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Adsorption of Methylene Blue Dye via Adsorbents Derived from Banana Peel in Batch Experiments

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Abstract

Among a variety of technologies developed for wastewater treatment process, the physical-chemical process or an adsorption process has been the most alternative due to low cost and reusability of an adsorbent. This research focuses on studying the removal of methylene blue (MB) dye in aqueous solution via the naturally derived adsorbents prepared from cultivated and silver bluggoe banana peel (CBP and SBBP). From the results of batch experiments, it was found that CBP, achieving the highest removal of methylene blue dye up to 91% within 30 minutes, exhibited higher adsorption capacity, compared to SBBP. In addition, the optimum condition was CBP size of 12 mesh, CBP dosage of 3 g at initial methylene blue dye concentration of 10 mg/L and the solution pH only affected the removal of MB dye in the first 5 minutes. The better adsorption performance of CBP was presumably due to higher surface area and less effect of banana sap. According to the adsorbent surface investigation by means of scanning electron microscope (SEM), CBP had rougher surface than SBBP. In the case of banana sap, it was revealed that the banana sap could not adsorb the methylene blue dye. It was confirmed by characterizing with UV-vis spectrophotometer at a wavelength of 644 nm. For the adsorption tests with SBBP, the yellow substance indicating as the banana sap obviously appeared. Moreover, the banana sap covering on the surface of SBBP could block methylene blue dye to adsorb on the adsorbent surface.

Keywords: Adsorption, Methylene Blue Dye, Cultivated Banana Peel (CBP), Silver Bluggoe Banana Peel (SBBP), Batch experiment surface

Introduction

Recently, several researches have been attempted to improve the technology for wastewater treatment. The promising wastewater in Thailand comes from the textile industries. This wastewater is typically contaminated with dyes. Commonly, dyes are soluble in water. Hence, the textile industries usually make a lot of wastewater contaminated with dyes, causing water pollution. It is necessary to find a suitable technology in order to treat the wastewater. Firstly, a chemical process [1] is mainly used to separate the substances or contaminants such as heavy metals, toxins, acidic and basic solution [2] from the wastewater by adding some chemicals. However, this process has some drawbacks such as an impact on the environmental concern and high cost for chemicals. For another wastewater treatment process, a biological process which based on the principle of using microorganisms to convert organic matter into carbon dioxide and ammonia is the best treatment for wastewater in terms of reduction of organic matter in water resource. Nonetheless, this process is quite complicated because it is difficult to control the amount of microorganisms, bacteria, and operating conditions. In case of physical process, it is a simple wastewater treatment process that separates insoluble solids from the wastewater. This method can separate 50-65% of the sediment while the separation of organic matter (BOD_5) is about 20-30% only. In this research, the physical-chemical process is selected that is an adsorption process. This technique is low cost due to low energy consumption and inexpensive materials [3]. In addition, the used adsorbent can be washed and regenerated [4]. The adsorbent can be a natural or commercial sorbent. Natural sorbents such as ash and bagasse which are agricultural residues has high potential to treat the wastewater. Additionally, the natural sorbent can be modified to gain high adsorption efficiency such as activated carbon synthesized from coconut shell [5], apple residue, straw, wheat bark, orange peel, hyacinth, palm, sawdust, neem leaf powder [6-7]. This research focuses on the treatment of wastewater from textile industry with containing dyes and chemicals by adsorption process. The synthetic wastewater, methylene blue (MB) dye solution, is used in this work. The available natural raw material in Thailand such as cultivated and silver bluggoe banana peel (CBP and SBBP) can be employed to synthesize the natural adsorbent. The use of these banana peels can reduce the cost of wastewater treatment and is the useful agriculture waste or natural material.

In this work, the adsorbent derived from CBP and SBBP was used in batch experiment for adsorption process. The effects of adsorbent size, adsorbent dosage, initial concentration of MB dye, and solution pH value were investigated. The optimum operating condition was achieved under the criteria of high adsorption capability.

Materials and methods

Materials

Adsorbate (MB dye solution)

The MB dye used in this work was purchased from Sigma–Aldrich (Thailand). The initial MB dye concentration was prepared by diluting the stock solution with distilled water to the desired concentration. The solution of 250 mL was prepared with different initial MB dye concentrations (3, 7 and 10 mg/L) at 30 °C. The pH value of solution was adjusted in the range of 3, 7 and 9 by adding NaOH or HCl solutions.

