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## Physical and Geochemical Characteristics of Coal Mine Overburden Dump Related to Acid Mine Drainage Generation

by

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### Abstract

The presence of water and oxygen are some of the important factors influencing the oxidation rate of sulfide minerals within overburden dumps. In overburden dumps, the availability of water and oxygen is strongly controlled by the physical structure of the dump, as well as the surface climate and geochemical reaction within the dump.

In this study, a series of field investigations, physical and geochemical laboratory characterization were conducted in order to evaluate internal physical structure and geochemical characteristics of coal mine overburden dumps. The study found that a multi bench structure consisting of 10 m height of inter-fingered slope layer is formed as the effect of the end dumping technique. In addition, overburden material was characterized to have high clay content and low durable characteristic when interact with water. These characteristics couple with mining equipment traffic has result in a compacted layer on the surface of each bench lift which then controls the groundwater flow path within the dumps. Moreover, the geochemical characteristics were random, alternating among potentially acid forming and non acid forming materials within the inter-fingered layer. Those alternate geochemical characteristics may control acidification-neutralization reaction of infiltrated water, precipitation of secondary mineral and determines the quality of the overburden dump drainage, subsequently. The internal structure formed and the spatial heterogeneity of geochemical characteristics in overburden dump controls the acid drainage inhibition process within the dumps.

**Keywords :** Coal mine, Overburden dump, Internal structure, Acid mine drainage

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## 1. Introduction

The main operation of surface coal mining is basically removal of topsoil and overburden in order to extract the coal. If the overburden rock contains a significant amount of reactive sulfide mineral rather than alkali mineral, severe acid mine drainage (AMD) is likely to occur when it is exposed and reacts with oxygen and water.

At mine sites, considering the fact that overburden dumps are the place where the ready oxidized material is stored for a long period, care should be paid to mitigate AMD generation. The geochemical characteristics and volume of AMD leachate emanating from sulfidic overburden dumps are largely influenced by the inherent geochemical properties of the overburden materials and also the physical conditions within overburden dumps. AMD development in overburden dumps occurs via complex physical and chemical weathering reactions. The different rates of the various mineral weathering reactions within the overburden coupled with the local climate conditions (i.e. interval of rainfall event, temperature) may cause temporal changes to the drainage chemistry<sup>1-2)</sup>.

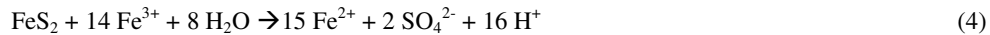
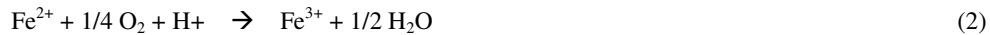
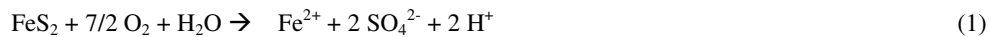
Several studies have been conducted in order to recognize the heterogeneity of overburden dumps with several purposes, such as those focusing on the field monitoring<sup>3,4)</sup>, large-scale testings<sup>5)</sup> and numerical methods<sup>6,7)</sup>. Azam et al. (2006), based on the result of both field investigation and laboratory characterization, proposed a generalized physical model of an unsaturated overburden dump of the Golden Sunlight Mine in Montana, USA<sup>4)</sup>. Most of those studies have consistently postulated that the spatial variability of material contributes to the presence of preferential water flow paths in the dump.

The internal structure of overburden dumps is influenced by several factors, including: (1) parent geology of rock (material properties and mineral composition); (2) mining operation (blasting and sequencing); (3) construction practice (hauling and dumping); and (4) climatic conditions (temperature and rainfall).

In this paper, the practice of overburden dumping in a coal mine in Indonesia is described and the formed-internal structures, due to the operation as well as physical and geochemical conditions related to the acid mine drainage generation, are discussed.

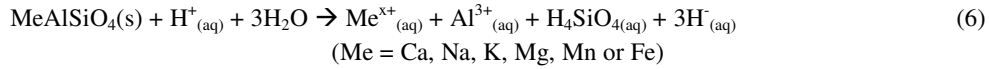
## 2. Chemistry of Acid Mine Drainage Generation

In the coal bearing rock, pyrite is known as the most common reactive sulfide mineral which can be oxidized when contacted with air and water by a series of reactions as shown below<sup>8)</sup>:



In many conditions, as the effect of low rate conversion of ferrous iron to ferric iron at pH values below 5 and under abiotic conditions, Eq. (2) may act as the rate-limiting step in pyrite oxidation. The secondary ferric hydroxide may precipitate (Eq. (3)) to form coating in the pyrite surface, hence lowering the reaction rate<sup>9)</sup>.

Carbonates minerals, such as calcite ( $\text{CaCO}_3$ ) and dolomite ( $\text{CaMg}(\text{CO}_3)_2$ ), which may co-exist in sulfide mineral containing rock, can neutralize the acidity generated by the oxidation of pyrite (Eq. (5)) as well as the silicates mineral (Eq. (6)), although it has a slower reaction rate than carbonates<sup>10</sup>.



