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STUDY ON EFFECTS OF THE COVER LAYER BY USING COAL ASH ON REVEGETATION IN INDONESIAN OPEN CUT COAL MINE

SHUNTAOGATA[1], AKIHIRO HAMANAKA[2], HIDEKI SHIMADA[3], TAKASHI SASAOKA[4] & IKUOMIYAJIMA[5]

[1,3,4]Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Fukuoka, Japan

[2]Mitigation for Advanced Research, Muroran Institute of Technology, Hokkaido, Japan

[5]Institute of Tropical Agriculture, Faculty of Agriculture, Kyushu University, Fukuoka, Japan

ABSTRACT

Indonesia is one of the most important coal suppliers for Japan since approximately 20% of coal is imported from Indonesia. Almost all of the coal is produced by open cast coal mine in Indonesia; however, mining operation in open cast coal mine leads to negative effect on surrounding environment. Acid mine drainage (AMD) is one of the serious impacts of open cast coal mine. AMD is caused by supply of oxygen and water to sulfide minerals (mainly pyrite) as a result of mining activity. As a countermeasure for AMD, a dry cover system is widely applied in Indonesian open cast coal mine. In this system, waste rock is classified as Potentially Acid Forming (PAF) and Non Acid Forming (NAF)by geochemical test: PAF is the source of AMD and NAF is not. PAF is covered with NAF so as not to contact with oxygen and water to prevent AMD in this system. On the other hand, energy demand has increased and new coal-fired power plants have been constructed due to high rates of the economic growth in recent years in Indonesia. These trends cause generation of a large amount of coal ash which is industrial waste; thereby, it is necessary to increase the effective utilization of coal ashwith the aim of processing the large amount of coal ash. Based on this background, coal ash was applied to a cover layer in the past research. However, it is concerned that the plant growth is affected by soil mixed with coal ash during revegetation since the cover layer is constructed near the surface and coal ash composed of various metals which affect plant growth. Therefore, this paper discussed the effect of coal ash on the plant growth by means of several laboratory tests and laboratory vegetation test with *Acacia mangium*. As the results of the discussions, the coal ash can be utilized as cover layer by mixing with soil at a proper rate from the view point of revegetation without effects on plants.

KEYWORDS: Coal Ash, Acacia Mangium, Revegetation, AMD, Dry Cover System

INTRODUCTION

Background

Indonesia was the largest coal exporter in the world in 2013 (Japan Coal Energy Center, 2013).Japan imported about 20% of coal from Indonesia in 2014; therefore, it can be said that Indonesia is one of the important coal suppliers for Japan.

Most of coal is produced in open cast coal mine in Indonesia. Themining operation in open cast coal mine leads to negative effect on surrounding environment. Acid mine drainage (AMD) is one of the most serious impacts of open cast mining. AMD is caused by supply of oxygen and water to sulfide minerals (e.g. FeS_2: pyrite) as a result of mining activity.

AMD is characterized by low pH and high concentrations of heavy metals which may raise the number of potential problems for the environment and human beings such as the impact on the aquatic life and communities in the downstream environment resulting from acidity and dissolved metals, and affects groundwater quality and revegetation (Skousen et al., 1998; Peppas et. al, 2000). One of the effective countermeasures is a dry cover system which is widely introduced to prevent the generation of AMD in open cast coal mines in Indonesia. In this system, waste rocks are classified as Potentially Acid Forming (PAF) and Non Acid Forming (NAF) by means ofseveral geochemical tests: PAF is the source of AMD and NAF is not. AMD is prevented by covering PAF with NAF in order not to contact PAF with water and oxygen as shown in Figure 1.

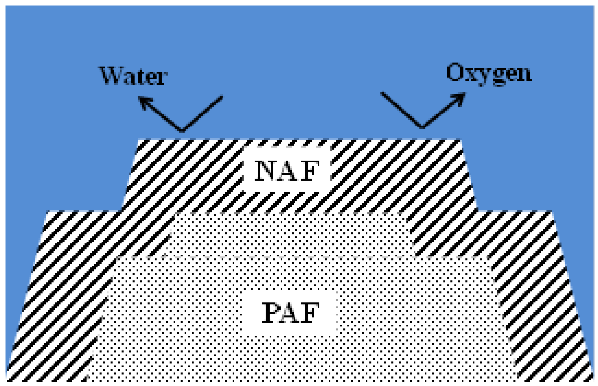


Figure 1: Conceptual Modal of a Dry Cover System

Since a large amount of NAF is utilized for a cover layer in this system, it is difficult to apply this method in the field where the amount of NAF is limited. An alternative material, therefore, is required in order to perform this system. Coal ash is considered to be as an alternative material owing to its properties and abundance. Coal ash has alkaline property due to the fact that it contains Ca (e.g. CaO, $Ca(OH_2)$, $CaCO_3$) (Xenidis et al., 2002). In actual, several researches have been conducted to control acid generation from sulfidic wastes and to neutralize the generated AMD with coal ash (Gautama et al., 2010; Pérez-López et al., 2007).

