Non-aqueous phase liquids distribution in three-fluid phase systems in double-porosity soil media: Experimental investigation using image analysis

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ABSTRACT

Over the last few decades, contamination of groundwater and soil by non-aqueous phase liquids (NAPLs) has become a serious and wide-spread problem for the environment In this research, a light transmission visualization (LTV) method was used to observe the migration of dense non-aqueous phase liquid (DNAPL) and light non-aqueous phase liquid (LNAPL) in double-porosity soil within a three-fluid phase system (air-NAPL-water). The double-porosity characteristics of the soil were created using a composition made up of local sand and sintered kaolin clay spheres arranged in a periodic manner. Toluene was used to simulate LNAPL while tetrachloroethylene (PCE) represented the DNAPL. Both NAPLs were dyed using Oil-Red-O for better visualization. For comparison purposes, the same experiments were carried out using just local silica sand acting as a type of single-porosity soil. A significant difference in the migration of the toluene and PCE was observed as both the NAPL migration rates in the double-porosity medium were much faster compared to the migration rates found in the single-porosity medium. This result is most likely due to the occurrence of inter-aggregate pores in the double-porosity soil that contribute to increasing velocity of fluids migration through porous media. Other factors such as the wettability of fluids and capillary pressure characteristics that exist in the soil pores were found to be influential factors in fluid migration within porous media. In addition, the results show that chemical properties have a significant influence on the NAPL migration in porous media. It was found that the migration velocity of toluene was much faster compared to the migration velocity of the PCE. This observation is most likely caused by the fact that the distribution coefficient of toluene was higher than that of PCE which in turn means that the retardation factor of toluene is lower than that of PCE in the same porous media. This paper proved that the LTV provides a non-intrusive and non-destructive technique for studying multiphase flow in double-porosity soil media where rapid changes in fluid distribution in the entire flow domain is not easy to measure using conventional tools.