Original Article

An Investigation of Dispersion on Tracer Transport through Variably Saturated Porous Media Using VS2DT Modelling

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ABSTRACT

The objective of this study is to investigate dispersion on tracer transport through variably saturated porous media using Vs2dt modeling. To investigate the tracer transport a numerical model is developed according to the advective dispersive contaminant transport equation in saturated porous media with the help of Vs2dt software. Pressure head, Total head, Concentration profile and velocity vector configuration is shown below by different bitmap images. The results reveal that the enhancement of dispersivity induces the flow path distance and decreases of pore velocity. Using the coloured images the range of variations has been investigated. The tracer transport affect can be perfectly viewed in the computational domain.

Keywords: Dispersion, Porous media, Vs2dt modelling.

INTRODUCTION

Chemical substances have been used as tracers to estimate the migration of contaminant in a porous medium. Oceanographers use a variety of chemical substance to track diffusive and advective processes in the ocean. These chemical tracers can be divided into two primary categories, conservative and non-conservative traces.

Water moves due to gravitational force and carries many contaminant species. The transport processes of contaminants in porous media results from the advection and dispersion contaminated fluid in such environment. The contaminants tend to spread due to molecular diffusion and hydrodynamic dispersion. Several Scientist (Fetter[1], Nutzmann[2] et al. , Toride[3] et al. , Schnoor[4]) have worked on the study of dispersion in porous media.

Transport models can be solved using two methods (i) Analytic approach, (ii) Computational technique. Computational techniques can be solved using Matlab software and other software also. Most of the problems have been solved using these approaches.

Our interest here in this paper is to study the dispersion using domain configuration and simulation using VS2DT Modelling. The U.S. Geological Srurvey based models have been used for simulation in which one model which is prescribed for study flow and simulation has been used (VS2DT) (Healy[5]; Lappala and other[6]). VS2DT is a finite-difference model that solves Richard's equation for fluid flow, and the advection-dispersion equation for solute transport. The model can analyze problems in one or two dimensions using either cartesian or radial coordinate systems. Experimental work on vertical and streamwise dispersion of tracer stones has been done and explained in a report by Wang et al.[7] which signifies the importance of research work in this area. Various type of computational models have been developed which are important for practical approach as well as physical phenomenon (Arti and Manisha[8], Sunita and Anita[9], Sergey[10]). The effective investigation on transport of tracer through unsaturated porous media has been done by Busri et al.[11].

Model Configuration

Computer program VS2DT has been used for investigating tracer transport in variably saturated porous media. The flow equation has been approximated using the finite difference method, which is developed by combining the law of conservation of fluid mass with a nonlinear form of Darcy's equation, and the advection-dispersion equation. The rectangular domain has been considered.

For using Vs2dt modeling first we have to plot the proper computational domain according to the requirement of problem, For the purpose we have used proper domain with two different texture class for the Sand CP and Yolo light with proper parameters to study dispersion of tracer transport. Initial equilibrium profile has been set as 1.25 and minimum pressure head is taken as zero. Domain size is defined as 10 cm in height and 15 cm in depth. Initial concentration of tracer transport is assumed to be same at two corners. Recharge period is defined for proper simulation and period limit is defined 100sec. and initial time step is taken as 10 sec. Initial pressure and concentration is defined on above and below boundary. Left as well as right boundary.

Texture class

To add texture class window, by clicking add option we have different range of texture class. According to the requirement of this problem we have taken the case of Sand CP and Yolo light and consider the proper parameters of the texture class.

Initial equilibrium profile

Initial hydraulic conductivity is defined in terms of initial equilibrium profile. The pressure head equals the negative elevation head above a water table. The other users may also replace the upper part of the equilibrium profile by a constant minimum pressure head.

Initial concentration

Beginning by selecting "initial concentration" from the active data selector. The distribution of initial concentration is specified by drawing contours of integration. By giving a proper value of the contour concentration is defined.

Recharge period

A recharge period is a time span during which the boundary conditions and stress remains unchanged. Recharge periods are contained in a table in the recharge period window. If the window is not visible then display it by clicking the show menu and selecting recharge period window. In the given table we provide suitable values of periods and time span for running the simulation.

Boundary conditions

Boundary conditions are specified by recharge period. For each recharge period the boundary conditions must be assigned to each segment an exterior boundary and interior boundary as well. In the transport simulation, each boundary segment must be assigned a transport boundary condition for all recharge periods.

