Study on Capping Options For Overburden Encapsulation to Prevent Acid Mine Drainage in Lati Coal Mine, Kalimantan, Indonesia

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Abstract Lati coal mine in Kalimantan, Indonesia suffers from Acid Mine Drainage (AMD) because its overburden and interburden are dominated by potentially acid forming (PAF) material. One of the methods employed to prevent the formation of Acid Mine Drainage in the overburden dump area is encapsulation or capping of the PAF material. It is conducted by creating a barrier system which encapsulates the acidic overburden in order to minimize oxygen diffusion and surface water infiltration. This paper discusses the studies conducted to develop the most appropriate method of AMD management, particularly for the implementation of encapsulation method. The studies to be reviewed are compaction characteristics, NAF layer and the potential to use coal combustion ash.

Keywords acid mine drainage, dry cover, compaction, NAF layering, coal combustion ash utilization

Introduction

Lati coal mine is one of the four currently-running mine sites owned and operated by PT Berau Coal. The mine is located in East Kalimantan Province of Indonesia (Fig. 1) and has been operating since 1995. The Lati mine is the biggest mine site at PT. Berau Coal with a production capacity of 15 Mt of coal per year and more than 120 × 10^6 m^3 of overburden movement annually. The coal deposits are mined using the conventional open pit mining method, using shovels and trucks as the main mining equipment for both overburden removal as well as coal mining.

Lati coal mine is suffering from Acid Mine Drainage (AMD) since most of the overburden as well as inter-burden materials are classified as potentially acid forming (PAF). According to the recent geochemical rock model, the amount of PAF material is up to 80 %. AMD was not considered as an important environmental issue at this mine until 2007 when it was discovered that AMD had impacted the water quality of the river Ukud, located in the southern part of the mining area. The pH values monitored in the river were between 3 to 4 (Abfertiawan and Gautama 2011). Since then, along with the increasing awareness on the en-

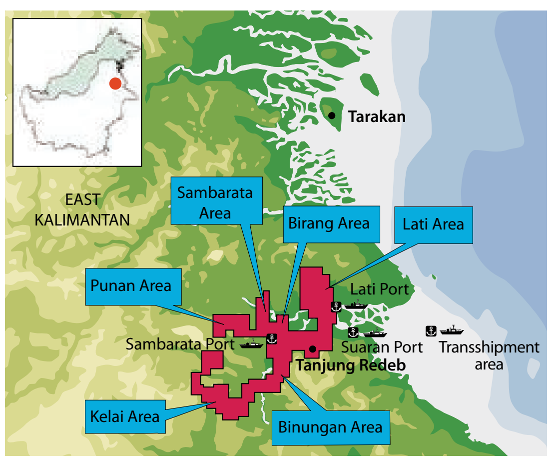

Fig. 1 Lati Coal Mine

vironmental protection, several studies have been conducted to identify the most appropriate and effective methods to minimize the AMD by considering the conditions of the site as well as available resources.

For surface coal mines, there are generally two sources of AMD generation. The first source is the mine pit, because of exposure of PAF material in the pit wall which could not be avoided. The second source is the overburden dump, mainly the out-pit overburden dump. Overburden often contains pyrite which can oxidise and generate long-term AMD in large quantities. At the overburden dump, AMD is potentially generated at the surface and subsurface depending on the water percolation and oxygen ingress. Based on the factor of AMD generation, the idea of AMD prevention is how to minimize water as well as oxygen. This way, the oxidation of sulfide mineral could be minimized.

A dry cover system is commonly used to minimize AMD generation in the overburden dump. The main objectives of a dry cover system are to minimise the influx of water and provide an oxygen barrier. The types of dry cover vary from single cover to multi-layer cover. Generally, it can be classified into three categories: resistive cover, store and release cover and mixed/novel type cover. A resistive cover is a method that reduces the permeability of the disposal overburden. It is commonly made from clay as well as compacted clay to minimize the percolation of water as well as oxygen diffusion. Store and release covers rely on the storage capacity of a certain layer of cover in which the precipitation in the wet season is stored and subsequently released as evaporated moisture in the dry season, therefore preventing further water percolation into the acidic waste. The last type of cover is a combination of either resistive and store and release cover as well as the application of an oxygen consuming layer (such as the organic waste or low reactive material); thus, preventing the oxygen ingress into the protected waste underneath in addition to the limited water deep infiltration (Shimada *et al.* 2011).

The effectiveness of the encapsulation and layering is governed by the availability of capping materials, the general balance between acid producing and acid neutralizing materials, the type and reactivity of acid-consuming material, the nature and flow of water through the dump, and chemical armoring of alkaline materials.