On the other hand, coal demand has been increasing for the increase of energy demand in recent year in Indonesia. In order to deal with the increase of energy demand in domestic associated with high rate of economic growth, Indonesian government regards coal as important source of energy supply, and promotes policies putting emphasis on coal for the supply source of energy such as construction of new coal-fired power plants. Such tendencies give rise to a vast amount of coal ash generated as industrial waste. Although coal ash is generally disposed by landfill, the capacity of landfill is limited. The demand for the utilization of coal ash has increased for the reasons in recent year. Utilization of coal ash is one of the opportunities in dealing with this situation, rather than conserving and dumping the coal ash as waste. Some of the coal ash is currently utilized as a raw material of cement in Indonesia; however, the effective utilization of coal ash should be discussed in the view of the decrease of the demand for the cement due to the economic growth slowdown.

On the basis of these backgrounds, it is considered that coal ash is applied to a cover layer to prevent AMD (Hamanaka et al., 2014).However, the plant growth could be affected by soil mixed with coal ash during revegetation since the cover layer is constructed near the surface and coal ash composed of various metals which affect plant growth. Therefore, this paper discussed the effective utilization of coal ash as cover layer for post-mining area in open cast coal mine in Indonesia, and investigated the effect of coal ash on the plant growth by means of several laboratory tests and laboratory vegetation test.

MATERIALS AND METHODS

Characterization of Coal Ash

Several tests were performed with 2 types of coal ash: Fly ash (FA) and Bottom ash (BA)produced in Kaltim Prima Coal (KPC) mine.KPC mine is the biggest open cut coal mine in Indonesia located in East Kalimantan. In this mine, there are some coal-fierd power plants to supply the energy to activate the facilities. Sincenew power plants are to be built in order to supply the energy for new facilities, it is expected to increase the production of coal ash. Given the increase of its production, it is important to discuss an effective utilization of coal ash.

Coal ash have to be characterised for the effective utilization since the characteristics of coal ash differ depending on the coal type and specification of power plants. XRF (X-ray Fluorescence) analysis, particle size analysis, and SEM (Scanning Electron Microscope) analysis were conducted to understand the characteristics of coal ash in this study.

Applicability of Coal Ash as Cover Layer

Applicability of coal ash as cover layer was assessed in terms of revegetation. In this section, simulated soil was prepared based on soil data in KPC mine (Table 1) in view of the fact that coal ash or mixed soil with coal ash is applied as cover layer. In order to assess the application of coal ash as cover layer, soil pH and EC test and permeability were performed for 9 types of samples at different mixture rate of simulated soil and coal ash. Besides, the effect of harmful elements eluted from coal ashafter the certain period of time was investigated by performing column leaching test assuming the Indonesian climate. Assuming the temperature and a half-year precipitation, 100 mL of deionized water was poured into each column every 24h in the laboratory at 30 ºC.

Table 1: Soil Data in KPC Mine and Properties of Simulated Soil

Sample	Sand (%)	Silt (%)	Clay (%)	Texture	Soil pH
Soil in KPC	2.7~48.9	26.6~57.8	24.4~39.6	Clay Loam, Light Clay, Silty Clay	3.4~5.7
Simulated soil	36.7	26.7	36.6	Light Clay	4.8

Laboratory Vegetation Test

In order to discuss the effect of coal ash on the plant growth, laboratory vegetation test was conducted under the soil conditions in previous section. *Acacia mangium* was selected as a plant species for the laboratory vegetation test. This species is widely applied in the early stage of revegetation in open cut coal mine in Indonesia due to its vigorous growth rateand tolerance to high acidic and low nutrient soils (Kuroda, 2012). Thus, the effect of cover layer by using coal ash on plant growth was discussed with *Acacia mangium*. All pods were filled with soil mixed with simulated soil and coal ash, and the seedlings of *Acacia mangium* were planted to the pots one by one. This vegetation test had continued for 2 months, and the height and soil moisture content were measured every week. The diameter of seedlings was recorded at the end of this test. All pots were supplied with 500 mL of water every 3~4 days, while liquid fertilizerHYPONeX^{R} (N-P-K = 6-10-5) diluted to 1,000 ppm with water was applied weekly. The experiment was carried out at constant temperature and humidity: the temperature and humidity were set at 30°C and 70%, respectively.

