Study on Prevention of Acid Mine Drainage at Dumping Site by Using Cover System with Coal Ash and Organic Material in Open-cast Coal Mine, Indonesia

センディ, ドゥイキ

（様式２）

氏　　名　：Sendy Dwiki

論 文 題 名：Study on Prevention of Acid Mine Drainage at Dumping Site by Using Cover System with Coal Ash and Organic Material in Open-cast Coal Mine, Indonesia
（インドネシアの露天掘り石炭鉱山における石炭灰と有機資材を覆土工法に用いた廃石堆積場からの酸性坑廃水の抑制に関する研究）

区　　分　：甲

論　文　内　容　の　要　旨

Acid mine drainage (AMD) is a prominent issue in the coal mining area as it can pollute the surrounding area when it flows into the water bodies, brings along toxic constituents that are dangerous to living organisms. AMD is characterized by low pH (usually pH<4.5), high sulfate concentration and elevated heavy metal concentration. Three main factors that generate AMD are the available sulfide mineral, oxygen that acts as the primary oxidizer, and water. Coal-bearing rock contains abundant sulfide minerals that are exposed during exploitation stage of mining. This introduces the sulfide minerals to the oxidizing environment, meaning that the minerals become chemically unstable because the weathering process is promoted. In the presence of water, acidic water is produced. The acidic water dissolves more metals sourced from not only sulfides but also gangue minerals. Moreover, in acidic condition, microbial activity plays a vital role to accelerate the reaction of AMD generation. The reaction rate with microbial activity is several order magnitudes larger than the reaction rate of the abiotic conditions. Therefore, the study of AMD prevention considering the effect of microbial activity is significant to minimize the negative impact to the environment.

The dry cover method is one of the common methods to prevent AMD generation in mining site for a long term. In this method, the oxidation of sulfide mineral can be reduced with minimizing the oxidation reaction of the potential acid-forming (PAF) rock by encapsulating with the non-acid forming (NAF) rock. However, based on past studies, Indonesia coal mine faces a critical problem where NAF rock is not sufficient in volume and in the capacity of neutralizing. Hence, this study proposes the utilization of coal ash and organic material as the alternative materials of the additional cover layer. Coal ash and organic material are industrial waste, which easy to be found in the coal mine, with potential to neutralize AMD, impede the fluid and also consume oxygen. However, due to those materials status as waste, the application of these materials needs to be further investigated. The dissertation describes and discusses the application of coal ash and organic materials as the cover system for AMD prevention, and consists of six chapters as follows:

Chapter 1 presents about the background of the current situation in Indonesian coal mining, the process of AMD generation within the mine especially overburden dumping area, and the prevention of AMD. The problem statements and objectives of the studies, as well as an outline of the dissertation, are also introduced in this chapter.

Chapter 2 describes the current condition of Indonesian coal mine that related to AMD by performing site investigation. One of the Indonesian coal mines is selected to investigate the AMD problem including the sulfide mineral and geochemical capacities of coal-bearing rocks. It was found out that pyrite in the shape of framboid, a micromorphological structure common in sedimentary rock, dominated coal-bearing rock. This relates to the rapid reactivity of AMD generation reaction in coal mine compared to the ore mine. Furthermore, the dry cover method that is applied in this mine also investigated for its effectiveness to reduce oxygen and water infiltration. In the coal mine, PAF rock outsized in volume and also high capacity in producing acid. Additionally, the dry cover system with only NAF layer was not effective to reduce oxygen and water moisture in this mine based on the results of the direct measurement on-site.

