Zerovalent iron micro and nanoparticles for groundwater remediation: from laboratory to field scale

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Tiziana Tosco(*), Francesca Gastone (*), Michela Luna (*), Rajandrea Sethi (*)

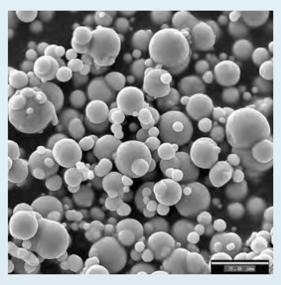
(*) DIATI - Dipartimento di Ingegneria dell'Ambiente del Territorio e delle Infrastrutture, Politecnico di Torino, corso Duca degli Abruzzi 24, 10129 Torino, Italia

Email: tiziana.tosco@polito.it; website: http://areeweb.polito.it/ricerca/groundwater/index_e.html

Improving colloidal stability of MZVI and NZVI using biopolymers

MZVI (microscale zero valent iron) and NZVI (nanoscale zero valent iron) are not stable when dispersed in water:

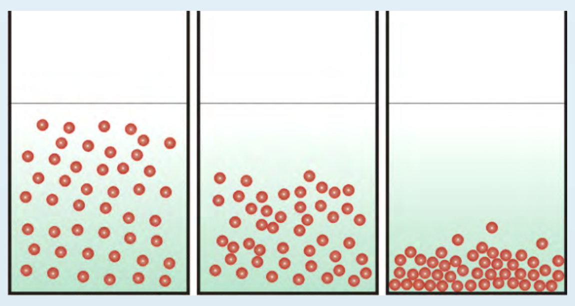
MZVI 1-5 µm



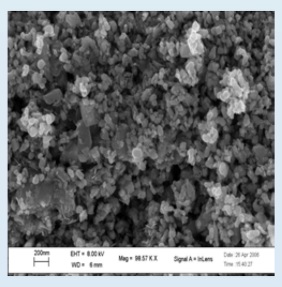
Relevant mass, high density

↓

Gravitational sedimentation



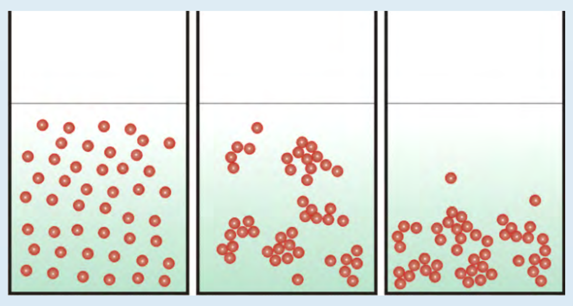
NZVI 5-100 nm



Particle-particle attraction (magnetic forces)