Adsorbent derived from banana peel

The cultivated or silver bluggoe banana peel (CBP or SBBP) were sliced into small pieces and then washed thoroughly with deionized water to remove physically adsorbed contamination. After that, it was dried in the sun and in an oven at 100 °C for 24 h. The dried adsorbent was crushed and then sieved with 12, 20 and 50 mesh for obtaining the desired particle size.

Methods

The study of batch experiments for MB dye adsorption

Batch experiments were carried out by adding an adsorbent derived from banana peel of 1, 2 or 3 g into Erlenmeyer flasks containing 250 mL of different initial MB dye concentrations (3, 7 and 10 mg/L). The solution with an adsorbent was stirred at speed of 150 rpm for 6 h at 30 °C. The cultivated and silver bluggoe banana peel (CBP and SBBP) were employed in the adsorption test in order to compare the capability of MB dye removal.

Calculation of adsorption capability

The initial and equilibrium MB dye concentrations were determined by means of a double beam UV–Vis spectrophotometer (Thermo Scientific) at the wavelength of 664 nm for measurement in terms of absorbance. The calibration curve between MB dye concentration and the intensity of absorbance at the same wavelength was firstly plotted. The solution from the batch experiments was collected at a certain time and then evaluated the remaining MB dye concentration by measuring the absorbance compared with the calibration curve. It was then computed into dye concentration and absorbance. For the amount of adsorption at each adsorption time and at equilibrium, the percentage of MB dye removal was calculated as the following equation.

$$\text{Removal of dye (\%)} = \frac{\text{The initial MB dye concentration - The remaining MB dye concentration}}{\text{The initial MB dye concentration}} \times 100$$

Characterization of adsorbent

Scanning electron microscopy (SEM) (LEO 1455VP) analysis was carried out to investigate the morphology and surface texture of the cultivated and silver bluggoe banana peel before testing the batch adsorption experiment.

Results and discussion

The effect of two kinds of banana peel

The batch experiments for MB dye removal by using adsorbent derived from different kinds of banana peel i.e., cultivated and silver bluggoe banana peel (CBP and SBBP) were investigated. The adsorption parameters were the initial MB dye concentration of 10 mg/L in volume of 250 mL with adsorbent dosage of 20 g. As shown in Figure 1, the percentage of MB dye removal at equilibrium in case of using CBP was at 71% which was higher than that for SBBP case (68%). For the adsorbent synthesized from SBBP, it was found that a yellow substance came out into the solution more than another adsorbent. It was presumed that it should be banana sap. Moreover, banana sap was peeled off and might hinder the MB dye adsorption. In this work, the adsorbent derived from banana peel was processed by drying but it was not calcined at high temperature. Therefore, the banana sap should be remained in the adsorbent. In addition, the effect of yellow substance on the MB dye adsorption was investigated by characterizing via UV-vis at the wavelength of MB dye adsorption (664 nm). It was revealed that no absorbance signal was observed as illustrated in Figure 2. Hence, the absorbance detected from the batch adsorption experiments at the wavelength of 664 nm was reasonably assigned to the MB dye adsorption on the banana peel only. For the banana sap, it affected to adsorption capacity by blocking the active sites without helping the MB dye adsorption.

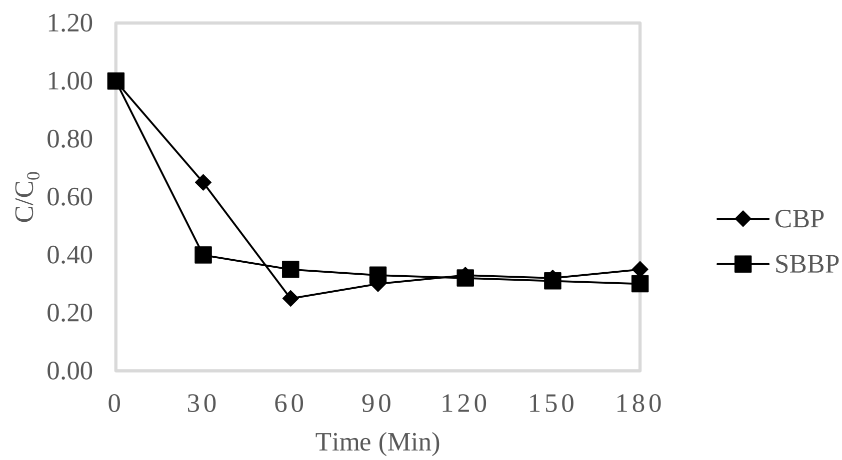

Figure 1 Removal of MB dye from batch experiments by using CBP and SBBP at the condition: adsorbent size of 12 mesh, the initial MB dye concentration of 10 mg/L and adsorbent dosage of 20 g at 30 °C.