Chapter 3 discusses characterization of coal ash and organic material related to the application in dry cover system. Coal ash is divided into fly ash and bottom ash, due to its distinguished collect location. It is separated due to the particle size, which affect the settlement of particle. The conventional classification systems of coal ash , i.e. ASTM C618 and JISA6201, are usually for the use in concrete; they do not include to assess the neutralizing capacity of coal ash. Therefore, another approach is needed to classify the coal ash in terms of cover layer for AMD prevention. Based on the shape and mineral observation, coal ash can be classified in the temperature of coal burning process. This affects coal ash composition, which influence the neutralization capacity of coal ash. The coal ash from the burning process with high temperature more than 700 °C can be classified as Type 1 which has spherical particles and high neutralizing capacity (>100 kg H_2SO_4/ton). On the other hands, the coal ash of Type 2 from the lower coal burning temperature has the particles of irregular shape and the intermediate neutralizing capacity (<50 kg H_2SO_4/ton) with unburned carbon. The different neutralizing capacity of Types 1 and 2 can be explained by the mineral contained in coal ash, meaning that the acid neutralizing minerals, i.e. the calcite and dolomite, are left as the dominant minerals due to dihydroxylation under the high temperature of coal burning. In addition, bottom ash is not effective to use for AMD prevention because it has insignificant neutralizing capacity. The organic material which is suitable in Indonesia coal mine under the humid tropical climate is the less inherent moisture content, as shown by plant based empty fruit bunches of palm oil (EFB) compared to well-studied sewage sludge. Moreover, based on the oxygen consumption rate measurement, the plant-based organic material can consume more oxygen in weight basis compared to sewage sludge. The rate can differ into 3.6 folds higher than the sewage sludge.

Chapter 4 discusses the optimization of both materials for utilization in dry cover system. Laboratory-scale simulations to understand the effectiveness of these materials as cover layer are carried out with monitoring the behavior of leachate water. Net acid producing potential (NAPP) ratio of coal ash and PAF rock can be utilized to determine the sufficient amount of coal ash to be used. Based on the results of the experiment to simulate the balance of coal ash and PAF, it is recommended to have NAPP ratio less than 10 kg H_2SO_4/ton in order to make sure the acidic water can be completely improved by the addition of coal ash. Additionally, coal ash of Type 2 which has low acid neutralizing capacity can be used if the waste rock is classified as PAF low capacity: NAPP ratio is less than 10 kg H_2SO_4/ton and NAG pH is below 4.5. Thickness ratio is also an important factor to be considered. It was reported that the hydraulic conductivity was reduced due to the sedimentation of Ca and Mg in PAF rock when the coal ash was placed on PAF. From the results of the experiment to discuss the effective thickness of coal ash, the reduction of hydraulic conductivity can be expected when the thickness of cover layer is more than 0.25 times for the coal ash of Type 1 and 0.5 times for the coal ash of Type 2, respectively. For organic material, it can be expected to enhance the oxygen consumption in the layer. However, it was indicated that the reduction of the thickness had to be taken into consideration for long-term AMD prevention since the EFB was decomposed by the microorganisms activity. Based on the result of a simulation on dry cover method combined with coal ash and organic material, leachate water shows an improvement in pH value and the reduction of metal concentrations without negative impacts, meaning that the cover layer is effective for AMD prevention. Therefore, the utilization of these cover layer is promising to apply in the overburden dumping area.

Chapter 5 describes the effect of iron-oxidizing bacteria existence and the inhibition due to the application of a dry cover layer. The same leaching test as described in the Chapter 4 is utilized to understand the behavior of leachate water and metal dissolution that related to the iron-oxidizing bacteria. It is found out that AMD reaction is enhanced due to the existence of the iron-oxidizing bacteria in the PAF rock. Moreover, the effect of the iron-oxidizing bacteria on AMD reaction cannot be ignored with the conventional dry cover system. However, utilization of coal ash and organic material could inhibit the iron-oxidizing bacteria activity in the dry cover system. Additionally, the useful life of the cover system can be extended with increasing the thickness of the cover layer. Therefore, the materials are recommended to be used in a dry cover system as it could comprehensively reduce AMD generation, both biotic and abiotic conditions.

Chapter 6 summarizes the conclusions of each chapter, including the recommendations.