Geophysical Research Abstracts
Vol. 21, EGU2019-6683, 2019
EGU General Assembly 2019

Physical and biochemical processes under extremely high wastewater infiltration fluxes

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Soil Aquifer Treatment (SAT) systems are used around the world as tertiary treatment for waste water reclamation. In SAT systems, waste water are infiltrated through infiltration ponds into the aquifer, in cycles of flooding and drying. SAT systems are able to enhance water quality using natural traits of the soil environment (such as its microbial community, which plays an important role in organic compound degradation), combined with site-specific hydraulic operation. While such sites operate successfully for decades, the need to increase infiltration with already high hydraulic fluxes (up to 100 m/year) and low water quality create unique challenges for optimal operation.
In this work, we present a series of experiments and developments associated with SAT operation, starting with geophysical monitoring, treatment of entrapped air, field monitoring and column experiments tracking the biochemical dynamics under variety of hydraulic conditions. Our focus is on the long column experiments, designed to examine the effect of different drying periods and influent composition on oxygen content and redox potential in a 6-meter sand column. Our experimental set up included four main experiments, in which three different influent solution-types were infiltrated through the column in varying cycles of wetting and drying. We hypothesize that the hydraulic operation of the column during the experiments (i.e. different wetting-drying ratios and durations) and the different influent composition will result in different bio-geo-chemical conditions in the soil profile. Our results confirm that the deeper parts of the column are aerated less effectively during the drying periods compared to the upper parts, the oscillation patterns of the oxygen concentrations throughout the wetting-drying cycles indicate that advective fluxes are significant in almost all parts of the column and become increasingly more dominant as depth increases. Further, we show that oxygen supply at different depths is dominated by different mechanisms (convection of air phase, advection as dissolved phase, and diffusion). The longer (240 minutes) drying periods had an advantage over the shorter (150 minutes) periods in terms of oxygen concentrations in the upper parts of the column as well as in the deeper parts. Chemical analysis confirmed that nitrogen species, as well as organic carbon were found in smaller concentrations in the experiment with longer drying times. The data we gathered show that the duration of the drying periods is detrimental for the bio-geo-chemical state of the soil profile. Short drying periods might be beneficial for the aeration of the upper vadose zone but may not be substantial enough to allow oxygen recovery in the deeper parts and thus inflow quality will be compromised. The quick oxygen recovery after an increase in the drying periods suggests that combining short and long drying periods in the same infiltration campaign might be beneficial for both the amount of influent infiltrated and reclaimed water quality. To examine this, however, additional research is needed.