

Study Of The Adsorption Of Methylene Blue Dye From An Aqueous Solution Using Water Hyacinth Leaf Powder

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Abstract

The adsorption of Methylene Blue from an aqueous solution onto the surfaces of powdered water hyacinth leaf was examined in this work. Water hyacinth leaf powder was utilized for conducting batch testing. The study also investigated the impact of contact time, leaf powder dosage, and initial pH on the effectiveness of removal. We investigated the equilibrium and kinetics of MB adsorption on this adsorbent at a temperature of 25°C. The kinetic data were analyzed using models for pseudo first-order and pseudo second-order. The sorption data were subsequently utilized to fit the Langmuir and Freundlich adsorption isotherm models. The most effective dose of WH leaf powder for removing MB was found to be 0.4 g/l, resulting in a removal efficiency of 95.90% when the contact period was 3 hours. The adsorption kinetics of MB on WH leaf powder has been found to follow a pseudo second-order model. The isotherms exhibited a strong correlation with the experimental results. The WH leaf powder has a capacity of 52.35 milligrams of MB per gram of WH leaf powder. The findings indicate that WH leaf powder can serve as a very efficient adsorbent for the removal of MB from an aqueous solution.

Keywords: Methylene Blue dye, Water Hyacinth, Batch study, Isotherms.

INTRODUCTION:

Industry innovations in recent years have had an impact on both the environment and society. Adegoke, K.A., and O.S. Bello¹ Rubber, plastics, textiles, paper, and leather industries use a variety of synthetic dyes to colour their goods. Nirmala S et al.² As a result, they generate a large quantity of colourful effluent. The textile industry uses dyes for fibre colour more than any other industry. The global textile industry uses 10,000 tonnes of dye each year, with an estimated 90% of that being absorbed into clothes. The remaining 10% of dyes (about 1000 tonnes per year) enter the streams as coloured wastewater. Marc S.R.³ Synthetic colouring has mainly replaced natural colouring due to its inexpensive cost and diverse selection of new colours. H. Gabriel and J. Hong.⁴ There are currently around 10,000 commercially available colourants with varying chemical compositions. S. Arivoli and M. Thenkuzhali.⁵ Significant amounts of these colourants can be found in effluents from the textile, paper and pulp, paint, printing, and cosmetics industries, which must be treated before being discharged into water bodies in accordance with environmental standards. S. Tezer and Z. Aksu.⁶ The discharge of dye-bearing wastewater into rivers and other bodies of water has a multitude of consequences for aquatic life, the stream ecosystem, and food chains, in addition to impacting the aesthetic quality of the ecosystem. S. T. Ramesh and K.S. Bharathi.⁷ The removal of colour from textile wastewater is crucial since the emitted colours might pollute the environment and have harmful and cancerous effects on living beings. As a result, the treatment of textile wastewater has become a serious issue. Hameed B.H. et al.⁸

Many treatment methods have been used in the textile industry to remove dye from wastewater, including photo-catalytic and combined electrochemical methods Neelavannan M. G. et al.⁹, integrated chemical-biological degradation Sundarjanto G. et al.¹⁰, biodegradation Daneshvar N. et al.¹¹, Fenton biological treatment scheme Lodha B. and Chaudhari S.¹², Photo-catalytic degradation by TiO₂/UV Sohrabi M. R. and Ghavami M.¹³, photo/ferrioxalate method Huang Y. H. et al.¹⁴), Fenton process (Behnajady M. A. et

al.¹⁵), Electrochemical degradation Fan L. et al.¹⁶, Photo-Fenton method Garcia-Montano J. et al.¹⁷, Sonochemical degradation Abbasi M. and Asl N. R.¹⁸, process of adsorption Hameed B.H. et al.¹⁹, chemical precipitation, oxidation, ion exchange, cloud point extraction, coagulation/flocculation, nano-filtration, reverse osmosis, and ultra-filtration. (Malik P. K. and Saha S. K.²⁰; Lorenc-Grabowska E. and Gryglewicz G.²¹). Each strategy has unique advantages and disadvantages.

Among the options discussed above, adsorption is gaining prominence as a means of treating aqueous wastewater. Adsorption technique has several advantages, including expected low cost regeneration, the availability of standard process devices, sludge-free service, and sorbate recovery. I.K. Kapdan and F. Kargi.²² Because of its wide specific surface, microporous geometries, high adsorption potential, and high surface reactivity, activated carbon is the most commonly used adsorbent for dye removal. However, commercially available activated carbon is relatively expensive, with significant regeneration expenses. Furthermore, solution generation produces a modest quantity of extra effluent, whereas refractory regeneration causes a 10-15% loss of adsorbent and adsorption capacity. P. Waranusantigul et al.²³. This has prompted a hunt for cheaper materials. Researchers are continually attempting to develop more appropriate, efficient, sustainable, and low-cost adsorbents, particularly from industrial solid waste, agricultural by products, and natural materials.

