Bacterial communication in porous media flows

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Résumé

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In many environmental, biological and engineered systems, bacteria live in sessile communities termed biofilms. In these multi-cellular groups, coordinated behaviors can emerge. Bacteria are highly interactive and communicate via chemical signaling, what is known as quorum sensing (QS). QS regulates gene induction and relies on the synthesis and group-wide detection of small molecules, called autoinducers, which diffuse in and out of the bacterial cell (1). When biofilms are exposed to fluid flow, advective transport can transport autoinducers, thus leading to a spatially distributed QS response (2). While this phenomenon has been studied in simple microfluidics channels, little is known about how communications develop in more complex structures, such as porous media. This could play an important role in medical devices such as prosthetic parts and implants which are primarily porous (3). QS under flow likely also influences soil ecology, nutrient cycling and the overall condition of the soil ecosystem (4).

QS activation plays a critical role in bacterial detachment (6). For instance, in the case of *Staphylococcus aureus,* it has been reported that activation of quorum sensing leads to degradation of the biofilm extracellular matrix and as consequence detachment and dispersal (2) (7). In porous media, complex couplings develop between biofilm growth, flow and detachment. Growth leads to pore clogging, which can control flow channels, solute transport and microbial competition (5). In such systems, QS-induced detachment will unclog some

*Intervenant

pores, change the flow paths through the structure and may play a central role in regulating bacterial communities. We thus hypothesize that QS-induced detachment is a fundamental component of biofilm dynamics in porous media (Fig.1).

To test this hypothesis, we used *S. aureus* equipped with a dual-labeling system, which can be tracked by fluorescence imaging for viability and communication. First, we examined the effect of flow on QS in a single pore microfluidic chip. We observed that under sufficient flow rate, QS is activated close to the solid/biofilm interface but not at the flow/biofilm interface. This is because advection can wash away the autoinducers, thus prohibiting communications, whereas autoinducers can accumulate when transport is diffusion dominated (Fig.2), a phenomenon that has been already observed previously (2). We further proceeded with the use of a complex network in a microfluidic device (Fig.3). We observed a rich spectrum of dynamics where clogging and communication phenomena alternate between pores through time. To understand the basic mechanisms driving these dynamics, we considered a simpler T junction geometry. We will use these results to discuss the interplay between flow, biofilm growth, communication and detachment in porous media (Fig.1).