Can we control biofilm-induced clogging in porous media?

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Résumé

Bacterial biofilms are sessile communities that develop on surfaces and represent the dominant form of life for bacteria (1)(4) (Figure1.A). Biofilms play a key role in a variety of engineering problems found in porous media sciences, ranging from soils bioremediation to bioreactors for the production of proteins of interest or for filtering wastewater (2). On the other hand, uncontrolled growth can induce clogging and loss of efficiency in technical systems, biofouling in industrial and medical devices, or even resistant contaminations (3)(6) (Figure1.B). Developing approaches to regulate the development of the biomass in porous structures could pave the way towards a new field in control engineering, aiming at controlling the permeability of porous media colonized by biofilm (5).
In particular, it has been observed recently that a competition between growth and detachment leads to large amplitude fluctuations of the pressure drop (6). For example, in a bioreactor system for the filtration of wastewater or the production of a protein of interest, such fluctuations could induce important changes of yield (2)(3). In this work, we ask the question of whether we can avoid such fluctuations and more generally control the permeability of porous structures colonized by biofilms. We hypothesized that a closed loop control could be implemented to reach a target permeability in a demonstration microfluidic device.

We will first present a novel experimental technology that allows us to measure the dynamics of the pressure drop across a porous structure, while working in a microfluidic system with accurate control of environmental conditions. The core of the system is a 3D printed microbioreactor containing a porous structure, where biofilms develop. The porous structure is printed by stereolithography and composed of 300μm wide/700μm long channels, with a connectivity of 3. This system is adapted for control because we can: precisely define and change the structure and the material of the porous media; change nutrient types, concentrations and flow rate through programmable gear pumps; impose temperature to favour or not growth with a thermostat cell, while measuring the effect of those different parameters through a pressure sensor and oxygen sensor (Figure2). The system can also be imaged via X-ray microtomography with a newly developed contrast agent based upon gold nanoparticles.
We will show a simple example of how pressure fluctuations can be controlled for a biofilm of *Pseudomonas aeruginosa* and discuss the implications in terms of the definition of a cost function. We will further present our global strategy for control, which relies on feedback control of four environmental conditions (Figure2.A): nutrient concentrations, temperature, flow and the presence of bacterial predators-in particular *Bdellovibiro bacteriovorous* (8).

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