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Fluid dynamics during spontaneous imbibition in multimodal porous media

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Using porous materials for fluid management has been practised for thousands of years, e.g. water storage and release or filtration purposes. Thereby, the chemical nature of the porous material and the pore geometries determine the capacity of a porous material to take up a specific fluid through spontaneous imbibition. This talk addresses how geometric and chemical features impact multiphase flow dynamics and macroscopic performance using multiple examples of porous systems.
For instance, surface-engineered sponges for wastewater filtration: The sponges consist of a polyurethane-based fibre network and contain a porosity of ~98%. The fibres are made hydrophobic by chemical functionalization for wastewater filtration and oil spillage clean-up [1]. However, the displacement mechanism within them is guided through the hierarchical pore structure. First, the porous fibres are filled with oil, which then facilitates macroscopic displacement or nucleation of oil drops out of an emulsion between the fibres.
In another example, water imbibing an air-filled porous rock, we observe reverse behaviour. The large pores in between the grains are filled first, whereas the air from intergranular pores is released slowly [2].
These examples illustrate the careful considerations needed for the efficient design of porous materials in various applications and guide future design choices.

1. Cherukupally, P., Sun, W., Wong, A. P. Y., Williams, D. R., Ozin, G. A., Bilton, A. M., & Park, C. B. (2019). Surface-engineered sponges for recovery of crude oil microdroplets from wastewater. Nature Sustainability, 3(2), 136–143.
2. Wensink, G., Schröer, L., Dell, H. P., Cnudde, V., & Rücker, M. (2023). Spontaneous Imbibition and Evaporation in Rocks at the Nanometer Scale. Energy & Fuels, 37(23), 18713-18721.

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