Mechanisms of transport and retention of silica nano particles in saturated porous media

influence of input concentration and size

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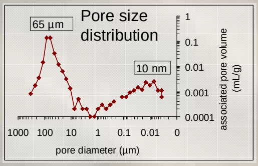
Introduction

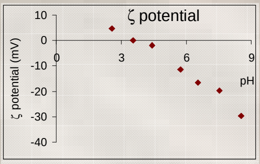
General abstract : Engineered (nano particles) and natural (bacteria) mobile *colloids* are suspected to be a **threat for the environment.** Mechanisms of transport and deposition of colloids in natural porous media such as aquifers are complex and depend on many factors. In this study some silica nano particles are used as colloid tracers with controlled properties to determine the influence of two factors (size and concentration) on the transport and retention in porous media.

Technical abstract : There are many factors influencing deposition and remobilization of colloids in porous media, such as flow velocity, nature of electrolyte, physical and chemical properties of porous grain and colloids… In this study, retention due to geometrical aspects, namely *straining* (Bradford and al., 2002) is highlighted establishing **conditions unfavorable to *attachment*** and using tracers with **different sizes**. *Blocking* is emphasized by **changing the input concentration.** Both breakthrough curves and spatial distribution are studied.

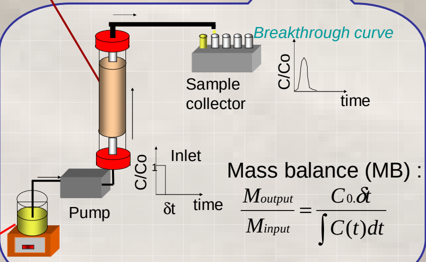
Materials and methods

Porous media : Hostun sand (d_{50} = 205 µm)





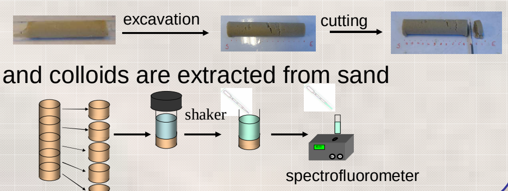
ζ potentials are used to calculate electrostatic interaction



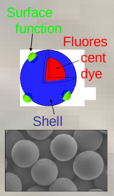
Spatial distribution :

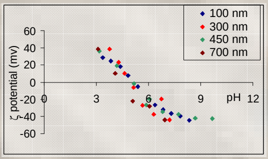
At the end of the experiment, the column is cut,

and colloids are extracted from sand



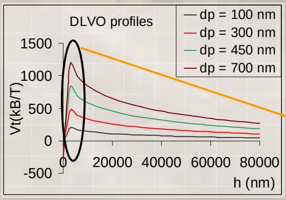
Silica Nano particles





Experimental conditions:

pH	8.5
Electrolyte	DI water
Flow velocity	Q = 10 mL.h^{-1}
Particle diameter	d_p = {100;300;450;700 nm}
Inlet concentration	Co ε [0.03;10 mg.mL^{-1}]



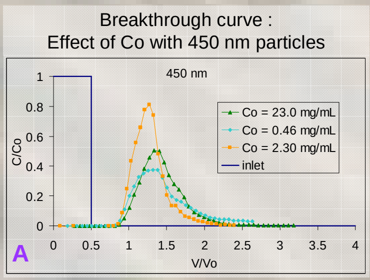
DLVO profiles are calculated with :

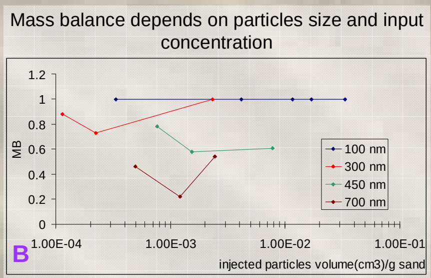
$V_{tot} = V_{vdw} + V_{edl}$

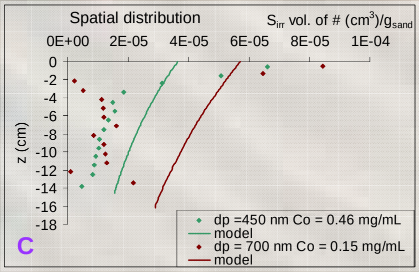
Total interaction potential — Van der waals — Electrostatic

Energy barrier : condition unfavorable to attachment

Results







Experimental profiles are compared with those calculated with a first order kinetic deposition rate. The coefficient k has been calibrated on experimental breakthrough curves

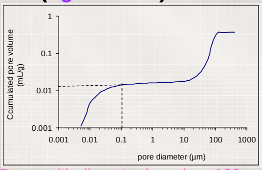
$$\frac{\partial c}{\partial t} = D.\frac{\partial^2 c}{\partial z^2} - v\frac{\partial c}{\partial z} - \frac{\rho}{\theta} v_{part}\frac{\partial S_{irr}}{\partial t}$$

$$\frac{\partial S_{irr}}{\partial t} = kc$$

Discussion

• For **100 nm particles, there is no retention at all** for all input concentration investigated. The conditions are indeed unfavorable to attachment. When the particles diameter increases, the Mass Balance (MB) decreases, which indicates a **retention due to geometrical properties (fig B)** (all other conditions are the same), named straining mechanism.

• When the input concentration increases, the MB first decreases then increases : Particles are blocked until the blocking sites are filled **(fig A and B)**.



Pores with diameter less than 100 nm represent 0.014 mL/g.

In our experiments, particles do not fill all pores with diameter less than dp (particles diameter) and are partially restituted at the outlet of the column (**fig B**). **Particles may not reach little pores** and do not fill them.

• The profiles indicate that the **deposition is not a first kinetic law (fig C) as predicted by the *Colloid Filtration Theory*** (Yao and al., 1971) Some mechanisms not considered in this theory may occur. We suppose that blocking and straining explain partially the deviation from the CFT.

Conclusions & perspectives

Particles with diameter less than 100 nm are not deposed at all in our experimental conditions.

Retention depend on (at least) the two properties studied here : concentration and size. Colloid filtration theory cannot explain experimental results. We explain the deviation of CFT with two mechanisms : straining and blocking, not considered in this theory.

Following task will be the integration of observed mechanisms in an adapted transport model.

Yao, K. M., M. T. Habibian, and C. R. O'Melia, 1971, Water and Waster Filtration : Concepts and Applications: Environmental Science & Technology, v. 5, p. 1105-1112.

Bradford, S. A., S. R. Yates, M. Bettahar, and J. Simunek, 2002, Physical factors affecting the transport and fate of colloids in saturated porous media: Water Resources Research, v. 38.

Glossary

Colloids :"particles" between 1nm 1µm,

Breakthrough curve : concentration of the specie considered versus time in the outflow

DLVO theory : has been developed to calculate particle potential near an electrical charged surface (Derjaguin, Landau, Verwey and Overbeek, 1940)

Colloid filtration theory (CFT) : deposition rate is estimated with the *sphere-in-cell model* considering gravitation, diffusion and interception.

Attachment : (here) retention of colloid due to electrostatic properties of collector and colloid surfaces

Straining effect : geometrical trapping of colloid particles in pore throats that are too small to allow their passage (not taken into account in CFT)

Blocking effect : diminished retention with time due to the filling of retention site (not taken into account in CFT)