Post-doctoral position at GeoRessources (Nancy, France)

Pore-scale coupled simulation of multiphase flow and electrical geophysical methods: Application to LNAPL contamination in unsaturated zone

Background and Objectives

Petroleum hydrocarbons account for a significant amount of soil contamination sources, posing serious risks to human health and groundwater quality. These light non-aqueous phase liquids (LNAPLs) infiltrate the unsaturated soil zone and accumulate at the water table, forming a floating layer, while some remain trapped as droplets or ganglia under capillary forces [1].

- Repeated drainage and imbibition cycles imposed by seasonal hydrological variation and exacerbated by the effect of future climate change can alter the LNAPL release near the water table. LNAPL phase distribution and reactivity are controlled by complex mechanisms which may be directly described in the pore scale.
- Electrical geophysics have been used experimentally to study the contamination of groundwater by NAPLs [2, 3]. Indeed, the bulk electrical conductivity of the porous media is directly affected by the composition of the fluid phase. The link between LNAPL content and electrical conductivity are described by petrophysical laws which are mostly based on empirical relationships. The applicability of such relationships for three-phase flow and heterogeneous media are put to question.

To tackle these challenges, pore-scale multi-physics models are of particular interest.

In the context of the ANR (French National Research Agency) project BatNap, we aim at studying the impact of groundwater table variations induced by climatic changes on petroleum hydrocarbons remobilisation through a multiscale numerical study [4, 5]. **The present post-doc focus of pore scale modeling. The aim is to improve understanding of the evolution of drainage / imbibition curves, but also electrical resistivity and/or permittivity, in relation to the microstructure and the composition of the soil, especially in regards to variable physical properties (e.g. wettability). Besides, considering the project focus on the smear zone, modelling of water-NAPL-gas three-phase flow in porous media is important.**

Methods

The **Lattice Boltzmann Method (LBM)** will be used as the main numerical method during this project. An in-house software has been developed and will be improved. Building upon the pre-existent LBM custom-made software developed within our Consortium and already applied to single [6] and multiphase flow [7], solute transport [6], reactive transport [8,9], electrostatic potential and ionic transport [10], we will investigate mass and electrical charge transfers. LNAPL dynamics will be assessed primarily by referring to the pore scale theoretical geometry of the porous medium, phase distribution and composition. Further developments include coupling with the electrical charge under multiphasic conditions, including both static, and dynamic distribution of multi-phase flow. As a further step, both aspects can be considered jointly to assess the impact of ternary phase distribution and its evolution on the electrical response. On top of that, the results are upscaled in spatial dimensions to obtain the larger scale (continuous medium) parametrization (e.g. ternary phase distribution, retention curves, electrical conductivity and permittivity) that can be used in Darcy scale simulations. The presented methodology is expected to shed light on certain aspects associated with the hydrodynamics behavior and description of three-phase flow in Darcy scale. In addition, some of the sources of uncertainties related to the use of empirical or semi-empirical petrophysical relationships are expected to be clarified.

Prerequisite

The candidate must have a strong background in programming (especially C/C++) and a fundamental knowledge of the principles of fluid mechanics and preferably knowledge in porous media and geophysics. The candidate must be a highly motivated and autonomous person with a PhD in either fluid mechanics, geosciences, geophysics, reservoir engineering, applied mathematics or other relevant field. Experience in the development of LBM would be a strong asset. The candidate should be fluent in English (or French).

Funding

The proposed post-doctorate fellowship is funded by ANR through the BatNap project for 1 year (with a possibility of extension). The expected start is somewhere in spring 2026. The work will be carried out within the GeoRessources laboratory (Université de Lorraine / CNRS) (https://georessources.univ-lorraine.fr/) , team Multiscale Hydrogeomechanics (HGM) in Nancy, France. The monthly gross salary is about 2500 €, including social benefits and health care.

Contacts : Candidates are invited to send their CV and cover letter by email to :

anne-julie.tinet@univ-lorraine.fr, behshad.koohbor@univ-lorraine.fr

References :

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