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Treatment Of Acid Mine Drainage Using Fly Ash, Bottom Ash, And Lime Mixed

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ABSTRACT
Coal mining will form acid mine drainage in former open pit mines. If acid mine water enters community waters, it will cause disturbance to biota and decrease water quality. Sawahlunto is one of the cities in Indonesia that has a coal mining area located near a settlement. With the acid mine drainage, if it rains, the water will flow into the river where the water is used by the community. Part of the coal is used as fuel for the Sijantang Sawahlunto PLTU. The fuel also produces waste in the form of combustion ash known as fly ash and bottom ash (FABA). This study uses FABA to neutralize acid mine water to meet the community's irrigation water needs. This research will determine the appropriate mass of FABA in neutralizing acid mine drainage. Acid mine water comes from the former mining pit of PT. High Guguak Coal with a pH of 2.88. Then the acid sample is brought to the laboratory to be mixed with FABA and lime. 4.98 grams of FABA with 0.02 lime can neutralize 200 mL of acid mine drainage and change the pH from 2.88 to 7.91. FABA can be included in the settling pond to neutralize acidic water before it is released into community waters.

INTRODUCTION

Sawahlunto City is located in West Sumatra Province in Indonesia. In this city, there is a power plant in the village of Sijantang. The location is about 15 km from the town of Sawahlunto. The Sijantang power plant produces 2 x 1000 watt of energy to meet the electricity needs of several cities/districts in West Sumatra. The Sijantang power plant uses coal from the Sawahlunto and surrounding areas as fuel.

The use of coal as fuel raises several problems. One of the problems in the Sijantang power plant is the fly ash and bottom ash (FABA) waste. Fly ash and bottom ash (FABA), the residue after producing 2 x 1000 watts, is 400 tons per day. The unused fly ash and bottom ash (FABA) become waste and pollute the surrounding settlements [1]. This coal combustion ash formed amorphous and poisonous pozzolan particles. Fly ash is alkaline, but the value is largely determined by the amount of Sulfur in the coal, the type of coal used, and the amount of Sulfur in the fly ash [2].

Combustion ash is divided into two, namely, fly ash and bottom ash. Fly ash has grayish fine grain size particles and is a residue of coal combustion. The bottom ash is ash generated from the furnace bottom after the combustion process.

Several previous studies have proven that fly ash and bottom ash (FABA) can be used to neutralize acid mine drainage [3] [4] [5]. Not only FABA, this study also uses lime to neutralize acid mine drainage. From this study, we can analyze how much lime needed to neutralize the acid mine water. Furthermore, this research also mixes fly ash, bottom ash, and lime to neutralize mine acid water. The aim is to reduce fly ash and bottom ash by using them to neutralize acid mine drainage.

Sawahlunto City has many mine dumps, one of which is the Guguak Tinggi Coal mine dump. It has acid mine drainage with a pH of 2.88. This research uses acid mine water from the Guguak Tinggi Coal mine dump. Based on the explanation above, There are four purposes of this study. This study aims to obtain mineral compositions of fly ash and bottom ash (FABA). This study also means to find out the amount of fly ash and bottom ash (FABA) needed to neutralize acid mine water and get normal acidity. Besides, it also intends to seek the amount of limes for neutralizing acidic mine water to get a normal degree of acidity. Another purpose is to figure out the optimum proposition of FABA and lime mix in neutralizing the acid mine water and obtain water with balance pH.

Acid Mine Drainage

Acid mine drainage formation happened due to the oxidation of FeS (pyrite) minerals. Acid mine drainage (AMD) or acid rock drainage (ARD), collectively called acid drainage (AD), is water that comes from mines or rocks that contain certain sulfide minerals that are exposed and oxidized. Acid mine drainage is from layers of sedimentary rocks of coal containing acidic sulfate, which is then oxidized by oxygen and contaminated by water after a certain time.

