Master thesis of Camille Kerboas:
Flows through confined micro-structures in presence of microbial growth

Abstract

Small scale processes taking place in the natural subsurface environment are spatially heterogeneous and control the underground fluid flow where chemical and biological dynamics play a key role in natural and industrial systems.

Microorganisms in the subsurface contribute to these dynamics: they can be mobile or attached to surfaces by secreting EPS to keep microbial community physical together as biofilms. The classical way to investigate these biochemical systems is through careful analysis of well mixed batch reactors: while powerful to investigate the biomass response to variations in chemical and biological parameters, this approach misses the possibility to investigate the system response to and interaction with the physical parameters of the close environment. The formation mechanisms and growth rate of biofilms structures under heterogeneous flow conditions has not been strongly investigated yet.

During this master thesis, a novel set-up and procedure have been designed and tested in order to measure the hydraulic conductivity variations associated to the flow, driven by a constant pressure gradient, through a confined material (mimicking the subsurface or soil). Using time-lapse video-microscopy applied to microfluidics devices, it will be visualized and quantified the biofilm formation and growth rate under controlled flow conditions within a simple straight channel as well as within a more complex pore network.

Biofilm growth and its interaction with the close environment or with other growing biofilms has received a lot of attention due to the important role played by the biological activity. The microbial growth is expected to play a leading role in determining the conductivity K of a flowing system, which is proportionally to the square of the pipe radius. Occupying more and more space, a growing biofilm is confining more and more fluid motion. We link the macroscopic measurement of hydraulic properties (flow and pressure) to the microscopic analysis, done with video-microscopy, of the microbial population growth.

The main results are that i) we quantify K, ii) we relate the K decrease to the available space, iii) we observe that microbial growth mostly takes place close to the inlet and iv) we propose a physical model to explain this observation.

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