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Removal of Methyl Orange Dye from Aqueous Solution onto Sustainable Sugarcane Bagasse *(Gramineae Saccharum)* Biomass

Nurul Suhada Daroies[1], Hazren A. Hamid[1]*

[1] *Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn, 84600 Pagoh, Johor MALAYSIA*

*Corresponding Author: norhazren@uthm.edu.my
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Abstract

The river and its environment are irreplaceable resources that must be cared for and preserved so that they are not exploited excessively and without control, which will ultimately result in the destruction of the environment and water pollution that is too costly and difficult to restore. It was discovered that the textile industry's effluent was highly acidic and colored. The textile sector also contributes to river pollution by discharging untreated effluent into surrounding drains. This will affect and cause problems during the water treatment procedure later. Sugarcane bagasse, due to its particular properties, can be employed as a biomass adsorbent to mitigate these problems. This research examines the efficacy of sustainable sugarcane bagasse in removing methyl orange dye from aqueous solutions. Initial dye concentration, sorbent dosage, and contact time were parameters. According to the data, sugarcane bagasse may be a good methyl orange dye adsorbent. Batch experiment adsorption data was analyzed using Langmuir and Freundlich isotherms and pseudo 1st and 2nd order kinetic models. Sorbent dosage of 6g, dye concentration between of 237 to 388 ADMI, and contact time of 60 minutes are optimum parameter. The optimal estimation of this parameter is based on the analysis of a significant decrease in readings from a concentration of 237 to 63 ADMI, as well as from a concentration of 388 down to 98 ADMI. The application has demonstrated satisfactory absorption which means that the water meets the required quality standards A for industrial effluent to be discharged into the river. It is possible that the practical usability and sustainability of this approach in real-world circumstances could be improved by further optimization and research of regeneration approaches.

1. Introduction

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Synthetic dyes have become increasingly important to dyeing industries in recent decades. The world is undergoing a transformation due to enormous advancements in technology. Rapid development pollutes and disrupts the environment. Industrial water usage is rising rapidly, resulting in large amounts of contaminated wastewater. Dye-related pollution comes from paper, tanning leather, processing food, dealing with plastics and cosmetics, rubber and ink, printing, and dyeing [1]. Colored effluent has the potential to affect aquatic ecosystems through the inhibition of light penetration and disruption of photosynthesis, both of which are essential for the development of aquatic organisms and plants [2]. Chemical additives used in the dyeing process, including fixing agents, levelling agents, and surfactants, also contribute to effluent contamination [3]. When these additives are discharged into the wastewater, they contribute to the overall pollution burden and may present additional treatment challenges. Wastewater treatment resulting from industrial processes employs an assortment of technologies. A diverse array of methodologies and technologies are employed during the treatment of wastewater originating from industrial sources to effectively mitigate the unique characteristics of the wastewater.

Saccharum officinarum is the scientific name assigned to sugarcane, a member of the *Gramineae* family of plants (*grasses*). Bagasse from sugarcane is the fibrous byproduct that remains following the crushing of sugarcane stalks in order to extract liquid for sugar production. The principal constituent of bagasse is cellulose, an intricate carbohydrate that makes up an estimated 40-45% of its total dry weight. Bagasse is predominantly composed of hemicellulose, a mixture of various polysaccharides that accounts for approximately 25-30% of its overall structure. Bagasse contains an estimated 20-25% lignin content, which is a complex polymer responsible for imparting mechanical stability [4]. This project has been conducted to removal of methyl orange (MO) dye from aqueous solution onto sustainable sugarcane bagasse (SCB) biomass. The parameter that has been conducted in this study included dye concentration, sorbent dosage and contact time. The dosage of the sorbent can affect the kinetics of the adsorption process and the time necessary to reach equilibrium. Due to the increased availability of sorption sites, higher dosages may cause faster adsorption rates and shorter equilibrium durations. In order to optimize the sorbent dosage and obtain effective and efficient dye removal, it is necessary to consider the concentration and characteristics of the dye and the contact time [5]. Numerous binding sites are provided by the sorbent material for the dye molecules, and a higher initial dye concentration increases the likelihood of interaction and adsorption [6]. According to previous research, a substantial amount of researcher make use of SCB that has been treated and modified, which is referred to as activated carbon SCB. By utilizing natural SCB, it is possible to draw the conclusion that raw SCB has the capacity to act as an effective adsorbent.

