pH Neutralization of Acid Mine Drainage Using Open Limestone Channel with Addition of Fly Ash and Silica Sand on Laboratory Scale Testing

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Abstract. This research aims to neutralize the pH of acid mine drainage using a passive open limestone channel method using limestone as a neutralizing agent, which is then modified by adding other test materials such as fly ash and silica sand. This test will be carried out through three repetitions which will later be called the AA-0 Combination, AA-1 Combination, and AA-3 Combination. The pH value of the acid mine drainage before the test was 3.75 and after the test was carried out, the final pH Combination AA-0 was 7.39; The final pH of the AA-1 Combination was 7.3; and AA-2 Combination final pH is 7.21.

Keywords : Open Limestone Channel, Neutralize pH, Acid Mine Drainage, Silica Sand, Fly Ash

1 Introduction

The number of mining companies in Indonesia turned out not only to be a source of income or income for the government, but mining to have adverse side effects, especially for the community. There are many conflicts or reports between residents and environmental activists against mining companies, because of the large negative effects of mining waste due to not implementing good mining engineering principles, especially in companies that do not implement *clear and clean* principles or illegal mining.

This pollution will cause various consequences ranging from itching, vomiting, and cancer, and in the long term, heavy metals that accumulate can interfere with the condition of the body more - especially organs that lead to loss of life. It will continue to be bad if people consume fish contaminated with this pollutant because this metal cannot be neutralized by the body.

For this reason, efforts need to be made to find other options or solutions in terms of neutralizing the pH of acid mine drainage. One of them is through this research by carrying out acid mine drainage neutralization trials using the passive open limestone channel method which is modified with the addition of test materials in the form of fly ash and silica sand, this research will be tried on a laboratory scale.

2 Literature Review

2.1 Definition of Acid Mine Drainage (AMD)

Acid Mine Drainage (AMD) is water that has a large level of acid from the results of mining activities. Not only has a low pH, acid mine drainage also contains a large concentration of heavy metals, this heavy metal oxidation will cause the pH of the water to become acidic [1] so that it can pollute rivers and require good drainage planning in acid mine drainage management [2]. Acid mine drainage is created due to the oxidation of sulfide minerals that are open or exposed such as pyrite (FeS_2) in contact or reaction with water, O_2, and other supporting aspects [3].

2.2 Acid Mine Drainage Formation

Acid mine drainage (AMD) arises due to the weathering of sulfur or sulfide minerals found in mining zones, ores, or various types of waste produced as a result of mining activities. There are 5 chemical reaction stages for the formation of acid mine drainage [4], which can be seen in reaction 1 to reaction 5 below:

$$2FeS_{2(s)} + 7O_{2(g)} + 2H_2O_{(aq)} \rightarrow 2Fe^{2+}_{(aq)} + 4SO_4^{2-}{}_{(aq)} + 4H^+_{(aq)} \quad (1)$$

$$FeS_{2(s)} + 14Fe^{3+}_{(aq)} + 8H_2O_{(aq)} \rightarrow 15Fe^{2+}_{(aq)} + 2SO_4^{2-}{}_{(aq)} + 16H^+_{(aq)} \quad (2)$$

$$4Fe^{2+}_{(aq)} + O_{2(g)} + 4H^+_{(aq)} \rightarrow 4Fe^{3+}_{(aq)} + 2H_2O_{(aq)} \quad (3)$$

$$Fe^{2+}_{(aq)} + 1/2O_{2(g)} + 5/2H_2O_{(aq)} \rightarrow Fe(OH)_{3(s)} + 2H^+_{(aq)} \quad (4)$$

$$FeS_{2(s)} + 15/4O_{2(g)} + 7/2H_2O_{(aq)} \rightarrow Fe(OH)_{3(s)} + 2SO_4^{2-}{}_{(aq)} + 4H^+_{(aq)} \quad (5)$$

2.3 Coal Mining Wastewater Quality Standards

In conducting testing, it is necessary to have standards or quality standards as a benchmark for test results [5], for quality standards from wastewater for coal mining businesses and / activities can be seen in Table 1.