Mining drainage can be classified into 5 types [6], namely:

1. *Acid Mine Drainage Type 1*

The Acid Mining Drainage contains dissolved solids containing high Fe and Mn, has little or no oxygen, and pH > 6. Under oxidizing conditions, the pH of this type of water can drop significantly and turns into acid drainage type 1.

2. *Acid Mine Drainage Type 2*

The Acid Mining Drainage contains dissolved solids containing high Fe and Mn, has little or no oxygen, and pH > 6. Under oxidizing conditions, the pH of this type of water can drop significantly and turns into acid drainage type 1.

3. *Acid Mine Drainage Type 3*

This acid drainage has moderate to high concentrations of dissolved solids. It also has a low to moderate concentration of Fe and Mn without or little oxygen. The pH is more than 6, and it has a higher alkalinity than acidity. It is commonly called alkaline mine drainage. In oxidizing conditions, the acids from metal hydrolysis and deposition reactions will be neutralized by alkaline compounds in the water.

4. *Acid Mine Drainage Type 4*

The Acid Mining Drainage contains dissolved solids containing high Fe and Mn, has little or no oxygen, and pH > 6. Under oxidizing conditions, the pH of this type of water can drop significantly and turns into acid drainage type 1.

5. *Acid Mine Drainage Type 5*

The AMD has been neutralized so that the pH is more than 6 and contains high concentrations of dissolved solids. After almost all metal hydroxide has been deposited in the settling pond, the main cations left in the water with high concentrations are generally dissolved calcium (Ca) and magnesium (Mg). Dissolved anions such as bicarbonate and sulfate remain in the water. However, If the neutralization process lacks alkalinity, this type of AMD will not be formedAcid Mining Drainage contains dissolved solids containing high Fe and Mn, has little or no oxygen, and pH > 6. Under oxidizing conditions, the pH of this type of water can drop significantly and turns into acid drainage type 1.

Acid Mine Drainage Treatment

The acid mine drainage treatment generally uses chemicals containing lime. It can be in the form of CaCO3, Ca(OH)2, CaO, or the addition of caustic soda (NaOH), and ammonia (NH3). The acid neutralization reaction with lime-containing material is as follows:

$$Ca(OH)2+H2SO4<=>CaSO4+2H2O \tag{1}$$

$$Ca(OH)2+FeSO4<=>Fe(OH)2+CaSO4 \tag{2}$$

$$3Ca(OH)2+Fe2(SO4)3<=>2Fe(OH)3+3CaSO4 \tag{3}$$

Many researches on the treatment of Acid Mine Water have been carried out, such as passive treatment and active treatment [7].

Fly Ash Bottom Ash (FABA)

1. The Process of Forming Fly Ash Bottom Ash

Coal combustion systems are generally divided into two namely fluidized bed systems and fixed bed systems or grate systems [8]. Besides that, there is a third system, namely the spouted bed system, also known as the transmitting bed. Fluidized bed system is a system where air is blown from below using a tool so that the solid objects above it behave like fluid. Fluidization technique in coal combustion is the most efficient technique in producing energy. Sand or corundum which acts as a heating medium is preheated. Heating is usually done with fuel oil. After the sand temperature reaches coal combustion temperature (300^{o}C), coal is fed. This system produces fly ash and ash which drops under the tool. The gray is called fly ash and bottom ash. Fluidized bed technology is usually used in power plants.

2. Composition of Fly Ash and Bottom Ash

Coal fly ash contains some chemical elements including silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3), and calcium oxide (CaO). It also contains other additional elements, namely magnesium oxide (MgO), titanium dioxide (TiO_2), alkaline (Na_2O, and K_2O), sulfur trioxide (SO_3), phosphorus oxide (P_2O_5), and carbon. Some factors affecting the physical, chemical, and technical properties of fly ash are coal type, coal purity, coal crushing level, the heating, and operating method, as well as the keeping and storing method [8].

