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A REVIEW OF LIGHT REFLECTION AND TRANSMISSION METHODS IN MONITORING NON-AQUEOUS PHASE LIQUID MIGRATION IN POROUS MEDIA

Motasem Y. D. Alazaiza[1], Su Kong Ngien[1], Wan Mohd Faizal Ishak[2] and Samira A. Kamaruddin[3]
[1]Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, Gambang, Kuantan, Pahang, Malaysia
[2]Centre for Earth Resources Research and Management, Universiti Malaysia Pahang, Malaysia
[3]UTM Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
E-Mail: my.azaiza@gmail.com

ABSTRACT

Recently, image analysis techniques in monitoring non-aqueous phase liquid (NAPL) migration have been gaining attention from researchers. Over the last two decades, photographic methods such as light reflection and light transmission methods have been shown to be applicable and effective tools for characterization and measuring NAPL migration. A review of recent studies published on light reflection and light transmission methods used in NAPL migration is summarized and presented in this paper. Besides discussion on the research efforts, recommendations for future research in using light reflection and light transmission methods are provided. This study concluded that, although having some limitations and drawbacks, photographic methods are still a promising and valuable tool for measuring NAPL migration.

Keywords: NAPL, light reflection, light transmission, image analysis.

INTRODUCTION

Groundwater is the main source of drinking water for many countries around the world. During the past decades, many sources of groundwater contaminants such as leakage of petroleum products, underground storage tanks, pipelines and spills of hydrocarbon have been reported. These affect the quality of groundwater and make it inadequate for human and irrigation uses (Kamaruddin *et al.* 2011a). These contaminants exist in subsurface soil as a separate phase because of their low solubility in water and are known as non-aqueous phase liquids (NAPL), considered as one of the most spread hazardous chemicals (Newell *et al.* 1995). Based on liquid density, NAPLs are classified into two categories; the first category is light non-aqueous phase liquid (LNAPL) which has density less than water and the second category is dense non-aqueous phase liquid (DNAPL) which is denser than water. Relative density influences the migration of NAPL. LNAPL will pass through the unsaturated zone and migrate downward due to gravity then float on the surface of the water table causing deterioration for groundwater quality (Sharma and Mohamed, 2003), while DNAPL will pass through the unsaturated zone and continue its downward migration under the effect of gravity until it reaches the saturated zone. The movements of LNAPL and DNAPL are shown in Figure-1.

It is difficult to observe directly the processes that occur in the porous media of the soil structure. Due to this reason, the investigation of the contaminants in hydrological processes often relies on indirect measurement of the parameters of the system or direct measurements at only a few locations, in some cases as a function of time. Therefore, it is important to find methods or tools that permit direct observation or imaging of the porous media characteristics and the processes that occur within them.

It is not easy to characterize and remediate sites that are polluted with the compounds of NAPL due to their special physical and chemical properties (Mercer and Cohen, 1990). It is difficult to perform field studies on NAPL due to its toxic and hazardous nature, so laboratory and numerical simulations are the natural alternatives. Over the past two decades, more information has been available on laboratory and numerical simulation of NAPL (Kamaruddin *et al.* 2011a).

A review paper was published by (Mercer and Cohen, 1990) about the properties, characteristics and remediation of NAPL. They reported that future research should concentrate on field measurements of NAPL properties to improve knowledge and understanding of the mechanisms of mass transfer. A number of image analysis techniques have been used previously to measure multiphase fluid contents in laboratory experiments (Oostrom *et al.* 2007). These techniques include photon-attenuation methods and photographic methods. Photon-attenuation methods such as Gamma radiation and X-ray are often used in measuring fluid content accurately. These methods have limitations such as slow measurement time, high energy source which is a risk to human health, high cost and cover only small regions at one time. Therefore, because of these limitations, photographic methods such as light reflection method (LRM) (Van Geel and Sykes, 1994), (Conrad *et al.* 2002), and (Ngien *et al.* 2012), and light transmission visualization method (LTV) (Hoa, 1981), (Tidwell and Glass, 1994), (Darnault *et al.* 1998), (Niemet and Selker, 2001) and (Bob *et al.* 2008) are gaining more attention and popularity to measure fluid contents (Bob *et al.* 2008) and (Kamaruddin *et al.* 2011a).