Previous studies used a variety of adsorbents to remove colours from industrial effluent, including fly ash, peat, saw dust, rice husk, brown coal, jackfruit leaf powder, grapefruit peel, and ginger waste, among others. Exploration of good low-cost and novel adsorbents may help to ensure environmental sustainability. Water hyacinth is known for its rapid, invasive growth, which has a severe influence on biodiversity. However, because to its adsorptive properties, the facility is currently the subject of numerous studies and researches on wastewater treatment, namely the removal of impurities such as heavy metals, colouring agents, and various organic and chemical substances. With this in mind, water hyacinth was selected as an adsorbent for the current investigation.

MATERIALS AND PROCEDURES.

Water hyacinth was employed as an adsorbent and was manually harvested in sufficient quantities from streams in Guntur. The material is thoroughly cleansed with water to eliminate dirty particles that have adhered to the plant. Next, the roots, stems, and leaves of the water hyacinth plant are separated. Now, the material is exposed to the atmosphere in order to remove the water content of the plant, causing the plant to dry. After the material has been dried, it is separated into powders for roots, stems, and leaves.

An aqueous solution was prepared using methylene blue dye. The solution (10 mg/L) was created by dissolving sufficient volumes of Methylene Blue dye in double-distilled water. The working solutions were created by diluting the stock solutions to the proper amounts. This material was combined with the dye solution, and the adsorption investigation was conducted by adjusting the adsorbent dosage, contact time, and solution pH. All of the trials were carried out in batches.

RESULT & DISCUSSION

BATCH STUDY

The synthetic solution was mixed with water hyacinth leaf powder and shaken at 250 rpm and 27°C (Room temperature). The UV-visible spectrophotometer is used for all analysis, and it can determine a specific dye concentration. As previously stated, the investigation will be conducted in three stages: kinetic (optimisation of contact duration), isotherm (optimisation of adsorbent dosage), and pH.

THE EFFECT OF CONTACT TIME

The retention of MB dye increased with contact time for a fixed adsorbent mass and a fixed MB dye concentration. The adsorption rate initially increased quickly, as shown in Figure 1, and the optimal

removal efficiencies for MB were reached within around 3 hours: 64.89%, 12 hours: 75.10%, 24 hours: 80.71%, 36 hours: 93.68%, and 48 hours: 98.49%. However, the equilibrium (highest) value for MB was reached at roughly 12 hours, with adsorption rates of 75.10%, respectively.

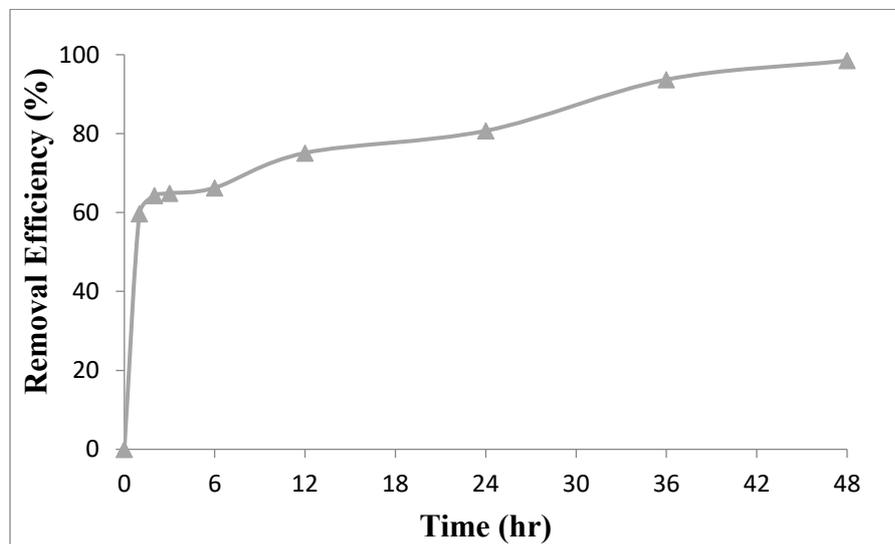


Fig. 1 the Influence of Contact Time on MB Removal

EFFECT OF ADSORBENT MASS.

