Evaluation of Geochemical Tests in Predicting Acid Mine Drainage Potential in Coal Surface Mine

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Abstract

Geochemical tests that are generally conducted to predict AMD potential have been studied using samples from a coal mine area in Kalimantan, Indonesia. Acid base accounting and net acid generation (NAG) tests were used to classify whether the samples were potentially acid forming or non acid forming material. A modified free draining column leach test was conducted on the potentially acid forming samples to understand the kinetics of acid generation. The results of more than 200 days of observation are presented in this paper. Both comparisons and findings were analyzed. There were some deviations between the result of acid base accounting analysis and the result of kinetic test. This study could be used to revisit the interpretation of test results for a better prediction on AMD potential in coal mines.

Key words: acid mine drainage, coal surface mines, static test, kinetic test

Introduction

Acid mine drainage (AMD) is considered one of the most significant environmental issues in most coal surface mines in Indonesia. Efforts have been made by the governmental agencies in mining and the environment to control such issues in mining activities. It is expected that a thorough geochemical assessment of overburden to identify potentially and non-acid-forming (PAF and NAF) lithology should be conducted as a baseline for overburden management plans particularly dealing with AMD prevention. But, in the case of small and medium scale mines, the most common practices are controlling the AMD by monitoring the mine water quality, especially pH, before discharging into the natural surface water body, and adding lime if necessary; or only a limited number of rock samples is geochemically analyzed, due to budget limitations.

Acid base accounting through static testing is the most popular method of predicting the AMD potential. Gautama & Hartaji (2004) studied the accuracy of geochemical rock modeling based on the static test using samples collected from blast hole drill cuttings during the operation of a modern large scale coal mine in East Kalimantan. The findings showed that, in general, the amount of PAF material tends to be over-estimated. Kinetic testing has been conducted to analyze the long term behavior of rock samples being classified PAF by the static test. The objective is to understand the reliability of different tests in predicting the AMD potential and to find the most appropriate and economic method to predict AMD.

Rock samples and experiment procedure

Rock samples taken from drill cores were collected from a coal mine area in Kalimantan. Static tests consisting of total sulfur determination, acid neutralizing capacity, net acid generation as well as paste pH test had been conducted to classify PAF and NAF samples. Ten PAF samples representing different lithologies were then selected for kinetic testing. Geochemical characteristics of the samples for the kinetic test are shown in Table 1.The kinetic test conducted was a modified free draining column test with a 100 mm height and 100 mm diameter Buchner funnel. The room temperature was kept in the range 35-40 ºC using a 40 Watt *spottone* lamp to represent the local climate condition in the mining area. As much as 300 gram of sample with known particle size distribution was put in each funnel and then flushed by approximately 120 mL de-ionized water once per day. The leachates were collected daily and parameters measured were pH and electric conductivity. Metal content in the selected leachate was also analyzed. The daily water spraying and leachate measurement were conducted up to day-89, with a week's break between day-69 and day-77. After another long break of 33 days, kinetic testing was continued from day-124 to day-257 with a measurement interval of every 7 days.

***Table 1** Geochemical characteristics of rock samples*

No.	Sample code	Lithology	TS %	MPA	ANC	NAPP	pH_{paste}	NAGpH	$NAG_{(kg\ H2SO4/ton)}$		Type
									pH 4.5	pH 7	
1	33EV04	MS	2.33	71.30	39.60	31.70	4.26	6.36	0.00	0.66	PAF
2	33EV06	MS	1.24	37.94	8.23	29.71	4.28	2.43	11.75	16.45	PAF
3	33EV10	SS	3.57	109.24	30.59	78.65	8.75	9.06	0.00	0.00	PAF
4	33EV16	MS	2.56	78.34	2.92	75.42	7.82	2.06	40.19	49.36	PAF
5	33EV17	MS	0.37	11.32	0.00	11.32	2.59	1.87	57.00	68.05	PAF
6	33EV20	MS	1.25	38.25	16.61	21.64	3.18	2.33	24.33	32.91	PAF
7	33EV21	MS	2.84	86.90	0.72	86.18	7.42	2.08	51.01	57.94	PAF
8	33EV22	CC&MS	4.89	149.63	0.00	149.63	5.89	2.09	93.20	112.24	PAF
9	33EV25	C	0.55	16.83	0.00	16.83	8.66	5.88	0.00	3.03	PAF
10	34EV04	MS	3.11	95.17	0.00	95.17	3.73	2.19	49.78	64.13	PAF

