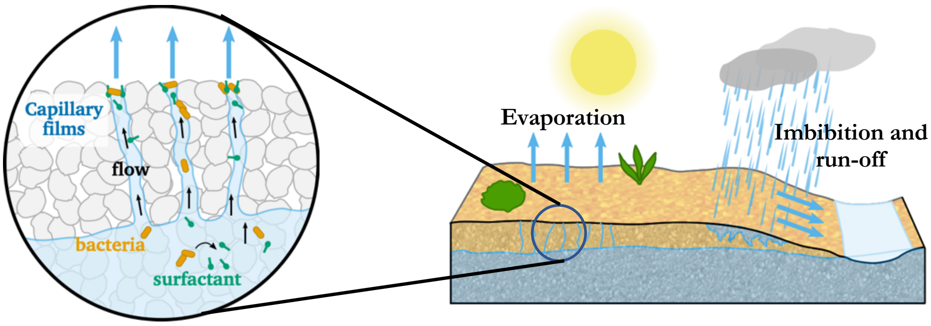
PhD proposal:
Impact of bacteria on soil water dynamics

Institut de Physique de Rennes, Université de Rennes (Brittany)

Scientific project: Surface evaporation from bare soils is a key component of the Earth's hydrological cycle, returning 20% of rainfall from land masses to the atmosphere. This "drying" of the soil is controlled at microscopic scales by capillary flows along water films linking water at depth to the surface. Drying dynamics are therefore sensitive to the physicochemical properties of the soil environment, such as the surface tension of water or its contact angle with soil particles. Bacteria are a ubiquitous feature of the soil environment, present in concentrations up to 10 billion per gram of soil. They produce molecules with strong activities at water-air interfaces – surfactants – which can significantly lower surface tension. Despite this, the impact of these bacteria on drying dynamics – and other microscale water dynamics such as imbibition – remains almost completely unexplored. As extreme climatic events such as droughts become more frequent, it becomes even more crucial to understand how soil bacteria modify water dynamics, and to explore their potential for soil bioaugmentation.



Soil drying and imbibition dynamics are environmentally dependent on microscopic capillary flows. For drying dynamics, the way bacteria modify capillary pumping remains unknown.

This PhD project will work on idealized porous media with model soil bacteria to quantitatively understand the coupling between the production of biosurfactants and microscale water dynamics in pores. This will involve microscopic observations on a combination of fabricated microfluidic chips and granular columns to characterize water dynamics at the scale of microscale films, microbial dynamics, and interfaces properties, and shed light on their coupling. The project will also aim to capture key effects in simple mathematical models to shed light on water dynamics at a larger scale in the environment. The PhD work will be in close collaboration with soft matter and granular matter physicists of the Institut de Physique de Rennes, and biologists and geoscientists from other institutes at the Université de Rennes.

During the project, the PhD student will gain **theoretical and experimental expertise** in **soft-matter** physics, in particular capillary flows and interface physico-chemical characterisation, **experimental microbiology**, **microscopy** and image analysis, design, fabrication and implementation of **microfluidic devices**, as well as **environmental sciences** and environmental microbiology. Several opportunities for the development of transferable skills will also be available throughout the project.

Project setting: the project will take place at the Institut de Physique de Rennes (UMR 6251), within the Soft Matter and Divided Media departments. Collaborations with the research units Geosciences Rennes (UMR 6118) and Ecobio (UMR 6553) will permit more extensive exploration of the project's environmental aspects, and can provide support for extension of the biological aspects of the project. These interdisciplinary collaboration benefit from the support of OSUR, an organisation promoting and facilitating interactions across the above laboratories at the University of Rennes. A network of international collaborators (e.g., USA, UK, Switzerland) will further provide opportunities for interactions and lab visits.

PhD candidate: we are looking for a highly motivated candidate with a keen interest in interdisciplinary sciences. The PhD candidates should have an MSc or comparable degree in biophysics, physics, mechanical or chemical engineering, or microbiology with a solid physics background. Previous experience in experimental techniques (microscopy, microfluidics, fluid dynamics, rheology, microbiology), image processing and data analysis is appreciated but not essential.

Start date: this **fully funded PhD** (3 years) should start in **October 2023**.

Informal inquiries are welcome, if you are interested, please contact:

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Related readings:

- D. Or, P. Lehmann, E. Shahraeeni, and N. Shokri, "Advances in Soil Evaporation Physics - A Review," Vadose Zone Journal, 12(4) 2013.
- J Q Yang *et al.*, "Evidence for biosurfactant-induced flow in corners and bacterial spreading in unsaturated porous media," PNAS, 118(38), 2021.