Utrecht University

Structures of Strength

Fundamental Insight into Permeability Reduction by Particle Clogging in Porous Media

From Microfluidic Perspective

Qianjing Tang, Amir Raoof

Department of Earth Sciences, Faculty of Geosciences, Utrecht University

Introduction

In a wide range of hydrological and environmental applications, the interaction between liquid-phase particles and porous media, especially particle clogging, plays a pivotal role. We have developed state-of-the-art setups that merge microfluidic technologies with fluorescence microscopy. These setups allow for real-time, high-resolution observation of particle clogging behaviours and their effects on porous media. Using this direct observation and complementing it with numerical modelling, we've gained critical insights. These insights are instrumental in guiding sustainable use of practices for the future.

Representation of Porous Media on Microfluidic

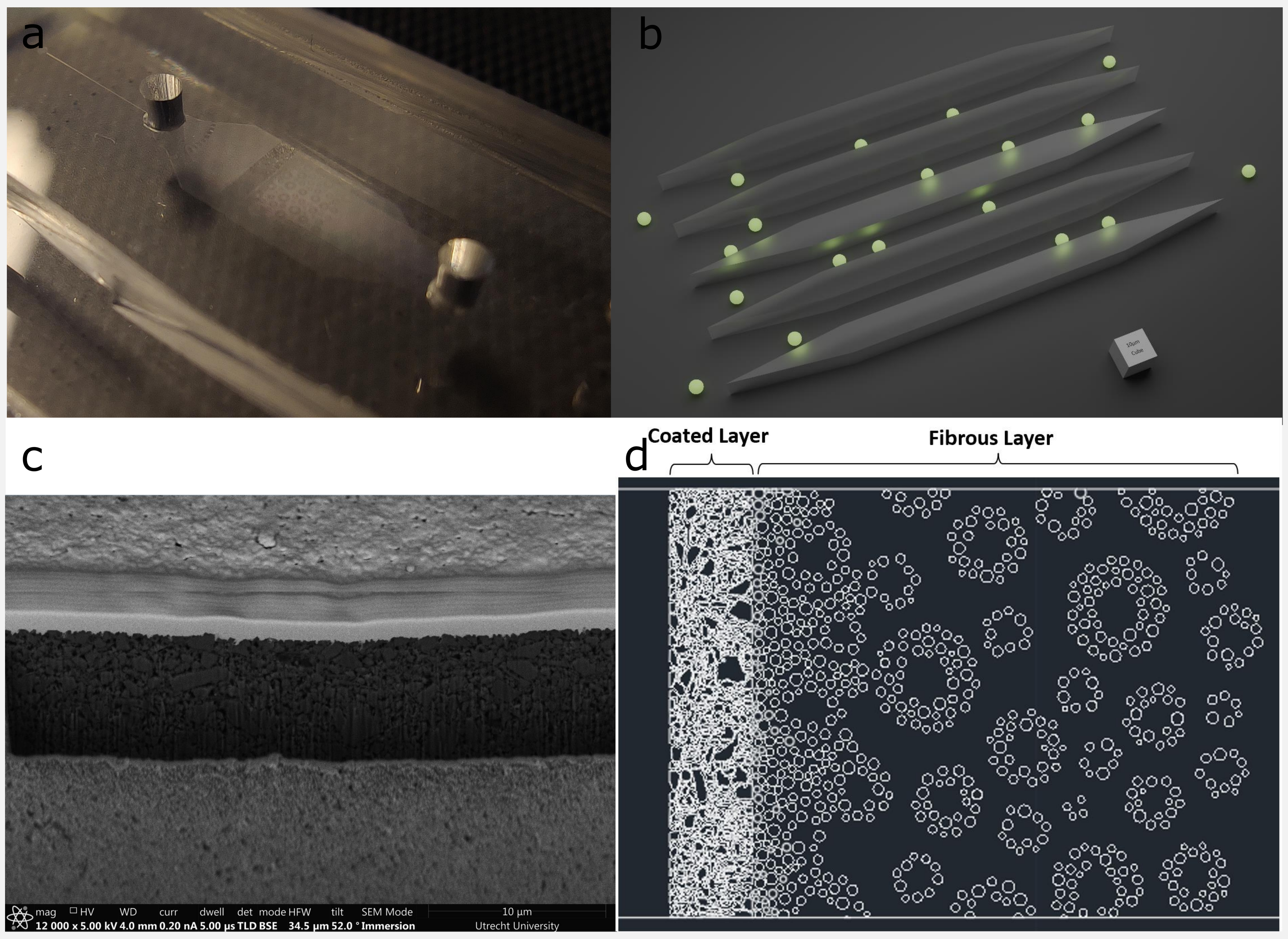

Figure 2

a) Example of a PDMS microfluidic chip. b) schematics of particle clogging experiment in parallel channels. c) FIB-SEM image of a paper coating layer cross-section. d) A microfluidic design derived from the FIB-SEM scan that represent a cross-section of paper.

