Groundwater Utilisation from Density-Stratified Non-Homogeneous Unconfined Aquifers*

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Key words: groundwater modeling, density-stratified aquifer, saltwater intrusion, piezometric head variation, well penetration.

Introduction

Many basic studies have been conducted to formulate the flow of fluids and mass transport equation, of salt pollutant in porous media. These studies have resulted in analytical solutions to simple flow problems with simple boundary conditions. Because of the inadequate techniques in analytical solutions and the advances I numerical and computer technology, an interest has arisen in developing a numerical solution to describe the flow and dispersion processes in selective withdrawal problems taking into account density variation and the non-homogeneity of an aquifer. The objectives of the study are: 1) to develop a numerical model describing the flow and mass transport of salt pollutant towards a pumped well in a density-stratified non-homogeneous unconfined aquifer, and 2) to provide the needed guidelines for selective withdrawal from such groundwater reservoirs to meet a desired water quality constraints.

Materials and Methods

The study involved both analytical and experimental works. Numerical equations governing the groundwater flow and solute transport in an aquifer system were analysed and solved, and experiments to validate the numerical solutions were carried out. The equations were solved by the finite element method using the Galerkin technique. A computer software, called SUTRA, was employed to generate results for various well depths and discharge rates. The experimental works were performed on a laboratory scale groundwater system model with facilities to monitor the hydraulics head at several radial distances from the discharging well and the saltwater concentration at several depths in the aquifer. The head and concentration were monitored throughout the period of an experimental run.

Results and Discussion

The results show that the numerical solutions are comparable with the experimental observations with maximum departures of about 10% for the pressure head and 11% in the case of salt concentration distributions. The saltwater concentration at various locations in the aquifer when the shallower well is used is lower than the concentration due to a deeper well. In the case of piezometric head profiles, abstraction using the shallower well resulted in smaller drawdown, compared to the deeper well. A smaller discharge rate induced less saltwater into the aquifer. However, with long period of abstraction the difference in the salt concentration at various points tend to diminish. Although comparison of both solutions had shown the consistency that is needed for the purpose of modelling, it is observed that all these discrepancies need to be investigated further. In this study, for the case of concentration ratio distributions, it was apparent that the values of the numerical solution were greater than experimental solutions, while for the case of pressure head distributions; experimental solutions always had higher values. In reality, the situation may be different because solute reaction processes are neither linear nor equilibrium controlled, and the numerical model may not necessarily represent the true complexities of the reaction. Difficult problems also arise when the concentration of the solute of interest is strongly dependent on the presence of numerous other constituents that exist in the porous media. Here, mineralogical variability may be significant and may affect the rate and of reactions, and yet be ignored in the mathematical modelling instead. At the same time, in many groundwater flow systems, sorption may also cause the retardation of the movement of the contaminants. Sorption refers to the uptake of the dissolved constituents from solution by the porous medium. These phenomena may have caused the numerical values of concentration distribution becoming greater than experimental solutions in this study. Larger movement of solute experienced in the numerical modelling also meant that higher velocity of groundwater flow in the porous media, and this could generate bigger drawdown in water table.

Conclusions

The numerical solution was developed for the hydraulic head and concentration distributions in two-dimensional axi-symmetric flow towards a partially penetrating well through an unconfined, non-homogeneous and isotropic aquifer. Comparisons between the numerical results and those from experimental tests indicate that the model can accurately simulate the movement of pollutant (saltwater) in the saturated zone of a non-homogeneous unconfined aquifer.

Benefits from the study

A numerical method to describe the phenomenon of selective withdrawal of groundwater. This will assist the users in determining the rate and the duration of groundwater withdrawal so as to avoid the problem of saltwater intrusion

Literature cited in the text

None.

Project Publications in Refereed Journals

Jong Tze Yong, Abdul Halim Ghazali, Suleyman Aremu Muyibi, Salim Said, Aziz F. Eloubaidy. 2000. Modeling of

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None.

Graduate Research

Jong Tze Yong. 2000. Groundwater modeling [M.S]. Universiti Putra Malaysia.

* *An update of the abstract published in UPM Research Report 1998.*

I·R·P·A INTENSIFICATION OF RESEARCH IN PRIORITY AREAS

Research funded by the Intensification of Research in Priority areas (IRPA) - Supported by IRPA RM-7 (1996-2000), Cycle 1996, Grant 08-02-04-0003.