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Modification of solid surface physicochemistry by formation of conditioning films and adsoption of differently charged cations

M.-O. Goebel (1), A. Lamparter (1), S.K. Woche (1), G. Mühl (2), J. Rühlmann (2), and J. Bachmann (1)

(1) Institute of Soil Science, Leibniz University of Hannover, Germany (goebel@ifbk.uni-hannover.de), (2) Institute of Vegetable and Ornamental Crops Großbeeren, Germany

Solid interfacial properties play an important role for the distribution and continuity of fluid phases in soil. Under unsaturated conditions a reduced water film connectivity and a larger proportion of air/water interfaces in case of a hydrophobic matrix (low surface free energy) is observed when compared to a wettable counterpart (high surface free energy), indicating that interfacial properties are of great importance for transport and sorption of colloids. In turn, interfacial properties itself can be modified by sorption of organic compounds and cations from soil solution. To investigate the significance of these processes for the alteration of solid interfacial properties we used model materials (acid-washed soda-lime glass beads and quartz sand) as well as natural soil (Gleyic Podzol). To get unconditioned material (free of organic matter) with different interfacial properties a fraction of the glass beads and quartz sand was treated with dichlorodimethylsilane (DCDMS) which produces highly nonpolar particle surfaces indicated by a significant increase of the solid-water contact angle. To initiate the formation of conditioning films on the particle surfaces dissolved organic matter (DOM) solution of different concentration was added. The natural soil was saturated with cations of different charge (i.e. Na+, Ca2+, Al3+). The modification of interfacial properties was quantified in terms of surface charge and solid-liquid contact angle (CA) of different test liquids (i.e. water, ethylene glycol, diiodomethane), which allows the calculation of solid surface free energy (SFE).
The measurements indicated a significant impact of conditioning film formation on the CA for both glass beads and quartz sand. While the acid-washed (wettable) glass beads and quartz sand become more water repellent (i.e. increasing CA and decreasing SFE), the DCDMS-treated (hydrophobic) material becomes more wettable (i.e. decreasing CA and increasing SFE). With increasing concentration of DOM we found an increasing approximation of the surface properties by the formation of conditioning films. For the Gleyic Podzol the measurements revealed a significant effect of cation saturation. While Na+ saturation lowers the CA and increases the SC, Al3+ saturation increases the CA and lowers the SC. Saturation with Ca2+ causes no significant changes in CA and SC which could be expected as the original cation saturation was dominated by Ca2+.
The results clearly showed that interfacial parameters like CA, SFE and SC are subject to change in relation to soil solution chemistry, which must be considered in the interpretation of breakthrough curves obtained from column experiments.