Adsorption of Methylene Blue by Banana Stem Adsorbent in a Continuous Fixed Bed Column Study

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Abstract. Methylene Blue is a cationic dye that releases aromatic amines in many textile industries and can cause potential harm to human health. Agricultural waste has been explored for their adsorption abilities towards Methylene Blue dye from textile wastewater. This study described the performance of fixed-bed column using banana stem as filter media under the effect of various bed height (10, 30, 50 cm) and initial concentration of Methylene Blue (0.02 and 0.03 mg/L) to assess the breakthrough curve. From the fixed-bed column study, the column with initial Methylene Blue concentration of 0.02 mg/L and bed height of 50cm performed well in removing Methylene Blue from the synthetic Methylene Blue solution. The breakthrough time and exhaustion time were 953.57 minutes and 4560 minutes, respectively. As a conclusion, banana stem filter media is an effective alternative in removing Methylene Blue from textile wastewater.

1. Introduction

Textile wastewater is one of the most polluted wastewaters due to its characteristics, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, colour, and other organic and inorganic soluble substances [1]. When improperly disposed, such effluents can cause serious environmental problems and public health concerns [2]. More than 10,000 colours are used in textile manufacturing [3]. This heavily coloured element interrupts the oxygenation potential of the receiving water and adsorption of sunlight when released into the water bodies of wastewater, thus disturbing biological activity of aquatic life [4]. As the variety of textile products developed, various dyes are used in this industry with different chemical properties, which further complicates the treatment of textile wastewaters [5]. Dyes have carcinogenic, teratogenic and mutagenic impacts on aquatic organisms [6]. Therefore, treating the coloured effluents before being released into water bodies is a necessity [7]. However, colour removal due to the remaining dyes has been a great challenge over the past decades.

Methylene Blue is most widely used for painting of all varieties of dyes. It is one of the synthetic colours that dissolves in water to give an intense violet colour. Methylene Blue is more harmful because it can bind quickly with negative cells and is concentrated in the cytoplasm [8]. A small amount of Methylene Blue that is found in highly visible water will disrupt aquatic life by impeding light absorption and oxygen transfer [9]. Therefore, effective methods for removing Methylene Blue is necessary.
A wide range of methods for the treatment of colours have been created and implemented. The methods can be classified into three major categories: biological, chemical and physical methods. These methods include coagulation, adsorption, degradation, transfer of ions, and filtration [10]. The most common method used is adsorption using activated carbon to remove colours and other pollutants. Adsorption using activated carbon has been proven to be one of the most successful yet costly methods for a wide scale of operation [11]. Due to its high cost, the use of activated carbon as an adsorbent in underdeveloped countries is less preferred. Therefore, for a full-scale treatment, many researchers have focused on developing low-cost adsorbent [12].

Agricultural wastes such as peanut hull [13], jackfruit leaf [14], watermelon [15], and banana stem [16], are considered good sources of waste to be used as low-cost adsorbent materials. These waste materials can benefit from their usage as adsorbents while reducing the amount of waste materials released into the environment and simultaneously reduce the cost of wastewater treatment [4]. Among these wastes, banana stem has a high capacity as an adsorbent in removing coloured industrial wastewater [16]. For this reason, the utilization of banana stem as an adsorbent in filter media becomes potential.

Several operation systems can be used to remove Methylene Blue from wastewater such as batch [17], continuous moving bed, continuous fixed bed (up flow and down flow) [19], continuous fluidizing bed and pulsed bed. However, fixed-bed columns are often preferred in adsorption processes due to the simple design, inexpensive manufacturing, minimal adsorbent attrition, high efficiency and easy usability from the laboratory [4].

Therefore, the aim of this present study is to evaluate the potential of banana stem as the filtration media in removing Methylene Blue using a fixed-bed column operation. Its main objectives are to study the effect of bed height and initial concentration of Methylene Blue solution.

### 2. Methodology

#### 2.1. Preparation of synthetic solution

Methylene Blue was taken as the model adsorbate in this study. The stocks of synthetic solutions (0.02 and 0.03 mg/L) were prepared by diluting the Methylene Blue powder with distilled water. The initial concentration of colour was measured using spectrometer DR2800 (Model: HACH, 127181-D).

