Remobilization of Colloids by the Moving Fluorinert-water Interface through a PDMS Micro-model

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Introduction

- Mobilized colloids can serve as carriers and facilitate contaminant transport through the vadose zone to groundwater.
- Colloids mobilization was found during transient column experiments.(Torkzaban et al., 2006; Cheng and Saiers, 2009).
- Visualization of colloids transport, retention, and mobilization in unsaturated porous media is needed for a better understanding of these mechanisms.
- As a representation of a porous medium, PDMS micro-models were designed and used to study colloids transport, during two-phase flow.

Main Objectives

1) Observe colloids remobilization with moving fluid-fluid interface at the pore-scale;
2) Quantify colloids transport and remobilization by measuring effluent concentration breakthrough curves.

Experimental Set-up

The experimental system included the following main components:

A) Injection assembly (A reversal syringe pump; two syringes; three selection valves; bulk reservoirs for fluorinert, water, and colloids), shown in Fig.1A;

B) Imaging system (an inveted laser confocal microscope with a 63×oil immersion objective) as shown in Fig.1A below;

C) The PDMS micro-models (shown in Fig.1B);

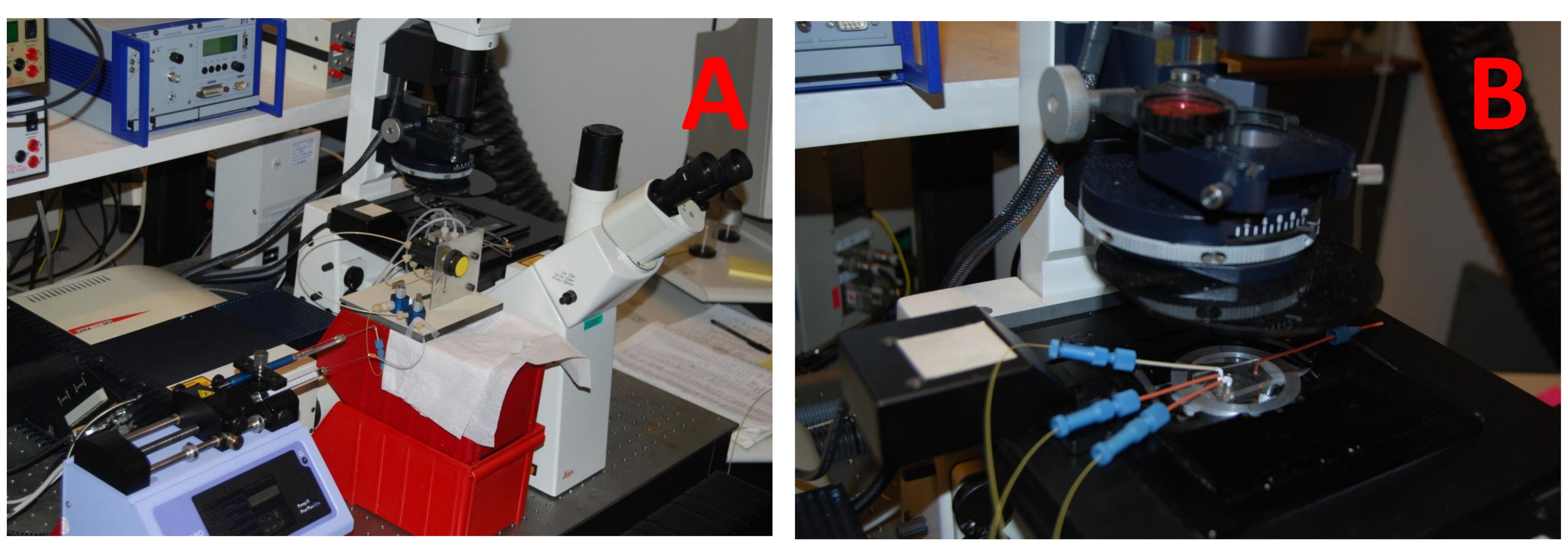


Fig.1 Experimental set-up.

Micro-model

The structure of the micro-model is shown in Fig. 2.

(1) The three inlet reservoirs are for wetting phase, non-wetting phase, and colloids suspension;

(2) The flow network dimensions are 1×10 mm;

(3) The flow network has 30 pore bodies and roughly 50 pore throats;

(4) The mean pore size is around 30 μm;

(5) The micro-model is hydrophobic;

(6) Fluorinert is the wetting phase and water is the non-wetting phase.

