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Geochemical Characterization and Mineralogy Control of Rocks to Assign Overburden Management

Waterman Sulistyana Bargawa[1, a)] and Ira Mughni Pratiwi[1, b)]

[1]*Master of Mining Engineering UPNVYK, Jalan SWK 104 Condongcatur Yogyakarta Indonesia*
Email: [a)] waterman.sulistyana@gmail.com, [b)]mughniira@gmail.com

ABSTRACT

This research is conducted at coal mine, located on Barito Basin, South Kalimantan, Indonesia. The purpose is to characterize geochemistry and mineralogy control of rocks for acid mine drainage prediction to prevent acid mine drainage formation. Rocks geochemical characterization of PAF (Potential acid Forming), NAF (Non Acid Forming), and uncertain material is obtained based on result of overburden geocheminal test comprise paste pH, NAG (Net Acid Generating), TS (Total Sulphur), ANC (Acid Neutralization Capacity), percentage of rocks mineral composition analyzed using XRD. The result of this reasearch shows material is classified into NAF material (81%) and PAF LC (Low Capacity) material (5%); PAF MC (Medium Capacity) material (10%); PAF HC (High Capacity) material (1%); an uncertain data (3%). NAF material is dominated by mudstone. Based on the research material of neutralization is low and comprise of silica, plagioclase, and aluminosilicate mineral thus acid mine drainage formation should be prevented uses dry cover method with encapsulation.

Keywords: Acid mine drainage; geochemical characterization; mineralogy; overburden.

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1. Introduction

The risk assessment related to overburden management plan is conducted as part of the mine closure planning, primarily based on geochemical characterization. In addition, material characterization is required but it is more important how and where the overburden material were placed.

Material characterization is to express the important risk of acid mine drainage such as PAF material then determine the specific of management method such as encapsulation, as a part of the placement strategy to minimize acid mine drainage risk. Actually, geochemical characterization method has no correlation with the field condition. Field conditions will bring up a variety of risks. For example the reaction rate increase exponentially, not linearly, with temperature. Furthermore, these risks will change with different placement techniques which vary on specific field. The common factor that controls risks level of actual risks include sulphur content, metal content, and mineralogy material, the physical properties of material (grain size and distribution, the rate of weathering), the structure of overburden due to the placement of the material (the path for the air and water movement), and climate [1]. Encapsulation system is a reliable method to prevent sulphide minerals exposure to the oxygen and water which is control acid mine drainage formation due to its low cost and less work done. In this method, the overburden material is classified into PAF, NAF, and uncertain.

Various studies to prevent acid mine drainage formation has been done however only focus on an evaluation of disposal construction and geochemical and mineralogical characterization [2] [3] [4] [5]. Alternative of encapsulation solutions is still focus on the conceptual design development [6].

Overburden material consists of 81% material NAF, and 19% material PAF. Rainfall record on site and its surrounding is about 401-500 mm/month. Overburden material has a potency to produce acid and also has high intensity of rainfall, it will potentially form acid mine drainage.

2 Objective

This paper aims to (a) characterize the geochemistry and mineralogy characterization of overburden rocks in the coal mine assosiated with rocks depositional environment which has potential of acid mine drainage (b) develop a prevention model of acid mine drainage formation and overburden management.

TABLE 1. Acid Mine Drainage Classification

Type	Rocks Type	Explanation
Type 1	Non Acid Forming (NAF)	NAG pH ≥ 4,5 and/or NAPP value is negative
Type 2	Potential Acid Forming Low Capacity (PAF LC)	NAG pH < 4,5; NAG value at pH 4,5 < 5 kg H_2SO_4 per ton, NAPP (0-10) kg H_2SO_4 per ton
Type 3	Potential Acid Forming Medium Capacity(PAF MC)	NAG < 4,5; NAG value at pH 4,5 ≥ kg H_2SO_4 per ton, NAPP ≥ 5 kg H_2SO_4 per ton, NAPP ≥10 kg H_2SO_4 per ton
Type 4	Potential Acid Forming High Capacity (PAF HC)	NAG < 4,5; paste pH < 4,5; NAG at pH 4,5 ≥ 5 kg H_2SO_4 per ton, NAPP > 10 kg H_2SO_4 per ton

