

# Assessment of innovative *in situ* techniques for groundwater and soil remediation: nanoremediation and thermal desorption

Susanne Laumann

## Abstract

Contamination of soil and groundwater by organic and inorganic contaminants is a serious environmental issue in many industrial countries. Chlorinated solvents are among the most frequently found contaminants in soil and groundwater. Once released into the environment, they can contaminate large volumes of soil and groundwater and persist in the subsurface for decades. Consequently, sustainable and effective remediation strategies are needed to clean up such contaminated land and to improve environmental quality.

The overall objective of this PhD thesis was to investigate the use of two selected innovative remediation techniques: nanoremediation and *in situ* thermal desorption. More specifically, the objectives were (1) to close some of the gaps in knowledge with respect to the mobility of nZVI in the subsurface that currently limit the practical use of nanoremediation for *in situ* groundwater treatment and (2) to evaluate the effectiveness of *in situ* thermal desorption in a contaminated soil by means of material flow analysis. The main findings can be summarized as follows:

## Nanoremediation

- The mobility of commercially available, polyacrylic acid coated nZVI (PAA-nZVI) was significantly reduced in carbonate-containing porous media and in the presence of high dissolved calcium concentrations.
- The maximum predicted travel distance of PAA-nZVI was reduced from approximately 1.6 m in quartz sand to just a few centimeters in pure carbonate sand.
- Modification of the aquifer grain surfaces by means of a polyelectrolyte coating (natural organic matter, humic acid, carboxymethyl cellulose, and lignin sulfonate) affects the PAA-nZVI mobility in carbonate porous media.
- The co-injection of polyelectrolytes has been shown to increase the mobility of PAA-nZVI in carbonate-containing porous media and also in the presence of high dissolved calcium concentrations (as typically found in carbonate-rich aquifers).
- Lignin sulfonate, an environmentally friendly and inexpensive agent, was identified as the most suitable polyelectrolyte for field applications.

- The greatest increase in PAA-nZVI mobility in carbonate sand was achieved with co-injected lignin sulfonate concentrations of 50 mg L<sup>-1</sup> or more. At these concentrations the maximum PAA-nZVI travel distance in carbonate porous media was double that measured in the absence of lignin sulfonate.

### ***In situ* thermal desorption (ISTD)**

- At the investigated field site, ISTD was effective in removing the majority of chlorinated solvents from soil. The target remediation value in soil vapor (10 mg m<sup>-3</sup>) was achieved after nine months of remediation, demonstrating the efficiency of ISTD for this particular site.
- Material flow analysis is shown to be a suitable tool for evaluation of soil remediation performance. It reveals contaminant emissions into the environment, before and during remediation and provides an overview of processes occurring throughout soil remediation.

The results presented in this PhD thesis demonstrate that the optimization of innovative techniques is necessary in order to effectively remediate contaminated land. The comprehensive assessment of a remediation performance is another important step in the further development and optimization of innovative remediation techniques. This assessment should consider all environmental effects of the remediation in order to achieve the best environmental management practices.