Assessment and Countermeasure of Acid Mine Drainage Generation with Characteristics of Potential Acid Forming Waste Rock in Open-pit Gold Mine, Myanmar

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論 文 題 名 : Assessment and Countermeasure of Acid Mine Drainage Generation with Characteristics of Potential Acid Forming Waste Rock in Open-pit Gold Mine, Myanmar（ミャンマーの露天掘り金鉱山における酸性水発生岩の特性による酸性坑廃水の評価と対策）

区　　分　: 甲

論 文 内 容 の 要 旨

Acid Mine Drainage (AMD) is caused by the reaction in water with oxygen and the sulfide minerals contained in excavated rocks in the mine. The dissolution of high concentrations of metal ions (iron, aluminum, manganese, zinc, copper, nickel, arsenic, cadmium) has an environmental impact on the rivers and the surrounding environment. AMD is a site-specific problem because the characteristics of AMD depend on the minerals contained in the rocks, climatic conditions, and the local hydrology. Currently, many open-cut mines are in operation in Myanmar. However, the research about AMD problems in Myanmar is limited, meaning that the sources and the potential of AMD generation are unclear though AMD generation has been reported to the government from some mines. Additionally, the countermeasures to mitigate AMD generation for the long term usually have to be discussed from the early stages of mine development with a source control strategy, i.e. dry cover method.

Hence, this study focuses on the identification of the source of rock to generate AMD and assesses the potential of AMD generation by investigating the Kyaupahto gold mine, which is the largest and oldest open-pit gold mine with the epithermal deposit in Myanmar. Additionally, the backfilling design of the proposed dry-cover system takes the geochemical characteristics of waste rocks into consideration. In order to achieve the objective of this study, the dissertation consists of six chapters as follows:

Chapter 1 presents the background of the current situation in the gold mines of Myanmar, the process of AMD generation within the open-pit mine, and the general countermeasures of AMD prevention. The requirements to discuss the application of the dry cover system in the gold mine and an outline of the dissertation are introduced in this chapter.

Chapter 2 describes the results of the field investigations in Kyaukpahto gold mine, which is the largest and oldest open-pit gold mine in Myanmar. The field investigations were carried out in order to identify the location that generates AMD and to examine the AMD characteristics, including the current countermeasures to mitigate AMD. As a result, AMD generation is confirmed in the open-pit and the low-grade ore dump and it contains a high concentration of arsenic. Despite this, there is no water pollution in the surrounding environment while the current countermeasure is the addition of limestone to neutralize the acidic water. Considering that AMD has been identified at the mining site and the current countermeasure is just for temporary management, it is necessary to evaluate the potential of AMD pollution in the future and to discuss effective countermeasures for long term management.

Chapter 3 discussed the identification of the source of rock that generates AMD and assessed the potential of AMD generation by means of the geochemical analysis of rock samples from the open-pit and the waste rock dump in Kyaukpahto gold mine. The results show that the presence of potentially acid forming (PAF) which may form acidic water is confirmed in the open-pit and low-grade ore dump where AMD generation is identified. Additionally, AMD generation is clearly found from low-grade ore, which is the waste rock under the cut-off grade. On the other hand, the presence of non-acid forming (NAF) with the high acid neutralizing capacity due to the carbonate minerals has been found. Based on the results of X-ray diffraction, PAF contains pyrite and arsenopyrite as the major sulfide mineral and NAF contains calcite and dolomite as the carbonate mineral. The current risk of water pollution due to AMD generation is expected to

be low because the volume of low-grade ore is quite small compared to that of waste rocks. Moreover, there is a possibility to adopt the dry cover system in this mine due to the high stripping ratio and the large volume of the waste rock with carbonate minerals, which have acid neutralizing capacity.

Chapter 4 describes the classification of PAF by investigating the elution behavior of the acidic water by means of the batch leaching test and column leaching test. From the results of the batch leaching test, it is revealed that a long-term metal elution is expected from the rocks which contain a lot of As regardless of pH. Additionally, the elution of metal ions is found not only in acidic conditions, but also neutral conditions due to the effect of acid buffering reaction. These facts mean that PAF can be classified with the sulfur content, ANC, and constituent metal elements. The results of column leaching test also show the same trend with those of the batch leaching test, meaning that the higher arsenic elution is confirmed by the end of the column leaching test from rock samples which contains a large volume of arsenic and the pH shows higher if the samples have the high acid neutralizing capacity (ANC). Moreover, the oxidation and buffering reaction due to sulfide and carbonate minerals are well balanced in PAF, which shows the highest pH because the elution of sulfate and total cation are balanced. From these results, the different backfilling designs must be discussed for the different characteristics of PAF to achieve the efficient prevention method of AMD.

Chapter 5 discussed the backfilling design of waste rock as a dry cover system considering the characteristic of PAF. The same column leaching test was conducted with different cover scenarios by using the PAFs which have various characteristics and NAF which has a higher ANC. The results show that the pH of leachate improves as the layer thickness of NAF increases while the small amount of cover is enough to prevent AMD generation if PAF has a higher ANC. The ratio of NAF/PAF to minimize the AMD generation in terms of pH should be determined with net acid producing potential (NAPP) and ANC of the column. For the metal elution, the high concentration of the arsenic elution is confirmed from PAF containing a lot of arsenic even in the case of increasing the cover thickness, meaning that it is difficult to reduce the arsenic elution with only the upper layer cover from such PAFs. Therefore, the sandwich design to place NAF not only on the upper layer, but also as a bottom layer, is suggested to prevent metal elution efficiently. According to the results, the significant suppression of arsenic elution has been confirmed. This suppression is due to the co-precipitation of the arsenic with iron hydroxide (III) in the bottom layer. It is also confirmed that the elution of arsenic and iron reduces from leachate and these metals rises in the bottom layer from the results of SEM-EDX. Finally, the guideline for the application of the dry cover system in the epithermal gold mine of Myanmar is suggested in this chapter.

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