Evaluation of Acid-Base Accounting to Predict the Acid Water of Overburden in Coal Mines in Horna Areas, West Papua Province, Indonesia

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Abstract

Acid-Base Accounting (ABA) is an analytical procedure to measure the balance between the acid neutralization and acid generation properties of any geologic material. ABA is considered tools to predict post-mining water. Overburden samples were collected from the coalfields of Horna coalmines. Maximum potential acidity (MPA), acid neutralizing capacity (ANC), acid net neutralization potential (ANG), Net Acid Producing Potential (NAPP), net acid generation (NAG), and ANC/MPA ratios were determined for each site based on ABA. Most of the sample from R1, R4, R-13, and R14 showing the pH of net acid generation of overburden ranges from 3.2 – 4.47 and positively acid net neutralization potential (be classified as the PAF-LC (Low Capacity Potential Acid NAPP) varies from 2.07 – 21.27 2.4 kg/t H2SO4 indicate that the samples are classified as the PAF-LC (Low Capacity Potential Acid Former (LC-PAF) to the PAF-MC (Moderately Capacity Potential Acid Former (MC-PAF). Other samples from R13 (four samples) has negatively NAPP and pHNAG between 6,21 – 7,10, therefore should be classified as the NAF; two samples from R13 indicated the uncertainty (UC) due to high pHNGA (6,82-7,15).

Keyword: acid-base accounting, overburden, maximum potential acidity, acid net neutralization potential, potential acid former

1. Introduction

Currently, environmental problems in mining activities are often the focus of the public community. In y mining activities, environmental management planning should be conducted in conjunction with exploration, mining exploitation and processing planning. The activities that do not take into consideration environmental problems both physical and biotic environments will arise problems and may even cost more to overcome them than for prevention. One of the problems that may arise in coal mining activity is the acid mining water due to handling processing i.e. removing and stockpiling of overburden/inter-burden material during coal production (Perry, E. 1998).

The materials that block coals may be material that covering coal (overburden) or material that lies between layers of coals (inter-burden). The material must be removed and then dumped in a landfill (disposal area) or directly used for re-mining of ex-mining area. Both materials may contain sulphide – containing minerals, particularly iron sulphide (FeS) as pyrite (Blowes et.al., 1992; Brady K.B., 1990), so that when exposed in air and water will produce acidic water from sulfuric acid as the result of oxidation of sulfide compounds assisted by microbial activity. Acidic water can also be produced in the area mining itself as a result of exposure of sulphide mineral in air and water. The acidic water of the mining activity is called acid mine water. The presence of acidic water can also dissolve harmful metal compounds / toxic substances such as mercury, lead, arsenic and other cadmium contained in minerals thereby increasing the amount of dissolved metal ions in water that are very harmful to life in the water. This acid mine water is very dangerous for the environment both biotic and abiotic environment

Based on the above mentioned, it is necessary to research the acid water prediction that can be generated by each layer at the location of the coal mining plan. The results of this acid water prediction can be used as consideration in mining design and environmental

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management efforts to minimize undesirable environmental impacts. Acid-Base Accounting (ABA) is an analytical procedure that provides values to help assess the acid- or alkaline-producing potential of overburden rocks prior to coal mining.

The aim of this research is to predict the potential of acid formation of acidic water at each overburden layer at the coal mine site.

2. Coal Geology and Acid-Base Accounting

2.1. Coal Geology

Geologically, the Horna Coal Mine Site is located in Ayamaru Sub-Basin which have been formed in Early Tertiary. In its development Ayamaru Sub-Basin has experienced twice the cycle of transgression and regression. The first cycle occurs in the early Eocene to Oligocene. While the second phase occurs in the early Miocene to the early Pliocene. During the second regression phase was deposited the Steenkoll Formation which act as the coal-bearing formation at the study area.

