OBSERVATION OF THE MIGRATION PROPERTIES OF NANOIRON BASED ON 2D-EXPERIMENT

POZOROVÁNÍ TRANSPORTNÍCH VLASTNOSTÍ NANOŽELEZA NA ZÁKLADĚ 2D-EXPERIMENTU

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Abstract:
Besides testing the reactivity of nanoiron particles with a given kind of contaminant it is equally important to find out, how far the nanoparticles are able to migrate to ensure contact with the contaminant in the subsurface.
To observe the migration properties of different modifications of nanoiron particles in the subsurface a 2D-experiment with dimensions of 1m x 0.12m x 0.7m (l x w x h) was designed and constructed by the Research Facility for Subsurface Remediation (VEGAS) at the University of Stuttgart. This experiment enables the visualization of migration of the iron nanoparticles by injecting into the source zone of contamination (direct-push), as well as a comparison of the migration properties of different particles and a calculation of the spread efficiency of the particles in the subsurface.

Keywords:
Modification of nanoiron particles, injection of particles, source zone of contamination, spread efficiency in the subsurface

Introduction

The direct-push method applied to remediate DNAPL source zones using iron nanoparticles is economical even in hard to reach areas (deep underground or under buildings, etc.). The application of reactive iron nanoparticles, which are pushed in the form of a suspension into the porous media directly into the source of the contamination, appears to be beneficial from several perspectives. The nano-scale of the particles means they can easily enter the pore space of the medium where they have a high reactivity with the contaminant due to their large specific surface. In addition, nanoparticles are applicable on a wide range of contaminants such as organic substances, heavy metals, pesticides etc.
The author’s thesis was focused on the determination of initial and boundary conditions, as well as performance, documentation and evaluation of the experiment.

Methods

The aim of the experiment is to present in the best possible way a homogeneously filled two-dimensional cross-section of a confined aquifer (Figure 1). The box is made of stainless steel and safety glass, and the confined state is created by two fixed boundary conditions i.e. Constant Head #1, and Constant Head #2 (Figure 2). The box was filled with sand (DORSOLIT® Nr.8) and an impermeable layer (Geba weiß). Two containers located on the inlet side of the box served as deoxygenated water tanks. The contaminant and the iron nanoparticles were subsequently applied to the porous medium through four injection ports at the rear of the box. Prior to injection of the iron the suspension with a concentration of 10 g/L had to first be prepared in a mixing container. Since iron nanoparticles rapidly clump together and have a tendency to form large impermeable agglomerates the suspension had to be dispersed before and during injection.

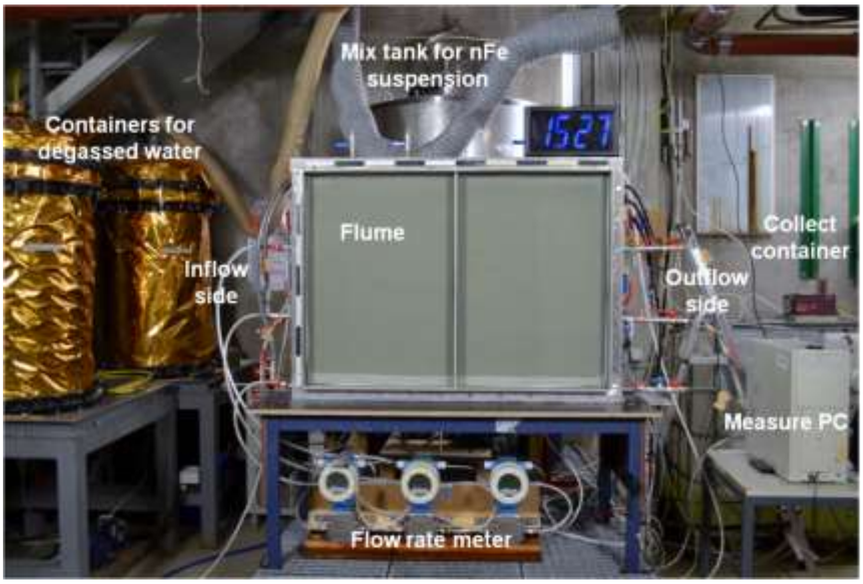

Figure 1: Real photograph of the 2D experiment workstation at the VEGAS research centre, Stuttgart