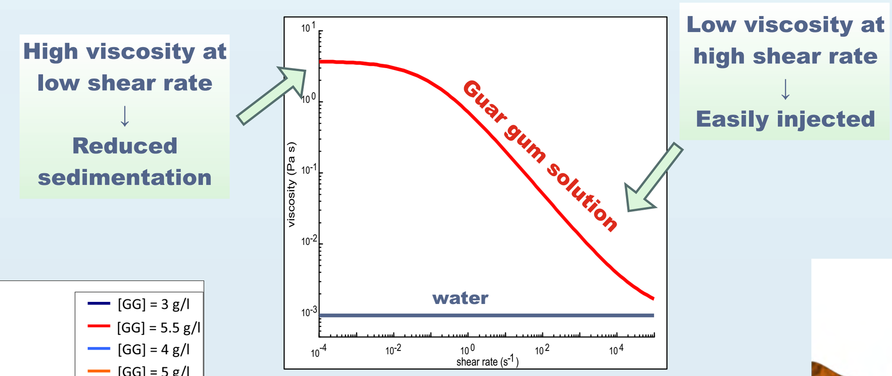
↓

Aggregation and sedimentation

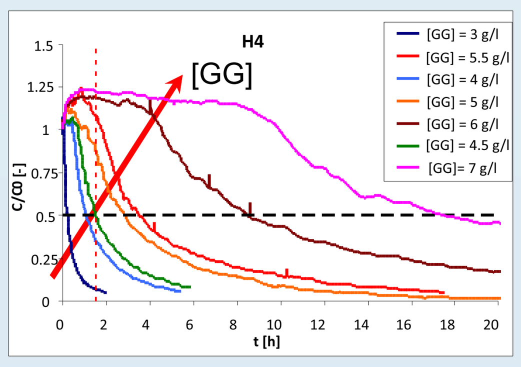


Green polymers (guar gum and xanthan gum) can improve stability via

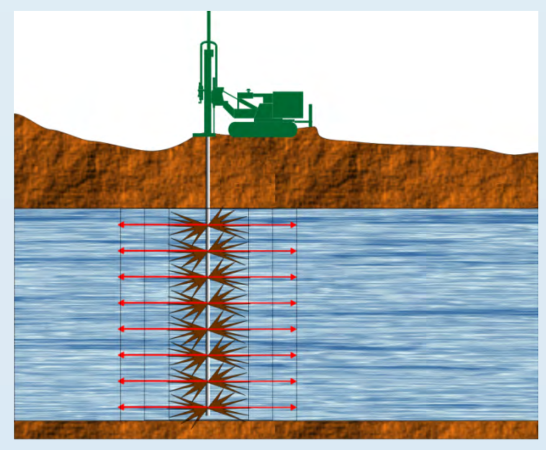
Kinetic stabilization → Increased fluid viscosity



Rheogram of water and guar gum



Sedimentation curves of MZVI

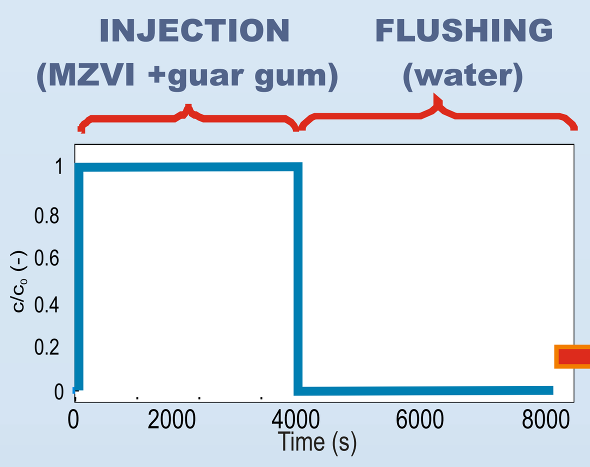


MZVI and NZVI injection in porous media

The mobility in porous media of MZVI and NZVI dispersed in guar gum and xanthan gum was tested in column transport tests (1-D) and a finite-differences model was developped for 1D and radial simulation of MZVI/guar gum injection:

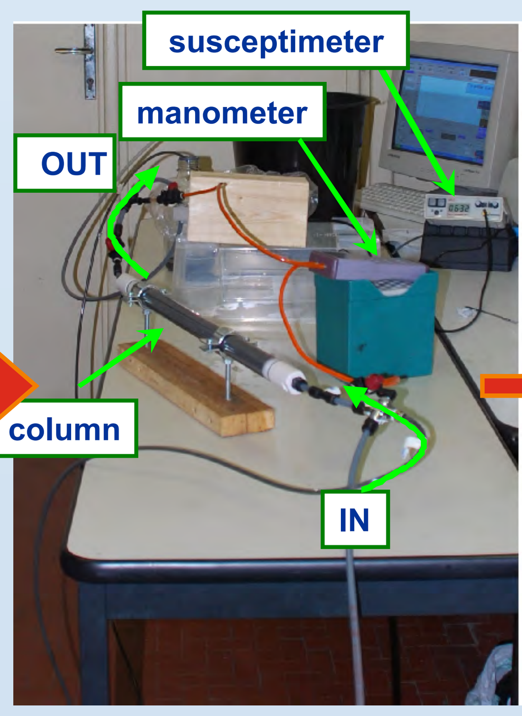
Column tests provide information on:

- porous medium clogging
- pressure build up during Injection
- interactions among iron particles and porous medium



INITIAL CONDITIONS:

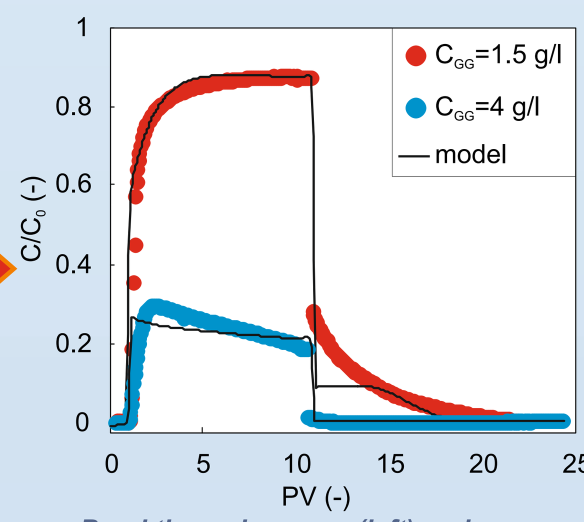
- [GG] = 1.5, 3, 4 g/l
- Different flow rates

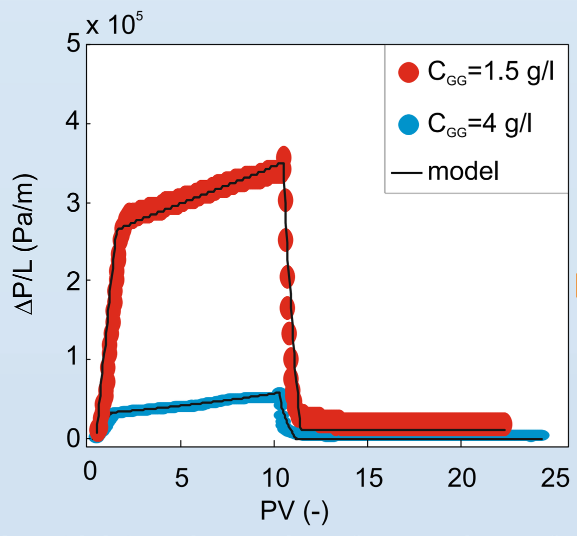


Transport modelling

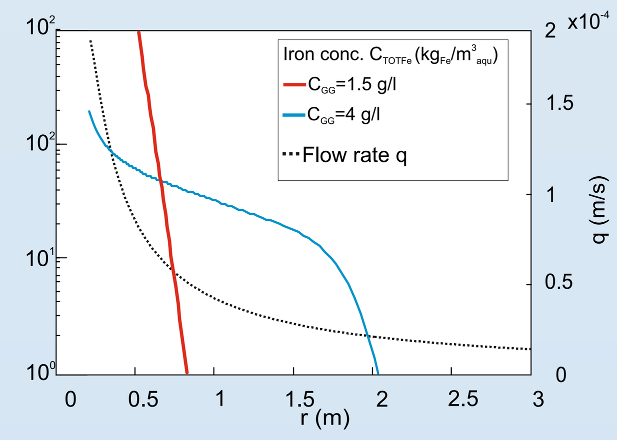
1D transport tests performed at different flow rates and polymer concentration were fitted using MNMs (www.polito.it/groundwater/software).

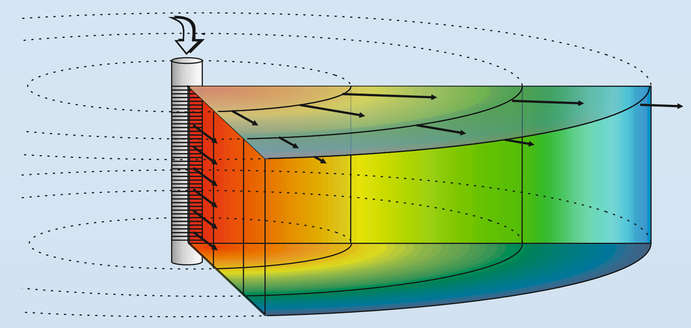
Results were used to develop a radial transport model.