Fly ash from coal combustion can absorb water and some nutrients so that it can improve the adsorption quality. Besides, it is also useful as an adsorbent for various pollutant substances such as SOx, CO, and dust particulates including lead (Pb). Coal fly ash is also used in molding materials in the metal casting industry because it has a much smaller grain size than printed sand. Therefore, the molding process will produce a smoother surface [9]. Fly ash and bottom ash is also used as a road compactor [10]. The addition of FABA into the base layer mixture that can increase the bearing capacity of the base layer in road pavement construction [11]

Limestone

Limestone is a type of sedimentary rock that contains carbonate compounds. Widely available limestone is the one containing calcite. The colors of limestone are white, yellowish-white, gray to black color. The colors depend on the mixture composing the limestone, for example, clay, quartz, iron oxide, manganese, and organic elements. Limestone is formed from the remains of shells in the sea, and the process of chemical precipitation.

Chemically the reaction equation between lime and water is written as follows:

$$CaO(s) + H_2O \rightarrow Ca(OH)_2 (aq) \tag{4}$$

The reaction of limestone ($CaCO_3$) will produce $Ca(OH)_2$. This compound is a base compound so that if it reacts with H^+ ions, it will generate the following reaction [5] [12] [13]:

$$Ca(OH)_2 + 2H^+ \rightarrow Ca^{+2} + H_2O \tag{5}$$

Therefore, it can be concluded that the CaO in quicklime can reduce the amount of H^+ ions contained in the acid mine water.

METHOD

This study is experimental research. The experimental research is intentionally done by giving certain treatments to stimulate an event or a condition on the subjects. The purpose is to examine changes as well as the result. Another definition states that the experimental research is research on variables for which data do not yet exist, so it is necessary to manipulate the process by giving certain treatments to study the subjects being observed or measured for their impact [14].

Location and Direction to the Research Site

Geographically, the Sijantang Steam Power Plant is located at 100˚45'14.21" E and 0˚36'31.93" S of Talawi District, Sawahlunto, West Sumatra. The distance between the Power Plant to Padang is about 103 Km. It can be reached by two-wheeled or four-wheeled vehicles from Padang to Sawahlunto for about 3 hours from Universitas Negeri Padang. The location can be seen in Figure 1.

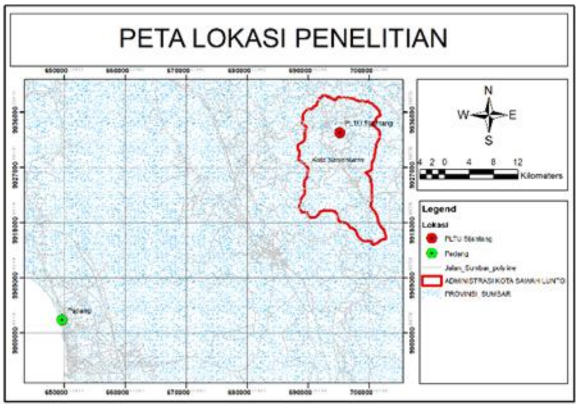

***Fig 1.** Sample Location*

Acid Mine Drainage Neutralization Testing

Equipment used in the testing of acid mine drainage are:

1. KERN: ABS 220-4 Digital Scales
2. Multimatic-5N JP.SELECTA Magnetic Stirrer
3. 100 ml and 250 ml of Volume Measuring cups
4. Magnets
5. Aluminum foil
6. Lutron PH-222 pH meter

Research Design

Stages of neutralizing acid mine drainage testing by mixing fly ash, bottom ash (FABA), lime, and both mixes begin with the measurement of sample mass with the KERN digital scale: ABS 220-4. The weight of the samples used as the test materials are in Table 1.

Table 1. Variations in Mass of Samples Used in Testing

Variations in Sample Mass Used			
FABA (gr)	Lime (gr)	Mixed	
		FABA (gr)	Lime (gr)
3	0.005	2.98	0.02
5	0.01	2.84	0.16
6	0.02	2.5	0.5
7	0.025	2	1
9	0.03	4.98	0.02
10	0.04		
15	0.08		
20	0.16		

From Table 1, each weight composition of the sample will be used as a test material for neutralizing acid mine water. Each sample will have three times testing.

