes from the aqueous dye solution, as the carbon surface acquires a positive charge below its zero point charge (6.8 for PP) and, by extension, below pH 7. As the pH of the solution increases, the removal of cationic dyes increases, as the association of dye cations with more negatively charged sites of carbon adsorbent occurs, thereby increasing the removal of cationic dyes [49].

A 100ml dye solution with an initial concentration of 100 mg/l was injected into beaker containing 100 mg of PP adsorbents at 32 ± 2°C. Batch mode adsorption experiments were conducted by adjusting the pH of the dye solution from 2 to 10 using 0.1 N $H_2SO_4$ or 0.1 N NaOH. These experiments were conducted in the present investigation. In Tables and Figures, the findings were illustrated.

In 120 minutes of adsorption time, the adsorbent PP increased the percentage adsorption of cationic dye CV from 60.32 to 89.46 % when the pH of the dye solution was raised from 2.0 to 10. Because positively charged dye molecules are repelled by positively charged surfaces, CV dye may show reduced adsorption at acidic pH.

Furthermore, excess $H^+$ ions compete with cationic dye molecules for adsorption sites [51]. The positively charged dye molecules are attracted to the adsorbent's surface by electrostatic attraction, which is facilitated by the negative charge that arises at higher pH levels. Analogous outcomes were observed for the adsorption of Crystal Violet dye on Fertilizer plant waste carbon [52] Chitosan [53], Mustard waste ash and Buffalo dung ash [54], and Malachite Green dye on sea shell [55].

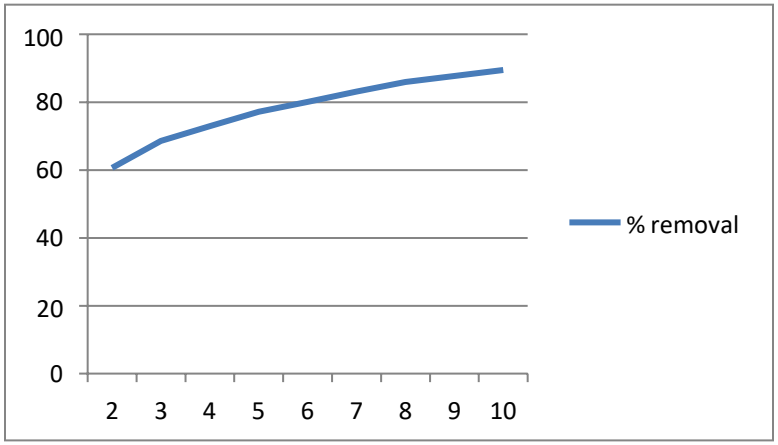



**Figure: 2 Effect of pH for the Adsorption of CV Dye from Aqueous Solution onto PP**

**Effect of Temperature on Dye Removal:** In order to find out how temperature affects the adsorption of Crystal Violet dye, adsorption tests were carried out using temperature changes. Using 100mg of adsorbent PP, batch mode adsorption experiments were conducted with a 100ml dye solution of initial concentration 100 mg/l, at pH 6.8±0.2. The efficiency of PP adsorbents in removing dyes increased as the temperature was raised from 30°C to 50°C (Figures). The

mobility of the dye molecules is enhanced by the rise in temperature, which also provides sufficient kinetic energy to facilitate a positive interaction between the dye molecules and the surface active sites of the adsorbents. Furthermore, the rise in temperature may induce a swelling effect within the internal surface of the adsorbents and facilitate the movement of dye molecules within the pores of the adsorbents [45]. Similar findings were observed for the adsorption of Crystal Violet dye on Grapefruit rind [46].

