PhD offer at the University of Orléans– Particle transport by diffusiophoresis in porous media

General information

Research lab: Institute of Earth Sciences of Orléans (ISTO), 45100 Orléans (FRANCE)
Contacts: Sophie Roman, sophie.roman@univ-orleans.fr; Cyprien Soulaine cyprien.soulaine@cnrs-orleans.fr
Contract: fixed-term contract
Duration of the contract: 36 months, full time
Starting date: flexible, from 1st November 2022

Context

ERC project “TRACE-it” (2022-2027), summary:

Many engineering applications foreseen the usage of small particles for groundwater remediation or for sealing damaged geological confinement barriers, however, delivering materials to a contaminated or damaged region is challenging. TRACE-it aims at controlling the flow of colloidal particles in subsurface geological environments using in situ solute concentration gradients. The phenomenon, known as diffusiophoresis, has a tremendous potential to move colloids to regions that are inaccessible by conventional transport. Diffusiophoretic transport in porous media, however, has received very little attention so far, especially in standard transport in porous media models where it remains unconsidered.

What is the magnitude and location of solute concentration gradients produced during subsurface processes? How to use these gradients to transport colloids towards target regions? The answers will be found through a combined experimental-modelling approach to: (i) measure coupled hydro-electro-chemical dynamics, (ii) characterize concentration gradients generated in situ in geological porous media, (iii) identify the influence of concentration gradients on particle transport and develop a macroscale model of transport in porous media that includes diffusiophoresis. TRACE-it integrates the usage of microfluidic experiments, observation techniques, and multi-scale computational fluid dynamics to describe the transport mechanisms at the pore-scale before upscaling to the continuum-scale.

The experimental-modelling toolset will open new ways for moving colloidal particles by sensing chemical gradients generated naturally or from human activity, leading them to their target such as oil, contaminants, or reacting minerals. During column-scale experiments, controlling colloid transport will be achieved through the characterization of solute concentration gradients and the use of specifically designed particles.

Role of the PhD student

The objectives of this PhD are to propose a model for the transport of colloids by diffusiophoresis in porous media, and to understand the role of concentration gradients in particle transport in heterogeneous porous structures. For that, we will describe diffusiophoretic transport of colloids in porous media at the pore-scale before including diffusiophoresis in transport models at the macroscale. Given the state-of-the-art on diffusiophoretic transport, a description of this phenomenon in complex geometries is needed. Besides, in current diffusiophoresis models the distribution of chemical concentrations relies on oversimplified models, e.g. linear concentration profile in a straight
channel. In this work, for the first time, we will couple solute distributions predicted for subsurface processes and diffusiophoretic transport, at the pore-scale and at the macroscale. The PhD candidate will study the transport of particles having different properties in terms of radius and surface charges in porous media of well-controlled geometry, subject to chemical gradients, both numerically and experimentally. We will start with rigid spherical particles, then extending to porous, soft particles, or droplets. A numerical model will be developed that couples fluid/solute/particle dynamics, it will be compared with experimental microfluidic data through an iterative process: from single pores, to network of pores, to macroscale models. This work will allow also to obtain new continuum-scale parameters for colloidal transport in porous media: diffusiophoretic velocity and effective diffusiophoretic mobility.

References:

Work environnement
Institut des Sciences de la Terre d’Orléans (ISTO)
The Institute of Earth Sciences in Orléans is a joint research unit (UMR) comprising members of the University of Orléans, the CNRS (the French National Centre for Scientific Research), and the BRGM (the French Geological Survey). It is part of the Observatory of Sciences of the Universe in the Region Centre (OSUC), a federal organization. Application domains of ISTO’s research activities include the mineral, energy and water primary resources, the volcanic hazards, and the environmental impacts of anthropic activities. ISTO leads two major projects at Investissements d’Avenir (IA): the LabEx VOLTAIRE, concerning the transfer and the reactivity of fluids from the deep crust to the atmosphere, and the EquipEx PLANEX, a platform for in situ analyses of geomaterials at high pressure and temperature. ISTO actively participated in setting up the PIVOTS program, led by the BRGM, funded by the Region Centre as part of its Ambition Research Development program. This project is devoted to environmental monitoring and development. ISTO is leading two of the six platforms, pertaining to the deep unsaturated zone of polluted soils and Earth’s ground-atmosphere interface.

Collaboration
It is planned that the Ph.D. student spend time at Princeton University in the group of Prof. Howard Stone who is internationally renowned for studying the dynamics of complex fluids including extensive work on diffusiophoresis phenomena.

Constraints and risks
No constraints or risks, except classic chemical, laser, and electrical risks.

Additional information
Candidate profile: MSc degree (or engineering school), background in engineering, physics, soft matter, or fluid mechanics. A strong taste for research and laboratory work. Drafting quality.
To apply: Send a CV, cover letter, reference letter(s), MSc grades, https://euraxess.ec.europa.eu/jobs/814559
Deadline for application: until the position is filled