Effectiveness of carbon active processed from coal in treating the acid mine drainage at a laboratory scale

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Abstract. Low to medium calorie coal reserves dominate Indonesia area. Referring to such amount, the potential for coal synthesis into activated carbon is also massive. The potential utilization of activated carbon from coal to process the acid mine drainage is still developing. This research aims to see the effect of activated carbon to the acid mine drainage from coal mining in a laboratory scale using a weight basis and the contact time between activated carbon and acid mine drainage. The sample is taken from one of the mining locations in East Kalimantan Province. The results showed the effect of the activated carbon weight changes in its pH value, which indicated an increase in pH from 2.19 to a decrease in Fe metal content from 45.2 to 0.1 mg/L and a decrease Mn metal content from 7.22 to 5.3 mg/L. The activated carbon from coal is very effective as an adsorbent for Fe metal but less effective for Mn metal.

1. Introduction

Acid mine drainage is a product of mining activities, due to the reaction of exposed sulphide minerals with oxygen and the presence of water [1]. The presence of acid mine drainage can cause problems to the surrounding environment. Even the impact can exceed the life of the mine, as happened in the Iberian Pyrite Belt region, Spain, where mining activities have stopped BC, but the impact of acid mining water is still forming until today [2]. Acid mine drainage has a pH value ranges below 5, which is also characterized by high concentrations heavy metals such as Fe and Mn. The government has issued regulations for environmental quality standards according to the Minister of Environment Decree No. 113 the year 2003, where the parameters are pH 6 to 9, TSS 200 mg/L, Fe 7 mg/L, and Mn 4 mg/L.

Acid mine water treatment can use with an active or passive system [3,4]. Active processing that generally uses lime. The alkaline nature of lime increases the pH value. Passive processing uses natural materials whose application does not require much human intervention. Passive processing commonly used is the use of wetlands, using plant media that can absorb heavy metals in acid mine drainage [5]. Thus it can increase the pH value. Acid mine drainage treatment continues to develop with several studies such as alternative alkaline materials (marl, sandstone, calcareous crust) [6], bauxite refinery [7], alumina refinery [8], cryptocrystalline magnesite tailings [9], membrane separation [10] and wood ash [11]. Based on the several examples of acid mine water treatment with various alternative materials, it makes the idea to look for alternative acid mine water treatment using the activated carbon.

Indonesia is one of the largest coal producers in the world. In 2019, Indonesia's coal production reached 489,1 million tons [12]. By the end of 2019, Indonesia's coal resources reached 149 billion tons.
and coal reserves of 37 billion tons[13]. Coal reserves classified as low to medium calorie coal that are amounted to 22.72 billion tonnes [14]. Referring to the great potential of low to medium-calorie coal, it can be used as activated carbon.

This research aims to see the adsorption capacity of activated carbon against the adsorption of heavy metals in acid mine drainage, mainly Fe and Mn. The use of activated carbon is directly because it can be produced in mines with coal classified as low to moderate. Activated carbon itself is an amorphous carbon with a large surface area and volume, so it has a high adsorption capacity due to the carbonization process. This research continues the previous research related to the activated carbon for processing the acid mine drainage [15,16]. With this research, it can become the alternative management of acid mine drainage using the activated carbon.

2. Materials and Methods

2.1. Sampling
The acid mine drainage sample used in this study came from a mining company in East Kutai Regency namely, at the sump of one mining pits that currently is still active. Taken on January 2020, then the samples are analyzed at the laboratory for physical properties testing.

![Coal sampling](image)

**Figure 1.** Coal sampling.

2.2. Synthesis of activated carbon
The synthesis of activated carbon goes through three stages, namely the dehydration process which is performed by heating up to 170°C, and the carbonization process carried out by burning the raw materials using an airtight furnace at a temperature of 500°C while flowing with nitrogen gas for 1 hour. This carbonization process impacts the decomposition of organic compounds that make up the structure of the material to form methanol, acid vapor of acetate, tar, and hydrocarbons. The manufacture of activated carbon uses a chemical activation process using ZnCl₂ because it makes the tar melt in the combustion process. The use of ZnCl₂ so that the melted tar does not close the activated carbon pores. This study used coal-activated carbon with a coal composition of 60% and 40% ZnCl₂ [17].

