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Laboratory investigations on the interaction between aluminum and organic matter and its impact on soil permeability

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The utilization of natural processes for in situ permeability reduction has seen a growing interest in recent years since controlling infiltration or seepage of water is one of the most challenging tasks in water management and civil-engineering. We hereby propose a novel geoengineering tool for in situ permeability reduction, namely Soil Sealing by Enhanced Aluminum and organic matter Leaching (SoSEAL). SoSEAL makes use of the interaction between organic matter (OM) and aluminum (Al). Complexation and subsequent precipitation of OM by Al results in the formation of soil layers with reduced permeability; a process which is well known from podzols. This study demonstrates the suitability of the SoSEAL technique for permeability reduction in laboratory experiments.

All experiments have been performed using humic acid (HUMIN P775, Humintech, Germany) as an OM source and aluminum chloride as the metal component. Batch experiments were conducted to study the interaction between OM and Al at various metal to organic carbon (M/C) ratios and pH levels. Results show that the precipitation of Al-OM flocs depends on the Al concentration and therefore the M/C ratio, which is well-known from OM removal in drinking water treatment. Precipitation of the hereby used humic acid starts to occur at a molar M/C ratio of 0.01 and almost all OM is removed at M/C ratios larger than 0.04. The size of the Al-OM flocs ranges between 20 and 1000 μm, which enables them to cover micro- and mesopores in porous media and therefore reduce the permeability.

In order to quantify the permeability reduction that can be achieved by Al-OM flocs, saturated column experiments were performed using sand with three different grain size distributions and applying various injection strategies to induce in situ mixing of the two separately injected components (i.e. Al and OM). We were able to reduce the hydraulic conductivity in the sand column to a range between 10 and 40% of its initial value. Results show that the reduction in permeability depends on several factors including the sand type, the injection technique, mixing and reaction of the two components in situ, and the orientation of the precipitation band.

We conclude that the precipitation of Al-OM flocs induced by in situ mixing of Al and DOM can significantly reduce the permeability of different sand types. These results are the proof of principle of the SoSEAL concept.