

# Coal Bottom Ash as a Low Cost Adsorbent for Removing Dye Pollutant

Nor Fadilah binti Mohamad<sup>a</sup>, Noor Hidayu binti Abdul Rani<sup>b</sup>, Aini Sofia binti Mohd Zopri<sup>c</sup>, Muhammad Naqib Saifullah bin Noor Azman<sup>d</sup>

<sup>a,b,c,d</sup> Faculty of Chemical Engineering, Universiti Teknologi MARA Johor, Kampus Pasir Gudang, Jalan Purnama, Bandar Seri Alam,

81750 Masai, Johor Darul Ta'azim

---

## Abstract

The thermal power plant waste material, coal bottom ash (CBA) was utilized as a potential adsorbent for the dye removal. The effectiveness of coal bottom ash (CBA) and activated coal bottom ash (ACBA) waste material in adsorbing dyes from aqueous solutions was studied as a function of contact time and the effect of adsorbent dosage. The performance of coal bottom ash (CBA) and activated coal bottom ash (ACBA) were carried out by using of two basic dyes namely-Methylene blue (MB) and Methyl Red (MR) due to their dyes removal efficiency. Coal bottom ash (CBA) was dried up by using oven at 105°C for 24 hour to remove moisture contents and further kept in furnace at temperature of 500°C for 6 hour in presence of air. Adsorption studies was carried out by batch technique for 50 mL of stock solution with initial concentration of 16 mg/L of methylene blue (MB) and 13.5 mg/L of methyl red (MR) respectively. The optimum for contact time for the methylene blue (MB) on both adsorbents is 3 hours for 7.09% of CBA and 20.58% of ACBA whereas it only took 1 hour of the contact time for methyl red (MR) with both adsorbents (61.28%) and (78.53%) to reach higher adsorption. The higher uptakes of both dyes removal efficiency were found at 3 gram where methylene blue were 90.32% for CBA and 95.91% for ACBA and for the methyl red were 83.09% for CBA and 91.34% for ACBA. The increase of amount of adsorbent were increase the amount of dye uptakes due to the adsorbent sites and surface area that contact with the dyes and consequently leads to a better adsorption. The present study showed that the use of coal bottom ash (CBA) as an adsorbent would provide an effective on colour removal of dye solution.

*Keywords:* Coal bottom ash; Methylene blue; Methyl red; Adsorption; Dye pollutant

---

## 1. Introduction

Worldwide annual textile production is currently 30 million tons with expected growth of 3% per annum (Walker & Weatherley, 1997) and about 10,000 dye available commercially (Nigam et al., 2000). Consequently, many industries releases dyes into wastewater which have a high levels of contamination that are difficult to other chemical coagulant and flocculation process to reduce the pollutant since reactive dyes are highly soluble in water. Instead of that, the development of environmentally-friendly practices for reducing the industrial pollutants creates a challenge due to the growth in the modern technology since different textile processes differ in their contaminant contents (Reynolds & Richards, 1995).

Many industrial use dyes and pigments to colour or design their final products or their intermediate component. Consequently, the wastewater contaminant are highly coloured and the disposal of these wastes into the out of their plant that causes damage to the environment as their wastewater may significantly affect photo-synthetic activity in aquatic life. This colored wastewater may mix with surface-groundwater systems and thus pollute the drinking water. Water with high amount of color is not suitable for cloth washing, dyeing, paper industry, beverages production, dairies and other food products, textile industry, or plastic production (Malakootian & Fatehizadeh, 2010). Most of the dyes are resistant to biological degradation. The conventional techniques of treated wastewater treatment was basically based on biological oxygen demand (BOD) removal, but this technique ineffective in

removing colour from the effluent (Ali et al., 2007). Hence, removal of dyes from such wastewaters is a major environmental problem and complete dye removal is necessary (Papić et al., 2004).