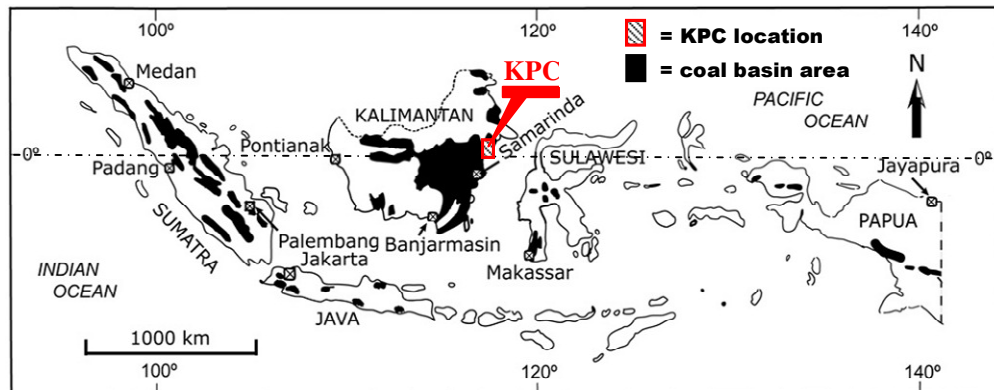
The presence or absence of carbonate and silicate minerals in the rock sample/materials is extremely important in AMD generation. If the amount of these minerals in the rock is sufficient to offset the acid producing potential of the material, acid drainage will not eventuate due to the neutralization process as long as the reaction rates of the respective materials are similar. Furthermore, these minerals would inhibit pyrite oxidation by buffering the pH at a level where ferric iron may precipitates as ferric hydroxide rather than oxidizing additional pyrite (Eq. (3)).

### 3. Site Information

#### 3.1 General overview

PT Kaltim Prima Coal (KPC) is the biggest coal mine company in Indonesia which operates in Sangatta-East Kalimantan Province, Indonesia (**Fig. 1**). The mine site has a tropical climate with an average seasonal rainfall varying from 1.6 to 2.5 meters annually, and an average temperature varying from 26 to 32° C. Geologically, the mine site is located at the northeast part of the Kutei tertiary sedimentary basin, which is one of the most significant hydrocarbon basins in Indonesia. The mining operation consists of two mining areas, Sengata and Bengalon, in which several pits are operated in parallel. In 2010, the total overburden removal at KPC's was 460,278 kilo bank cubic meter (kbcm), and coal production was 39,302 kt, which means an average of 11.71 bcm of overburden is removed for each ton of coal mined.

The geological features in this area are characterized by a folding structure with a northeast-southwest trending axis and a dome structure, called Pinang dome, as result of intrusion, within the western part of the mining area. The pressure and temperature exerted by the intrusion elevated the coal rank above its natural age.



**Fig. 1** Location of KPC mine site.

The coal resources mined are from Miocene of the Balikpapan Formation which consists of a sequence of alternating mudstone, siltstone, sandstone and coal seams, and is dominated by fine-grained lithology. Hitherto, there are 112 coal seams have been identified, of which 41 numbers are defined as major coal seams which have become the mining target. Coal seam thickness varies from less than 0.5 m up to more than 20 m, with most in the range of 2 – 6 m. Dips normally vary between 3° and 20°, except in some syncline flanks which could reach 40°. Thickness of interburden varies in 30 – 40 m thick and consists of an alternating lithological sequence.

In terms of the strength of coal bearing rocks, Kramadibrata et al.<sup>11)</sup> and Nugraha et al.<sup>12)</sup> reported that, generally, the coal bearing strata in this area can be classified as soft rock since the uniaxial compressive strength (UCS) is less than 20 MPa. Moreover, most of these rocks are susceptible to physical and chemical weathering and deteriorate in mechanical strength due to slaking and swelling behavior when contacted with water.

### 3.2 Mine operation

An open pit coal mining method is implemented at all mine sites of KPC using shovel and truck. The selection of combination of shovel and truck equipment is based on the specific site conditions that the multi coal seams and geological conditions are varied and complex which require flexible methods and tools that are easy to maneuver. Several pits and multi coal seams are excavated and mined simultaneously in order to perform coal blending to meet required coal product quality.

The mining stages are like other open-pit mining systems, after land clearing and top soil and overburden/interburden removal must be done in order to recover the coal reserve underneath. The shovel capacity used to mine overburden varies between 27 to 33 m<sup>3</sup> and haul dump trucks with a payload capacity range 80 – 360 t. Furthermore, controlled blasting with the ANFO base explosive is performed for excavating the overburden/interburden and extracting the coal seams which have a minimum thickness of 2 m in order to increase the productivity of mining equipment

Considering the size of the shovel being used, which has a bucket width range 2 – 4 m, the grain size distribution of transported and dumped materials varies from clay size (origin of mudstone particle size) up to 4 m of boulder-sized.

Associated with the efforts to prevent acid mine drainage generation in the overburden dumping area, KPC has developed a standard procedure that includes characterization, spatial geochemical modeling, verification and a dumping system of overburden. The spatial geochemical data, which were developed based on geochemical characterization of rock samples, are then used as a guide to handle and dispose each overburden in accordance with its geochemical characteristics. Details about this procedure can be seen in some of the following references<sup>13-14)</sup>.