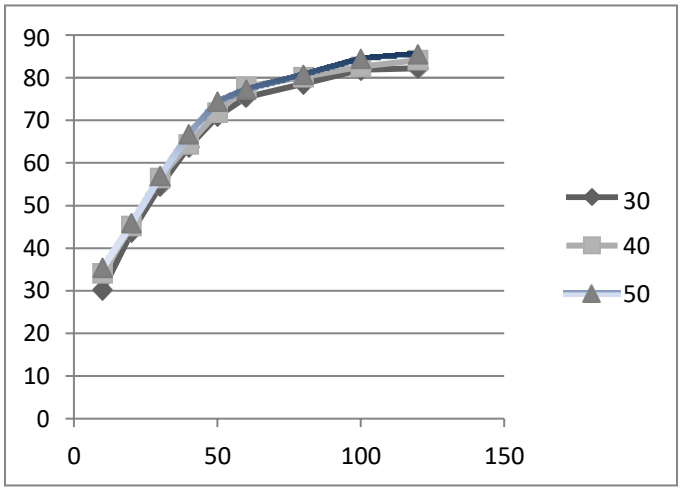



**Figure: 3 Effect of temperature for the Adsorption of CV Dye from Aqueous Solution onto PP**

**Effect of Adsorbent Dosage on Dye Removal:** The effectiveness of adsorbent dosage in the removal of CV and dyes from aqueous solution was investigated by varying the dosage of the adsorbents (PP 50 to 200mg). We conducted batch mode adsorption experiments by adjusting the adsorbent dosage in a 100ml dye solution with an initial concentration of 100mg/l at a temperature of 32±2℃ and a pH of 6.8 ± 0.2 ( Tables). Increased surface area and an increased number of adsorption sites on the adsorbent surface were the reasons for the improved dye removal efficacy as the amount of adsorbent material increased.

Similar outcomes have been reported for the adsorption of Methylene Blue dye on Bael tree bark [40], Acid Blue on Cellulose-based biosorbent [41] Cibacron Reactive Yellow dye on modified Alumina [38] Congo Red dye on lignocellulosic jute fiber [42], and Acid Orange dye on Coconut shell and Coal ash [43].

| **Time in minutes** | **Removal of Crystal Violet Dye (%)** | | | |
|---|---|---|---|---|
| | **50 mg/l** | **100 mg/l** | **150 mg/l** | **200 mg/l** |
| **10** | **32.78** | **41.85** | **49.60** | **56.01** |
| **20** | **40.05** | **50.20** | **58.00** | **67.38** |
| **30** | **46.60** | **57.54** | **66.64** | **75.45** |
| **40** | **52.70** | **63.70** | **73.83** | **82.55** |
| **50** | **57.85** | **69.90** | **82.90** | **89.30** |
| **60** | **61.09** | **76.35** | **88.40** | **94.12** |
| **90** | **68.64** | **85.25** | **96.60** | **99.05** |
| **120** | **72.84** | **92.85** | **99.20** | **100.00** |
| **150** | **73.00** | **93.20** | **100.01** | **100.00** |

**Table: 1 Adsorption of CV Dye from Aqueous Solution with Adsorbent Dosage Variation (PP)**

**Adsorption Kinetics**

The examination of adsorption kinetics is of paramount importance in the assessment of adsorbents for the removal of dyes from various sources effluent, as adsorption is a time-dependent process [44]. Kinetics is employed in adsorption experiments to provide valuable information regarding the adsorption rate and reaction path pathways, which in turn regulate the adsorption mechanism. The Lagergren pseudo-first order and second order rate equation, Elovich rate equation, and intraparticle diffusion rate equation were employed to investigate the kinetics of adsorption of CV dyes.

**Lagergren Pseudo-First Order Rate Equation**

The linearized form of the Lagergren pseudo-first order rate equation is expressed as

$$\log (qe-qt) = \log qe (k1/2.303) \times t$$

qt - amount of dye adsorbed at time ‘t’ (mg g-1), qe - amount of dye adsorbed at equilibrium time (mg g-1), k1 - the rate constant of pseudo first order kinetics (min-1), t - agitation time in minutes.

| **Time in minutes** | **log(qe-qt)** | | | |
|---|---|---|---|---|
| | **CRYSTAL VIOLET** | | | |
| | **30 mg/l** | **50 mg/l** | **70mg/l** | **100 mg/l** |
| **10** | **1.21** | **1.44** | **1.06** | **1.70** |
| **20** | **1.07** | **1.31** | **1.43** | **1.56** |
| **30** | **0.88** | **1.15** | **1.28** | **1.44** |
| **40** | **0.63** | **0.94** | **1.08** | **1.25** |
| **50** | **0.25** | **0.68** | **0.81** | **1.05** |
| **60** | **-0.11** | **0.41** | **0.60** | **0.75** |
| **80** | **------** | **------** | **0.24** | **0.39** |
| **Slope (-k1/2.303)** | **-0.025** | **-0.020** | **-0.024** | **-0.021** |
| **Intercept (log qe)** | **1.285** | **1.414** | **1.654** | **1.764** |
| **k1 × 10-2 (min-1)** | **5.9778** | **4.6060** | **5.5271** | **5.065** |
| **Correlation Coefficient (r2)** | **0.9534** | **0.9825** | **0.9721** | **0.969** |