RESULTS AND DISCUSSIONS

Characteristics of Coal Ash

Table 2 shows the result of XRF analysis. Major elemental composition of coal ash was similar to that of soil in KPC mine though ignition loss of coal ash was much higher than that of soil in KPC mine due to unburned carbon in the results. Thereby, it can be supposed that coal ash can be applied as a planting soil in terms of chemical composition.

Moreover, the coal ash produced in KPC mine had characteristics of sandsince the most of the particle size of FA and BA were classified as sand. Coal ash, additionally, has the higher water holding capacity due to the macro- and micro-pores in their body (Haynes, 2009).The results of SEM showed that FA and BA had the higher water holding capacity sincea lot of macro- and micro-pores were observed on their surface.

Table 2: The Result of XRF Analysis

Sample	SiO_2 (%)	Al_2O_3 (%)	FeO (%)	CaO (%)	MgO (%)	K_2O (%)	Ignition Loss (%)
Topsoil in KPC	66.1	19.3	4.02	0.02	0.97	1.56	7.00
FA	30.9	13.3	5.93	1.82	2.24	1.54	41.0
BA	44.6	16.4	7.59	2.34	2.72	1.69	22.3

Assessment of the Applicability of Coal Ash as Cover Layer

The results of soil pH, soil EC and permeability test are shown in Table 3 with the standard value for effective plant growth. As the results, soil pH, soil EC and permeability of mixed soil with simulated soil and coal ashexhibited moderate value compared to the standard value. In particular, soil EC which indicates nutrient content in soil met the standard value; thereby, it was indicated that nutrient materials in coal ash can work as fertilizer for plant growth(Japan Landscape Contractors Association, 2005). Based on these results, the coal ash can beutilized for a cover layer due to the favorable characteristics for plant growth.

Table 4 shows the results of leachate analysis for heavy metals which affect plant growth. From the results of leaching test, it was suggested that plant growth is not affected by the harmful materials eluted from coal ash since the concentration of the dissolved heavy metal contentswere quite low compared to the Indonesian soil standard value as shown Table 4.

Table 3: The Results of Soil pH, Soil EC and Permeability

Sample	Soil pH	Soil EC (mS/cm)	Permeability (cm/sec)
Simulated soil	4.81	0.650	$<1.00\times10^{-7}$
FA	7.35	1.210	9.52×10^{-3}
BA	9.18	0.260	1.42×10^{-2}
Simulated soil : FA (1 : 0.5)	5.66	0.870	2.19×10^{-5}
Simulated soil : FA (1 : 1)	5.81	0.890	1.61×10^{-4}
Simulated soil : FA (1 : 2)	5.90	0.920	9.97×10^{-4}
Simulated topsoil : BA (1 : 0.5)	5.77	0.570	1.09×10^{-3}
Simulated soil : BA (1 : 1)	6.28	0.440	1.15×10^{-3}
Simulated topsoil : BA (1 : 2)	6.67	0.370	1.73×10^{-3}
Standard value	4.5~7.5	0.10~1.0	10^{-4}~10^{-3}

Table 4: The Results of Leachate Analysis

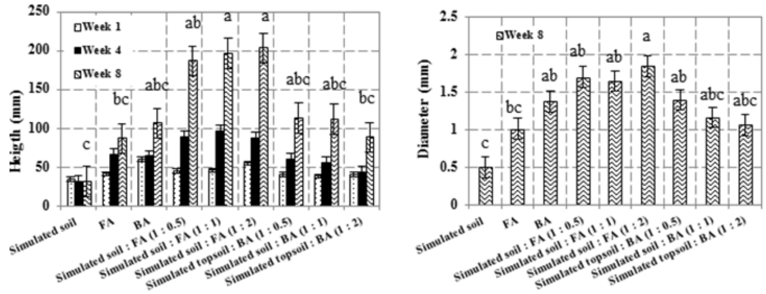
Sample	Cr (ppm)	As (ppm)	Se (ppm)	Cd (ppm)	Pb (ppm)
Simulated soil	*N.D.	0.002	N.D.	0.031	N.D.
FA	N.D.	0.036	N.D.	0.031	N.D.
BA	N.D.	0.060	N.D.	0.032	N.D.
Simulated soil : FA (1 : 0.5)	N.D.	N.D	N.D.	0.160	N.D.
Simulated soil : FA (1 : 1)	N.D.	0.027	N.D.	0.032	N.D.
Simulated soil : FA (1 : 2)	N.D.	0.052	N.D.	0.032	N.D.
Simulated soil : BA (1 : 0.5)	N.D.	0.052	N.D.	0.032	N.D.
Simulated soil : BA (1 : 1)	N.D.	N.D	N.D.	0.032	N.D.
Simulated soil : BA (1 : 2)	N.D.	0.063	N.D.	0.033	N.D.
Standard value	5.0	5.0	1.0	1.0	5.0

