INVESTIGATION OF DNAPL MIGRATION IN DOUBLE-POROSITY MEDIA USING IMAGE ANALYSIS

LIM CHIA NI

B. ENG (HONS) CIVIL ENGINEERING

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Thesis submitted in fulfillment of the requirements for the award of the degree of
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JUNE 2016

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Civil Engineering (Hons.).

Signature	:
Name of Supervisor	: DR. NGIEN SU KONG
Position	: SENIOR LECTURER
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Signature	:
Name	: LIM CHIA NI
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LIST OF SYMBOLS

%	Percentage
℃	Degree Celsius
W	Watt
Å	Angstrom
A	Cross section area of sample in permeameter
C_c	Coefficient of gradation
C_u	Uniformity coefficient
D_{10}	Value corresponding to 10 % finer in PSD curve
D_{25}	Value corresponding to 25 % finer in PSD curve
D_{30}	Value corresponding to 30 % finer in PSD curve
D_{60}	Value corresponding to 60 % finer in PSD curve
D_{75}	Value corresponding to 75 % finer in PSD curve
G_s	Specific gravity
K_t	Hydraulic conductivity
L	Length of sample
V	Volume of acrylic chamber
a	Cross section area of used manometer tube
h_1	Starting level of manometer tube
h_2	End level of manometer tube
m	Mass of S300 kaolin
ρ	Density of kaolin
ρ_{S}	Density of soil sample
ρ_{w}	Density of water
t	Measured time interval

cm	Centimeter
cm/s	Centimeter per second
cm^3/g	Centimeter cube per gram
g	Gram
g/l	Gram per litre
h	Hour
lum	Luminosity
kg	Kilogram
m	Meter
m/s	Meter per second
m^2/g	Meter square per gram
ml	Milliliter
mm	Milimeter
mm^2	Milimeter square
min	Minute
s	Second

LIST OF ABBREVIATIONS

2-D	Two dimensional
BET	Brunauer, Emmett and Teller
BS	British standard
DNAPL	Dense non-aqueous phase liquid
LL	Liquid limit
LNAPL	Light non-aqueous phase liquid
LTV	Light transmission visualization
MSDS	Material safety data sheet
NAPL	Non-aqueous phase liquid
PCE	Tetrachloroethylene
PI	Plasticity index
PL	Plastic limit
SL	Shrinkage limit
TCE	Trichloroethylene
UMP	Universiti Malaysia Pahang
USCS	Unified Soil Classification System

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ABSTRACT

Nowadays, non-aqueous phase liquids (NAPL) are one of the common contaminants that lead to soil pollution. In this study, laboratory experiments were carried out to investigate the dense non-aqueous phase liquid (DNAPL) migration in double-porosity media using light transmission visualization (LTV) method. Two experiments were conducted in different types of double-porous media; namely aggregated kaolin with moisture content of 30% as well as a mixture of sintered clay spheres and Ottawa sand. An experimental setup was specially designed to execute the LTV method. Dyed tetrachloroethylene (PCE) which is one of the DNAPLs was poured into both experiments in order to study the behavior of DNAPL migration. The instantaneous migration of PCE in the double-porosity media was captured by a digital camera. Image analysis was applied to all the captured images. Experimental results obtained from the image analysis were discussed qualitatively in terms of area, vertical distance travelled, velocity and saturation. Besides, the comparison was made between the pouring method and injection method of PCE in 30% moisture content of aggregated kaolin sample. Regarding to the obtained results from different release methods of PCE, the coverage of PCE was larger under pouring method. Furthermore, for the experiment of a mixture of sintered clay spheres and Ottawa sand, PCE migration ceased at the half height of test sample due to the absorbability of sintered clay spheres only. This phenomenon was credited to Ottawa sand has no effect to the absorption of water and air. Hence, coverage of PCE in aggregated kaolin test sample was bigger than the mixture of sintered clay spheres and Ottawa sand. It was found that different release methods of PCE and the types of double-porosity soil media can become the influential factors in PCE migration.