**Table: 2 Pseudo-First Order Rate Equation for the Adsorption of CV Dye from Aqueous Solution onto potato peel**

**Intraparticle Diffusion Model :** There are four successive stages that elucidate the adsorption process of a chemical substance over a porous adsorbent: [23] Movement of adsorbate from the bulk solution to the liquid film or boundary layer that encircles the adsorbent, Surface or film diffusion: the transfer of adsorbate from the boundary film to the adsorbent's external surface , The movement of adsorbate from the adsorbent's surface to its interior pores (pore diffusion or intra-particle diffusion). The interior surface of the adsorbent is responsible for the adsorption of dyes. Control of the adsorption process's overall rate will be achieved through the weakest stage.

Steps (1) and (2) do not regulate the rate of adsorption, as the first step is not associated with the adsorbent and the fourth step is a highly rapid process. Due to this, the rate-limiting stages are primarily influenced by step two (film diffusion) and step three (intra-particle diffusion). According to Dawood and Sen (2014) [24], the slower of the two will be the rate-determining step, as they operate sequentially. Using the Weber-Morris equation [25] the probability of the adsorbate species diffusing into the inner sites of the adsorbent particles was assessed.

$$\mathbf{q = kid\ t^{1/2} + C}$$

**where, kid = intraparticle diffusion constant (mg g-1min-0.5), C = intercept**

Adsorption studies (batch mode) using adsorbents PP were carried out at 32±2°C and pH 6.8±0.2, with the aim of investigating the intra-particle diffusion process. Figures:3 displayed the findings. The slope of the straight line plots of qt vs $t^{1/2}$ was used to calculate the intra-particle diffusion rate constant (kid). The intra-particle diffusion model's high correlation coefficient ($r^2$) results agreed well. The values of kid increased as the dye concentration rose, indicating that the dye molecules' transmission via the adsorbents' stomas controls the adsorption rate. Plots that are linear and pass through the origin often indicate that the particle diffusion mechanism is the sole factor influencing the reaction's rate. The study's findings, which demonstrated that the plots were linear but did not pass through the origin, demonstrated that other kinetic models simultaneously restrict the adsorption rate, indicating that intra-particle diffusion was not the sole step limiting the rate [26]. Figure no 3 revealed that as the initial concentration of adsorbate molecules grew, so did the values of the intercept (C). An estimate of the boundary layer's thickness may be found in the intercept values. The boundary layer impact is bigger the greater the intercept. This might be because the adsorbent surface's most easily accessible active sites are used up right away [27]. The removal of Crystal Violet using water hyacinth [28], adsorption of Acid Blue 92 on agricultural wastes [29], adsorption of Congo Red on Jute fiber [30] and adsorption of Crystal Violet dye onto Opal [31] have all been documented in the literature as similar phenomena.

