Study of Physical Properties of Rocks and Acid Mine Drainage Potential at Banko Barat Tanjung Enim

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ABSTRACT

One of the factors that generate acid mine drainage (AMD) is the presence of sulphide minerals in rocks because sulphide minerals will have oxidation with oxigen and water to generate AMD. Learning sulphide minerals in rocks can not be separated from the rocks themselves. Present paper is an attempt to study how the physical properties of rocks are and their influences in generating acid mine drainage. At Banko barat, especially at PIT 3 timur, the lithology of rocks is complex. It is assumed that the complexity of rocks will influence the complexity of formation of acid mine drainage. Thus by knowing the characteristics of each rock it is expected to be useful in identification of which rocks require special attention in the mine planning process.

Keyword: acid mine drainage, rocks, physical properties of rock.

1. INTRODUCTION

One of coal mining problems is the presence of acid mine drainage waste. AMD becomes an environmental problem when natural forms of neutralization such as carbonate minerals are not available in sufficient quantities to neutralize the drainage. The metal rich, low pH effluent is highly toxic to life downstream of the waste rock pile, e.g. Barry et al. (2000), Soucek et al. (2001) [1,2]. Acid mine drainage is very dangerous for environment so that it is very important to identify factors affecting AMD formation.

Factors that control formation of acid mine drainage can be classified into two broad categories : 1) source characteristics/factors such as type, sulphide distribution and abundance, and other minerals with their acid neutralization capacity (ANC), rock texture and type, pore and interconnectivity (porosity and permeability), segregation and compaction degree, and 2) other environment factors such as climate, rainfall, air temperature, hydrogeology, waste volume and disposal method [3].

In general, pyrite (FeS_2) is a sulphide mineral that is commonly found on the waste rocks and will have oxidation when exposed. The typical oxidation is in accordance with the following reaction [4] :

$$FeS_2 + \frac{15}{4}O_2 + \frac{7}{2}H_2O \rightarrow 2SO_4^{2-}(aq) + Fe(OH)_{3(s)} + 4H^+_{(aq)} \quad (1)$$

The characteristics of sulphide-bearing rocks play important role in formation of acid mine drainage. Consequently this study was particularly intended to understand characteristics of rocks especially their physical properties and acid mine drainage potential at Banko barat Tanjung Enim.

2. METHODS

In order to achieve the aims of the study, some core samples from different wells were used to be analysed. Samples consist of coal and non-coal lithologies of boreholes located in PIT 3 Timur Banko Barat Bukit Asam coal mining area. Goals of laboratory analysis are to determine some physical properties such as density and porosity; and while acid mine drainage potential was reviewed through literature study compared to physical properties results and secondary data (rock acidity analysis) from PT. BA analysis result.

Laboratory analysis was done by measuring rock parameters and mineralogy analysis with use of X-Ray Diffraction and SEM-EDS.

3. RESULTS

3.1 Waste Roks at Mine Site

Rock samples were obtained from PIT 3 timur and analysed using XRD. Result of overburden and interburden layer is shown by Figure 1 and 2.

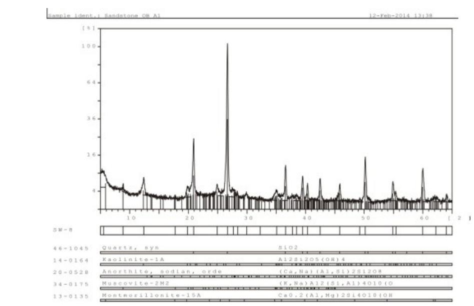


Figure 1. XRD Analysis of Sandstone of Overburden Layer

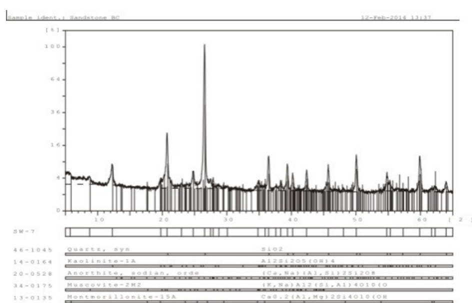
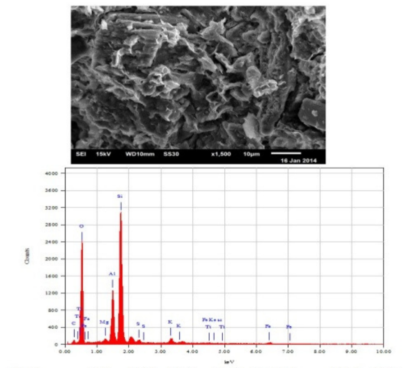


