CHAPTER I

INTRODUCTION AND OBJECTIVES

1.1 Rationale

Mining activities generally generate substantial amounts of wastes that may become problematic for the environment and human health. Many studies have shown that potentially toxic metals, released from mine wastes, can lead to adverse impacts on the environment, and adverse health effects on animals and humans (Protano and Riccobono, 1997; Macro et al., 2002; Passariello, 2002; Ramirez Requelme et al., 2002; Lottermoser, 2003; Abut et al., 2003). Although the metal pollutants such as lead, zinc and nickel may be at trace quantities they can be toxic to organisms and humans when exposed over a prolonged period of time. In addition, the toxic metals are persistent and can accumulate in the environment for decades to millennia. An example of pollution from mining is the gold-mining activities in Brazil, where mercury is used to concentrate the gold. These activities have resulted in high concentrations of mercury in sediments and fish with long-term consequences owing to cycling of the metal in tropical aquatic and forest systems (Salomons, 1995). The long term effect is shown by the presence of medium to high amounts of mercury in soil and sediments of the Nambija Mineral District, located in the southeastern part of Ecuador, in the Ecuadorian Amazon. Another example is an abandoned mining district located in southern Tuscany, Italy where soils were found to contain as high as 100 mg kg^{-1} of Hg (100 mg kg^{-1}), 2000 mg kg^{-1} of As (2000 mg kg^{-1}) and 200 mg kg^{-1} of Pb (200 mg kg^{-1}) affecting the water quality downstream of the mine area (Marco et al., 2002).

Another serious problem facing the mining industry is the vast masses of mine tailings. The current amount of mine tailings is forecast to double over the next 20 to 30 years (Aswathaarayana, 2003). With acid mine drainage conditions at many mines, the transport of potentially toxic metals is accelerated. Consequently, mine tailings may be a major source of pollutants released into subsurface environment. Additionally, the severity of the negative environmental effects associated with a tailing impoundment may not be evident until long after the mine closure and the tailings impoundment decommissioned (Blowes, 1997).

In the past, many researchers have conducted batch and column experiments to investigate the sorption and transport of single heavy metals through soils (Kookana and Naidu, 1997; Nedunuri et al., 1998; Leitao et al., 2000; Seuntjens et al., 2001; Miretky et al., 2006). At most contaminated sites such as a mine tailing impoundment facility, several metals are released simultaneously into the subsurface. Therefore, it is important to understand the retention/release of a specific toxic metal in the presence of other metals in the system. Moreover, many mine soils when removed from the subsurface, are rapidly oxidized and become acidic, leaching large quantities of cations such as calcium, manganese, and iron. In recent years, many studies have focused on the competitive sorption of heavy metals in soils under equilibrium conditions using batch sorption technique (Gutierrez and Fuentes, 1991; Srivastava et al., 2005; Serrano et al., 2005, Arias et al., 2006). However, there are very few studies investigating the transport of simultaneous presence of heavy metals in soils using continuous flow column technique with mine soils. Use of column experiments provide a better approximation of field conditions and provide information such as dispersivity effects and non-equilibrium sorption which are not assessed using equilibrium batch experiments (Plassard et al., 2000; Miretzky et al., 2006).

There is a need to understand the leaching/desorption of metals from and sorption of metals onto mine tailings and investigate the movement of these heavy metals in mine soils under different environmental conditions such as pH, and initial concentration of metals and cations to assess the risk and impact of the leached metals on the environment. To accomplish these objectives, a systematic characterization of the mine tailings including metal analysis and batch sorption/desorption, and column desorption experiments of mine tailings are needed. In addition, column studies investigating the transport of one or more metals for various pH conditions in mine soils will provide data on the simultaneous transport behavior of heavy metals and possible competition for sorption sites. There is a need to understand the transport behavior of these heavy metals under environmental conditions using various models such as linear/nonlinear or equilibrium/nonequilibrium models. Sorption and transport parameters estimated using these models will provide more accurate prediction of the heavy metals migration from these sites and assist in selection of appropriate strategies in remediating/monitoring the contaminated site.