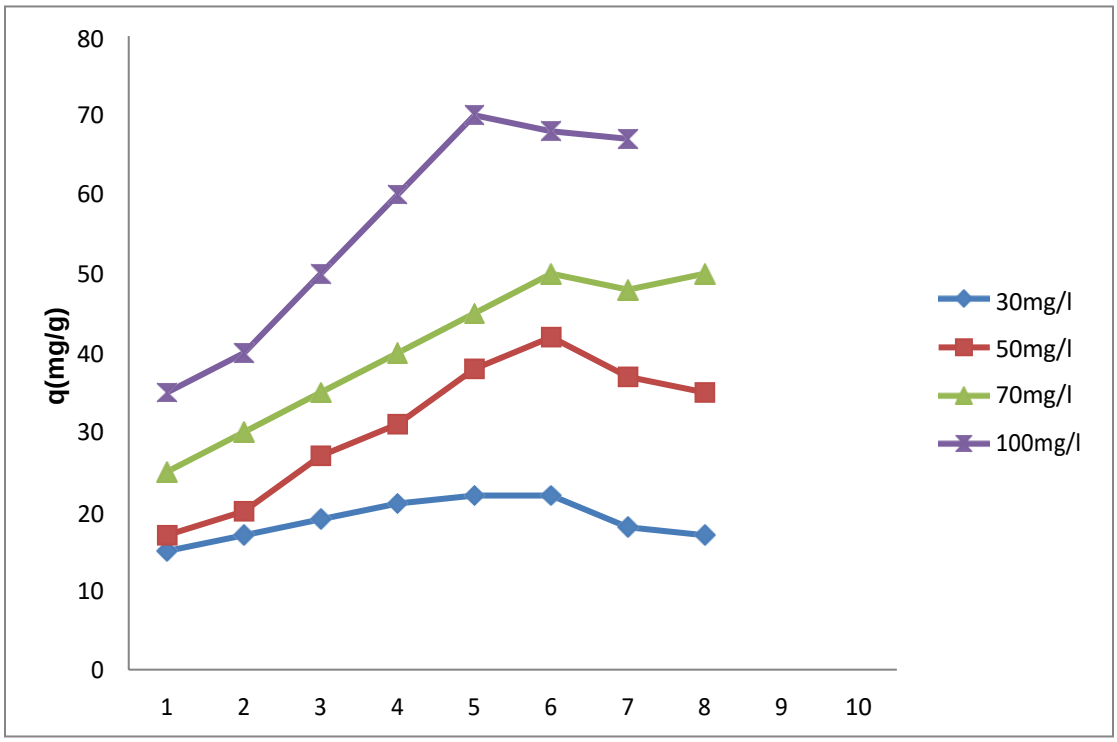



**Figure: 4 Intra practical diffusion Rate equation of CV dye from Aqueous solution onto PP**

**Elovich Kinetic Model:**

**Elovich model**

Using the Elovich equation below, one may investigate the kinetics of gas chemisorption onto solids.

$$qt = 1/\beta \ln(\alpha\beta) + 1/\beta \ln t$$

Where ‘qt ‘is the amount of dye adsorbed at time ‘t’(mg/g), α is the initial adsorption rate (mg g -1 min-1) and ‘β’ is desorption constant (g mg -1).

By graphing qt vs ln t, the values α and β may be calculated. From the intercept and slope of the straight line plots, one may determine the value of α and β, respectively. Figures- 4 provide the graphical depiction of the α and β values obtained in this work for the adsorption of CV dyes from aqueous solution for the adsorbents PP. The study conducted by [32] revealed that the potato peel adsorbents had more active sites on their surface for the immediate adsorption of dyes from aqueous solutions, as shown by the initial adsorption rate α increasing with dye solution concentration. According to studies conducted by [33], and [34], there is an increase in the adsorption of dye species as the initial concentration of the adsorbate solutions rises, as

shown by the values of β dropping down. [35] reported similar outcomes for the adsorption of Direct Yellow 12 dye on Coconut Shell carbon, [36] for the adsorption of Light Green anionic dye on surfactant modified Peanut Husk, [33] for the removal of Congo Red using, [37]for the adsorption of Malachite Green dye onto Sea .

