Laboratory Experiments to Characterize the Transport and Reactivity of Zero-Valent Iron Colloids in the Subsurface

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Introduction

State of the Art:

Fe^0 is known to be a remediation reagent for chlorinated hydrocarbons and other contaminants.

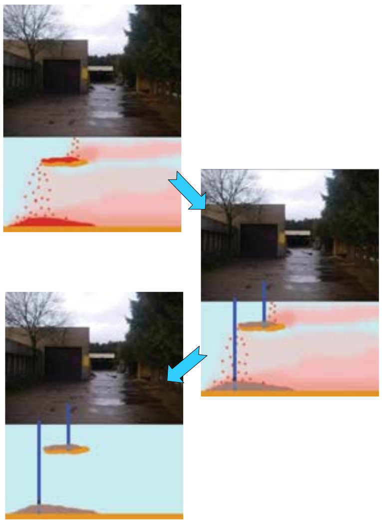
Up to now, Fe^0 has been emplaced into the subsurface in granular form as permeable reactive barriers, restricting the application to the **plume area.**

Recently, the injection of colloidal Fe^0 suspension into the subsurface using injection wells has been proposed.

New Concept:

Fe^0 colloids are injected into the **source zone** and will dechlorinate the pollutants as soon as the pollutants are dissolved, cutting off the plume production.

The colloids can be distributed in the subsurface to a reasonable distance. They will remain in location after the injection as a reactive zone.



Research Goal and Open Questions

Feasibility study for the use of zero valent iron (ZVI) in colloidal form as an in-situ remediation technology focusing on:

Transport (during injection):

Which transport distances are achievable under field conditions?

What influences and controls the transport distances and distribution?

How to determine and prove the Fe^0 concentrations in the aquifer?

Reactivity (long term):

How well do the chosen Fe^0 colloids react with the contaminant?

What is the longevity and efficiency of the Fe^0 colloids?

Monitoring (long term):

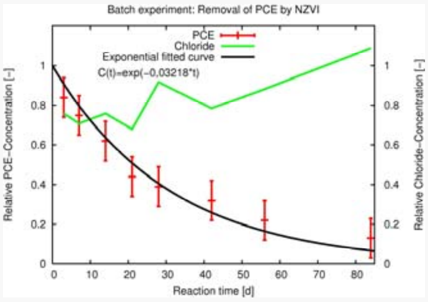
Can the consumption and the behavior of Fe^0 be measured in-situ?

When is a re-injection necessary?

Chemistry

The general reaction between zero valent iron and a chlorinated solvent is given by: $R-Cl+Fe^0+H_2O \rightarrow R-H+Fe^{2+}+Cl^-+OH^-$

Batch experiments are commonly used for chemical studies on the behavior of iron particles

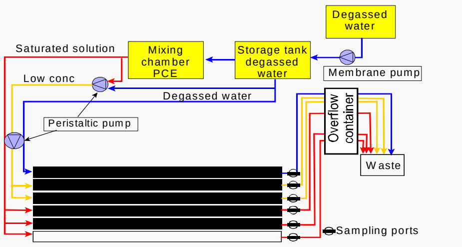


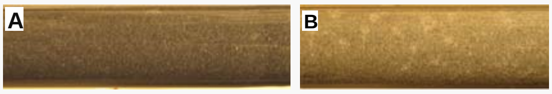
Reaction of PCE with nano iron and the production of chloride during the reaction

However, chemical behavior in batch experiments differs significantly from column experiments and the field. In batch the pH quickly increases due to corrosion resulting in **self inhibition**

➔ Corrosion is strongly pH dependent: $Fe^0+2H_2O \rightarrow Fe^{2+}+H_2(g)+2OH^-$

H_2-gas production in long term column experiments was significantly reduced by adding solid $Ca(OH)_2$ (increasing pH to 11) to the iron suspension

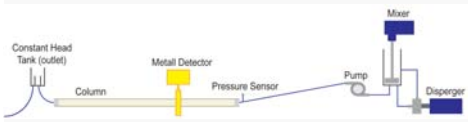




Comparison of a column with $Ca(OH)_2$ (A) and without $Ca(OH)_2$ (B)

Transport & Monitoring

Fundamental questions related to transport are being investigated using column experiments

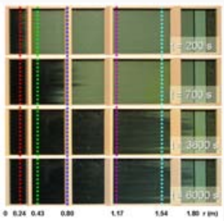


A metal detector can be moved along the column to quantitatively measure Fe^0 concentration distributions inside the column

Several conditions for radial symmetrical flow were tested in a confined aquifer experiment

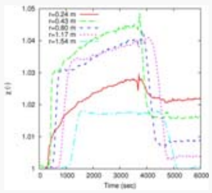
Under realistic field flow velocities and concentrations, transport of 2 meters was possible

Injection of nano sized zero valent iron (nZVI) in a container with a radial flow field (r = 200 cm, h = 60 cm, Q=1000 l/h, sand: 0.3 – 0.8 mm)

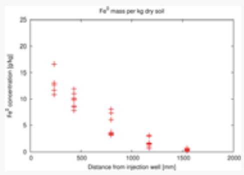


4 snapshots during an injection of nZVI colloids at 1000 l/h, colored lines correspond to colors below

Measured concentrations of sensors were verified by chemically analyzing the sand inside the coil



In-situ dual-coil sensors record Fe^0-break through curves due to the change in the magnetic susceptibility of the medium inside the sensor at different locations during the injection



Results of chemical analysis derived from hydrogen production after adding acid (HCl)

NAPASAN (Einsatz von Nano-Partikeln zur Sanierung von Grundwasserschadensfällen)

Criteria to the **nanoZVI (nZVI) colloids**:
- facilitate transport in porous media
- ensure contact with contaminants and thus their reduction

The **measuring technique** is being improved and optimized for detection and verification **in the field**.

Extension of experiments to directly **measure effects in the source zone**.

Long term experiments in columns are conducted, to assess **long time behavior of nZVI colloids**.

Setups may be used to study behavior of other colloids (e.g. **environmental risk assessment**).

The risks of different nano-sized colloids will be assessed to find **suitable particles for a safe, successful remediation**.

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NAPASAN
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