1.2 Objectives

The overall objective is to investigate the effect of simultaneous presence of various metals and pH conditions on the sorption and transport of potentially toxic metals in lateritic soils beneath the mining site.

The specific-objectives are as follows:

1. Characterize the physical-chemical properties of mine tailings from Akara Mining area and estimate the amounts of metals desorbed/leached from the tailings under different pH conditions.

2. Investigate the transport of single heavy metal in column studies using lateritic mine soils for different pH conditions.

3. Investigate the transport of primary heavy metals in the presence of other heavy metals in column studies containing lateritic soils.

4. Determine the effects of pH, metal types, and initial concentrations of the tested metals on primary heavy metals transport in lateritic soils.

5. Assess the sorption and transport behaviors of heavy metals under different environmental conditions in lateritic soils using linear/nonlinear and equilibrium/ nonequilibrium modeling.

1.3 Hypothesis

The hypothesis guiding this research is that the simultaneous presence of metals leaching from mine tailings and the pH of the aqueous phase will decrease/increase metal sorption onto soil and the migration of metals through the aquifer materials due to competition among metals for the available sorption sites on the lateritic soils.

1.4 Methodology

This study is divided into 3 parts:

1. Conduct field survey, soil and tailings sampling, metal analysis of lateritic soil to obtain background concentrations and chemical analysis and batch leaching studies of metals from mine tailings.
2. Analyze physico-chemical properties of lateritic soil and conduct column transport studies for each metal under different pH conditions to estimate sorption parameters for various pH conditions.
3. Conduct column transport studies for two or three metals to study the effects of the presence of other metals and their concentrations on sorption and transport of heavy metal.

1.5 Site Description and Research Assumption

The Akara mining site is located about 280 km north of Bangkok in Phichit Province, central Thailand. This mining site comprises of two open pits, a processing plant to crush and mill the ore before passing to carbon in the leaching technology to extract the gold. A storage facility has been designed to safely store the tailings. The tailing storage facility is located on the southern portion of the site and . covers an area of approximate 320,000 m^2.

Shallow groundwater level in the surrounding area conforms to the surface topography. A north-south orientated hydraulic groundwater divide is located through Khao Mo and Khao Pong. Natural groundwater movement appears to flow from the northwest passing through the C-H mining pit and tailing storage facility to southwest area (Figure 1.1) (URS, 1999). The shallow wells in the villages are mainly located in the lateritic layer between 1.5 to 7 metres below ground level which is the main shallow unconfined aquifer. This aquifer has approximate groundwater yields of 0.4 to 0.5 litres per second (1,500 to 2,000 litres per hour) (URS, 1999). The soil profile can be generally divided into 3 layers (i.e., top soil, lateritic soil and thick clay layer). The thickness of the top soil layer for the whole area vary from approximately 20 to 40 cm.