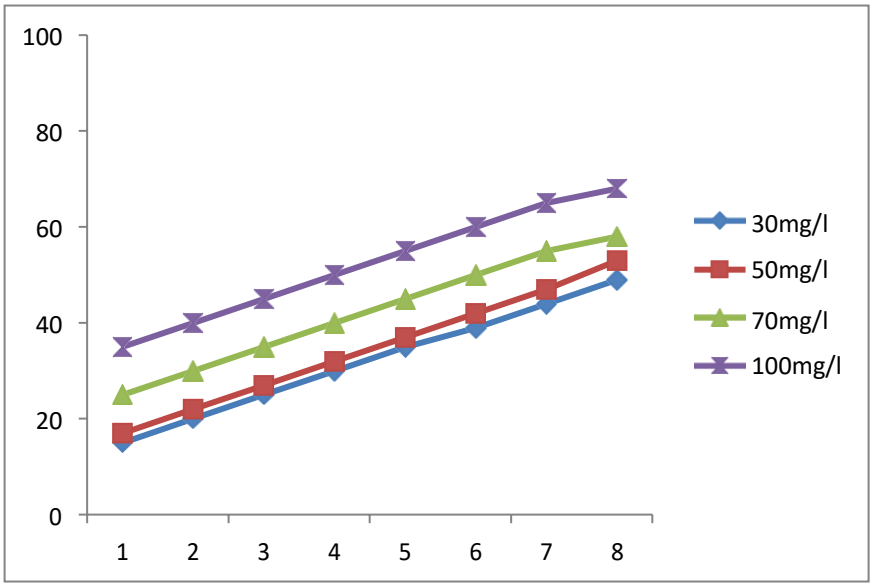



**Figure: 5 Elovich Rate Equation for the Adsorption of CV Dye from Aqueous Solution using PP**

**Adsorption Isotherms:** According to Bharathi Ramesh (2013) [23], the adsorption isotherm may be utilized to estimate the adsorbent's adsorption capacity as well as to evaluate the relationship between the adsorbate and adsorbent in any system. Adsorption isotherms may explain the relationship between the concentration of the adsorbate at equilibrium and the mass of the adsorbate retained per unit mass of the adsorbent [38]. The present work used the Langmuir and Freundlich adsorption isotherm models to demonstrate the experimental data in order to determine the adsorption capabilities of the adsorbents for the removal of dyes from aqueous solution. Using the adsorbents PP, adsorption isotherms were investigated by adjusting the starting concentration of the CV dye solutions.

In order to depict the surface coverage of the adsorbate on a solid adsorbent surface, Irvin Langmuir created the Langmuir adsorption isotherm. Adsorbate monolayer coverage over a homogenous adsorbent surface with energetically equal adsorption sites is described by the

Langmuir adsorption isotherm model [39] Furthermore, it is thought that compounds that have adsorbed at one location won't have an impact on molecules that haven't adsorbed at other sites [40]. The Langmuir adsorption equation in linear form is often written as

$$\mathbf{C_e / q_e = 1/ (q_m .K_L) + C_e/ (q_m)}$$

Where, Ce is the concentration of dye solution at equilibrium (mg/l), qe is the amount of dye adsorbed per unit mass of adsorbent (mg/g), Qm is theoretical monolayer adsorption capacity (mg/g) and $k_L$ is Langmuir equilibrium constant (l/mg) related to the affinity of the binding sites.

Figures 5 through 63 show the linear plots of Ce/qe vs Ce at various temperatures, which support the validity of the Langmuir isotherm model. The dye molecules seem to be covered in a monolayer on the surface of the adsorbents (PP) based on correlation coefficient values ($r^2$) that are near to unity. The slope and intercept of the plots (Ce/qe against Ce) were used to compute the parameters Qm and kL. The findings are shown in Tables--. Equation may be used to describe equilibrium parameter, also known as separation factor RL, a dimensionless constant that expresses the essential properties of the Langmuir isotherm.

$$\mathbf{R_L = 1/1 + k_L C_0}$$

Where, $C_0$ is the initial concentration (mg/l), $k_L$ is the Langmuir constant

From **figure 5** it was found that RL values for the removal of dyes (CV) lies in the range 0.0228 to 0.3650 indicates the favorable uptake of dyes onto potato peel adsorbents.