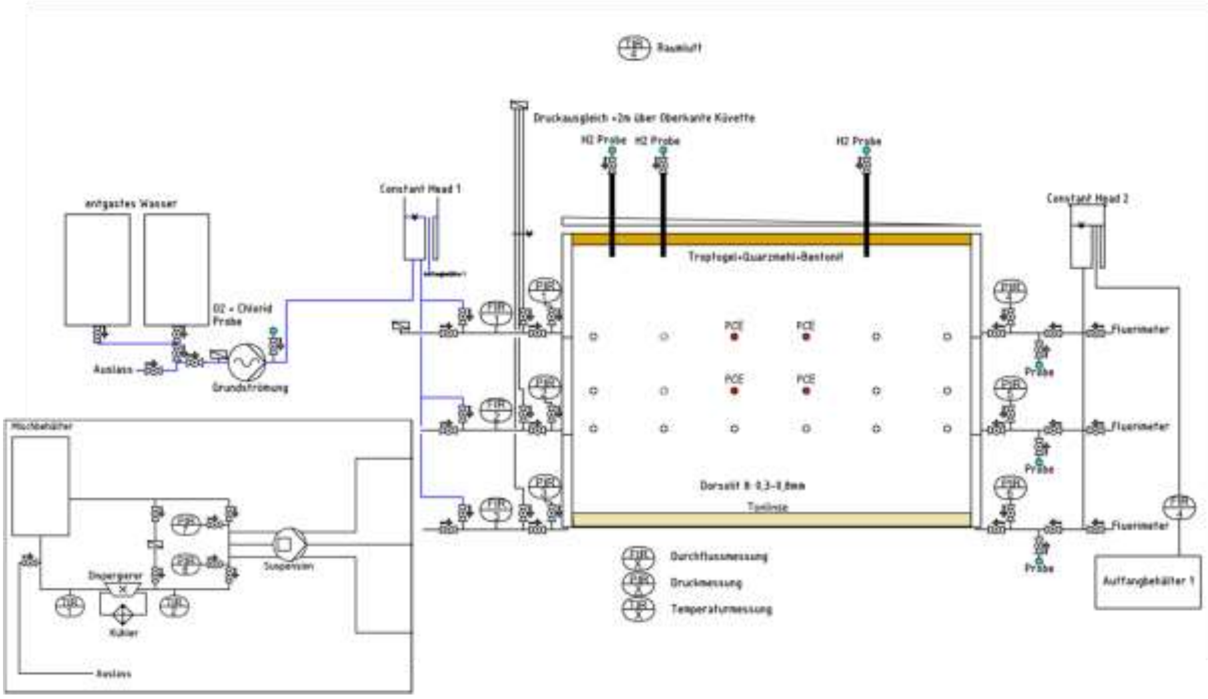

Figure 2: Diagram of the 2D experiment designed and constructed at the VEGAS research centre, Stuttgart

The box was first assembled and filled with sand and then the first tracer test was performed to confirm that the system is homogeneously filled and there are no preferential flow paths in the system. Subsequently, the first (reference) migration experiment was performed without the presence of contaminant in order to observe the spread of nanoparticles through the medium without the presence of harmful substances. After the first migration experiment, the second tracer test was carried out in order to observe changes in the water flow after injection of the particles. After the experiment, the box was emptied layer by layer. The individual layers were documented, analyzed and the results were used to calculate the spread efficiency of the particles in the porous medium. The entire migration experiment was then repeated under the same conditions but this time with the presence of a contaminant, tetrachloroethene (PCE). This experiment served to visualize the spread of the iron nanoparticles in the porous medium with the presence of PCE and thus to verify the direct-push method. The experiment was performed with commercially available nanoparticles NANOFER 25S (NF 25S) from NANO IRON s.r.o. The migration capabilities of NF 25S were compared with the migration capabilities of “NAPASAN” iron particles prepared by UVR-FIA GmbH.

