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Mathematical modelling of bacterial growth at different scales: numerical simulations and laboratory experiments

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Biofilms are sessile communities of bacteria housed in a self-produced adhesive matrix consisting of extracellular polymeric substances (EPS), including polysaccharides, proteins, lipids, and DNA. [1]. Biofilm provokes chronic bacterial infection, infection on medical devices, deterioration of water quality, and the contamination of food [2]. On the other hand, biofilm can be used for wastewater treatment and bioenergy production [3]. In microbial enhanced oil recovery (MEOR), one of the strategies is selective plugging, where bacteria are used to form biofilm in the high permeable zones to diverge the water flow and extract the oil located in the low permeable zones [4]. Therefore, it is necessary to build mathematical models that better describe the biofilm mechanisms. One of the motivations to derive upscaled models is to describe the averaged behaviour of the system in an accurate manner with relatively low computational effort compared to fully detailed calculations starting at the microscale [5]. In the laboratory, biofilm is growth in a T-shape micro-channel. We built a mathematical model including water flux inside the biofilm and different biofilm components (EPS, water, active bacteria, and dead bacteria). Using the best estimate of physical parameters from the existing experiments, we perform numerical simulations. The stress coefficient is selected to match the experimental results. A sensitivity analysis is performed to identify the critical model parameters. A reduction of the biofilm coverage area as the water flux velocity increases is observed. Homogenization techniques are applied in a strip and a tube geometry. Numerical simulations are performed to compare both upscaled mathematical models. In the macro-scale laboratory experiments, biofilm is growth in cylindrical cores. Permeability changes over time at different flow rates and nutrient concentrations are studied. Numerical simulations are performed to compare with the experimental results.

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