Breakthrough curves (left) and pressure drop (right) vs the number of pore volumes for MZVI injection with a guar gum concentration of 1.5 and 4 g/l





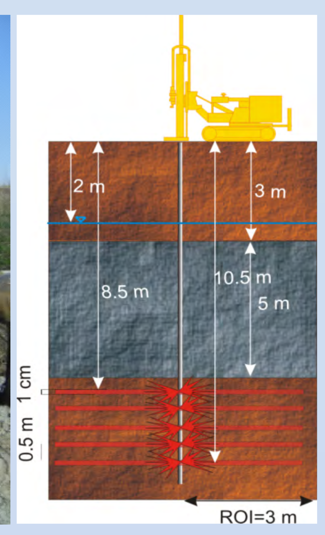
Simulation of radial injection of 5 m^3 of MZVI slurry (20 g/l of iron, 1.5 and 4 g/l of guar gum) at a discharge rate of 1 m^3/h: final concentration of total iron (suspended + retained) per aquifer volume (left axis) and Darcy flow rate (right axis) as a function of radial distance

Field applications

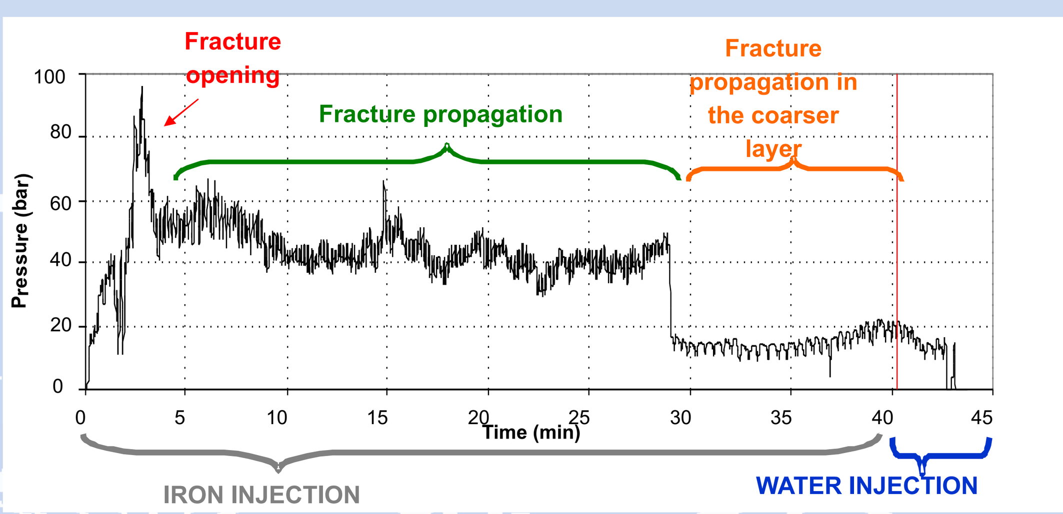
Pilot field injection via fracturing

Delivery: Direct push systems (high pressure & discharge rates)

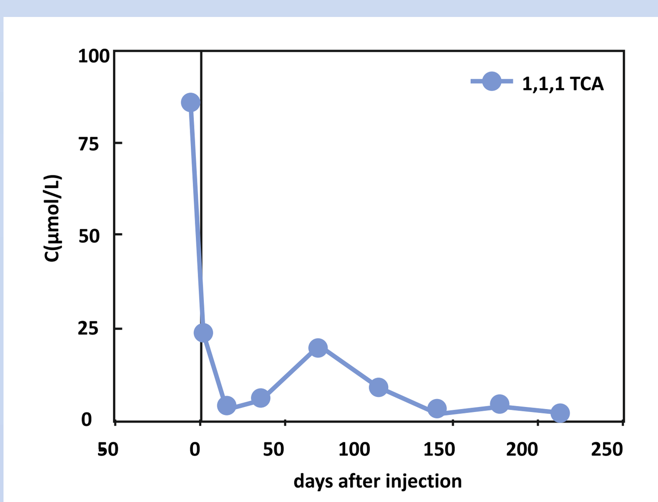
Site: Aarschot (Belgium)
Contamination: 1,1-DCA, 1,1,1-TCA, TCE, cis-1,2-DCE
MZVI: H20 (d50=56 mm, Hoganas)
Guar gum: 5 g/l
Slurry: 1.5 m3, iron conc. 66 g/l
Injection design: 5 injections:
10.5 - 8.5 m bgl, 0.5 m spacing
Q=0.55 m3/h



Field injection via direct push (cortesy of Carsico S.r.l., left) and scheme of stratigraphy and injection points (right)



Pressure record during injection n. 5 (8.5 m bgl).