Figure 2. XRD Analysis of Sandstone of Interburden Layer

Results of overburden and interburden layer show that there is no indication of pyrite mineral. It is assumed that the condition of samples is no longer fresh caused by contamination from outside influences or the origin condition of samples itself. Because pyrite is basically not spread evenly on a rock.

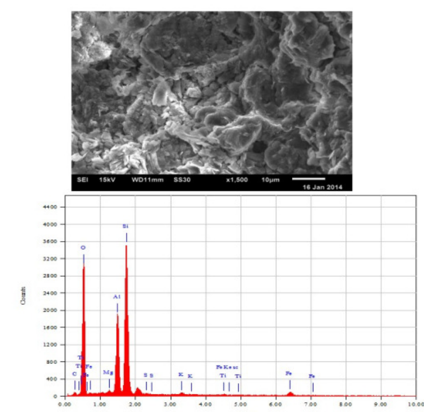
Rock morphology and element content of rock from SEM-EDS analysis are shown by Figure 3 and Figure 4.

Sulfur (S) and Fe elements shown by SEM-EDS result below indicates that there is possibility of sulphide mineral of rocks. The sulphide minerals can be pyrite, pyrrhotite, marcasite or non-ferrous sulphides according to element content.



Element	(keV)	Mass%	Error%	Atom%	Compound	Mass%	Cation
C K	0.277	5.21	0.09	8.61			0.9199
O K	0.525	47.89	0.07	59.35			50.3195
Mg K	1.253	0.54	0.06	0.44			0.4826
Al K	1.486	9.95	0.06	7.31			10.0479
Si K	1.739	30.64	0.07	21.63			31.8545
S K	2.307	1.02	0.08	0.63			1.0752
K K	3.312	2.05	0.13	1.04			2.4309
Ti K	4.508	0.39	0.20	0.16			0.4149
Fe K	6.398	2.30	0.43	0.82			2.4545
Total		100.00		100.00			

Figure 3. SEM-EDS Analysis of overburden layer



Element	(keV)	Mass%	Error%	Atom%	Compound	Mass%	Cation
C K	0.277	3.77	0.07	6.35			0.6514
O K	0.525	47.81	0.06	60.46			52.2111
Mg K	1.253	0.33	0.05	0.28			0.2826
Al K	1.486	13.45	0.05	10.09			12.9248
Si K	1.739	28.08	0.06	20.23			27.0730
S K	2.307	0.29	0.07	0.18			0.2904
K K	3.312	0.79	0.11	0.41			0.9094
Ti K	4.508	0.43	0.16	0.18			0.4447
Fe K	6.398	5.04	0.36	1.83			5.2125
Total		100.00		100.00			

Figure 4. SEM-EDS Analysis of Interburden A1-A2

3.2 Borehole Rocks at Pre-mining Area

Following results is several physical properties of borehole rocks at pre-mining area. Acid mine drainage is affected by characteristics such as pore size, particle size, permeability, and mineral composition of the materials being oxidized. The size of particles directly influences the surface area of rock exposed to weathering and oxidation. Particle size is inversely related to surface area. Therefore very coarse grain substances expose less surface area; however, they have deeper crevices between particles. This characteristic may let air and water penetrate further, thereby exposing more substance to oxidation and ultimately generating more acid. Conversely, fine grain substances may prohibit air and water flow, but they also have more surface area exposed to oxidation.