### 3.3 Overburden dump construction

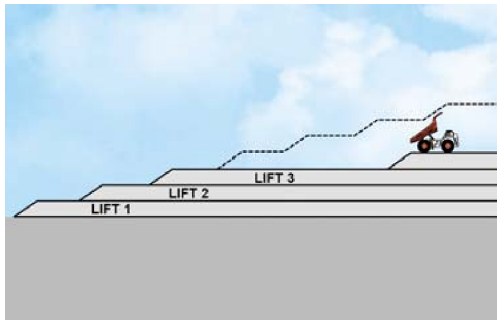
The overburden dumping area is largely expected to be built within the pit footprint as part of the backfilling program as much as possible. However, at the beginning phase of open pit mining, the placement of the overburden dump outside the pit becomes inevitable, until the period when there is sufficient space to construct the in-pit overburden dump without disturbing operation of safe mining work.

Based on economic reasons, the overburden hauling distances vary between 500 – 1,500 m. Normally, overburden dumping is conducted by a bottom-up dumping method, in a series of lifts (**Fig. 2**). The design parameters of overburden dumping are of 10 m bench height with a slope angle following the angle of repose of dumping material. Total lift is determined based on

geotechnical considerations. Dumping is initially started from the bottom, where dump trucks tip overburden to the outer side of the pile. Gravitationally, the overburden material slides down to some extent where the particle motion is limited due to the smaller slope-angle than the angle of repose of the material. The dumping location of each truck is different, thus allowing the occurrence of an inter-fingered bedding system in each dumping event (**Fig. 3**).

This method has several advantages for some aspects including:

- All layers of the dump get at least some truck compaction, improving stability.
- Rehabilitation of waste dump face can be conducted immediately.
- If the dump construction is interrupted, the landform is close to a stable configuration and can be stabilized or rehabilitated with little effect.



**Fig. 2** Bottom up dumping method.



**Fig. 3** Dumping site overview.

#### 4. Internal Structure of Coal Overburden Dump

In this section, an investigation of an exposed overburden dump which was conducted at the KPC coal mine is described. The in-pit overburden dump at the Bendili pit, which was constructed more than 5 years, was chosen. The Bendili in-pit dump is an uncompleted overburden dump construction which was re-handled due to expansion of coal production capacity. This study was conducted in order to investigate the internal structure of coal overburden dump as a result of the current practice of dumping method. Evaluation the possible related-mechanism of the acid mine drainage generation from sulfide containing overburden dumps is also discussed.

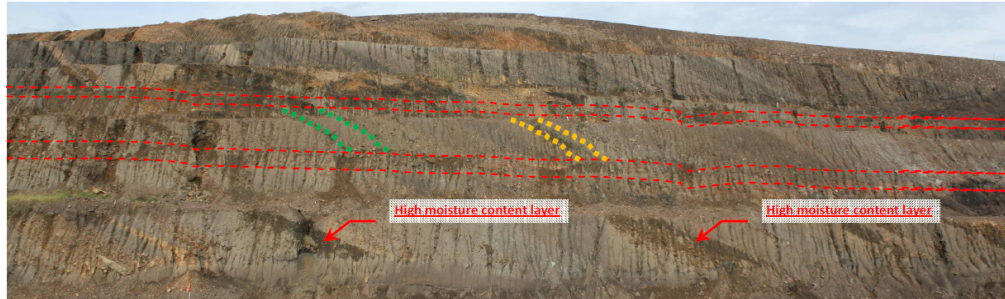
The investigation was conducted by both a visual method and the results of laboratory tests in regards to the physical conditions and the geochemical characteristics related to the potential for acid drainage generation.

##### 4.1 Field investigation

The exposed face of the Bendili overburden dump, which was re-handled due to the expansion of coal production capacity, is shown in **Fig. 4**. Visually, it is revealed that the internal structure of the overburden dump is controlled by the dumping technique that was involved in the mining method.

Compacted horizontal layers as thick as 0.3 to 1 m were found at intervals of around 10 m high benches, indicating the platforms supporting the heavy mining equipment trafficking result in particle size degradation. The inclined layer at the angle of repose ( $30^\circ - 35^\circ$ ), within a thickness range of 0.4 to 1.5 m, as a result of gravity sorting and internal mixing, was observed below the platform. The multiple inclined layers occurrences were distinguishable because of variation in

lithology, grain-size, texture and color of the overburden. The internal structures obviously controlled the flows of infiltrated water due to the different permeability characteristics of each inclined layer.



**Fig. 4** Front view of the exposed face of Bendili overburden dump.

Fresh rock material suffered from deterioration as a result of mechanical force during the dumping process and subsequent weathering. The weathering occurrence was a combination of physical and chemical weathering those involved on the reaction between the contained minerals with water (**Fig. 5a**). However, difference in degree of weathering occurred due to various slakes durability characteristics of overburden. Less durable rock, such as mudstone, deteriorates more quickly compared to sandstone or siltstone and subsequently produces smaller grain size<sup>20</sup>. Furthermore, the existence of this small grain size particle coupled with the swelling characteristic of containing clay mineral was revealed to be responsible for filling the inter-particle gap of boulder size (**Fig. 5b**) which may decrease the permeability of that layer.

Moreover, chemical weathering had visibly occurred, as indicated by the brown-yellow color within the overburden. This color is the evidence of the existence of a secondary mineral precipitate as a result of sulfide oxidation or carbonate dissolution. The precipitate may coat or even encapsulate the acid producing or buffering mineral while making the mineral less susceptible to continued weathering and dissolution. Precipitated minerals may include hydroxides (e.g. goethite, ferrihydrite, lepidocrocite), sulfates (e.g. jarosites, gypsum, melanterite), or sulfides (e.g. covellite), which fill the inter-granular pores and cement the overburden matrices<sup>15</sup>.



a) The weathering occurrence.

b) Filling of the inter-particle gap.