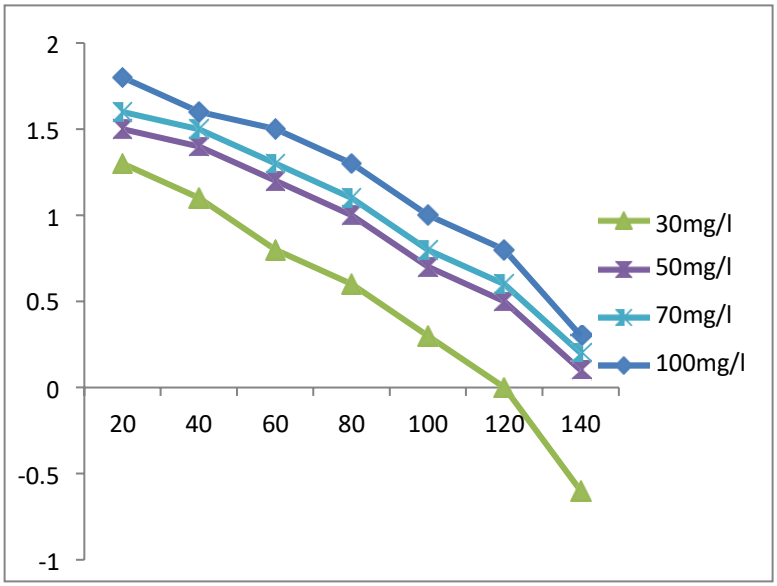
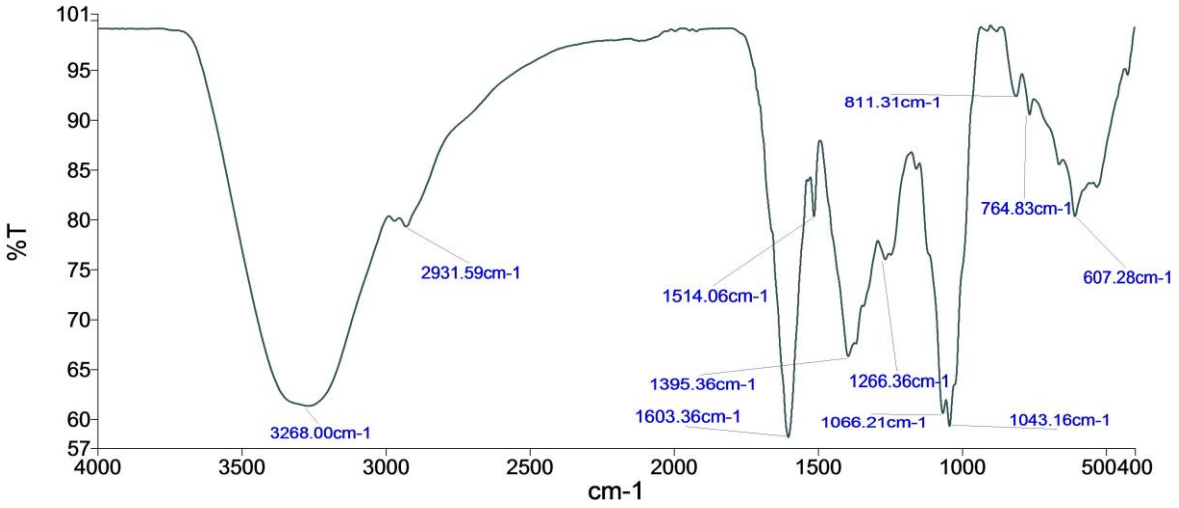
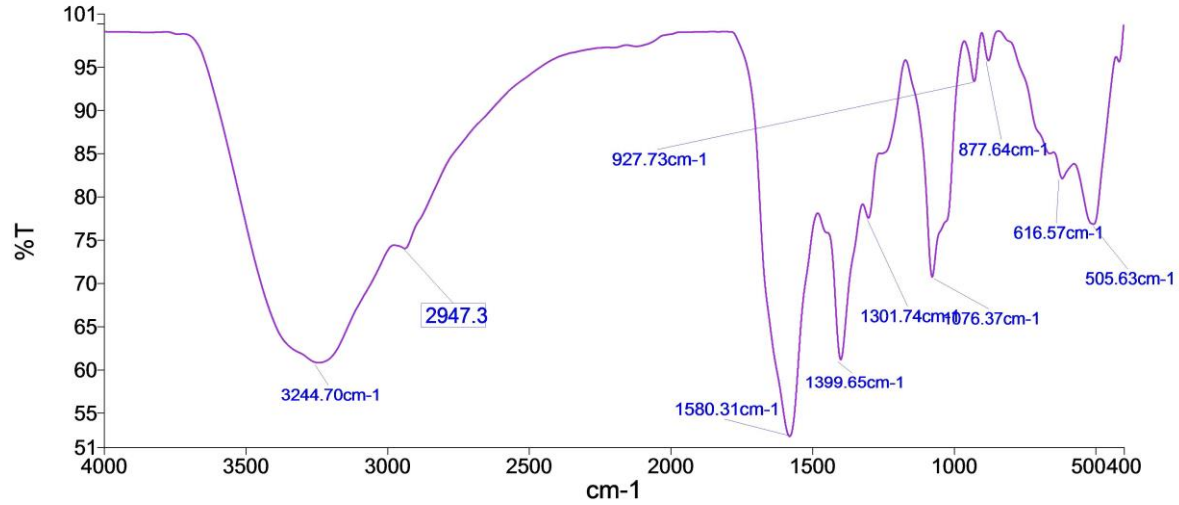



