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Analysis of PAF and NAF Tests Using NAPP and ANC Methods at Hajak Site, North Barito, Central Borneo

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Abstract

Acid mine drainage (AMD) is a significant challenge for the global coal mining industry, necessitating specialized treatment to prevent its occurrence. A crucial step in AMD prevention is identifying rocks that contribute to its formation. These rocks are classified into Potential Acid-Forming (PAF) rocks and Non-Acid-Forming (NAF) rocks. PAF rocks have the potential to produce acid, while NAF rocks do not. Laboratory analyses, including Maximum Potential Acidity (MPA), Acid Neutralizing Capacity (ANC), Net Acid Producing Potential (NAPP), and Net Acid Generating (NAG) tests, identified 3 sample points with potential PAF characteristics out of 35 samples tested (see Table 3.1). Among these, 2 sample points were classified as Potential Acid Forming-Low Capacity, and 1 sample point was categorized as Potential Acid Forming-Medium Capacity (NAG pH 4.5, NAPP > 10 kg H2SO4/ton). The acidity level of mine water resulting from landfilling varies significantly based on the mineral content and landfilling techniques used. Mined material with high carbonate mineral content tends to have lower acidity levels in leachate and can even neutralize formed acid. The stockpiling strategy implemented involves layering PAF material followed by a final cover of NAF material and a rooting zone to mitigate acid formation.

1. Introduction

Coal mining activities have the potential to damage the environment because of the nature of the activity which can change the natural landscape. In mining activities, AAT can occur in open mines and underground mines. In general, this situation is caused by sulfide minerals contained in naturally oxidized rocks and supported by high rainfall, which will further accelerate the change in oxidation of sulfur to acid [1]. This is a real impact resulting from mining activities which can cause pollution and decrease the physical and chemical properties of the soil. If there is a decrease in quality in this aspect, this will create undesirable conditions, such as loss of soil fertility due to mining, then the agricultural or plantation results obtained will be unsatisfactory and could cause losses.

One issue that is always present in the mining industry is acid mine drainage. Environmental problems of pollution from acid mine drainage have occurred for many years. Acid Mine Water characterized by a very high acidity level (PH<5) is long-term pollution. the results of weathering or chemical reactions between air and minerals when washed by rain runoff or groundwater seepage and also reactions between water and minerals can result in changes in the quality of rain runoff or groundwater. If the changes that occur are indicated by a high level of acidity, this is referred to as Acid Mine Drainage (AMD) [2]. In some cases, acid mine drainage is still present hundreds of years after the mining pit from which AAT has been sourced has finished operating. Acid Mine Drainage (AMD) or acid mine drainage (AAT) is a term used to describe surface water pollution that occurs around mining activities.

According to the Decree of the State Minister for the Environment Number 113 of 2003 [3] that every person responsible for mining business or activities is obliged to carry out processing of waste water originating from mining activities and waste water originating from processing/washing activities so that the quality of waste water discharged into the environment does not exceed waste water quality standards. Mining (AAT) is water with a low pH and high metal solubility as a result of reactions between sulfide minerals exposed due to excavation activities, oxygen and water. In open-pit mining, AAT has the potential to form in active mining areas and be disposed of.

The presence of AAT in the environment, especially surface water and ground water, has the potential to impact environmental quality and habitat disruption [4]. Another term that is often used is Acid and Metallic Drainage (DAL) or Acid and Metalliferous Drainage (AMD). The term AMD is used considering that not all drainage problems related to sulfide oxidation are acidic. In some locations, near-neutral but metal-laden drainage can be as difficult to manage as acid water [5]. Overburden rock in coal mining can be used as an indicator to predict the potential for acid mine drainage other than that originating from the coal itself. Backfilling is an effective method for reducing the acid content of current mining activities or abandoned mine fields [6]. The acidity level of mine water resulting from landfilling varies greatly depending on the amount and type of minerals it contains and the landfilling technique. If the mining material contains a lot of carbonate minerals, the acidity level of the leachate is lower and can even neutralize the acid formed. This situation causes mine water to be neutral or alkaline and also reduces the amount of dissolved metal ions. The nature of each layer can contain different minerals, especially in the cover layer, so the stockpiling technique greatly influences the acid-base properties of the mine water produced. Incorrect landfill techniques can cause the released mine water to be very acidic, causing undesirable environmental problems [7]