The effect of adsorbent dosage on MB dye removal was investigated by altering the dosage of water hyacinth leaf powder, and the findings given in Fig. 2 reveal that removal effectiveness rises as the water hyacinth leaf powder dose increases from 0.01 to 0.5 g/l for MB. This is mostly owing to the saturation of adsorbent sites caused by dye adsorption at dosage levels of 0.06, 0.2, and 0.4 g/l. Thus, the optimal doses for MB dye removal are 0.06, 0.2, and 0.4 g/l, with removal efficiencies of 75.16%, 91.10%, and 95.90%, respectively.

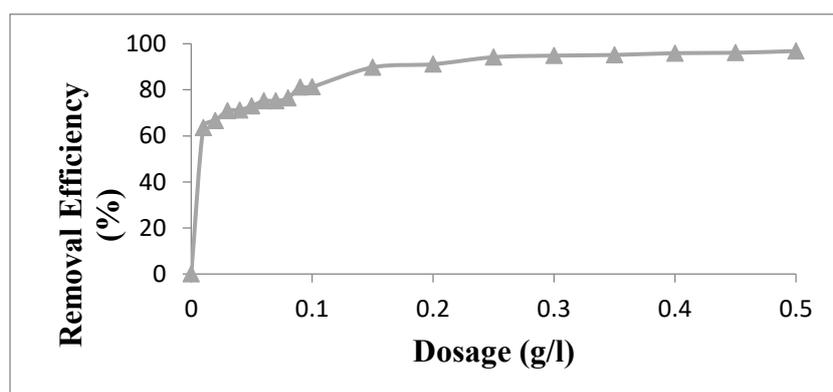


Fig. 2 Effect of dosage on removal of MB

EFFECT OF PH

The pH of the solution influences Methylene blue dye uptake significantly since it controls the adsorbent's surface charge, as well as the degree of ionisation and speciation of the adsorbate. The figure 3 depicts the % elimination of MB dye as a function of pH at a concentration of 10 mg/l. In general, the amount of methylene blue removed increases as pH climbed, reaching above 90% at a certain pH level. As pH rises from 4 to 8, the WH surface gets increasingly negatively charged. As pH increased, more favourable

electrostatic attraction forces facilitated cationic dye ion adsorption. The elimination of MB dye was approximately 90.87% at pH 6 and increased to 95% at pH 12.

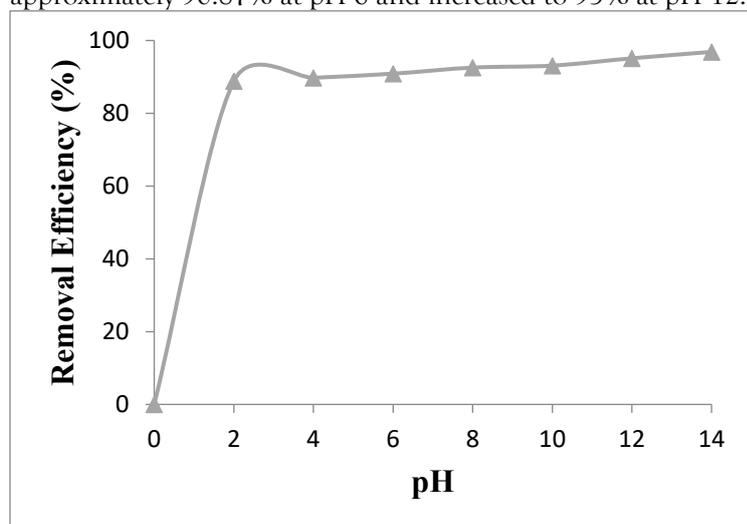


Fig. 3 the Effect of pH on MB Removal

DETERMINATION OF ADSORPTION ISOTHERM

The capacity studies, commonly referred to as equilibrium adsorption isotherms, are essential for designing adsorption systems because they illustrate the distribution of MB dye as a function of dye concentration between the liquid and adsorbent phases at equilibrium. Methylene blue concentration on an adsorbent's surface rises in response to an MB dye solution until a dynamic equilibrium is established, at which point dye ions are evenly distributed between the liquid and solid phases. The methylene blue dye has a fixed adsorbent mass and pH, and its concentration is 10 mg/l.

Two important adsorption isotherms, Langmuir and Freundlich, were evaluated for their ability to fit the experimental data. When compared to the Freundlich isotherm, the Langmuir isotherm plot produced a satisfactory fit with experimental data, as seen in Figure 4 & 5. The Langmuir and Freundlich isotherm constants are shown in Table 1, and the linear correlation coefficients for MB in the plots are satisfactory. The isotherm plot in Fig. 4 shows that the Langmuir isotherm was well-suited to the adsorption of Methylene blue dye on WH.

