CHAPTER I
INTRODUCTION

Sanitary landfill is the most common method of disposal of solid waste all over the world and is the oldest and the most popular ultimate disposal option. Most of our household waste and non-hazardous industrial waste disposed of in municipal solid waste (MSW) landfills contain a mixture of many chemical compounds originating from the various discarded products. Batteries, paints, dyes and inks on paper, pesticides and fertilizers in yard waste are examples of household and commercial wastes, which contain high quantities of heavy metals. A number of these chemicals are released during the lifetime of the landfill and result in released of heavy metals to the environment. Thus, an unknown number of toxic substances (organic, inorganic and colloidal) will be present in the landfill leachate, where they constitute a potential risk to the quality of receiving water bodies (e.g. surface water or groundwater), when the leachates are released into the environment (Buan et al., 2004).

Considering heavy metals in landfill leachate, in general some heavy metals are beneficial, necessary elements whereas some of them are toxic to the growth and development of organisms. When their content exceeds the background value of the element, it will result in pollution by the heavy metals, causing soil quality to decline and the ecological environment to deteriorate. They cannot be decomposed and their mobility is very low, so it is easy for them to accumulate in soil and in organisms, especially as some of them being transferred to the methyl form which is more toxic and could affect the quality of agricultural products, get into the food chain and threaten human health (Yuan et al., 2006).

The major environmental problem experienced at landfills is the loss of leachate from the site and the subsequent contamination of soil, surface and groundwater (Barker et al., 1988). It can take years before groundwater pollution reveals itself; and chemicals in the leachate often react synergistically and often in unanticipated ways to affect the ecosystem (Lee, 1996). Waste containment and remediation problems require an understanding of the physical and chemical characteristics of the subsurface and the ability to engineer pollution control and removal of contaminants (Sharma and Reddy, 2004).

1.1 Background Information

Khon Kaen province has been set to be the center of development of the Northeast region. The rapid growth of Khon Kaen town in the past decades has created pollution problems that pose a serious threat to the environment. Solid waste management is one of the environmental problems encountered. Disposal of waste is theoretically designed as sanitary landfill (CAPEQM, 2003). However, in practice open dumping has been carried out so that the waste is improperly disposed off. The disposal site is located at Kham Bon Village 17 km north of Khon Kaen town, Muang District, Khon Kaen Province. Municipal wastes have been disposed of at this site since 1968. Generally, the landfill site can carry approximately 200 tons per day of solid wastes. From field observations, it is indicated that the disposal efficiency is unlikely to function as planned. The landfill receives mixed wastes of both solid and hazardous types. The different wastes are commingled together without proper sorting being piled on the open ground by open dumping. Frequently, the wastes have been burnt on the ground so as to reduce their volume. By such inappropriate disposal methods, the waste has created not only a serious environmental pollution but also has become a threat to public health and safety. It is a source of houseflies and produces unpleasant odors. Moreover, it distributes the disease pathogens and generates contaminated leachate. This leachate contains various pollutants and toxic substances, especially heavy metals which are transported in the soil profile and cause the contamination of nearby water resources. Consequently, there are strong complaints by the residents who live around the landfill about annoying smells and claims that their fish and plants died as well as their surface water and groundwater supplies had been seriously polluted (Boonsener et al., 1994 ; Buaphan and Boonsener, 2003).

In reviews so far, most researchers are focused only on the impact of landfill leachate on surface water and groundwater. In contrast there are few studies of the occurrence of heavy metals in soil which is the direct receptor before leachate runoff to surface water and percolation to groundwater. Therefore, it is necessary to study the mechanisms of sorption and transport of heavy metals in soil that can be correlated with groundwater and surface water impact assessment.

There are three basic questions to be answered for the Kham Bon landfill; what contamination is present? how far? and how deep? These questions lead into to the site characterization issue. This thesis deals with this issue, not neglecting the fact that three other problems remain unsolved. These problems are: the migration problem (where are the contaminants going to?); the impact problem (is the impact significant?); and, the remediation problem (what can be done about it?). To understand the fundamentals of soil contamination, it is necessary to envision the variety of mechanisms for pollutants to become entrained in soil.

1.2 Description of the Study Area

1.2.1 Study Area

Khon Kaen landfill site is located at Kham Bon village, Muang District, Khon Kaen Province, Northeast Thailand (Figure 1.1). It is about 17 km north of Khon Kaen Town along the Friendship Highway. It comprises an area of 0.15 square kilometers and is shown on the 1: 50,000 scale topographic map (sheet 5542 II series L 7017). The study area is about 0.32 square kilometers covering four villages namely; Kham Bon; Sam Chan; Bung Kae and Non. The landfill has been serviced by Khon Kaen municipality and eight local government organizations.

1.2.2 Topography and Drainage Systems

The topography of the Khon Kaen province is characterized by highland plain and plateau. The western region is occupied by the Phu Kradung and Petchabun mountains. To the east and west, the area is formed by the floodplain of the Chi and the Phong river basins. Within the study area, the elevation is approximately 200 m above mean sea level (MSL). Its relief ranges from 1 to 6 m.