RESULTS AND DISCUSSIONS

Pressure head, Total head, Concentration profile and velocity vector configuration is shown below by different bitmap images. The simulation time is 100seconds. It is shown that the mass balance error is 7.17% for fluid in different configuration profiles. Through different bit map images the concentration effect, pressure effect and velocity profiles can be seen and understood different color scales.

The pressure at time t = 0.0 has been given in Fig. 1 but as the domain is simulated for the proper time step at t = 100.0 the figure shows the values of pressure head ranges from 4.0 to 5.0 which predicts that dispersion of tracer transport increases in saturated porous media.

In fig. 3 and in fig. 4 the total head has been shown for the domain, which shows that there is no significant changes after dispersion of tracer transport in porous media. But the fluid/ solute balance is changing through the simulation process.

Concentration of tracers has been shown before and after the simulation in fig. 5 and fig. 6 respectively. Before the simulation at t = 0 the domain color is sky-blue observing the value by scale 0.4 but as the domain is simulated by t = 100.0 its color changes to green marking the value 0.6. With the dispersion of tracer transport in variably saturated porous media the concentration of tracer increases due to saturation of sandy loam.

The velocity vector has been shown in fig. 7 and fig. 8 at t = 0.0 and t = 100.0 respectively which shows that the velocity of tracer transport in variably saturated porous media decreases.

CONCLUSIONS

The advective-dispersive solute transport was the main governing equation for the developed model. The model was solved numerically using the VS2DT Model. Variable saturated flow velocity was estimated using Richards' equation. It is concluded that VS2DT Model provides an easy method for calculating the advection and dispersion movement of water and tracer in variable saturated porous media. During water flow in a porous media, the dissolved tracer tends to spread because of the dispersion, which relates the dispersivity and pore velocity. The simulations suggest that the dispersivity of the variable saturated media is higher than the fully saturated porous media.

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Table 1. Parameters defined for tracer transport using vs2dt modeling.

1.Texture class	Alpha - L	Alpha - T	Mol. Diff.	decay	density	Km	Q^	C_0	
Sand CP	0.45	0.25	0.34	0.43	0	0	0	0	
Yolo light	0.45	0.23	0.45	0.34	0	0	0	0	
2.Initial equilibrium profile	z- coordinate of water table	Min. pressure head							
	1.25	0							
3.Domain size	height	width							
	10.0 cm	15.0 cm.							
4.Initial concentration	Contour value 1	Contour value 2	Contour value 3	Contour value 4					
	0.25	0.35	0.35	0.25					
5. Recharge period	Period Limit	Initial Time step	Time step multiplier	Max. Time step	Min Time Step	Time step Reduction factor	Max. Head change	Steady state heat criterion	Maximum hight of ponding
	100	10	20	50	10	0.56	8.9	10.5	40.0
6. Boundary conditions	On above boundary	On above boundary	On below boundary	On below boundary	On side1 boundary	On side1 boundary	On side 2 boundary	On side 2 boundary	
	Pressure	Concentration	Pressure	Concentration	Pressure	Concentration	Pressure	Concentration	
	0.64	0.6	0.26	0.32	0.5	0.43	0.34	0.2	

