

Effect of pH on the Removal of RB₅ Dye Using Activated Carbon Derived from Banana Stem

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KEYWORDS	ABSTRACT
Adsorption Reactive black 5 dye Activated carbon Banana stem pH	The presence of Reactive Black 5 (RB ₅) dye in wastewater poses significant environmental concerns due to its toxicity, stability, and resistance to conventional treatment methods. Since pH has a significant influence on adsorption effectiveness, it is crucial to investigate its effect on RB ₅ dye removal using activated carbon derived from banana stem. This study aims to examine the influence of pH on RB ₅ adsorption using activated carbon banana stem and to determine the optimal pH condition for maximum color removal. To accomplish this, sample preparation and batch adsorption studies were conducted. The result show that pH 7 was the best condition for RB ₅ removal using banana stem activated carbon with 99.31% of dye removal and 16.55 mg/g of adsorption capacity. This finding indicates that pH is significantly affects dye removal efficiency.

1. INTRODUCTION

Reactive Black 5 (RB₅) is an anionic azo dye utilized in the textile sector, characterized by its durability, vibrant hue, and resistance to biodegradation, which complicates its removal from wastewater [1]. The release of RB₅ into aquatic habitats results in water pollution and introduces hazardous that endangering both ecosystems and human health [2]. Adsorption of activated carbon generated from banana stems has proven to be an efficient treatment method due to its cost-effectiveness, elevated porosity, and plentiful surface functional groups, rendering it appropriate for dye removal applications [3].

The pH of the solution has a significant impact on adsorption because it regulates both the surface charge of the adsorbent and the ionization state of dye molecules. Understanding its role is critical to maximizing dye removal efficiency. The purpose of this study is to assess the influence of pH on RB₅ adsorption using activated carbon banana stem and to establish the optimal pH level for maximum dye removal. By determining this ideal state, the researchers seek to obtain considerable knowledge into the adsorption mechanism and contribute to the development of cost-effective wastewater treatment solutions.

2. EXPERIMENTAL PROCEDURE

2.1 Materials and Chemicals

The sample preparation followed the procedure reported by [4]. With few modifications, banana stems were collected at Jeniang, Kedah, thoroughly washed with distilled water, cut into small pieces and dried at 105 °C

for 24 hours. To achieve fine powder shown in Figure 1, dried banana stem samples were crushed and then ground using a grinder and sieve. Reactive Black 5 (RB₅) dye was purchased from Sigma-Aldrich, while phosphoric acid (H₃PO₄) was used for chemical activation, hydrochloric acid (HCl) and sodium hydroxide (NaOH) were used for pH adjustment.



Figure 1. Banana stem powder.

2.2 Preparation of Activated Carbon

The dried banana stem powder was impregnated with H₃PO₄ solution at a ratio of 1:3 (w/v) and left 24 hours. The impregnated sample was subsequently carbonized at 400 °C for 1 hour in a muffle furnace. The produced activated carbon was rinsed with distilled water until achieving a pH 7, dried at 105°C, and preserved in an

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airtight container for adsorption analysis. The activated carbon powder is shown in Figure 2.



Figure 2. Activated carbon banana stem.

2.3 Batch Adsorption Experiments

Batch adsorption was conducted to determine the influence of pH on RB₅ removal. In 250 mL conical flasks, 100 mL of dye solution (200 ppm) was mixed with 0.6 g of activated carbon. The solution was modified using 0.1 M of HCl or NaOH to get initial pH of 3, 5, 7, 9, and 11. Samples were shaken at 100 rpm for 2 hours at room temperature. Following adsorption, the solutions were filtered and then was quantified utilizing a UV-Vis spectrophotometer at a wavelength of 597 nm.

2.4 Data Analysis

In wastewater treatment, dye removal from aqueous solutions is an essential step, particularly for industries that release colored effluents. The equation of dye removal percentage that use to measure how well dye removal and adsorption capacity works is represented by Equations (1) and (2):

$$\text{Dye Removal \%} = \frac{(C_0 - C_t)}{C_0} \times 100\% \quad (1)$$

$$\text{Adsorption Capacity} = \frac{(C_0 - C_t) V}{m} \quad (2)$$

where C_0 represents the initial concentration of the dye solution (mg/L), C_t is the concentration of the dye solution at a specific contact time, t while V is the solution volume (L) and m is the weight of adsorbent (g).

3. RESULTS AND DISCUSSION

The adsorption of RB₅ dye at different initial pH values are presented in Table 1 and Figure 3. The results clearly show that pH exerts a significant influence on dye removal efficiency. Previous investigations also shown that

adsorbents' adsorption capability varies with pH [5]. At acidic pH (3 and 5), dye removal efficiencies were 98.20% and 98.48%, with adsorption capacities of 16.37 mg/g and 16.41 mg/g, respectively. A considerable increase was found at neutral pH (7), where the maximal dye removal (99.31%) and adsorption capacity (16.55 mg/g) were measured. This may result from hydrogen bonding or weak interactions between dye solution and activated carbon [6]. The increased adsorption at neutral pH is due to favorable electrostatic interactions between the functional groups on the activated carbon banana stem surface and dye molecules [7] Beyond this threshold, at alkaline circumstances (pH 9 and 11), the adsorption capacity dropped to 16.40 mg/g and 16.30 mg/g, with dye removal efficiencies of 98.43% and 98.02%, respectively which contribute to the increased competition between hydroxyl ions (OH⁻) and dye anions for adsorption sites leads to reduced dye uptake [8]. These results show that pH 7 was the best condition for RB₅ removal with banana stem activated carbon.

Table 1 Dye removal and adsorption capacity at different pH

pH	Dye removal (%)	Adsorption Capacity (mg/g)
3	98.20	16.37
5	98.48	16.41
7	99.31	16.55
9	98.43	16.40
11	98.02	16.32

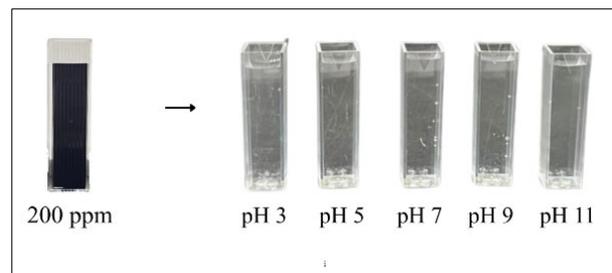


Figure 3. Visual comparison of RB₅ dye removal at different pH.

4. CONCLUSION

This study found that the solution pH has a significantly influence the adsorption of Reactive Black 5 (RB₅) dye onto activated carbon derived from banana stem. Among the investigated circumstances, pH 7 exhibits the highest dye removal efficiency and adsorption capacity indicating neutral condition was more favorable than acidic and alkaline settings. The fluctuation in performance across pH levels can be related to changes in the surface charge of the adsorbent and the dye molecules' ionization state, both of which have a direct impact on electrostatic interactions and binding affinity.

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