The procedure for testing acid mine drainage are as follows:

1. Pour the acid mine water into a measuring cup of 250 ml to a volume of 200 mL. Then, the measuring of the acidity of water is using a pH meter. The pH of acid mine water is 2.88. Acid mine water is the controller in later testing.
2. The weight of Fly ash, bottom ash (FABA), lime, and a mixture of both are initially scaled based on the mass composition of the sample determined in Table 1. After weighing, the sample is wrapped using aluminum foil
3. Poured acid mine water into a 250 ml measuring cup for 200 ml.
4. Mix the samples weighed in step number 1 with 200 ml volume of acid mine water
5. Insert the magnet into the measuring cup that already contains acid mine water and FABA. This magnet (Figure 5) functions as a stirrer.
6. Stir the solution with the Multimatic-5N JP.SELECTA Magnetic Stirrer for 15 minutes
7. Record the pH value of the stirred acid mine water and do the same for each variation of the sample mass tested
8. Check the pH controller again.
9. Record the measurement resultsThe experimental steps are also carried out for lime, and a mixture of lime and FABA.

RESULTS AND DISCUSSIONS

The Steam Power Plant location is in the Sijantang district. Sawahlunto is an electricity producer city. The electricity is distributed to several cities/regencies in West Sumatra. This Sijantang power plant uses coal as the fuel to produce electricity. The use of coal as for the power plant generates waste in the form of fly ash and bottom ash, which can be seen in Figure 2.

Fig 2. *The Buildup of Fly Ash and Bottom Ash (FABA) Waste*

Coal fly ash is coal combustion residue materials that have grayish fine grain particles. The Power Plant coal combustion produces solid waste in the form of fly ash and bottom ash. The ash particles carried by the flue gas are called fly ash, while the ash left behind and removed from the bottom of the

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furnace is called bottom ash. It causes environmental and health problems because the fly ash resulting from the coal incinerator is disposed of as a large amount of fly ash and bottom ash deposits. It requires proper management so as not to cause environmental problems, such as air or water pollution. Furthermore, it causes deterioration in ecosystem quality [15].

Fly Ash and Bottom Ash (FABA) Chemical Content

Fly ash is a material that has a fine grain size, blackish gray and is obtained from the combustion of coal . X-Ray Fluorescence (XRF) tests were carried out at the chemical laboratory of the Faculty of Mathematics and Science to find out the chemical content of fly ash and bottom ash (FABA) in Universitas Negeri Padang.

Based on X-Ray Fluorescence (XRF) test the minerals contents of fly ash and bottom ash (FABA) are as follows: 48.1% Silica (SiO2), 24.2% Alumina (AL2O3), 8.7% Iron Oxide (Fe2O3), 5% Magnesium Oxide (MgO), 4.2% Alkaline (K2O), 3.8% Calcium Oxide (CaO), 2.7% Phosphorus Oxide (P2O5), and 1.6% Titanium Oxide (TiO2).

Neutralizing Acid Mine Drainage

1. *Neutralization by Using Fly Ash and Bottom Ash (FABA)*

In previous studies, 55gr fly ash bottom ash (FABA) can neutralize 1 liter of acid mine drainage. Because of the Multimatic-5N JP.SELECTA Magnetic Stirrer can only hold a 250 ml tube with a 20 ml volume of acid mine water, the fly ash bottom ash (FABA) used is 11 gr.

$$\frac{55gr}{1000ml} = \frac{X}{200ml}$$

$$X = 11gr$$

Therefore, the mass of fly ash and bottom ash (FABA) variation are in a range of 3gr, 5gr, 6gr, 7gr, 9gr, 10gr, 15gr, and 20gr. The first step of the test is to mix 200 ml of acid mine water, add fly ash and bottom ash (FABA). The next step is to stir the mixture using the Multimatic-5N JP.SELECTA Magnetic Stirrer for 15 minutes. The results of neutralizing acid mine drainage testing using fly ash and bottom ash (FABA) can be seen in Table 2.