*N.D.: Not Detectable

Laboratory Vegetation Test

Figure 2(a) and (b) show the results of the laboratory vegetation test: height of seedlings, diameter of seedlings. The different alphabets in the figure show a significant difference obtained by the Tukey-kramer method (Nagata and Yoshida, 2001). This method is one of the statistical tests to show the clear differences among the each result. According to the results, the growth of *Acacia mangium* was favourable in soil mixed with coal ash and simulated soil. The growth of *Acacia mangiuma* was rather promoted by mixing simulated topsoil and coal ash compared with the height and diameter in the simulated soil. This was due to improvement of permeability by mixing coal ash in the light of the fact that the permeability of simulated soil was much lower than standard value. Besides, FA had higher fertilizer effects than BA due to high EC of FA as shown in Table 3. This was the reason why the height of *Acacia mangium* in mixed soil with FA was larger than that of BA.

On the other hand, excess mixing of FA inhibited the plant growth since the height of *Acacia mangium* in FA was much lower than mixed soil with simulated soil and FA while the growth of *Acacia mangium* was not affected by excess mixing of BA.As the plant growth was not affected by the harmful materials eluted from coal ash according to the results of leachate analysis, this was due to water holding capacity of the differences between FA and BA. Figure 3 shows the relationship between height and volumetric water content. From this result, volumetric water content increased with the increase of the mixing ratio of the FA which has high water holding capacity. In contrast, volumetric water content was not changed by the increase of the mixing ratio of the BA. Furthermore, the height of *Acacia mangium* in mixed soil with FA increased up to a certain volumetric water content, followed by the sudden-decrease of the height at approximately 68% of volumetric water content. In usual, high water holding capacity has favourable effects for plant growth due to the increase of the available water in soil, whereas most plants suffer from the high volumetric water content in soil due to lack of oxygen for root propagation (Bartholomeus, 2008). Accordingly, it was considered that large amount of FA inhibited plant growth at about 68% of volumetric water content.



(a) Height **(b) Diameter**

Figure 2: Results of Laboratory Vegetation Test: Different Alphabets Denote a Significent Difference Obtained by the Tukey-Kramer Method

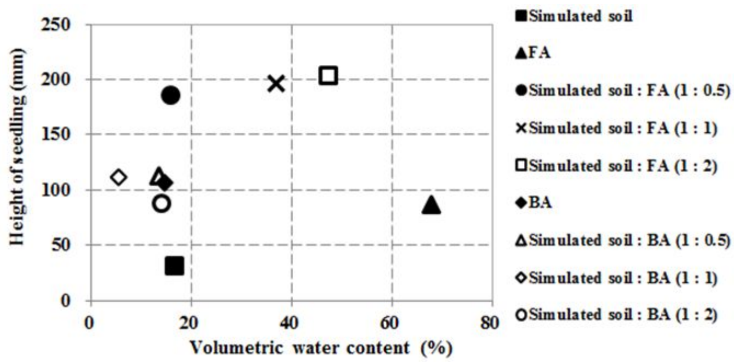


Figure 3: Relationship between Height and Volumetric Water Content

In summary, it can be said that the coal ash used in this study has high applicability as a cover layer in the light of the effects on plant growth. FA, particularly, has higher applicability than BA due to the favourable plant growth in mixed soil with FA. However, it should be considered the proper mixing ratio of FA owing to the inhibition of the plant growth by excessive use of FA.

CONCLUSIONS

It is considered that the application of coal ash as cover layer resolves the problems such as the lack of cover material and the treatment of the large amount of coal ash. However, the plant growth may be affected by the cover layer by using mixed soil with coal ash during revegetationsince the cover layer is constructed near the surface.

In this research, the utilization of coal ash as cover layer for post-mining area in open cast coal mine in Indonesia was discussed, and the effect of coal ash on the plant growth was investigated through several laboratory tests and laboratory vegetation test with *Acacia mangium*.

As the results, the plant growth was favourable in soil mixed with coal ash and simulated soil; therefore, it was suggested the coal ash used in this study has high applicability as a cover layer. Furthermore, FA has higher applicability than BA since the growth of *Acacia mangium* in mixed soil with FA was larger than that of BA. The plant growth, however, was affected by excess mixing of FA.Thus, FA can be utilized ascover layer at a proper mixture rate of itwithout negative impacts on revegetation.

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