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A high-resolution non-invasive approach to quantify oxygen transport across the capillary fringe and within the underlying groundwater

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Abstract:

Oxygen transport across the capillary fringe is relevant for many biogeochemical processes. We present a non-invasive technique, based on optode technology, to measure high-resolution concentration profiles of oxygen across the unsaturated/saturated interface. By conducting a series of quasi two-dimensional flow-through laboratory experiments, we show that vertical hydrodynamic dispersion in the water-saturated part of the capillary fringe is the process limiting the mass transfer of oxygen. A number of experimental conditions were tested in order to investigate the influence of grain size and horizontal flow velocity on transverse vertical dispersion in the capillary saturated zone, therefore allowing a direct comparison with oxygen transfer across the capillary fringe. The outcomes of the experiments under various conditions show that oxygen transport in the two zones of interest (i. e., the unsaturated/saturated interface and the saturated zone) is characterized by very similar transverse dispersion coefficients. An influence of the capillary fringe morphology on oxygen transport has not been observed. These results may be explained by the narrow grain size distribution used in the experiments, leading to a steep decline in water saturation at the unsaturated/saturated interface and to the absence of trapped gas in this transition zone. We also modelled flow (applying the van Genuchten and the Brooks-Corey relationships) and two-dimensional transport across the capillary fringe, obtaining simulated profiles of equivalent aqueous oxygen concentration that were in good agreement with the observations.

Key-words: capillary fringe, oxygen transport, hydrodynamic dispersion, 2-D experiments, fiber-optical sensor technique