Table 2. The test result of Acid Mine water with FABA

Time (mnt)	15							
Vol Acid Mine Water (mL)	200							
Initial pH	2,88							
pH test control	2,88							
Experiment								
FABAMass (gr)	3	5	6	7	9	10	15	20
pH test result	3.98	6.43	6.16	7.16	6.79	7.23	7.4	7.53
	5.78	6.57	6.79	6.8	7.2	7.06	7.42	7.51
	4.13	6.4	6.46	6.86	7.13	7.18	7.48	7.54
pH Avrg	4.63	6.46	6.47	6.94	7.04	7.15	7.43	7.52

From Table 2 shows that there is a change in the pH of acid mine drainage which is quite varied, which initially had a pH of 2.88 rising to a pH of 7.54 and is shown in Figure 3. Based on Figure 3, it can be seen that the addition of FABA quickly increases the pH from 4.63 to 6.46. However, the addition of FABA mass with other variations no longer increases the pH of acid mine water rapidly. In general, the effect of adding FABA to the pH of acid mine drainage meets the following logarithmic equation:

$$y = 1{,}3689\ln(x) + 3.859$$
$$R^2 = 0{,}8071 \text{ so } R = 0{,}9$$

Changes in pH with the addition of FABA follow the trendline with a nonlinear regression coefficient logarithmic of 0.9. This study provides a lower FABA level of 35gr/L than previous studies of 55gr/L [2] within 15 minutes. Research [16] obtained a result of 1.6gr/L in 125 minutes.

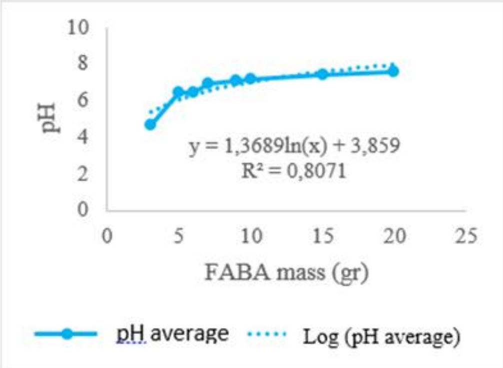

Fig 3. *FABA to neutralize AMD*

2. *Neutralization by Using Limestone:*

Table 3. Results of Acid Mine Water Test with Limestone

Time (mnt)	15							
Volume Acid Mine Water (mL)	200							
Initial pH	2.88							
pH test control	2.88							
Experiment								
Lime mass (gr)	0.005	0.01	0.02	0.025	0.03	0.04	0.08	0.16
pH test Result	3.01	0.01	7.64	8.73	9.8	9.25	10.16	11.05
	3.13	3.2	7.79	8.54	9.67	10.11	10.43	11.38
	3.08	3.53	8.3	7.89	9.74	10.34	11.25	11.87
pH Average	3.07	3.44	7.91	8.38	9.73	9.9	10.61	11.43

Table 3 shows that there are varied changes in the pH of acid mine drainage. The acid water initially had a pH of 3.07, then the pH rises to 11.43. The pH changes are shown in Figure 4.

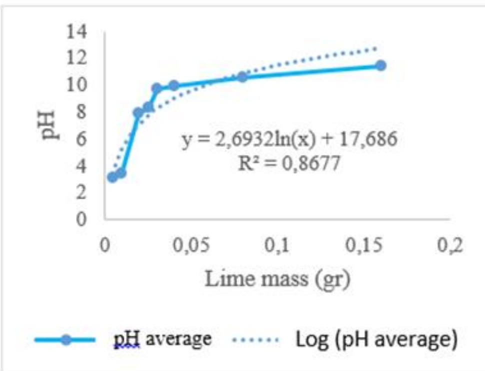

Fig 4. *Graph of Acid Mine Water Test Results with Lime*

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Based on Figure 4, it can be seen that the addition of lime increases the average pH from 3.07 to pH 7.91. In general, the effect of adding lime to the pH of acid mine water meets the logarithmic equation as follows:

$$y = 2{,}6932\ln(x) + 17.686$$
$R^2 = 0{,}8677$ so, R=0.93

Changes in pH with the addition of lime follow the trendline with a nonlinear regression coefficient logarithmic of 0.93. Thus, 93% of Lime affects the neutralization of acid mine drainage.

