



Influence of flow velocity on denitrification in a pore-scale lab experiment

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Assessing and understanding biogeochemical reactivity in aquifers is an important issue worldwide. Although hydrodynamic processes are known to impact on biogeochemical reactions, their influence is still not well identified. Particularly, the effects of physical factors such as pore-scale flow velocity versus diffusion within biofilms need to be evaluated.

We used an experimental approach to study the relationship between hydrodynamic parameters and reactivity at the pore-scale. In the experimental setup, denitrification occurs in 2 mm diameter reactive tubes for different flow velocities which control the fluid residence-time and may impact on reaction kinetics. Conversely to most of the experiments, the carbon source is the tube itself and C is present in a homogeneous manner all along the tubes. This experiment shows reaction kinetics close to the ones observed at the field- or lab-scale with aquifer material (both water and rocks).

For short time scales, the experiments show two main phases: a first phase where the nitrate consumption is biologically controlled and a second phase where the nitrate consumption is physically controlled. The reactivity becomes localized and migrates towards the tube inflow with increasing time. This experiment provides useful information on the time scale needed for in situ reactivity assessments and for the building up of a reactivity model, in which the maximum concentration variation ($C_{in}-C_{out}$) is controlled by fluid velocity whereas the initial concentration variation is independent of fluid velocity.

For long time behavior we study the reactivity response to cyclic variations of tube flow velocities. The long term assessment of the system reveals a complex reactive scheme leading to an oscillatory behavior of the reactivity. This complex evolution of reactivity to cyclic hydrodynamic conditions involves different biological and physical controls such as biofilm growth, bioaccumulation of by-products but also residence times, diffusion depth in the biofilm and shear stresses. The experiment is mostly in transient conditions from a reactivity point of view despite simple physical conditions. It highlights that biologically mediated reactivity may be highly dependent upon the history of the system.

These studies show how biological and physical processes may be coupled to control the initiation of denitrification process at the pore-scale. The complexity of the reactivity highlights the relevance of dynamic experiments over static ones for the understanding of dynamic processes.