Contribution ID: **547** Type: **Oral Presentation**

Evaluating the interaction of biofilms, organic matter and soil structures at the pore scale

Monday, 31 May 2021 16:10 (15 minutes)

Key functions of soils, such as permeability or habitat for microorganisms, are determined by structures at the microaggregate scale (< 250 μm).
Although advanced imaging techniques now allow snapshots even down to the nanoscale, the evolution of elemental distributions and dynamic processes still can often not be assessed experimentally. So mechanistic models operating at the pore scale can help to study and understand such phenomena.
We consider the complex coupling of biological, chemical, and physical processes in a hybrid discrete-continuum modeling approach. It integrates dynamic wetting (liquid) and non-wetting (gas) phases including biofilms, diffusive processes for solutes, mobile bacteria transforming into immobile biomass, and ions which are prescribed by means of partial differential equations. Furthermore the growth of biofilms as, e.g., mucilage exuded by roots, or the distribution of particulate organic matter in the system, is incorporated in a cellular automaton framework (CAM) presented in [1, 2, 3]. It also allows for structural changes of the porous medium itself (see, e.g. [4]). As the evolving computational domain leads to discrete discontinuities, we apply the local discontinuous Galerkin (LDG) method for the transport part.
Finally mathematical upscaling techniques are used to incorporate the information from the pore scale to the macroscale [1,5].
The model is applied for two research questions: Although a continuous re-organization of disintegrating and assembling soil aggregates can be observed, we still lack understanding of the mechanistic relationship between aggregation and organic matter sequestration in soils. We model the incorporation and turnover of particulate OM influencing soil aggregation. We hypothesize that soil mineral surfaces co-located with decomposing OM develop into spatially discrete 'gluing'hotspots that enhance aggregation locally and tested different numerical scenarios of OM input regimes, OM turnover, particle size distribution and 'gluing'hotspots.
As a second application, we quantify the effective diffusivity by upscaling on 3D geometries from CT scans of a loamy and a sandy soil. We see that conventional models for diffusivity cannot account for natural pore geometries and varying phase properties. Upscaling allows also to quantify how root exudates (mucilage) can significantly alter the macroscopic soil hydraulic properties.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

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[4] S. Zech, S. Dultz, G. Guggenberger, A. Prechtel and N. Ray. Microaggregation of goethite and illite evaluated by mechanistic modeling. Applied Clay Science 198, 105845 (2020).
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Session Classification: MS5

Track Classification: (MS5) Biochemical processes and biofilms in porous media