Weathering Behavior of Overburden-Coal Ash Blending in Relation to Overburden Management for Acid Mine Drainage Prevention in Coal Surface Mine

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Abstract Encapsulation of potentially acid forming (PAF) material with non-acid forming (NAF) material is counted as one of the best practices in overburden management for a sustainable prevention of acid mine drainage (AMD) in surface coal mine. In some mines, however, where only limited amount of non-acid forming material is available, appropriate overburden management methods should be developed. Those include the compaction technique of NAF as well as the use of ash from coal fired power plant (fly- and bottom ashes) as blending material in capping material. In both cases, understanding of weathering behavior of capping material is important. The weathering process of blending of overburden and coal combustion ash was simulated in the laboratory using free draining column leach test. Different blending schemes were studied in different columns. The weathering process was simulated by spraying deionized water once per day, and leachates were collected and analyzed. Infiltration rate was also observed. X-ray diffraction and fluorescence analyses were also conducted to identify the mineral composition of the samples. The simulations were conducted within 14 weeks. From the different configuration of the samples in general, it can be concluded that the weathering process played an important role in controlling the infiltration rate, and furthermore could increase the capability of capping material to prevent infiltration into the PAF material. The use of coal fly- and bottom ash could also improve the capping performance.

Key Words weathering process, coal fly and bottom ash, overburden management, AMD

Introduction

Lati coal mine is one of the three mine sites owned and operated by PT Berau Coal and is located in East Kalimantan. The mine is suffering from AMD problem since most of the overburden as well as interburden materials is classified as potentially acid forming. The deficit on non-acid forming material leads to the attempt to investigate the alternatives in AMD mitigation, one of which is the use of coal combustion (fly and bottom) ash from the nearby coal fired power plant.

The chemical composition of the coal combustion ash depends on the coal quality and combustion conditions. Due to the Indonesian regulation, coal combustion ash is classified as a hazardous waste. It is, however, encouraged to re-use the ash as long as it is proved to be safe for human health and the environment rather than conserve and dump the ash as a waste. Due to its pozzolanic, cementious and alkaline properties, the coal combustion ash has been used in some industries, such as cement industry.

Physical rock weathering, that was initially induced by wet and dry cycles condition, will reduce the particle size of rock. It will increase the reactive surface area and trigger chemical weathering. The increase of the total reactive surface area by sulphide-bearing rock will accelerate the chemical process, both the oxidation rate of sulfide (Davis and Ritchie 1987) and also the neutralizing reaction. On the other hand, from the physical condition point of view, reducing particle size means decreasing permeability that will reduce water infiltration and oxygen diffusion/advection onto and within the waste rock dump and further will minimize the AMD generation.

Materials and Methods

Samples

Overburden samples were taken both from the mine pit and the waste dump. The sample taken from the mine pit East was identified as Fresh Rock (FR), while the sample taken from the waste dump (Disposal Q10) was identified as Overburden (OB). Fly ash (FA) and bottom ash (BA) were collected from the ash disposal in the power plant. Mineral composition of every sample was iden-

***Table 1** Major Chemical Composition of Samples*

	Major Chemical Composition (%)											
	SiO_2	CaO	Fe_2O_3	Na_2O	AL_2O_3	MgO	K_2O	TiO_2	MnO	P_2O_5	SO_3	LOI
Fly Ash	19.68	15.00	12.77	10.95	8.72	3.02	0.93	0.50	0.10	0.09	22.64	5.18
Bottom Ash	16.11	17.56	26.47	4.53	7.09	2.99	0.78	0.67	0.16	0.07	10.42	12.27
OB	55.88	0.88	7.07	0.73	15.71	1.46	1.68	0.64	0.10	0.05	0.23	15.21
Fresh Rock	58.92	0.43	5.02	1.28	16.11	0.94	1.60	0.62	0.07	0.11	0.34	14.08

***Table 2** Geochemical Static Test Result*

No	Sample	Paste pH	Tot. Sulfur*)	ANC**)	NAPP**)	NAG pH	NAG**)	
							pH4.5	pH7
1	Fly Ash (FA)	11.87	5.60	86.46	84.90	9.70	-	-
2	Bottom Ash (BA)	9.21	1.71	51.52	0.81	5.90	-	2.37
3	Overburden (OB)	3.14	1.92	59.22	-0.47	3.00	8.29	16.58
4	Fresh Rock (FR)	4.54	1.94	0	59.36	2.47	28.42	40.56

Note : *) = in %; **) = in Kg H_2SO_4/ton ; ANC = Acid Neutralizing Capacity; NAPP = Nett Acid Producing Potential; NAG = Net Acid Generation

tified using XRD analysis. The major chemical composition of samples, analyzed by XRF, was shown in Table 1. Both fly and bottom ashes were classified as Class C ash (ASTM C 618—03) with self-cementing properties in addition to its pozzolanic properties.