Table 1. Wastewater Quality Standards for Coal Mining Businesses and/or Activities

Parameter	Unit	Up to Maximum	
		Mining	Processing/ Laundering
Acidity (pH)		6-9	6-9
Suspended Residue	mg/l	400	200
Iron (Fe) Total	mg/l	7	7
Manganese (Mn) Total	mg/l	4	4

(Source : Kepmen LH No.113 Tahun 2003)

2.4 Acid Mine Drainage Management

Acid mine drainage can be formed from three elements, namely sulfide minerals, water, and oxygen. To the management strategy, eliminating one of the forming elements will eliminate the possibility of acid mine drainage formation. This process is also related to the natural attenuation process, which is a process of reducing mass, concentration, mobility, and toxicity from pollution contaminants [6,7], where in acid mine drainage things that must be reduced or minimized such as concentration or metal content which when oxidized can affect the pH of the water.

Sulfide minerals that generally come from mining rocks in the form of ore and waste are options that are impossible to eliminate in mining activity, so the other two elements are still possible to manage. There are three strategies in acid mine drainage management [8], namely:

a. Reduces the occurrence of oxidation of sulfide minerals.
b. Control and reduce contaminant loads that came out towards the neighborhood.
c. Active and passive management apps that enable managed water to be utilized returned or discarded.

According to [8,9,10] in the implementation of an acid mine drainage management strategy, several things can be done, as follows:

a. Dry Cover Method

One method known as dry cover is generally applied by placing a protective NAF (Non-Acid Forming) material around the PAF (Potential Acid Forming) material. With the placement of NAF material protection, it is hoped that the potential for water infiltration into PAF rocks can be reduced. But in general, this technique cannot completely prevent the formation of acid mine drainage. In the refinement of this technique, generally the backfill layer is equipped with a cover crop (surface cover plant) and is equipped with a drainage system to drain acid mine drainage that is still forming as shown in Figure 1.

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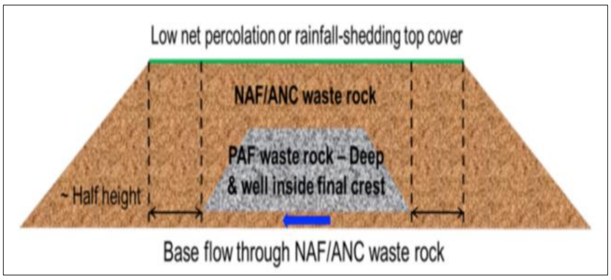


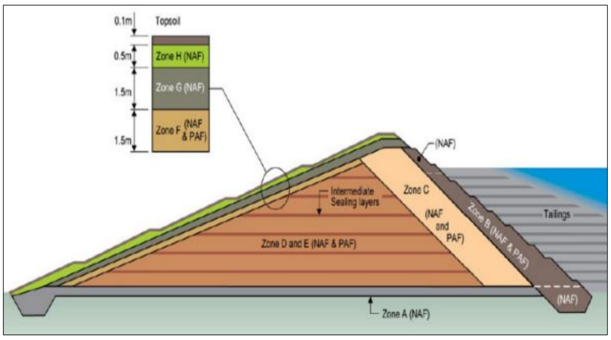
(Source : LPSPD, 2016)

Figure 1. Dry Cover Methods Illustration

b. Wet Cover Methods

This strategy is aimed at eliminating the exposure of sulfide rocks/sulfide waste to oxygen so that the oxidation process can be eliminated where one example is storing sulfide tailings under the water table such as in reservoirs or lakes.

