PhD student – Microfluidic experiments to study mass transfer at fluid/fluid interfaces in geological porous media

General information

Workplace: Orléans (France)

Scientific leader: Sophie Roman

Research lab: Institute of Earth Sciences of Orléans (ISTO), 1A rue de la Férollerie, 45100 Orléans

Other laboratories associated with the project:

- CEMHTI, 1D avenue de la Recherche Scientifique, Orléans
- GREMI, 14 rue d'Issoudun, Orléans

Contract: fixed-term contract

Duration of the contract: 36 months, full time

Starting date: from 1st October, 2021

Gross salary: 2 135 € /month

Context

Keywords: microfluidic, porous media, multiphase flow, vibrational spectroscopy (Raman, FITR), plasma treatment, plasma jet, energy storage, soil pollution

The project: 80|PRIME INTER-AQ

INTER-AQ is a project supported by the MITI (Mission pour les Initiatives Transverses et Interdisciplinaires) from CNRS (the French National Centre for Scientific Research). The call for proposal « 80|Prime » from the MITI funds interdisciplinary research projects between different CNRS teams. The project includes a PhD fellowship. The objective of the INTER-AQ project is to reveal the complex and coupled dynamics of mass transfer and transport at fluid-fluid interfaces and its impact on the redistribution of fluids and species in porous media. For that, we need an interdisciplinary approach that combines the concepts and tools for microfluidics to represent subsurface processes, vibrational spectroscopy to develop in situ quantification methods, and plasma physics to control the surface properties of the pores.

Scientific context

To use the soil and subsurface for environmental (decontamination) or energy (geological storage) engineering, we need to control multiphase flow and interphase mass transfer in porous media. This PhD position is part of an interdisciplinary project that involves three laboratories in Orléans (France). The objective of the thesis is to assess how mass transfer at fluid-fluid interfaces impacts capillary trapping in geological porous media. The project relies on microfluidic experiments, also called aquifer-on-a-chip, enabling a direct optical visualization of flow and transport processes at the pore-scale. The project proposes developments in experimental microfluidics, using innovative methodologies and advanced post-processing in vibrational spectroscopy that allows to reveal the dynamics and reactivity

at interfaces in well-controlled porous systems. We will also use plasma jet technology at atmospheric pressure to modify the wettability of the pores.

Role of the PhD student

The PhD candidate will be at the center of the interdisciplinarity of the project. The objective of the PhD deals with mass transfer problem coupled with capillary physics. The PhD student will have to design microfluidic chips with geometry of increasing complexity that will serve for the project. He/she will learn to use the plasma reactor to generate a plasma that propagates in the microchannels of a micromodel to modify its surface properties. The PhD candidate will set up spectroscopic measurements, then perform data acquisition for all experimental configurations. Data processing, using statistical tools, will allow him/her to determine the influence of hydrodynamic conditions (trapping, redistribution, two-phase flow properties) and of wettability on mass transfer and species transport. Experimental results will be combined with numerical simulations at the pore-scale to predict the mean behavior at larger scale of a natural reservoir. Finally, the PhD candidate will study numerically the impact of the results on the propagation and persistence of a NAPL contamination (Non-Aqueous Phase Liquid) and propose in situ remediation strategies.

References

[1] S. Roman, C. Soulaine, M. AbuAlSaud, A. Kovscek, H. Tchelepi, *Particle velocimetry analysis of immiscible two-phase flow in micromodels*, Adv. Water Resour., vol. 95: 199–211, 2016.

[2] S. Roman, C. Soulaine, A. R. *Kovscek, Pore-scale visualization and characterization of viscous dissipation in porous media*, *J. Colloid Interface Sci.*, vol. 558: 269–279, 2020.

Work environment

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. ISTO is a research laboratory in Earth Science dedicated to the external envelops of the Earth from the upper mantle to the atmosphere. Studies focus on the heat and mass transfers at the interface between the mantle and the crust as well as between the crust and the atmosphere. 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.

Conditions Extrêmes et Matériaux : Haute Température et Irradiation (CEMHTI)

CEMHTI is a research unit with the objective to understand the physico-chemical properties of materials under extreme conditions, by developing a better description of their structures at the atomic scale, in solid and molten state. CEMHTI develops expertise and original tools for in situ analysis: high resolution and high temperature spectroscopy, aerodynamic levitation for molten media, particle accelerator, and defect analysis. CEMHTI is also working on the development of new materials: transparent and refractory ceramics, nanoporous media for energy and environment.

Groupe de Recherches sur l'Energétique des Milieux Ionisés (GREMI)

The GREMI is a joint research unit of the CNRS, and University of Orléans in the field of plasmas and plasma processes. GREMI uses a multidisciplinary approach in physics, optics, chemistry, material science, and energetics. The applications are mainly for energy engineering, micro-nano-electronics, the environment, life sciences, electrical safety.

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, vibrational spectroscopy, fluid mechanics or geosciences. A strong taste for research and laboratory work. Drafting quality.

To apply: https://bit.ly/3tzp4zR

Deadline for application: June,4 2021