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

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State of the Art:
Fe⁰ is known to be a remediation reagent for chlorinated hydrocarbons and other contaminants. Up to now, Fe⁰ 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 Fe⁰ suspension into the subsurface using injection wells has been proposed.

New Concept:
Fe⁰ 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.

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.

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.

\[ Fe^0 + 2H_2O \rightarrow Fe^{2+} + H_2(g) + 2OH^- \]

H₂-gas production in long term column experiments was significantly reduced by adding solid Ca(OH)₂ (increasing pH to 11) to the iron suspension.

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 Fe⁰ concentrations in the aquifer?

Reactivity (long term):
How well do the chosen Fe⁰ colloids react with the contaminant?
What is the longevity and efficiency of the Fe⁰ colloids?

Monitoring (long term):
Can the consumption and the behavior of Fe⁰ be measured in-situ?
When is a re-injection necessary?

Transport & Monitoring

Fundamental questions related to transport are being investigated using column experiments.

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.

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.

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

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