#### 2.2. Preparation of adsorbent

Banana stems were collected near the UiTM campus, Pulau Pinang. The stems were peeled by layers and washed using tap water to remove impurities. The banana stems were then cut into small sizes between the ranges of 1 cm to 2 cm. The banana stems were washed several times with distilled water to remove its colour. This step was repeated several times to release the colour from the banana stems. Then, the banana stems were dried in the drying oven at 105°C for 24 hours. When the sample was completely dried, it was used as an adsorbent in the column experiment.

#### 2.3. Sample compression and dumbbell cutting

The banana stem adsorbents were packed in a three Perspex glass column with dimension of 1.6 cm inner diameter and 53 cm in height, as shown in figure 1. Three different columns were being used to study the effect of bed height (10 cm, 30 cm and 50 cm) and initial concentration of Methylene Blue (0.02 mg/L and 0.03 mg/L). The final effluent of each column was collected at specific interval and the final concentration of Methylene Blue was measured using spectrometer DR2800 (Model: HACH, 127181-D). The loading behaviour of Methylene Blue to be adsorbed from a fixed-bed solution is usually described in terms of \( \frac{C_t}{C_0} \) as a function of the time [19]. The graph of \( \frac{C_t}{C_0} \) (ratio of final concentration to initial concentration) versus bed height and \( \frac{C_t}{C_0} \) versus initial concentration of Methylene Blue were plotted to evaluate dynamic behaviour of Methylene Blue dye removal using banana stem adsorbent. The breakthrough time and saturation time were also obtained when \( \frac{C_t}{C_0} \) reached 5% and \( \frac{C_t}{C_0} \) reached 95%, respectively.
3. Result and Discussion

3.1. Effect of bed height

Methylene Blue accumulation in the fixed bed column depends on the amount of adsorbent inside the column. The effect of bed height was investigated by enabling dye solutions of various bed heights (10, 30, and 50 cm) to flow through the column at initial concentration of 0.02 mg/L and a fixed flow rate of 14.3 mL/min (up flow). Based on figure 2, the removal efficiency of Methylene Blue breakthrough time and exhaustion time were increasing with the increasing of bed height because more binding areas were available for adsorption. The duration of a breakthrough was also found to take longer (Ct / Co exceeds 0.05) with increased bed height for all situations. The breakthrough time increase with increase of bed height. The breakthrough time was recorded at 66, 655.26 and 953.57 minutes for 10, 30 and 50 cm of bed height, respectively. The results obtained are similar to the results from the previous research which showed similar pattern with increase of bed height. The exhaustion time for 50 cm bed height was higher compared to 30 and 10 cm of bed height. The exhaustion times were recorded at 1488, 4155, 4560 min for 10, 30 and 50 cm depth of Methylene Blue. When bed height increases, the Methylene Blue solution needs more time to be in contact with the banana stem adsorbents, resulting in higher efficiency of removal of Methylene Blue dye in the column, while at the same time causing a decrease in the effluent concentration of the solution [4]. As a result, the adsorption and uptake ability of Methylene Blue ions on banana stem adsorbent granules in the column will be increased with the increased in bed height.
3.2. Effect of initial concentration

Figure 3 indicates the breakthrough curves for effluent at optimal bed height of 50 cm, fixed flow rate of 14.3 mL/min and the initial dye concentration of 0.02 and 0.03 mg/L.

The curves showed that the breakthrough time, \( t_b \) decreased with increasing initial concentration of Methylene Blue. At lower initial concentration of Methylene Blue, the breakthrough occurred slowly. At 0.02 mg/L of MB concentration, the breakthrough time was 1818 min. However, for 0.03 mg/L of initial MB concentration, the breakthrough time was at 260 min. As the initial concentration increases, the breakthrough time will decrease and the breakthrough curves become sharper as the initial concentration increases, resulting in shorter breakthrough and exhaustion points due to more binding sites [4]. The result found that the change of concentration affects the breakthrough time and saturation time because more adsorption site of banana stem adsorbent being covered as the Methylene Blue concentration increases [19].
4. Conclusion
This research found that banana stem adsorbent is an effective adsorbent in removing Methylene Blue in wastewater. Experimental data indicated that bed height and initial concentration influenced banana stem adsorption for removal of Methylene Blue. The longest breakthrough time was obtained at 50 cm bed height and 0.02 mg/L of initial concentration. As a conclusion, the banana stem adsorbent is capable of removing Methylene Blue for wastewater using filtration system. Therefore, as a low-cost adsorbent, banana stem adsorbent can substitute activated carbon as a filtration media.

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