Amongst the numerous techniques of dye removal, adsorption is the procedure and gives the best results as it can be used to remove different types of coloring materials (Derbyshire et al., 2001). Activated carbon adsorption has been widely used for wastewater treatment compared to other physical and chemical methods, for example, flocculation, coagulation, precipitation, and ozonation, and their possess inherent limitations, such as expensive cost, formation of hazardous by-products, and intensive energy requirements (Lee et al., 2006). Few studies were conducted towards finding other alternative adsorbents that fulfil their main criteria such as cost effectiveness, availability and adsorption characteristic for selecting an adsorbent to remove colour compounds.

The 'coal bottom ash' was an undesired collected material obtained by thermal power generation plants after combusting solid fuels which is transported and dumped near the surrounding land. Its disposal has always been a matter of concern to the station authorities, as the dumped ash is considered highly unsuitable for the agricultural lands (Gupta et al., 2004). In the present study, attempts have been made to utilize coal bottom ash, an industry waste, as a low-cost adsorbent as replacement for the current expensive method of removal pollutant from wastewater. The prepared adsorbent was characterized and used for the removal of two basic dyes namely- Methylene blue and Methyl red as adsorbate from aqueous solution.

The objective of this research is to prepare activated coal bottom ash (ACBA) and to evaluate the performance of coal bottom ash (CBA) and activated coal bottom ash (ACBA) towards colour removal efficiency of dye.

## 2. Methodology

### 2.1 Materials

Coal bottom ash was obtained from Manjung's coal-fired power plant. In the plant, it was produced which includes coal ash in the fraction of about 75-85% fly ash (FA) and of about 15-25% coal bottom ash (CBA). Coal bottom ash (CBA) was utilized as potential adsorbent in the study for removal dye. The dyestuffs were used as the stock solution. Methylene blue (M.F=  $C_{16}H_{18}ClN_3S$ ) and Methyl red (M.F=  $C_{15}H_{15}N_3O_2$ ).

### 2.2 Preparation of activated bottom ash

In pre-treatment process, coal bottom ash was dried up by using oven at 105°C for 24 hour to remove moisture contents and further kept in furnace at 500°C for 6 hour in presence of air (Gupta et al., 2005).

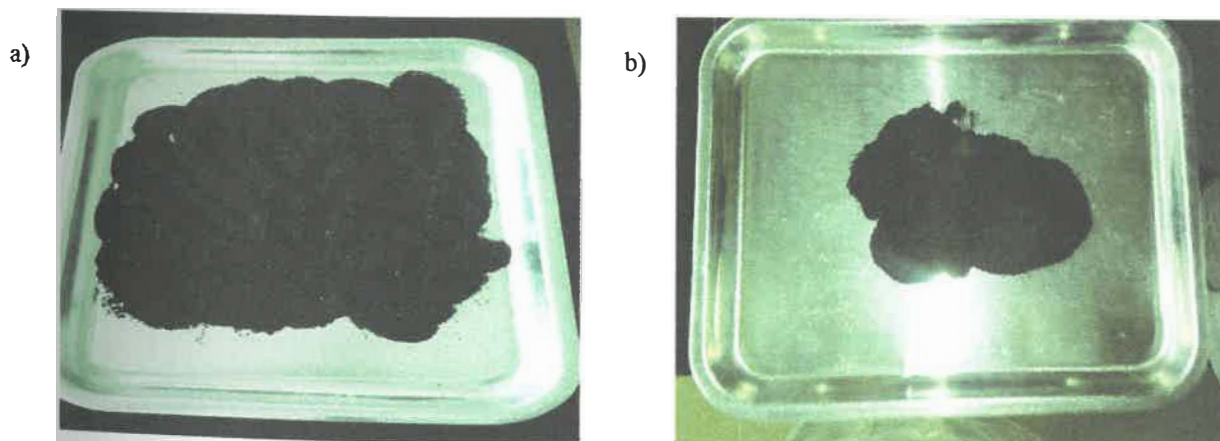


Figure 1. Coal bottom ash (a) before dried up by oven and (b) after dried up by using oven at 105°C for 24 hour

### 2.3 Analytical method

The sample of stock solution for before the adsorption and after the adsorption on both type of dyes was measured for the dye removal efficiency by using UV spectrophotometer (DR2800) region of 465 nm on 125 Colour

### 2.4 Adsorption studies

Adsorption studies were performed by batch technique for two type of dyes in aqueous suspensions of coal bottom ash (CBA) and activated coal bottom ash (ACBA). A series of 500 mL beaker were used and each beaker was filled with 50 mL of stock solution with initial concentration of 16 mg/L of methylene blue (MB) and 13.5 mg/L of methyl red (MR) respectively (Gandhimathi et al., 2013). A known amount of adsorbent was then added into each beaker and agitated intermittently at 150 rpm with magnetic stirrer on a hot plate at constant temperature of 50°C.

