The impact of porosity on organic matter cycling in a two-dimensional porous medium

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Carbon sequestration has been a popular research topic in recent years as the rapid elevation of carbon emission has significantly impacted our climate. Apart from carbon capture and storage in e.g. oil reservoirs, soil carbon sequestration offers a long term and safe solution for the environment and human beings. The net soil carbon budget is determined by the balance between terrestrial ecosystem sink and sources of respiration to atmospheric carbon dioxide. Carbon can be long term stored as organic matters in the soil whereas it can be released from the decomposition of organic matter. The complex pore networks in the soil are believed to be able to “protect” microbial-derived organic matter from decomposition. Therefore, it is important to understand how soil structure impacts organic matter cycling at the pore scale. However, there are limited experimental studies on understanding the mechanism of physical stabilization of organic matter. Hence, my project plan is to create a heterogeneous microfluidic porous microenvironment to mimic the complex soil pore network which allows us to investigate the ability of organisms to access spaces starting from an initial ecophysiological precondition to changes of spatial accessibility mediated by interactions with the microbial community.

Microfluidics is a powerful tool that enables studies of fundamental physics, rapid measurements and real-time visualisation in a complex spatial microstructure that can be designed and controlled. Many complex processes can now be visualized enabled by the development of microfluidics and photolithography, such as microbial dynamics in pore-scale soil systems and pore network modification mimicking different soil environments – earlier considered impossible to achieve experimentally. The microfluidic channel used in this project contains a random distribution of cylindrical pillars of different sizes so as to mimic the variations found in real soil. The randomness in the design creates various spatial availability for microbes (preferential flow paths with dead-end or continuous flow) as an invasion of liquids proceeds into the pore with the lowest capillary entry pressure. In order to study the impact of different porosity in isolation of varying heterogeneity of the porous medium, different pore size chips that use the same randomly generated pore network is created. Those chips have the same location of the pillars, but the relative size of each pillar is scaled. The experiments will be carried out using sterile cultures of fluorescent bacteria, fungi and protists, synthetic communities of combinations of these, or a whole soil community inoculum. We will quantify the consumption of organic matter from the different areas via fluorescent substrates, and the bio-/necromass produced. We
hypothesise that lower porosity will reduce the net decomposition of organic matter as the narrower pore throat limits the access, and that net decomposition rate at the main preferential path will be higher than inside branches