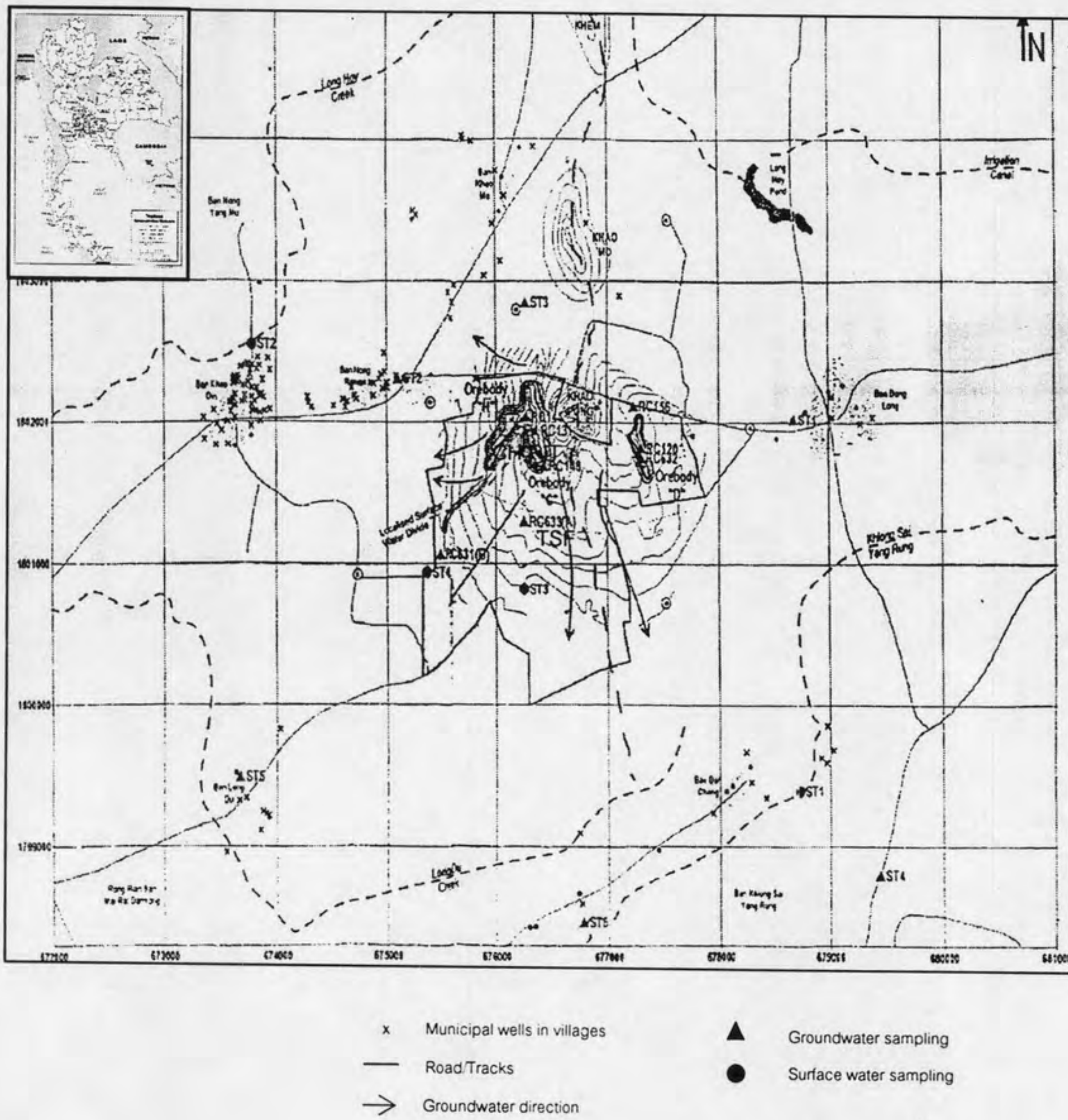

Figure 1.1 Direction of shallow groundwater flow around the Akara mining site and adjacent area (from URS, 1999)

Lateritic soil layer beneath the top soil is the main taget of shallow ground water under this study. The thick clay layer beneath the lateritic soil appears to be bottom cap of the shallow groundwater and its thickness varies from 6 to 20 m. The average groundwater levels in the mining site and adjacent areas vary between 4 to 6 metres beneath the surface.

For this study, it was assumed that there is leakage of heavy metals under acidic condition from the tailing storage facility through the cracked clay liners with the possibility of migration of heavy metals in the shallow groundwater system.

1.6 Organization of Dissertation

The dissertation is organized into six chapters with the Introduction and Objectives and the Literature Review in Chapters 1 and 2, respectively. The Literature Review is followed by three chapters that contained three manuscripts prepared for publication in international journals. Each chapter addresses the specific objectives listed above with Chapter 3 describing the metals leaching experiments from mine tailings, Chapter 4 describing single metal column studies in lateritic soils and Chapter 5 describing multiple metals column studies in lateritic soils. Finally, application of the sorption and transport results for various field scenarios is given in Chapter 6 and the general conclusions and recommendation are presented in Chapter 7.