Remarks:

TS = Total Sulfur [%]
MPA = Maximum Potential of Acidity [kg H_2SO_4/ton of rock]
ANC = Acid Neutralizing Capacity [kg H_2SO_4/ton of rock]
NAPP = Nett Acid Producing Potential [kg H_2SO_4/ton of rock]
NAG = Nett Acid Generation [kg H_2SO_4/ton of rock]
PAF = Potential Acid Forming
MS = Mudstone
SS = Sandstone
C = Coal
CC&MS = Carbonaceous Clay & Mudstone

Results and discussion

pH and electric conductivity

Based on the results of daily measurement of pH and electric conductivity of leachate, there were three characteristics of pH and EC distribution with time.

Group 1 was represented by samples 33EV04 and 33EV10, characterized by pH 3.7 and 3.9 at the first day of experiment, rapidly increasing to pH 7.1 at day-5 and day-3 respectively (see figure 1). The EC values decreased from 3-6 mS/cm to 0.2 – 0.4 mS/cm as pH increased. After a one-week break without water spraying (day-77) sample 33EV04 started with pH 4.2 and sample 33EV10 with pH=7.1. The acid base accounting analysis classified both samples as potentially acid forming since the NAPP values were 31.70 kg H_2SO_4/ton and 78.65 kg H_2SO_4/ton respectively (see table 1). Although pyritic sulfur was dominant, the reactivity of sulfur was low as indicated by paste pH and NAG pH, and the neutralizing capacity (ANC) was effective. The kinetic test confirmed that both samples could be classified as non acid forming material, and even sample 33EV10 probably had the potential to neutralize acid.

***Table 2** Characteristics of group 1 samples*

Sample	NAPP	Paste pH	NAG pH	pH kinetic	Total S (%)	Pyritic S (%)
33EV04	31.70	4.26	6.36	3.7-8.3	2.33	0.95
33EV10	78.65	8.75	9.06	3.9-8.3	3.57	3.17

Samples 33EV21 and 33EV25 represented the second group, which was characterized by slow increase of pH from 3.2 and 2.7 respectively at the beginning to the 4 - 4.3 (see figure 1). During the one-week break in water spraying, there was only a small change in pH. Significant change occurred after the 33 day break. The pH at day-124 was 7.5 and slowly decreased to 5.6 at day-257. Both samples were classified as potentially acid forming according to the acid base accounting method, but with relatively high paste pH values (7.42 and 8.66). The reactivity of sulfur was quite high although pyritic sulfur was dominant (33EV21) as shown by low NAG pH. The kinetic test confirmed the static test classifying both samples as potentially acid forming with low to medium acid generating capacity.

Figure 1 *pH and EC of samples representing group 1 and group 2*

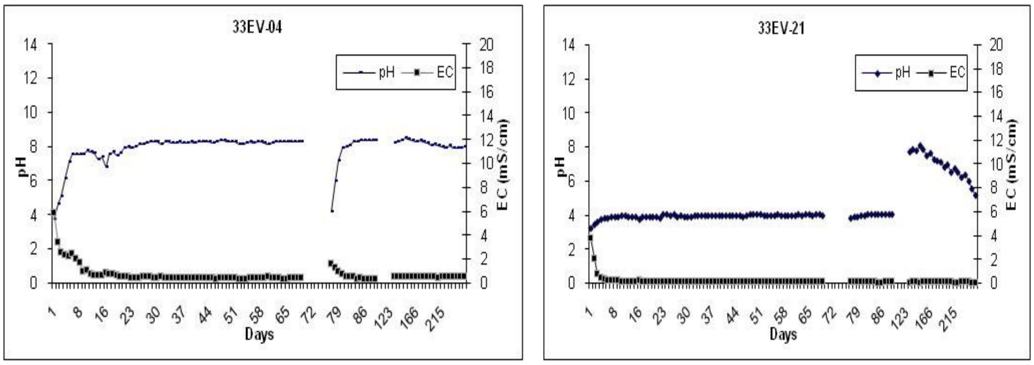


Table 3 *Characteristics of group 2 samples*

Sample	NAPP	Paste pH	NAG pH	pH kinetic	Total S (%)	Pyritic S (%)
33EV21	86.18	7.42	2.08	3.2-4.0	2.84	2.23
33EV25	16.83	8.66	5.88	2.7-4.3	0.55	0.13

The rest of the samples (33EV06, 33EV16, 33EV17, 33EV20, 33EV22 and 34EV04) were classified into the third group. This group consisted of highly acid generating material and was characterized by relatively constant pH values, 1.7 to 2.4, during kinetic testing (see figure 2). Although some samples had relatively high paste pH, low NAG pH indicated the acid generating capacity. The samples had also high sulfur content which was dominated by pyritic sulfur. Kinetic testing confirmed that those samples were highly PAF material.