Toolbox for Direct Observation

In order to directly observe the dynamic of particle clogging and its interaction with the flow and porous media, we have incorporated particle detection, surface property control, internal pressure measurement with fibre-optic sensor and solute flow field marking with fluorescence recovery after photobleaching (FRAP) technique.

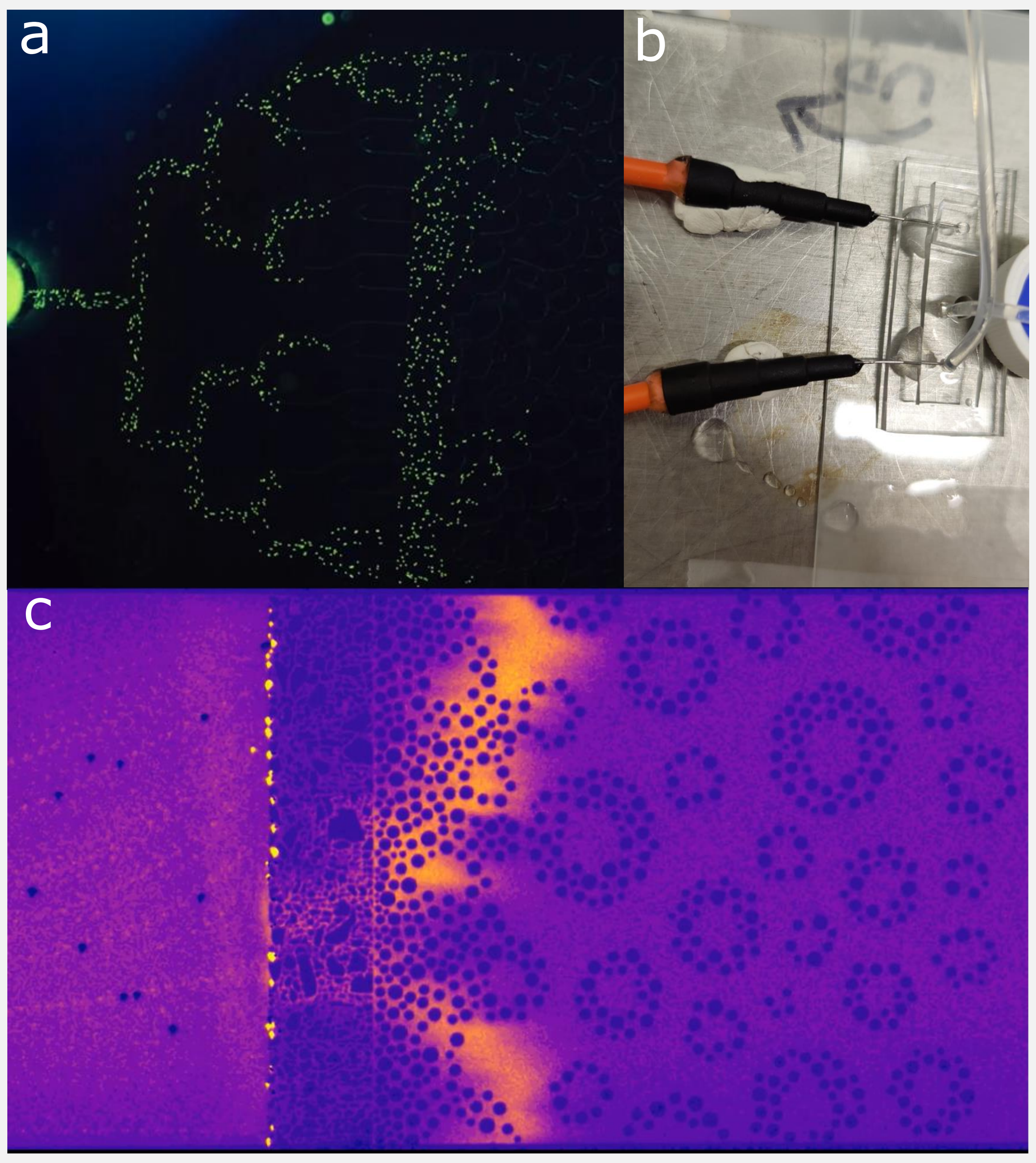

Figure 1

a) Image of fluorescent particles entering the microfluidic. b) Fibre-optic pressure sensors probing pressure inside the microfluidic. c) Photobleached solute plume transporting through the porous medium (in pseudo colour).