In the case of Lati mine, the limited amount of non-acid forming material is the main issue in the AMD management. Encapsulation of PAF material should be optimized to achieve the pre-defined criteria. The result of several studies covering compaction characteristics, multi-layer NAF material and the use of coal combustion ash will be discussed in the following section.

Studies for Capping Options

Compaction Test

The study on compaction was intended to understand the effect of compaction on the permeability of certain materials. Two types of rock samples, namely SS-NAF and CS-PAF were taken from Lati Mine Pit West. Those two rock samples represented the typical rock composition at Lati mine in which NAF material is typically sandstone whereas PAF material is in general claystone.

In the laboratory, the air dried samples were crushed and screened until it could pass a no 4 sieve (<4.75 mm). Five mixes with different moisture content were made by adding water as much as 150 mL, 300 mL, 450 mL, 600 mL, and 750 mL to each samples. The mixed samples were then loaded to the compaction mold with three compaction layer stages. The compaction in each layer was conducted by 25 blows using a standard hammer for the proctor test. Part of the compacted specimen was sampled for dry density determination and the rest of the specimen was formed and loaded into a permeability test unit to measure the hydraulic conductivity of the specimen using a constant head method.

Compaction test results indicated that the dry density of NAF material which was predominantly sandstone was generally lower than the density of claystone PAF material (Fig. 2 left). This similar trend was also shown in the hydraulic conductivity measurements (Fig. 2 right). The maximum dry density of NAF material was 1.71 g/cm³ obtained on 11.3 % moisture content and the hydraulic conductivity value was as low as 1.28×10^{-7} m/s, while the maximum dry density of 1.85 g/cm³ of PAF material obtained on 15.9 % moisture content and the lowest hydraulic conductivity value of 4.67×10^{-8} m/s.

This compaction study led to the conclusion that compaction should be implemented to the sandstone NAF material for use as a capping material. Optimum capping performance to prevent oxygen diffusion and water infiltration seems difficult to achieve mainly because of the limited thickness of the capping layer due to the limited amount of this material type.

NAF Layer Simulation

Simulation of different layers of NAF and PAF materials has been conducted in the laboratory to understand the performance of NAF material in preventing AMD generation. Using a modified free draining column leach test with a height of 300 mm and a diameter of 150 mm (Fig. 3) different scenarios of layering NAF and PAF materials were simulated. There were columns used for a control. The results of the four columns represented NAF mudstone and NAF sandstone. The characteristics of the samples obtained from static test are shown in Table 1.

As shown in Table 1 neither the NAF mudstone nor the NAF sandstone have a neutralizing capacity. This characteristic was verified in the control columns containing both materials. The pH values of leachates from simulated columns with different amount of NAF materials are shown in Fig. 4.

For the first 6 weeks the pH of leachates from all four columns were still neutral, meaning that oxidation of PAF material beneath the NAF layer had not started. Afterwards pH values in columns containing sandstone (both 25 % and 50 %) dropped to less than 3. It seems that oxidation of PAF materials in both columns already took place without any neutralization process. But it did not happen in the columns containing a mudstone layer. It can be explained that the oxidation process of PAF material did not occur until week 23 even in the column containing 25 % PAF mudstone.

The oxidation of PAF materials in the sandstone columns could occur because the sandstone layer has a higher permeability to let oxygen diffuse through the sandstone layer. On the other hand, NAF mudstone has lower permeability and became a physical barrier for oxygen diffusion into the PAF material beneath.