Table 1. Results of Physical Parameters of several borehole rocks at Banko PIT 1 Barat

Borehole	Elevation		Lithology	Stratigraphy Layer	Density		Water Content (%)	Degree of Saturation (%)	Porosity (%)
	From	To			Wet (gr/cm^3)	Dry (gr/cm^3)			
BKGT 28	6.00	9.20	Claystone	OB A1	0.232	0.189	18.143	79.629	4.299
BKGT 29	55.80	59.73	Sandstone	OB A1	0.255	0.202	18.279	69.863	5.283
BKGT 29	79.50	82.30	Siltstone	OB A1	0.351	0.291	15.618	75.490	6.015
BKGT 28	106.00	112.00	Claystone	IB A1A2	0.341	0.272	17.636	52.856	6.934
BKGT 29	198.10	199.30	Claystone	IB A1A2	0.350	0.297	10.047	56	5.331
BKGT 28	170.00	171.00	Sandstone	IB A2B1	0.351	0.304	2.473	16.279	4.626
BKGT 29	213.36	214.50	Carbonaceous clay	IB A2B1	0.290	0.251	4.671	23.543	3.941
BKGT 27	178.00	184.00	Carbonaceous clay	IB B1B2	0.245	0.304	22.455	66.942	5.596
BKGT 27	196.00	202.00	Sandstone	IB B2C	0.283	0.149	80.37	88.374	13.451

In addition lithology or rock type also influences spoil and drainage quality. Physical characteristics of the rock, such as porosity, and accessory minerals can exert various constraints or enhancements to the overall chemical weathering process [5]. Argillaceous rocks tend to release their acid load over a longer period of time. Accessory minerals such as clays and other silicates may dissolve, form new minerals, or attenuate the acid and alkaline weathering products. Pyrite can occur in grain sizes ranging from invisible to the eye up to several inches. Framboids and other fine grained pyrites with a large surface area are much more chemically reactive than the coarser forms [6].

Table 2. Acidity Analysis of Borehole Core at Pre Mining Area in Banko PIT 1 Barat