**Fig. 5** The exposed face of the overburden dump.

In order to evaluate more quantitatively, sampling of overburden material was then conducted in the selected bench. Total nine samples of as much as 30 kg each, were taken randomly at each

bench on the three benches (three sampling points of each bench) chosen (Fig. 6 and Fig. 7). These samples were then sent to the laboratory for physical and geochemical analysis.

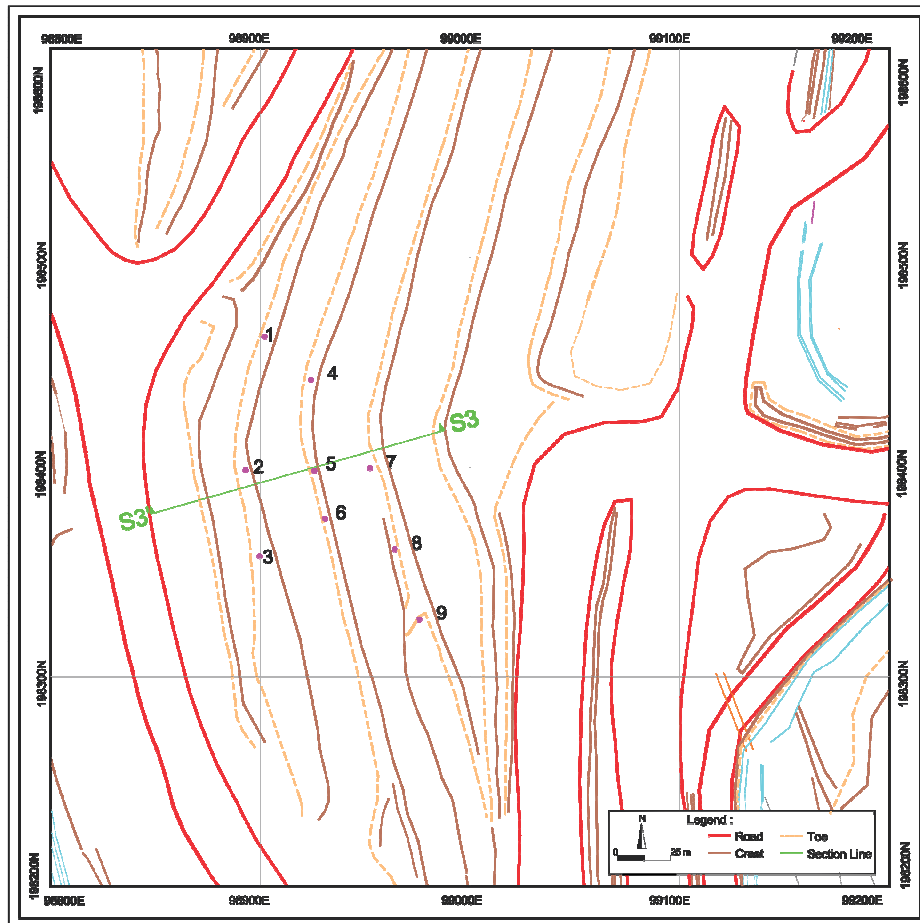


Fig. 6 Plan view of sampling locations.

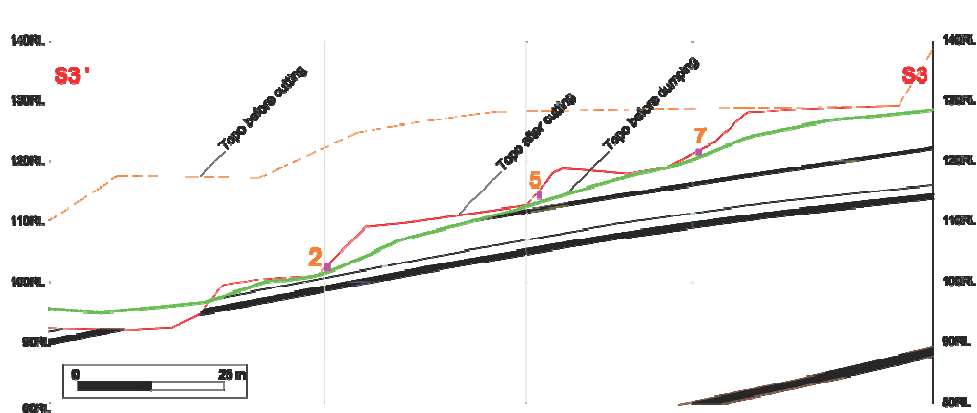
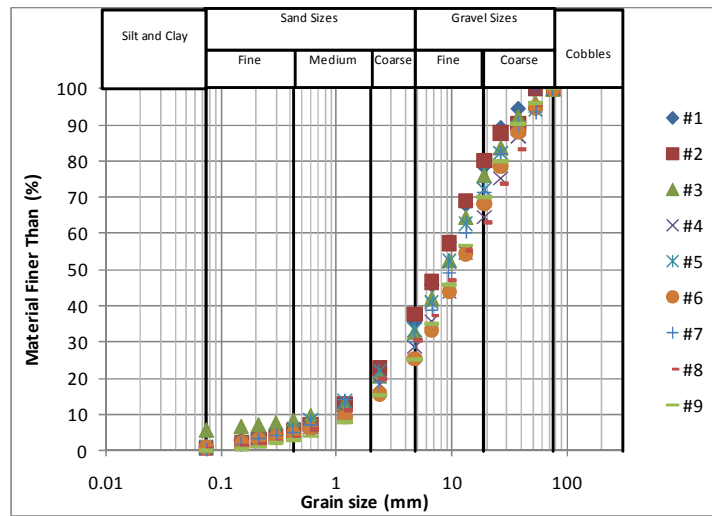


Fig. 7 Section view of sampling points.