The research method used is

3 Method and material

The research method use comparative descriptive through literature studies, fieldwork, and laboratory test to analyze data. Literature study on acid mine drainage has been done [7] [8]. Fieldwork is a stage for the retrieval of data related to the research. The data are cores and these are to analyze geochemical and mineralogy characterization of rocks.

The study is conducted at 42 drill holes (DH) and the distance between drill hole is 200 m. Core interval for non coal is 5 meters. Coaly shale with thickness > 20 cm uses independently sampling. Based on data, drill testing parameters as much as 975 samples, sample involves the determination of acid-forming potential and neutralizing potential, which is an important part of the overburden characterization.

First screening tool uses the result of geochemical analysis. Acid mine drainage includes [9] TS, ANC, paste pH, and NAG pH (pH 4.5 and pH 7). Second, the determination of PAF-NAF by calculating MPA and NAPP value. The last is classification and characterization into PAF-NAF groups. Table 1 shows the classification of acid mine drainage.

Subsequently, five samples from drilling data chosen and these are include one NAF rock samples, one sample of rock PAF LC, the rock samples PAF MC, and two samples of PAF HC. The objective take on five samples of different classes of acid mine drainage is to investigate the mineral composition of each sample uses XRD method. XRD analysis results in the form of a peak graph and then analyzed using software Match. Then the results will be compared between the geochemical test results and the percentage of minerals in overburden material.

4. Results

Geochemical analysis is obtained by the lowest paste pH is 2.9 in the DH25 at the depth of 112.4-113.1 m and the thickness is 0.7 m while the highest paste pH is 8.8 in the DH31 at the depth of 132.50-136.80 m with the thickness 4.3 m. One sample contains 0.02% total sulfur, eight samples contain 0.03% total sulfur, and the other has a total sulfur content range from 0.04 - 3.70% which is at claystone lithology in the southern of the mine coal. Most rocks are classified as 81% of NAF material; 5% of PAF LC material; 10% of PAF MC material; 1% of PAF HC material; and 3% of uncertain material. The ratio of PAF: NAF is 1: 5. Uncertain material will be dumped as PAF material in an attempt to minimize the risk of acid mine drainage formation at post-mining. When uncertain material calculated as the ratio of material PAF PAF: NAF is 1: 4.

Based on XRD analysis shows that DH1 is NAF material without the presence of sulphids, DH2 is PAF low capacity material with the presence of sulphids (chalcopyrite), DH3 is PAF medium capacity material with the presence of the pyrite and DH4 and DH5 is PAF high capacity material with the presence of the pyrite.

5. Discussions

Based on geochemical test, it indicates that range level of TS which varies, ie between 0.02%<TS<3.70%. TS content variation causes the variation of the NAG pH range about 2.0<pH<9.1. High sulphur concentration indicates that material has potential to produce acidity when in contact with the air. Essential observation from this assessment find that overburden on the upper level (represent the initial mining area) consists of oxidized rock, with a low sulphur percentage and it compares with the concentration of sulphur in the fresh rock at the deeper. From the perspective of overburden management, oxidized rocks characterization will be used to assist issues arising management from the zone of high sulphur content that found at fresh rock.

High concentration of sulphur indicates that the proportion of the sample has potential to produce acid upon contact with the air.

