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Microbial growth and transport in saturated and unsaturated porous media

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There is a considerable ongoing effort aimed at understanding the behavior of microorganisms in porous media. Microbial activity is of significant interest in various environmental applications such as *in situ* bioremediation, protection of drinking water supplies and for subsurface geochemistry in general. The main limiting factors for bacterial growth are the availability of electron acceptors, nutrients and bio-available water. The capillary fringe, defined - in a wider sense than usual - as the region of the subsurface above the groundwater table, but still dominated by capillary rise, is a region where all these factors are abundantly available. It is thus a region where high microbial activity is to be expected.

In a research unit “Dynamic Capillary Fringes - A Multidisciplinary Approach (DyCap)” founded by the German Research Foundation (DFG), the growth of microorganisms in the capillary fringe was studied experimentally and with numerical simulations. Processes like component transport and diffusion, exchange between the liquid phase and the gas phase, microbial growth and cell attachment and detachment were incorporated into a numerical simulator.

The growth of the facultative anaerobic *Escherichia coli* as a function of nutrient availability and oxygen concentration in the liquid phase is modeled with modified Monod-type models and modifications for the switch between aerobic and anaerobic growth. Laboratory batch experiments with aqueous solutions of bacteria have been carried out under various combinations of oxygen concentrations in the gas phase and added amounts of dissolved organic carbon to determine the growth model parameters by solution of a parameter estimation problem.

For the transport of bacteria the adhesion to phase boundaries is also very important. As microorganisms are transported through porous media, they are removed from the pore fluid by physicochemical filtration (attachment to sediment grain surfaces) or are adhering to gas-water interface. The cell attachment and detachment model was based on flow-through experiments and the parameters were obtained by fitting the model to measured bacteria breakthrough curves.

Experiments on bacterial growth in porous media with and without groundwater flow were performed in Hele-Shaw cells filled with quartz sands. The cell density was determined by the fluorescence of a special protein produced by the genetically modified strain of *E. coli*. The simulation results are compared to experimental data and different modeling approaches are discussed.