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Liquid relative permeability through foam-filled porous media

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In the context of soil remediation or oil extraction, foam flooding is useful to mitigate effects due to permeability contrast within the soil layers. For some applications, the liquid relative permeability of the foam-filled porous medium is a crucial parameter to control the liquid flow rate at which active substances or nutrients (for bacteria) can be delivered deep into the medium. In pioneer works and in more recent studies, it was concluded that the presence of foam lamellae does not change the liquid (water) relative permeability with respect to the foam-free porous medium at same liquid saturation larger than 20%. Here, we are interested in the liquid relative permeability of foam-filled porous media within the range of low liquid saturations, i.e. 5%-20%. Our goal is to demonstrate that there are situations where the characteristics of the foam trapped into the porosity has significant impact on liquid permeability.

We used two surfactants, alkyl polyglucosides (APG) and saponin, and we produced well-controlled liquid foams in terms of bubble diameter and liquid volume fraction. It is shown that the dimensionless bulk permeability (liquid permeability divided by squared bubble diameter) for APG foam is about 5 times larger than for saponin foam at same liquid fraction, which is explained by the respective intrinsic viscosities of the liquid-air interfaces.

Model porous media made of packed spherical grains were prepared and then filled with the controlled foam. Particular attention was paid to ensure that the bubbles were not destroyed during the filling step, which allowed to have foam-filled porous media with controlled parameters, namely the bubble-to-grain size ratio r and the liquid saturation.

We show that the liquid relative permeability of such foam-filled porous samples is non-monotonous for saponin foams as a function of r and exhibits an optimal permeability value. For APG foams, the relative permeability increases significantly with r. When plotting the ratio of the relative permeabilities APG/saponin as a function of r, two regimes are revealed: (1) for r≅ 0.25, the ratio is equal to the ratio measured for the bulk foams; (2) for larger r values this ratio is increased by one order of magnitude. This behavior can be explained by the configurations of the bubbles into the pores: the latter are filled with foam for small r values, while each pore contains about one bubble for r values close to 0.35. For such high r values the liquid is distributed in the form of foam liquid bridges, which are reminiscent of the classical pendular liquid bridges, but here they are connected together by parietal liquid channels formed by the foam on the surface of the grains. For APG foams, significant permeability is ensured thanks to that particular geometrical configuration.

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References

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Time Block B (14:00-17:00 CET)

Participation

In person

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