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Adsorption Study Of Methylene Blue Dye Using Banana Peel Derived Activated Carbon: Isotherm And Kinetic Modelling

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Abstract
This paper reports the adsorption performance of banana peel derived activated carbon (BPAC) for the removal of Methylene Blue (MB) dye from aqueous solutions. The adsorbent was prepared via chemical activation using phosphoric acid and characterised for adsorption efficiency through batch experiments. The effects of contact time, adsorbent dose, pH, and initial dye concentration were systematically evaluated. The adsorption process followed pseudo-second-order kinetics with a correlation coefficient (R^2) of 0.991, suggesting chemisorption as the predominant mechanism. Equilibrium data were best described by the Langmuir isotherm model with a maximum adsorption capacity (qmax) of 82.45 mg/g. The study demonstrates that banana peel waste can be effectively utilised as a sustainable and low-cost adsorbent for dye-contaminated wastewater treatment.

Keywords: *Banana Peel Waste, Activated Carbon, Methylene Blue, Adsorption Kinetics, Isotherm Models, Wastewater Treatment*

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I. Introduction

The discharge of synthetic dyes such as Methylene Blue (MB) into aquatic systems poses a severe environmental threat due to their toxicity and persistence. Conventional treatment techniques like coagulation and filtration often fail to effectively remove such dyes. Adsorption has emerged as a simple and efficient process for dye removal owing to its low cost and high efficiency. Banana peel, a lignocellulosic agricultural residue, contains functional groups like hydroxyl and carboxyl, which can serve as active sites for dye adsorption. The present study investigates the adsorption potential of banana peel derived activated carbon (BPAC) for MB removal under batch conditions.

II. Materials And Methods

Preparation of Activated Carbon

Banana peels were washed, dried, powdered, and soaked in 1 M H_3PO_4 solution for 24 hours. The material was then carbonised at 550°C for two hours, washed to neutral pH, and dried at 110°C.

Batch Adsorption Experiments

The adsorption experiments were conducted using 100 mL MB dye solution at varying initial concentrations (10–100 mg/L). The effects of contact time (0–150 min), adsorbent dose (0.1–1.0 g/L), and pH (3–10) were studied. Dye concentration was measured using UV–Vis spectrophotometry at 664 nm.

Data Analysis

Adsorption capacity (qe) and removal percentage were calculated using standard equations. Isotherm and kinetic models were applied to interpret the adsorption mechanism.

III. Results

Table 1: Adsorption Data for MB Dye on Banana Peel Activated Carbon

Time (Min)	Dye Removal (%)	Adsorption Capacity (Mg/g)
0.0	0.0	0.0
15.0	22.3	11.2
30.0	47.8	24.1
45.0	61.4	31.2

60.0	73.1	37.9
75.0	80.6	41.8
90.0	84.3	43.8
105.0	86.9	45.1
120.0	87.5	45.5
150.0	87.5	45.5

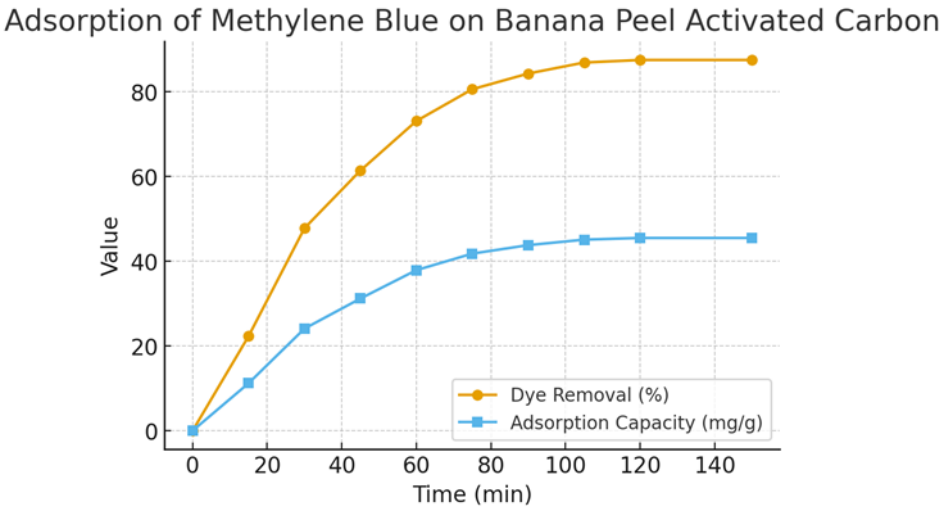

Figure 1: Adsorption kinetics of Methylene Blue dye using Banana Peel Activated Carbon.

IV. Discussion

The adsorption of MB dye onto BPAC was rapid in the initial stages due to the abundance of available active sites. Equilibrium was achieved after 120 minutes, beyond which no significant adsorption occurred. The pseudo-second-order kinetic model provided the best fit with $R^2 = 0.991$, suggesting chemisorption as the controlling mechanism. The Langmuir isotherm model exhibited the best correlation among the tested models, indicating monolayer adsorption behaviour. The maximum adsorption capacity (qmax) was 82.45 mg/g, which is higher compared to many other bioadsorbents reported in literature. These results confirm that banana peel activated carbon can serve as a viable, eco-friendly adsorbent for the treatment of dye-polluted water.

V. Conclusion

The study concluded that banana peel derived activated carbon is an efficient and economical adsorbent for Methylene Blue dye removal. The adsorption process followed pseudo-second-order kinetics and the Langmuir isotherm, indicating a monolayer chemisorption mechanism. The findings support the utilisation of agricultural waste materials in the development of sustainable wastewater treatment technologies.

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