ABSTRAK

Pada masa kini, cecair fasa bukan akueus (NAPL) adalah salah satu daripada bahan cemar biasa yang membawa kepada pencemaran tanah. Dalam kajian ini, eksperimen makmal telah dijalankan untuk menyiasat tidak berair fasa cecair (DNAPL) penghijrahan padat dalam media dua keliangan menggunakan cahaya visualisasi kaedah (LTV). Dua eksperimen telah dijalankan dalam pelbagai jenis media dua berliang; iaitu diagregatkan kaolin dengan kandungan lembapan sebanyak 30% serta campuran bidang tanah liat tersinter dan pasir Ottawa. Persediaan eksperimen telah direka khas untuk melaksanakan kaedah LTV. tetrachlorethylene dicelup (PCE) yang merupakan salah satu daripada DNAPLs telah dicurahkan ke dalam kedua-dua eksperimen untuk mengkaji tingkah laku DNAPL migrasi. Penghijrahan merta PCE dalam media dua keliangan telah ditangkap oleh kamera digital. analisis imej telah digunakan untuk semua imej yang ditangkap. Keputusan eksperimen yang diperolehi daripada analisis imej telah dibincangkan secara kualitatif dari segi kawasan, jarak menegak mengembara, halaju dan tepu. Selain itu, perbandingan itu dibuat antara kaedah dan suntikan mencurah kaedah PCE dalam kandungan lembapan 30% daripada sampel kaolin agregat. Berkenaan dengan keputusan yang diperolehi daripada kaedah pelepasan berbeza PCE, liputan PCE adalah lebih besar di bawah kaedah mencurah. Tambahan pula, untuk eksperimen daripada campuran bidang tanah liat tersinter dan pasir Ottawa, PCE penghijrahan terhenti pada ketinggian separuh daripada sampel ujian disebabkan oleh penyerapan sfera tanah liat tersinter sahaja. Fenomena ini telah dikreditkan ke pasir Ottawa tidak memberi kesan kepada penyerapan air dan udara. Oleh itu, liputan PCE dalam agregat sampel ujian kaolin adalah lebih besar daripada campuran bidang tanah liat tersinter dan pasir Ottawa. Ia telah mendapati bahawa kaedah pelepasan berbeza PCE dan jenis dua keliangan media tanah boleh menjadi faktor yang berpengaruh dalam PCE migrasi.

CHAPTER 1

INTRODUCTION

1.1 Background

In this advanced era, technology is an important factor that globalizes the world. Advanced technology changes the life of society to become more leisurely. But troubling behind this advanced technology is pollution. Soil pollution is one type of pollution that is getting serious nowadays. The contamination of soil is caused by hazardous substances such as industrial waste and agricultural waste that might harm lives. For example, non-aqueous phase liquids (NAPL) are one of the contaminants which lead to soil pollution. NAPL are immiscible hydrocarbons in the subsurface that have very low water solubility. Chlorinated solvents and petroleum products usually exist as non-aqueous phase in the subsurface. Hence, NAPL will form a visible layer and flow separately in the subsurface.

According to Huling and Weaver (1991), NAPL contain different the physical and chemical properties compared to water. Hence, a layer can be formed physically between the mixtures of hydrocarbon liquid and water. NAPL can be classified into light non-aqueous phase liquids (LNAPL) and dense non-aqueous phase liquids (DNAPL). LNAPL means that the hydrocarbons can float on top of the water (less dense than water) while the hydrocarbons that sink below the water table (denser than water) are called as DNAPL. The examples of LNAPL are gasoline, benzene, toluene, and so on. Tetrachloroethylene (PCE) and trichloroethylene (TCE) are the examples of DNAPL. The movement of NAPL is due to capillary forces, gravity, and soil texture.

