Visualization of residual LNAPL in sandy soil using micro-focused X-ray CT scanner

JSPS postdoctoral fellow ○Tinet, Anne-Julie
Kumamoto University K. Mikami, K. Sugimura and T. Mukunoki

Introduction

Air sparging method is known as the most effective and proven remediation technique for this difficult contamination status[1), 2), 3)]. The process of air sparging can be defined as the injection of compressed air into the saturated zone below, or within, the areas of contamination. In order to better understand the effect of air injection on NAPL location it is of importance to observe contaminated and remediated soil in micro scale.

The objective of this paper is to develop a new investigation method to understand the residual mechanism of LNAPL due to air injection, as the first step to clarify the entire remediation mechanism of LNAPL in air sparging process. In order to evaluate the micro scale effect of air injection rate, newly developed system of injection experiment and micro X-ray CT scanner were combined[4)]. Pores occupied by LNAPL in remediation process are visualized with injected air and KI solution in soil. The obtained CT data was analyzed to evaluate each blob quantitatively on the basis of its displacement condition with injected air.

Experiment

The experiment apparatus used for air injection is shown Fig. 1. It allows measurement of injection pressure and release liquid mass. In order to achieve distinction of both liquid phases with the micro-CT water was modified into a KI solution with similar viscosity and superficial tension but higher density. However, the flow behavior of water and KI solution is assumed similar. The LNAPL used for the experiment mainly consists of isoparaffin. It has a density ratio with water of 0.75 and a viscosity ratio of 1.29.

Toyoura sand was used for the test as the soil material. It possesses 170 μm of effective grain size and 1.29 of uniformity coefficient. The dry density of the specimen for this experiment was set 1.60 t/m^3. It's pore volume is calculated as 1PV=5.74ml.

The main experiment steps are as follows:

1) Injection of 5 PV of LNAPL with 25ml/h of injection rate (to the specimen which is filled with KI solution);
2) Injection of 5 PV of KI solution with 25ml/h of injection rate to create the initial condition of the contamination;
3) Scanning by micro CT (labeled initial condition or pre-injection state);
4) Injection of 5 PV of air with injection rate of 50ml/h (case 1) and 500ml/h (case 2) to create the remediated condition of contamination; and
5) Scanning by micro CT (labeled remediated condition or post-injection state).

Results

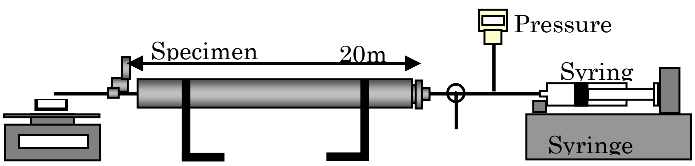


Fig.1 Schematic of injection apparatus

3D images obtained from CT showing the location of NAPL before and after air injection are shown Fig. 2. It can be observed that the saturation indeed diminishes (from 17% and 20% respectively to 5% in both cases) but does not reduces to 0%. Moreover, while the pores occupied by NAPL diminishes in size they increase in

Keywords LNAPL, Air spaging, micro X-ray CT
Address 1-39-2 Kurokami Chuou-ku Kumamoto city, Kumamoto 〒860-8555 Kumamoto University TEL096-342-3545

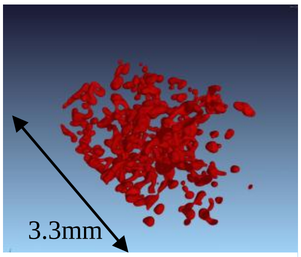
number. It seems consequently quite clear that there is movement including removing and re-trapping of NAPL during the air injection process. In order to understand this removing and re-trapping of NAPL, image analysis is performed to track the pores occupied by NAPL. Results may be observed Fig. 3. Image analysis demonstrates that 46% of the residual NAPL was re-trapped in the first case and 67% in the second case. Air injection allow the removing of liquid from pore space, however because both NAPL and water may be removed, some NAPL can be re-trapped due to capillary effects during the fluid transfers. It can be observed that a strong air injection allows more liquid removing but also more re-trapping of NAPL leading to overall similar results in terms of residual saturation.