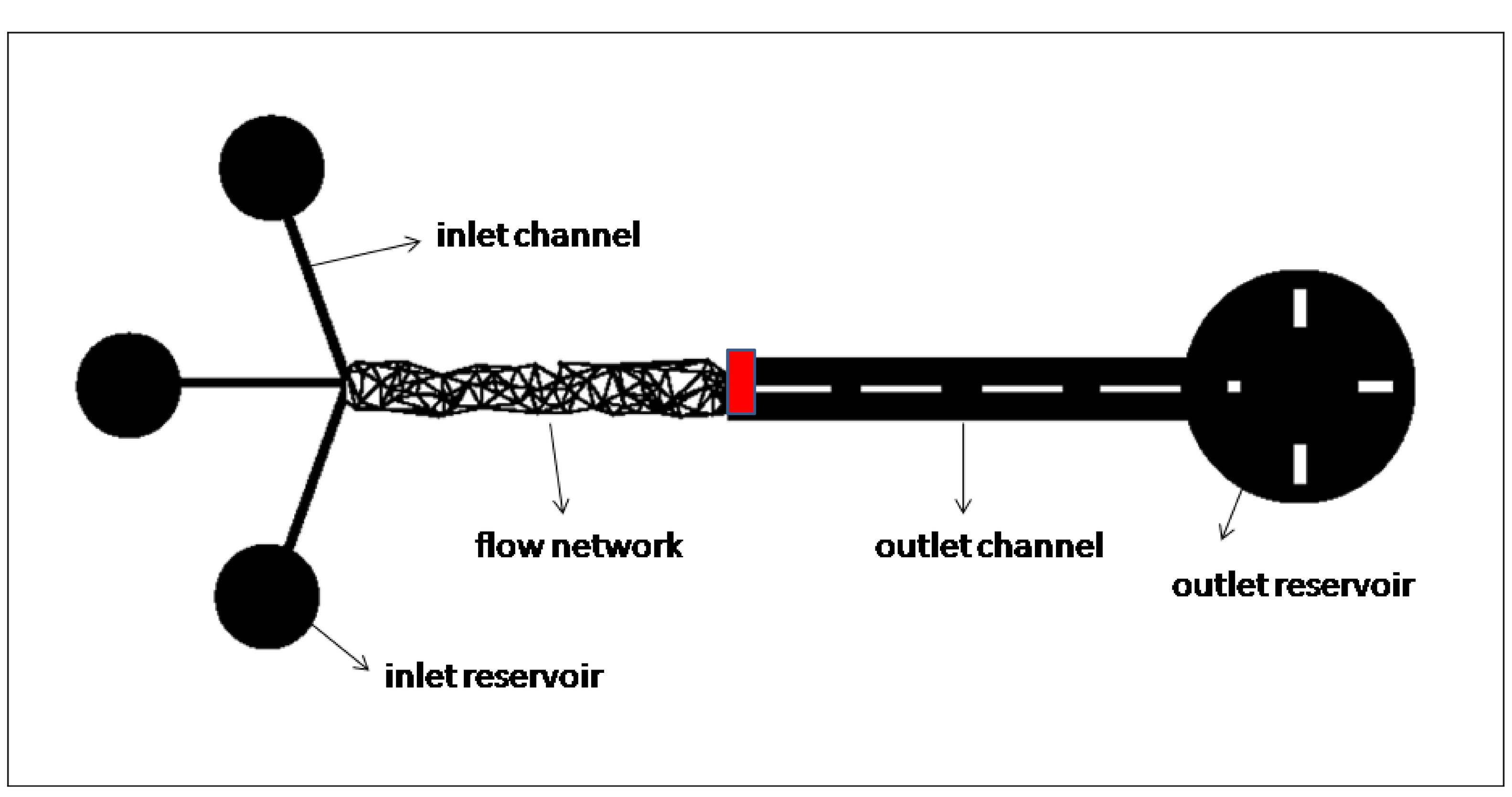
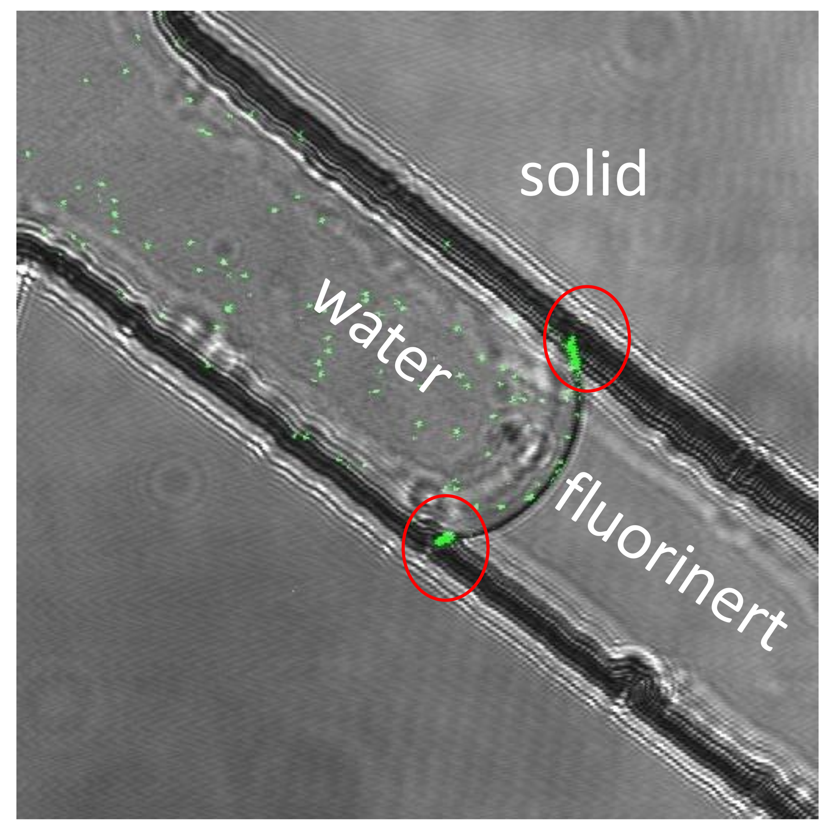