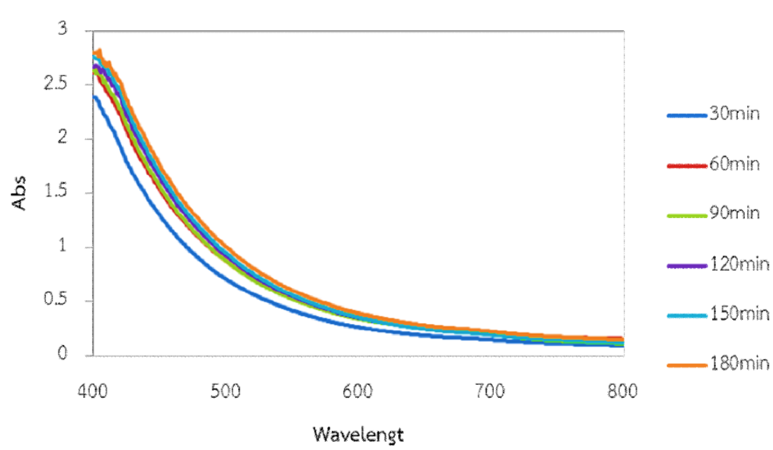

Figure 2 The absorbance spectra of adsorption via banana sap in water at various adsorption times.

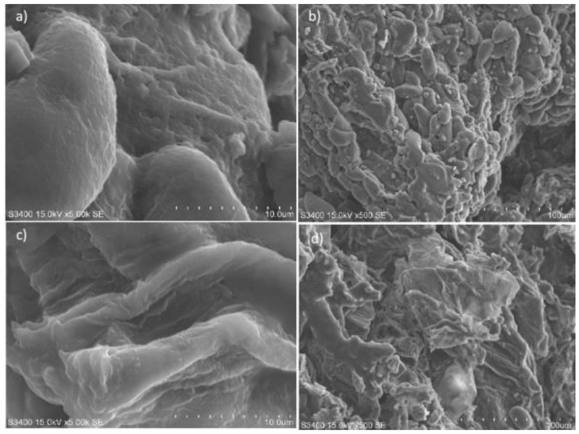

Figure 3 SEM micrographs of (a) CBP (magnification: 5.00 K), (b) CBP (magnification: 500), (c) SBBP (magnification: 5.00 K), (d) SBBP (magnification: 500)

Figure 3 shows the surface structure of CBP and SBBP with different magnification. It exhibited that the CBP had rough surface while the presence of smooth surface was observed for SBBP. It could be implied that the rougher surface of CBP could provide higher adsorption capacity, compared to SBBP. Therefore, the adsorbent derived from CBP will be used to study further for other effects.

The effect of adsorbent size

For this study, the mesh sizes of adsorbent synthesized from CBP were varied as 12, 20, and 50 mesh (1.70 mm, 850 micron, and 3000 micron, respectively) for testing in the batch adsorption experiments. The batch experiments were set at the initial MB dye concentration of 10 mg/L and CBP dosage of 3 g. According to the experimental results as shown in Figure 4, with 12 mesh size for the first 20 minutes, it could be adsorbed MB dye ca. 85% and reached the equilibrium after 30 minutes, obtaining 91% of MB dye removal. For the mesh size of 20, the percentage of MB dye removal was around 58% for the first 20 minutes and approached the equilibrium after 80 minutes with 80% of MB adsorption. In case of the smallest size (50 mesh size), it took very long time to reach equilibrium around 160 minutes with the least ability of MB dye adsorption (29%). It evidently indicated that the larger size of adsorbent derived from CBP exhibited higher in adsorption capability. The suitable adsorbent size was at mesh size of 12. It might be proposed that the banana sap was a major effect because the amount of banana sap peeled off relied on the adsorbent mesh size, especially at 50 mesh. The banana sap might inhibit the adsorption of MB dye. Moreover, when the banana sap were detached, the MB dye attached to CBP also came out into the solution along with the banana sap resulting in less percentage of MB dye removal. Thus, the proper mesh size of adsorbent derived from CBP was 12 mesh.