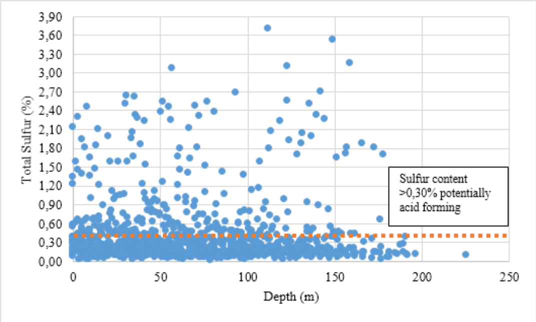

FIGURE 1. Total Sulfur Dsitribution by the Depth

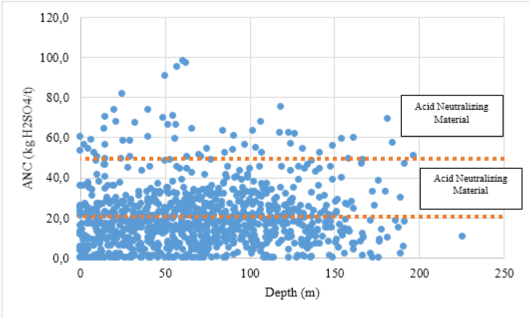

FIGURE 2. ANC Value by the Depth

TABLE 2. Result of Acid Mine Drainage Classification

Hole id	NAPP	NAG pH	NAPP vs NAG pH	Explanation
DH1	-51	7.7	NAF	NAG $\leq$ 4.5 and/or NAPP is negative
DH2	10	3.3	PAF LC	NAG < 4.5; NAPP (0-10) kg H_2SO_4 per ton
DH3	11	2.7	PAF MC	NAG < 4.5; NAPP $\geq$10 kg H_2SO_4 per ton
DH4	68	2.5	PAF HC	NAG < 4.5; paste pH < 4.5; NAPP > 10 kg H_2SO_4 per ton
DH5	102	2.4	PAF HC	NAG < 4.5;paste pH < 4.5; NAPP > 10 kg H_2SO_4 per ton

Even though, in the short-term response due to weathering reactions, indicate that the acid neutralizing acid produces is balance due to the availability of acid neutralizing minerals with sulphur concentration >0.30% potentially acid forming, and conversely, the concentration of sulphur <0.30% has no potential acid form is presented in Figure 1.

Overall ANC value assesses range from 0 to a maximum of 98 kg H_2SO_4/t. Material with ANC value between 20 kg H_2SO_4/t to 50 kg H_2SO_4/t or above and sulphide-S contains <0.3% and/or <0.5% is classified as acid neutralizing material, these circumstances will generally produce alkaline water [9] is presented in Figure 2. Table 2 shows the four acid mine drainage classifications. Each classification is determined by the NAG pH value and NAPP that NAF; ie. PAF LC; PAF MC, and PAF HC.

pH of NAF material has a normal pH which gives an early indication of NAF material is apart the consideration NAPP value or acid neutralizing potential is greater than the potential of acid-forming. Range of NAG pH value from 2.1-9.0 and NAPP value is about -96 kg H_2SO_4/t until 108 kg H_2SO_4/t. Generally, the highest NAG value has a correlation with the highest NAPP value. Figure 3 shows classification of NAPP >0 and NAG pH <4.5 is classified as PAF material and NAPP <0 and NAG pH >4.5 is classified as NAF material while samples with a apparent NAPP value >0 and NAG pH >4.5, or otherwise constitute uncertain data (UC), the geochemical classification plot. The material are in the uncertain zone indicates that data is in doubt.

The presence of neutralizing capacity is observed from the correlation between NAG pH and paste pH. Figure 4 indicates that sample has a NAG pH value is more than paste pH value means that most of the material have been oxidized but still has the potential neutralization material, primarily from carbonate minerals. A material contain reactive sulphide minerals (eg pyrite framboidal) would seem responsive to the paste pH test and provide a low pH value.

Based on the Figure 5, DH1 is in quadrant NAF (gold color). DH2 is in quadrant PAF (green). DH3 is in quadrant PAF (blue). DH4 is in quadrant PAF (red). DH5 is in quadrant PAF (black). Table 3 shows balance between acid generation (oxidation of minerals sulfide) and acid neutralizing processes (dissolution of alkaline carbonates, movement of bases that can be exchanged and the weathering of silicates) by ratio of PAF-NAF material NAPP value.

