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Investigation of the influence of particle size on the migration of DNAPL in unsaturated sand

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ABSTRACT: Four experiments were conducted to investigate the migration of dense non-aqueous phase liquid (DNAPL) in unsaturated porous media using Light Reflection Method (LRM). The porous media was natural sand collected from a river and segregated into different sizes through sieving. Three different sizes of the sand were used in the first three experiments while the fourth experiment used a mixture of these sands. The sands were packed separately in rectangular acrylic columns and then DNAPL was injected from the top of the column. The migration of DNAPL, modeled by tetrachloroethylene (PCE), was observed using a digital camera connected to a laptop and controlled using special software. The images were captured according to a predetermined time interval set into the software. The results show a significant difference in the migration of PCE through these sands. The migration of PCE in Experiment 3 was much faster than the migration in the other experiments. This is most likely due to the large pores in the sand samples. Moreover, in the experiment using mixture sand, it was observed that the migration was uneven and relatively slower than other experiments. LRM provides a non-intrusive and non-destructive tool for studying fluid flow for which rapid changes in fluid flow in the entire flow domain is difficult to measure using conventional techniques.

1 INTRODUCTION

Non-aqueous phase liquids (NAPLs) have a low solubility in water and occur in the subsurface as a separate phase and are considered as one of the most spread hazardous chemical (Newell et al., 1995). Theses NAPLs can be resulted from leakage of underground storage tanks and huge pipelines. NAPLs are classified into two types based on its density: the first type is light non-aqueous phase liquid (LNAPL) which has density less than water and the second type which is termed dense non-aqueous phase liquid (DNAPL) is denser than water. LNAPL include many hydrocarbon fuel components, for instance, toluene, benzene, xylenes (BTEX) and ethyl benzene. Tetrachloroethylene (PCE) and trichloroethylene (TCE) are examples of DNAPL materials (Newell et al., 1995). NAPL migration in the subsurface system depends on its relative density. When LNAPL enter the subsurface system, it will pass through unsaturated soil and migrate downward due to gravity and float on the surface of water table (Morris et al., 2003) resulting in deterioration of groundwater quality. On the other hand, DNAPL will pass through unsaturated zone and continue its downward migration under the effect of gravity until it reaches the saturated zone (Soga et al., 2004).

In laboratory scale experiments, non-destructive imaging techniques have gained more attention during the last decades which make the characterization and understanding of the multiphase system more accurate (Agaoglu et al., 2015). In the last few decades, there was a quantum leap in the using of image analysis techniques to investigate and measure multiphase fluid contents in laboratory experiments (Oostrom et al., 2007). Accordingly, LRM technique based on image analysis is one of the most important and promising techniques. LRM was used by several researchers to investigate NAPL infiltration using digital cameras under controlled lighting conditions (Kechavarzi et al., 2000). LRM is considered a cheap technique and requires only limited equipment [7, 8]. This paper qualitatively analyze the migration of PCE in three different sizes of natural sand, whereas the forth experiment used a mixture of these sizes using LRM technique. The migration of PCE was monitored using digital camera and capturing of the photos was carried out according to specific time intervals.