Dechlorination of solvents by nanoscale zero-valent iron particles: applying flake shaped nanoparticles in an aerobic aquifer with restricted solvent dissolution

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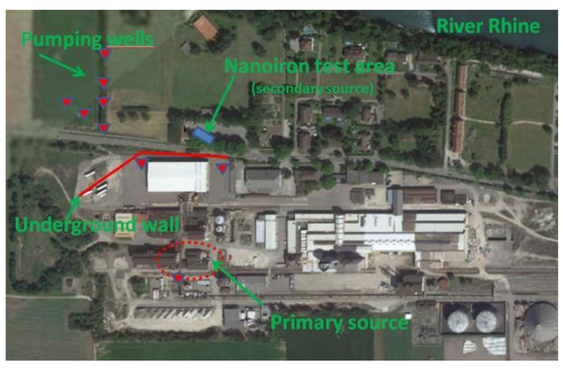
Motivation

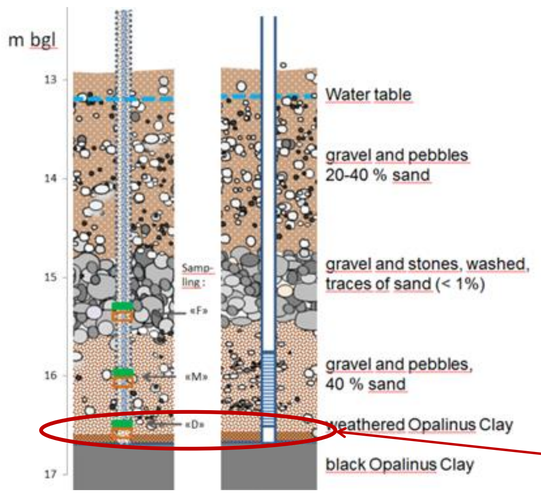


The Zurzach site is located in the Rhine valley in northern Switzerland. The main ground-water contaminants are PCE, TCE and Hexachloroethane (HCA) which were manufactured at this site until 1976.

A pump-and-treat system has been in operation for 12 years, but the efficiency of this installation is decreasing, thus there is an interest in alternative technologies for groundwater remediation. Injection of nanoscale zero-valent iron (nZVI) is an innovative technology, which could have the potential to expedite the remediation. The flake shaped, milled nanoiron FerMEG12 was selected for this field-scale pilot test because of its special physical-chemical properties.

Geology and Hydrogeology

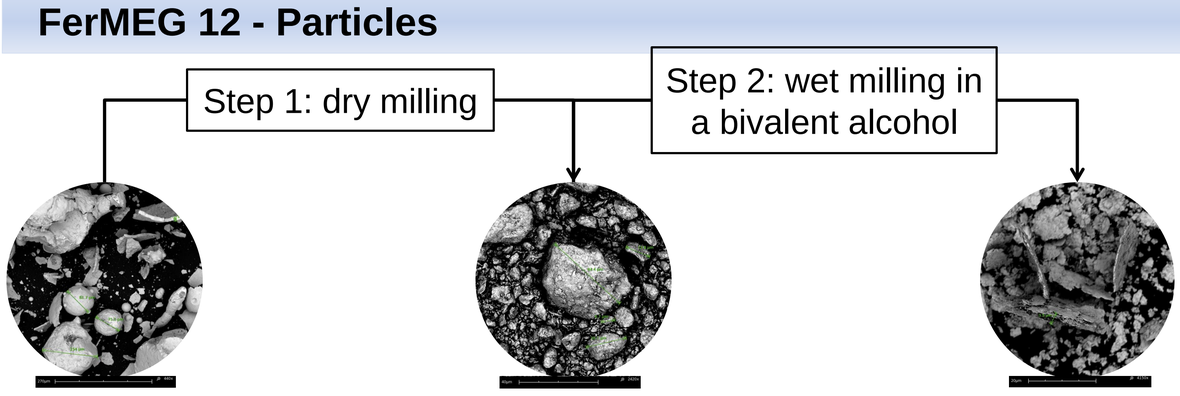
The test field ground consists of unconfined alluvial sediments of sand and gravel. However, stones and boulders prevalent in distinct layers in the vadose zone prevent the use of direct push techniques. The bedrock (Opalinus Clay) is found at 16.5 m bgl and the average water table at 13 m bgl.



Position of sampling points/iron sensors in the new monitoring wells and filter screen of the injection wells relative to the different geological layers of the aquifer.