Bore Series	Elevation		Lithology	Layer	Sulfur Total (%)	MPA (Kg H2SO4/ton)	ANC (Kg H2SO4/ton)	NAPP (Kg H2SO4/ton)	pHpaste	pH NAG	pH NAG		TYPE
											pH 4,5	pH 7	
	From	To			TS	PKM	KPA	PPAN	pH PASTA	PAN pH	PAN		
					%	Kg H_2SO_4/Ton	Kg H_2SO_4/Ton	Kg H_2SO_4/Ton			pH 4.5	pH 7	
BKGT_27	178,00	184,00	SANDSTONE	IB B2 - C	0,59	18,07	21,34	-3,27	6,44	2,61	8,95	21,96	NAF
BKGT_27	184,00	190,00	SANDSTONE	IB B2 - C	0,64	19,60	23,58	-3,98	6,39	2,78	8,54	21,56	NAF
BKGT_27	190,00	196,00	SANDSTONE	IB B2 - C	0,94	28,79	24,19	4,60	6,49	2,67	13,42	29,28	PAF
BKGT_27	196,00	202,00	SANDSTONE	IB B2 - C	0,71	21,74	27,44	-5,70	6,95	2,87	8,54	22,78	PAF
BKGT_27	202,00	205,00	CARBONACEOUS CLAY	IB B2 - C	2,27	69,52	25,00	44,52	4,93	2,00	50,84	76,87	PAF
BKGT_28	6,00	9,20	CLAYSTONE	OB A1	1,16	35,53	24,38	11,15	7,93	2,59	22,65	34,96	PAF
BKGT_28	9,20	12,80	SANDSTONE	OB A1	0,38	11,64	42,60	-30,96	8,55	3,21	5,91	15,27	NAF
BKGT_28	20,80	26,80	SANDSTONE	OB A1	0,00	0,00	29,55	-29,55	8,56	3,89	2,46	9,85	NAF
BKGT_28	26,80	30,00	CLAYSTONE	OB A1	0,55	16,84	31,27	-14,43	9,07	3,13	4,92	10,34	NAF
BKGT_28	30,00	36,00	CLAYSTONE	OB A1	0,66	20,21	30,78	-10,57	9,14	2,76	11,82	22,16	NAF
BKGT_28	36,00	43,50	CLAYSTONE	OB A1	0,91	27,87	43,58	-15,71	8,80	2,53	18,71	32,50	PAF
BKGT_28	43,50	48,00	SANDSTONE	OB A1	0,04	1,23	40,88	-39,66	9,23	3,78	2,46	12,80	NAF
BKGT_28	57,80	67,70	SANDSTONE	OB A1	0,01	0,31	24,87	-24,56	7,32	3,42	2,95	10,83	NAF
BKGT_28	77,00	79,00	SANDSTONE	OB A1	0,11	3,37	33,24	-29,87	9,01	4,26	0,49	14,28	NAF
BKGT_28	79,00	82,50	CLAYSTONE	OB A1	0,41	12,56	64,27	-51,71	9,60	3,68	2,95	11,33	NAF
BKGT_28	82,50	84,40	SANDSTONE	OB A1	0,09	2,76	34,47	-31,71	9,20	5,33	-	24,13	NAF
BKGT_28	84,40	94,00	CLAYSTONE	OB A1	0,76	23,28	31,27	-8,00	8,75	2,89	11,33	5,91	PAF
BKGT_28	94,00	100,00	CLAYSTONE	OB A1	1,92	58,80	24,13	34,67	6,60	2,37	43,83	58,60	PAF
BKGT_28	100,00	106,00	CLAYSTONE	OB A1	1,20	36,75	48,12	-11,37	7,23	3,06	12,47	24,94	PAF
BKGT_28	106,00	112,00	CLAYSTONE	OB A1	0,66	20,21	60,09	-39,88	8,15	4,39	1,50	6,98	NAF
BKGT_28	112,00	118,00	CLAYSTONE	OB A1	0,76	23,28	54,85	-31,58	7,96	3,59	3,99	12,97	PAF
BKGT_28	118,00	126,00	CLAYSTONE	OB A1	0,78	23,89	59,54	-35,65	7,59	3,46	4,99	18,96	PAF
BKGT_28	130,00	133,75	CARBONACEOUS CLAY	OB A1	0,99	30,32	37,27	-6,95	7,48	4,14	1,00	3,99	PAF
BKGT_28	145,00	145,60	CARBONACEOUS CLAY	IB A1 - A2	0,70	21,44	24,06	-2,62	6,68	2,47	67,34	112,23	PAF
BKGT_28	145,60	148,20	SANDSTONE	IB A1 - A2	0,17	5,21	26,55	-21,34	8,23	4,25	1,00	10,97	NAF
BKGT_28	149,00	152,74	CLAYSTONE	IB A1 - A2	0,00	0,00	40,88	-40,88	8,36	4,59	-	10,48	NAF
BKGT_28	162,00	165,00	CLAYSTONE	IB A2 - B1	2,50	76,56	7,10	69,46	4,20	2,07	114,73	170,60	PAF
BKGT_28	165,00	169,00	CLAYSTONE	IB A2 - B1	1,38	42,26	21,66	20,60	5,36	2,75	26,44	42,90	PAF