2. Materials and Methods

2.1 Materials

For the preparation of sorbent, sugarcane bagasse was collected from sugarcane water stalls on the roadside. the SCB was rinsed and washed three times with tap water and then rinsed it again with distilled water to eliminate grime, dust and other foreign particles. SCB has been dried to reduce its moisture content following the washing process. The SCB was dried for 19 hours at a temperature of 105°C in a drying oven. After the SCB has been completely dried, the SCB was cut into small pieces and then moved to the grinded process for becoming a powder by used a grinding machine. The SCB then was sieved through a mesh of more than 300 µm. The parameters used in the adsorption process consist of adsorbent doses of 2, 4, and 6 grams.

Methyl orange (MO) has been used as the synthetic dye. The stock solution was diluted to meet specifications. In this project, dye solution with a concentration of 237, 388 and 527 ADMI has been prepared by using 0.001 g of methyl orange (MO) that have been diluted with 1000 mL distilled water. The pH of the dye solution has been adjusted by adding a small volume of hydrochloric acid (HCl) to get the neutral pH range which is 6.5 to 7.5. The dye solution then been transferred to an appropriate storage container which is conical flask with labelling. Then, the dye solution has been keep prevented from degrading due to exposure to light, it was kept in a cool room and dark location.

2.2 Orbital shaker

In this project, 100 mL of a 237, 388 and 527 ADMI dye solution concentration methyl orange was mixed with 2, 4, and 6 grams of sugarcane bagasse has been run by using orbital shaker for 60, 90 and 120 minutes at 100 rpm.

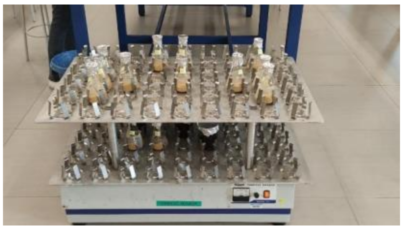


Figure 1 Run orbital shaker

2.3 ADMI color measurement

Color testing to get rid of dye involves figuring out how well a SCB biomass sorbent makes a dye solution less concentration. Using the absorbance or transmission of light at certain wavelengths, the Hach DR6000 Spectrophotometer has been used to measure how much the color has changed. Water samples were prepared by filtering to remove any suspended particles and then the readings have been taken to obtain data.

2.4 Equation removal efficiency

The experiments was conducted as shown in Figure 2. The initial dye concentration was prepared with three different concentration which is 237, 388 and 527 ADMI. The sorbent dosage SCB that has been used was 2, 4 and 6g with three different contact time which is 60, 90 and 120 minutes.

Figure 2 Adsorption process

In this study, after the solution has been shaken, the samples have been measured their final dye concentration and compared with the initial dye concentration. For the percentage removal efficiency of treatment test calculated based on the following formula:

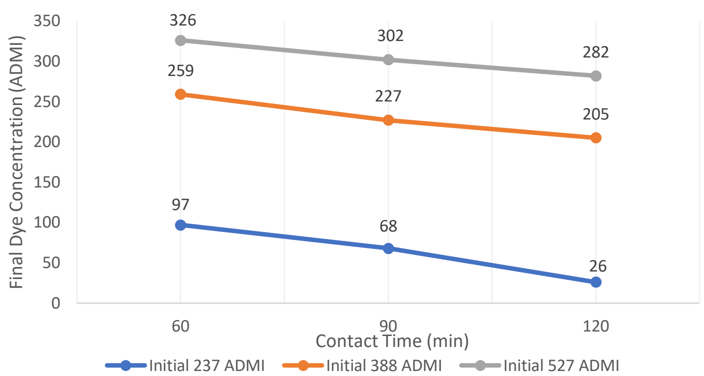
$$\%\ Removal\ Efficiency = \left(\frac{Ci - Ce}{Ci}\right) x\ 100 \quad (1)$$

Where C_i is initial dye concentration and C_e is final dye concentration.

