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Oxygen Transfer in a Fluctuating Capillary Fringe: Impact of Microbial Respiratory Activity

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Abstract:

Laboratory-scale flow-through experiments in a sand-filled chamber were performed to investigate the impact of aerobically growing *Escherichia coli* HB101-K12 on oxygen transfer across the capillary fringe (CF) to oxygen-depleted groundwater. In the experiments, both the effects of different nutrient concentrations and transient flow conditions were tested. The results of biotic experiments under oligotrophic and eutrophic conditions (6.8 g organic C L^{-1}) were compared with those of an abiotic experiment. Moreover, in each experiment steady-state and transient conditions were considered, the latter induced by changing the water-table height. Growth of *E. coli* was quantified by cell counting in effluent samples and could be monitored due to intracellular production of the green fluorescent protein (GFP). Under eutrophic conditions, highest cell densities and strongest cell attachment were observed in the transition region of the CF. In this region intensive bacterial respiration decreased oxygen concentrations relatively quickly, causing a steep oxygen gradient that resulted in a higher oxygen flux across the unsaturated-saturated interface. Under oligotrophic conditions, this effect was considerably reduced, but was still detectable. Due to oxygen supply from entrapped air, bacterial growth was slightly enhanced within the upper, newly formed CF region, directly after raising the water table. After lowering the water table to the initial height only a minor microbial impact on oxygen transfer was noticed, even under eutrophic conditions, because of the fast diffusion of oxygen in the (partially) air-filled pore spaces. Bacteria that remained in the transition region of the CF grew to higher densities due to better oxygen supply.

Keywords: *oxygen transfer, capillary fringe, microbial respiration, transition region, oxygen flux, eutrophic conditions*