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Effects of Soil Acidification on Soil Erosion in Open-Cast Coal Mines in Indonesia[1]

Shinji Matsumoto,[1] Shunta Ogata,[1] Hideki Shimada,[1] Takashi Sasaoka,[1] and Ginting Jalu Kusuma[2]

[1]*Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Fukuoka 819-0395, Japan*

[2]*Departnent of Mining Engineering, Faculty of Mining & Petroleum Engineering, Institute Technology Bandung, Bandung 40191, Indonesia*

Abstract

Soil erosion which easily progresses due to heavy rain in the tropical climate is a serious issue for mined-land reclamation in Indonesia. Moreover, acidification of soils occurs because of sulfide minerals in mining area. The physical properties of soils are changed by the acidification of soils according to previous studies. Thus, since the erosion rate of soils greatly depends on physical characteristics of soils, the relation between the change of physical properties of soils caused by soil acidification and soil erosion has to be considered for erosion control in mining area. In this study, physical properties of the soil samples in which the soil-pH was adjusted with H_2SO_4 were measured, followed by the artificial rainfall test with the samples in order to understand the effect of acidification of soils on erosion rate. The results showed that the decrease of cohesive strength among soil particles caused by the decline of atterberg limit with soil acidification resulted in the increase of erosion rate. Hence, soil acidification should also be prevented for the measures against soil erosion.

1. Introduction

Soil erosion is one of serious environmental issues in terms of land degradation.[2] In the tropical climate, heavy rain frequently triggers soil erosion. Soil erosion is also a serious issue for mined-land reclamation in Indonesia in the tropical climate since it causes plant death. As physical characteristics of soils have a close connection with soil erosion, soil management and measures against rainfall play an important role to prevent soil erosion.[3]

In the waste dump in mines, soil acidification and soil erosion simultaneously proceeds. Soil acidification is caused by the exposure of sulfide in waste rocks to atmosphere with excavation activities, and it has been reported in the world.[4, 5] In open-cast mine, this situation easily progresses due to the large scale mining. Moreover, physical properties of soils, such as shear strength and atterberg limits, change under acidic conditions according to past studies.[6, 7] For the reasons, the changes in physical properties of soils through soil acidification possibly affect soil erosion. There are, however, few studies which investigate the relationship between soil acidification and soil erosion.

In this research, artificial rainfall test was conducted with simulated soil which was adjusted to soil properties in the waste dump in open-cast coal mine in Indonesia and different pH with H_2SO_4 in order to understand the effects of acidic conditions on soil erosion.

2. Method

Simulated topsoil was prepared based on soil properties in the waste dump in A coal mine in Indonesia. The physical properties of the simulated soil was investigated after adjusting soil pH to acidic conditions, followed by the artificial rainfall test with the simulated soil samples.

3. Changes in Physical Properties of Soils under Acidic Conditions

Simulated soil mainly consisted of quartz, kaolinite, montmorillonite, and illite based on the result of XRD analysis. This simulated soil was adjusted to different soil pH with H_2SO_4, and it was used for atterberg limits test. The result showed that W_P, W_L, and I_P declined with the decrease of soil pH from 6.0 to 2.0. Besides, particle size of simulated soil increased with the decrease of soil pH based on the result of particle size distribution test. Thus, the decrease of soil pH led to the increase of particle size of simulated soil along with the decline of atterberg limits.

Furthermore, zeta potential of simulated soil increased with the decrease of pH from 6.0 to 2.0.

This suggested that pH-dependent charge of soil particle edges became positive, resulting in the attraction between positive and negative permanent charge.[8, 9] The aggregation of soil particles due to the attraction caused the increase of particle size of simulated soil. Moreover, it would appear that dissolved Al^{3+} derived from clay minerals caused aggregation of soil particles as an aggregating agent, leading to the increase of particle size of simulated soil. In short, the decrease of soil pH caused the change in physical properties of soils with the decrease of atterberg limits and the increase of particle size.

4. Soil Erosion with the Change of pH

In the standard of soil erosion in Indonesia, the risk is very low when soil loss (cm/year) is < 0.15, low when it is 0.15 - 0.9, moderate when it is 0.9 - 1.8, and high when it is 1.8 - 4.8.[10] In the results of the artificial rainfall test, annual soil loss gradually increased with the decrease of soil pH. Since the cohesive strength between soil particles was low due to low consistency limit caused by aggregation of soil particles as described above, simulated soil was easily eroded by simulated rainfall. The risk of soil erosion was classified into moderate when soil pH was 6.0; however, the risk was classified into high with the decrease of soil pH. This suggested that soil erosion may occur over time with soil acidification even if the risk of soil erosion is categorized into low. In regards to acid generation from sulfide minerals in waste rocks in mines for a long term, soil acidification over time may result in soil erosion during the operation.[11] Therefore, a regular monitoring for soil conditions is required to prevent soil erosion in the area where soil acidification possibly occurs such as in the waste dump and in pit in mines.

5. Conclusions

Since the erosion rate of soils greatly depends on physical characteristics of soils, the relation between the change of physical properties of soils caused by soil acidification and soil erosion has to be considered for erosion control in mining area. In this study, physical properties of the soil samples in which the soil-pH was adjusted to acidic conditions with H_2SO_4 were measured, followed by the artificial rainfall test with the samples in order to understand the effect of acidification of soils on erosion rate.

With the decrease of soil pH, atterberg limits of simulated soil sharply declined and the particle size increased in this study. Positive charge of soil particle edge with soil acidification caused the attraction between positive and negative permanent charge, leading to the result. Moreover, dissolved Al^{3+} derived from clay minerals in simulated soil under acidic conditions possibly caused aggregation of soil particles as an aggregating agent, resulting in the increase in particle size of simulated soil. Additionally, since the cohesive strength between soil particles decreased due to low atterberg limits by aggregation of soil particles with the decrease of soil pH, simulated soil was easily eroded by simulated rainfall in artificial rainfall test. Hence, soil acidification should also be prevented for the measures against soil erosion in mining area.

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Email: matsumoto11r@mine.kyushu-u.ac.jp