3. Results and Discussion

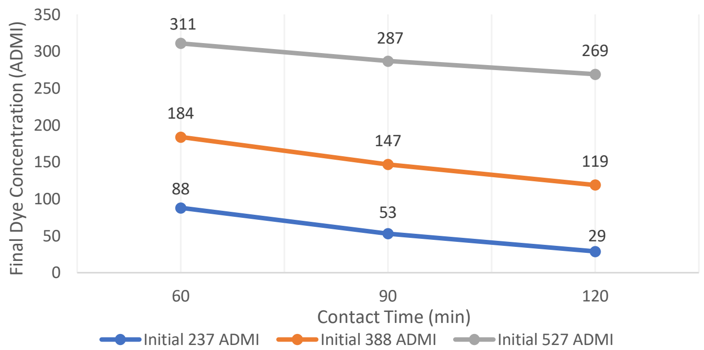
3.1 Effect of dye concentration of adsorbent and contact time

The effect of different concentrations of methyl orange (MO) on the adsorption efficiency of SCB biomass was investigated with sorbent dosage of 2, 4 and 6g, three different concentrations of methyl orange (MO) dye which is 237, 388 and 527 ADMI at different contact times.



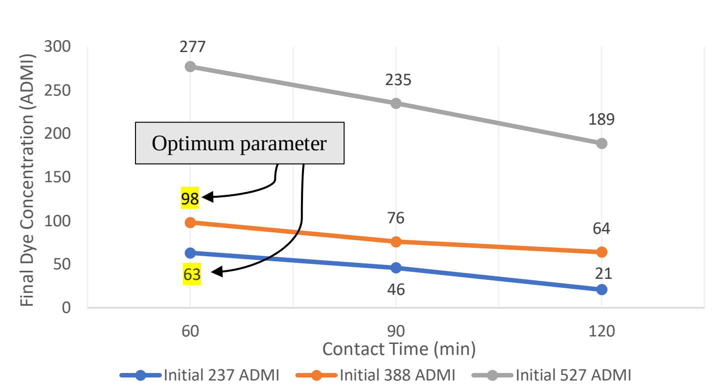
Parameter	Unit	Standard A	Standard B
Colour	ADMI	100	200

Figure 3 Graph of final dye concentration vs contact time for 2g sorbent dosage



Parameter	Unit	Standard A	Standard B
Colour	ADMI	100	200

Figure 4 Graph of final dye concentration vs contact time for 4g sorbent dosage



Parameter	Unit	Standard A	Standard B
Colour	ADMI	100	200

Figure 5 Graph of final dye concentration vs contact time for 6g sorbent dosage

According to the Figure 3, the application of 2g of sorbent dosage has demonstrated satisfactory absorption at a dye concentration of 237 ADMI, which means that the water meets the required quality standards A for industrial effluent to be discharged into the river. Nevertheless, the 2g sorbent dosage is unable to absorb the dye solution at a high concentration when the concentration is between 388 and 527 ADMI. Therefore, it is not possible to discharge it into the river because it was still in a hazardous condition.

Figure 5 more thoroughly shows that the application of 6 grammes of sorbent dose has showed excellent adsorption at a dye concentration of 237 and 388 ADMI. This is demonstrated by the fact that the adsorption was successful. In the meantime, the 6g sorbent dosage is still unable to absorb the dye solution at a high concentration, and it does not fulfil the needed quality standards A for industrial effluent to be discharged into the river. This is the scenario for the dye concentration of 527 ADMI. Based on the findings of this data analysis, the optimal parameter has been determined to be the sorbent dosage of 6g, with the dye concentration being between 237 and 388 ADMI, and the contact time being 60 minutes. The optimal estimation of this parameter is based on the analysis of a significant decrease in readings from a concentration of 237 to 63 ADMI, as well as from a concentration of 388 down to 98 ADMI. It is appropriate to use this parameter for the testing that will take place in the actual industrial effluent discharge.

