CHAPTER VI

TRANSPORT OF METALS FOR THE FIELD CONDITION

Abstract

Heavy metal contamination leached from the mine tailings of Akara mining site could contaminate the municipal shallow groundwater wells located near the mining site. This study simulated the transport of Pb^{2+} and Mn^{2+} under single metal and multi-metal systems through lateritic aquifer materials approximately 5 km downgradient of the tailing pond by numerical modeling, HYDRUS-2D. The sorption parameters fitted by the chemical nonequilibrium two-site model obtained from the column studies were used as inputs for the simulations. The simulations showed that the time to reach the Thailand drinking water standard at a specific location were in the order of: Mn^{2+} (for multi-metal system) > Mn^{2+} (for single metal system) > Pb^{2+} (for multi-metal system) > Pb^{2+} (for single metal system). Time to reach the drinking water standard at well no. 1 (1 km. downgradient, nearest well from the source) were about 70, 130, 240, and 550 years for Mn^{2+} in multi-metal and single metal systems and Pb^{2+} in multi-metal and single metal systems, respectively. The timing of heavy metal contamination leached from tailings will be a source of pollution for hundreds to thousands of years. As indicated by the simulation results, the predicted impacts of contamination of the TSF on the groundwater quality in the lateritic aquifer indicate that sorption parameters must be carefully determined and used in the simulation of heavy metal transport under field conditions.

Keywords: Lateritic soil; Heavy metal transport; HYDRUS-2D; Modeling

6.1 Introduction

The transport of heavy metals leached from the mine tailings to groundwater systems needs to be realistically predicted to assess the risk and, consequently, to develop and select the most appropriate strategies in monitoring and remediating the contaminated site. As mentioned in the previous chapters, the chemical nonequilibrium two-site model described the heavy metals transport in lateritic soil better than the equilibrium convection-dispersion models. Thus, the parameters obtained from chemical nonequilibrium two-site model were applied for field-scale metal transport simulations. The numerical model used for field-scale simulation in this study was HYDRUS-2D which could evaluate the potential transport and contamination of heavy metals in groundwater. The objective of this study was to simulate the movement of heavy metals leached from mine tailings through shallow groundwater systems under different environmental conditions.

6.2 Study Area

The Akara mining site (Figure 1.1) is located about 280 km north of Bangkok in Phichit Province, central Thailand. A storage facility has been designed to safely store the mine tailings. The tailing storage facility (TCF) is located on the southern portion of the mining site. It covers an area of approximately 320,000 m^2.

Groundwater levels typically conform to the surface topography. A north-south orientated hydraulic groundwater divide is located through Khao Mo and Khao Pong. Natural groundwater flows from the ore bodies in C-H mining pit in a southwest direction to the adjacent areas (Figure 1.1). The shallow groundwater wells in the nearby villages were mainly dug into the shallow aquifer of the lateritic layer at depths between 1.5 and 7 metres. The soil profile in the surrounding area consists of a top soil layer over the whole area with a thickness of approximately 20 to 40 cm, . a lateritic layer with a thickness from 1.5 to 7 meters and a thick clay layer between 4.3-11 meter thick, forming the bottom of soil sequence.

The simulations assumed that heavy metals were leaked under acidic condition (pH 5) from the tailing storage facility passes through the cracked liners and then through the lateritic soil reaching the shallow groundwater system.

6.3 Forecast of Long Term Impact

To investigate the importance of proper sorption parameters obtained from column studies under different environmental conditions, the sorption parameters deriving from different environmental conditions were applied to a field scenario where the compacted clay liner was assumed to be cracked.

Figure 6.1 shows the schematic simulation of the heavy metals transport from the TSF. For simplicity, it was assumed that the lateritic layer has a uniform thickness of 7 meters and hydraulic gradient is 0.001 m/m. It was assumed that the maximum concentrations of heavy metals leached from the column desorption experiments (see Chapter III) were transported continuously to the lateritic soil. Consequently, the municipal shallow wells located nearby villages may be contaminated. Forecast of such potential impact will provide important information for proper monitoring and remediating programs. In this study, the transport of Mn^{2+} and Pb^{2+} were simulated through lateritic aquifer because Mn^{2+} is the highest concentration and Pb^{2+} is the highest toxic metal leached from mine tailings. The simulations were predicted using the HYDRUS-2D for heavy metal transports through aquifer media.