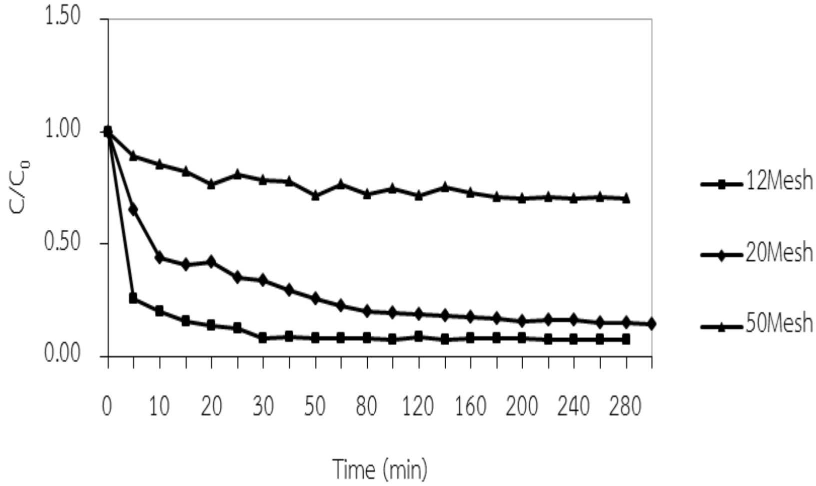

Figure 4 Removal of MB dye at various mesh sizes for the adsorbent derived from CBP

The effect of adsorbent dosage

For another effect, the MB dye adsorption capability was studied by varied the amount of adsorbent in the range of 1-3 g. The operating condition for batch experiments was at initial dye concentration of 10 mg / L with adsorbent size of 12 mesh. As the results in Figure 5, in case of 1 and 2 g, the adsorption profiles had the same trend with approaching ca. 88% at the equilibrium. The profile for case of 3 g obviously differed from other profiles. It could adsorb 85% of MB dye in the first 15 minutes and start to reach the equilibrium after 25 minutes with the percentage of MB dye removal of 91. With the same mesh size of adsorbent, the adsorption ability was dependent on the adsorbent dosage. This was probably due to higher surface area for adsorption with increasing of adsorbent dosage. Therefore, the increase in the amount of adsorbent resulted in faster adsorption process and enhancement the adsorption capacity.

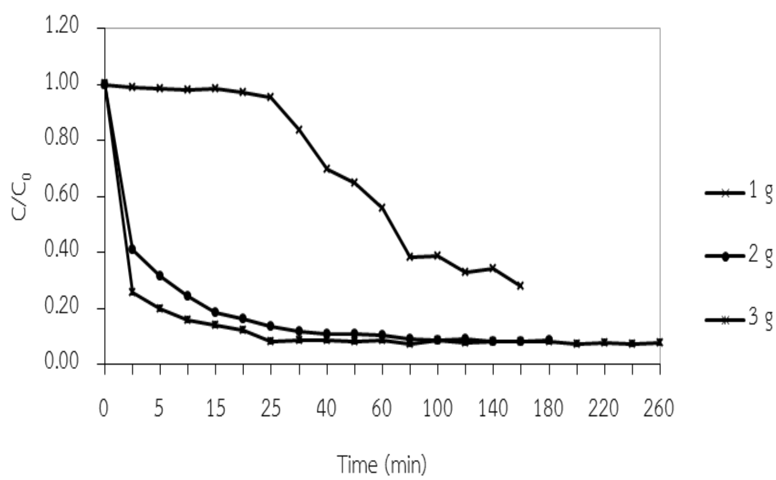

Figure 5 Removal of MB dye at various adsorbent dosages for the adsorbent derived from CBP

The effect of initial concentration of MB dye

In Figure 6, the adsorption profiles are illustrated when the initial MB dye concentration was studied in the range of 3-10 mg/L. The batch experiments were carried out under the condition of the adsorbent derived from CBP mesh size of 12. The tendency of these profiles was not different. However, the initial MB dye concentration of 10 mg/L exhibited the highest percentage of MB dye removal among three initial MB dye concentrations, providing 91%. Increasing initial concentration of MB dye led to improvement of MB dye adsorption capacity.

