Effects of a capillary zone on water movement in a soil column with tailings

Gil Jae Yim, Young Wook Cheong, Dae Sik Min, Sang Woo Ji

Korea Institute of Geoscience & Mineral Resources(KIGAM), Korea, gjyim@kigam.re.kr

Abstract This study was performed to understand the variation of water contents, conductivities and capillary phenomena in artificially constructed columns with tailings, a capillary break and a soil cap. Infiltration of rain and rise of groundwater through the synthetic column were induced and effects measured by sensors. Therefore, if the chemical properties of the mine wastes is expected to potentially produce acid, an appropriate capping system must be applied to prevent rainwater infiltration.

Key Words capillary zone, tailings, soil column, water contents

Introduction

The primary objective of a capping system is to prevent the formation of leachate caused by surface water infiltration, and to minimize the oxidation of wastes due to the import of oxygen from the atmosphere. In addition, the capping system is expected to keep the dumped wastes from being washed away as a result of erosive action, and to prevent flying dust. It also functions to promote the growth of vegetation.

Factors affecting the design of a capping system include climate conditions, nature and type of mine wastes (i.e. rock waste or tailing), hydrogeological conditions, and underground water conditions. The design process of a capping system usually proceeds from very simple to a more complex system, evolving progressively.

Research published previously suggests to evaluate the performance of a capping system and the successful permanent enclosure of mine wastes by measuring climate factors such as the amount of rainfall and temperature and the water distribution in the mine wastes (Wels et al., 2003; Massmann and Farier, 1992; Lefebvre et al., 2001; Smolensky et al., 1999).

The objectives of this study were to determine effects of a capillary break on 1) water content and conductivities in a soil column with tailings, and 2) capillary phenomena in artificially controlled multi-layered systems with a capillary break layer.

Methods

10 samples of tailings from 7 mines across the country were collected for a soil analysis. This analysis was done complying with KS norms. Tests items included plastic limits (KS F 2303) and shrinkage (KS F 2305), density (KS F 2308) and the analysis of particle size (KS F 2302). Laboratory testing was done to ascertain both the static capillarity and the dynamic infiltration of rainfall depending on the thickness of the cap.

Capillarity was measured utilizing the soil cylinder in which artificial tailings were placed on the bottom and then capped with soil. Infiltration was measured by installing Volumetric Water Content (VWC) sensors at regular intervals and soaking the column with water, so that it maintained a fixed supernatant level of water.

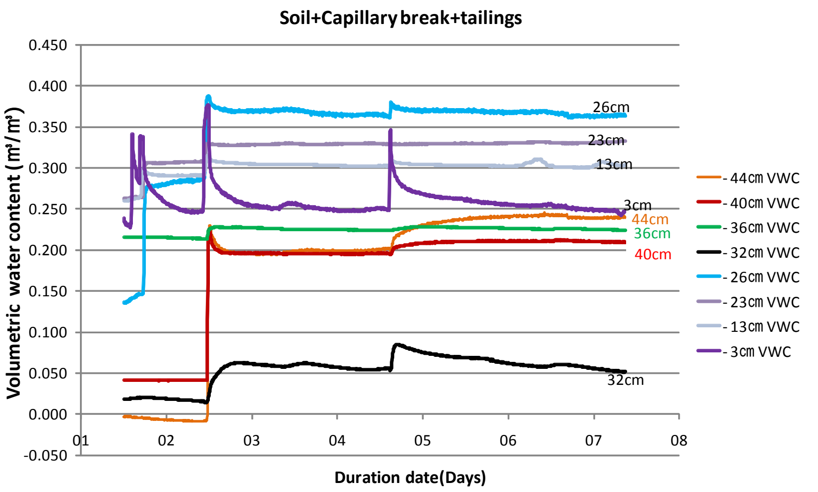
The factors considered in this study were slope, depth, grain size of soil layer and infiltration (volume and frequency of addition of water). Volumetric Water Content (VWC), electric conductivity and temperature were monitored in each column layer. Sensors (ECH2O-TE, Decagon Devices, Pullman, WA) installed were 4 centimeters apart vertically. A preliminary experiment using tailings and distilled water was used to determine sensor response. Density, plasticity index and grain size distribution were determined in the laboratory using standard methods on tailings samples taken near where the sensors were installed. Rainfall infiltration tests were conducted by forming layers of tailings, capillary break and of soil to find out the extent of water distribution and the role of the capillary.

Results and Discussion

Most of the tailings showed characteristics lacking liquid and plastic properties because of a high percentage of sand (Tab. 1). The average grain size (D_{50}) of 10 tailings collected from 7 mines was 0.2 mm (fine to medium sand).

