The adsorption of dye waste using black carbon from polyethylene terephthalate (PET) plastic bottle waste

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Abstract. Black carbon from PET plastic bottles has been successfully synthesized by heating methods. Six gram sample of PET plastic bottle were heated by furnace for 2 hours with various heating temperature as 300°C, 350°C, 400°C, and 450°C. Black carbon then mixed with methylene blue in aqueous solution with various masses as 20 mg, 40 mg, 60 mg, 80 mg, and 100 mg. This study shows that the black carbon which synthesized at temperature of 450°C performs as the most effective absorbent. The solution of methylene blue changed its color significantly and became clearer after the adsorption process. The absorbance spectra of methylene blue lies at the wavelength of 550-700 nm and decreasing the absorbance intensity. It indicates that the concentration of methylene blue is decreased during adsorption process which predicted due to the oxygen molecule and the porosity. The analysis of carbon morphology showed that black carbon which synthesized at temperature of 450°C has more pores, while the black carbon which heated at temperature of 400°C has few pores. The EDX analysis shows that black carbon that heated at temperature of 450°C contains 32.4% oxygen, whereas black carbon that heated at temperature of 400°C contains 24.3% oxygen.

1. Introduction
Plastics waste is one of the crucial environmental problems in this modern era. Plastics have become a crucial part of lifestyle due to their substantial benefit properties i.e. lightweight, low cost, transparent, and good insulator [1]. The global plastic production has increased immensely during the past of 50 years [2]. Plastic bottle—made of PET—is one kind of plastic which people use the most. Approximately 200 billion of plastic bottles have been consumed by people worldwide. This massive consumption has proportional to the production of plastic waste.

PET plastic bottle waste is harmful for the environmental life because their non-biodegradable properties which extremely difficult to be decomposed by microorganism in nature. Plastic waste is now a hazardous pollution to soil and water environment [3]. Many studies have been done by researchers to recycle plastic waste into more valuable material.

Fortunately, PET plastic bottles have rich of carbon structure. The structure of carbon in the plastic waste is potentially useful as black carbon material for water impurities adsorption. Black carbon material has the ability to adsorb organic and inorganic pollutants [4]. This paper aims to study the adsorption of dye waste from aqueous solutions using black carbon from PET plastic bottle.

Black carbon from PET plastic bottle could be a simple absorber material for water purifications from impurities such as dye waste. The synthesis of black carbon is quite easy and requires low cost production.
2. Methods
Black carbon was synthesized from waste plastic bottle by heating process. The PET plastic bottles were cut into tiny size with each mass of 6 gram and then it was heated by furnace for 2 hours with various temperatures as 300°C, 350°C, 400°C, and 450°C. The optimum result of temperature variation then experimented with various masses as 20 mg, 40 mg, 60 mg, 80 mg, and 100 mg. These both variations were applied to adsorption process in 30 ml of methylene blue 20 ppm. The solution was stirred for 30 minutes while the absorption process. The purified solution then was analyzed using Vis-NIR spectrometer to measure the absorbance spectra. The effectiveness of black carbon from PET plastic bottle as an adsorbent was determined by the absence of methylene blue in the water. In addition used SEM-EDX to analyze the morphology of carbon.

3. Results and Discussion
Black carbon from PET plastic bottles successfully adsorbs methylene blue in the water. The result of the adsorption process are various solutions that adsorbed by black carbon synthesized using various heating temperatures as shown in Figure 1.

![Figure 1. Methylene blue solutions after absorption using black carbon from PET plastic bottle synthesized with: (a) various temperature and (b) various mass.](image)

The color of methylene blue as shown in Figure 1 are different as depend on heating temperature of black carbon. The concentration of methylene blue solutions that absorbed by black carbon synthesized with temperature of 300°C, 350°C, and 400°C are remain high as shown by their blue color. On the other hand, methylene blue solution becomes more clear and change its color significantly when it absorbed by black carbon heated by temperature of 450°C. Therefore, synthesized temperature of 450°C resulted black carbon with effective porosity.