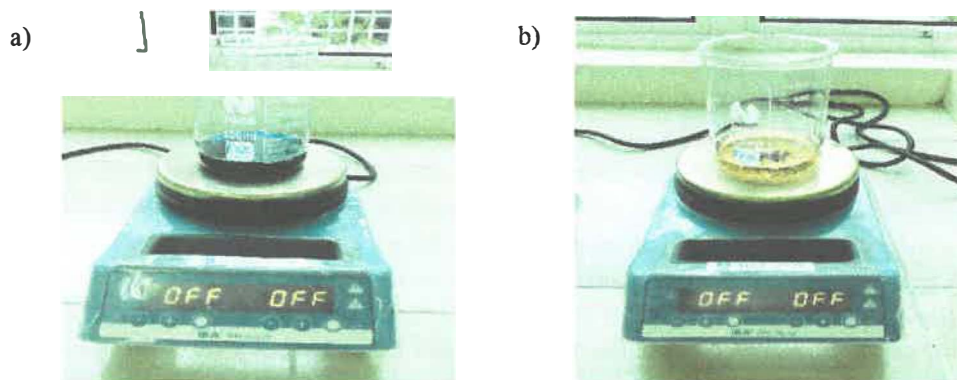


Figure 2. Methylene blue (a) and methyl red (b) for this experiment

#### 2.4.1 Effect of contact time

The contact time for the adsorption of dyes to the adsorbent was conducted with the known dosage of coal bottom ash/activated coal bottom ash (1 g) added to the 50 mL of stock solution. The solution were shaken at an agitation rate of 150 rpm. The solution were withdrawn at time interval from 1 hour, 2 hour and 3 hour with constant temperature of 50°C. The sample then being analyzed spectrophotometrically to determine the uptake of the dyes by using UV spectrophotometer (DR2800) region of 465 nm on 125 Colour.

#### 2.4.2 Effect of adsorbent dosage

This study was carried out by varying the amount of coal bottom ash/activated coal bottom ash from 1 g, 2 g and 3 g at fixed temperature of 50°C and 50 mL of stock solution and kept in the shaker at an agitation rate of 150 rpm for constant duration from 1 hour to 2 hour. The sample then being analyzed spectrophotometrically to determine the uptake of the dyes by using UV spectrophotometer (DR2800) region of 465 nm on 125 Colour.