The test results show that mixing acid mine water with lime samples can increase the pH of acid mine water with an optimal mass of 0.02 grams increasing the pH to 7.91. Therefore, a mass of 0.02 grams of lime can neutralize acid mine drainage by changing the pH from 2.28 to 7.91. It means 1 gram of lime can neutralize 10,000 mL of acid mine drainage. It appears that lime is very effective in neutralizing acid mine drainage. Based on these results, we can minimize the FABA mass and mix it with lime. The purpose is to avoid too much use of FABA because it also contains heavy metals such as Alumina, Magnesium Oxide, Iron Oxide, and Titanium Oxide. Many studies using lime to neutralize acid mine water have been carried out because lime is a base that will neutralize acid mine water [17] [18] [19].

The procedure for testing acid mine drainage are as follows:
In acid mine neutralization using a mixture of FABA and lime, the first step is mixing 200 ml of mine acid water with a mixture of fly ash, bottom ash (FABA), and lime. The nest step is stirring the mixture using Magnetic Stirrer Multimatic-5N JP.SELECTA for 15 minutes. Determining the amount of lime to be added to the mixture is rather difficult because 0.02gr lime can neutralize acid mine drainage. By testing many variations of mass between FABA and lime, the results can be concluded. The results of neutralizing acid mine drainage tests using fly ash bottom ash (FABA) can be seen in Table 4.

Table 4. Results of Acid Mine Water Test with a Mix of FABA and Lime

Time (mnt)	15				
Vol Acid Mine Water (mL)	200				
Initial pH	2.88				
pH test control	2.88				
Experiment					
FABA+Lime (gr)	2.98+0.02	2.84+0.1	2.5+0.5	2+1	4.98+0.02
pH Test Result	8.59	10.28	11.66	12.09	7.19
	8.27	10.46	11.54	12.38	8.4
	8.91	10.11	11.48	12.43	8.26
pH Average	8.59	10.28	11.48	12.3	7.95

Table 4 shows that there is a change in the pH of acid mine drainage from 2.28 to 7.95.

The management of FABA is expected to be carried out by the company so that in accordance with Government Regulation (PP) Number 22 of 2021 concerning Implementation of Environmental Protection and Management, it still has an obligation to be managed until it meets the standards and technical requirements set [20].

CONCLUSION AND SUGGESTION

Conclusion
The mineral composition of fly ash and bottom ash (FABA) is as follows: 48.1% Silica (SiO_2), 24.2%

Alumina (AL2O3), 8.7% Iron Oxide (Fe2O3), 5% Magnesium Oxide (MgO), 4.2% Alkaline (K2O), 3.8% Calcium Oxide (CaO), 2.7% Phosphorus Oxide (P2O5), and 1.6% Titanium Oxide (TiO2).
Based on the results of laboratory tests, the optimal mass of fly ash bottom ash (FABA) for neutralizing acid mine drainage is 7 grams for 200 ml of acid mine drainage. Based on the test, the optimal lime mass to neutralize acid mine drainage is 0.02 gram for 200 ml of acid mine water.
The optimal composition for neutralizing acid mine drainage with a mixture of fly ash bottom ash (FABA) and lime is 4.98 grams of FABA plus 0.02 grams of lime for 200 ml of acid mine drainage.
The implication of this research is that FABA and lime can be included in the settling pond to neutralize acid mine water, so that it can flow into community waters. So that the accumulated FABA can be utilized as well, not only as waste at the Sijantang PLTU.

Suggestions
The waste from coal combustion residue or fly ash and bottom ash (FABA) produced by the power plant can be reused by coal mining companies to overcome acid mine drainage in the mining area. Thus, reducing a buildup of fly ash and bottom ash (FABA) in the area of the Stem Power Plant. Besides, it will reduce environmental pollution for the surrounding residents.

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