2.3. Scanning electron microscope (SEM) test and iodine number of activated carbon
*SEM* is a microscope to observe the objects with high magnification with the help of electrons. This tool can scan the objects at high speed. The SEM has a magnification of 10 - 3,000,000 times, a depth of field of 4 - 0.4 mm, and a resolution of 1 - 10 nm. The primary function of SEM is to determine the topography, morphology, and composition of the tested material [18]. When moving quickly, an interaction between the electrons and the sample is testing. The interaction between electrons and the sample will produce two electrons, namely Secondary Electrons (SE) and Backscattered Electrons
(BSE). Secondary Electrons (SE) is used to analyze the surface information on topographic and morphological shapes. Meanwhile, Backscattered Electrons (BSE) analyzed the difference in composition within sample. Each composition (molecule or atom) will reflect electrons with different intensities depending on the type of composition of the sample itself. This study uses Hitachi Scanning Electron Microscope SU3500 to analyze the morphology of the activated carbon.

2.4. Weight and contact time variation
Activated carbon that has been synthesized is used in the adsorption test to determine its adsorption ability. A total of 150 mL of acid mine drainage samples from the field were added with activated carbon with a certain weight variation (Figure 2). Then this mixture is put in a shaker at speed of 150 rpm for 3 hours. This study also analyzes the effect of contact time on heavy metal removal. Variations of contact used include 1, 3, 5, 7, and 9 hours. Concentration of metal ions in acid mine drainage before and after adsorption was measured using the AAS so that the ability of activated carbon to remove heavy metal ions could be analyzed.

![Figure 2. Weight activated carbon variation.](image)

3. Results and Discussion

3.1. Acid mine drainage characteristic
Water samples taken from the field are in the sump. The water in the sump results from leaching, a reaction between the water and the pit wall, while direct precipitation. Based on the test results, the physical characteristics of the sample are the pH value of 2.19; the Fe content 45.2 mg/L, and the value of Mn 7.22 mg/L. Based on the results, the pH value is acidic with a pH value below 6; having Fe and Mn values do not meet the water quality standards in coal mining following the Decree of the Minister of the Environment No. 113 of 2003 [19].

3.2. Coal characteristic
Coal samples used as raw materials for activated carbon were obtained from mining sites in the South Sumatra region. Based on the results of the coal quality test, the calorific value is 5.927 Cal/g, the water content is 16.20%, the ash content is 2.45%, the volatile matter content is 41.27%, the fixed carbon value is 40.08% and the sulfur value is 0.24%. The coal sample used is included in the category of coal with moderate calorific value (using the classification from the Geology Agency, ESDM) which is in the range of 5,100 – 6,100 Cal/g (adb).

3.3. Scanning electron microscope (SEM) characterization
Figure 3 shows SEM tests' results on coal samples and activated carbon from coal. Figure 3A shows that the coal surface appears to have only a few cavities with a large enough size, and the surface is still solid and has a few cracks. Figure 3B shows that activated carbon has many fractures and pores. The
addition of pores and cracks in the activated carbon product of coal occurred due to ZnCl₂. The SEM results of activated carbon show potential for binding or adsorbs to heavy metals such as Fe and Mn in the water sample and then increasing the pH value.

![Figure 3. SEM test results: A. coal & B. activated carbon.](image)

Determination of adsorption of iodine was carried out using activated carbon that had been heated in the oven, weighed as much as ± 0.5 g and put into Erlenmeyer. The sample was given an iodine 0.1 N solution of 50 mL, stirred using a shaker for ± 15 minutes, and left for 15 minutes. Next, 10 mL of filtrate is taken and titrated with a solution of 0.1 N Na₂S₂O₃.

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Iodine\ Number\ (mg/g) = \left\{\frac{(V1 \times N1 - V2 \times N2)}{W}\right\} 
\]

with V1 is the iodine solution analyzed (mL), N1 is iodine normality, V2 is the required thiosulfate solution (mL), N2 is the normality of sodium thiosulfate, and W is the weight of activated carbon. The result of analysis of iodine number is 437 mg/g of coal and 1393 mg/g of activated carbon from coal. The activated carbon results of the study have high adsorption as adsorben.

