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An experimental and numerical pore-scale study of bio-enhanced NAPL dissolution in porous media

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Nonaqueous phase liquids (NAPLs) are still a major challenge for all traditional groundwater treatment technologies. NAPLs often contaminate the subsurface following an accidental spill or due to a defect in the oil storage tank. These pollutants remain trapped in the form of droplets and / or immiscible clusters within the aquifer, thus constituting a persistent source of pollution that is difficult to decontaminate. Predicting the fate of this pollutant requires characterizing all the mechanisms involved and in particular the biodegradation, which can occur in the vicinity of the pollutant source or further, to the dissolved plume. If a significant research effort has been put into investigating the transport and biodegradation of dissolved contaminants, comparatively very few works (e.g., Bahar et al., 2016) are focused on the study of such processes in multiphase conditions (oil/water/biofilm systems).
In this study, we give an attempt to address this open issue from an experimental and numerical perspective. First, we illustrate impact of bacteria on dissolution of pure organic phase from micromodel experiments. The experimental set-up is made of a micromodel (i.e. 2D transparent flowcell) used to study the dissolution of oil phase. Changes in toluene saturation are directly monitored from recorded two-dimensional images and dissolved concentrations at the outlet are measured by gas chromatograph. Results of toluene dissolution and biodegradation by a toluene-degrading strain (Pseudomonas putida F1) are compared with experiments in abiotic conditions.
In parallel, we present a two-dimensional pore-scale numerical model (Benioug et al., 2017) to investigate the main mechanisms governing biofilm growth and NAPL dissolution in porous media. Fluid flow is simulated with an immersed boundary–lattice Boltzmann model while solute transport is described with an interface reconstruction finite volume approach (Benioug et al., 2015). A cellular automaton algorithm combined with the immersed boundary method was developed to describe the spreading and distribution of biomass. Different conditions are considered (spatial distribution of biofilm, reaction kinetics, biosurfactant production, NAPL toxicity) and their impacts on the dissolution process are analyzed.

References

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