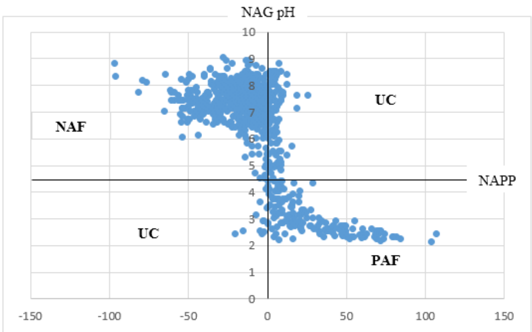

FIGURE 3. Plot of Geochemical Classification

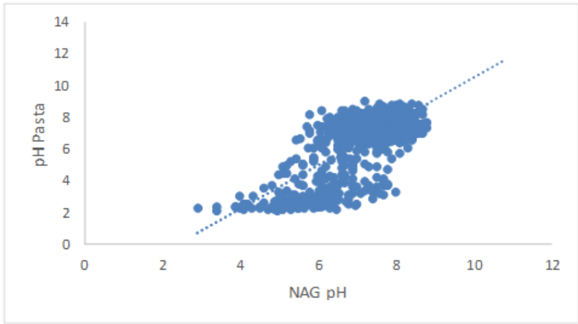

FIGURE 4. Paste pH vs NAG pH

TABLE 3. Result of XRD and Geochemical Analysis

Hole id	Mineral	Compound	Quantity (%)	pH Pasta	TS	ANC	MPA	NAPP	NAG-pH	NAG 4.5	NAG 7.0	Class	Lytho
DH1	Anorthite	$CaAl_2Si_2O_8$	44.5										
	Kaolinite	$Al_2Si_2O_5(OH)_4$	27.8										
	Mica	$AlFe_3H_2KSi_3O_{12}$	13	7.82	0.25	58.2	7.7	-51	7.7	0	0	NAF	Mudstone
	Albite	$NaAlSi_3O_8$	8.3										
	Quartz	SiO_2	6.3										
DH2	Kaolinite	$Al_2Si_2O_5(OH)_4$	71										
	Mica	$AlFe_3H_2KSi_3O_{12}$	25.7	6.45	0.35	1	10.7	10	3.3	3	10	PAF-LC	Mudstone
	Kalkopirit	$CuFeS_2$	3.2										
DH3	Kaolinite	$Al_2Si_2O_5(OH)_4$	40.1										
	Albite	$NaAlSi_3O_8$	17.4										
	Anorthite	$CaAl_2Si_2O_8$	15.9	5.2	1.32	29	40.4	11	2.7	21	36	PAF-MC	Mudstone
	Mica	$AlFe_3H_2KSi_3O_{12}$	15.9										
	Quartz	SiO_2	6.5										
	Pyrite	FeS_2	4.3										
DH4	Kaolinite	$Al_2Si_2O_5(OH)_4$	47.7										
	Mica	$AlFe_3H_2KSi_3O_{12}$	21.9										
	Quartz	SiO_2	10.4	4.8	2.94	22	90.0	68	2.5	65	87	PAF-HC	Mudstone
	Calcite	$CaCO_3$	9.1										
	Pyrite	FeS_2	8.3										
	Pyroxene	$MgSiO_3$	2.6										
DH5	Kaolinite	$Al_2Si_2O_5(OH)_4$	48.6										
	Mica	$AlFe_3H_2KSi_3O_{12}$	21.2										
	Quartz	SiO_2	11.1										
	Calcite	$CaCO_3$	9.3	4.7	3.32	0	101.7	102	2.4	69	96	PAF-HC	Mudstone
	Pyrite	FeS_2	7										
	Pyroxene	$MgSiO_3$	2.8										