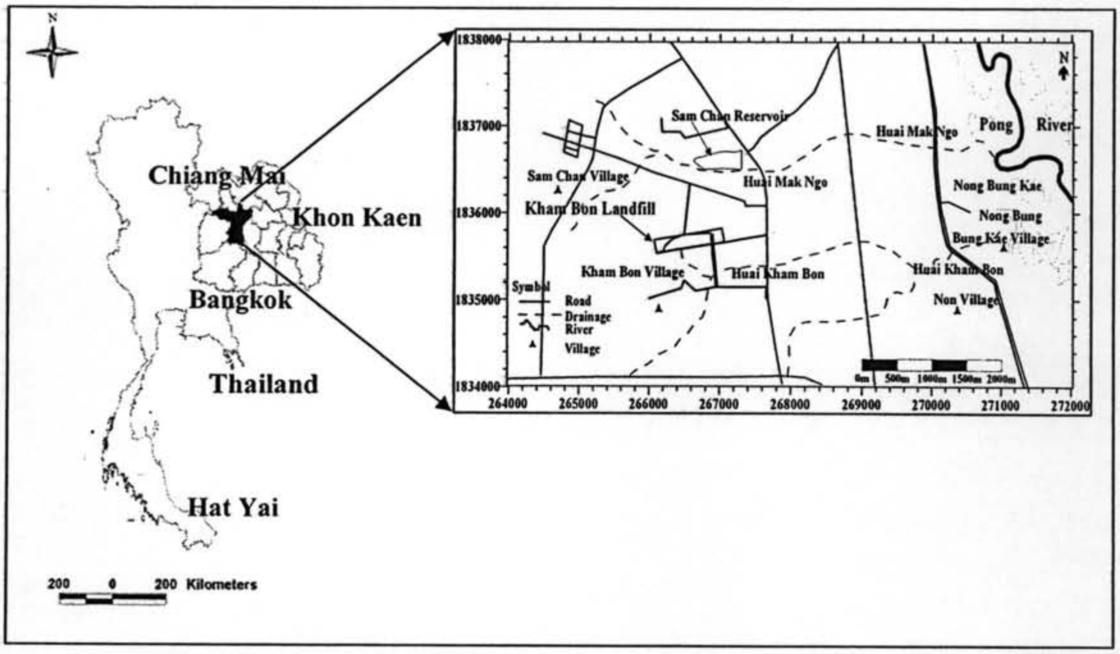

Figure 1.1 The location of the study area at Kham Bon village, Khon Kaen Province, Northeast Thailand

1.2.4 Existing Monitoring Wells in the Municipal Landfill Site

Eight existing boreholes (MW-1, MW-2, MW-3, MW-4, MW-9, MW-10, PZ-1 and PZ-2) and one pumping well (MW-8) were used as the monitoring wells in the study area (Figure 1.2). The up-gradient borehole, MW-1, located south of the landfill site was damaged by fire. Of the eight boreholes in the down-gradient position, five penetrate to shallow depths between 8 and 12 metres below the ground level (mbgl) and there are two boreholes, MW-9 and MW-10, installed at 27 mbgl and 40 mbgl respectively. MW-8 is a production well which was constructed at 27 mbgl.

1.3 Geology of Khon Kaen Landfill

1.3.1 Geographical Settings

Khon Kaen province is located in the northeastern region of Thailand at a distance of 445 kilometers from Bangkok. This province is bounded by the latitude of 15° N and17° N and longitude of 101° E and 103° E. Khon Kaen has a total area of about 10,886 square kilometers. The province is bounded by Udontani, Loei, and

Nong Bua Lam Pu in the north, by Nakorn Ratchasima in the south, by Kalasin, and Maha Sarakam in the east, and in the west by Chaiyabhum, and Petchabun.