BKGT_28	170,00	171,00	SANDSTONE	IB A2 - B1	2,12	64,93	11,05	53,88	4,61	1,95	103,26	148,15	PAF
BKGT_28	171,00	175,40	SILTSTONE	IB A2 - B1	0,80	24,50	30,66	-6,16	6,53	2,93	10,48	25,44	PAF
BKGT_28	188,55	192,86	CLAYSTONE	IB B1 - B2	2,21	67,68	1,68	66,00	4,22	2,15	80,81	123,21	PAF
BKGT_28	196,00	198,00	SANDSTONE	IB B2 - C	1,18	36,14	2,92	33,22	4,89	2,34	35,42	50,38	PAF
BKGT_28	198,00	200,00	CLAYSTONE	IB B2 - C	1,06	32,46	15,69	16,77	5,78	2,89	16,46	32,42	PAF
BKGT_29	25,40	28,00	CARBONACEOUS CLAY	OB A1	3,37	103,21	29,46	73,75	3,92	2,18	83,81	119,31	PAF
BKGT_29	28,00	36,00	CLAYSTONE	OB A1	1,08	33,08	30,38	2,69	7,08	2,92	13,80	29,09	PAF
BKGT_29	36,00	42,00	CLAYSTONE	OB A1	1,28	39,20	26,19	13,01	7,16	2,86	20,71	35,99	PAF
BKGT_29	42,00	48,00	CLAYSTONE	OB A1	0,71	21,74	53,61	-31,87	8,22	3,94	2,96	13,80	PAF
BKGT_29	48,00	55,80	CLAYSTONE	OB A1	0,74	22,66	32,35	-9,69	8,62	3,48	6,41	15,28	PAF
BKGT_29	55,80	59,73	SANDSTONE	OB A1	0,14	4,29	37,22	-32,93	8,77	5,93	-	1,97	NAF
BKGT_29	59,73	63,20	CLAYSTONE	OB A1	0,88	26,95	54,85	-27,90	8,76	2,92	6,41	22,19	PAF
BKGT_29	63,20	66,80	SANDSTONE	OB A1	0,30	9,19	27,42	-18,24	8,51	2,94	1,48	6,41	PAF
BKGT_29	67,20	73,20	SANDSTONE	OB A1	0,03	0,92	56,32	-55,41	8,97	5,47	-	3,45	NAF
BKGT_29	73,20	79,50	CLAYSTONE	OB A1	0,65	19,91	60,76	-40,85	8,51	3,25	4,93	12,82	NAF
BKGT_29	79,50	82,30	SILTSTONE	OB A1	0,32	9,80	57,80	-48,00	8,64	4,18	1,48	8,87	NAF
BKGT_29	82,30	91,00	CLAYSTONE	OB A1	1,08	33,08	38,09	-5,01	8,04	2,77	32,54	44,37	PAF
BKGT_29	91,00	93,90	SANDSTONE	OB A1	0,03	0,92	22,74	-21,82	8,84	5,09	-	3,45	NAF
BKGT_29	93,90	98,00	CLAYSTONE	OB A1	0,08	2,45	39,81	-37,36	8,88	4,08	1,97	13,80	PAF
BKGT_29	98,00	100,20	CARBONACEOUS CLAY	OB A1	0,12	3,68	40,30	-36,63	8,68	4,35	1,48	11,83	PAF
BKGT_29	100,70	101,90	CLAYSTONE	OB A1	0,17	5,21	41,78	-36,58	8,16	4,66	-	5,92	NAF
BKGT_29	101,90	107,00	SANDSTONE	OB A1	0,18	5,51	43,26	-37,75	6,81	3,31	4,44	15,28	NAF
BKGT_29	124,60	125,40	CLAYSTONE	OB A1	0,80	24,50	50,02	-25,52	8,96	3,67	13,00	28,89	PAF
BKGT_29	128,70	132,20	CLAYSTONE	OB A1	0,29	8,88	33,07	-24,19	8,98	4,52	-	7,22	NAF
BKGT_29	132,20	134,10	SANDSTONE	OB A1	0,07	2,14	33,07	-30,93	8,68	7,01	-	-	NAF
BKGT_29	150,30	154,00	CLAYSTONE	OB A1	0,85	26,03	26,33	-0,30	8,10	3,61	13,48	25,52	PAF
BKGT_29	178,00	183,00	SILTSTONE	OB A1	0,71	21,74	19,25	2,50	7,01	3,65	9,63	23,59	PAF
BKGT_29	184,00	185,40	CARBONACEOUS CLAY	OB A1	1,54	47,16	16,22	30,94	3,66	3,06	67,88	99,65	PAF
BKGT_29	197,20	198,10	CARBONACEOUS CLAY	IB A1 - A2	0,74	22,66	238,78	-216,12	5,30	2,92	50,07	87,62	PAF
BKGT_29	198,10	199,30	CLAYSTONE	IB A1 - A2	0,09	2,76	31,87	-29,11	8,43	5,63	-	8,18	NAF
BKGT_29	213,36	214,50	CARBONACEOUS CLAY	IB A2 - B1	1,81	55,43	29,80	25,63	5,71	3,33	36,11	75,10	PAF
BKGT_29	214,50	219,70	SILTSTONE	IB A2 - B1	0,89	27,26	-7,14	34,40	5,74	3,49	19,74	35,63	PAF