One use of this technique is combined with the application of NAF material on slopes and tailings. This application is used at the Martha Gold Mine Site in Waihi, New Zealand. Mining activities produce material waste in the form of PAF and NAF where the existence of these two types of waste can be used as a support in the management strategy of acid mine drainage. PAF material as a cause of acid mine drainage formation is limited and surrounded by NAF material by forming parts where this is intended so that PAF waste rock is not oxidized and exposed to air (oxygen). For illustration is shown in Figure 2.



(Source : LPSPD, 2016)

Figure 2. Illustration of PAF and NAF Combination System

c. Active Management and Passive Management

The management of the active method itself is the handling of acid mine drainage through the addition of materials that have alkaline properties such as the application of quicklime (containing calcium elements such as dolomite, calcite, and magnesite), and coal ash [11,12,13].

Then there is passive method management which is a management process that does not require intervention, operation, or maintenance by humans continuously, relying on the formation of bio-geochemical processes, which take place continuously naturally in increasing pH and deposition of dissolved metals. These systems use naturally occurring energy such as tilt, metabolic energy from microbes, photosynthesis, and chemical energy and require regular maintenance but are not often required to operate throughout their design life [11]. The process does not require large power sources or additional chemicals after construction and can be decades old with minimum human intervention [11].

The passive method management system can be carried out through anoxic limestone drains, wetlands [14], and open limestone channel systems [10], as well as direct management in the field by covering rocks that have the potential to form acid mine drainage using materials that do not have the potential to form acid mine drainage [8].

For example, management with a wetland system that utilizes plants as mineral absorbers in acid mine drainage has been applied to several mines. The wetland system is carried out by flowing acid mine drainage through a series of channels that allow reducing the pH level through the use of alkaline and plant materials [9]. An example of a wetlands application is illustrated in Figure 3.

(Source : LPSPD, 2016)

Figure 3. Wetland System in Acid Mine Drainage Management

Some things to consider to determine an effective management method are:

a. Chemical characteristics of water to determine the major ions contained in acid mine drainage.
b. Water discharge that will affect the cost and extent of water management.
c. Management targets for the quality of water produced adjust to field conditions.

3 Research Methodology

3.1. Types of Research

This research is classified as experimental research. Experimental research is research that is very reliable scientifically (very valid or very accurate) because it is through strict control of confounding variables outside the one to be experimented [15].

3.2 Research Objects

The object of this study is acid mine drainage. The acidic pH condition of water in acid mine drainage storage or treatment ponds makes it necessary to conduct trials through research or studies to obtain a good neutralization method for acid mine drainage management.

3.3 Research Methods

This study used the open limestone channel method or limestone open channel that uses limestone as a neutralizing material. Limestone will be arranged in the channel and will dissolve when exposed to acidic water and carry alkalinity that can increase the pH value of the water [16]. An illustration of the open limestone channel can be seen in Figure 4.

(Source : Skousen, et al, 2016)

Figure 4. Open Limestone Channel Illustration

3.4 Test Material Specifications

In this study, three iterations of trials will be carried out using the planned test materials and then this test will be named AA Combination (AA-0, AA-1, and AA-2). Before testing, material preparation will be carried out such as test materials, size adjustments will be made by reducing, and sieve tests will be carried out to obtain the distribution of gradation of test materials, then the test materials will be washed and dried in the sun to remove impurities and moisture content so that it is expected to be able to maximize the neutralization process. Then it is weighed based on the needs in the test compartment. For specifications of test materials can be seen in Table 2 and illustrations of test materials can be seen in Figure 6.

Acid mine drainage in this study uses acid mine drainage formed in acid mine drainage storage ponds in the stockpile of one of the coal mining companies in Sawahlunto City. An illustration of acid mine drainage ponds can be seen in Figure 5.

