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Removal of Methylene Blue of Textile Industry Waste with Activated Carbon Using Adsorption Method

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Abstract

The colorant that is often used in the textile industry is methylene blue which is a cationic heterocyclic aromatic compound. This compound is very stable and is difficult to decompose naturally leading to environment in large concentrations. Therefore, a waste treatment technology to reduce the concentration of dye waste in water becomes importannt. So far, adsorption method with activated carbon remains the most efficient and effective technique in removing dyes from liquid waste due to its relatively large adsorption capacity. Activated carbon is one of the non-metallic mineral commodities or multipurpose industrial minerals, one of which is as an adsorbent or adsorbent media. This study aims to determine the potential of activated carbon in adsorbing methylene blue with variations in the concentration of methylene blue and particle size of activated carbon. The procedures in this experiment include, the preparation of activated carbon with size variations (20-60, 60-100 and> 100 mesh) and variations in the concentration of methylene blue (15 ppm, 30 ppm and 45 ppm) with contact time (0 to 180 minutes). From the results of the study, it was found that the smaller the size of activated carbon used, the greater the adsorption capacity, ie at mesh size> 100 mesh, the adsorption capacity was 9.8%. Whereas, the smaller the concentration of methylene blue, the activated carbon could work optimally at a concentration of 15 ppm at 30 minutes with adsorption capacity as high as 100%.

Keywords: *adsorption; Methylene Blue; activated carbon; concentration; time; particle size*

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INTRODUCTION

Dyes are one of the main components of the textile industry process. So far, the textile is the major user of dyes. More than 100,000 commercially available dyes with an estimate annual production of more than 70,000 tons of textile commodities, of which 15% of textile dyes are lost during the coloring process. Textile dyes are lost into waste and found aacumulated in industrial waste streams (Tunc *et al*., 2009). Textile industry wastes contain dyes that are difficult to decompose naturally and cause disruption of water ecosystems (Anshar *et al*., 2016). Dyestuffs produced from the textile industry are generally non-biodegradable compounds which cause environmental pollution, especially to aquatic environments (Gupta *et al*., 2012).

The textile industry is a prominent foreign exchange contributor, but handling environmental sustainability should be an important concern. Therefore, it is needed a waste treatment technology that can reduce the pollution of the aquatic environment generated by the textile industry. The dyestuff waste treatment method that is often applied is the adsorption method. The adsorption method has been proven to have a high effectiveness in removing dyes in liquid waste.

In recent years, a lot of research has been done to develop an effective adsorption method for processing of dye waste. One of the commonly used adsorbents is activated carbon. So far, the adsorption method with activated carbon remains the most efficient and effective technique in removing dyes because of its high adsorption capacity (Hameed *et al*., 2007). Activated carbon (powdered or granulated) is the most efficient adsorbent used for dye removal (Anshar *et al*., 2016; Nandiyanto *et al*., 2017; Nandiyanto *et al*., 2018). In this research, activated carbon with micropore character as adsorben was used. In addition, characterization and activity testing of activated carbon adsorbents was carried out.

MATERIALS AND METHOD

Materials

The materials used in this study were activated carbon as an adsorbent and methylene blue (95% analytical grade, Sigma Aldrich) used as the synthetic waste. The pore structure of activated carbon was characterized by using an N_2-sorption analyzer (Nova 2000, Quantachrome). While the ultraviolet / visible (UV / Vis) spectrophotometer (Shimadzu Mini 1240) was used to analyze the concentration of methylene blue per unit time.

Adsorption Process

Prior to adsorption process, a total of 200 ml of methylene blue solution with the appropriate concentration of variables respectively 15, 30 and 45 ppm were prepared in a glass beaker. The solution was stirred with a magnetic stirrer at a constant speed of 450 rpm and a room temperature of 30^0C. Furthermore, 0.025 grams of activated carbon adsorbent with various particle size were put into a glass beaker each containing a methylene blue solution. Sample containing of 2 ml of the solution were taken at intervals for 3 hours. Furthermore, the concentration of methylene blue in solution (C) at any given time interval was analyzed with a UV-Vis spectrophotometer at a wavelength of 663 nm.

Analysis Method

The adsorption data were analyzed using a UV / Vis spectrophotometer with wavelength λ = 663 nm. The results of the analysis are used to calculate the concentration of methylene blue in liquids per unit time.

RESULTS AND DISCUSSION

Characterization of Activated Carbon Adsorbents

Table 1 shows data on the characteristics of activated carbon adsorbents including specific surface area, average pore diameter and pore volume. Based on Table 1, it can be concluded that the adsorbent used is micropore carbon (IUPAC classification) with a mean diameter of 1.82 nm.

In addition, related to the pore size distribution calculated by the Quenched Solid State Functional Theory (QSDFT) model. Based on the results of calculations with the Quenched Solid State Functional Theory (QSDFT) model, it can be seen a large pore size distribution of particles below 2 nm, so that it further strengthens that the activated carbon adsorbent used is micropore carbon (IUPAC classification). The results of pore size distribution with QSDFT-N_2 model can be seen in Figure 1.

The morphological analysis performed using Scanning Electron Microscopy (SEM) shows the morphology and that the pores of the adsorbent surface are uniformly distributed. These pores will later provide the surface area during the process of adsorbing synthetic methylene blue waste. The larger surface area of the adsorbent exihibes a more evenly distributed pore size leading to a greater the adsorption capacity. Morphological analysis results can be seen in Figure 2.

