GELSHORN Luca (2023) : Transport and filtration of colloids with different shapes and finite-size in porous media

Abstract

Colloidal transport and filtration are processes that can be found frequently in natural systems, such as groundwater and soil (Miele, de Anna & Dentz, 2019). This process also occurs from anthropogenic systems, like wastewater treatment processes, which have a significant importance for the health of humans and the environmental protection (Molnar et al., 2015; Hunt & Johnson, 2017; Ma et al., 2020; Scheidweiler et al., 2020). In a river, groundwater or lake, the water contains non-monodispersed particles (Auset et al., 2005).

In past years, studies have mainly focused on classical, macroscopic approaches, such as Colloid Filtration Theory (CFT, e.g., Tufenkji 2007), where the filtration phenomenon is described in terms of average quantities, such as Darcy's fluid velocity, dispersion coefficient, Deposition Profile (DP) and BreakThrough Curve (BTC). However direct observation with field, laboratory experiments or numerical simulations show that CFT fails in predicting colloids transport in scenarios characterized by a heterogeneous porous structure. In particular, it has been shown how the host medium structural heterogeneity and the individual colloids transport properties (in terms of Particle Tracking) control the macroscopic BTC and DP (Battin et al., 2016; Scheidweiler et al., 2020).

Previous studies consider point-like colloids, i.e., their size is neglected, and each individual particle is considered to be advected by the fluid velocity field following the flow streamlines. The aim of this work is to investigate how the particles shape and size together with the host medium structure control the overall transport properties. In this study, combining experiments with microfluidic devices and timelapse microscopy, is analyzed the transport phenomenology of colloids that have finite sizes and rodelike shape. Time-lapse video-microscopy allows us to track individual colloid trajectories, but also to measure the overall BTC. The latter is the time series of the arrival concentration at a fixed-point, the medium outlet and the individual velocity Probability Density Function (PDF) resulting from Particle Tracking (PT) experiments (as in Scheidweiler et al., 2020). Then through the stochastic model, the microscale can be combined with the macroscale and then upscaled to get a broader view of the complex transport of colloids of different shapes and sizes in a porous medium.

It is shown that BTC are affected by the finite-size of the transported colloids as result of volume exclusion: larger colloids tend to stay further away from the grain walls experiencing, on average, larger velocities (Ma et al., 2020). This is confirmed with PT experiments, where velocity PDF are shifted towards are higher for particles of rode-shape than for spherical ones.