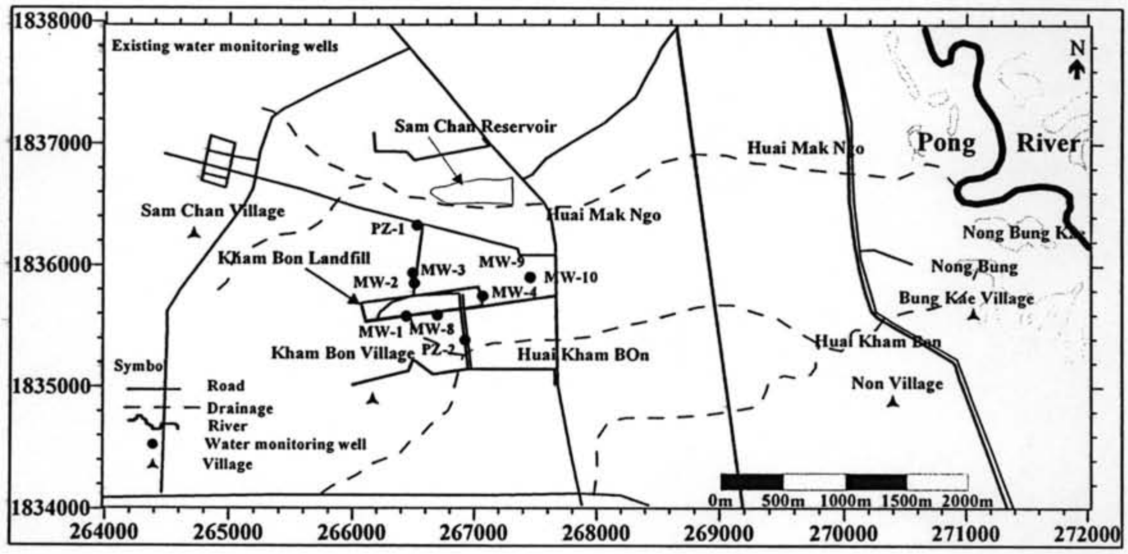

Figure 1.2 Location of groundwater monitoring wells in the study area

1.3.2 Geologic Settings

Geologically, the landfill site is underlain by fractured, reddish-orange siltstone and mudstone of the Maha Sarakham Formation of the Khorat Group, consisting mainly of sedimentary rocks. These red beds form the foundation of the landfill. The bedrock is overlain by silty sand soil attributed to the "Red Loess" which is one of the lithostratigraphic units of the Quaternary deposits of northeast Thailand (Boonsener, 1991). Red loess is composed of silt and fine to very fine sand. It is homogeneous, with no internal structure and quartz is a predominant mineral component. It has very high dry strength but it will lose grain cohesion rapidly when it is wet, due to the dispersive reaction being D2 and the coefficient of collapsibility 0.12. The permeability of this red loess ranges from 1.2×10^{-7} - 1.4×10^{-7} cm/sec. In terms of consistency of red loess, the liquid limit was 18.3%, plastic limit was 15.3%, plasticity index was 3.0. (Boonsener, 2004). With reference to the collapsible behaviour of this loess, it can be interpreted that in the rainy season, the leachate can flow through this loess more easily than in the dry season. Generally, the red loess layer varies in thickness from 1 to 8 metres. The average thickness is about 5 metres.

It is situated approximately 180 to 220 metres above mean sea level. It is estimated that the average drilled thickness of the landfill is 5 m.

1.4 Objectives:

The overall objective is to investigate the sorption and transport behaviors of heavy metal contaminants of landfill leachate on soil, which is affected by the physical and chemical characteristics of soil at the Kham Bon landfill site and adjacent areas.

The specific objectives are as follows:

1. to study the Kham Bon landfill site characterization;
2. to compare the sorption and transport behaviors of Cr, Cd, Pb, Cu, and Zn contaminants in the actual leachate and the synthetic leachate onto the soil taken from the landfill site;
3. to determine the compound forms of Cr, Cd, Pb, Cu, and Zn generated in the adsorbed soil for both actual /synthetic leachate;
4. to simulate the heavy metals transport through the subsurface environment.

1.5 Hypotheses

The physical and chemical characteristic of the soil play an important role in controlling sorption behaviors onto the soil in the study area.

1.6 Scope of Study

The study was divided into three parts: landfill site characterization, measurement of sorption and transport of heavy metals onto soil, and simulation of heavy metals transportation. The landfill site characterization was subdivided into two steps: preliminary frameworks delineation and landfill site characterization. The first step was to describe the existing site conditions for understanding the climate/meteorology, hydrology, geology and hydrogeology of the study area. Data obtained from the first step was used in planning the second step. In the second step, the surface and subsurface environments were investigated as well as environmental testing of the physical and chemical properties of leachate, soil, surface water and groundwater.

In relation to sorption and transport of heavy metals in soil, representative samples of soils in the landfill site and adjacent areas were collected to study the capability of soil in attenuating the transport of heavy metals by conducting batch and column experiments. Moreover, SSE was also conducted to study the retention mechanism of heavy metals in the soil profile and to determine the distribution of the partitioned heavy metals at the high affinity zone of heavy metals in soil obtained from adsorption isotherms. SSE can be divided into five stages as follows: exchangeable cations; carbonates; oxides and hydroxides; organics, and residual fractions.

Finally, simulation of heavy metals transportation, the data obtained from part one were employed to estimate the amount of water generated from the landfill by using Visual HELP model. The HYDRUS 2D model was used to simulate advective-dispersive transport and chemical reaction of the contaminants in two dimensions. The required data were obtained from both parts one and two. They include weather data, soil properties, and the distribution coefficient (K_d), as well as retardation factor, and diffusion coefficients obtained from column experiments.

1.7 Expected Output

1. to understand the behaviors of heavy metals in landfill leachate as affected by the physical and chemical properties of the soil in landfill site and its vicinity;

2. to understand the degree of landfill leachate impact on the surface and subsurface environments;

3. to understand in more detail, both in quantity and quality, the long-term fate of heavy metals in soils and find out the best solution for the protection and rehabilitation of the landfill site in the future as well as to design practical remedial measures for landfill leachate.