Furthermore, we used the effective black carbon—black carbon synthesized by temperature of 450°C—as a control variable in experiment with masses variation. The result of adsorption methylene blue solutions using various masses of black carbon is shown in Figure 1b.

Methylene blue solutions are significantly degraded by various mass of black carbon as shown in Figure 1b. The greater the mass of black carbon the more significant degradation of methylene blue. The degradation process has been indicated by alteration solution’s color became clear. This result indicates that black carbon from PET plastic bottle is an effective absorbent. The adsorption is influenced by the porosity and amount of oxygen in the black carbon [5-6]. The morphology of carbon was analyzed used SEM-EDX as shown in Figure 2.
Figure 2. The morphology of carbon black from PET plastic bottle synthesized with heating temperature of (a) 400°C and (b) 450°C

Samples of black carbon from PET plastic bottle as shown in Figure 2 a and b have difference size of pore according to the various heating temperature of black carbon as 400°C and at 450°C. Black carbon which synthesized at temperature of 450°C has more pores, while the carbon black which heated at temperature of 400°C has few pores. The EDX analysis shows that black carbon that heated at temperature of 450°C contains 32.4% oxygen, whereas black carbon that heated at temperature of 450°C contains 24.3% oxygen. The greater oxygen containing in the surface structure has negative charge so that it can bind the cationic materials (positive charge materials) such as methylene blue [7-8]. The oxygen is formed during the heating process in the furnace.

The adsorption of methylene blue by black carbon has been investigated by Vis-NIR spectrophotometer as shown in Figure 3.

Figure 3. Absorbance spectra of methylene blue after adsorption by various: (a) heating temperature of black carbon (b) mass of black carbon

According to the Figure 3, methylene blue has spectra in 550-700 nm. The wavelength spectra of methylene blue is 550-700 nm with maximum absorption wavelength (λ_max) at 665 nm [9]. The absorbance intensity of methylene blue shows that color degradation is occur with the increasing mass as well as the heating temperature of black carbon. Figure 3a shows that carbon with temperature of 32°C, 300°C, 350°C, and 400°C do not have capability to adsorb methylene blue. This is showed by
the high intensity of the absorbance spectra of methylene blue. It was possibly occurred due to the carbon do not have pores which essentially needed to adsorb methylene blue. In addition, there is no absorbance peak for the methylene blue solution which absorb by black carbon heated at temperature 450°C. It indicate that this black carbon has more pores. The pores can adsorb methylene blue dye and result more clear solution with lower concentration of the methylene blue. The decreasing concentration of methylene blue is according to the Lambert-Beer law which states that the amount of absorbance spectra is proportional to the concentration of the contained substance as in equations 1 and 2 [10-11].

\[ I_i = I_o e^{-\alpha l C} \]  
\[ \log \frac{I_o}{I_i} = \alpha l C = A \]

where \( \alpha \) is the absorption coefficient, \( l \) is the path length, \( A \) is the absorbance, \( I_o \) is the initial intensity, and \( I_i \) is transmission intensity.

Figure 3b shows that the absorbance intensity of methylene blue is decreased with the increasing of black carbon mass. The greater the mass of black carbon, the more the methylene blue particles adsorb by the carbon pores. In addition, the oxygen content in the black carbon also plays a role in the absorption of methylene blue. The oxygen in the black carbon has the ability to bind the charge in the methylene blue solution. The larger the mass of black carbon the larger the number of oxygen.

4. Conclusion
Black carbon has been successfully synthesized from PET plastic bottles using simple heating method. The effective black carbon as absorbent of methylene blue is synthesized at temperature of heating 450°C. Furthermore, the larger the mass of black carbon in the adsorption process the less intensity of the absorbance spectra of methylene blue. The concentration of methylene blue is decreasing during the adsorption process which predicted due to the oxygen molecule and the porosity. The analysis of carbon morphology showed that black carbon which synthesized at temperature of 450°C has more pores, while the black carbon which heated at temperature of 400°C has few pores. The EDX analysis shows that black carbon that heated at temperature of 450°C contains 32.4% oxygen, whereas black carbon that heated at temperature of 400°C contains 24.3% oxygen.

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