Direct Observation

Flow and Permeability Alteration by Particle Clogging

Combining these techniques, we have conducted flow through experiments revealing the process of particle clogging and its impact on fluid flow. Furthermore, we have investigated the clogging behaviour of particle mixture of different sizes.

Flow Field Alteration During Particle Clogging

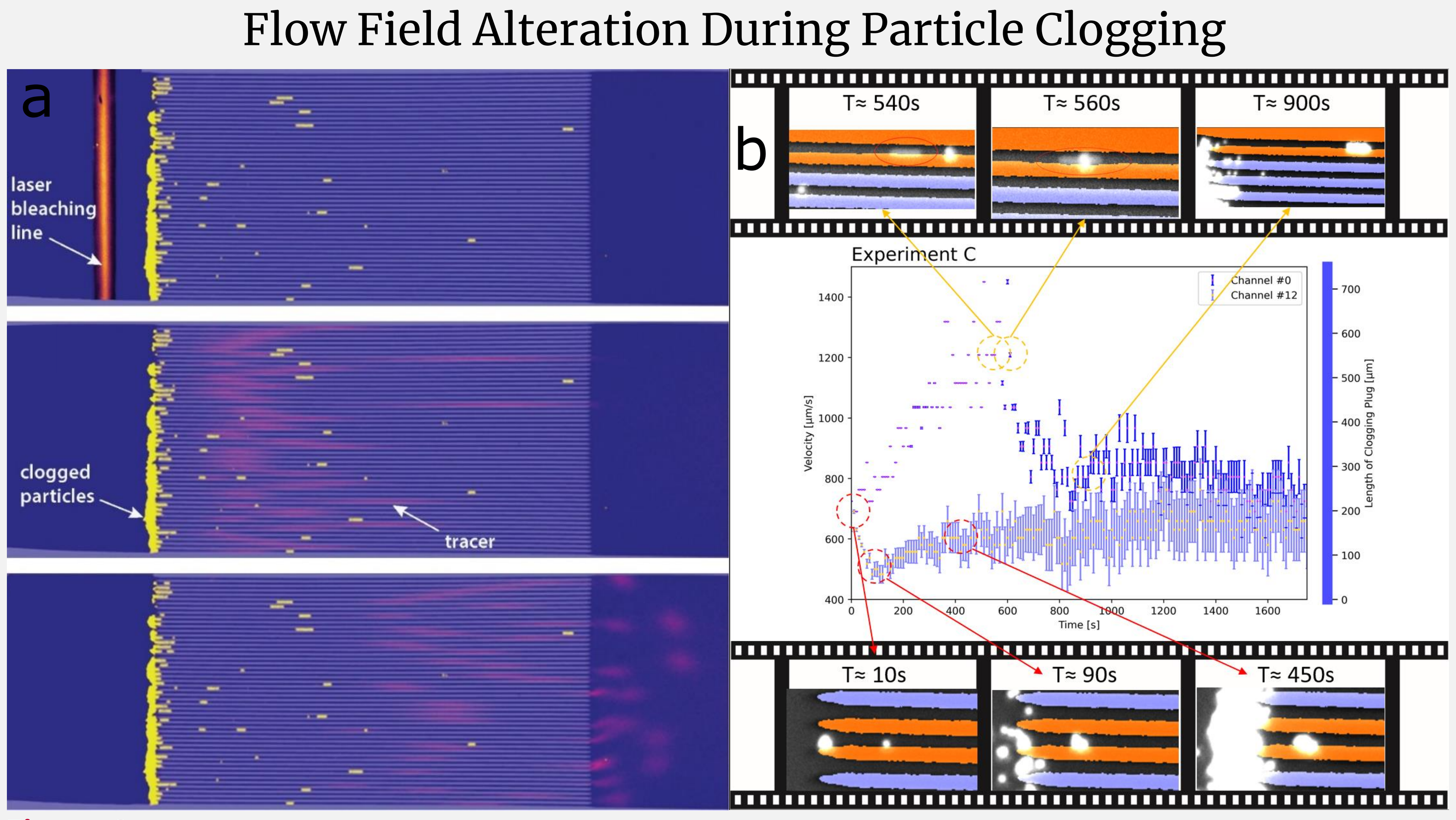

Figure 3

a) Visualization of photobleached plume through parallel channels with different state of clogging (light blue: channel wall; yellow: attached particles; violet: solute plume). b) Flow rates measured by FRAP in different channels at different stages of clogging. A clear redistribution of flow field was observed in channel #12 when the micromodel is fully clogged