Acid mine drainage is one of the most serious challenges faced by the coal mining industry worldwide. Acid mine water with a low pH value (<4) usually increases the distribution of heavy metals and silica in the water [8]. At the post-mining stage, treatment plans generally involve removing pollutants from mine water which is quite effective. However, operating costs, maintenance and capital costs need to be considered, such as calculating the alkalinity needed to raise the pH high enough, thereby reducing operating costs [9]. There are 2 (two) main issues that must be considered in overburden removal, namely minimizing transportation costs and preventing acid mine drainage (AMD) problems [10]. Therefore, special treatment is needed to prevent the occurrence of acid mine drainage, one of which is identifying rocks that can cause the formation of acid mine drainage. These rocks are classified into two, namely PAF rocks and NAF rocks. PAF (potential acid forming) rocks are rocks that have the potential to produce acid. Meanwhile, NAF (Non-Acid Forming) rocks are rocks that do not have the potential to produce acid. In determining the properties of PAF or NAF rocks, an acid balance calculation is required by looking for parameters such as MPA (Maximum Potential of Acidity), ANC (Acid Neutralizing Capacity), NAPP (Net Acid Producing Potential), NPR (Net Potential Ratio), and NAG (Net Acid Generating) [11]

2. Methodology

Prevention of the formation of acid mine drainage begins with identifying the geochemical characteristics of rocks to determine whether a rock has the potential to generate acid PAF (Potential Acid Forming) or not NAF (Non-Acid Forming). NAF rocks can be divided into rocks that have the potential to neutralize acid (acid neutralizing) and rocks that do not have the ability either to neutralize acid or to form acid [12]. To prevent environmental damage due to acidic material, drilling can be done to get an idea of the rock composition in the pile, especially if there is not sufficient information beforehand, as well as monitoring changes in the rate of weathering and leaching which can affect the quality of mine water [12]. Then laboratory analysis is needed whose results can be used in efforts to prevent environmental damage caused.

In this research, NAF and PAF testing was carried out at the Mining Technology Laboratory, Lambung Mangkurat University. Parameters carried out in the laboratory such as MPA (Maximum Potential of Acidity), ANC (Acid Neutralizing Capacity), NAPP (Nett Acid Producing Potential), and NAG (Net Acid Generating):

2.1 NAPP (Net Acid Producing Potential).

NAPP is a method used to identify rock acidity, taking into account the rock's ability to produce acid and the rock's ability to neutralize it. NAPP calculation is based on the formula:

NAPP (kg/ton) = MPA – ANC (kg/ton)

MPA = Maximum Potentially Acidity
ANC = Acid Neotralisin Capacity
If a rock sample has a NAPP value greater than zero, it is categorized as having the potential to produce acid, and a rock sample with a NAPP value of less than or equal to zero is included in rock that does not produce acid or is an acid neutralizer.

2.2 NAG (Net Acid Generating)

NAG or Net Acid Formation (PAN) or is carried out by reacting rock samples with a strong oxidizer, namely hydrogen peroxide (H2O2), to completely oxidize all sulfide minerals in the rock sample quickly. During the oxidation process, the formation and neutralization of acid occur simultaneously so that the final result of this test represents the net amount of acid produced from the rock sample [12].
In this test, experiments are carried out in the laboratory with hydrogen peroxide, the pH and volume of NaOH used for titration are measured. If the pH result in the NAG test is less than 5, then the sample includes cover soil that can produce acid and the final titration volume will show the amount of acid that will be produced.

2.3 ANC

ANC is a method of determining the amount of neutralizing minerals (generally carbonate, CO3-2) in rock samples that can react with acidifying minerals (generally SO4-2 sulfate) in rock samples. Different from the method of determining the amount of acidity (actual and potential acid), this method is used to determine the ability of the sample to neutralize the acid contained in the sample itself using a Mettler Toledo titration apparatus. The large number of ANC values will affect the alkalinity of a rock sample [13].

The formula for finding ANC is as follows: ANC = (Y × M. HCl / Sample Weight) x C…...
From the test results above, the NAPP value can be determined based on the formula below.