Conclusion

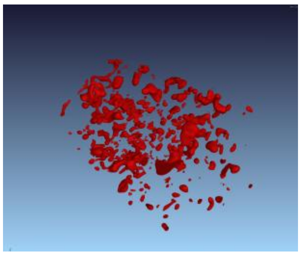
In order to establish a new investigation method to understand the residual mechanism of LNAPL in air injection process, newly developed injection system showed effective performance in combination with micro focus x-ray CT. This combination made it possible to create and visualize the contamination status by trapped LNAPL in saturated zone, and the remediated status by air injection. It was demonstrated that air injection permits a significant decreases in NAPL saturation without however completely removing the contaminant. Removing and re-trapping due to capillary effects of NAPL with air injection was showed and resulted in a residual saturation of about 5%. The air injection rate proved to affect the removing and retrapping processes but resulted in little variation in the final NAPL residual content.

References

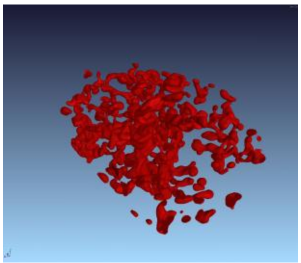
1) David, H. B., Nicholas, A. H. and Richard, A. B. : Performance of air sparging systems: a review of case studies, Journal of Hazardous Materials, Vol.72, Issue2-3, pp.101-119, 2000
2) Culligan, K.A., Wildenschild, D., Christensen, B. S. B., Gray, W. G.. and Rivers, M. L.: Pore-scale characteristics of multiphase flow in porous media: A comparison of air-water and oil-water experiments, Advances in Water Resource, Vol.29, pp.227-238, 2006.
3) Krishna, R. R., Robin, S. and Jeffrey, A. A. : Air flow optimization and surfactant enhancement to remediatetoluene-contaminated saturated soils using air sparging, Environmental Management and Health, Vol.10, Issue.1, pp.52-63, 1999.
4) Wildenschild, D., Hopmans, J. W., Rivers, M. L. and Kent, A. J. R. : Quantitative analysis of flow presses in a sand using synchrotron-based x-ray microtomography, Vadose Zone Journal, Vol.4, pp. 112-126, 2005.



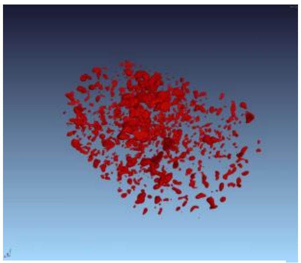
(a.1) Case 1 (50ml/h) as initial condition



(a.2) Case 1 (50ml/h) as remediated condition

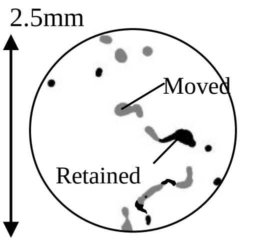


(b.1) Case 2 (500ml/h) as initial condition

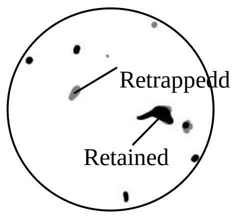


(b.2) Case 2 (500ml/h) as remediated condition

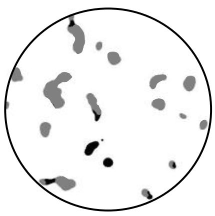
Fig. 2 3-D images of LNAPL location



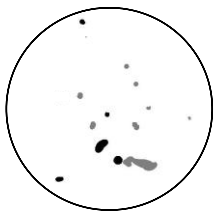
(a.1) Case1 (50ml/h): initial condition



(a.2)Case1 (50ml/h): remediated condition



(b.1) Case2 (500ml/h): initial condition



(b.2)Case2(500ml/h): remediated condition

Fig. 3 Results of image calculation