Variable-density flow and mass transport in unsaturated-saturated aquifers under horizontal groundwater flow conditions

*Jiaqi Liu[1], Tomochika Tokunaga[1]

1. The University of Tokyo

Density-induced fingering is an important mass transport process in a variety of groundwater flow settings. This study numerically investigated density-driven flow and mass transport in a 2-D vertical conceptual model of an unsaturated-saturated aquifer. The modeled domain consisted of 300 m long, with horizontal groundwater flow and vertical injection of dense solute from the top. In total, 158 numerical simulation cases were designed with various configurations of horizontal groundwater flow, the rate of solute injection, aquifer properties, and dispersivity. The numerical code FEFLOW was adopted which can solve both variable-density groundwater flow and unsaturated-saturated flow in porous media. Three dimensionless numbers, the convective ratios M_x and M_z and the Rayleigh number Ra_d, were applied to quantitively evaluate the relative magnitudes among the driving forces in the simulation cases. Three end-member flow regimes were identified that were dominated by the horizontal hydraulically-driven flow, the vertical hydraulically-driven flow, and the vertical density-driven flow, respectively. The plots of the simulation results in the M_x-M_z-Ra_d diagram enabled a clear distinction among the clusters of flow regimes and suggested the dominant driving force of each flow regime. The parameter sensitivity and regime shifts were also analyzed with the M_x-M_z-Ra_d diagram. The classification of flow regimes and the proposed M_x-M_z-Ra_d diagram provided a basic reference and a useful tool for understanding the mechanisms of variable-density flow processes under complex field situations.

Keywords: Variable-density flow, Numerical simulations, Dimensionless numbers