**Figure: 6 Lagergren rate Equation for the adsorption of Dye from Aqueous solution onto PP**

**FT-IR Spectral Analysis:** Applying infrared spectra may provide a significant portion of the information about the bonding mechanism in the dye complex. To learn more about the function groups that react with the dye in such a situation, the spectrums of AC(PP) and the AC(PP)-dye species are often compared. Figure 6 shows the FT-IR spectra of the absorbed and activated carbon (PP). The FTIR spectra of the adsorbent (AC) both before and after adsorption are shown in Figure 6(b). The FTIR spectrum of AC revealed distinct bands corresponding to –OH, carboxylic acid, N-H, S=O, -C-O, -C-H,- C-I were all assigned bands at 3244.70, 2947.3, 1580, 1399,1301.7,877.64,767.37 and 505.63 and cm−1. The full adsorption of the CV dye is shown by changes in bands to higher and/or lower in the FTIR spectrum of the AC-CV with the emergence or disappearance of other bands.




(a)




(b)

**Figure 7: FTIR for (a) activated carbon (PP) and (b) activated carbon with crystal violet dye.**

## Conclusions and Future Perspectives

The studies stated above demonstrate that the leftovers from the supercritical extraction of marigold may be used to create activated carbon adsorbents, which are very efficient at removing organic dyes from aqueous solutions. It is important to note that the samples produced in this

manner demonstrate a broad variety of applications by effectively removing pollutants from the gas phase as well as having a high efficacy of adsorption of liquid contaminants. The investigated activated carbons' adsorption qualities are on par with, if not superior to, those of commercial adsorbents and other adsorbents mentioned in the literature. It should be noted that the carbon adsorbents that have been reported by other authors have typically been produced by chemical activation using pricy activators, which significantly raises the cost of manufacture. Physical activation was used to generate the samples that we analyzed and acquired; this method was much less expensive and allowed for the acquisition of high sorption capacities.

In order to elucidate the viability of CV dye elimination, batch mode adsorption experiments were conducted by varying variables such as initial dye concentration, adsorbent dosage, pH, and temperature that have a substantial impact on adsorption performance. As the concentration of the dye solution increased with the adsorbents PP, the % adsorption of CV dyes from the aqueous dye solution showed a declining trend. This might be the result of fewer surface active adsorption sites being present on the adsorbents' surface at greater starting dye concentrations. The bio adsorbent dose was adjusted from 50 mg to 200 mg, which resulted in an improvement in the dye removal efficiency. The increased surface area and quantity of adsorption sites on the adsorbents' surfaces contributed to the rise in dye removal efficiency that occurred when adsorbent material was added. The proportion of cationic dye CV removed from the aqueous dye solution grew quickly as the pH of the solution rose. As the temperature was elevated from 30 to 50°C, the PP adsorbents' dye removal efficiency improved. As the temperature rises, the dye molecules become more mobile and have access to enough kinetic energy to form a strong bond with the adsorbent surface active sites. According to the adsorption kinetic investigations, the adsorption procedure adhered to the pseudo-first order kinetic rate equation proposed by Lagergren. The increased $r^2$ values show that this model did a good job of describing how the dyes employed in the research were adsorbed onto the adsorbents PP. Because there was more competition among adsorbate molecules for the surface binding sites of the adsorbents utilized in this investigation, the Lagergren rate constant $k_1$ values declined as dye concentration increased. Plots of the intraparticle diffusion, qt vs $t^{1/2}$, were linear and did not cross the origin, indicating that the adsorption rate was simultaneously limited by other kinetic models and that the intraparticle diffusion was not the sole step limiting the rate. The Elovich rate equation indicates that the initial adsorption rate, represented by α, increases as the

concentration of dye solutions rises. This suggests that the PP adsorbents have more active sites on their surface that facilitate the early adsorption of dyes from aqueous solutions. Langmuir and Freundlich adsorption isotherm models were used to examine the surface characteristics and adsorption behavior of the produced adsorbents PP. The high $r^2$ values found in this work suggest that the Langmuir isotherm is appropriate for CV dye adsorption onto PP adsorbents. The fact that the equilibrium parameter values obtained are smaller than one suggests that the dyes have a favorable absorption onto the adsorbents produced in this work. The straightforward absorption of CV dyes onto PP adsorbents is shown by the Freundlich adsorption plots, which show a linear relationship between log qe and log Ce. Additionally, the observed $K_f$ values, or adsorption capacity, increased with increasing temperature.

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