The overburdens of Steenkool mostly are claystone and mainly composed of quartz, kaolinite, siderite, pyrite, and muscovite. Quartz and kaolinite are major mineral phases whereas other occurs as minor to trace quantity. The proximate analysis of coal samples from Steenkoll Formation in study area which analyses in Coal Laboratory of Succofindo, Jakarta (2017) as follow (Table 1):

Table 1. Result of Coal Analysis

Parameter	Unit	R1	R4	R13	R14	Method
Total Moisture	%, ar	2.8	2,6	2.4	3,4	ASTM D. 3302-15
Proximate Analysis						
Moisture Analysis	%, adb	2,8	2,6	2,4	3,1	ASTM D. 3173-11
Ash Content	%, adb	2,1	3,2	2,0	4,1	ASTM D. 3174-12
Volatile Matter	%, adb	44,9	44,3	45,1	45,2	ISO 562-2010
Fixed Carbon	%, adb	49,8	48,1	50,6	46,8	ASTM D. 3172-13
Total Sulphur	%, adb	0,4	1,8	0,30	0,8	ASTM D. 4239-14
Gross Calorific Value	%, adb	7812	7182	7731	7686	ASTM D 5865-13

2.2. Formation of Acid Mine Water

For the first time Dr. Richard M. Smith and his associates at West Virginia University at the end of 1960s developed a procedure for to identify acid-producing materials in 1965 (Perry, 1998). During period of the late 1960s and 1970s, the procedure was refined and termed "Acid-Base Accounting" (ABA) (Smith et al., 1976). Skousen et. ll., (1990) mentioned that ABA is the first technology which can use to predict the quantity of acid-producing materials from mining operations. At this time ABA has widely accepted as a procedure of overburden characterization and prediction of acid-materials (Sobek et al, 2000). The values arising from the acid-base account are referred to as the maximum potential acidity (MPA) and the acid neutralizing capacity (ANC), respectively. The difference between the MPA and ANC is referred to as the net acid producing potential (NAPP).

The formation of acid (H +) generally occurs when iron sulphide minerals react

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with oxygen (either from air or dissolved in water) and the presence of water dissolving it. This process can be strongly catalyzed by bacterial activity. Oxidation of sulfides produces sulfuric acid and orange precipitate, hydroxide ferries (Fe (OH) 3), as summarized in Reaction 1

$$FeS_2 + 3.75O_2 + 3.5H_2O \leftrightharpoons Fe(OH)_3 + 2SO_4^{-2} + 4H^+ \quad (1)$$

2.3. Acid-Base Accounting

For the first time Dr. Richard M. Smith and his associates at West Virginia University at the end of 1960s developed a procedure for to identify acid-producing materials in 1965 (Perry, 1998). During period of the late 1960s and 1970s, the procedure was refined and termed "Acid-Base Accounting" (ABA) (Smith et al., 1976). Skousen et. ll., (1990) mentioned that ABA is the first technology which can use to predict the quantity of acid-producing materials from mining operations. At this time ABA has widely accepted as a procedure of overburden characterization and prediction of acid-materials (Sobek et al, 2000). The values arising from the acid-base account are referred to as the maximum potential acidity (MPA) and the acid neutralizing capacity (ANC), respectively. The difference between the MPA and ANC is referred to as the net acid producing potential (NAPP).

2.3.1. *Maximum Potential Acidity*

The MPA parameter is usually an estimated pyrite sulfur of total sulfur content using a factor of 30.6 (MPA =% S x 30.6). The use of total sulfur is a conservative approach because some sulfur may be in forms other than pyrite. Mineral sulphate (gypsum, anhydride, alunite) and sulfur as an element is a form of sulfur instead of acid-forming. Some other metal sulfides (such as covellite, chalcocite, sphalerite and galena) produce less acidity than pyrite or, in some cases, non-forming acid. This MPA is expressed as is kg H2SO4/t.

2.3.3. *Acid Neutralising Capacity*

The acid neutralizing capacity (ANC) is usually determined by the addition of chloride acid to a sample (sample), then back titrated with sodium hydroxide to determine the amount of acid consumed (Sobek et. al., 1978). The ANC parameters are used to measure the capacity of a sample in neutralizing the acid. Like the MPA, the determination of ANC is not appropriate and is susceptible to potential interventions and may not represent the ANC that is actually available to neutralize acid mine water. Ferrous carbonates such as siderite, ankerite and ferroan dolomite have the potential to cause errors in calculated the ANC. The amount of acid consumed by reaction expressed in the same units as the MPA, that is kg H2SO4/t.