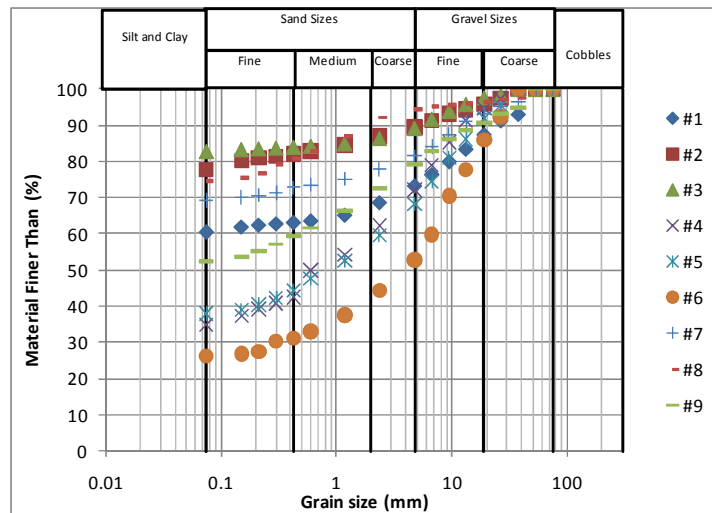


**4.2 Physical characteristics**

Physical evaluation of samples was limited to the samples which had a size less than 100 mm due to equipment compatibility limitation. **Figure 8** shows the grain size distribution of the overburden samples. All nine samples showed no significant grain size differences in the unwashed sieving (**Fig. 8a**), while a difference was revealed in the washed samples (**Fig. 8b**). For the unwashed samples, the  $D_{60}$  ranged from 10 to 16 mm, while that for the  $D_{60}$  for the washed sample ranged from 0.02 – 6 mm. This condition may indicate that particle size degradation rates were similar for overburden from all sampling locations. However, the potential of further particle size degradation was controlled mainly by the nature of the parent rock type and strength (e.g. sandstone, siltstone or mudstone).



a) Unwashed sieving.



b) Washed sieving.

**Fig. 8** Grain size distribution of overburden materials.



The liquid limit (LL) value, the water content at which a soil changes from plastic to liquid behavior, ranged from 32.7 to 41.6%, whereas the plastic limit (PL) value ranged from 13.9 to 20.2%. Hence, the plasticity index (PI) ranged 17.4 – 25.8%. These values are suitable with the recommended value of LL and PI for material used as low permeable liner >20% and >10%, respectively<sup>17-18)</sup>. Moreover, based on correlation between a plasticity index value, ranging from 13.9 to 20.2%, and a liquid limit, ranging from 32.7 to 41.6%, and based on the criteria of the unified soil classification system (USCS), these samples can be classified as “CL” which means “inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, and lean clays” (Fig. 9).

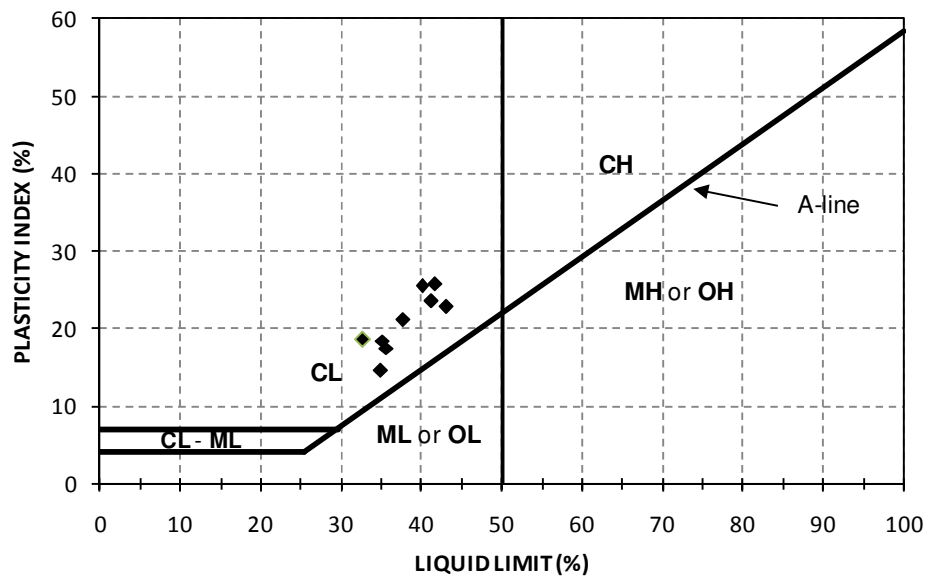


Fig. 9 Plasticity chart of rock samples.