Fig.2 Schematic representation of the micro-model.

Visualization results

Colloids retention during water steady-state flow and colloid remobilization as a result of moving fluid-fluid interfaces during imbibition were observed.



Observed locations for colloids retention under unsaturated steady-state flow:

1)Contact line (FWS)

2)Fluid-fluid interface (FWI)

3)Solid-water interface (SWI)

Fig.3 Images of colloids retention taken under steady-state two phase flow.

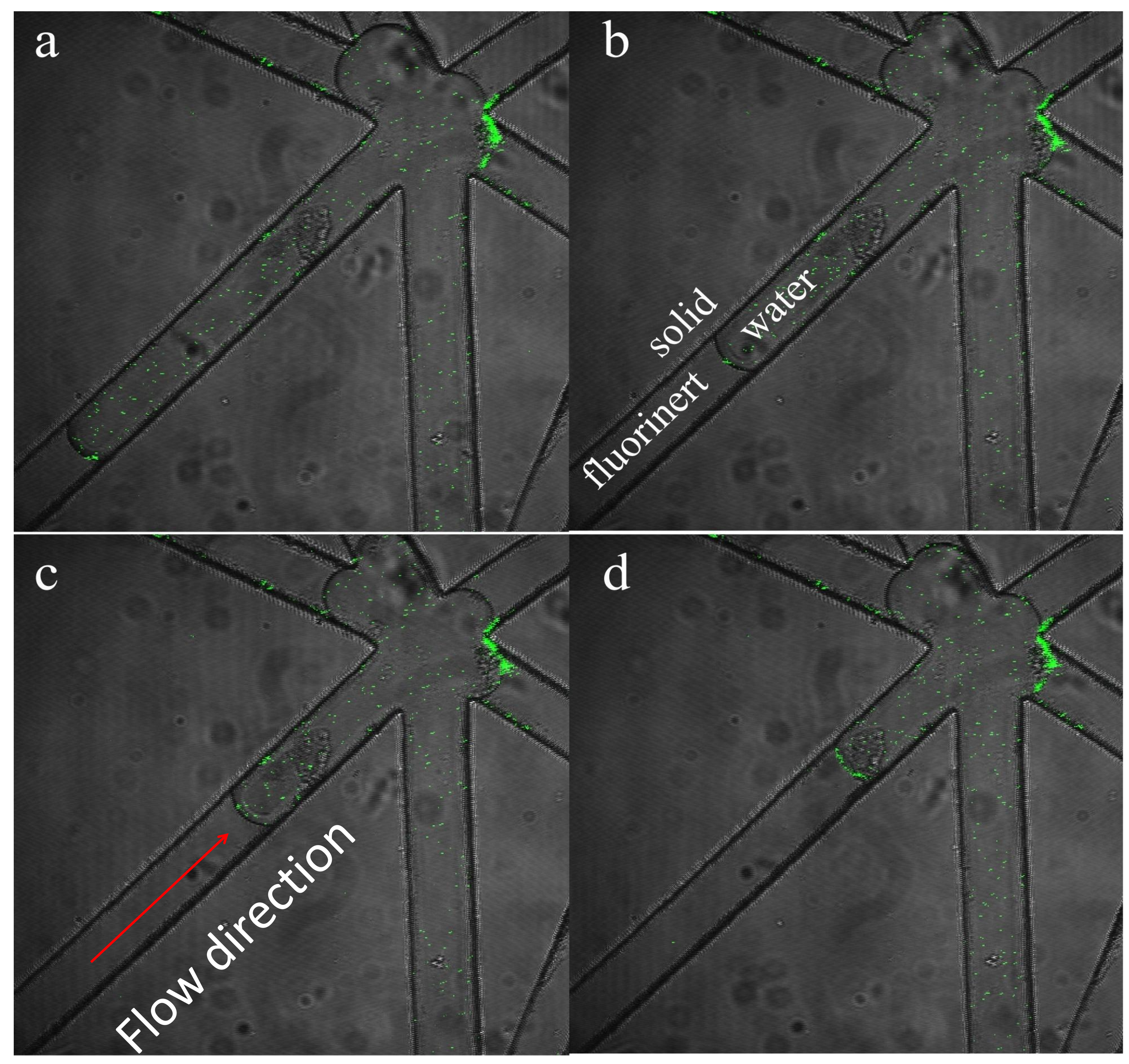
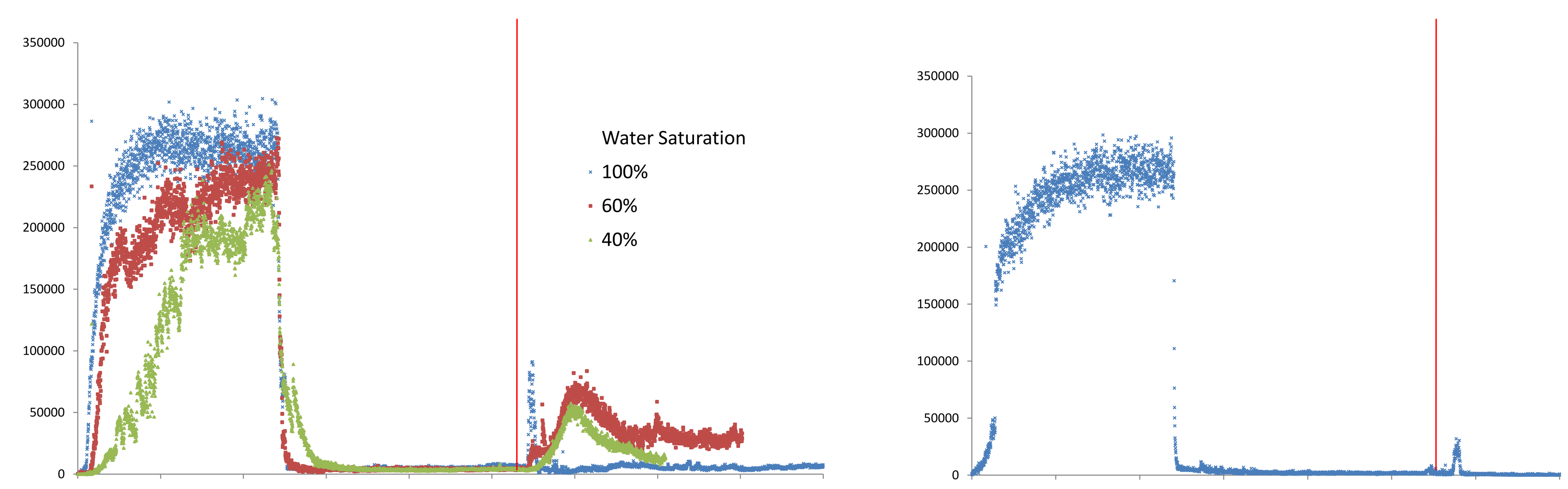


Fig.4 Observation of colloids remobilization caused by injecting fluorinert (imbibition).

Breakthrough curves

Breakthrough curves at the outlet of the flow network (highlighted in red in Fig.2) were obtained by measuring fluorescent intensity of the particles at intervals of 834 ms using a confocal microscope.



Left : Measured breakthrough curves first steady-state at a given water saturation then saturation was decreased to residual by injecting fluorinert.

Right: Remobilization of colloids as a result of change in flow rate from q to 10q (saturation was kept constant at 100%).

Red lines stand for the starting time of transient condition.

Conclusions

- More colloids retention at the FWS was observed than at the FWI under steady-state flow.
- Remobilization of colloids as a result of imbibition was observed from both visualization and from breakthrough curves.
- High flow rate caused more remobilization of colloids than low rate.
- Colloids retention increased with the decrease of saturation. According to our visualization, retention occurred at the FWS, FWI, and SWI.
- Large saturation change caused higher remobilization.