Source : PT. BA, 2013

Particle size is a fundamental concern since it affects the surface area exposed to weathering and oxidation: smaller particles have more surface area and therefore more reactive sites than larger particles. The relationships between particle size, surface area, and oxidation play a prominent role in acid prediction methods. This fact is shown by Table 2 indicating sandstone which has coarser grain size than claystone or siltstone or carbonaceous clay tends to cause NAF result in acidity analysis. In addition the silt and clay content in the rock influences the plasticity behaviors and will exhibit low permeability [7]. Permeability is directly proportional to the porosity so that claystone and siltstone porosity is less than sandstone porosity (Table 1).

Important mineralogical factors lead to formation of acid mine drainage are: type and quantity of sulphide minerals (pyrite, pyrrhotite, marcasite and non-ferrous sulphides), texture and morphology, degree of rock fracture, content of acid consuming minerals. These factors affect both the chemical rates of acid formation and neutralization [8].

Mineralogy and other factors affecting the potential for AMD formation are highly variable from site to site because of the difference of climate and parent rock type of each site and other condition. Thus the determination of the acid mine drainage from a particular site should be based on the physical characteristics (which include particle size, sorting and rock type) as well as the chemical characteristics of the rock mass.

4. CONCLUSION

It is concluded that physical properties of rocks as well as chemical properties of rocks influence rate of formation of acid mine drainage. Physical characteristics such as grain size and rock type affect physical properties of rock such as porosity, permeability and density.

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REFERENCES

[1] Barry, K. L., J. A. Grout, C. D. Levings, B. H. Nidle, and G. E. Piercey. "Impacts of acid mine drainage on juvenile salmonids in an estuary near Britannia Beach in Howe Sound British Columbia." Canadian Journal of Fisheries and Aquatic Sciences 57(10): 2031-2043, 2000.

[2] Soucek, D.J., Cherry, D.S., and Zipper, C.E. “Aluminum-dominated acute toxicity to the cladoceran Ceriodaphnia dubia in neutral waters downstream of an acid mine drainage discharge”. Canadian Journal of Fisheries and Aquatic Sciences , 58: pp. 2396-2404, 2001.

[3] Paktunc, A. D., Characterization of Mine Waste for Prediction of Acid Mine Drainage in Environmental Effects og Mining Activities, J.M. Azcue (ed.), Springer-Verlag Berlin Heidelberg, 1999

[4] Sengupta, M.. “Environmental Impacts on Mining – Monitoring, Restoration and Control”, Lewis Publisher, 1993

[5] Ziemkiewicz, P., J. Renton and T. Rymer. "Prediction and Control of Acid Mine Drainage: Effect of Rock Type and Amendment," in Proceedings Twelfth Annual West Virginia Surface Mine Drainage Task Force Symposium, April 3 - 4, 1991, Morgantown, West Virginia, 1991,

[6] Evangelou, V.P.,. “Pyrite Oxidation and its Control”. CRC Press, N.Y., 293 p, 1995

[7] Benson, C.H., Zhai, H. and Wang, X. “Estimating hydraulic conductivity of compacted clay liners, Journal of Geotechnical Engineering”, ASCE, pp. 366–387, 120 (2) (1994),

[8] Otwinowski, M., “Quantitative Analysis of Chemical and Biological Kinetics for the Acid Mine Drainage Problem”, Report Prepared for Mine Environment Neutral Drainage Program, Canada, 1994