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Dynamics of reactive microbial hotspots in concentration gradients

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In subsurface environments, bacteria play a major role in controlling the kinetics of a broad range of biogeochemical reactions. In such environments, nutrients fluxes and solute concentrations needed for bacteria metabolism may be highly variable in space and intermittent in time. This can lead to the formation of reactive hotspots where and when conditions are favorable to particular microorganisms, hence inducing biogeochemical reaction kinetics that differ significantly from those measured in homogeneous model environments. To investigate the impact of chemical gradients on the spatial structure and temporal dynamics of subsurface microorganism populations, we develop microfluidic cells allowing for a precise control of flow and chemical gradient conditions, as well as a quantitative monitoring of the bacteria's spatial distribution and biofilm development.

Using the non-motile Escherichia coli JW1908-1 strain and Gallionella as model organisms, we investigate the behavior and development of bacteria over a range of single and double concentration gradients in the concentrations of nutrients, electron donors and electron acceptors. To quantify bacterial activity we use Fluorescein Diacetate (FDA) hydrolysis by bacterial enzymes which transforms FDA into Fluorescein, whose local concentration is measured optically. We thus measure bacterial activity locally from the time derivative of the measured fluorescence. This approach allows time-resolved monitoring of the location and intensity of reactive hotspots in micromodels as a function of the flow and chemical gradient conditions. We discuss consequences for the formation and temporal dynamics of biofilms in the subsurface.