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Clay with Desiccation Cracks is an Advection Dominated Environment

S. Baram (1), D. Kurtzman (2), Y. Sher (1), Z. Ronen (1), and O. Dahan (1)

(1) Department of Environmental Hydrology & Microbiology, Zuckerberg Institute for Water Research, Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus, Israel 84990, (2) Institute of Soil, Water and Environmental Sciences, Agricultural Research Organization, The Volcani Center, Bet Dagan 50250, Israel.

Heavy clay sediments are regarded "safe" from the hydrological point of view due to their low hydraulic conductivities. However, the formation of desiccation cracks in dispersive clays may dramatically change their bulk hydraulic properties. The impact of desiccation cracks on water percolation, dissolved salts and contaminants transport and redox related reactions (microbial ammonium oxidation and denitrification) were investigated in 6 -12 m clay layer near a diary farm waste lagoon. The study implemented unique vadose-zone monitoring systems that enable in-situ measurements of the temporal variation of the sediment's water content along with frequent sampling of the sediment's pore water along the entire vadose zone (> 30 m). Results from four years of continuous measurements showed quick rises in sediment water content following rain events and temporal wastewater overflows. The percolation pattern indicated dominance of preferential flow through a desiccation-cracks network crossing the entire clay sediment layer. High water-propagation velocities (0.4 – 23.6 m h-1) were observed, indicating that the desiccation-crack network remains open and serves as a preferential flow pathway year-round, even at high sediment water content ($\sim$0.50 m3 m-3). The rapid percolation bypassed the most bio-geo-active parts of the soil, transporting even highly sorptive contaminants (testosterone and estrogen) in to the deep sections of the vadose zone, accelerating the underlying groundwater contamination. The ammonium and nitrate concentrations in the vadose zone and the high number of nitrifying and denitrifying bacteria ($\sim$108 gene copies gdry-sediemt-1, each) found in the sediment indicated that the entire vadose zone is aerated even at high water content conditions ($\sim$0.55 m3 m-3). The dissolved salts concentration in the pore-water and the δ2H-H_2O and δ18O-H_2O values of the pore-water substantially increased with depth (becoming less depleted) in the clay sediment, indicating deep soil evaporation. Daily fluctuation of the air temperature in the desiccation cracks supported thermally induced air convection within the cracks void and could explain the deep soil salinization process. Combination of all the abovementioned observations demonstrated that the formation of desiccation cracks network in dispersive clay sediments generates a bulk advection dominated environment for both air and water flow, and that the reference to clay sediments as "hydrologically safe" should to be reconsidered.