### 3. Results and discussion

#### 3.1. Effect of contact time

Dye uptake capacities were determined as a function of time to determine an optimum contact time for the adsorption of dye on coal bottom ash (CBA) and activated coal bottom ash (ACBA). In both dyes, the investigations were made by the varying the contact time from 1 hour to 3 hour at fixed amount of adsorbent, constant temperature and initial dye concentration. The colour removal efficiency onto the dye solution was calculated by the difference between the content of the dye in the influent solution and that of the effluent solution, and it is expressed in percentage. An adsorption band is observed in the UV region of 465 nm on 125 Colour (Sun et al., 2008). The result for dyes, methylene blue (MB) were illustrated in Figure 3(a). Based on the results, the adsorption is quite rapid initially, gradually shows an increasing in adsorption with the increase in contact time (Ahmad Said, 2014). The uptakes of MB were found to be 3.22% for CBA and 3.23% for ACBA at 1 hour time interval. At 2 hour, the colour removal efficiency for CBA and ACBA were 3.83% and 4.51% respectively whereas at 3 hour of contact time, it was observed that dye uptake in the ACBA was higher than the CBA found to be 20.58% and 7.09% respectively (Dinçer et al., 2007). It was due to the properties of ACBA is more availability of the adsorbent sites (Hameed et al., 2007). The more the adsorbent sites will increase the contact of surface area with the dyes resulting the increases the dye uptakes. For the methyl red (MR), the uptakes of dye removal were found to be 61.28% for CBA and 78.53% for ACBA at 1 hour time interval as shown by the Figure 3(b). At 2 hour, the colour removal efficiency for CBA and ACBA were 43.39% and 76.72% respectively whereas at 3 hour of contact time, it was observed that dye uptake on coal bottom ash (CBA) and activated coal bottom ash (ACBA) were 30.41% and 69.93% respectively. Table 1 also shows for methyl red (MR), the decrease of the colour removal efficiency between 1 hour to 3 hour time interval on both type of adsorbent. It due to the methyl red (MR) just took 1 hour of the contact time to reach higher adsorption (Haris & Sathasivam, 2009). The low colour removal efficiency can be attributed in part to the lower initial concentration of MR (13.5mg/L) resulting the dyes was enough to reach higher adsorption (Egwuonwu, 2013). These results also indicate that the sorption process can be considered very fast based on the significant amount of adsorbents (Dey, 2014). During adsorption of dye solution, initially the dye molecule reached the boundary layer then they had to diffuse into the adsorbent surface. Last but not least, they had to diffuse into the process structure of adsorbent. Hence, this phenomenon will take a relatively longer contact time.

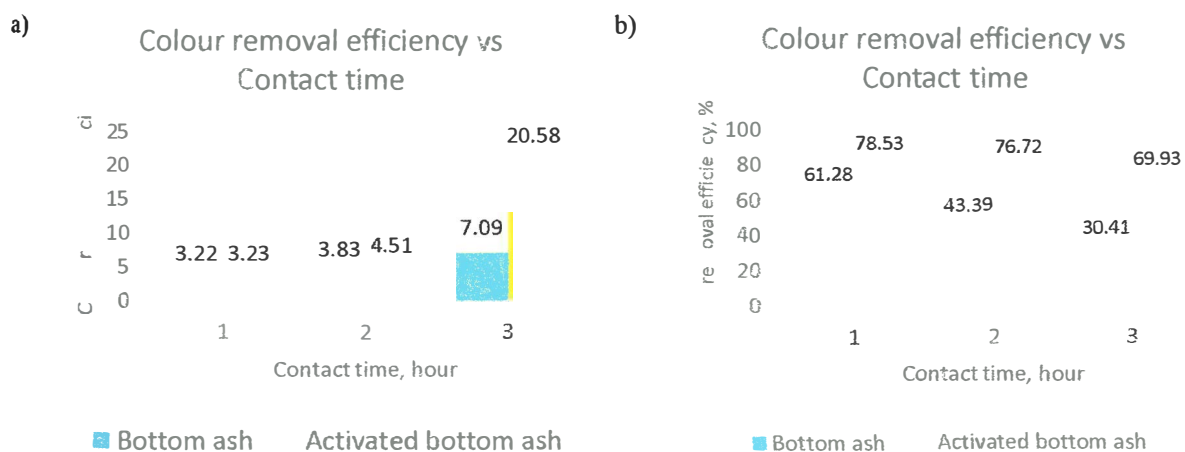


Figure 3. Colour removal of (a) methylene blue at fixed initial concentration = 16 mg/L ; (b) methyl red at fixed initial concentration = 13.5 mg/L, temperature = 50°C and amount of adsorbent = 1 g

Table 1. Contact time for activated bottom ash and bottom ash on different dyes solution

	Coal Bottom Ash (CBA)					Activated Coal Bottom Ash (ACBA)					
	Methylene Blue		Methyl Red			Methylene Blue			Methyl Red		
1 hour	2 hour	3 hour	1 hour	2 hour	3 hour	1 hour	2 hour	3 hour	1 hour	2 hour	3 hour
3.22%	3.83%	7.09%	61.2%	43.39%	30.41%	3.23%	4.51%	20.58%	78.53%	76.72%	69.9%