2.3.3. *Net Acid Producing Potential (NAPP)*

The potential of Net Acid Production (NAPP) is calculated based on ABA measurement. PPAN is a qualitative measure of the difference between sample capacity to form acid (MPA) and its capacity to neutralize acid (ANC). NAPP, MPA and ANC are expressed in kg H_2SO_4 / tons of rock and NAPP is calculated by the equation and expressed in units of kg H2SO4/t:

$$NAPP = MPA - ANC \quad (9)$$

Note:

1. If NAPP negative (MPA< ANC), indicated that samples may have sufficient ANC to prevent acid formation.
2. If NAPP positive (MPA>ANC), indicated that that the material may be acid-forming.

2.3.4. *ANC/MPA Ratio*

The ANC / MPA ratio shows an indication of whether or not a single material is safe. Various ANC / MPA ratio values are referenced in the literature to indicate safe values for the prevention of acid formation (Skousen et al.,2000) These values are: <1 should produce acid water; the values between 1 and 2 can produce either acid or alkaline water conditions, and >2 should produce

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alkaline water. A general rule, an ANC / MPA ratio of 2 or more indicates that it is likely that the material will remain near-neutral pH and does not cause acidic acid water problems.

2.3.5. Net Acid Generation Test (NAG)

The NAG test is used in conjunction with NAPP to characterize the acid generation potential of a sample. The NAG test involves the reaction of a sample with hydrogen peroxide to rapidly oxidize any sulphide minerals. Both the formation and the neutralizing of acids occur simultaneously and the results represent a direct measurement of the resulting acid. The pH value after reaction (pH NAG) of less than 4.5 indicates that the sample is a net acid builder. The amount of acid is determined by the titration and expressed in the same unit as PPAN (kg H_2SO4 / ton).

2.3.6. Classification

Individually, NAPP and NAG tests have limitations, but when combined their reliability to predict phenomena acid mining water will increase greatly. The risk that occurs when one misrepresents the material as Non-Formic Acid (NAF) as Potential Acid Former (PAF), and vice versa PAF material as NAF, significantly would be reduced by using both NAPP and NAG tests. The counting NAPP can be compared with the test results to classify samples NAG. The geochemical classification of samples based on NAPP and NAG data from the Managing Acid and Metalliferous Drainage Handbook as set out in Table 2.

Table 2. The criteria of geochemical classification based on NAPP and NAG test

Rock Type	pH NAG	NAPP
Potential Acid Former (PAF)	< 4.5	> 10
Low Capacity Potential Acid Former (LC-PAF)	< 4.5	0 - 10
Non-Forming Acid (NAF)	≥ 4.5	0
Neutralized Acid (NA)	≥ 4.5	< 100
Uncertain	≥ 4.5	Positive
	< 4.5	Negative

3. Methods

3.1. Sampling

Rock samples taken composite / grab with a size of about 3 kg and put in an airtight container which is then taken to the laboratory for preparation and testing. Thirty-six (36) samples was take from the well coal exploration of R1 (4 samples), R-4 (5 samples), R13 (17 samples) and R-14 (10 samples)

3.2. Screening test

To understanding ABA several screening tests are used in classification the relative acid forming potential of a sample; as follows: Determination Total Sulphur by Leco Apparatus, Measurement of Maximum Potential Acidity, Measurement of Acid Neutralizing Capacity, Calculating Net Acid Producing Potential (NAPP) based on S and ANC, Measurement of Net Acid Generation (NAG)

4. Result and Discussion

The location of the overburden rock sampling was conducted at 4 coal drilling locations that included R1, R2, R13 and R14. Depth data for drilling and sampling for each sampling site are listed in Table 3.

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Table 3. Overburden rock sampling tabulation

Well	Total Drill Depth (m)	Coal		Overburden Samples	
		Depth (m)	Thickness (m)	Amount	Interval Depth (m)
R1	16,40	3.10-3.40	0.30	4	3.90 – 5.10
		5.10–5.50	0.20		
		6,70-7,10	0,40		
R4	30.00	0.40 – 1.60	1.20	5	10.52 – 26.00
		3.0 – 4.00	1.00		
		10.20 – 10.60	0.40		
		13.25-13.50	0,25		
		17.50 -18.10	0,60		
		20.50-21.10	0,60		
R13	20	5.40 – 5.75	0.35	17	1.00 – 6.75
		6.75- 8.20	1.45		
R14	30	2.30 – 2.70	0.40	10	1.50 – 6.70
		3.20 – 3.80	0.60		
		9.10 – 9.50	0.40		

The total number of samples from locations of R1, R4, R13 and R14 which were analyzed in the laboratory is 36 samples. The prediction of Potential of Mining Acid Water Formation analyzed by determining pH NAG, MAP, ANC and NAPP. The result of analysis is listed in Table 4.

