# Visualization of LNAPLs distribution in sandy soil using micro-CT scanner

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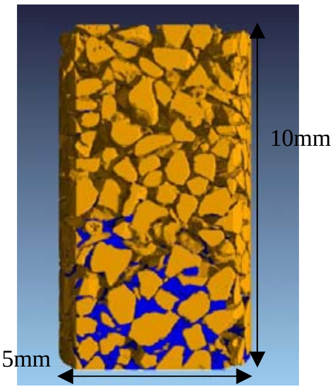
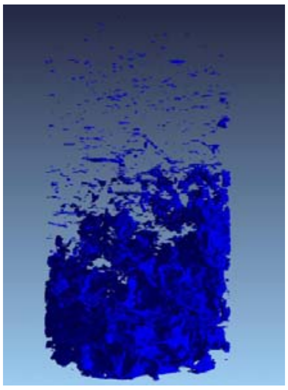
## 1. Introduction

*Light Non-Aqueous Phase Liquids* (LNAPLs) such as gasoline and diesel fuel would be transferred to underground with gravity and capillary force[1]. In order to remediate LNAPLs from the ground, it is significant to understand how water and LNAPLs are distributed in the pore space.

The objective of this paper is to visualize the water and LNAPLs distribution in the sand material using micro-focus X-ray Computed Tomography (CT) scanner to be available to scan the pore space in sandy soil. Figure 1 shows 3-D distribution of sand specimen and residual water in pore space in the specimen. Likewise, micro-focus X-ray CT scanner already can visualize the pore structure and water distribution in the sandy soil. This report tried to evaluate the residual condition of ethanol as LNAPL in sandy soil.




(a) Water in pore space of sandy soil



(b) Water distribution without soil

Figure 1 3-D reconstructed image

## 2. Test method

### 2.1 Prepared materials

Table 1 shows the properties of water and ethanol used in this study. Hostun sand was used and it had effective grain size of 0.354 mm and uniformity coefficient of 1.342. Figure 2 shows grain size distribution curve of Hostun sand used.

### 2.2 Experiment system

Picture 1 shows the entire system of test apparatus. Table 3 shows main scanning parameters. Figure 3 shows the schematic of the experiment apparatus. Mariotte bottle can provide liquid to the specimen with constant elevation head, hence, in this system, driving force of liquids into the specimen is only capillary pressure.

### 2.3 Test procedures

The conducted test procedures were as follows;

(i)To compare the absorption process between water and ethanol using diorama images, which are real-time image of the inside during the absorption test;

(ii)To compare the saturation degree in pore space between water and ethanol after absorption test.

Table.4 shows these performances as test cases.

## 3. Results and discussion

### 3.1 Comparison of the absorption process

Figure 4 shows the subtraction diorama images of water and ethanol in the sand specimen between each time step. Purple region of each diorama image indicates liquid part.

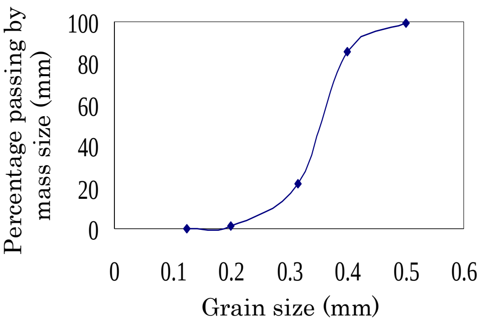



Figure 2 Grain size distribution curve

Table 1 Properties of liquids (25℃)

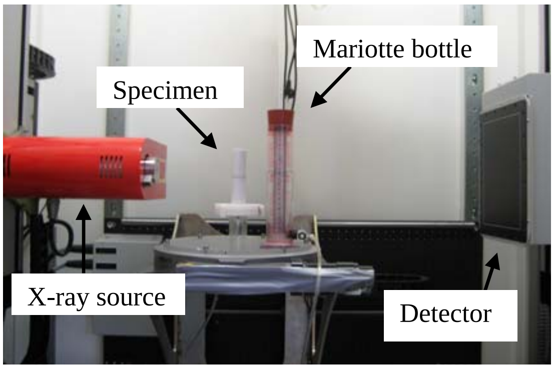
| | Water | Ethanol |
|---|---|---|
| Surface tension (mN/m) | 71.96 | 21.97 |
| Viscosity coefficient (mPa・s) | 0.890 | 1.083 |
| Density (t/m$^3$) | 1.000 | 0.824 |

Table 2 Main scanning parameter

| | |
|---|---|
| Voltage (kV) | 120 |
| Current (mA) | 83 |
| Projection averaging | 4 |
| Number of aquisitions | 1200 |
| Video frame rate | 2 |

Table 3 Test cases

| | Scanning moment | Resolution (μm) | Porosity | Liquid | |
|---|---|---|---|---|---|
| (i) | During absorption | - | 0.43 | Water | Ethanol |
| (ii) | After absorption | 9.5 | 0.43 | | |