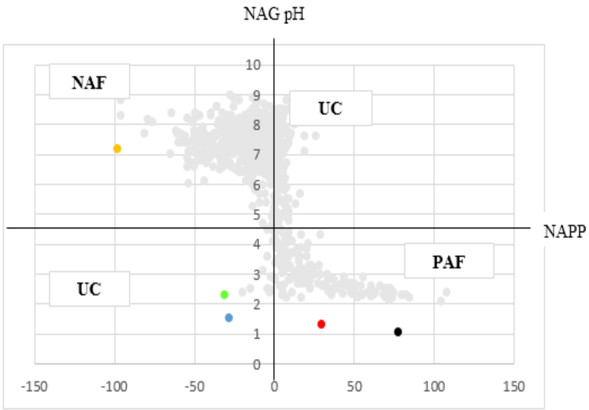

Figure 5. XRD Plot on Geochemical Classification

Pyrite has a majority control in acid production with low, medium, or high capacity. Variability in the nature and chemical composition/mineralogy of the rocks surrounding affected predominantly by four geological processes. These are ancient climate (paleoclimate) and ancient depositional environment (paleodepositional environment), and two of them are surface weathering and glaciaci [10].

Ancient depositional environment is an important control on the distribution of pyrite and carbonate. Based on research, rocks is deposited in brackish water environments. It generally has the potential acid rock drainage which is great because brackish environment provides the optimum conditions for the sulphuric pyrite formation which formed in brackish water and iron from the surrounding area. In addition, calcareous mineral content is low. Freshwater depositional environment usually do not generate acid water. While rocks deposited in marine environments produce water quality varies. Based on the research has had a variation of depositional environments both vertically and laterally and is influenced by the inherent distribution of pyrite and carbonate will result in the formation of acidic water is different.

Research area is a part of Barito Basin comprise South Kalimantan Indonesia. At this basin, North Barito Basin is the edges of tertiery depositional at Barito Basin with the formation of coal-bearing including Tanjung Formation, Batu Ayau Formation, and Warukin Formation. Research study located on Warukin Formation at middle Miosen characterized by fine until medium grain of quartz sandstone, insert by carbonaceous claystone, and carbonaceous siltstone. Rocks depositional of Warukin Formation be held in an early of tertiery sea shrinkage (regression). Warukin Formation comprise by turn of quartz sandstone, claystone, shale, and limestone. At calcareous sandstone and claystone is found an iron concretion.

Depositional environment of the sea shrinkage affects claystone as a material of acid mine drainage formation. This is due to processes occurring in the environment is influenced by the presence of sea water as a source of sulphate and sediment as a source of iron. Sulphate reaction, Fe element, and bacteria aid in reducing will form sulphide minerals in carbonaceous claystone which makes this material has a sulphur content and great of H_2SO_4 as an acid producer.

Neutralizing minerals is dominated by aluminosilicate, plagioclase and mica mineral. Neutralizing minerals play an important role in the sulphide oxidation to provide a buffer for the acid produced. If the amount of minerals in rocks enough to compensate for the potential for the production of acid in the material, acid mine drainage will not be formed because of the neutralization process, as long as has a equal mineral rate reaction. Generally carbonate minerals with enough composition provide a neutralizing capacity and swiftly reaction to follow the rate of acid production from sulphide oxidation. In comparison, insoluble silicate minerals swiftly enough to prevent the acid formation in various situations. Mafic rocks/base composed of minerals such as plagioclase, pyroxene, olivine and amphibole give neutralization as same as silicate minerals that consist of alkali feldspar, quartz and mica minerals [11]. On the other hand, quartz has no acid neutralization potential, and this is mainly because of this physical property, hardness scale of 7 on the Mohs scale. The presence of clay minerals, in small amounts control the permeability and water retention characteristics of the porous medium, and is very sensitive to pore thus restricting water flow and oxygen to and at the disposal of the pyrite oxidation process.

