学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（工学）　　氏名　中村　晋作

学　位　論　文　題　名

Study on dispersion of lead-zinc-bearing mine wastes by considering local weather conditions and waste properties in the Kabwe mine, Zambia
(ザンビア国カブウェにおける気象条件および鉱滓性状を考慮した鉛・亜鉛系鉱山廃棄物飛散に関する研究)

Mining is a key industry in Zambia. Lead (Pb), zinc (Zn), cobalt, and copper were mined and smelted in Kabwe, Zambia between 1902 and 1994. Mine tailings from these activities have been littered at the dumping site, and it has huge impacts on environmental and human health issues through heavy metal contamination. Impacts and circumstances have been studied and analyzed, but the mechanisms of heavy metal dispersion and deposition by the local weather factors in Kabwe have not been evaluated well. In this study, for elucidating the mechanisms of heavy metal dispersion by winds and other weather conditions, dispersion models were designed and applied to the Kabwe mine. Environmental factors, such as local weather data and water condition in soils were analyzed for understanding their own impacts on the heavy metal contamination in Kabwe.

In Chapter 1, the importance, methods, and the study site for evaluating mechanisms of heavy metal dispersion and deposition were described through discussion on environmental impacts and issues by heavy metal contamination in Kabwe by introducing the background of mining activities and current situations of heavy mental contamination and its impacts on human health especially children and infants.

In Chapter 2, dispersion of Pb-bearing tailings (ISF slag) was simulated for reproducing Pb contamination of soil in Kabwe. Local weather data of year 2019 were monitored in situ and used for the simulations. The plume model, weak puff model, and no puff model were adopted for calculation of Pb dispersion under different wind conditions. The results showed that Pb dispersion from the Kabwe mine was directly affected by wind directions and speeds in the dry season, although it was not appreciably affected in the rainy season. This may be because the source strength is lower in the rainy season due to higher water content of the surface. This indicates that Pb-bearing soil dispersion patterns depend on the season. In addition, the distribution of the amount of deposited Pb-bearing soils around the mine corresponded to the distribution of measured Pb contents in soils. These results suggest that Pb contamination in soils primarily results from dispersion of mine tailings, in particular finer wastes.

In Chapter 3, the effects of local weather factors on mechanisms of heavy metal contamination were analyzed based on the results in Chapter 2. Weather in Kabwe was calm through the year, but there were significant differences of solar radiation, barometric pressure, humidity, and air temperature between rainy and dry seasons. Correlation between wind speed and solar radiation was inversely proportional, and affected the accumulated amounts deposited by simulations. Although high wind

speeds had huge impacts on Pb-bearing tailings dispersion on the playground in shorter distance from the source, high and low wind speeds did not affect the accumulated amounts deposited at certain distances from the source. Wind directions had large impacts on dispersion and deposition areas. These results indicate that not only wind speeds and directions but also complicated relationships among weather factors cause Pb-bearing mine tailings dispersion and deposition.

In Chapter 4, for evaluation of dispersing situations and impacts of ponding water at Pb-bearing Zn plant leach residue site, which is often found in the mine throughout a year, simulation of Pb dispersion from the plant leach residue site was performed with modified normalized difference water index (MNDWI) under the actual weather conditions in year 2019. The MNDWI was demonstrated by data analysis of Sentinel-2 datasets, which were acquired in year 2019. The index was an indicator for monitoring the soil condition of the source and it is one of parameters necessary for estimating Pb dispersion. Ponding water is an effective inhibiting factor on windborne Pb dispersion. Wind speeds and directions had large impacts on windborne Pb dispersion when MNDWI indicated negative values. Analyzing and understanding environmental conditions that can be factors for windborne Pb dispersion are crucial for countermeasures on Pb dispersion and remediation of soil contamination.

In Chapter 5, all results in this dissertation were summarized, and the expected practical utilization of the results and methods were proposed.