Picture 1 Entire system of test

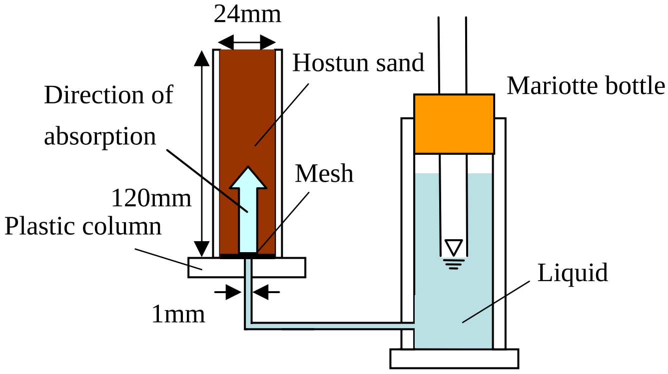
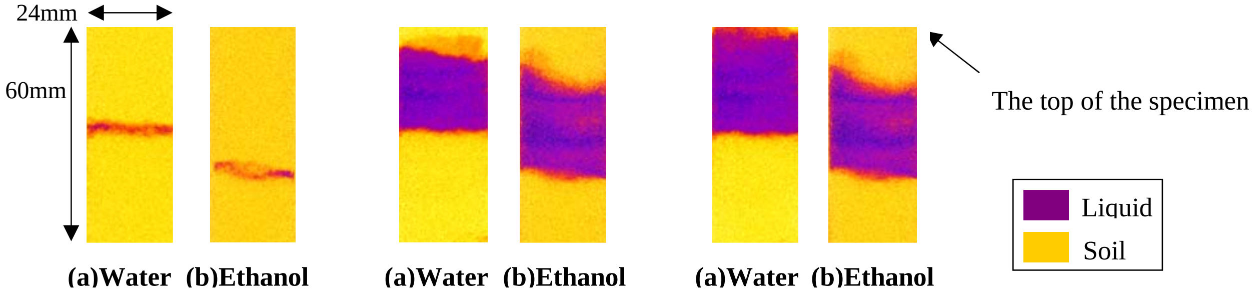
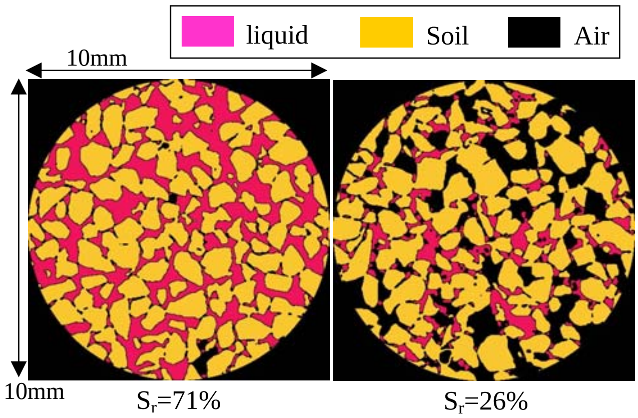



Figure 3 Schematic of experiment apparatus




**(a)Water (b)Ethanol** Step(i) : 0.5 minutes **(a)Water (b)Ethanol** Step(ii) : 10 minutes **(a)Water (b)Ethanol** Step(iii) : 20 minutes

Figure 4 The subtraction diorama images on the absorption process in the sand specimen




**(a)Water** **(b)Ethanol**

Figure 5 Threshold image after absorption

At step(i), compared the elevation of absorbed liquid between water and ethanol, water level is higher than ethanol level. Compared step(ii) to step(iii), water moved up as shown in Figure 4 step(iii); on the other hand, ethanol almost did not move. These differences of absorption behavior are caused with the difference of the value of surface tension.

### 3.2 Comparison of the amount of liquid

Figure 5 shows cross-sectional CT images at the middle elevation of the specimen for each absorption test. In each image (i.e. water and ethanol, respectively), purple region indicates liquid part and $S_r$ means saturation degree of liquid. Compared saturation degree of water to ethanol, water is 2.7 times greater than ethanol as shown in Figure 5. Here, the equation of capillary pressure is given by:

$$h_c = 2T\cos\theta / d\gamma \text{ -----(1)}$$

$h_c$ is head of capillary pressure, $T$ is surface tension, $\theta$ is contact angle, $\gamma$ is density of liquid, and $d$ is pore size. Based on this equation, surface tension of water is greater than ethanol so that water was moved up more than ethanol in the sand specimen. The residual condition of water and ethanol in the sandy soil was visualized by micro-focus X-ray CT scanner. It concluded that the surface tension of liquids is a key factor how water and ethanol were residual in the sandy soil. Once LNAPLs spill into the ground, it would migrate vertically till the ground water table because of less surface tension than water.

## 4. Conclusions

Micro-focus X-ray CT scanner is a powerful tool to visualize LNAPLs distribution in sandy soil. As the next step, the 3-D image analysis will be needed for more detailed discussion.

### Acknowledgment

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### References

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