Agar agar stabilized milled zerovalent iron particles for *in situ* groundwater remediation

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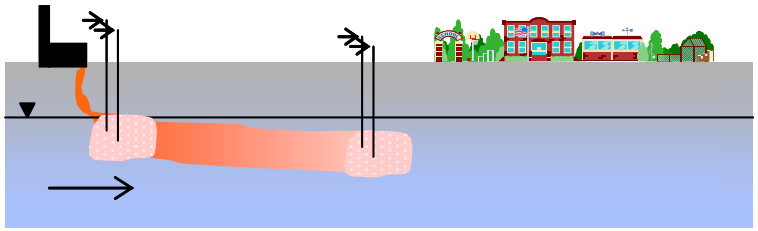
In situ reactive zone (IRZ) treatment of CAHs

Nano-scale (n)ZVI and micro-scale (m)ZVI (15 nm → 100 µm)

Technique under development

Plume *(& source)* treatment

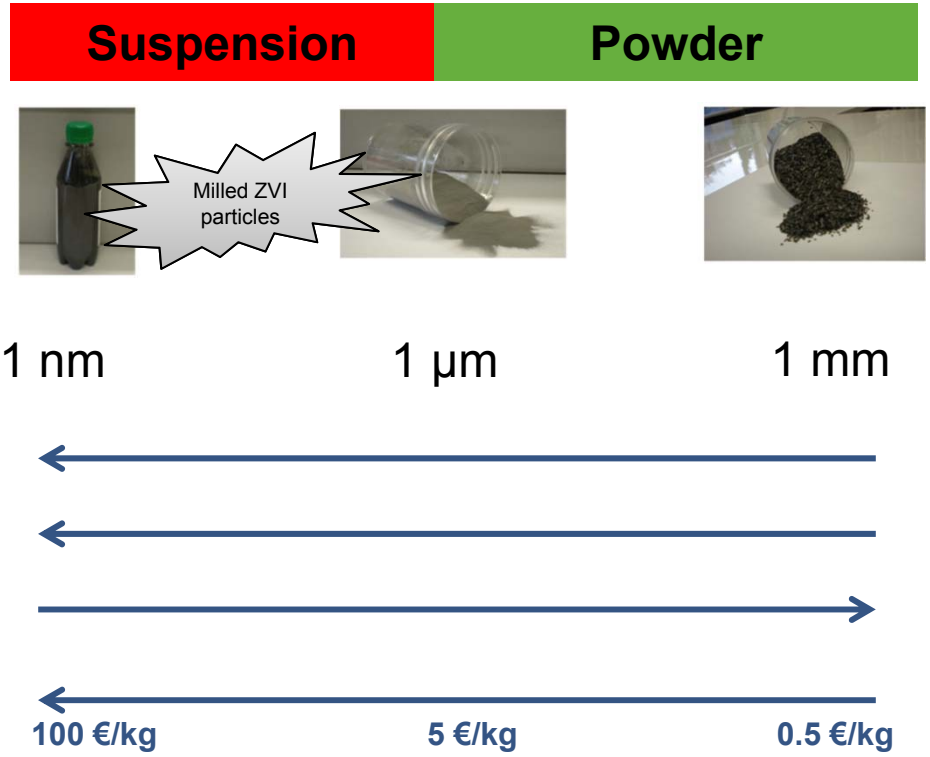


A wide range of pollutants can be treated
Hardly accessible places can be reached

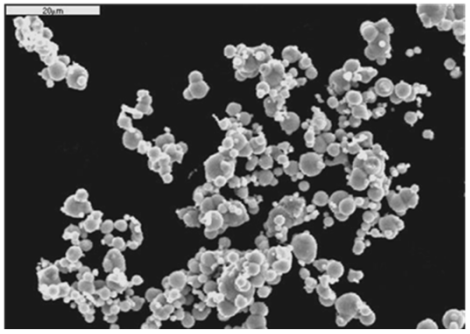
Shorter lifetime
Limited mobility and stability
Non-selective reactivity

