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A study on control of contaminant transport through the soil using equal double sheet piles

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KEYWORDS

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Abstract Control of groundwater moving using sheet pile is very important for minimizing the potential of groundwater contamination. Present study aims to control the contaminant transport through soil by using equal double sheet piles. Physical sand box model was implemented symmetrically in order to examine the effect of depths of double sheet piles, distance between them and distance of contaminant upstream the sheet piles. The regional contaminated porous field is studied numerically using simulation software MODEFLOW and M3DMS. Average absolute difference time between experimental and numerical results that contamination moved from upstream to point under the second sheet pile and arrives the surface of soil at downstream, equals 9.31% and 6.11% respectively. Design charts are presented for quantifying the effects of equal double sheet piles on the hydraulic control of the groundwater flow field. From the charts, the double sheet piles depth can be selected according to the needed condition.

1. Introduction

Around the world, groundwater contamination has become a major problem that is strongly connected to both protection of environment and the need of water. Once groundwater is polluted, it could remain so for decades, or even for hundreds of years to be cleaned, if cleaning is indeed possible. When aquifers are contaminated, it is very difficult to restore them. Moreover, the cost of monitoring extend of groundwater contamination is very high, so is the cost of analysis. Therefore, preventive strategies and identifying the sources and methods of contamination control are much more desirable and will save a lot of money and time. Impermeable medium such as sheet pile cutoff walls has been used as an effective method to control groundwater flow and contaminant transport through porous medium and for management of contaminated groundwater plumes.

The flow through the partially saturated zone is two phase problem (single fluid and soil). If the fluid contains in the meantime a foreign matter (contaminant), the situation

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Nomenclature

d	sheet pile depth	T_1	time for arrival to contaminant under the second sheet pile
d_*	relative sheet pile depth	T_2	time for arrival to contaminant to downstream surface for soil
H	head difference between upstream and downstream sheet piles	X	distance between the two sheet piles
K	permeability coefficient	X_*	dimensionless distance between the two sheet piles
L	distance of contaminant	ρ_c	density of contaminant
L_{max}	maximum distance of contaminant	ρ_w	density of water
L_*	dimensionless distance of contaminant		
t_*	relative time		

changes to a three phase problem that depends on a series of complex chemical and hydraulic phenomena. Bear [1] presented the fundamentals which describe the complex processes of contaminant transport by advection–dispersion components. The derivation of the generalized partial differential equation describing the fate and transport of contaminants in three-dimensional transient groundwater flow systems was carried by generalization of Darcy's law and applying the principle of mass balance to an element of porous medium and considers the processes of advection and dispersion.

Zheng et al. [2–4] introduced the concept of using dividing surfaces or streamlines to express quantitatively the effectiveness of hydraulic control. A theoretical framework using stream function and particle tracking approaches and field applications were investigated. They concluded that by defining the position of the dividing streamlines or dividing surfaces, the effectiveness of the proposed remedial schemes in controlling groundwater contamination under various hydrogeological conditions can be quantified. Gupta et al. [5] investigated the effects of hydraulic barriers on the hydraulic control during surfactant flushing at a contaminated site. The purpose was to reduce the demand for surfactant solution for an injection/extraction system by focusing the circular flow through a dense nonaqueous phase liquid source without loss to the surrounding aquifer. The comparison of numerically simulated flow patterns showed that hydraulic barriers could efficiently deflect the flow of surfactants into targeted zones and reduce the required pumping and injection rates. Guglielmetti and Butler [6] used a geo-membrane/steel sheet pile vertical barrier system as part of an emergency response action to curtail contaminated groundwater seeping out of a river bank at a Super fund site in Delaware. Nasr et al. [7] studied the effects of side cutoff wall depth, length and position on controlling the seepage around hydraulic structures. The three dimensional finite element method was used to produce the study approach. Anderson and Mesa [8] demonstrated the effect of vertical barrier walls and/or well on the hydraulic control of contaminated groundwater. They used impermeable circular arc wall with finite length where the center of curvature is downstream the arc. Oluwapelumi [9] described the goals, design and implementation of a quasi-natural gradient, laboratory scale, sand tank (aquifer) model experiment and used the model to study the transport of an inorganic tracer (Chloride) in groundwater, within a tropical porous medium material.

Basha et al. [10,11] used a numerical model to study the effect of vertical sheet pile on contaminant transport and its distribution over time. The contamination source was assumed as a point source with constant rate. The variations of sheet pile depths and its position were investigated. They constructed Physical model by using sand box model to verify numerical model validation. A group of design charts were presented to quantify the effects of sheet pile walls on hydraulic control of groundwater flow and contaminant transport through porous medium.

The main objective of the present study is to control the contaminant transport through porous medium by using double sheet pile walls as vertical barriers. Process of controlling is the process of containing or redirecting of contaminants to a certain direction or position for a period of time. The influence of different penetration depths of the double sheet piles, the distance between them, the distance between first sheet pile and contamination source, and the difference head between upstream and downstream sheet piles on the rate of contaminant transport are studied. A physical modeling using sand box model and a mathematical modeling using two products software were applied to analyze the problem under consideration.

2. Experimental works

In order to study the regional contaminated groundwater flow field, a Sand Box Model was developed in the laboratory.

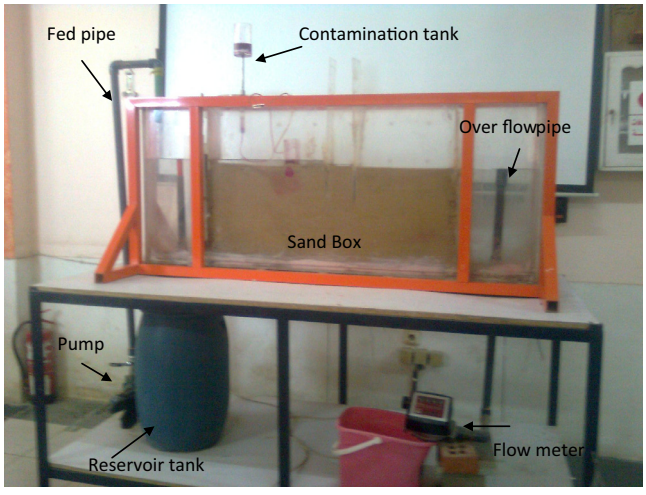

Plate 1 Fabricated sand box model.