Photographic method has been carried out to determine the migration of NAPL. Light transmission visualization (LTV) method had been first developed by Hoa (1981) to determine the variation of water content in sandy porous medium. Calibration procedure is required in his research. Later, Tidwell and Glass (1994) improved the LTV by eliminating the need to carry out calibration procedure. In this research, LTV method is used to visualize the migration of PCE in double-porosity media.

1.2 Problem Statement

Soil contamination will lead to groundwater pollution. The discharge of hazardous waste into the subsurface will cause the soil and groundwater to become contaminated. This is not only destroying the water quality but also causing health hazard for the society.

Most petroleum products and chlorinated solvents are NAPLs. Thus, the presence of NAPL in the subsurface will affect the groundwater remediation system. Until now, there is no technology to remove all the NAPL in the subsurface. NAPL found underground is a long term source of contamination because the free phase or mobile phase NAPL is accumulated into the continuous mass of NAPL by hydrostatic pressure. There are some residual NAPL left after the removal of mobile NAPL under pressure. This residual can be referred as “blobs” which are trapped by capillary forces in pore spaces of soil particles. (Newell et al., 1994). The free-phase and residual NAPL are illustrated clearly in Figure 1.1.

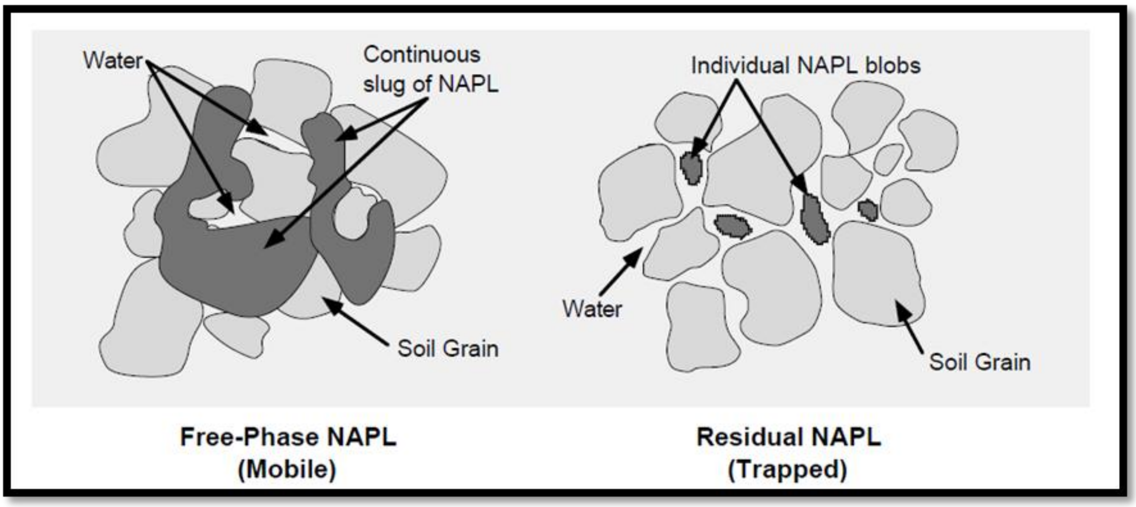

Figure 1.1: Free-phase NAPL and residual NAPL

Source: (Newell et al., 1994)

The importance of this research is to determine the factors that affect the migration of DNAPL because one litre of NAPL can contaminate one million litres of groundwater at 10mg/L (University of Idaho, 1998). Normally, the large amount of NAPL is difficult to dissolve and it might take up many years.

1.3 Objectives

The main aim of this research is to investigate the migration of DNAPL (PCE) in double-porous media systems. The objectives are as follows:

- To qualitatively analyse the behaviour of DNAPL (PCE) in double-porosity soil structures using image analysis.
- To compare the results when using different types of double-porosity soil media on the DNAPL (PCE) migration.
- To study the behaviour of DNAPL (PCE) migration in double-porosity soil under different release methods of PCE.