Modelling a field experiment of enhanced dissolution of chlorinated solvents

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Enhanced dissolution is thought to be an important physico-chemical process that can strongly affect overall mass fluxes from organic pollutant source zones and the rate at which they deplete. The process has been validated in several laboratory column studies and, although scarsely, also in the field. Numerical modelling studies suggest that the enhancement is induced by the increase of concentration gradients at the mm-scale. However these models were so far unable to closely reproduce observations from laboratory column experiments and, on the other hand, have never been applied to assess data from field-experiments.

In this study we present a detailed analysis of a field-scale remediation experiment for a PCE contaminant source zone and provide clear evidence for the occurrence of enhanced dissolution. We demonstrate that NAPL dissolution mostly occurred within thin layers of silts in conjunction with subsequent mass transfer towards interbedded, more permeable, sandy layers.

As a first objective of this study an analytical solution for the enhanced dissolution of a single NAPL component from the interbedded thin silt layers was developed and validated by mm-scale numerical simulations. For an extension to the case of a sequential degradation of PCE to VC and ethene in the presence of organic matter a semi-analytical solution that relates the dissolution rate to the average local pollutant concentration was derived. With the solution being scale-independent it is directly applicable to field-scale simulations.

In the analysis of our field data we used conservative transport simulations to estimate the precise thickness of the silty layers and local permeabilities. This step was followed by reactive transport simulations in which the enhanced dissolution rate considers the local concentration, sand layer thickness, local flow velocities and degradation rates. Incorporating the results of the conservative transport simulations the degradation rate was adjusted until a satifactory agreement with measured data was achieved.

Overall, this step-wise analysis allowed to differentiate between the individual effects of degradation and dissolution on the source depletion rate. For the studied case the results suggest that the dissolution was enhanced by a factor >3. The calibrated model allowed to undertake long-term scenario simulations that were then used to identify the most efficient remediation approach.