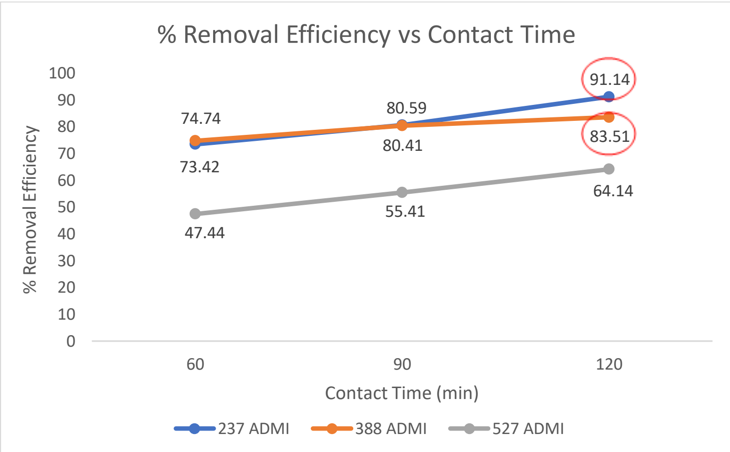


Figure 6 Graph of percentage removal efficiency for 6g sorbent dosage

Based on the graph shown in the Figure 6, the best results can be shown for the percentage of removal efficiency at dye concentrations of 237 and 388 ADMI for 6g. The success of the adsorption capacity may be determined by the use of the parameters that were discussed previously, which is sufficient evidence to be highly optimistic.

3.2 Kinetic study

The investigation of the methyl orange (MO) adsorption rate on SCB biomass adsorbents is conducted relying on pseudo-first-order and pseudo-second-order kinetic models. Analyses of the characteristics of adsorption and calculation of adsorption rate constants were accomplished using the models. Moreover, a correlation between experimental data and kinetic models was established utilising R^2 values.

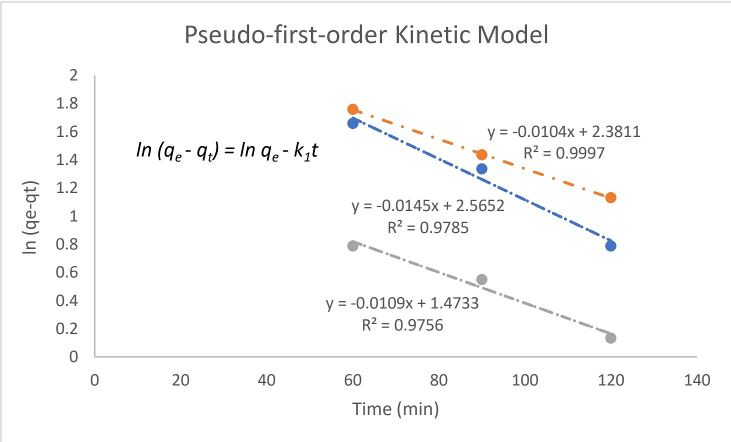


Figure 7 Pseudo-first-order Kinetic Model

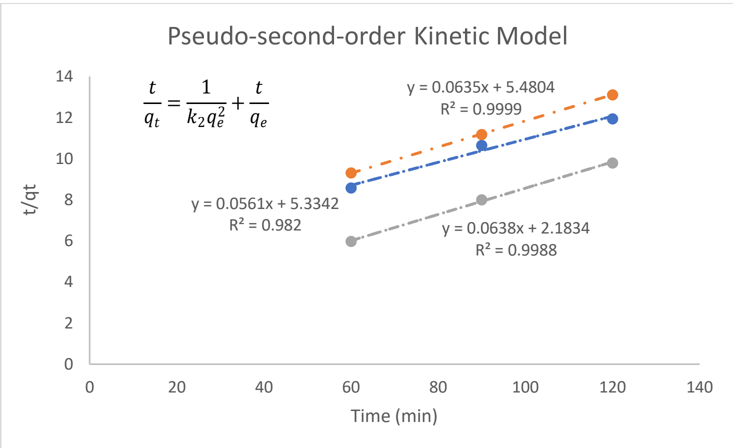


Figure 8 Pseudo-second-order Kinetic Model

It is evident from these graphs and the kinetic parameters that in pseudo-2nd-order kinetic models, the adsorbents exhibit larger linear regression coefficients compared to 1st-order kinetic models. In light of this, it can be concluded that pseudo first order inadequately characterizes the earlier mentioned adsorbents' kinetics, whereas pseudo second order best describes the kinetics of 237 ADMI methyl orange (MO) adsorption onto the adsorbents. According to the results of this kinetic investigation, the adsorption of 237 ADMI methyl orange (MO) onto adsorbents that were synthesized works through a chemical adsorption mechanism in which the surface of the adsorbent is the rate-limiting factor.