NAPP = MPA – ANC
NAPP = kg H2SO4/tonne rock
MPA = %TS × 30.625 kg H2SO4/tonne rock
ANC = kg H2SO4/tonne rock

2.4 Encapsulation Method

To manage the possibility of acid mine drainage from embankment soil, soil accumulation management is carried out as follows: during embankment, soil containing sulfide minerals is placed at the bottom, then covered with a layer of soil that is waterproof and does not contain sulfide minerals (encapsulation method). One way to prevent acid mine drainage is to carry out an encapsulation method where PAF (Potentially Acid Forming) and NAF (Non-Acid Forming) materials are handled so that there is no contact between water, air, and sulfide minerals originating from PAF materials. The concept of the encapsulation method is to break the reaction chain to avoid the occurrence of acid mine drainage [14]. The encapsulation method can be shown in Figure 1, where the treatment consists of coating the PAF material using NAF material so that water and air do not enter the PAF material which results in inhibiting the formation of acid mine drainage.

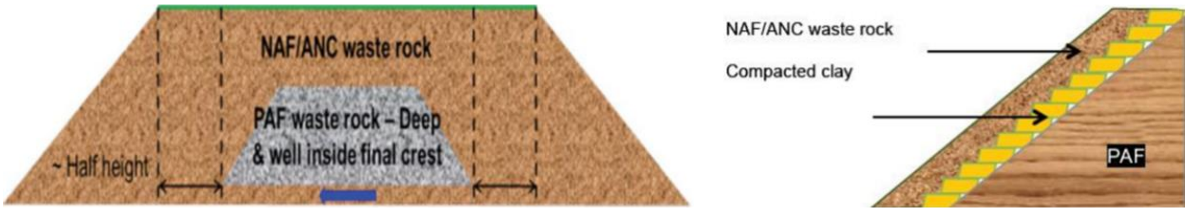

Figure 1. Encapsulation process [15]

