The Aerobic Critical Zone: deep transport and reactivity of dissolved oxygen in fractured bedrock aquifers

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The persistence of dissolved oxygen in deep groundwater, sustains microbial life and biogeochemical reactivity, with potential impacts on large scale nutrient cycling. In aquifers, dissolved oxygen distribution is often heterogeneous and intermittent, but the driving factors of this variation remain poorly identified. This study is based in two fractured-bedrock catchments in Brittany, one under natural flow-regime and the other one under pumping regime. The study site is characterized by strong surface-groundwater connectivity, rapid hydrologic response and deep microbial hot-spots.

Multi-parameter borehole-logs, CFC data and groundwater level time series from the period 2009-2019 were analyzed over 34 piezometers located both in recharge and discharge zones of both catchments. The variance of dissolved oxygen concentrations decreases with depth: shallow concentrations range between 2 - 8 mg/L while deep concentrations range between 0.05 – 2 mg/L. Resulting from the competitive effects of transport and reactivity, the observed distribution of dissolved oxygen concentrations with depth was modelled with an analytical solution of a first-order transport-reaction model, which allowed constraining Damköhler numbers related to dissolved oxygen in groundwater. Advection times and reaction rates were also estimated through Darcy's law calculations, CFC's interpretations and batch tests, allowing an independent estimation of Damköhler number range related to dissolved oxygen in groundwater.

The spatial distribution of dissolved oxygen within the natural flow-regime catchment is transport-limited while being reaction-limited in the pumped site. Dissolved oxygen distribution is shaped by a different chemical reactivity linked to the weathering front. Moreover, preferential transport through fractures or enhanced hydraulic gradients under pumping conditions allow deep oxygen delivery and mixing between recent and aged groundwaters forming reactive hot-spots in subsurface.

Mots-Clés : Reactive transport; hotspot reactivity; Damköhler number; Critical Zone; fractured bedrock hydrogeology

Merci de ne rien inscrire dans cette zone et ne pas modifier les marges des pieds de page et entêtes.