In situ reactive zone (IRZ)

nZVI vs mZVI

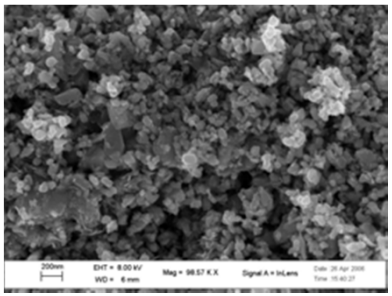


Stability of mZVI and nZVI suspensions



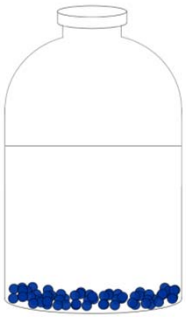
mZVI
(1-100 µm)
relevant mass

nZVI
(15–100 nm)
particle – particle interaction



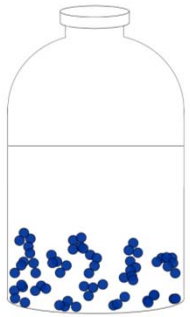
Milled ZVI particles

Sedimentation & Aggregation



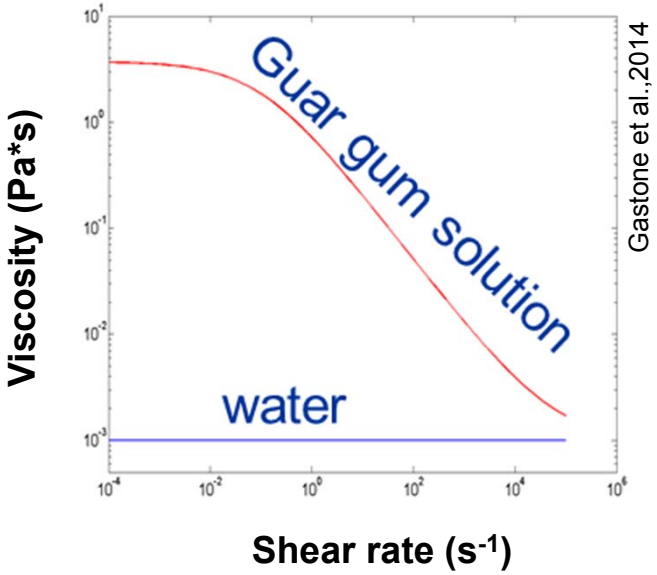
Sedimentation of mZVI particles in slurry reservoir, tubing and injection wells

Filtration in the porous medium

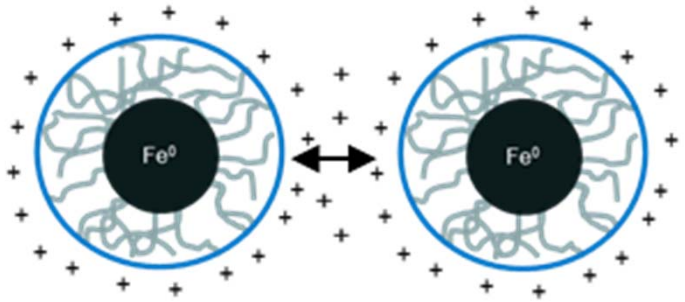


Improved stability of mZVI and nZVI suspensions

KINETIC: use of polymers to increase viscosity of the suspensions



THERMODYNAMIC: use of salts and polymers to increase the repulsion among particles (low viscosity)



AIM OF THE STUDY

I) to elucidate milled ZVI particle mobility-decisive properties

II) to prevent sedimentation of milled ZVI suspensions

III) to investigate mobility of stabilized milled ZVI

IV) to investigate reactivity of stabilized milled ZVI

AIM OF THE STUDY

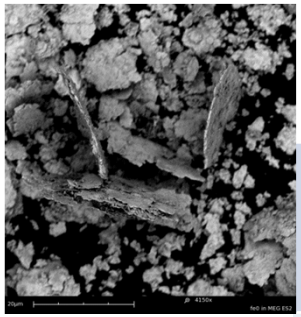
I) to elucidate milled ZVI particle mobility-decisive properties

Analyses:

1. Particle size parameters:
   geometric radius,
   volume equivalent
   spherical diameter,
   hydrodynamic radius;
2. pH, EC;
3. Zeta potential of particles in the suspension;
4. Sedimentation rate;
5. Zerovalent iron content.