3.3 Isotherm study

At a state of equilibrium, the adsorption isotherms analyse the relationship between the adsorbate that has not been adsorbed and the adsorbate that has been adsorbed. Analysis of the data after it has been integrated into various adsorption isotherms is considered to be a vital phase for adsorption-related research, as stated in the existing body of literature.

In this context, Ce represents the equilibrium adsorbate concentration of methyl orange (MO), and qe denotes the amount of colour adsorbed in. The Langmuir constant, denoted as K_L, is closely related to the adsorption energy, whereas q_{max} represents the maximal adsorption capacity. Figure 9 illustrates the representative graph of $1/q_e$ and $1/C_e$. R_L, an additional dimensionless quantity, is a critical element of the Langmuir isotherm, commonly known as the separation factor.

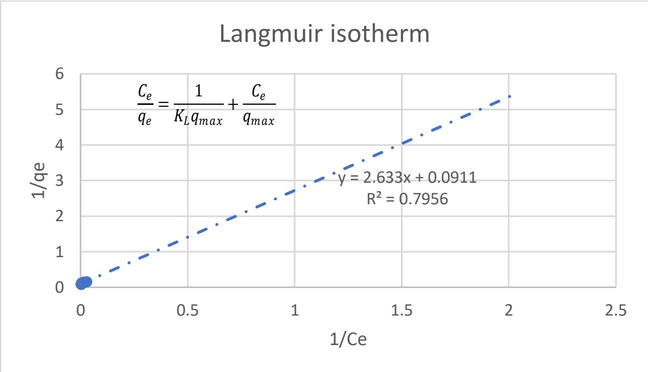


Figure 9 Langmuir isotherm

Whether it is linear ($R_L = 1$), irreversible ($R_L = 0$), favourable ($0< R_L <1$), or unfavourable ($R_L >1$) is indicated by the R_L value. The R_L value of 0.0004 examined in this study indicates that the adsorption of 2g sorbent dosage SCB biomass with methyl orange (MO) dye is favourable.

The current investigation revealed a 1/n value of 0.2544, indicating that the adsorption of MO onto the adsorbent that was prepared is heterogeneous and useful. In Figure 10, the representative plots (log C_e versus log q_e) are illustrated. Furthermore, in contrast to the other isotherms examined, the Freundlich model's R^2 value of 0.8726 in this investigation suggests the nonexistence of multilayer physisorption.

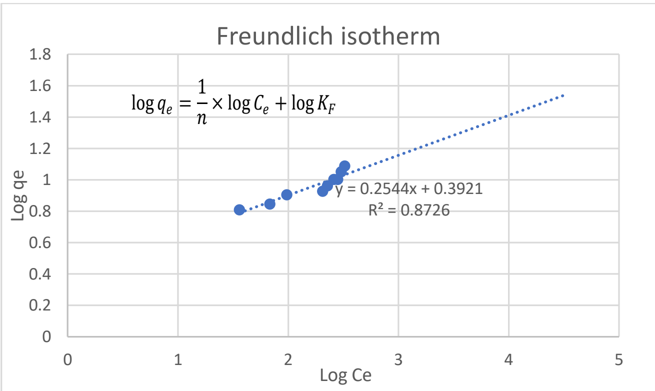


Figure 10 Freundlich isotherm

4. Conclusion

The elimination of methyl orange (MO) dye from aqueous solutions by the utilization of sustainable SCB biomass is a technique to water purification that is both promising and ecological environmentally friendly. It has been achieved via rigorous research and analysis that sugarcane bagasse, which is a waste product from agriculture that is readily available, possesses amazing potential as an effective adsorbent for the removal of methyl orange dye from water. According to the findings, the adsorption process is affected by a number of different elements, including the initial dye concentration, the contact time, and the recommended dosage of the adsorbent. The optimal parameter has been determined to be the sorbent dosage of 6g, with the dye concentration being between 237 and 388 ADMI, and the contact time being 60 minutes. it was demonstrated the flexibility and usefulness of sugarcane bagasse biomass as a material for adsorption.

Furthermore, the suggestion that the adsorption mechanism is comprised of a number of different variables, including surface area, porous structure, functional groups, and electrostatic interactions on the surface of the biomass. This insight could open the way for future optimization and exploitation of SCB biomass in wastewater treatment processes, which would contribute considerably to the development of environmentally remediation solutions that are both sustainable and cost-effective.

Acknowledgement

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