#### 4.3 Mineralogy and geochemical characteristics

The characteristics of mineralogy and geochemistry of overburden samples are important to understand the AMD generation process. A mineralogical study was conducted using a Rigaku Rint 2000 X-Ray Diffractometer (XRD). The geochemical evaluations consisted of several common static tests to determine the acid generation potential of rock samples being: paste pH, paste EC, an Acid Base Accounting (ABA) test by Sobek et al.<sup>19)</sup>, and a Net Acid Generation (NAG) test by Miller et al.<sup>20)</sup>. ABA is calculated by subtraction of maximum potential acidity (MPA) by Acid Neutralizing Capacity (ANC) which results in the Net Acid Producing Potential (NAPP) value. The MPA was calculated based on the total sulfur content that is obtained from XRF analysis using a Rigaku RIX 3100 X-ray fluorescence spectrometer, assuming that all sulfur types were in the form of sulfide.

Figure 10 shows the XRD spectra of the nine selected samples. It is indicated that quartz and clay minerals such as kaolinite, illite, and illite-montmorillonite are the dominant ones in each samples. Siderite was detected in samples #1, #3 and #7, while Pyrite was detected only at sample points #5, #8 and #9. Secondary minerals such as gypsum were detected in samples #1, #2 and #9.

The geochemical characteristics of samples taken in the Bendili panel 3 in-pit overburden dumps are shown in Table 3. Among those nine samples, six samples had a high paste pH (>4.5)

and three samples had a low paste pH value (<2.5). Paste pH values had a good reverse trending correlation with the paste EC which ranged from 0.3 – 4.7 mS/cm. When the paste pH was low, the paste EC value was high due to the higher dissolved free ion. Total sulfur content of the sample ranged from 0.2 to almost 4 % w/w, which may raise acidity as much as 7 to 118 kg H<sub>2</sub>SO<sub>4</sub>/ton rock, respectively. Otherwise, the ANC values were less than 27 kg H<sub>2</sub>SO<sub>4</sub>/ton rock, and some samples had zero value of ANC, which means those samples had no capacity to neutralize the acid. The NAG pH reflects the final balanced condition of acid and base content, and showed a distinguishable result for each sample. Three samples had a low NAG pH (<2.5), four samples were medium (3 < pH < 4.5), and the last two samples had almost a neutral pH. The NAG value expresses the amount of base needed to increase the pH solution to a certain targeted pH. The NAG value varied from 0 kg H<sub>2</sub>SO<sub>4</sub>/ton rock up to 92.51 kg H<sub>2</sub>SO<sub>4</sub>/ton rock for pH 7 and has reverse correlation to the NAG pH value.

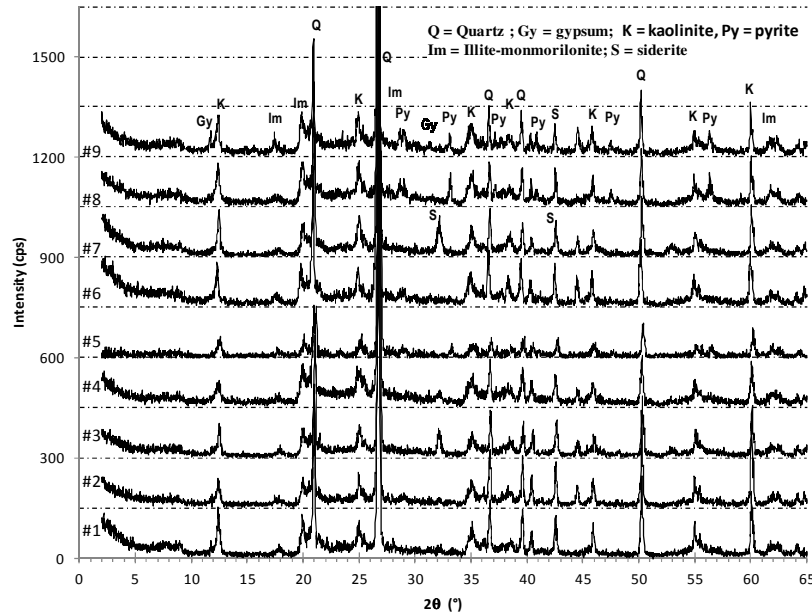


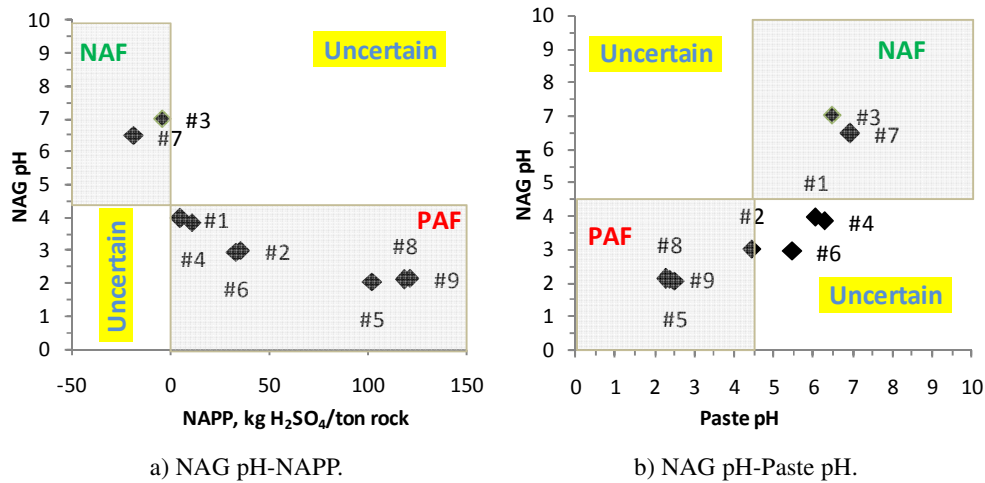
Fig. 10 X-ray diffraction pattern of overburden dump samples.