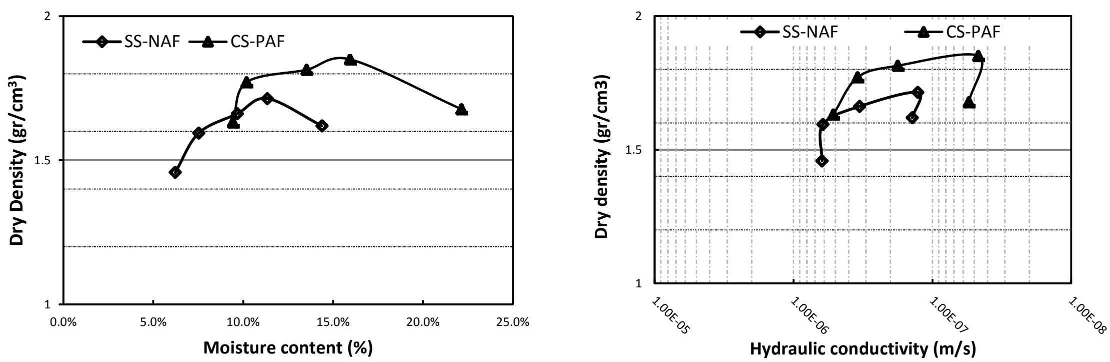

Fig. 2 Compaction characteristics of rock samples from Lati Mine

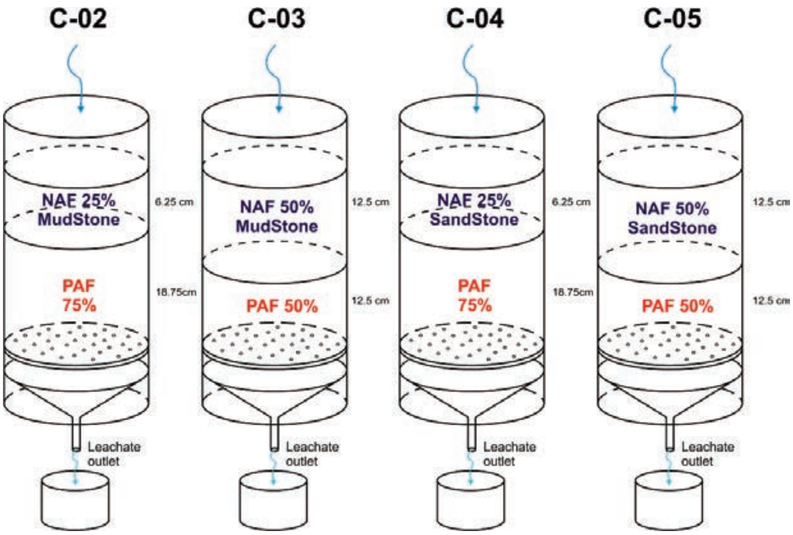

***Fig. 3** Simulation columns*

Coal Combustion Ash (fly and bottom ash) utilization

Since the NAF material in Lati mine is much lower in quantity than the PAF material with a PAF/NAF ratio of 80 %/20 % it is necessary to study the options to utilize materials found in the surrounding area. One of the options was to utilize coal combustion ash (fly and bottom ash) from a nearby coal fired power plant.

The weathering process of overburden materials and blending of overburden and coal ash were simulated in the laboratory usingamodified free draining column leach test with a height of 250 mm and a 100 mm diameter Buchner funnel. There were seven different scenarios being simulated, consisting of four blending scenarios and three layering scenarios. Detailed explanation and discussion on this study has been presented in 2010 (Gautama *et al.* 2010).

A summary of the study is as follows; the evaluation results showed that generally, permeability in all columns is decreasing. Since the permeability in the control columns consisted of 100 % fly ash and the bottom ash did not show any significant change, it could be concluded that the decrease in the permeability in the blending and layering columns might be resulted from the weathering of rock materials.

A higher decreasing infiltration rate occurred in the fly ash blending columns compared to that in the bottom ash blending columns. Lower permeability was identified in blending of smaller portion of FA (20 % compare to 30 %). Significantly different conditions were identified when the fly ash blending column was compared to the fly ash layering column. The filling of ash particles in the pores of rock samples resulted in a lower permeability

Rock Type	Tot. Sulfur*)	MPA**)	ANC**)	NAPP**)	Paste pH	NAG pH	NAG**)		ANC/MPA
							pH 4.5	pH 7	
CS-1(PAF)	0.88	26.93	0.00	26.93	6.80	3.55	3.85	2.25	0
CS-2(NAF)	0.17	5.20	5.74	-0.54	9.20	8.72	0	0	1.10
SS(NAF)	0.20	6.12	1.51	4.61	7.55	6.63	0	0.12	0.25

MPA: Maximum Potential Acidity; ANC: Acid Neutralizing Capacity; NAPP: Net Acid Producing Potential; NAG: Net Acid Generating; MS: Claystone; SS: Sandstone. *) in %; **) in kg H_2SO_4/t

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

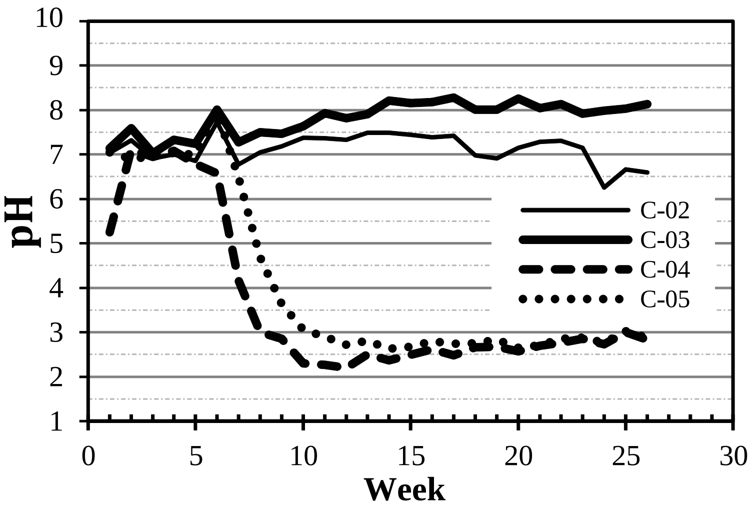

Fig. 4 *pH Value of leachates*

in the blending column compared to that in the layering column.