Table 1. Acid Mine Drainage in the Hajak site

NO	LAB.ID	SAMPLE NO	LITHOLOGY	TESTING									AMD CLASSIFICATION
				PH	EC	TS*	ANC	MPA	NAPP	NAG pH	NAG pH 4.5	NAG pH 7	
					µs/cm	%	(kgH, SO, /ton)				(kgH, SO,/ton)		
1	LE22.01680	GTM-HM-F/AMD1	*SOIL*	4.78	0.04	0.03	-2	1	3	-	<0.1	1.91	NAF
2	LE22.01681	GTM-HM-F/AMD3	*CLAYSTONE*	7.64	0	0.05	16	2	-14	8.53	<0.1	<0.1	NAF
3	LE22.01682	GTM-HM-F/AMD6	*CLAYSTONE*	7.51	0	0.07	18	2	-16	8.34	<0.1	<0.1	NAF
4	LE22.01683	GTM-HM-A/AMD1	*SOIL*	5.22	0.02	0.03	-2	1	3	5.8	<0.1	1.91	NAF
5	LE22.01944	GTM-HM-F/AMD9	*CLAYSTONE*	4.54	0.09	2.53	3	77	75	1.66	61.3	18.67	PAF-MC
6	LE22.01945	GTM-HM-F/AMD11	*CLAYSTONE*	7.48	0.41	0.01	9	0	-9	8.44	<0.1	<0.1	NAF
7	LE22.01948	GTM-HM-A/AMD2	*CLAYSTONE*	7.21	0.62	0.01	9	0	-9	8.61	<0.1	<0.1	NAF
8	LE22.01947	GTM-HM-A/AMD3	*CLAYSTONE*	7.14	0.38	0.06	7	2	-5	7.51	<0.1	<0.1	NAF
9	LE22.01048	GTM-HM-A/AMD4	*CLAYSTONE*	7.51	0.07	0.01	6	0	-6	7.78	<0.1	<0.1	NAF
10	LE22.01949	GTM-HM-B/AMD5	*CLAYSTONE*	7.55	1.44	0.07	11	2	-9	8.34	<0.1	<0.1	NAF
11	LE22.02147	GTM-HM-B/AMD2	*CLAYSTONE*	7.86	2.34	0.01	39	0	-39	7.28	<0.1	<0.1	NAF
12	LE22.02146	GTM-HM-B/AMD5	*SILTSTONE*	7.92	2.5	0.01	40	0	-40	7.94	<0.1	<0.1	NAF
13	LE22.02149	GTM-HM-B/AMD7	*SANDSTONE*	7.89	412	0.01	32	0	-31	8.08	<0.1	<0.1	NAF
14	LE22.02150	GTM-HM-B/AMD11	*SILTSTONE*	7.99	363	0.02	37	1	-37	8.17	<0.1	<0.1	NAF
15	LE22.02151	GTM-HM-B/AMD12	*CLAYSTONE*	6.5	2.08	0.75	37	23	-14	4.01	0.98	8.82	PAF-LC
16	LE22.02152	GTM-HM-CR/AMD2	*CLAYSTONE*	6.1	1.02	0.06	-1	2	3	8.01	<0.1	<0.1	NAF
17	LE22.02153	GTM-HM-CR/AMD4	*SANDSTONE*	7.7	538	0.02	22	1	-22	8.1	<0.1	<0.1	NAF
18	LE22.02154	GTM-HM-CR/AMD5	*SILTSTONE*	8.07	3.49	0.01	38	0	-38	9.8	<0.1	<0.1	NAF
19	LE22.02155	GTM-HM-CR2/AMD4	*CLAYSTONE*	7.48	418	0.02	4	1	-4	7.03	<0.1	<0.1	NAF
20	LE22.02156	GTM-HM-CR2/AMD7	*SILTSTONE*	7.15	0.26	0.36	2	11	9	3.91	0.98	4.9	PAF-LC
21	LE22.02157	GTM-HM-D/AMD1	*SOIL*	5.32	6.95	0.02	-6	1	7	8.1	<0.1	<0.1	NAF
22	LE22.02158	GTM-HM-D/AMD5	*CLAYSTONE*	7.6	54.6	0.06	15	2	-13	7.1	<0.1	<0.1	NAF
23	LE22.02159	GTM-HM-D/AMD8	*CLAYSTONE*	7.68	2.8	0.02	19	1	-18	7.22	<0.1	<0.1	NAF
24	LE22.02160	GTM-HM-D/AMD17	*SILTSTONE*	8.04	0.11	0.01	20	0	-19	8.59	<0.1	<0.1	NAF
25	LE22.02161	GTM-HM-D/AMD20	*SANDSTONE*	7.95	0.33	0.01	10	0	-10	7.21	<0.1	<0.1	NAF
26	LE22.02162	GTM-HM-E/AMD3	*CLAYSTONE*	7.74	3.33	0.02	10	1	-9	7.68	<0.1	<0.1	NAF
27	LE22.02163	GTM-HM-E/AMD6	*CLAYSTONE*	8.08	1.28	0.02	12	1	-11	7.99	<0.1	<0.1	NAF
28	LE22.02164	GTM-HM-E/AMD8	*SANDSTONE*	8.15	2.32	0.01	11	0	-11	7	<0.1	<0.1	NAF
29	LE22.02165	GTM-HM-E/AMD9	*SILTSTONE*	7.88	51.02	0.02	22	1	-21	8.11	<0.1	<0.1	NAF
30	LE22.02166	GTM-HM-E/AMD12	*CLAYSTONE*	7.9	3.46	0.02	5	1	-5	8.05	<0.1	<0.1	NAF
31	LE22.02167	GTM-HM-G/AMD2	*CLAYSTONE*	7.14	1.68	0.02	3	1	-2	7.07	<0.1	<0.1	NAF
32	LE22.02168	GTM-HM-G/AMD4	*CLAYSTONE*	7.06	13.49	0.15	24	5	-19	7.62	<0.1	9.31	NAF
33	LE22.02169	GTM-HM-G/AMD8	*SANDSTONE*	7.18	30.6	0.02	1	1	0	5.94	<0.1	1.71	NAF