Figure 5. Acid Mine Drainage Pond

Table 2. Test Material Specifications On Testing

Material Name	Size (mm)	Weight (gr)	Compartment Slope
Acid Mine Drainage	-	-	7^0
Fly Ash + AMD	-	125	
Silica Sand (A)	1,18-2,36	2200	
Silica Sand (B)	0,6-2	2200	
Limestone (A)	1.18-3.35 &; 25	2400	
Limestone (B)	4-19	2400	

3.5 Test Scheme

The creation of the open limestone channel will be simulated using PVC 4 inc gutters along ± 1.5 meters, the gutters will be divided into compartments that will be given dividers between compartments using the remaining part of the gutters with a partition size of 12x7 cm, the purpose of which is to ensure the test material is not mixed or enter other compartments, then also aims to maximize the contact time between test material with acid mine drainage. The test equipment will be given a slope aimed at maximizing the contact of the test material through water flow control, besides that this slope also simulates topography in the field, to measure the slope that is planned to use the help of an inclinometer.

Acid mine drainage in compartment 1 will flow with a mini pump to compartment 2, in compartment 2 an aerator will be added to help mix acid mine water with fly ash, then acid mine drainage from compartment 2 flows to the next compartment and will contact and react with test materials to the final compartment. In each compartment, a sample will be taken to measure the pH value. An illustration of the test scheme can be seen in Figure 7.

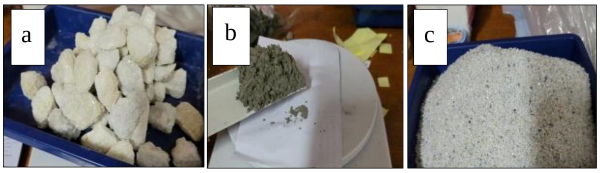


Figure 6. (a) Limestone, (b) *Fly Ash*, (c) Silica Sand

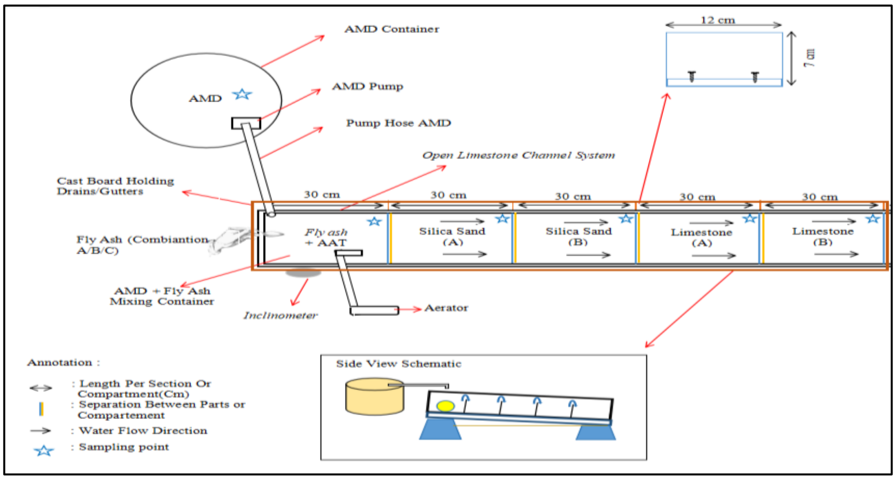


Figure 7. Test Scheme

3.6 Data Analysis

From the results of testing and measurement, an analysis will be carried out by referring to [5]. The analysis to be carried out is to measure the pH value in each compartment of the test results using a pH meter and litmus paper. The illustration of pH value measurement and test illustration can be seen in Figure 8 and Figure 9.

Figure 8. AMD pH Value Measurement

Figure 9. AMD pH Neutralization Testing

4 Results and Discussion

4.1 pH Value of Acid Mine Drainage AA-0 Test Results

In the AA-0 test, it was found that there was an increase in the pH value of acid mine drainage in compartment 2 (AA1) with the addition of fly ash proved to be able to raise the pH of acid mine drainage from pH 3.75 to pH 4.01. Then from compartment 2 (AA1) acid mine drainage comes into contact again with silica sand in compartment 3 (AA2) and compartment 4 (AA3) in this complement the pH of acid mine drainage rises from 4.01 to 4.91 and 5.17. From compartment 4 (AA3) acid mine drainage then comes into contact with limestone in compartment 5 (AA4) and compartment 6 (AA5), the pH value from 5.17 rises to 6.86 and 7.39.