In accordance with Bowen Reaction Series, the kaolinite, mica and quartz are acid/felsic mineral which have high levels of resistance so that the longer soluble in acid produced by the iron oxidation compared with calcite (carbonate minerals). Based on the analysis of geochemical characterization and mineral control on acid mine drainage formation, neutralizing minerals is naturally incapable to compensate the sulphide minerals oxidation reaction rate.

NAF material is dominated by claystone but the neutralizer material is in low capacity consists of silica, plagioclase, and aluminosilicate mineral. Thus acid mine drainage formation should be prevented uses dry cover method with encapsulation.

Framing disposal (Figure 6) is as follows:

- Dumping the NAF material and place at the lowest position to the first level disposal to a minimum height of 12 m.
- Then for the second level, dumping NAF material placed on the side of the frame disposal up to a height of 12 m and 74 m of wide frame.
- Sloping frame disposal adjusted to the design slope. Material top/subsoil in the disposal slope with a thickness of 0.30 m.
- Subsequently dumping the PAF material above the NAF material on the second bench to a height of 12 m with a distance of 50 m and the thickness of impermeable layer is 3 m.

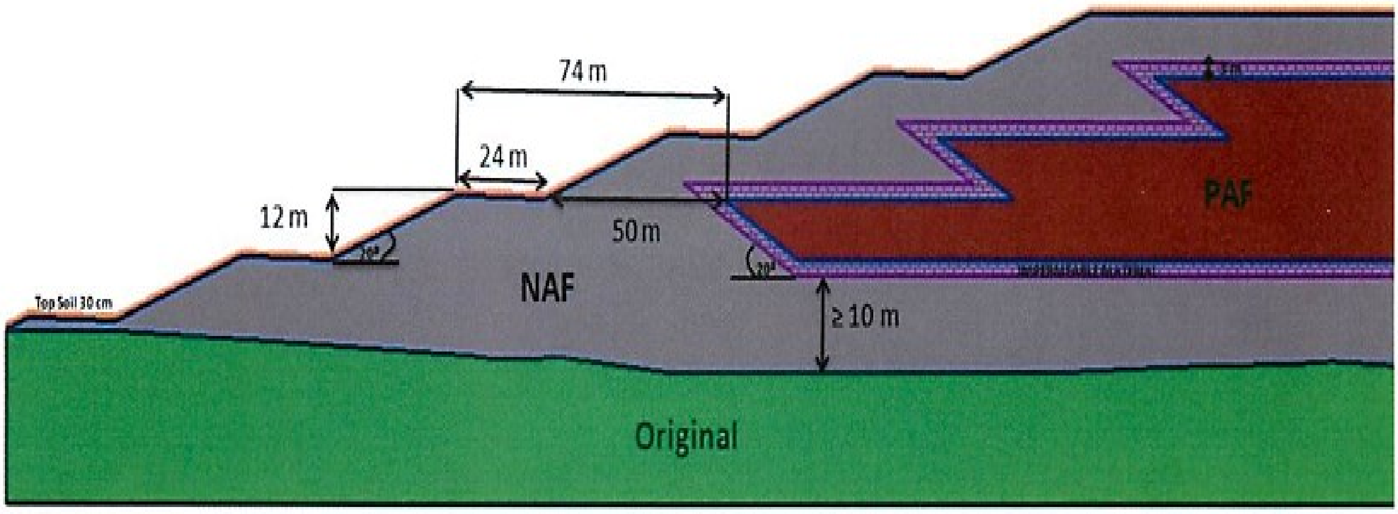

FIGURE 6. Cross Section of Disposal Design

6. Conclusions

On the coal mine activity, overburden removal accelerates the process of acid mine drainage formation due to exposure of sulphids and exposed to the air and water. There is a correlation between the mineral content and depositional environment of rocks. NAF material comprise silica, plagioclase, and aluminosilicate. These are incapable to neutralize acid material. Ratio of NAPP value between PAF LC-MC and NAF material is 1:5, it shows that neutral material is able to compensate the potency of acid formation. In contrary, ratio of NAPP value between PAF HC and NAF material shows that neutral material incapable to neutralize acid formation and it raises the material to produce acid mine drainage. In the other hand, percentage of NAF material is 81%; PAF LC is 5%; PAF MC is 10%; PAF HC is 1%; and uncertain material is 3%. Ratio of PAF:NAF material is 1:5. At the time when uncertain material is calculated as PAF material the ratio of PAF:NAF material is 1:4. Based on the mineralogy, the neutral mineral is naturally incapable to neutralize acid mine drainage however by the volume of PAF-NAF material, NAF material is sufficient to cover PAF material when dumped at disposal. Then preventive measures from acid mine drainage formation by dry cover method uses encapsulation.