Table 4. Result of analysis of all overburden samples

Sample No	Depth (M)	Total S	NAG pH	$NAG_{4.5}$ (kg/t H_2SO_4)	MPA (kg/t H_2SO_4)	ANC (kg/t H_2SO_4)	NAPP (kg/t H_2SO_4)	ANC/ MPA	Geochem class
R1 WELL									
R01-01	3,90-4.20	1,45	3,2	0,62	44,37	35,53	8,85	0,80	PAF-LC
R01-02	4.21-4.50	1,28	4,1	0,88	39,17	33,81	5,36	0,86	
R01-03	4.51-4.80	1,33	3,8	0,56	40,70	32,95	7,75	0,81	
R01-04	4.81-5.10	1,52	4,1	0,71	46,51	38,22	8,29	0,82	
R4 WELL									
R04-01	10.52-10.82	1,28	4,2	0,48	39,17	22,91	16,26	0,58	PAF-MC
R04-02	10.91-11.20	1,65	3,9	0.74	50,49	31,97	18,52	0,63	
R04-03	13.51-13.80	1,55	3,5	0.61	47,43	29,65	17,79	0,63	
R04-04	14.00-14.30	1,20	3,9	0.72	36,72	25,97	10,75	0,71	
R04-05	25.70-26.00	1.82	4,1	0,92	55,69	34,42	21,27	0,62	
R13 WELL									
R13-01	1.00-1,30	0.62	6,21	0,42	12,85	14,21	-1,36	1,11	NAF
R13-02	1.31-1.60	0.84	6,82	0,46	10,40	15,93	-5,52	1,53	
R13-03	1.61-1.90	0.72	7,18	0,52	15,91	16,91	-0,99	1,06	

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R13-04	1.91-2.10	1.06	4,20	0,76	32,44	29,40	3,04	0,91	PAF-LC
R13-05	2.11-2.40	0.44	4,10	0,28	44,06	10,78	33,28	0,24	PAF-MC
R13-06	2.41-2.70	0.5	3,80	0,41	45,90	13,23	32,67	0,29	
R13-07	2.71-3.00	1.12	4,20	0.82	34,27	26,71	7,57	0,78	PAF-LC
R13-08	3.01-3.30	0.66	7,15	0.38	26,32	15,44	10,88	0,59	UC
R13-09	3.31-3.60	0.58	6,82	0,32	22,64	17,40	5,25	0,77	
R13-10	3.61-3.90	0.82	6,56	0,51	9,79	17,52	-7,73	1,79	NAF
R13-11	3.91-4.20	0.68	3,60	0,48	20,81	12,99	7,82	0,62	PAF-LC
R13-12	4.21-4.50	1.04	4,00	0.74	31,82	25,97	5,85	0,82	
R13-13	4.51-4.80	0.88	3,80	0.61	26,93	22,54	4,39	0,84	
R13-14	4.81-5.10	0.90	3,50	0.72	27,54	16,29	11,25	0,59	PAF-MC
R13-15	5.80-6.10	1.07	4,10	0,92	32,74	17,52	15,22	0,54	
R13-16	6.11-6.40	1.18	4,30	0,88	36,11	22,05	14,06	0,61	
R13-17	6.41-6.70	0.74	3,60	0,52	22,64	19,6	3,04	0,87	PAF-LC
R14 WELL									
R14-01	1.55-1,80	0,82	4,3	0,42	25,09	17,40	7,70	0,69	PAF-LC
R14-02	1.81-2.05	1,14	4,1	0,46	34,88	25,73	9,16	0,74	
R14-03	2.06-2.30	1,02	4,1	0,52	31,21	21,44	9,77	0,69	
R14-04	2.70-2.95	1,36	4,3	0,76	41,62	33,32	8,30	0,80	
R14-05	2.96-3.20	0,74	4,1	0,28	22,64	14,70	7,94	0,65	
R14-06	4.80-5.05	0,80	3,9	0,41	24,48	15,68	8,80	0,64	
R14-07	5.06-5.31	1,42	4,3	0.82	43,45	35,28	8,17	0,81	
R14-08	5.31-5.56	0,96	3,7	0.38	29,38	22,79	6,59	0,78	
R14-09	5.56-5.81	0,88	4,1	0,32	26,93	20,21	6,72	0,75	
R14-10	5.81-6.06	1,12	4,1	0,51	34,27	24,62	9.65	0,72	