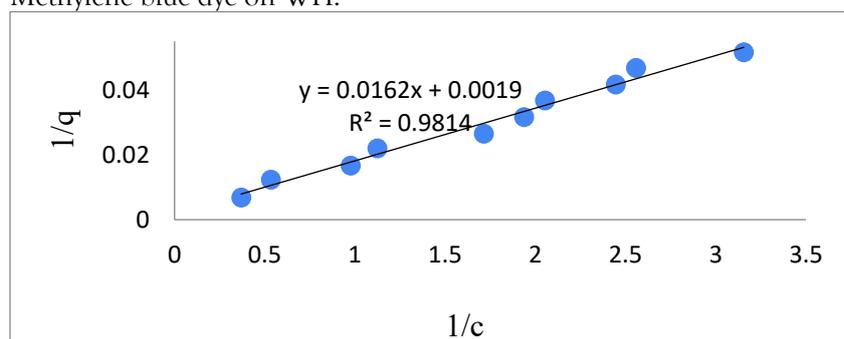


Fig. 4 Langmuir isotherm plot for sorption of MB by WH leaf powder

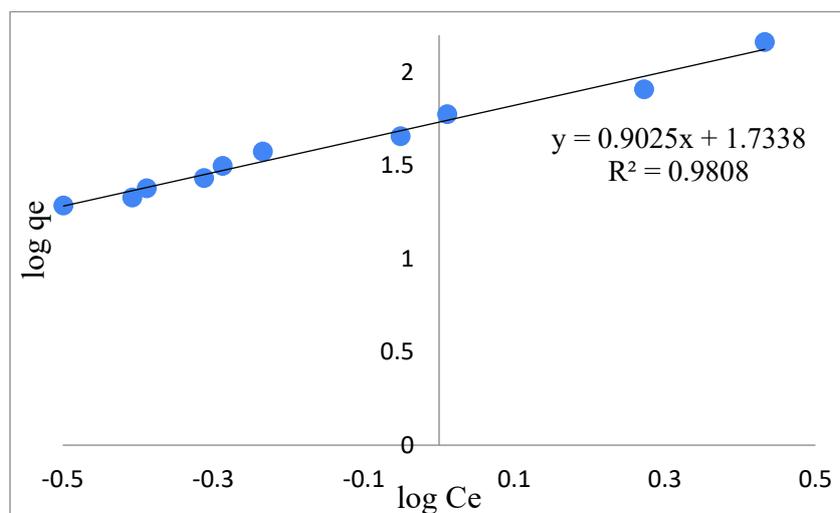


Fig. 5 Freundlich isotherm plot for sorption of MB by WH leaf powder

Table 1 Langmuir and Freundlich isotherm constants for MB dye

Dye	Langmuir isotherm parameters			Freundlich isotherm parameters		
	q_{\max} (mg/g)	K_a (mg/l)	R^2	K_f (mg/g)	n	R^2
MB	52.35	0.116	0.98	7.98	1.364	0.98

KINETIC STUDY

Kinetic tests involved shaking water hyacinth leaf powder conical flasks in an orbital shaker for 48 hours at 25° C. In these studies, 0.1 g of WH leaf powder was added to 100 ml of aqueous solution containing 10 mg/l of methylene blue solution. The MB concentrations were measured at various time periods. As illustrated, the WH leaf powder absorbed methylene blue at a quick pace. The MB clearance rate was 68.6% in the first 3 hours and 77.3% after 12 hours; MB equilibrium was achieved after 12 hours. At equilibrium, 77.3% of the MB was removed from the solution. The Lagergren equation was used to obtain the rate constants for MB adsorption on WH.

To elucidate the adsorption process, multiple adsorption models were used to assess the experimental data. For this objective, Lagergren's pseudo first-order and pseudo second-order kinetic models were investigated and fitted to the experimental data. Figures 6 & 7 depict the first- and second-order models for MB adsorption by the WH leaf powder, respectively. Table 2 lists experimental and theoretically estimated adsorption capacities at equilibrium (q_e) values, as well as coefficients for kinetic plots. The results in Table 3.2 show that the first-order model's linear correlation coefficients are inferior to the second-order models. Thus, our findings show that MB adsorption on WH leaf powder is not a first-order process. The results of the second-order model show that the correlation coefficients for MB are extremely high, and the actual and theoretical q_e values match well. These findings indicate that the MB adsorption on WH leaf powder occurs via a second-order kinetic process.