I) Mobility-decisive properties of milled ZVI suspensions

Milled ZVI particle concentration 1 g L^{-1}



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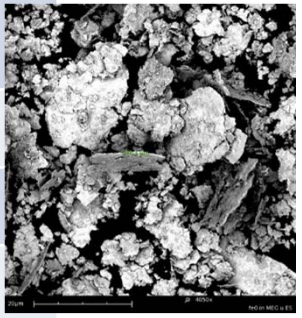
	milled ZVI
Size d_{10} [µm] d_{50} [µm] d_{90} [µm]	**6.4** **11.8** **16.9**
Zeta potential [mV]	**-22 ± 5**
Fe^0 content [wt-% of susp.]	**~12**
Sedimentation rate [m/d]	**25**



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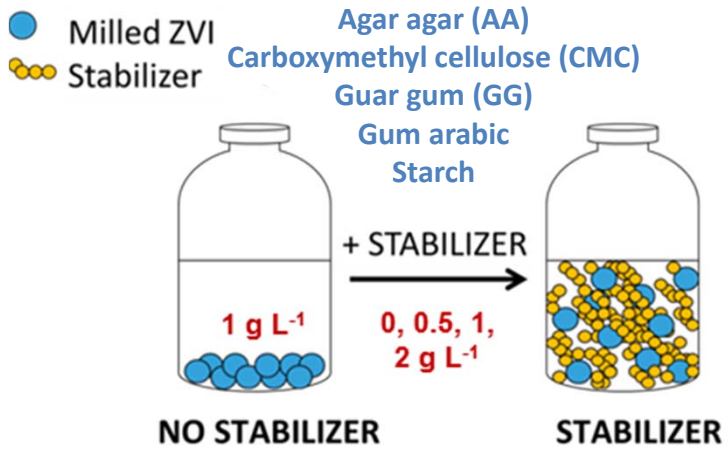
Fast sedimentation rate due to the particle size and shape!

AIM OF THE STUDY

II) to prevent sedimentation of milled ZVI suspensions

Set up:

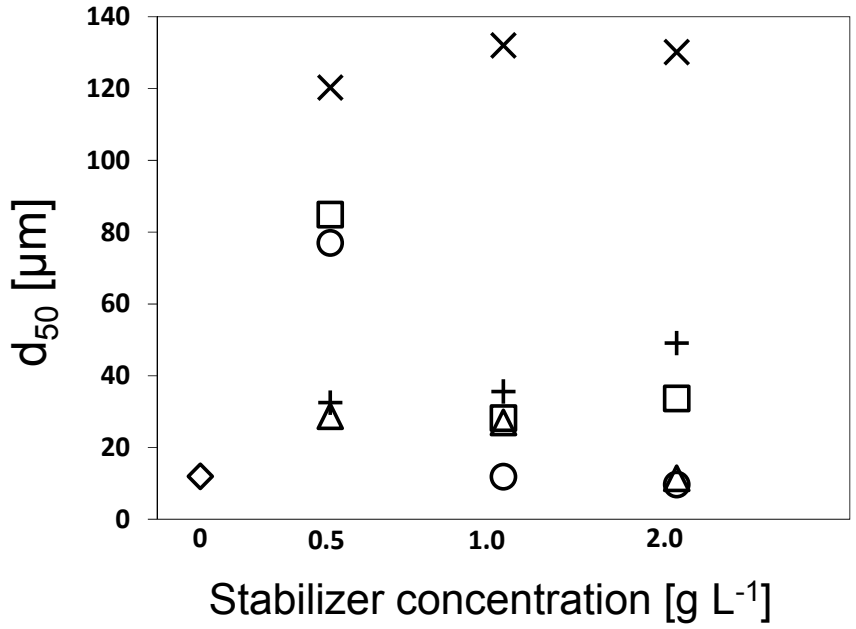


Analyses:

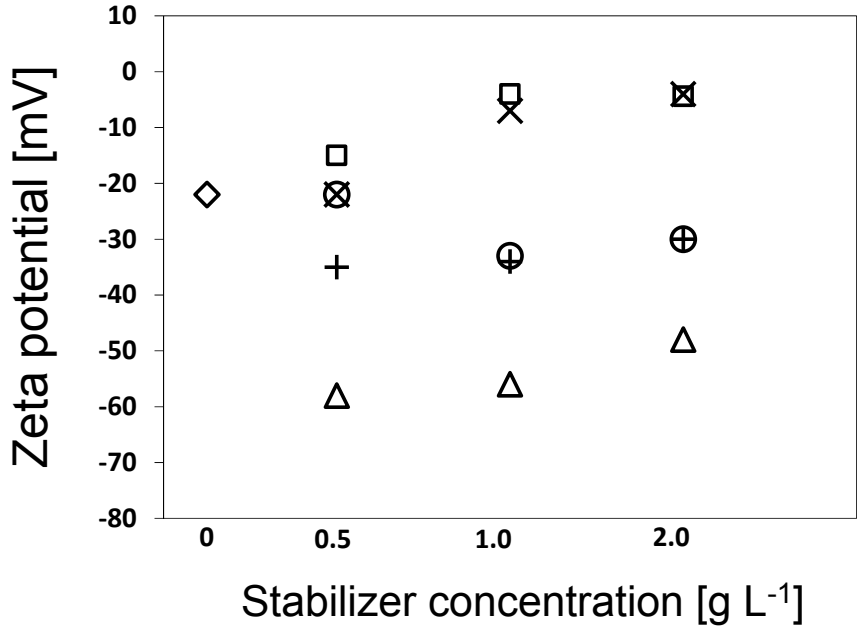
1. Particle size in the suspension,
2. Zeta potential of particles in the suspension,
3. Sedimentation rate, and
4. Viscosity of stabilizer solutions.