### 3.2. Effect of adsorbent dosage

Investigations were made by varying the amount of adsorbent from 1 gram to 3 gram at fixed temperature, initial dye concentration for methylene blue (MB) at 16mg/L and 2 hour of contact time. In case of methylene blue (MB), the uptakes of MB were found to be 90.32% for coal bottom ash (CBA) in Figure 4(a) and 95.91% for activated coal bottom ash (ACBA) in Figure 4(b) at amount of adsorbent (3g). It was clearly indicated that the increase the amount of adsorbent are proportional to the availability of the adsorbent sites. The increase of adsorbent sites and surface area that contact with the dyes will leads to a better adsorption. Figure 4 also indicates that the optimum amount of both adsorbents is 2 gram to 3 gram for higher adsorption whereas at 1 gram, it only low adsorption because of the lower availability of the adsorbent sites.

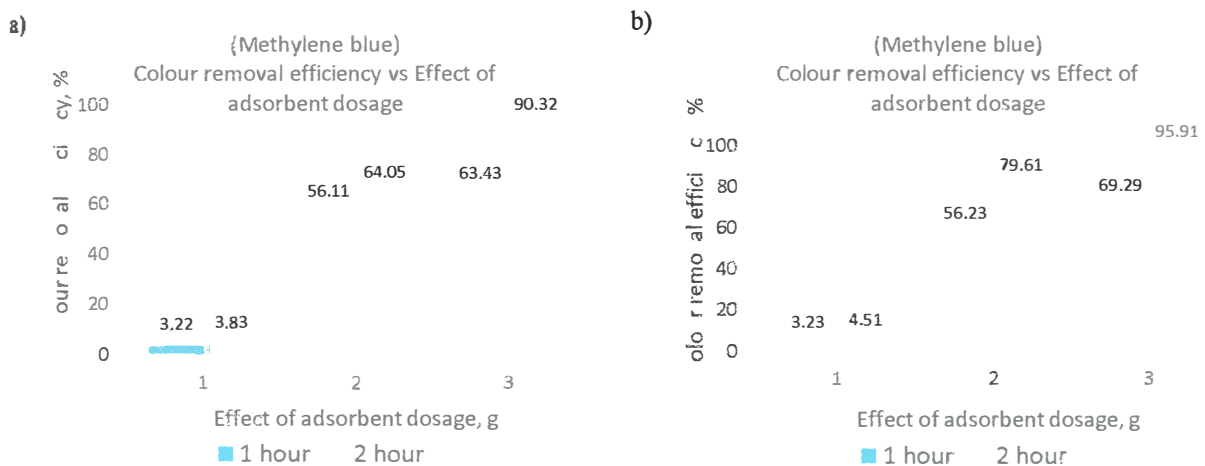


Figure 4. Colour removal of methylene blue for (a) coal bottom ash (CBA) ; (b) activated coal bottom ash (ACBA) at fixed initial concentration = 16 mg/L and temperature = 50°C

Figure 5 shows the effect of adsorbent dosage on both adsorbents to the dyes removal efficiency. The amount of adsorbent were manipulated from 1 gram to 3 gram at fixed temperature, initial concentration of methyl red (MR) at 13.5 mg/L and 2 hour of contact time. The uptakes of MR on the both adsorbents were found that gradually decrease on the increase of contact time (Hung et al., 2016). For time interval of 1 hour, the uptakes of MR were significantly has a higher adsorption of dyes removal for all amount of adsorbent dosage. It found that 61.28% of dyes removal for coal bottom ash (CBA) in Figure 5(a) and 78.53% for activated coal bottom ash (ACBA) in Figure 5(b) at 1 gram of adsorbent. However, at 2 hour, it clearly shows that the decreasing on the colour removal efficiency for each amount of adsorbent dosage. It due to sorption process for methyl red (MR) was only took 1 hour of contact time to reach higher adsorption. But, the increasing of amount of adsorbents dosage will results the higher adsorption of dyes into the adsorbent sites. The dye uptake at 3 gram of coal bottom ash (CBA) was higher than the