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Macro ATR-FTIR imaging for better understanding of organic matter dynamics in soil

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A grand challenge for mankind is to fight climate change, which involves both reducing and reverting CO_2 emissions. Soils store more carbon (C) than the atmosphere and biosphere combined, and it is microorganisms that govern whether C compounds remain in the soil, or whether they are decomposed and released to the atmosphere as CO_2. The microbial influence on C cycling range from the way they decompose soil organic matter (SOM) to their contributions on the formation of soil aggregates that are particularly important for physical C stabilization in soils. However, the relationship between the microbial activity, SOM properties and physicochemical microenvironment, including complexity of soil structure (i.e., arrangement of pore space in and between soil aggregates), and how each of these factors contribute to the prolonged residence of C in soils, is not well understood. Therefore, the aim of this work has been to develop and make use of an analytical approach for studying the influence of pore space architecture on microbial SOM decomposition and dynamics by integrating two novel tools in soil sciences – microfluidic chips, which mimic soil structure, and infrared (IR) spectroscopic imaging, which provides detailed information about chemical properties of materials within these chips.

We have used several microchip designs to simulate different levels of complexity of soil pore space. The hypothesis is that the more complex the chip structures – the less decomposition of SOM will be observed, as more of it will be 'hidden' from its decomposers within hard-to-reach spaces. For the IR spectroscopic imaging, macro attenuated total reflection (ATR) accessory has been used. In this mode, an ATR element of high refractive index is put in contact with a sample – the microchip - and total internal reflection signal at the boundary between the element and the sample is recorded. The signal is detected with an imaging focal plane array (FPA) detector and carries information about IR absorptions in the sample. With IR spectra serving as fingerprints for identifying molecules, spatially and temporally resolved observation of chemistry and chemical changes of a SOM substrate initially filling the microchip structures and undergoing decomposition by subsequently inoculated microbial cultures can be made. Our pilot data suggests feasibility of the approach for analysis of complex substrates such as lignin, maize leaves or SOM from real soils and its dependence on the complexity of chip. Evaluating molecular changes in parts of the larger molecules or of the compound mixture under decomposition could even contribute to quantifying, e.g., N mining within the compounds. Eventually, knowing the influence of spatial structure on the decomposition rate and pathways can help us understand how important is the spatial heterogeneity when we study organic matter degradation in soils.