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Foam flow and its blocking effect in high permeable saturated porous media

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Liquid foam has been studied as a blocking agent in porous media, especially for Enhanced Oil Recovery applications [1]. Initially, the goal of foam injection consists to block high-permeability layers in the media in order to reach the oil in low-permeability layers. This approach can also be applied in the remediation field to allow the accessibility of low permeability layers that are usually more contaminated and difficult to treat [2] as reaching pollutants in low-permeability layers can also be difficult during remediation processes. However, contrary to the deep stratums in oil industry, upper soils are non-consolidated porous media with high permeability as well as low pressure and temperature operational conditions. These differences present specific challenges regarding stability and flow of the foam, as there is still little literature on these issues.

The main goal of this study is to isolate the pollution treatment zone downstream of the groundwater flow by diverting it upstream. This study aims to give a better understanding of foam flow in heterogeneous and high permeability (100-10 000 darcys) porous media, with competition of high velocity groundwater flow (10 m/day).

Two different experimental setups were used to obtain the results. The first one is composed of a column of sand or glass beads, instrumented with pressure sensors to monitor the pressure gradient during foam flow. Mass balance was also conducted to measure the water saturation in the column. The second one is composed of a thin 1 m large and 50 cm high tank to model a 2D flow. The tank is instrumented with pressure and water saturation sensors. In addition, an imaging technique is used to measure the evolution of foam volumes, streamlines and water saturations. During the experiments, foam is injected from the bottom of the tank and water is injected from left to right to model a groundwater flow. Finally, the experimental results are compared with numerical models in order to validate them. The validated model can be then used to simulate foam injection for field scale studies.

The surfactant has been chosen based on foamability and foam stability tests. Then, thanks to the column experiments, specific behaviors of foam in high permeable porous media was identified with two successive different regimes of foam flow (“weak” and “strong” foam) as well as necessary injection conditions for its generation. Finally, the influence of injection parameters on foam blocking properties, such as the “Resistance Factor”, the residual water saturation, the radius of influence or the stability under a groundwater flow, has been investigated. The parameters studied are the injection method (gas and surfactant co-injection, Surfactant-Alternating-Foam (SAF), foam pre-generation), the flow rates, and the foam quality. The macroscopic experimental observations have been correlated to pore-scale phenomenon such as bubble generation and destruction, and viscous interactions between bubbles and pores or between bubbles themselves (several bubbles in one pore).

[1] R. Farajzadeh, A. Andrianov, and P. L. J. Zitha, Investigation of immiscible and miscible foam for enhancing oil recovery, Industrial & Engineering chemistry research, 49.4, 1910-1919 (2009).
[2] G. J. Hirasaki et al., Surfactant/foam process for aquifer remediation, International symposium on oilfield chemistry, Society of Petroleum Engineers (1997).