Static test, which consisted of total sulfur, acid neutralizing capacity (ANC), paste pH and net acid generation (NAG) test, was conducted to characterize the geochemistry of all samples including the coal combustion ashes. The results were summarized in Table 2. The geochemical rock type was defined mainly by using acid-base accounting calculation and NAG test results. Both rock samples were classified as potentially acid forming (PAF) materials, as expected. Coal combustion ashes showed the alkaline capacity to neutralize acid. Referring to the XRF result, the high sulfur content in the ashes was in the form of sulfur oxides.

Methods

The weathering process of overburden materials and blending of overburden and coal ash were simulated in the laboratory using the modified free draining column leach test with a 250 mm height and 100 mm diameter Buchner funnel. The room temperature was kept at 35—40°C using a 40 Watt spot-tone lamp to represent the local climate condition in the mining area (Kusuma et al. 2009). Several mix compositions of sample (see Table 3) with known particle size distribution were put in each funnel and then flushed by approximately 199 mL de-ionized water once per day. During the flushing process, the infiltration rate of water was also measured. The leachates were collected daily and the parameters measured were pH, electrical conductivity (EC) and total dissolved solids (TDS). Metal content was analyzed from the bi-weekly cumulative leachates.

Results and Discussion

Physical Characteristic and Permeability

The weathering process was influenced by the fluctuations of temperature and humidity and the flushing frequency. It could be visually observed in the form of physical changes of samples during

***Table 3** Composition of Samples for Testing (in %)*

	Blending				Layering			Control			
Sample	$BA_{30\%}$	$BA_{20\%}$	$FA_{30\%}$	$FA_{20\%}$	$FA_{30\%}$	$FA_{20\%}$	$FA_{10\%}$	BA	FA	OB	FR
Fly Ash	-	-	30	20	30	20	10	100			
Bottom Ash	30	20	-	-	-	-	-		100		
OB	70	80	70	80	-	-	-	-	-	100	
FR	-	-	-	-	70	80	90	-	-	-	100
Total	100	100	100	100	100	100	100	100	100	100	100

the time of the simulation. The significant visual changes were the reduction of grain size and the change in color from dark brown to brown. The changes were also identified in the color of the leachates. It was also observed that the physical changes occurred more in the rock samples rather than in the ashes, as shown in the control samples.

Permeability in all columns was calculated using the daily infiltration rate measurements. Both blending and layering columns showed the decreasing trend of permeability. Since the permeability in control columns that consisted of 100% fly ash and 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.

Larger decreasing infiltration rate occurred in the fly ash blending columns compared to that in the bottom ash blending columns as shown in Figure 1. Lower permeability was identified in blending of smaller portion of FA (20% compare to 30%). Significant different conditions were identified where 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 smaller permeability 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.

pH, Electrical Conductivity and Total Dissolved Solids

The simulation was conducted in 14 weeks. 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 (Figure 2). 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 smaller grain size and more effective in neutralizing the acid. Compare to blending the layering mix of fly ash showed higher pH values meaning higher neutralizing performance.

