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The effect of fractures and heterogeneity on the effective growth kinetics of microorganisms in large scale modelling of porous media

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Various microorganisms, such as Sulfate Reducing Bacteria (SRB), live in underground reservoirs. The growth rate of microorganisms in a reservoir is highly dependent on various parameters (e.g., the concentration of the nutrients and inhibitors, temperature, pH, and salinity). Especially in case of waterflooded hydrocarbon reservoirs, for large scale modelling of microbial processes, it is close to impossible to capture the exact distribution of these parameters without a certain level of simulation grid refinement, which increases computational costs, and without an accurate knowledge and definition of the distribution of static parameters in the model that control flow properties, such as heterogeneity in permeability distribution in various scales and the presence of fractures. Moreover, the distribution of the parameters affecting microbial growth in a reservoir is highly dependent on geochemical and thermal processes. For instance, the chemical interactions between reservoir fluids and rock (e.g., adsorption and desorption) under varying temperature can affect the concentration of nutrients and inhibitors for microbial processes as well as the measured produced water or gas compositions used for history matching. Geochemistry can also control the pH of the medium, which in turn affects the growth kinetics of microorganisms, the speciation of chemical species in the water phase, and the partitioning of chemical species among phases. The interconnected interactions among biological, hydrological, and geochemical processes as well as numerical challenges of nutrients and heat transport in large-scale models makes modelling and validating microbial growth in field scale particularly challenging.
This study demonstrates such challenges and presents a mathematical approach for upscaling microbial growth rates that corrects the effect of grid size on nutrient and temperature distribution in the reservoir and the corresponding effective growth rates. Moreover, the common way of representing fractures in field models using commercial reservoir simulators is re-evaluated, and it is shown how it can result in misleading reservoir models if the history matching is done using only production rates and pressure, neglecting the chemical composition of the produced water. Furthermore, the most important parameters in the model that highly affect the quality of the predictions are identified and proposed as research gaps for future experimental measurements.
The results show good predictions of upscaled (effective) microbial growth rates corrected for the effect of grid size on temperature distribution in course-grid simulation compared to refined simulation using non-upscaled growth rates. Moreover, it is demonstrated how the effective microbial growth behavior in presence of a fracture varies with the refinement level of the system and the method used to define the fracture in the model when the fluid production, pressure, and composition data match.

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