3.4. The effect of weight variation of activated carbon

It can be seen in Figure 4, which shows the results of the coal activated carbon adsorption test using variations in weight to the pH value in the sample. The results obtained showed a tendency to increase in pH value. At a weight of 0.50 g, the pH value becomes 2.9; at a weight of 1.2 g, the pH value becomes 3.72; at 1.8 g, the pH value becomes 4.26; at a weight of 2.4 g, the pH value becomes 4.44; and at a weight of 3 g, the pH value becomes 4.62. Based on these results, it can seem that the more weight of activated carbon used will also affect increasing the pH value. In this study, the optimal weight variation to increase the pH value was 3 g.

The effect of weight variation on the adsorption of heavy metal Fe. In the beginning, before processing, the Fe content in the sample was 45.2 mg/L, after processing it was obtained: at a weight of 0.5 g, the value of Fe was 21.2; at a weight of 1.2 g, the Fe value is 5.9 mg/L; at a weight of 1.8 g the Fe value is 1.3 mg/L; at a weight of 2.4 g the Fe value is 0.6 mg/L, and at a weight of 3 g Fe value is 0.1 mg/L (Figure 5).

The effect of weight variation on the adsorption of heavy metal Mn, in the beginning, before processing, the Mn content was 6.9 mg/L. The test results that have obtained are: at a weight of 0.5 g, the value of Mn is 7.3 mg/L; at a weight of 1.2 g, the Mn value was 6.9 mg/L; at a weight of 1.8 g, the Mn value was 6.3 mg/L; at a weight of 2.4 g the Mn value was 5.9 mg/L, and at a weight of 3 gr the Mn value is 5.3 mg/L (Figure 5).
3.5. The effect of variation in contact time of activated carbon

Based on the results obtained on the weight variation, the 3 grams variation was chosen, which resulted in an increase in the pH value and the adsorption of Fe and Mn metals. These results are used as a reference to proceed with variations in contact time. The contact times used in this study were 1, 3, 5, 7, and 9 hours.

The effect of the variation in contact time on the pH value showed in Figure 6. It can seem that in the first 1 hour, there was an increase in the pH value to 4.6; at the 3rd hour, the pH value increased to 4.68; at the 5th hour, it increases to 4.86; at the 7th hour, there was no change, still, at the same value, namely 4.86; and then at the 9th hour the pH value increased to 4.88. The effect of contact time on the pH value shows no significant change because there has been an increase of only 0.28 since the increase in the first hour.

The adsorption of Fe metal is very significant, as seen in Figure 7. Based on the processing results based on contact time, the Fe value decreased significantly at 1 hour to 1.4 mg/L, at 3 hours to 0.24 mg/L, after at the 5th, 7th, and 9th hours there was no more Fe content in the processed sample. It can seem that the adsorption of Fe metal in the sample is very significant, and there is a big influence between the contact time and the adsorption of Fe metal.

The adsorption of Mn metal show in Figure 7. Based on the processing results based on contact time, the value of Mn reduce at 1 hour, at the initial Mn value was 7.22, reduced to 6.26 mg/L. At the 3rd
hour, the Mn value reduces to 5.98 mg/L; at the 5th hour, the Mn value showed a decrease to 4.84 mg/L, at the 7th hour, the change was not too significant to 4.83 mg/L; At the 9th hour, the Mn value decreased to 4.71 mg/L. The effect of contact time on the adsorption of Mn values was not too significant compared to the adsorption of Fe values.

Figure 6. The effect of time variation on pH values.

Figure 7. The effect of contact time variation on Fe and Mn adsorption.

4. Conclusion
Based on the results obtained, variations in the weight of activated carbon have an effect on increasing the pH value at a weight variation of 3 g with the highest pH value being 4.62, the overall Fe content being absorbed and the lowest Mn content being 5.3 mg/L. Variations in contact time of activated carbon, the maximum pH value obtained was 4.88, the overall Fe value was absorbed and the lowest Mn value was 4.71 mg/L at 9 hours. Based on the results obtained on the adsorption of heavy metals, especially the Fe content, the use of activated carbon from coal to treat acid mine drainage can be used as an alternative. If the pH value and Mn content can meet the MED No. 113/2003, it needs to be combined with other AMD active treatment methods.

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