Table 3 Acid-base accounting of overburden dump samples.

	Paste pH	Paste EC <sup>*)</sup>	Total Sulfur <sup>**)</sup>	MPA <sup>***)</sup>	ANC <sup>***)</sup>	NAPP <sup>***)</sup>	NAG pH	NAG <sup>***)</sup>	
								pH=4.5	pH=7.0
#1	6.06	0.99	0.380	11.6	6.61	5.0	3.98	3.92	9.8
#2	4.44	1.07	1.175	36.0	0	36.0	3.01	5.68	14.11
#3	6.47	0.71	0.223	6.8	11.03	-4.2	7.02	0	0
#4	6.29	0.58	0.423	12.9	1.47	11.5	3.86	1.37	1.76
#5	2.50	3.20	3.334	102.0	0	102.0	2.04	60.76	68.4
#6	5.46	1.03	1.108	33.9	0.74	33.2	2.95	7.45	10.19
#7	6.93	0.49	0.271	8.3	26.95	-18.7	6.48	0	0.39
#8	2.36	3.40	3.879	118.7	0	118.7	2.13	76.44	92.51
#9	2.27	4.70	3.972	121.5	0	121.5	2.15	59.39	71.34

Note : \*) : in mS/cm ; \*\*) : % (w/w) ; \*\*\*) : in kg H<sub>2</sub>SO<sub>4</sub>/ton rock;

Based on these geochemical static tests, samples were then classified as acid producing acid or not. According to classification based on NAG pH and NAPP values, 7 samples were classified as potentially acid forming (PAF) materials and two samples were classified as non acid forming (NAF) materials (see **Fig. 11a**). As a comparison, the relation between NAG pH and paste pH was evaluated and the result showed that three samples were classified as PAF, two samples as NAF, and the rest were uncertain (**Fig. 11b**). Three samples classified as uncertain were due to the quite high paste pH (>4.5) while the NAG pH was less than 4.5. The low capacity to generate acid and the available inherent neutralizing capacity which has enough buffering capability to maintain the pH remain high are some of possibilities regarding the uncertainty condition<sup>12, 21</sup>).



**Fig. 11** Geochemical classifications.

The geochemical condition of bulk sampled materials showed that the acid and neutralization potential of the single samples relatively remained unchanged though chemical weathering (i.e., sulfide oxidation) occurring. It is supposed that the effects of preferential flow of infiltrated water make oxidation product remain un-flushed; hence the oxidation reaction and product transport is limited. The existence of ANC in some of the samples, although the amounts were smaller than the acid potential generation, may take an important part in the neutralization process in overburden dumps.

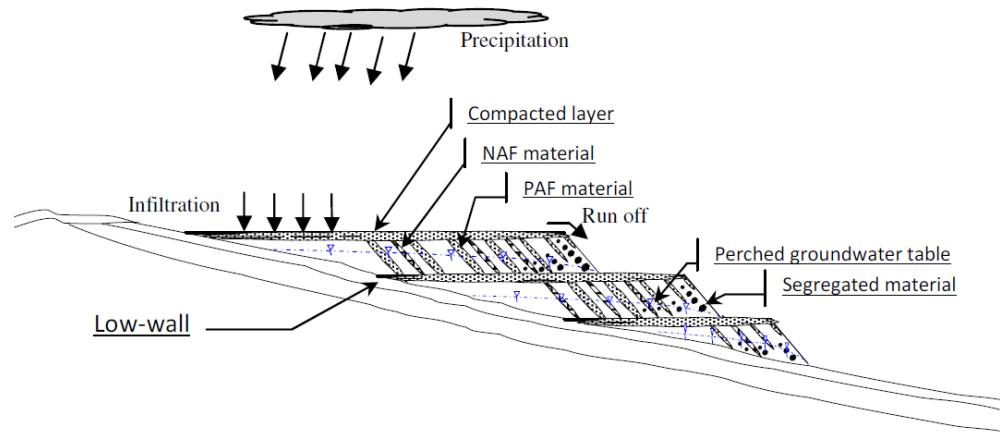
## 5. Model of internal structure of coal overburden dumps and its implications on acid mine drainage generation

### 5.1 Model of internal structure of coal overburden dumps

**Figure 12** shows a physical model to describe the internal structure of an overburden dump in the coal mine which is influenced by local conditions. Due to lift by lift construction as high as 10 m height, the overburden dump was bounded by a natural morphologic surface (i.e. low-wall slope) along which the deposited material developed an angle of repose face (30° – 35°), and a traffic surface at the top of each lift.

The presence of inter-fingered dipping beds was related to gravity sorting of the deposited material which may exhibit an extensive grain-size variation<sup>5</sup>. Due to dumping operation in which

overburden was dumped from various position in the bench tip of the pile, the fine grain portion of one load may mix with the coarse fraction of a previous load or vice versa. However, the distinct rumble zone as the result of material segregation during end dumping at the base of the dump cannot be observed as clearly as in the hard rock type overburden dump.