Table 1. Characterization of Activated Carbon Adsorbents (Amelia *et al*, 2019)

Characteristic	Value
Specific surface area (S_{BET}), m^2/gram	1320
Micropore area (S_{mic}), m^2/gram	1220
% S_{mic}	92
Total pore volume, cm^3/gram	0.60
Micropore volume (V_{mic}), cm^3/gram	0.45
% V_{mic}	75
Average pore diameter, nm	1.82

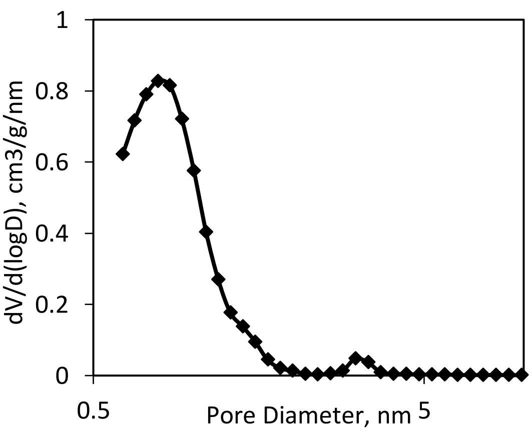

Figure 1. Pore Distribution with QSDFT-N2 Model (Amelia *et al*, 2019)

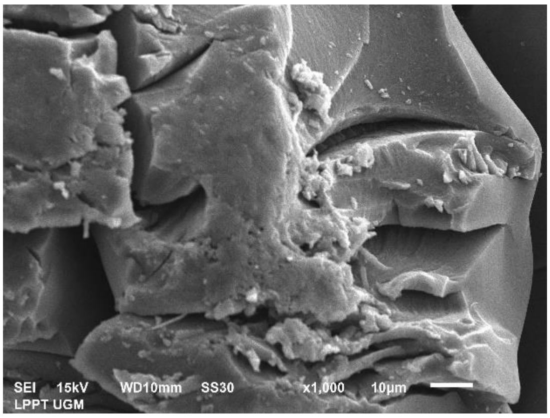

Figure 2. The SEM Image of Activated Carbon Adsorben

Adsorption Activity Test

In this study the variation in the concentration of methylene blue solution as synthetic waste of 15, 30 and 45 ppm was used to measure the adsorption capacity of activated carbon in the adsorption process. From Figure 3 it can be seen that the maximum adsorption is achieved at a methylene blue concentration of 15 ppm. Adsorption capacity of methylene blue at a concentration of 15 ppm reached 100% at 30 minutes contact time. Whereas, at the concentration of 30 ppm and 45 ppm the highest adsorption capacity was reached with a contact time of 180 minutes that was equal to 68.1% and 30.6%. This shows that the greater the concentration of synthetic methylene blue waste, a longer contact time required for activated carbon adorbents to adsorp the waste.

Figure 3 presents that there is a correlation between contact time and adsorption capacity. The adsorption process occur more rapidly at the beginning of the adsorption process (Khuluk *et al.*, 2019). Then after the adsorbate starts to be accumulated on the adsorbents, the adsorption process became slower so that a greater methylene blue concentration required a longer contact time.

In addition to the variation in the concentration of synthetic methylene blue waste, this research also uses variations in the size of the activated carbon mesh. The

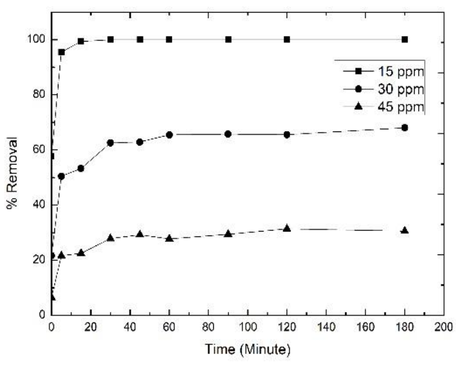

Figure 3. Effect of Methylene Blue Waste Concentration on Activated Carbon Adsorption Activity Test

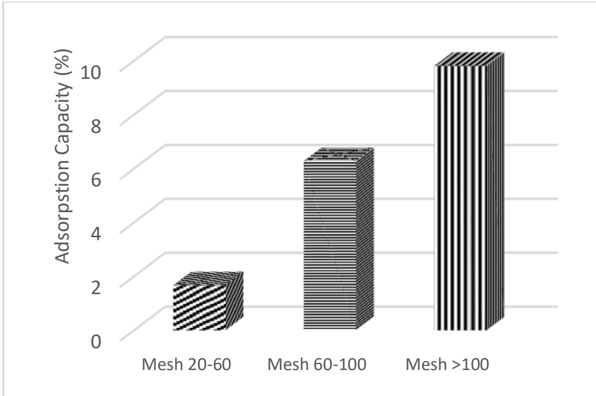

Figure 4. Effect of Adsorbent Size on Activated Carbon Adsorption Activity Test

activated carbon used were 20-60 mesh, 60-100 mesh and> 100 mesh. Based on Figure 4 it can be seen that activated carbon with particle size of > 100 mesh has the largest adsorption capacity. This shows that the smaller the size of the adsorbent, the greater the adsorption capacity produced. This can occur because the smaller the size of the adsorbent, the resulting surface area to adsorb the adsorbate is greater so that the adsorption capacity is even greater.

CONCLUSIONS

Based on the results of the research discussed above, it can be concluded that the difference in the concentration of synthetic methylene blue waste affects the adsorption capacity. The highest adsorption capacity was achieved at a concentration of synthetic ppm of 15 ppm which is 100% with a contact time of 30 minutes. In addition, the contact time during the adsorption process also affects the adsorption yield. The longer the contact time, the more adsorbate can be adsorbed by the adsorbent.

In addition, the smaller the size of the adsorbent provides a greater surface area of the adsorption field so that the resulting a higher adsorption capacity. The highest adsorption capacity is produced by activated carbon with a size < 100 mesh.

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