学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

pH-dependent leaching of arsenic from shield-tunneling excavated soils and its countermeasures
(シールド工法によって掘削された土壌からのヒ素溶出の pH 依存性とその対策)

Underground facilities have become common in most developed countries. In recent years, it is also becoming more common in developing countries to fulfill the demand of utilization of underground space due to rapid population growth and urbanization. A number of various purposes of using underground facilities such as subway, new bullet/high speed train routes, hydro-electric powerplants, shopping malls, parking spaces and sewer/utility systems have been reported. In order to build these kinds of facilities, tunnel excavation is important and the first step. Meanwhile, tunnel construction in soft alluvial deposits is generally done using the shield-tunneling method, a technique that requires the mixing of cementitious materials with excavated soils to reinforce and stabilize the excavated tunnel walls. Although the mechanical properties of soft soils and sediments are improved after introduction of cementitious materials, this process could increase the pH of these geological materials and mobilize naturally occurring arsenic (As). In other words, shield-tunneling excavation could create favorable conditions for As leaching. However, how cementitious materials addition releases As from shield-tunneling excavated soils is not well understood. In the present study, therefore, the effects of cement addition on As leaching from the excavated soils were clarified. Understanding As leaching behaviors helps better finding out the solution against As leaching. The countermeasures of As leaching by adding adsorbents were then investigated. Finally, the outcomes of the present study provide helpful information on management of these alkaline excavated soils. The dissertation contains five chapters.

In chapter 1, As contamination in soils, geochemistry of As in environments, the removal of As, and shield-tunneling excavation are briefly reviewed and introduced.

There have been a number of publications on the characteristics of As leaching from soils, rocks, or industrial wastes. However, these studies focused on soils, rocks, or materials other than shield-tunneling excavated soils, or the characteristics of As leaching from rocks/soils versus pH by changing the pH with hydrochloric acid (HCl) and sodium hydroxide (NaOH). In other words, the effects of pH on As leaching from shield-tunneling excavated soils by cement addition is not well understood. Therefore, chapter 2—literature review chapter—will give a brief summary of the recent studies regarding the As leaching characteristics, and the necessities and the objectives of the present study are then depicted.

In chapter 3, the effects of cement addition on As leaching from tunnel-excavated soils naturally contaminated with As were investigated. Sequential extraction experiments were also carried out to determine the chemical forms, solid-phase partitioning and leachability of As in the soils. In the absence of cement, sequential extraction showed higher As leaching from the soils when the exchangeable As fraction and total As content increased. In contrast, As leaching increased up to pH 10.3 and then decreased at higher pH values when cement was added. This trend was observed irrespective of the soil samples, which indicates that pH adjustment is an important countermeasure in restricting As leaching from excavated soils. The results of attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) showed slight changes in the chemical properties of soils due to cement addition but the chemical phases of As remained unchanged.

After identifying the effects of cement addition on As leaching from soils excavated by the shield-tunneling method, the countermeasures against As leaching should carefully be considered, which was presented in Chapter 4. One of the convenient methods is to add an adsorbent. Among potential adsorbents, magnesium oxide (MgO), half-burnt dolomite ($MgO.CaCO_3$), and iron oxide (Fe_2O_3) are considered as economical and easily available adsorbents. However, their performance on removal of As released from the soils is not well understood. Therefore, the performance of the adsorbents was evaluated by leaching experiments. The results showed that all of the adsorbents used at the ratio of less than 1% compared with soil worked effectively in restricting As leaching and that the performance of the three adsorbents was almost the same. These imply that As leaching is restricted by adding the adsorbents. ATR-FTIR was also applied to observe the changes in chemical bonding of soil with and without adsorbents. The results showed that a slight change in the chemical bonding of soil was detected in case of half-burnt dolomite addition whereas that in case of magnesium oxide and iron oxide addition remained unchanged.

Chapter 5 summarizes all general conclusions of the present study. The results could provide the fundamental knowledge of the management of these alkaline excavated soils.