第Ⅲ部門 Effects of Groundwater Fluctuation on the Migration of LNAPLs

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1. INTRODUCTION

Light Non-Aqueous Phase Liquids (LNAPLs) are liquid contaminants lighter than water. They are susceptible to the fluctuation of groundwater, which means they are affected by precipitation. In Asian countries, the average yearly number of rainy events is more than 100 (Figure 1). Most studies of the migration of LNAPLs don't consider water table fluctuation, or focus on a single dynamic event (drainage or imbibition) or a single cycle (drainage + imbibition).

In this study, we make use of the Simplified Image Analysis Method to study the behavior of low viscosity paraffin liquid, a LNAPL, when subject to four full drainage + imbibition cycles in a Toyoura sand 1D column.

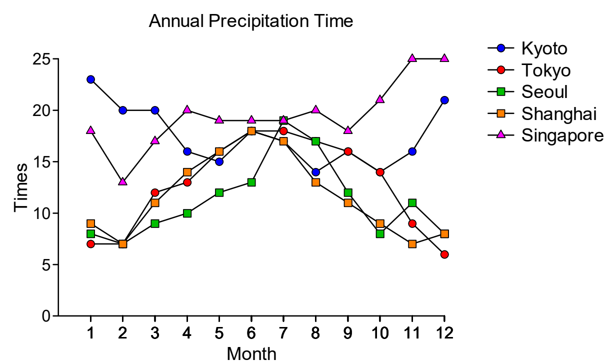

Figure 1. Annual precipitation times per month, in several Asian cities

2. SIMPLIFIED IMAGE ANALYSIS METHOD

The Simplified Image Analysis Method (SIAM) is a non-destructive technique devised by Flores *et al* (2011) to study the migration of NAPLs in laboratory settings. With this method, after three calibration pictures are taken with two digital cameras, the saturation distribution of both water and NAPL can be calculated by solving the following series of equations:

$$\begin{bmatrix} D_i \\ D_j \end{bmatrix}_{mn} = \begin{bmatrix} (D_i^{10} - D_i^{00}) \cdot S_w + (D_i^{01} - D_i^{00}) \cdot S_o + D_i^{00} \\ (D_j^{10} - D_j^{00}) \cdot S_w + (D_j^{01} - D_j^{00}) \cdot S_o + D_j^{00} \end{bmatrix}_{mn}$$

where *m* and *n* are the dimensions of the matrix, $[D_i]_{mn}$ and $[D_j]_{mn}$ are the values of the average optical density of each mesh element for wavelengths i and j, $[D_i^{00}]_{mn}$ and $[D_j^{00}]_{mn}$ are the average optical density of each mesh element for dry sand. $[D_i^{10}]_{mn}$ and $[D_j^{10}]_{mn}$ for fully water saturated sand, and $[D_i^{01}]_{mn}$ and $[D_j^{01}]_{mn}$ for fully NAPL saturated sand.

3. MATERIALS AND METHODS

TOYOURA sand with soil particle density of 2.58 g/cm^{3,} compacted state void ratio of about 0.87, and saturated density of 2.01 g/cm^3, was used as a sandy porous medium. Water dyed with Brilliant Blue FCF with a mass ratio of 10000:1 was used as wetting fluid. Low viscosity paraffin liquid dyed with

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Sudan III with a mass ratio of 10000:1 was used as experimental LNAPL.

The 1D column had an inner area of 3.5 × 3.5 cm, and a height of 50 cm. To reproduce changes in the groundwater level, the bottom of column was connected to pumps.

Two consumer grade digital cameras were used to capture photographs at two different wavelengths (λ = 450 and 640 nm) every 30 minutes. Two 60 W LED lamps were used to provide for constant lighting (Figure 2).

For this experiment, the column was initially filled with fully water saturated Toyoura sand. Then, 13.8 g of Low Viscosity Paraffin fluid was infiltrated from the top of the column. To reproduce the changes in groundwater level, suction pumps were activated for 24 hours producing a drainage stage, and then injection pumps were activated for 12 hours producing an imbibition stage. Both stages were repeated four times.

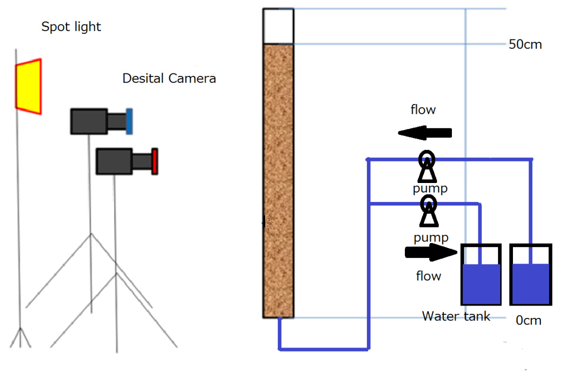

Figure 2. Experimental setup

4. RESULTS AND DISCUSSION

From Figure 3 we can observe drastic changes between the first cycle and the following ones. This confirms our initial assumption that observing many cycles is very important to correctly understand the behavior of LNAPLs in subsurface. During the first cycle, the water saturation of bottom part stayed at a high value, because the LNAPL at the top of column had a role similar of that of a cover, and the internal pressure of the column increased. After the second cycle, total bottom saturation didn't achieve 100%. During the drainage stages we can observe how the saturation of water slightly increases after each cycle, not reaching a stable condition even after the four full cycles studied here.

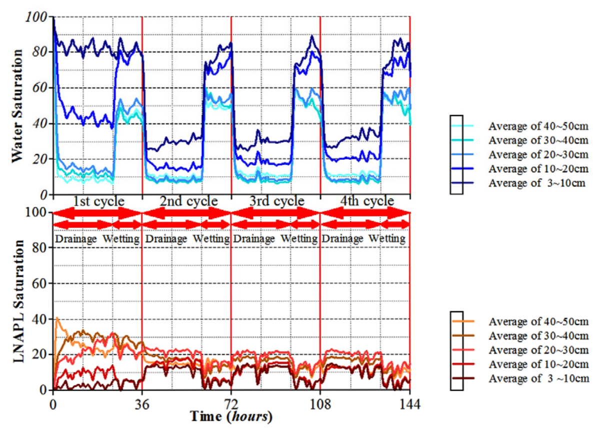

Figure 3. Saturation of both water and LNAPL at different column heights, per time

5. CONCLUSIONS

From these results, it is clear that is not enough to observe only one cycle to understand the behavior of LNAPLs, and it is also evident that it is not enough to measure saturation at only one point, but full domain saturation should be studied.

REFERENCE

1) Flores, G., Katsumi, T., Inui, T., and Kamon, M. (2011). A Simplified Image Analysis Method to study LNAPL Migration in Porous Media. *Soils and Foundations.* 51(835-847).