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Chemotaxis and flow disorder shape microbial dispersion in porous media

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Bacteria drive a plethora of natural processes in the subsurface, consuming organic matter and catalysing chemical reactions that are key to global elemental cycles. These macro-scale consequences result from the collective action of individual bacteria at the micro-scale, which are modulated by the highly heterogeneous subsurface environment, dominated by flow disorder and strong chemical gradients. Yet, despite the generally recognized importance of these microscale processes, microbe-host medium interaction at the pore scale remain poorly characterized and understood. Here, we introduce a microfluidic model system to directly image and quantify the role of cell motility on bacterial dispersion and residence time in confined, porous, media. Using the soil-dwelling bacterium Bacillus subtilis and the common amino acid serine as a resource, we observe that chemotaxis in highly disordered and confined physico-chemical environment affords bacteria an increase in their ability to persistently occupy the host medium. Our findings illustrate that the interplay between bacterial behaviour and pore-scale disorder in fluid velocity and nutrient concentration directly impacts the residence time, transport and bio-geo-chemical transformation rates of biota in the subsurface, and thus likely the processes they mediate.