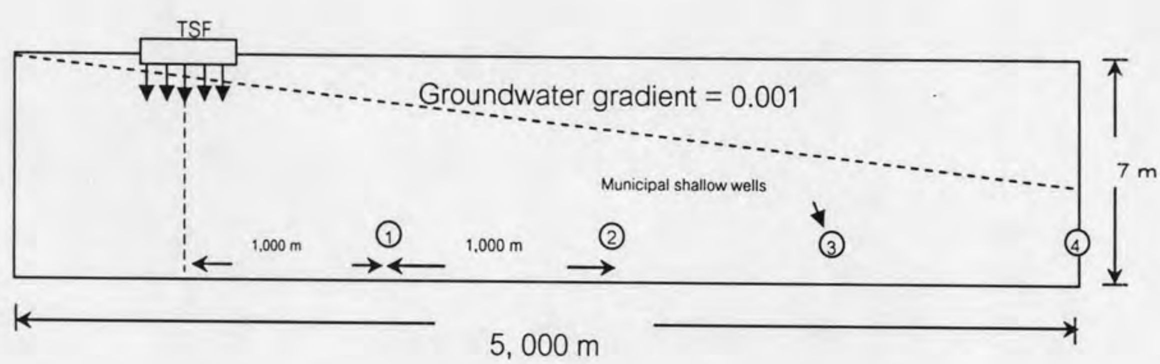

Figure 6.1 Schematic of the heavy metals transport leached from TSF through lateritic aquifer

The input parameters are listed in Table 6.1. The background concentrations of Pb^{2+} and Mn^{2+} in the lateritic aquifer layer were assumed to be zero. With the assumed initial concentration C_0, and the sorption parameters obtained from chemical nonequilibriuim two-site model (Table 6.1), the predicted heavy metal concentration in the municipal shallow wells are shown in Figure 6.2

Table 6.1 Input parameters for heavy metal transport for HYDRUS-2D simulations

Parameter	value
Longitudinal dispersivity, m	500
Transverse dispersivity, m	50
Bulk density (g cm^{-3})	1.23
Residual water content	0.1035
Saturated water content	0.5233
Saturated hydraulic conductivity, m day^{-1}	0.76
Water flux, mm day^{-1}	0.02
Sorption parameters, Q_{max}, mM g^{-1} and b,	0.2 and 3.34 for Pb^{2+} (single system)
L mM^{-1}	0.08 and 1.83 for Pb^{2+} (multi-metal system)
	0.12 and 0.80 for Mn^{2+} (single system)
	0.04 and 0.88 for Mn^{2+} (multi-metal system)
Nonequilibrium parameters, f (-) and α (hr^{-1})	0.31 and 0.01 for Pb^{2+} (single system)
	0.48 and 0.03 for Pb^{2+} (multi-metal system)
	0.33 and 0.02 for Mn^{2+} (single system)
	0.48 and 0.05 for Mn^{2+} (multi-metal system)
Initial concentration, C_0, mg L^{-1}	40 for Mn^{2+}
	18 for Pb^{2+}
Thailand drinking water standard, mg L^{-1}	0.3 for Mn^{2+}
	0.05 for Pb^{2+}

