EGU2020-4089
https://doi.org/10.5194/egusphere-egu2020-4089
EGU General Assembly 2020

High viscosity of polymer solutions supports life in soil hotspots

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Plant roots and bacteria alter the soil properties by releasing a polymeric blend of substances (e.g. mucilage and extracellular polymeric substances EPS). Despite extensive knowledge of their ecological importance, the physical mechanisms by which these polymers alter the spatial configuration of the liquid phase and the related hydraulic and biogeochemical properties remain unclear.

Here we show that upon drying in porous media polymer solutions form one-dimensional filaments and two-dimensional interconnected structures spanning across multiple pores. Unlike water, primarily shaped by surface tension, these structures remain connected upon drying thanks to their high viscosity. The integrity of one-dimensional structures is explained by the high viscosity and low surface tension of the polymer solutions (elegantly characterized by the Ohnesorge number). The formation of two-dimensional structures requires consideration of the interaction of the polymer solution with the solid surfaces and external drivers, such as the drying rate.

The implications of these physical processes for life in soils are manifold. After their deposition they enhance water retention by acting as a new solid matrix delaying the air entry, they maintain the connectivity of the liquid phase, thus enhancing the unsaturated hydraulic conductivity, diffusion and enzyme activity. Upon rewetting, the formation of extensive two-dimensional structures corresponds to a sudden increase in soil water repellency, which reduces the rewetting kinetics and maintains gas diffusion preventing sudden water saturation. In summary, these structures buffer fluctuations in soil water contents, protecting roots and soil microorganisms against severe drying and sudden rewetting in soil hotspots.