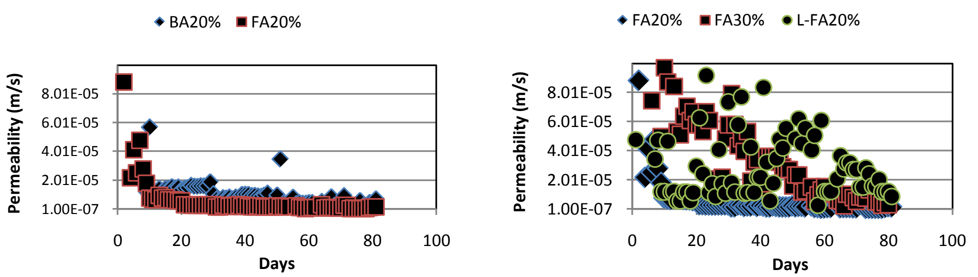

Figure 1 *Daily Permeability*

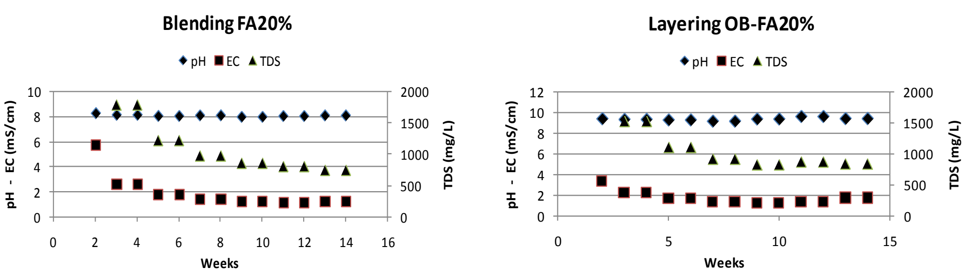

Figure 2 *pH, EC and TDS of Leachates*

Table 4 *Composition of Leachates*

	Fe (mg/L)			Mn (mg/L)			SO_4^{2-} (mg/L)			Cu (mg/L)			Zn (mg/L)		
	Max	Min	Avrg	Max	Min	Avrg	Max	Min	Avrg	Max	Min	Avrg	Max	Min	Avrg
BA	4.89	0.22	1.52	25.04	2.30	8.98	2,629	135	1,532	0.14	0.03	0.07	2.21	0.02	0.90
FA	459.40	0.04	139.91	139.70	0.11	33.83	16,475	112	5,146	0.53	0.00	0.26	2.65	0.01	1.10
FR	54.40	4.12	32.60	81.50	1.77	29.01	5,003	245	2,274	13.43	0.91	6.52	7.26	0.49	2.92
OB	5.69	0.44	2.61	22.05	0.69	8.13	1,279	208	679	4.48	0.38	1.60	2.90	0.38	1.52
Blend-BA30%	1.03	0.04	0.49	27.23	1.76	10.26	7,491	285	2,322	0.38	0.00	0.08	2.13	0.05	0.45
Blend-BA20%	0.99	0.12	0.56	30.72	0.60	15.66	12,295	132	3,213	0.08	0.00	0.02	0.30	0.02	0.10
Blend-FA30%	0.78	0.39	0.57	0.60	0.01	0.30	33,575	41	6,412	0.13	0.01	0.04	0.08	0.02	0.04
Blend-FA20%	0.56	0.02	0.29	11.65	1.02	6.34	21,610	130	5,068	0.07	0.00	0.02	0.05	0.00	0.03
Lay- FR-FA30%	6.10	0.02	2.16	5.90	0.03	1.55	23,860	559	5,946	0.20	0.01	0.06	0.41	0.02	0.10
Lay- FR-FA20%	30.50	0.03	8.58	11.32	0.46	6.14	17,545	772	5,232	0.18	0.01	0.07	0.80	0.02	0.26
Lay- FR-FA10%	0.55	0.04	0.26	1.39	0.31	0.85	13,470	101	2,997	0.04	0.00	0.02	0.05	0.01	0.03

Metal Content

The metal content was analyzed from bi-weekly cumulative leachates collected for each column. The major metals found in the leachates were Fe, Mn, Zn and Pb, though in an insignificant amount (Table 4). A higher metal content in the layering scheme might be caused by the AMD that was already generated in the rock sample prior to its neutralization during infiltration in the layer of fly ash.

Conclusion

Bench scale simulations have been conducted to study the weathering process of rock samples using leaching column usually used for kinetic test. Overburden samples taken from disposal as well as mine pit were mixed with coal combustion ashes from the nearby power plant. Different mixing schemes were tested including blending and layering.

There was a change of permeability relative to time due to the rock particle size reduction. In the blending columns the permeability decreased more significantly compared to that in the layering columns. It seemed that the ash particles in the blending scheme reduced the pores. The fly ash blending, due to a smaller grain size, gave lower permeability than the bottom ash.

The effectiveness of rock sample weathering in controlling the neutralization of AMD was measured in the quality of leachates in term of pH, electrical conductivity, total dissolved solids and chemical composition. Although layering schemes resulted in higher pH, but in general there was no significant difference in the metal content.

Overall, it could be concluded that overburden blending with coal combustion ashes, particularly fly ash, could prevent AMD generation. Scale up simulation is necessary.

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