The Impact of Microbial Growth on Hydraulic Properties in Saturated Porous Media

Holger Ott, *Neda* Hassannayebi, *Frieder* Enzmann, *Johanna* Schritter, *Martin* Ferno, *Andreas* Loibner

Abstract. Understanding growth and transport of microorganisms in porous media is essential for understanding various natural subsurface systems and applications in subsurface engineering. Such applications may be related to subsurface hydrogen storage for large-scale renewable energy storage (www.underground-sun-storage.at), in-situ methanization (www.underground-sun-conversion.at), soil remediation as well as microbial EOR.

In the presented work, we investigate accumulation and growth of microbes in microfluidics and its influence on the hydraulic properties of porous media. Even though the above given examples are related to multi-phase flow, the present study focuses on saturated flow, which provides sufficient complexity and unsolved questions.

The study takes advantage of the high spatial and temporal resolution of optical microscopy in order to investigate transport and accumulation of microorganisms in microfluidics, i.e. 2D porous media etched in glass. The experiments were performed in two phases by using *Lactobacillus casei* as model organisms. In phase 1, a bacterial suspension solution in a stationary growth phase was flooded through microfluidic chips leading to initial accumulation of microbes in the pore space. In phase 2, a nutrient (substrate) solution was injected; the supply of nutrients changes bacterial growth to an exponential mode.

The change of porosity over time has been determined by image segmentation of the water-saturated pore space and the accumulated biomass in the image sequences. Furthermore, the segmented images have been used as “digital twin” – a digital representation of the experimental results – for direct numerical flow simulations; by solving the Stokes and the Navier-Stokes equations in the pore space, we determined changes of the flow field and the permeability with increasing biomass. The study indicates (a) the formation of preferred flow pathways with increasing biomass, and (b) an associated porosity-permeability relationship, with a qualitatively different behaviour in suspension flooding (phase 1) and nutrient flooding (phase 2). Furthermore, an intermittent release of biomass and subsequent filtration have been observed, leading to a stepwise local increase of biomass by filtration. A first attempt to understand and simulate transport and filtration of microbes has been started by particle-flow simulations in the Digital Twin.