II) Stabilization of milled ZVI suspensions

Change of particle size



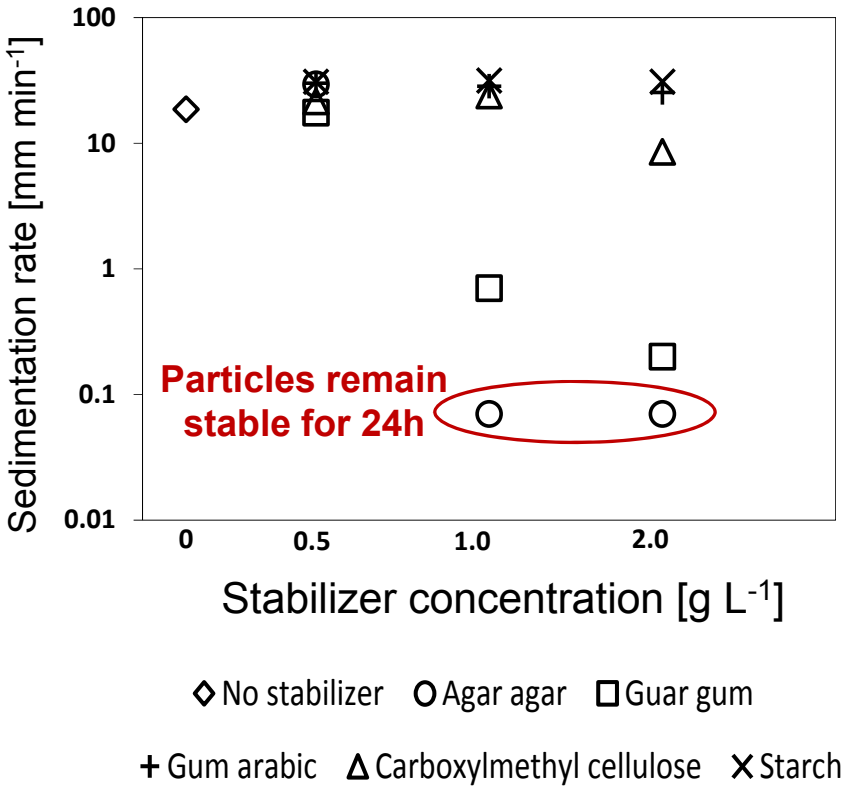
Change of zeta potential



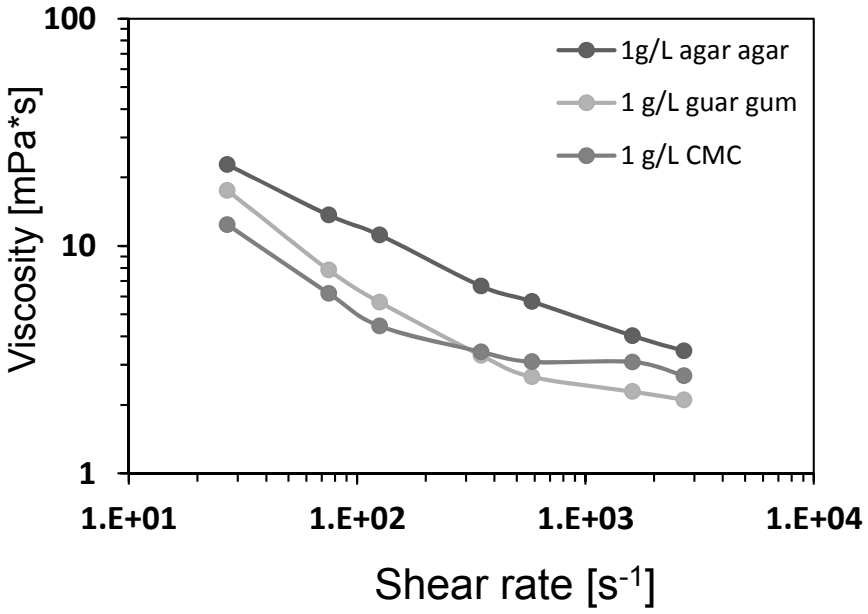
◇ No stabilizer ○ Agar agar □ Guar gum + Gum arabic △ Carboxylmethyl cellulose × Starch

II) Stabilization of milled ZVI suspensions

Change of sedimentation rate



Viscosity as a function of shear rate

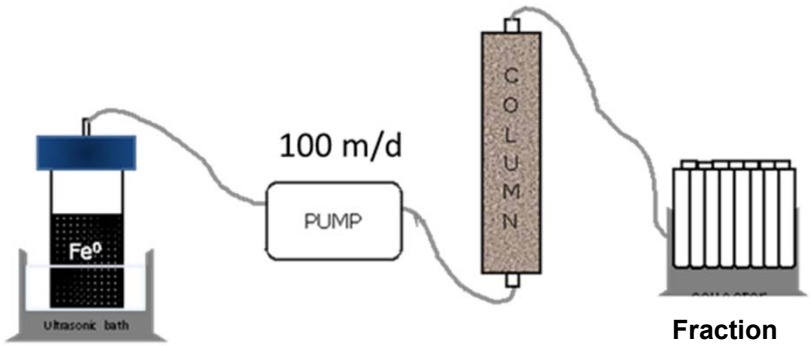


Improved stability by adaptation of suspension viscosity.

AIM OF THE STUDY

III) to investigate mobility of stabilized milled ZVI

Set up:



Agar agar stabilized milled ZVI

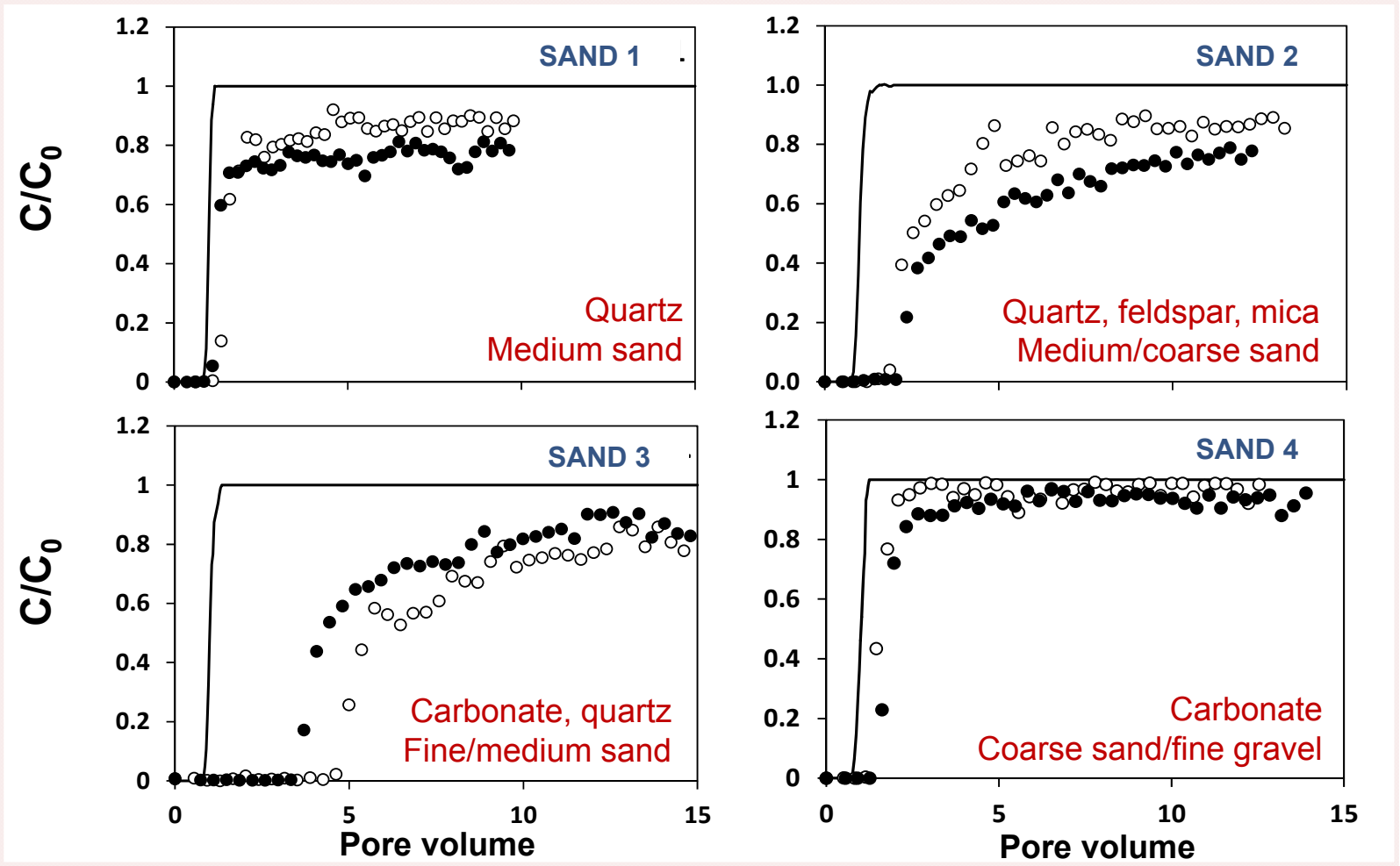
4 different porous media

Fraction collector

Analyses:

1. 4 different porous media: grain size distribution, mineralogical and chemical composition,
2. Zeta potenital of porous media,
3. Tracer Br^-, and
4. Total iron concentration.

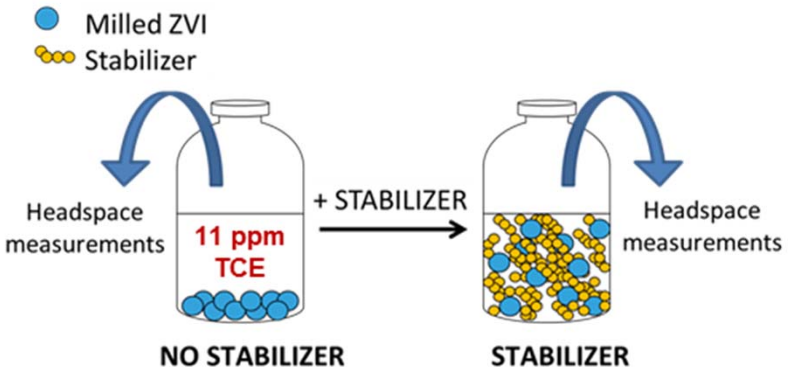
III) Mobility of agar agar-stabilized milled ZVI



AIM OF THE STUDY

IV) to investigate reactivity of stabilized milled ZVI

Set up:

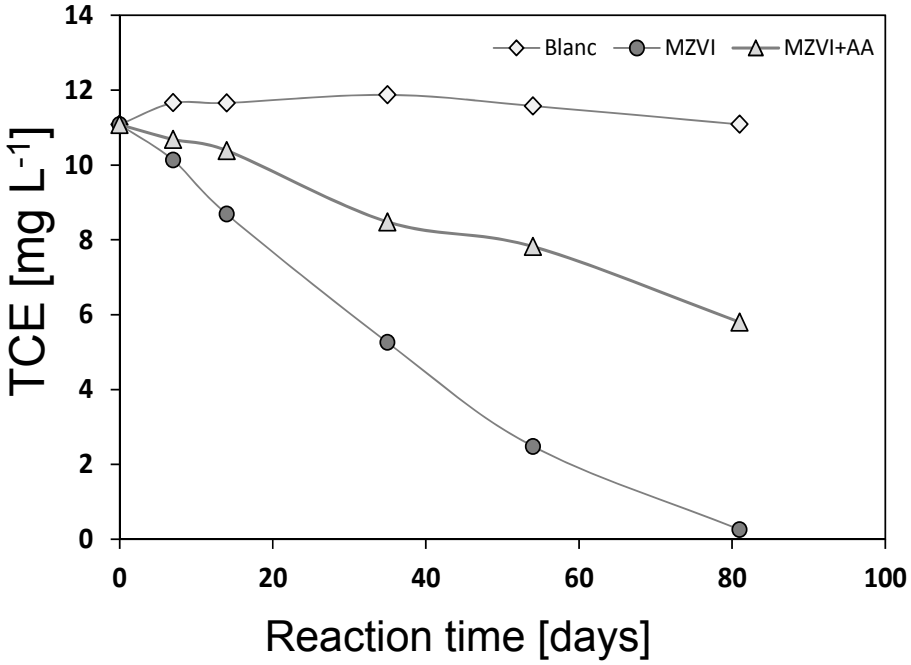


Analyses:

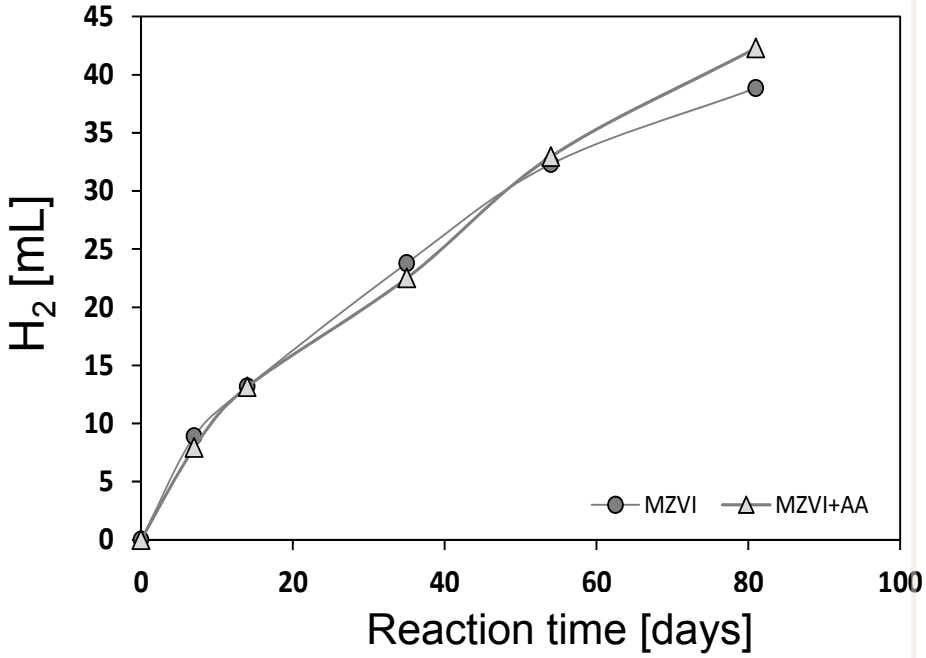
1. Trichloroethene (TCE), ethene, ethane, acetylene,
2. Hydrogen,
3. Cl^-, and
4. pH and ORP.

IV) Reactivity of agar agar-stabilized milled ZVI

Degradation of TCE



H_2 evolution



	k_{obs} (day^{-1})	$t_{1/2}$ (days)	R_{app} (mmol kg^{-1} d^{-1})
MZVI	3.80E-02	18	9.32
MZVI+AA	7.50E-03	92	9.73

Implication for field applications

- The **improvement** of milled ZVI suspension **stability**:
  best performing stabilizer - agar agar.
- The **improvement** of stabilized milled ZVI suspension **mobility**:
  nature of the porous media.
- **Decreased reactivity** compared to bare milled ZVI:
  diffusion limited process,
  superior to microscale ZVIs.

NEXT STEP: field-scale test

- Reactivity and the benefits of stabilization have to be considered together when planning *in situ* application of milled ZVI particles.
- Injection and distribution of agar agar stabilized milled ZVI in the larger scale set up?
- More detailed study on ecotoxicological effects of agar agar stabilized milled ZVI after injection in the subsurface?

Thank You for Your Attention!

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