4.2 pH Value of Acid Mine Drainage AA-1 Test Results

In the AA-1 test, it was found that there was an increase in the pH value of acid mine drainage in compartment 2 (AA11) with the addition of fly ash proved to be able to raise the pH of acid mine drainage from pH 3.75 to pH 4.01. Then from compartment 2 (AA11) acid mine drainage comes into contact again with silica sand in compartment 3 (AA21) and compartment 4 (AA31) in this compartment the pH of acid mine drainage rises from 4.01 to 7.12 and 7.3. From compartment 4 (AA31) acid mine drainage then comes into contact with limestone in compartment 5 (AA41) and compartment 6 (AA51), pH value of 7.3 remain stable at pH 7.3 and 7.3.

4.3 pH Value of Acid Mine Drainage AA-2 Test Results

In the AA-2 test, it was found that there was an increase in the pH value of acid mine drainage in compartment 2 (AA12) with the addition of fly ash proven to be able to raise the pH of acid mine drainage from pH 3.75 to pH 4.01. Then from compartment 2 (AA12) acid mine drainage comes into contact again with silica sand in compartment 3 (AA22) and compartment 4 (AA32) in this compartment the pH of acid mine drainage rises from 4.01 to 7.12 and 7.39. From compartment 4 (AA32) acid mine drainage then comes into contact with limestone in compartment 5 (AA42) and compartment 6 (AA52), the pH value from 7.39 rises to pH 7.48 and drops to pH 7.21 in compartment 6 (AA52).

In Table 3 it can be seen that from three tests there was an increase in the pH value of acid mine drainage with a peak pH value in the AA-0 Combination of 7.39 (AA5), AA-1 Combination of 7.3 (AA31), and AA-2 Combination of 7.48 (AA42). The results obtained prove that the use of test materials in the form of fly ash and silica sand in the open limestone channel method can increase the pH of acid mine drainage to reach a neutral pH point.

Table 3. Recap of pH Value Measurement Results Using AA Combination Testing

No. Comp	Test Material Name	Sample Code	AA-0 pH Measurement Results		Sample Code	AA-1 pH Measurement Results		Sample Code	AA-2 pH Measurement Results	
			pH Meter	Litmus Paper		pH Meter	Litmus Paper		pH Meter	Litmus Paper
1.	Acid Mine Drainage	AA0	3.75	3	AA01	3.75	4	AA02	3.75	4
2.	Acid Mine Drainage + Fly Ash	AA1	4.01	4	AA11	4.01	4	AA12	4.01	4
3.	Silica Sand (A)	AA2	4.91	4	AA21	7.12	7	AA22	7.12	7
4.	Silica Sand (B)	AA3	5.17	5	AA31	7.3	7	AA32	7.39	7
5.	Limestone (A)	AA4	6.86	6	AA41	7.3	7	AA42	7.48	7
6.	Limestone (B)	AA5	7.39	7	AA51	7.3	7	AA52	7.21	7

5 Conclusion

From the results of the acid mine drainage pH neutralization trial using the passive open limestone channel method and the addition of fly ash and silica sand, the following conclusions were obtained:

1. In Combination AA-0 or the first test, an increase in pH value was obtained from 3.75 to 7.39.
2. In Combination AA-1 or the second test, an increase in pH value is obtained from 3.75 to 7.3.
3. In Combination AA-2 or the third test there was an increase in pH value from 3.75 to 7.21.
4. From the results of three tests using these materials and methods have been able to achieve the final value of pH by the range of acid mine drainage quality standards applicable in Indonesia.

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