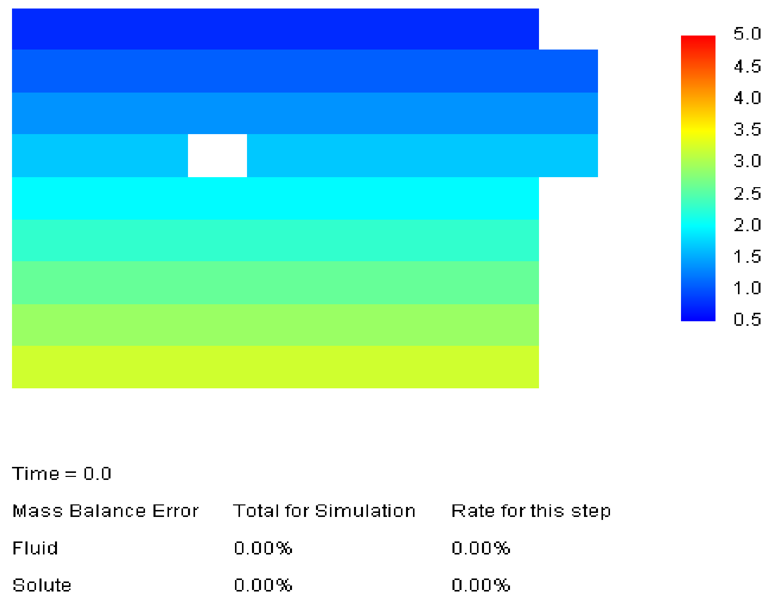

Figure 1. Pressure head configuration at time t = 0

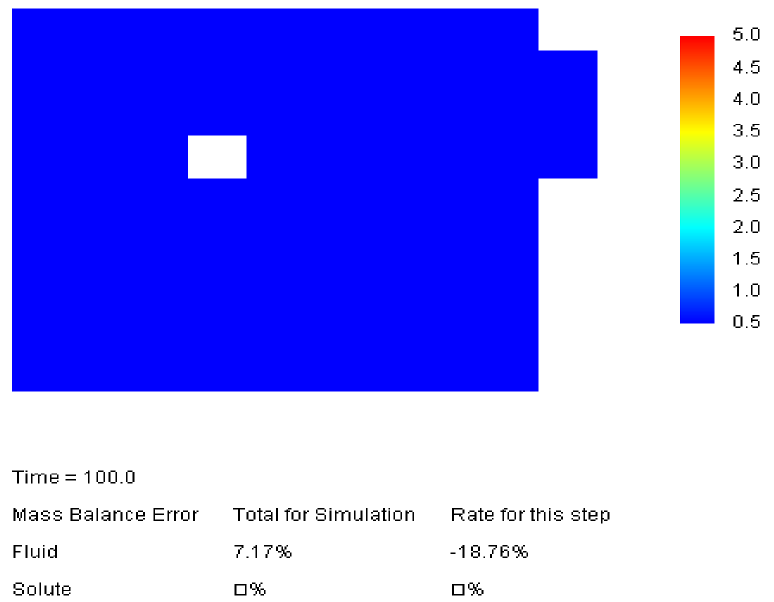

Figure 2. Pressure head configuration at time t = 100

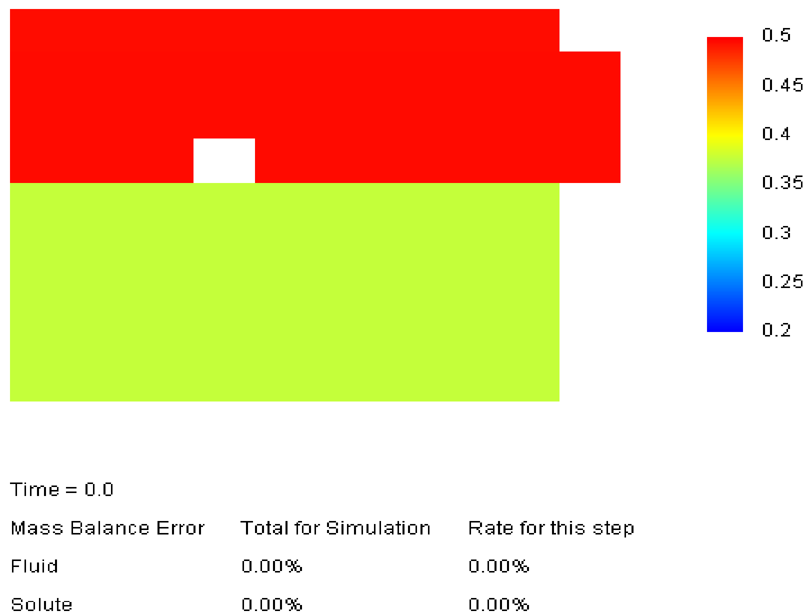

Figure 3. Total head at time t = 0

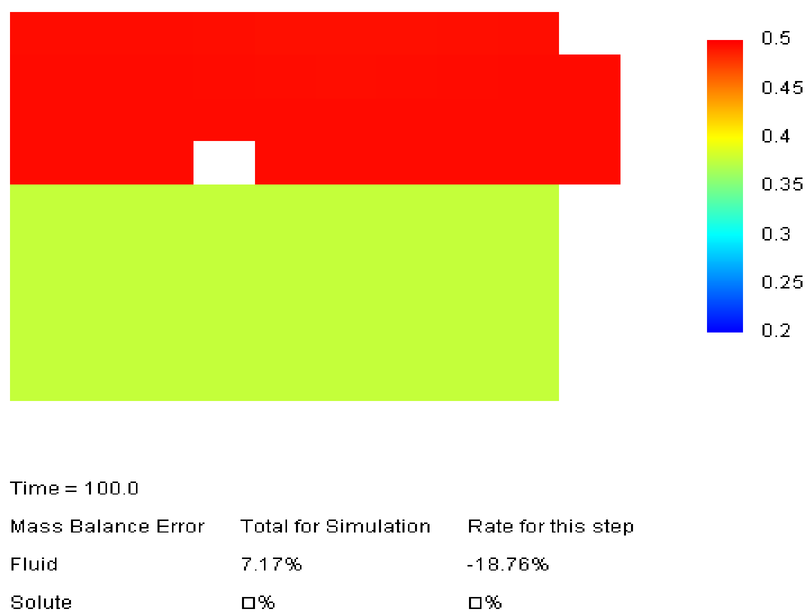

Figure 4. Total Head at time t = 100

Time = 0.0

Mass Balance Error	Total for Simulation	Rate for this step