REFERENCES

[1] Pearce, S., Lehane, S., Pearce, J., 2016, Waste Material Placement Options During Construction and Closure Risk Reduction - Quantifying the How, the Why and the How Much, Perth: Australian Centre for Geomechanics.
[2] Kusuma, G.J., Shimada, H., Sasaoka, T., Matsui, K., Nugraha, C., Gautama, R.S., Sulistianto, B., 2012 Physical and Geochemical Characteristics of Coal Mine Overburden Dump Related to Acid Mine Drainage Generation, *Memoirs of the Faculty of Engineering, Kyushu University*, Vol. 72, No. 2, hal. 23–38.
[3]Matsumoto, S., Shimada, H., Sasaoka, T., Kusuma, G.J., Gautama, R.S., 2016, Construction of Dry Cover System for Prevention of Acid Mine Drainage at Mine Waste Dump in Open Cast Coal Mines, Indonesia, Journal of Environmental Protection, 7, hal. 160-169.
[4] Novhe, N.O., Yibas, B., Netshitungulwana, R., Lusunzi, R., 2014, *Geochemical and Mineralogical Characterization of Mine Residue Deposits in the Komati/Crocodile Catchment, South Africa: an Assessment for Acid/Alkaline Mine Drainage*, Xuzhou: China University of Mining and Technology Press.
[5] Olds, W.E., Bird, B., Pearce, J.I., Sinclair, E., Orr, M., Weber, P.A., 2015, Geochemical Classification of Waste Rock Using Process Flow Diagrams, AusIMM New Zealand Branch Annual Conference, p. 307-318.
[6] Barritt, R., Scott, P., Taylor, I., 2016, Managing the Waste Rock Design – Can We Build A Waste Rock Dump that Works?, Perth: Australian Center for Geomechanics.
[7] Mackenzie, S., de Kever, N., Smedley, E., Gregory, S., 2016, Mine Waste characterisation – Complexities with Assessing the Physical Properties of Rock, Perth: Australian Center for Geomechanics
[8] Weber, P.A., Olds, W.E., Crombie, F.H., Thomas, D.G., Pope, J., Pizey, M.H., 2013, Acid Minae Drainage Investigations at the Reddale Coal Mine, Reefton, New Zealand, AusIMM New Zealand Branch Annual Conference, p.535-545.
[9] Sobek, A.A., Schuller, W.A., Freeman, J.R., dan Smith, R.M., 1978, *Field Laboratory* Methods *Applicable to Overburden and Minesoils*. Ohio: U.S. Environmental Protection Agency.
[10] Brady, K., Hornberger, R., chisholm, W., and Sames, G., 1998, Prediction of Water Quality at Surface Coal Mines Chapter 2: How Geology Affects Mine Drainage Prediction, West Virginia: The National Mine Land Reclamation Center.
[11] Eary, L. E. and Williamson, M.A., 2006, Simulations of the Neutralizing Capacity of Silicate Rocks in Acid Mine Drainage Environments, 7th International Conference on Acid Rock Drainage (ICARD), hal. 564 – 577.