This was because the increase in initial concentration of MB dye caused increasing the driving force for mass transfer. The difference between concentration of MB dye at the adsorbent and that in solution was higher when the initial concentration of MB dye increased. Among these cases, the initial concentration of MB dye of 10 was the appropriate condition.

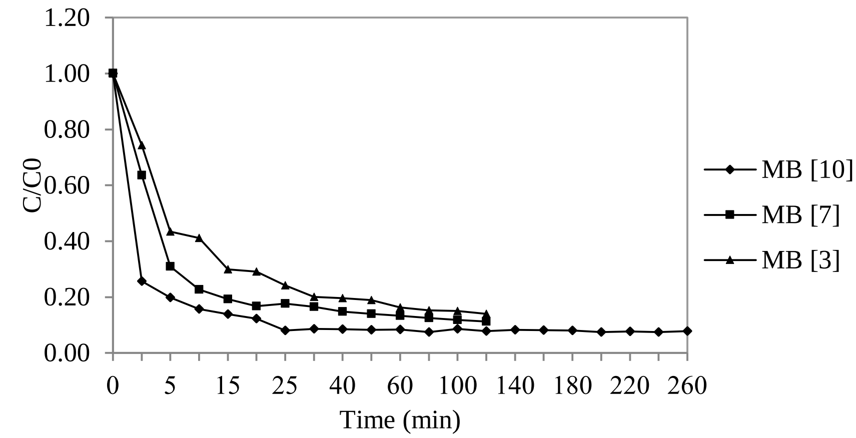

Figure 6 Removal of MB dye at various initial concentrations of MB dye for the adsorbent derived from CBP

The effect of pH value of MB dye

Typically, the pH was variable that should be taken into account in the adsorption process. In this work, the pH value in the range of 3-9 was selected to investigate the adsorption capability under the condition of 3 g of adsorbent derived from CBP with mesh size of 12 mesh and at the initail MB dye concentration of 10 mg/L.

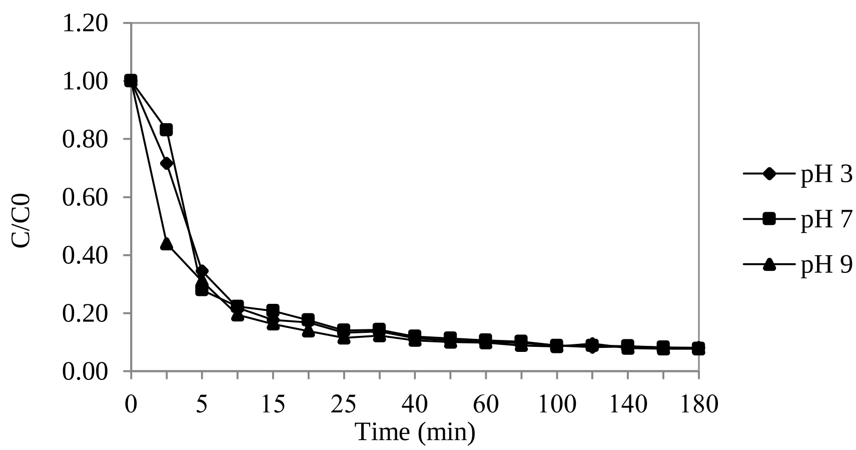

Figure 7 Removal of MB dye at various pH values for the adsorbent derived from CBP

As illustrated in Figure 7, the adsorption profiles only differed for the first 5 minutes. In this period, the pH of 9 showed the highest adsorption capability among three values of pH. However, after 5 minutes, the adsorption profiles were slightly different until insignificant difference at after 40 minutes. Therefore, pH value did not play an important role on MB dye adsorption by using adsorbent derived from CBP.

Conclusion

To investigate the adsorbent derived from two kinds of banana peel such as CBP and SBBP in the MB dye adsorption process, it was revealed that the adsorbent synthesized from CBP exhibited higher adsorption capacity, compared to that synthesized from SBBP. The effects of several variables such as the adsorbent size, adsorbent dosage, initial concentration of MB dye, and pH value were studied in this work. The appropriate adsorbent was 3 g of adsorbent derived from CBP with size of 12 mesh at the initial concentration of MB dye of 10 mg/L while the pH value did not affect to the adsorption capacity. These proper operating condition would be useful for further investigation in fixed-bed experiments.

Acknowledgements

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