Table 1 Physical properties of tailings (weight %)

Tailing	Liquid limit (%)	Plastic limit (%)	Shrinkage limit (%)	Density (Specific gravity)	Gravels d>0.075 (mm)	Sand d 0.075-2.00 (mm)	Silt & Clay d<2.00 (mm)
Keumjang Mine A	Non-plastic		23.41	2.82	0.00	99.51	0.49
Keumjang Mine B	26.54	22.35	24.29	2.78	0.00	80.74	19.26
Keumjang MineC	Non-plastic		22.80	2.75	5.31	82.68	12.01
Yeonhwa Mine (Jiknaegol)	Non-plastic		20.42	3.12	0.00	74.70	25.30
Yeonhwa Mine (Jiknaegol oxidized)	Non-plastic		19.28	3.23	0.00	81.35	18.65
Jangkun Mine	Non-plastic		18.02	3.13	9.38	77.46	13.16
Okbang Mine	Non-plastic		18.23	2.82	0.00	87.65	12.35
Junju1 Mine	Non-plastic		17.56	2.63	7.60	84.43	7.97
SSangjeon Mine	Non-plastic		16.62	2.78	0.00	84.52	15.48
Samkwang Mine	Non-plastic		17.02	2.72	0.22	87.66	12.12



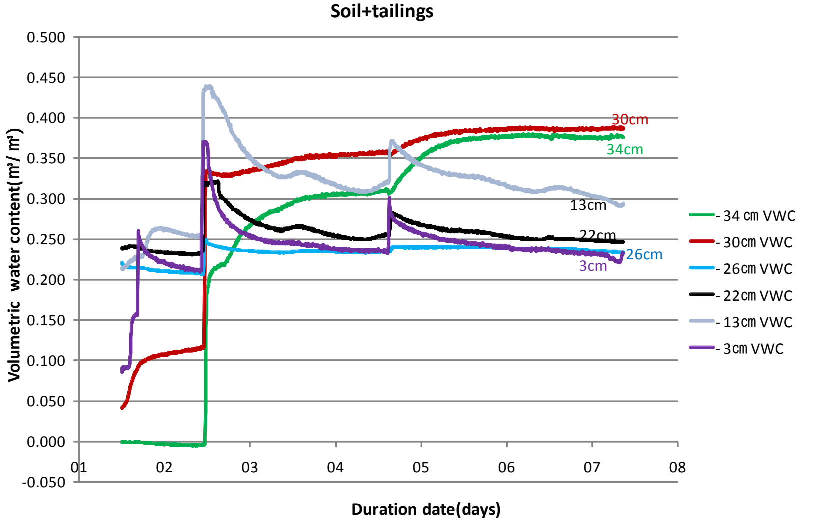


Figure 1 *Water content sensor response in a tailings to suction(simulated bottom) of distilled water(a:3 layers, b:2 layers)*

Figure 1 records changing water contents in the system which contains tailings, a capillary break layer and soil cover (three layers, a) and the case of a simple soil cap above tailings (two layers, b).

During infiltration, water content in the soil cap above tailings without a capillary break (Fig. 1b) increased. VWC in the layer of tailings rose to 0.36% as water flowed into the tailings.

In the capping system containing the capillary break layer (Fig. 1a) water contents of the soil cap increased similar to those of case 1b, but water in the tailings remained at 0.098%, indicating that water flow into tailings was inhibited by the capillary break. This proved that the capillary layer of the capping system not only shut out the water flowing from the bottom of the tailings but also keep the rainwater from flowing into the lower part of the system, thus playing a vital role of draining water out of the system by means of a slope of the capillary layer.

Conclusions

Mine wastes may cause death to vegetation by producing salt at the top layer of the tailings heap as a result of capillarity caused by granularity characteristics, rainwater permeation and evaporation. In particular if the chemical properties of the mine wastes is expected to potentially produce acid, an appropriate capping system must be applied to prevent rainwater infiltration.

Water passed through the soil cap of the two-layer system (soil/tailings) whereas the three-layer systems containing capillary break layers displayed very small water contents of the tailings.

Based on such findings it is believed that the capillary break layer in the capping system not only prevents the water flowing into from the bottom of the tailings but also keeps the water from rainwater infiltration from moving into the mine waste layer and effectively shut out air and water from the reactive mine wastes.

VWC measurements revealed that, in general, the water front had migrated or risen vertically through the fine soil column, depending on the water addition method, but water in the capillary barrier only passed through the fine soil and had not migrated further. The capillary zone with coarser grain can prevent the deep infiltration of rain and the rise of salts from mine wastes to the surface. In conclusion, since a coarse low-capillarity zone can break the vertical movement of water, capping systems with a capillary barrier may be used as an alternative method for reducing issues of acid rock drainage around mine waste piles.

Acknowledgements

This research was supported by the Basic Research Project of the Korea Institute of Geoscience and Mineral Resources (KIGAM) funded by the Ministry of Science and Technology of Korea.

References

Lefebvre, R., Hockley, D., Smolensky, J. and Gelinas, P. (2001) Multiphase transferprocesses in waste rock piles producing acid mine draiange 1: Conceptual model and system characterization, Journal of contaminant hydrology, 52:137—164.

Massmann, J.W., and Farier, D.F. (1992) Effects of atmospheric pressures on gas transport in the vadose zone, Water Resources Research, 28(3):777—791.

Smolensky, J., Hockley, D., Lefebvre, R. and Paul, M. (1999) Oxygen transport processes in the Nordhalde of the Ronnenburg mining district, Germany, In Proceedings mining and the environment II 1999, Sudbury, Ontario, Canada, p 271—280.

Todd, D. K. (2007) Groundwater Hydrology, 2nd Ed., John Wiley & Sons, Inc., India, 535pp.

Wels, C., Lefebvre, R and Robertson, A.M. (2003) An overview of prediction and control of air flow in acid-generating waste rock dumps, In proceedings 6th International Conf. on Acid Rock Drainage, Australasian Inst. of Mining and Metallurgy, Cairns, Australia, p 639—650.