CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Mining activities generally could generate substantial amounts of wastes that later contaminate from contamination sources (i.e., tailing ponds, waste rock damps) through surrounding soils and aquifer subsurface systems, causing adverse impacts on the environment and health effects in animal and human. Due to high toxicity and non-degradability of heavy metals, therefore the leaching and transport of heavy metal through soil are crucial for better understanding their behaviors. This study consists of three parts. Firstly, metal analysis of mill tailings and a series of batch and column desorption experiments under different pH conditions were conducted to estimate amounts of heavy metals in tailing and investigated sorption/ desorption behaviors leached from tailing under different pH conditions. Secondly, column studies for four metals (i.e., Pb^{2+} Zn^{2+}, Ni^{2+}, and Mn^{2+}) under pH 4 and 5 and their modeling were employed to investigated effect of pH on sorption and transport of these heavy metals. Finally, column studies of these heavy metals in binary and multi-metal systems were further employed to explain the simultaneous metal effects on metal transport and to describe observed data using different sorption approaches.

The results of metal analysis according to EPA Method 3051 showed that most of the metals found in the tailings, which collected from the TSF in the Akara mining area, did not exceed the soil standards for habitat and agriculture; Mn was the exception. The batch desorption experiments showed that a significant leaching of metals occurred for pH less than neutral (at about 5-6), indicating mobility of heavy metal increased under acidic condition. According to the column desorption experiments, indicating that some of potentially toxic metals leached from the tailings column exceeded the industrial effluent standards, especially those metals leached under acidic condition. Moreover, the batch and column desorptions showed that Mn and Pb was the highest and lowest mobility metals leached from tailings. This result was in agreement with concentration of Mn founded relatively high from UD and SP monitoring wells (shallow groundwater wells) located underneath the tailing storage facility. As for the mobility of metals released from tailings, their mobility could be described in the following order: Mn > Ni > Zn ~ Pb. This observation probably described by the competition between metals and proton in the aqueous solution and characteristics of their solubility values at different pH conditions.

According to previous researches, pH is one of the most significant factors on the sorption behavior of heavy metals onto soils. Therefore, in this study, the column experiments were performed to investigate sorption and transport of heavy metals under different pH conditions (pH 4 and 5). Retardation factor values and sorption capacity of these heavy metals at pH 5 were higher than at pH 4, causing amount of proton (H^+) competing with heavy metal ions onto lateritic soil at pH 4 was higher that at pH 5. Pb^{2+} pronounced the highest sorption capacity and retardation factor values under both pH 4 and 5. The bromide breakthrough curves showed symmetrical shape and optimized parameters obtained from two region model, suggesting that the absence of significant physical nonequilibrium or no stagnant flow in these soil columns. However, Due to the asymmetrical shape of heavy metals breakthrough curves with long extended tailing under pH 4 and 5, probably suggesting the evidence of chemical nonequilibrium during heavy metals transport through lateritic soil. In order to describe the behavior of heavy metal transport, we applied the prediction approach using batch sorption parameters obtained from previous study (only at pH 4) and fitted the observed data with the local convection-dispersion equilibrium model with linear and nonlinear(Langmuir) isotherm, and nonequilibrium model (Two-site model, TSM). The two-site model (TSM) gave the lowest sum of square errors (SSE), indicating that chemical nonequilibrium presented during displacement of heavy metals through lateritic soil. However, TSM does not describe well the extended tailing of observed data. That might be the rate of sorption/desorption of lateritic soil could not be described by first-order rate constant.

In order to understand sorption and transport under simultaneous presence of heavy metals through lateritic soil, column studies with the binary and multi-metal system were employed. The sorption capacity and retardation factor values of individual heavy metals in binary and multi-metal system was decreased, when comparing with those in single metal system. Due to the competition between/ among heavy metals in binary and multi-metal systems, the reduction of sorption capacity of individual metal was explored. This agrees with decreasing of retardation factor values of individual metals in the mutual metal system. Moreover, although the total sorption capacity of heavy metals in binary and multi-metal systems was nearly the same (~ 0.13 mM g^{-1}), but individual metal sorption was decreased when comparing with single metal systems due to metal interaction and competition for available sorption site. For column studies with binary and multi-metal systems, the observed breakthrough curves pronounced the asymmetrical shape, suggesting that chemical nonequilibrium presence in these column studies. To explain heavy metal transports in binary and multi-metal system, the local equilibrium convection-dispersion and nonequilibrium models were applied. In the similar results in single metal systems, the two-site model (TSM) fitted the experimental breakthrough curves better than local equilibrium convection-dispersion model for both binary and multi-metal systems. The TSM could describe well the rising limb and initial decreasing limb of the BTCs, but could not describe the extended tailing of the BTC. It is possible that more than one type of kinetic site must be considered in addition to the instantaneous sorption sites. This was not accounted for in the two-site model, and it needs to be estimated further for better description of heavy metals transport in this soil.

7.2 Recommendation

1. Groundwater monitoring wells should be carefully installed to monitor and evaluate the potential contamination from this gold mining site, even after mine site has been closed.

2. To more accuracy in describe heavy metal transports, the more complex models, for example, two or three sites kinetic sorption models should be further studied.

3. In real field conditions, many processes, for examples, physical (i.e., transient water flow), chemical (i.e., precipitation and dissolution of Fe-oxide) and biological processes affect to heavy metal transport. Therefore, future work should be to elaborate heavy metal transport under the real field as well as lysimeter experiments to provide better understanding for heavy metal transport.

4. There is a potential accumulation of heavy metal leachate in surrounding areas and is possible to contaminate to subsurface aquifer. The further study should be performed for site remediation approaches.