The decreasing permeability due to the weathering process could be important in improving the performance of capping in the encapsulation of PAF material. Covering the PAF material with layers of coal combustion ashes and with a blended rock and coal combustion ashes could be an appropriate option in preventing the AMD generation in the waste dump.

The pH values in the fly ash blending column was higher than that in the bottom ash blending but still lower than that in the layering column (Fig. 5). A similar trend was also found in eC and TDs. This indicated that the alkalinity of fly ash was more reactive and stable than bottom ash due to a smaller grain size and more effectiveness in neutralizing acid. Compared to the blending column, the layering mix of fly ash showed higher pH values meaning higher neutralizing performance.

Discussion

Encapsulation of PAF material has been defined as the most appropriate method in preventing AMD generation in overburden dumps. Particularly in Lati mine where the overburden as well as interburden is dominated by PAF material (approximately 80 %) the implementation of encapsulation has not been without its issues. It is therefore necessary to study different options of capping material or strategies to optimize AMD prevention.

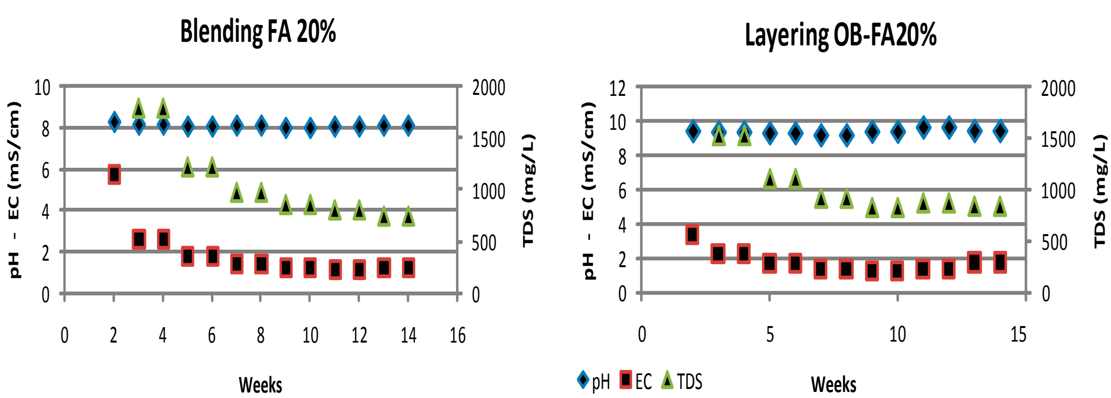

Fig. 5 *Result of coal combustion ash study: leachate parameters vs. time*

The compaction study on NAF material indicated that sandstone could only be compacted to a hydraulic conductivity as low as 10^{-7} m/s which might be insufficient to avoid oxygen diffusion and water infiltration into the capping layer. Increasing the thickness could not be implemented since the amount of sandstone is limited. An appropriate compaction technique should be developed accordingly.

In fact, NAF material in Lati mine has a low neutralization capacity. Studies on different layering schemes of NAF and PAF material has shown that the neutralization process of generated AMD did not occur. A layer of NAF should function as a capping material rather than a neutralizing one.

Due to its characteristics, fly and bottom ash from the nearby power plant could be used as a neutralizing agent as well as an impermeable layer to prevent oxygen diffusion and water infiltration, particularly fly ash. Fly ash blending seems to be the best option because the alkalinity of fly ash is more reactive and stable than bottom ash. The particle grain size of fly ash which is smaller than bottom ash also became an important factor in the reactivity of the neutralizing process. The coal combustion ash, particularly fly ash, could be used as an alternative material to prevent AMD generation.

Closing Remarks

Lati mine suffers from an AMD problem since most of the overburden and interburden material is classified as potentially acid forming (PAF). Lack of AMD management in the past has led to the AMD impacting the water quality of Ukud river. Even seepage from already rehabilitated overburden dump has a low pH.

Besides starting to geochemically characterize the overburden and interburden material and development of rock distribution model,Lati mine should study the most appropriate and reliable method in preventing AMD. Encapsulation has been considered to be the best method. To support this method different capping options have been studied.

Since most NAF material consists of sandstone it is important to develop a compaction strategy of sandstone as barrier layer to reduce its permeability. Most NAF material have a very low neutralizing capacity. Coal combustion ash from a nearby power plant is another potential source for alkaline material. Unfortunately the power plant's capacity is small, meaning that the amount of ash produced is small.

Acknowledgements

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