Clogging dynamics of a porous medium by colloidal particles

Clogging is a recurrent issue encountered during the flow of dilute colloidal suspension through natural or industrial porous media. Due to the high complexity of this process, several recent studies focus more specifically on the clogging at the pore scale, using mainly microfluidic devices. Thanks to this approach, we, at the IPR have been able to study the clogging dynamics in highly confined conditions with the pore throat slightly greater than particle diameter. In these cases, particles are captured by the pore wall but also by the immobile ones that reside inside the pore[1]. For less confined conditions, we showed that growth and merging of aggregates leads to pore clogging[2-3].

The main goal of this thesis is the determination of the dynamics of partial of complete clogging, by colloidal particles, of model porous media with interconnected pores (figure A). In such media, even for simple Newtonian fluids, there are preferential flow paths, chiefly coming from the pore size distribution (figure C, left). We will determine how the colloidal deposit within the porous structure will modify this repartition of the flow paths (figure C, right), which in turn will modify both the clogging dynamics and the spatial location of the clogged pores (figure A and B). We will also determine the structural features of the particle deposits, which will allow us to find the link between the local porosity of the deposits, i.e. their hydrodynamic resistance, and the flow path repartition in the entire porous medium. In the same time we will determine the flow properties as the porous medium get clogged, thanks to fluorescent dye injection[5]. We will try to develop a simple hydrodynamic model to link the velocity field with the local hydrodynamic resistance. Hereafter we will quantify the impact of various relevant parameters like the ionic strength of the suspension, that when it increases speeds up the particle aggregation, the distribution of the pore size and the flow velocities as well.

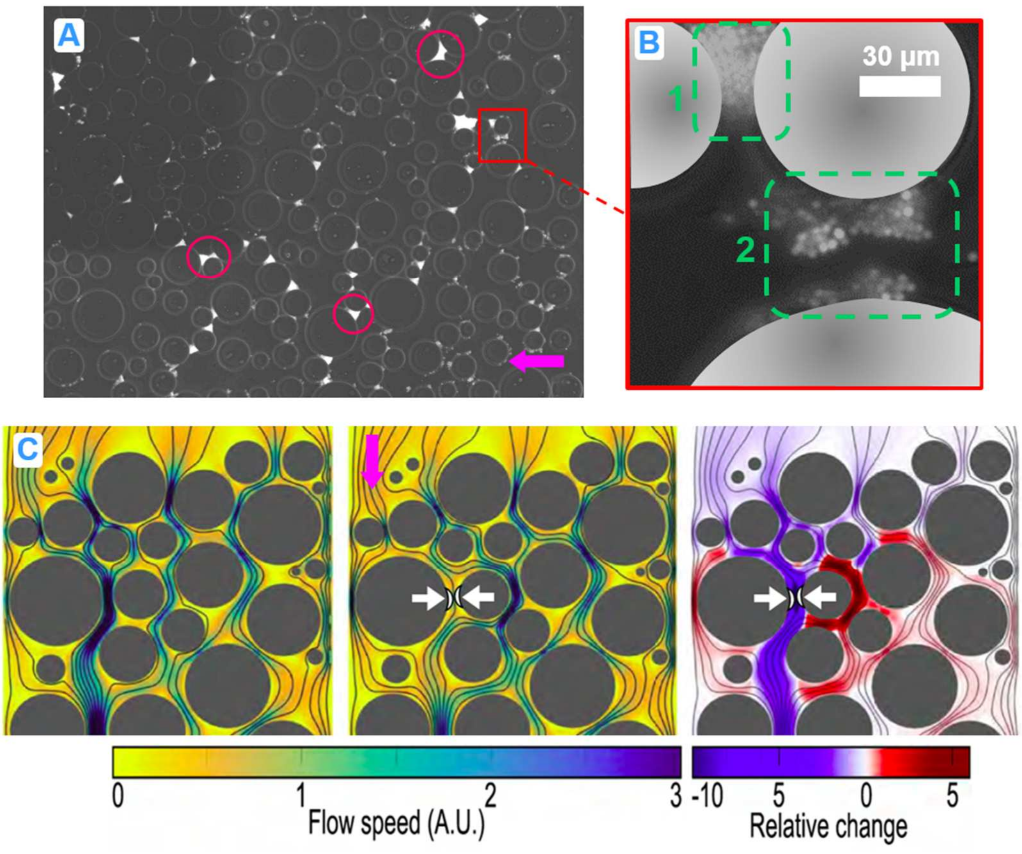

Figure: A-partial clogging of a porous medium as 1µm polystyrene particles flow through it. Some pores clogged are outlined with purple circles. B- Zoom on two pores bounded by three cylinders (grey), one fully clogged (1) and the other only partially (2). C-Flow in a porous medium composed of cylindrical posts (left).Arrow points towards the flow direction (left). The partial pore clogging (indicated by the two white arrows) leads to a substantial change of the velocity field over the entire porous medium (middle and right) [6].

This PhD thesis is mainly experimental and relies on a genuine methodology developed in our group at IPR (France), based on a fine control of the pore geometry, thank to microfluidics, and the use of fluorescent and confocal microscopy. Few numerical development will be performed in order to define the flow conditions within the porous medium as it gets clogged in collaboration with Pietro de Anna (Lausanne, Switzerland), a specialist of hydrodynamic in porous media. We will also use core-shell fluorescent colloidal particles synthetized by Joris Sprakel[4] (Wageningen, Netherlands). The particle structure will allow us to better define the internal structure of the particle deposits. New codes of image analysis will be developed to fully use these core-shell particles fluorescence properties.

Profil: Experimentalist in physics and fluid dynamics, with knowledge in physical-chemistry in colloidal suspensions. A suitable candidate will have a background in soft matter physics and chemistry.

Beginning of the thesis: October 2018. There will be short stays at Lausanne and Wageningen in the course of the thesis.

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