Fluid	0.00%	0.00%
Solute	0.00%	0.00%

Figure 5. Concentration profile at t = 0

Time = 100.0

Mass Balance Error	Total for Simulation	Rate for this step
Fluid	7.17%	-18.76%
Solute	□%	□%

Figure 6. Concentration Profile at t = 100

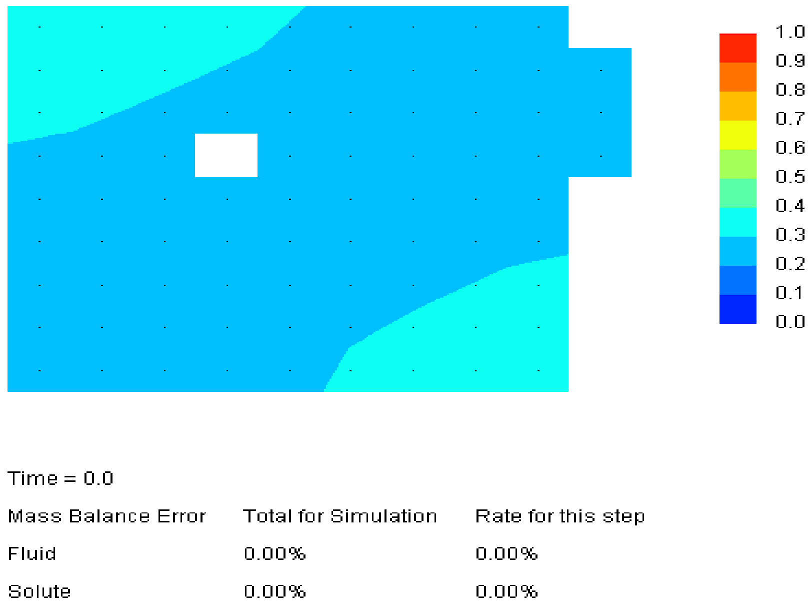

Figure 7. Velocity vector at t = 0

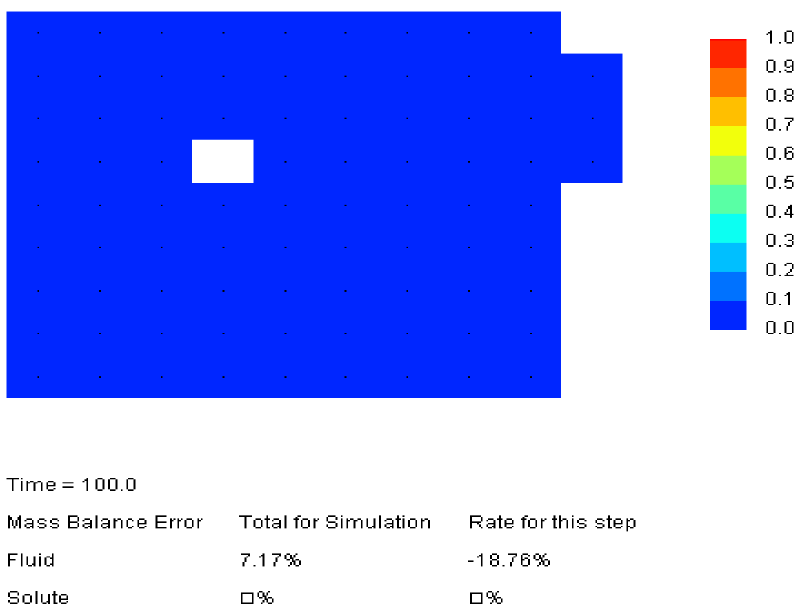

Figure 8. Velocity vector at t = 100