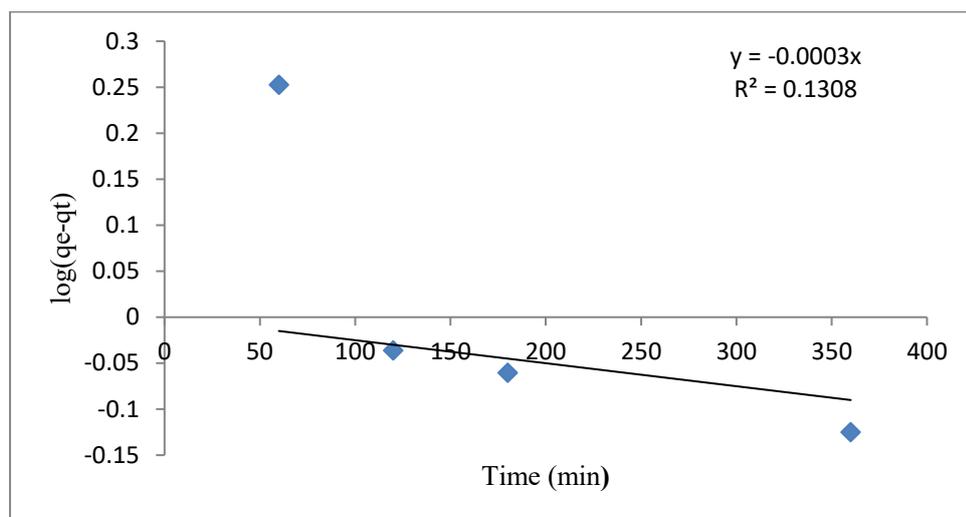


Fig. 6 Pseudo first order model for MB dye by WH leaf powder

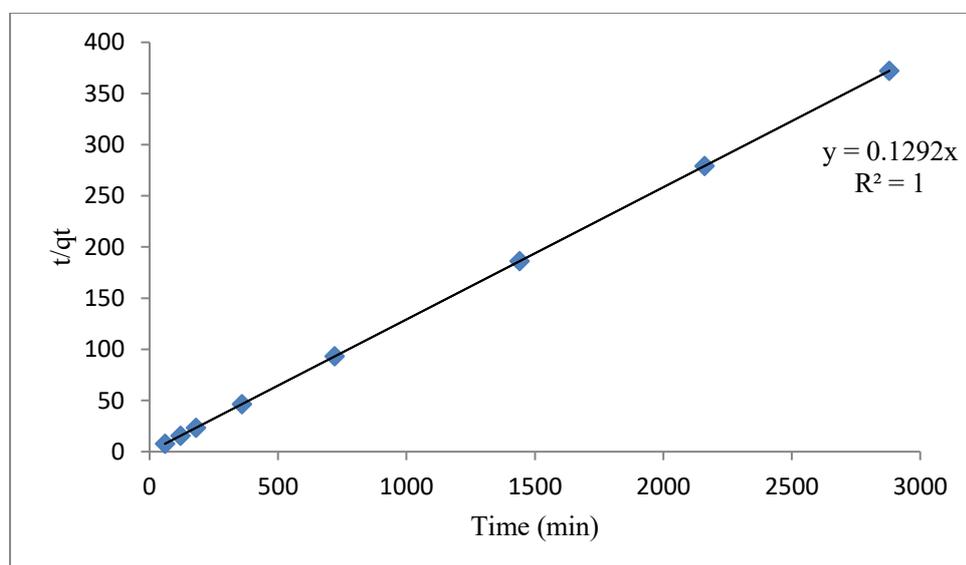


Fig. 7 Pseudo second order model for MB dye by WH leaf powder

Table 2 Adsorption kinetic model rate constants for MB

Dye	Pseudo first-order			Pseudo second-order		
	q _e cal (mg/g)	K ₁ (/min)	R ²	q _e cal (mg/g)	K ₂ (g/mg/min)	R ²
MB	-	0.00069	0.1	7.75	-	1

CONCLUSION:

The ability of Water Hyacinth leaf powder for MB dye adsorption was investigated utilising equilibrium and kinetic analysis. The results demonstrate that Water Hyacinth leaf powder is an effective adsorbent for extracting MB dye from aqueous solution. The optimal dose of Water Hyacinth leaf powder for MB dye removal has been determined to be 0.4 g/l, with a removal effectiveness of 95.90%. It is discovered that the MB adsorption kinetics on WH follow a pseudo second-order process. The Langmuir isotherm fit experimental data better than Freundlich isotherms. The adsorption capacity of WH leaf powder was determined to be 52.35 mg/g.

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