NO	LAB.ID	SAMPLE NO	LITHOLOGY	TESTING									AMD CLASSIFICATION
				PH	EC	TS*	ANC	MPA	NAPP	NAG pH	NAG pH	NAG pH	
					µs/cm	%	(kgH, SO, /ton)				4.5 (kgH, SO,/ton)	7	
34	LE22.02170	GTM-HM-GR/AMD3	*CLAYSTONE*	7.3	4.72	0.1	15	3	-11	7.28	<0.1	<0.1	NAF
35	LE22.02171	GTM-HM-GR/AMD7	*CLAYSTONE*	7.45	4.81	0.02	34	1	-33	7.65	<0.1	<0.1	NAF

Information:

TS *= Total Sulphur*

ANC *= Acid Neutralising Capacity*

MPA *= Maximum Acid Producing Potential*

NAPP *= Net Acid Producing Potential*

NAG *= Net Acid Generation*

NAF *= Non-Acid Forming (NAG pH > 4.5)*

PAF-MC *= Potential Acid Forming – Medium Capacity (NAG pH < 4,5 ; NAPP. 10 kg* H_2SO_4*/ton)*
= Not Accredited

PAF-LC *= Potential Acid Forming -Low Capacity*
= Not Accredited

3. Results and discussions

3.1 Research Area Results

In soil samples for testing NAF and PAF at the Mining Technology Laboratory, Lambung Mangkurat University, data was obtained that there was PAF in rock samples (Table 3). This test takes into account the ability of the rock to produce acid mine drainage and the ability of the rock itself to neutralize acid. The potential for acid formation (PAF) that occurs in this research area occurs due to changes in soil structure during demolition. Three sample points were found that had the potential to be PAF or 0.01 out of a total of 35 samples tested (table 3). 2 sample points are included in Potential Acid Forming - Low Capacity, while 1 sample found by PAF is considered Potential Acid Forming with the description Medium Capacity (NAG pH < 4.5; NAPP. 10 kg H2SO4/ton).

The testing process carried out to identify PAF/NAF materials uses the NAG and NAPP testing methods. In the NAG test, the classification results for the GTM-HM-F/AMD9 sample show an anomaly where the NAG value is very significant compared to other samples. This is because the GTM-HM-F/AMD9 sample is claystone material and the material at disposal is random material.

Neutralization potential ratio (NPR) criteria, which is the ratio of acid neutralizing capacity (ANC) to maximum potential acidity (MPA) seen from the sulfur limit value in the rock samples tested:

1. NAF contained in impurity rocks is determined based on the total sulfur content from <0.005% per kg to 0.25% per kg
2. The potential reaction to generate uncertain acids ranges from >0.2 per kg to 0.4% per kg of total sulfur weight
3. Sulfur found in impurity rocks >0.4%

The acid-base accounting (ABA) classification criteria use the neutralization potential ratio (NPR), which is the ratio of the acid neutralizing capacity (ANC) to the maximum potential acidity (MPA).

Table 2. Criteria *acid-base accounting* (ABA) [16]

Criteria	NPR (ANC/MPA)	NAPP(ANC-MPA)
Potentially acid forming	>Or equal to 2	> or equal to 5
Uncertain	1 to 2	0 to 5
Non-acid forming	< 1	>0

3.2 Handling NAF and PAF

Preventive measures are needed to reduce the risk and minimize the formation of acid mine drainage at overburdened material storage locations. This action can be carried out by isolating the material that forms acid mine drainage (PAF/Potential Acid Forming) with material that does not form acid mine drainage (NAF/Non-Acid Forming). This is done to prevent contact between water, oxygen and sulfide minerals. Therefore, good management of PAF and NAF materials is needed in the disposal area to minimize the potential for the formation of acid mine drainage.

In saturated soil layers, if treated properly it will create an oxygen-deficient environment, allowing the growth of sulfate-reducing bacteria. The growth of sulfate-reducing bacteria is driven by the presence of electron acceptors (sulfate) and electrons (organic carbon substrate). This can also minimize the population of other bacteria that will compete for electrons. This can be a basis for the company in making decisions regarding the treatment that will be carried out in anticipating the possibility of the formation of acid mine drainage originating from the overburden/disposal dump area. The planned management system should meet approaches such as; Prevention, Minimize the occurrence of acid mine drainage, Control of stagnant water, and Periodic checking.