Table 4 *Characteristics of group 3 samples*

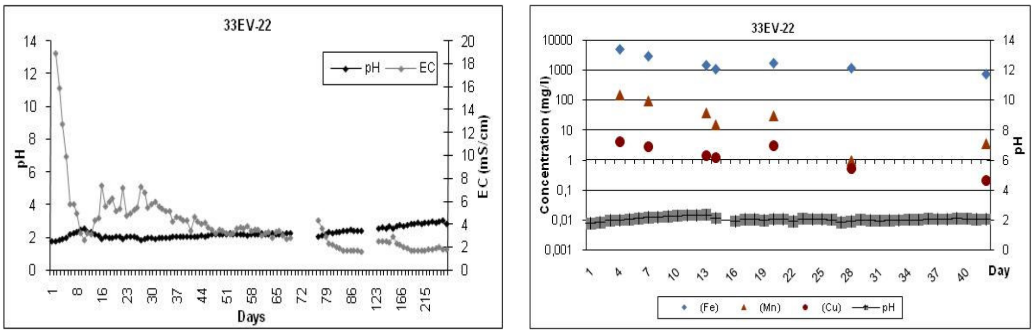
Sample	NAPP	Paste pH	NAG pH	pH kinetic	Total S (%)	Pyritic S (%)
33EV06	29.71	4.28	2.43	2.3-2.7	1.24	1.10
33EV16	75.42	7.82	2.06	2.3-2.3	2.56	1.97
33EV17	11.32	2.59	1.87	1.8-2.4	0.37	0.18
33EV20	21.64	3.18	2.33	2.4-2.4	1.25	1.01
33EV22	149.63	5.89	2.09	1.7-2.2	4.89	2.57
34EV04	95.17	3.73	2.19	2.4-2.4	3.11	1.72

Metal content

Metal content was analyzed from the leachates taken cumulatively at days 4, 7, 13 and 20 as well as individual samples from days 14, 28 and 42. The results confirmed the pH and EC values during the kinetic test. Group 1 samples contained only limited content of metal compared to other groups.

The highly PAF samples of group 3 had the highest metal content, as shown for sample 33EV22 in Figure 2b. For sample 33EV22, the Fe content in the cumulative leachate was 4956.99 mg/L at day-4 and 1691.4 at day-20, whereas in the individual leachate the Fe content was 1106.7 mg/L at day -14 and 747.8 mg/L at day-42. Such concentrations are much higher than the maximum allowable Fe concentration in the effluent of coal mining in Indonesia, which is 7 mg/L.

Figure 2 *pH, EC and metal content of sample group 3*



Conclusion

A free draining column leach test was conducted on 10 samples classified as potentially acid forming rocks by acid base accounting method. The result of the 257-day test was used to revisit the result of static test. There were three categories of samples. The first consisted of samples with high NAPP, high ANC, and low NAG pH. Such samples were usually classified as potentially acid forming based on acid-base-accounting method but the result of kinetic testing confirmed that such type of samples could be classified as non acid forming. The second category of samples was characterized by a slow increase of pH from around 2 to around 4. The samples were classified as medium to high acid generating materials. The third category was highly acid generating materials. For all types the results of the static test could accurately identify the potentially acid forming material.

In general, the acid base accounting method tends to give pessimistic results in the prediction of acid generating potential of rocks. If the rock sample has a higher ANC value, even though the NAPP is positive, there is a possibility that the sample could not be classified as potentially acid forming. Paste pH and NAG test could confirm whether such a sample should be treated as PAF or NAF. On the other hand, a sample with low sulfur content and ANC=0 could be potentially acid forming.

The preventive approach through development of a geochemical rock model integrated in the mine excavation model is proven to be the best practice to control the acid mine drainage problem in the long term. For small and medium scale mines, the static test which includes total sulfur, ANC, paste pH and NAG tests, is reliable enough to characterize the acid generating potential of rock samples.

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