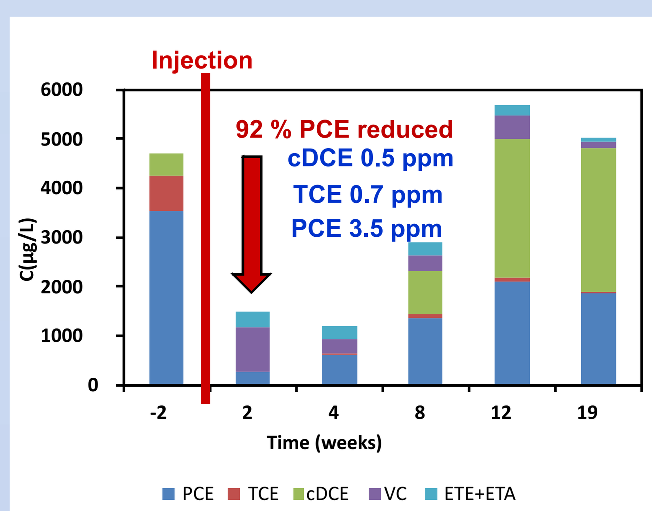
Changes in concentration of 1,1,1-TCA in groundwater over time in the MLDS4 at 4.5 m bgs

Pilot field injection via permeation

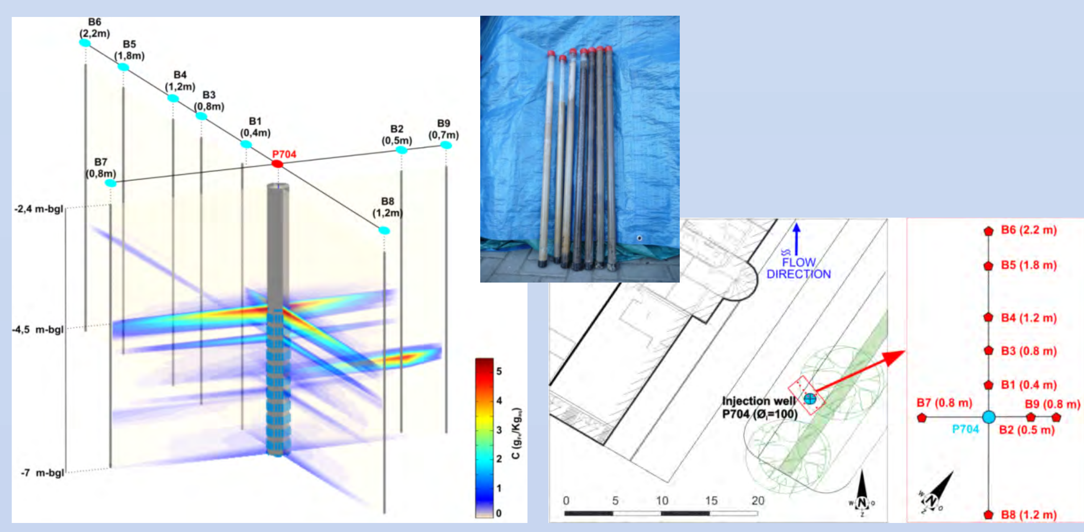
Delivery: low-pressure injection through a well

Site: Site P (Belgium)
Contamination: PCE @ 8.1-72.6 mg/l
MZVI: HQ (d50=1.2 mm, BASF)
Guar gum: 2 g/l
Slurry: 5 m3, iron conc. 10 g/l
Injection design: pressurized well
Screen: 4.5-7 m bgl
Q=1.5 m3/h

IMZVI field injection at Site P: (1) tank for slurry preparation (2) dispersion and recirculation unit, (3) tank for slurry storage, (4) ction pump, (5) injection well, (A) discharga rate mesurement, (B) magnetic susceptibility sensor, (C) pressure sensor.



Concentration along time of contaminants observed in the injection well P704



Iron distribution in the subsurface (left) determined from magnetic susceptibility analysis on core samples (centre) and map of the test area (right).

Acknowledgements and References

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