Results

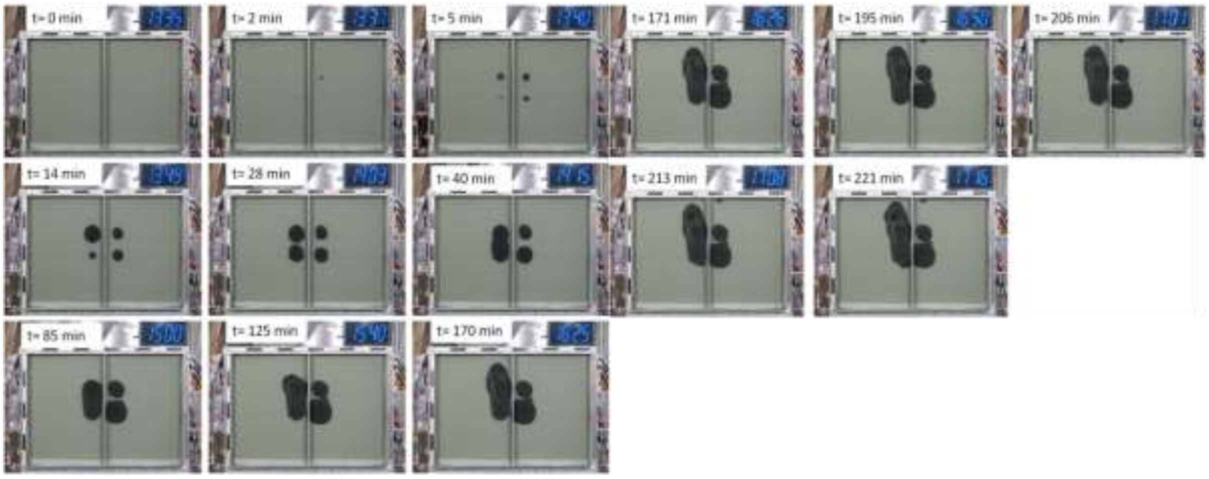

Figure 3: Visualization of the 2D-migration experiment using UVR-FIA iron particles without the presence of a contaminant

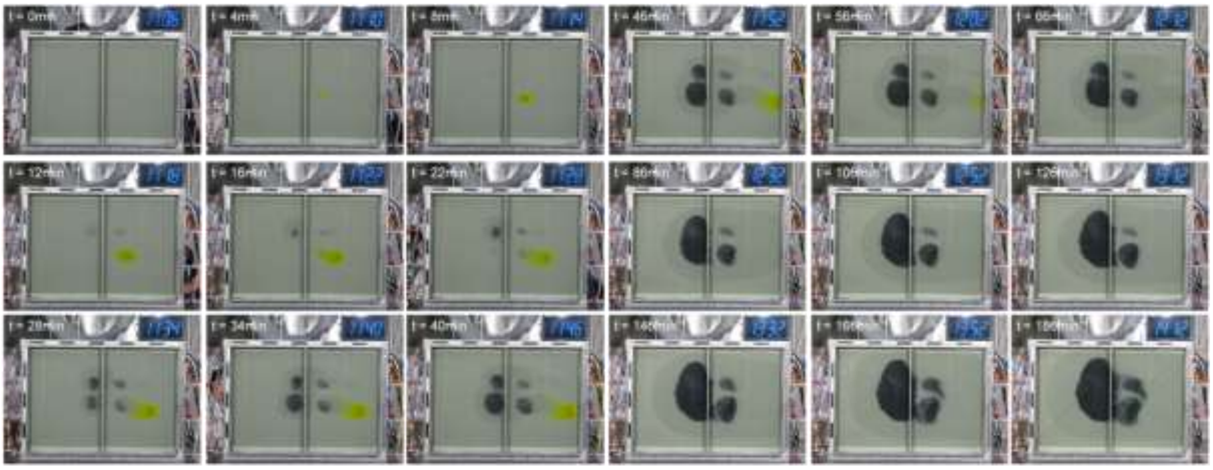

Figure 4: Visualization of the 2D-migration experiment using NF 25S without the presence of a contaminant