This impurity rock management plan also applies operational techniques and drainage designs to produce water that does not stagnate and seep into the ground. In general, handling of Acid Mine Water (AAT) can be done by preventing the formation of AAT and handling AAT that has formed, especially those that will leave the location of mining activities.

1. Prevention of AAT Formation

Prevention of AAT formation is to reduce contact between sulfide minerals, such as pyrite, with water and oxygen in the air, by arranging soil dumping to ensure that soil and/or rocks that have the potential to form acid (potentially acid forming, PAF) do not appear (exposed) on the surface. embankment, where the PAF will be filled with soil and/or rock that does not have the potential to form acid (non acid forming, NAF) using the following technique:

a. One meter of compacted clay cover

Placement of a one-meter thick layer of compacted clay on top of PAF soil and/or rock. Compaction is carried out in two lifts each half a meter.

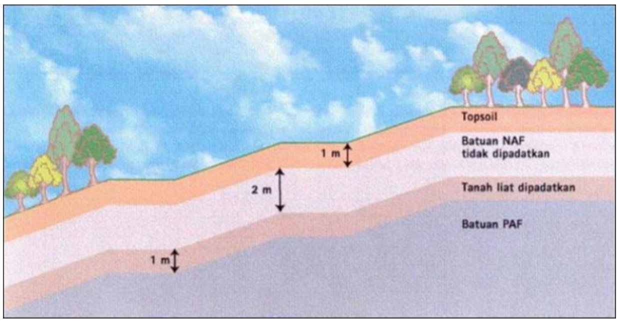

Figure 2. Example of one-meter compacted clay cover

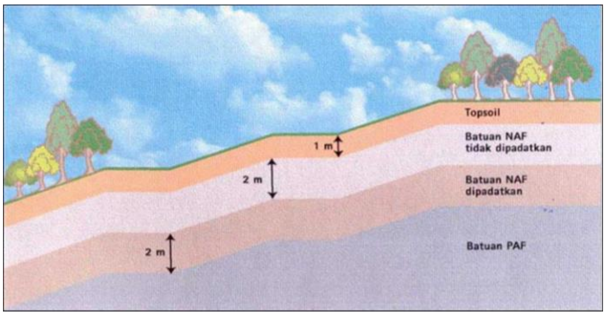

Figure 3. Example of a two-meter compacted NAF rock cover

b. Two Meter NAF Rock Cover Compacted
Placement of a two-meter thick layer of compacted NAF soil and/or rock on top of the PAF rock is carried out in four lifts, each half a meter thick. Each lift is conditioned and compacted before deployment of the next lift. Covering embankment areas can use the compaction method with clay or cover rock, or loose cover rock.

2. Handling AAT that has been formed
Handling of AAT that has been formed and has the potential to leave the mining site is carried out to achieve water quality conditions as required in Government Regulations on water quality. In general, there are two ways of processing water, namely active and passive. Active handling, for example, to raise the pH value to normal conditions, is done by adding chemicals such as lime. Actively, lime (in powder/flour form) is mixed directly into AAT in water channels or special containers, or in water storage ponds. Meanwhile, for passive handling, AAT is channeled through channels where there is lime (in the form of rock) as a "neutralizing medium" for the AAT that passes through it. Water pumped from the mine drainage system contains solid particles and sludge with a low pH (acid). Therefore, before it flows into a water body (river), it is first collected and deposited in a settling pond.

4. Conclusion

The conclusion that can be drawn from this research is that the acidity level of mine water resulting from landfilling varies greatly depending on the amount and type of minerals it contains and the landfilling technique. If the mining material contains a lot of carbonate minerals, the acidity level of the leachate is lower and can even neutralize the acid formed. This situation causes mine water to be neutral or alkaline and also reduces the amount of dissolved metal ions. In this research, the parameters used in laboratory testing used the NAG and NAPP testing methods. The materials found in the research area are soil, claystone, siltstone, and sandstone. With the results of rocks containing PAF acid, namely claystone and siltstone. The stockpiling system applied is by stockpiling PAF material and then the final design is coated with NAF material and topsoil. In the research area, 1 soil sample with sample number GTM-HM-F/AMD9 was found to contain PAF material which has the potential to form acid with a NAG pH value < 4.5; NAPP 10 kg $H2SO4$/ton).

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