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Contribution of peat soil structure to biogeochemical processes: A physical understanding of pore distribution and solute transport characteristics

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Peatlands are a valuable but environmentally vulnerable resource. They represent a globally-significant carbon and energy reservoir and play major roles in water and biogeochemical cycles. Peat soils are highly complex porous media with unique physical and hydraulic properties. In peat soils, the unique complex dual-porosity structure with mobile-immobile pore fractions controls water flow and solute migration, which, in turn, affect reactive transport processes and biogeochemical functions. In this presentation, we start with an introduction of key physical and hydraulic properties related to the structure of peat soils and discuss their implications for water storage, flow and the migration of solutes. Then, we present the results of two experiments to understand the effect of pore fractions on the denitrification process in a peat depth profile, with the main objective to show how this process is controlled by pore-scale mass transfer and exchange of nitrate between mobile and immobile pores. In these experiments, bromide and nitrate breakthrough curves were used to constrain transport parameters and steady-state nitrate reduction rates in the depth profile. The vertical distribution of potential denitrification rates were compared with depth distributions of partitioning mobile-immobile pores and the exchange coefficient between the pores. The results showed that an increase of immobile pore fractions with depth increases the common interface surface area between mobile and immobile pores which leads to a more pronounced exchange between the two transport domains and enhances the denitrification activities. Furthermore, the physical non-equilibrium approaches were linked to reactive geochemical transformation processes by comparing the different transport characteristics using the pore distribution analyses between degraded and un-degraded peats and their effects on denitrification activities. The conclusion was that in addition to a reducing condition, microbial activity/growth, temperature, flow rate and moisture content, the pore fractions and exchange rate of solutes between mobile and immobile phases play a major role in biogeochemical activity.