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　Cryton Phiri

学 位 論 文 題 名

Understanding of geochemical partitioning and surface complexation modeling of heavy metals during treatment of mine drainage for green mining: Case study of the Zambian Copperbelt
(グリーンマイニングのための廃水処理中の重金属分配の理解と表面錯体モデリングーザンビア国カッパーベルト地帯を例にー)

The metalliferous Zambian Copperbelt mining district which straddles along the frontier with the Democratic Republic of Congo (DRC), is famous for hosting large deposits of copper (Cu) and cobalt (Co) sulphide ore mineralisation of Central Africa. As a result of ore beneficiation, volumes of sludge effluents are generated and later stored as sludge deposits at large sectional areas of ponds and impoundments after the sedimentation process. During periods of heavy rainfall, surface erosion at storage facilities causes stream and river siltation resulting in subsequent non-compliance metal concentration discharges into the nearby surrounding environments. This condition, therefore, suggests that the sludges exhibit high potential to be of negative legacy in Zambia. In order to (i) minimise the generation of sludge volumes, (ii) reduce or minimise on the environmental contamination and (iii) to promote their recycling and reuse, understanding of geochemical partitioning and surface binding of heavy metals during treatment of mine drainage is unambiguously important for green mining.

Chapter 1 introduces the research background and problem statements. The targeted objectives were to: (i) investigate the physio-chemical and geochemical factors influencing metal partitioning onto sludge at solid-liquid interface, (ii) predict the geochemical behaviours of the contaminants with the host mineral surfaces and (iii) discover ways that the Zambian Copperbelt mining industry can reduce environmental impacts from sludge and make its practices more sustainable.

Chapter 2 reviews the literatures of surface complexation modeling (SCM) prediction of Cu and Co metals with the mineral surfaces such as kaolinite and hydrous ferric oxide (HFO) present in the sludges during treatment. These minerals are reportedly responsible for controlling the mobility of metals in natural systems and in the studied sludges. Based on the use of the available diffuse double layer modeling database and of previous literature, metal behaviours with the complex natural materials are easily predicted and understood.

Chapter 3 gives a brief background of the geology of the Zambian Copperbelt including the host minerals and dominant mineable ores. Site characteristics, target sampling points such as the drainages and storage ponds are described. The sampled materials in drainages were sludge effluents along the drainage course and solid sludge both along the drainage course and at storage ponds. The sampling protocols, onsite data collection, kinds and types of onsite field samples at each sampling site are described.

Chapter 4 discusses the physical and chemical partitioning of the metals (i.e., Cu and Co) with the host minerals in effluents and with the solid deposits. The differences in metal concentrations between

the dissolved and suspended solid particles were envisaged including the effects of lime treatment to drainage effluent. The chemical partitioning of metal onto sludge was generated by the eight steps chemical extraction sequence, with results showing the metals to be mostly partitioned in the labile fractions associated with anthropogenic mining related activities.

Chapter 5 focusses on the outcomes of batch adsorption experiments and metal binding behaviours at solid-liquid interface. Batch experiments revealed adsorption to be the main metal retention mechanism. Through SCM simulations, the effects of metal competition and the resultant concentrations of the metal binding sites onto kaolinite and HFO surfaces were revealed. Simulations by model predictions indicated that the metal binding surfaces were of loose and weak binding behaviours suggesting that the metals are potentially easily releasable and susceptible to high mobility conditions, thus indicating that the metal stability conditions in sludge is probably of a short-term condition especially under decreasing pH and changes in the reduction-oxidation conditions.

Chapter 6 discusses ways of making the Zambian Copperbelt mining activities more sustainable through the green mining concepts based on the studied sites and sludge characteristics. In this chapter, discussion on the lower impact mining techniques (i.e., heap/dump leaching), reusing mining waste (i.e., for backfilling surface mining open pits, for reconstructing mined terrain in a way that prevents soil erosion) and for making aggregates (e.g. sand) in construction engineering and rehabilitating mining sites (i.e., use of waste for land reclamation or fill in excavated areas) are emphasised

Chapter 7 highlights the research contributions, conclusion and recommendation. Although the study discussed and recommended the sustainable mining research technologies that might seem economically viable, however, the onus is on the mining industry as a whole to implements them, and so far, does seem to be moving in the direction of sustainability.