**Fig. 12** Conceptual model of the bendili overburden dump.

The spatial variability of the overburden dump, in addition to the effect of material segregation and inter-fingered bedding due to end dumping and mine sequencing, was also affected by the natural physical properties as well as geochemical properties of the materials and further weathering processes. The largely low strength of sedimentary soft rock experienced both physical and chemical weathering due to either the dumping operation, the fluctuating temperature or the high rainfall in the tropical climate. This condition resulted in the boulder size of as big as 1 m and rumble zone was rarely found and observed clearly. Furthermore, the interrelated physical processes such as abrasion, particle crushing, growth of mineral and slaking due to volume change of clay minerals as well as chemical processes including dissolution, oxidation, hydrolysis, diffusion and precipitation, imparted an extensive material heterogeneity within the overburden dump<sup>5</sup>.

Hydrogeological condition in the overburden was governed by the internal structure of overburden dumps. The compacted horizontal layer as the effect of heavy equipment traffic on the surface of each lift became the main infiltration barrier structure which controlled the vertical percolation of groundwater. Hence, a bench scale groundwater system may occur in the each bench lift. On the other hand, the inclined layer below the platform becomes the principle pathway of groundwater movement in the each bench lift in the form of an alternating inclined layer with different physical and geochemical conditions due to the effect of dumping operation.

## 5.2 Implication to acid mine drainage generation

Through this study, the internal structure of coal mine overburden dumps was successfully investigated. It was revealed that the internal structure is determined by several factors such as dumping and mining method as well as the physical and geochemical nature of the overburden. These factors simultaneously produce a heterogeneous internal structure of overburden dump. This finding is important as basic information, which is needed to get a better understanding of acid generation as well as the neutralization or inhibition mechanisms occurring within the dump.

Physically, the multi lifts overburden dumping construction contributes multi compacted layers as the result of heavy equipment traffic during construction. Though the degree of compaction may be far from the optimum, considering the relatively short interval of rainfall and the thickness of the compacted layer, which can reach more than 30 cm, this multi layer may play an important role in minimizing water infiltration and oxygen diffusion. In addition, the high proportion of clay fraction of coal bearing rock, coupled with the low strength and durability against weathering, may result in a self-developing cover layer. Moreover, an alternating inclined layer, which has different physical characteristics concordant to the absence of the rumble basal layer, also limits the occurrence of the air diffusion/convection into the overburden dump body.

Considering the spatial heterogeneity of geochemical characteristics in the coal bearing rock and the influence of mining sequence, it may result in an alternating NAF-PAF in the inclined layer along the dumping construction. Such a structure allows the acidification and neutralization of groundwater due to contact with overburden material to occur sequentially as described by Shimada et al.<sup>22)</sup>, who evaluated the performance of multi layer cover system of alternate NAF-PAF material. The evaluation shows that utilization of PAF layer to reduce the NAF materials considering the geochemical equilibrium condition at each layer, has been resulting in similar performance with the single layer of NAF material. Moreover, the neutralization process might occurred and be affected by the pH buffering in the region where the dissolved iron released by sulfide oxidation precipitates as ferric hydroxide, as visually observed in the field.

## 6. Conclusion

The internal structure of overburden dumps is controlled by several factors, such as parent geology of overburden, mining operation and construction practices, as well as the weathering process occurring within overburden dump. The resulting variable heterogeneity in such man-made earth structures requires site specific correlations. Based on the field investigation and laboratory characterization on physical and geochemical properties of overburden dump samples, a physical model was developed for the Bendili panel 3 in-pit-overburden dumps at the KPC coal mine.

Internally, the pile is comprised of several bench lifts as high as a 10 m height, which was bound by a natural morphologic surface (i.e. low-wall slope) along which the deposited material, developed an angle of repose face (30°-35°), and a traffic surface at the top of each lift. Gravity variation occurred along the mixed inter-fingered dipping beds due to the end dumping technique. However, the distinct rumble zone as the result of material segregation during the end dumping at the base of the dump cannot be observed as clearly as in hardrock-type overburden dumps, which may be caused by easily degradation of low strength categorized overburden.

Combination of physical and chemical weathering occurred resulting in the grain-size reduction. Coupled with the swelling characteristic of clay mineral, these factors control the permeability and groundwater flow of inner overburden dumps. Moreover, a multi-compacted layer, as the result of heavy equipment traffic during construction, combined with alternating inclined layer, which has different physical characteristics concordant to the absence of the rumble basal layer, also limits the occurrence of the air diffusion/convection into the overburden dump body.

The geochemical characteristics of overburden materials were random, alternating among potentially acid forming and non acid forming materials within the inter-fingered layer. Those alternate geochemical characteristics may control acidification-neutralization reaction of infiltrated water, precipitation of secondary mineral and determines the quality of the overburden dump drainage, subsequently. Moreover, the existence of secondary mineral precipitate may coat or even

encapsulate the acid producing or buffering mineral hence making the mineral less susceptible to continued weathering and dissolution. By time, the secondary mineral precipitation may grow and become denser since then start blocking the inter-particle gap and lowering the permeability of overburden dump afterwards.

Considering the spatial heterogeneity of the physical structure and geochemical characteristics in the coal overburden dumps as the result of such a site specific kind of dumping operation, a self-developing acid drainage inhibition/prevention system may occur in the long-term.

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