Impact of Particle Mixture Clogging

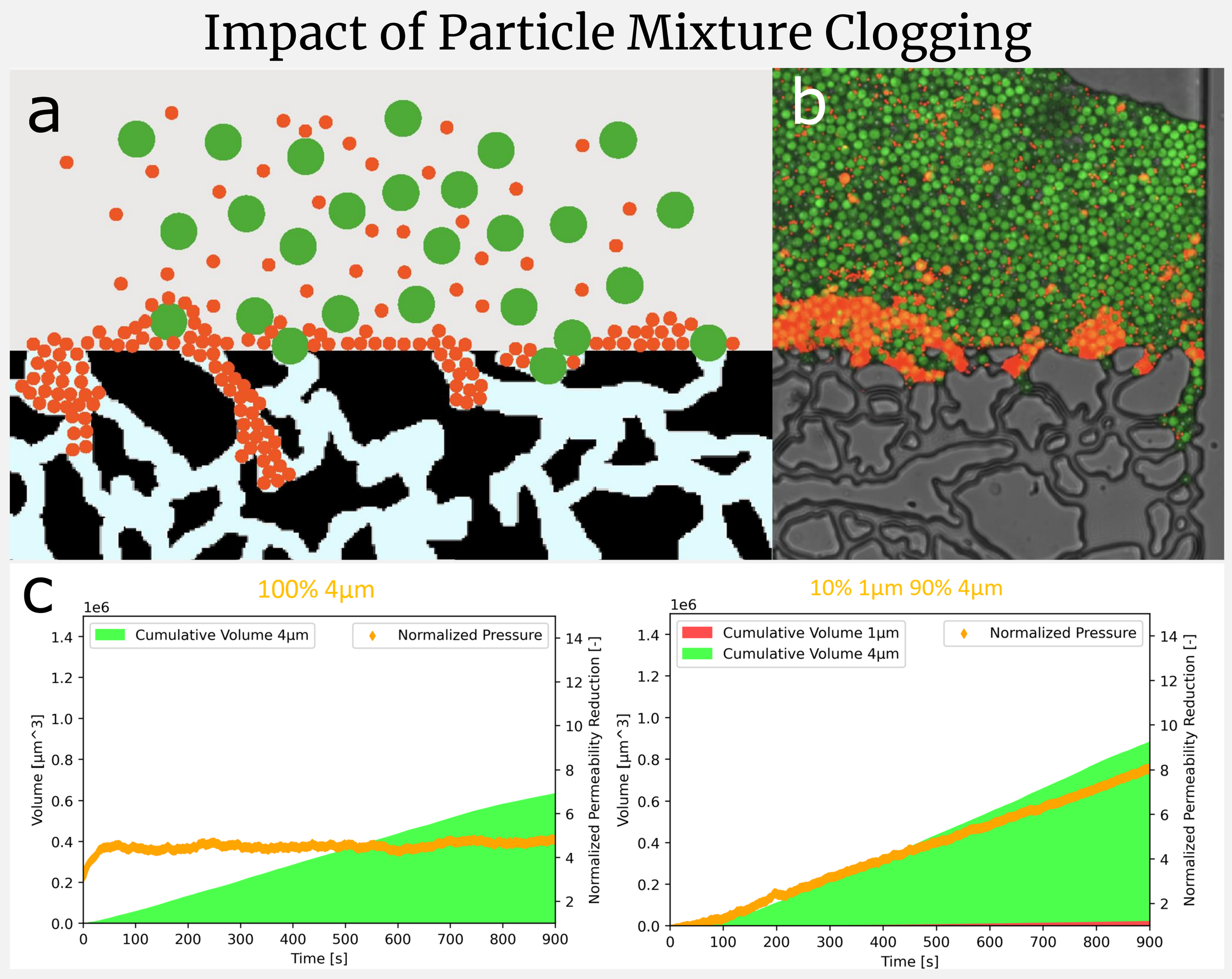

Figure 4

a) Schematic of the particle mixture layout (ΦGreen > pore size > ΦRed). b) End state of particle mixture clogged porous medium. c) Permeability reduction over time during particle mixture clogging.

References

de Vries, E. T., Tang, Q., Faez, S., & Raoof, A. (2022). Fluid flow and colloid transport experiment in single-porosity sample; tracking of colloid transport behavior in a saturated micromodel. Advances in Water Resources, 159, 104086.