Confirmed source zone
(highest contaminant concentrations, DNAPL presence)

FerMEG 12 - Particles



ATOMET 57
$S_{m, BET}$ = 0,1 m²/g

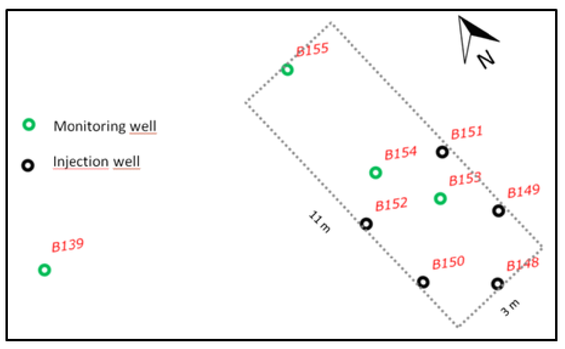
Intermediate
$S_{m, BET}$ = 0,7 m²/g

FerMEG 12
$S_{m, BET}$ ≈ 15 m²/g

The particles are produced in a two-stage top-down process. Dry grinding to get particles < 40 µm, followed by grinding in a bivalent alcohol to avoid H_2. With this technology, nanostructured, flake-shaped particles with thicknesses less than 100 nm are obtained.
Complete dry grinding without alcohol is in the planning stage.

Set-up of pilot test

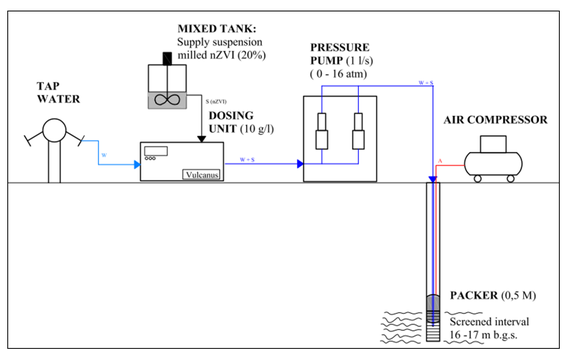
The map is showing the location of the new injection wells and monitoring points relative to the old monitoring well B139. The orientation of the pilot area is determined by the expected flow direction of the deeper ground water. Upper ground water might flow in the direction of B139.



Injection - Monitoring

A total of 500 kg of milled nanoiron was injected into 5 injection wells at the site. The nanoiron suspension was prepared with the use of a continual injection dosing system. The nanoiron concentrate was stored in a mixing tank, the dosing was provided with the use of an automatic system; the final concentration of 10 g/l was fixed as constant and was dosed automatically according to the water flow into the wells. Five injection wells were screened at the required depth (bottom 1 m screen interval) according to the proved vertical contaminant distribution.

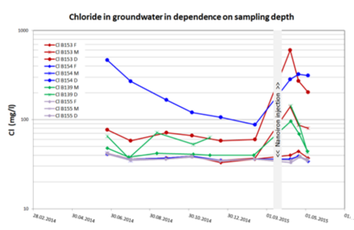
The final nanoiron suspension was injected with the use of a packer system to limit the residence time and to increase the flow velocity of the suspension in the wells and in the pipeline system.
The injection pressure was adjusted between 5 and 7 atm.

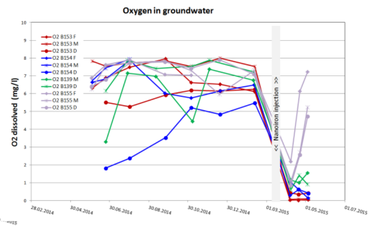


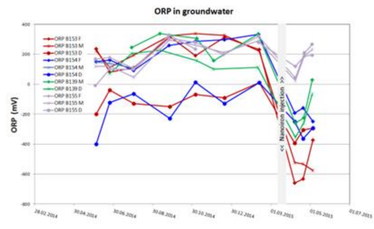
During the pressure injection Lithium tracer applied to follow the horizontal and vertical spreading of the liquid. Breakthrough curves confirmed the communication between all monitoring and injection wells.

Preliminary Results - Conclusions

- The travel distance of nanoiron particles is confirmed by water sample analysis from monitoring points (black color, iron concentrations).
- Nanoiron travelling distance > 2,0 m (iron particles found in all sampling levels of B153 and B154)
- Oxygen depletion and changes in ORP proves the activity of Nanoiron. Nanoiron is still active 6 weeks after injection.
- Final degradation products – H_2, ethane, ethene and chloride – are found in significant concentrations.
- Promising initial data show extensive degradation of chlorinated contaminants at some sampling points. Further monitoring is needed before final evaluation of test results.







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NanoRem - Taking Nanotechnological Remediation Processes from Lab Scale to End User Applications for the Restoration of a Clean Environment

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