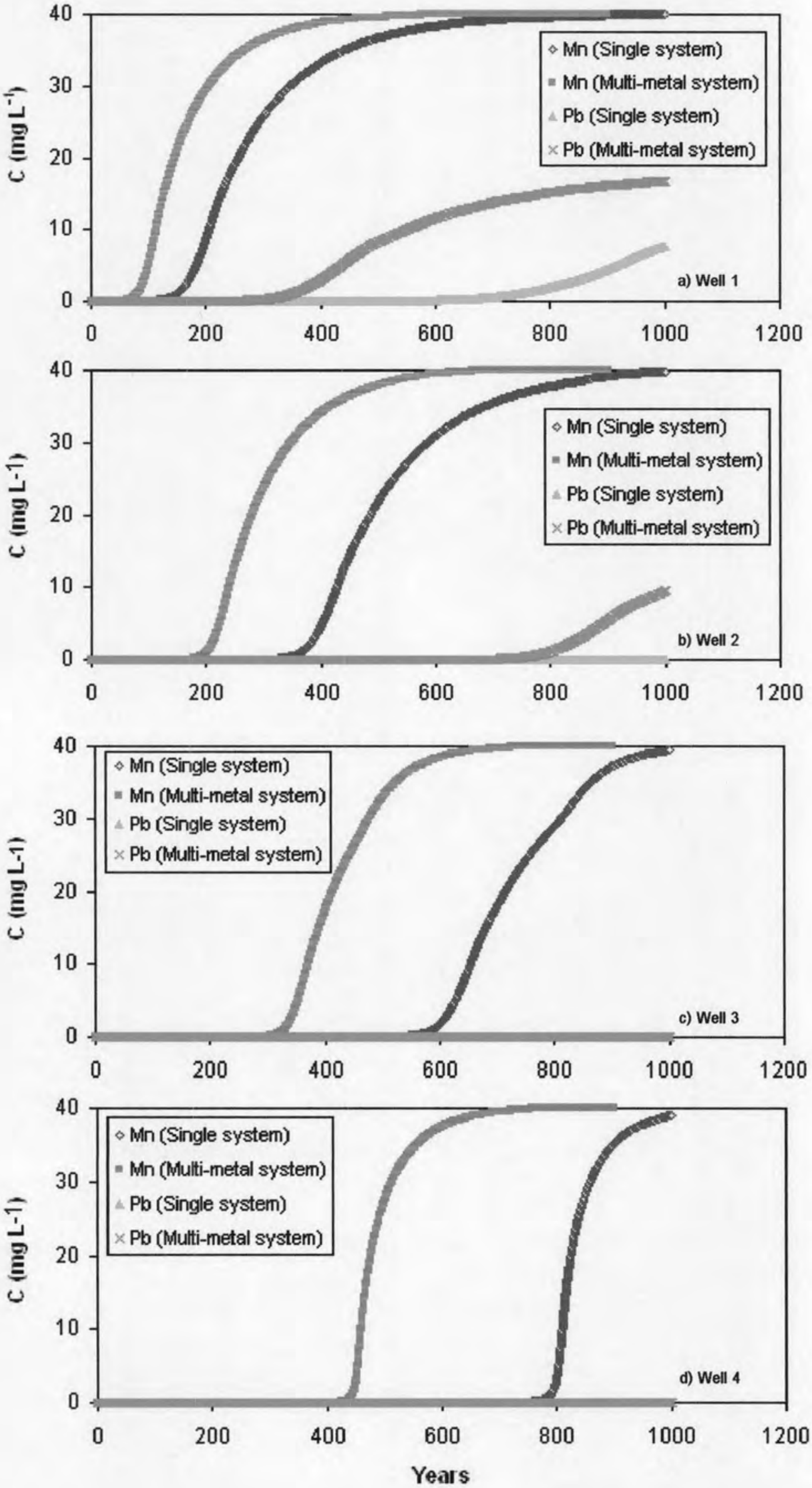

Figure 6.2 Concentrations of Mn^{2+} and Pb^{2+} in the lateritic aquifer for single metal and multi-metal systems for four wells at various distances from the contaminant source (see Figure 6.1)

Table 6.2 Arrival times at well nos.1 to 4 of concentrations exceeding the drinking water standards of Pb^{2+} and Mn^{2+} for single metal and multi-metal systems

Well	Time exceeding drinking water standard (years)			
	Mn^{2+}		Pb^{2+}	
	Single system	**Multiple system**	**Single system**	**Multiple system**
1	130	70	550	240
2	340	190	> 1000	680
3	560	310	> 1000	> 1000
4	770	430	> 1000	> 1000

The time needed to reach the drinking water standard at well no. 1 (nearest well from the source) were about 70, 130, 240, and 550 years for Mn^{2+} in multi-metal and single metal systems and Pb^{2+} in multi-metal and single metal systems, respectively. Pb^{2+} concentration fronts took a longer time to reach the wells than Mn^{2+} for both single and multi-metal systems. This means that Mn^{2+} for multi-metal systems could move faster than Pb^{2+} and Mn^{2+} concentration under multi-metal system and would exceed the drinking water standard faster than Pb^{2+} in 70 years. This potential impact to the shallow groundwater should be of concern in monitoring/remediating strategies. Moreover, transports of Mn^{2+} and Pb^{2+} in multi-metal system could move faster than in single metal system as affected from the competition of heavy metals on sorption sites. This is in good agreement with the lower values of maximum sorption capacities of Pb^{2+} and Mn^{2+} in multi-metal system as compared with those in the single metal systems that were derived from data of column studies in Chapter 4 and 5 (Table 6.1). As a result, it was concluded that the selection of the proper sorption parameters derived from column studies with different environmental conditions for individual heavy metals is very crucial. However, these predicted simulations were initiated for simplified cases. The simulation would be more accurate in its prediction when information for field conditions are used for model. For example, water levels or metal concentrations in the monitoring wells should be taken into account. Moreover, the heavy metal transports may be affected by other processes such as the precipitation and dissolution of Fe-oxides and other chemical and biological processes. Further work should be carried out in detail to better predict the heavy metals transport under the field conditions.

6.4 Conclusion

The application of HYDRUS-2D model provided visible descriptions of heavy metal movement in lateritic aquifer under different environmental conditions. The sorption parameters derived from column studies can be used as important parameters to predict heavy metal transport in field conditions. The predicted impacts of the TSF contaminated to the groundwater quality in the lateritic aquifer indicate that the impacts were affected by the selection of sorption parameters obtained from different models and different environmental conditions.