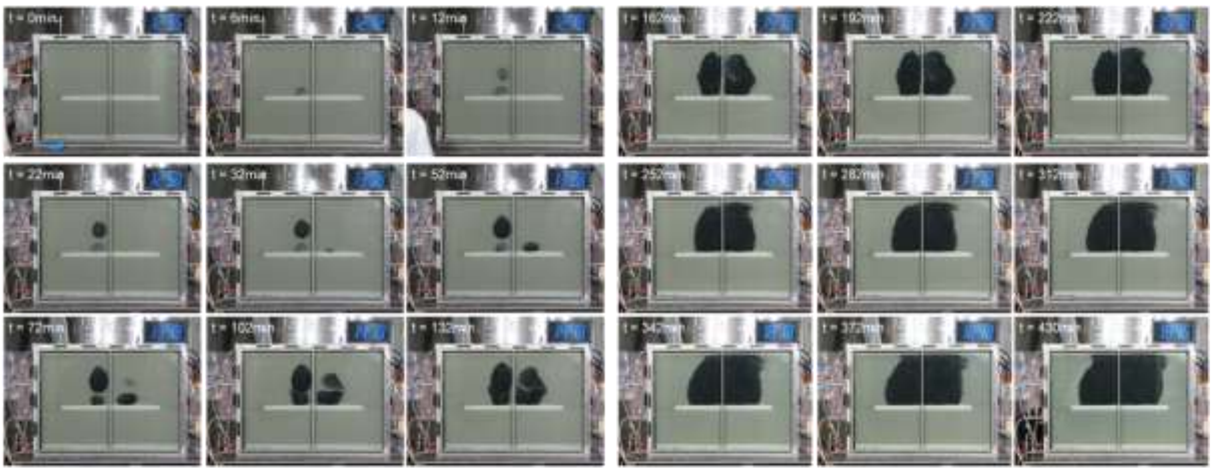

Figure 5: Visualization of the 2D-migration experiment using NF 25S with the presence of a contaminant

Figure 6: Comparison of the migration properties of the UVR-FIA and NF 25S particles without the presence of a contaminant

Discussion

The experiments demonstrated that iron nanoparticles spread radially from the injection point. For the NF 25S particles the more mobile disaggregated particle fractions were easily transported. After disassembling the experiment with the NF 25S particles it was apparent that the individual zones of nanoiron were connected in all of the layers and the greatest concentration of particles was very close to the injection points. The lighter parts of the zones in the flow direction were areas with a lower content of particles. Furthermore, this experiment confirmed that the iron nanoparticles also reached the areas of PCE contamination, whereby providing the necessary contact for the onset of the reaction of PCE with the iron nanoparticles. A limitation of this experiment proved to be the formation and accumulation of gases in the upper part of the box, which was the result of the reaction of the PCE with the nanoiron and anaerobic corrosion. During the tracer test the flow of water completely changed after injection of the nanoiron, with the area affected by the injection of nanoiron being bypassed. The 2D-experiment was designed so that the migration experiment could be repeatable and performed with other types of iron nanoparticles and the spread efficiency through the porous media could be compared. The migration ability of the NF 25S nanoparticles, which have a spherical form and n average particle size of 50 nm, was compared with the ground particles from UVR-FIA GmbH, which are more flat and have a particle size of between 200 and 1000 nm. Due to their preferable form for transport and the fact that the particles are on a nano-scale in all three dimensions, the NF 25S nanoparticles spread in the medium far more efficiently than the product from UVR-FIA GmbH and can therefore be regarded as better in terms of migration.

Conclusion

The 2D-experiment designed for the purpose of comparing the migration properties of different types of nanoparticles fulfils its task. The experiment can be repeated to determine how the individual particles behave in the given porous medium. By maintaining the same initial conditions of the experiment (the same porous medium, the concentration of particles in the suspension etc.) not only can the migration ability of the particles be compared but also the spread efficiency in the medium.

Acknowledgements

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nanotechnological remediation processes from lab scale to end user applications for the restoration of a clean environment.

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