All overburden samples from R1 well has a positive NAPP (> 10,00 kg/t H2SO4)) and a NAGpH less than 4.5, therefore the samples cam be classified as the PAF-LC (Low Capacity Potential Acid Former. Similarly, with this; is the samples from R14 well which also classified as the PAF-LC due to positively NAPP and NAGpH less than 4.5. However, the value of NAGpH for samples from well R13 (R13-01 – R13-03 and R13-10) which has greater than 4,5 (6,21 – 7,18) and have negatively NAPP (-0,99 – 7,73) and so the samples are classified as NAF (Non Forming Acid); the other samples from R13 have a positively NAPP between 3,04 to 7,82 (kg/t H2SO4) and pHNAG below 4,5 (R13-04, R133-7; and R13-11 -R13-13), whereas the samples are classified as the PAF-LC; and the rest samples classified as the PAF-MC due to high NAPP (>10 kg.H_2SO_4 ton) and lower pHNAG (, 4,5). Two samples from R13 (R13-08, R13-09) were classified as the uncertainty (UC) which marked by high pH (>4,5) and positively NAPP. The plot of NAPP against pHNAG as seen in figure 1, showing the geochemical classification of potential acid former.

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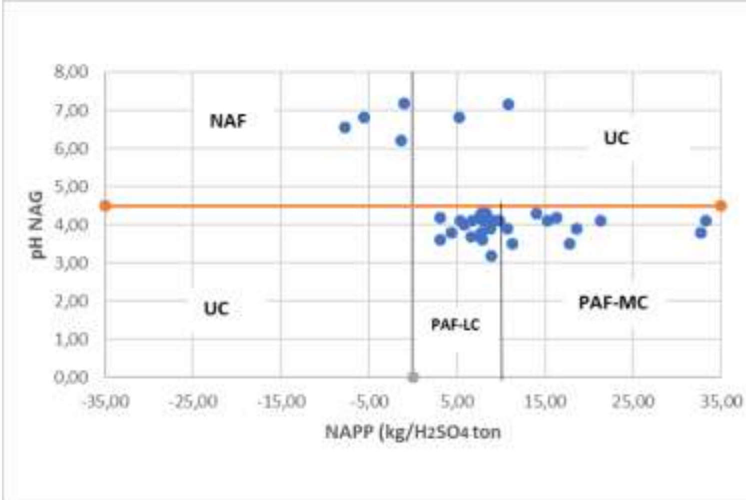

Figure 1. Geochemical classification plot of overburden samples in Horna coalmines. (NAF: Non-Forming Acid; PAF -LC: Low Capacity Potential Acid Former; PAF-MC: Moderately Capacity Potential Acid Former; UC : uncertainty)

The mean of ANC 23,08 9 kg H2SO4/t equivalent and mean of MPA 36,00 kg H2SO4/t equivalent indicated that the rocks has a sufficient to provide the acidity. The most of overburden samples from all well (R1, R4, R13 and R14) were geochemically classified as the PAF (potential acid former) are related the high content of silicate and aluminosilicate, and pyrite. Low carbonate minerals in rocks causes the high potential of rocks to form acids.

5. Conclusion

The minerals composition of overburden rock samples in Horna coalmine which dominated by quartz, aluminous silicate, sulphide minerals i.e. pyrite has contribution to the high potency acidity environment. The Acid-Base Accounting by measuring MPA, ANC, NAG indicating most of the samples are geochemically classified as the potentially acid forming (PAF).

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