Migration and Reaction of Iron oxide NP (Goethite) in the Large Scale VEGAS Container

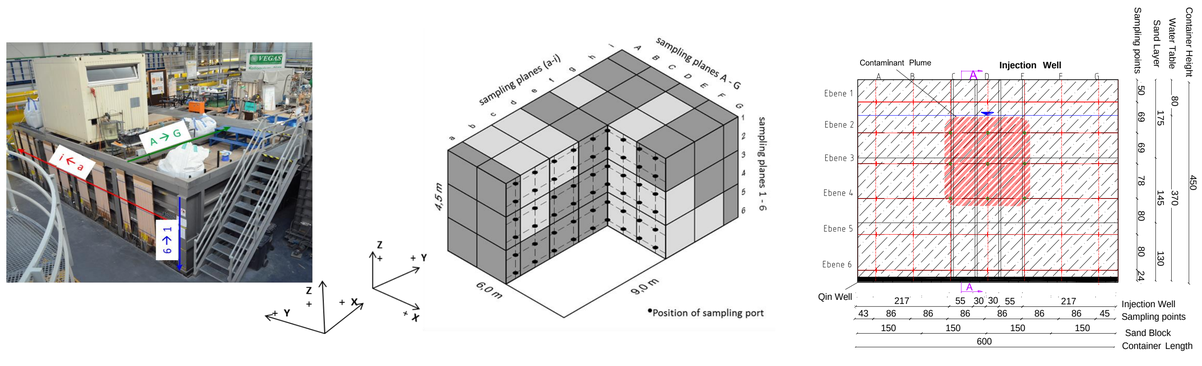
Kumiko Miyajima[1], Jürgen Braun[1], Rainer Meckenstock[2]

[1]VEGAS, University of Stuttgart, [2]University of Duisburg-Essen

www.nanorem.eu

NanoRem is a four year, €14 million research project funded through the European Commission FP7.

Large Scale Container



Artificial Aquifer in the Large Scale VEGAS Container

- Size: L/B/H = 9.0/ 6.0/ 4.5 m
- Layered heterogeneous sand aquifer ($K = 4 \times 10^{-4}$ and 4×10^{-3} m/s)
- Water table: 3.7 m
- Average seepage velocity: 0.42 m/d
- 380 Sampling ports: 378 in the aquifer, 2 in/outflow

LNAPL Plume Zone (Toluene)

- Plume cross-sectional area: 4.0 m² in the center of the aquifer (red colored area of right schematic image)
- Toluene dosing rate ≈ 1.6 g/h (~400 mg/L x 4 L/h)
- Toluene concentration in plume ≈ 70.0 mg/L

Goal of Experiment

Remediation of Toluene Plume Zone

- Enhancement of natural attenuation of toluene by goethite NP

Target Transport/Deposition of NP in Toluene Plume Zone

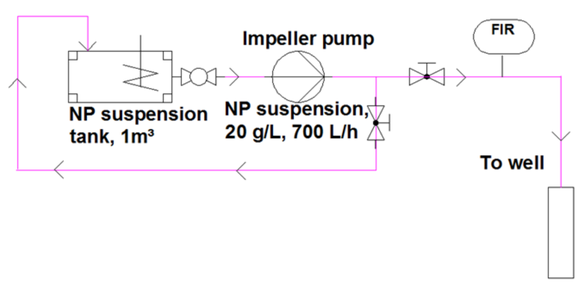
- Distance of deposition of NP: r = 1.5 m
- Mass of deposition of NP: Based on the stoichiometry 12.0 kg Goethite to treat 5.0 kg Toluene (in three months, the mass of toluene delivered by the plume to the injection zone amounts to approx. $m_{Tol} \approx 5.0$ kg (plume cross-sectional area = 4.0 m², v = 0.42 m/d, $c_{Tol} \approx 70.0$ mg/L)).
- Conditions/restraints

  Q_{max} ~ 1.0 m³/h, (unconfined aquifer)

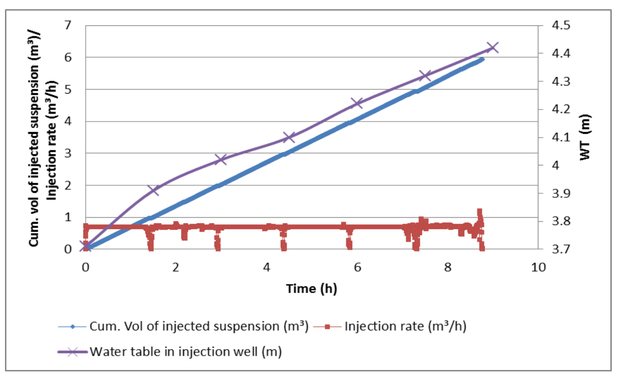
  Water table rise max ~ 0.8 m (shallow injection depth, 0.8 – 3.0 m BGL)

Injection Set-up

Boundary Condition for Goethite NP Injektion	
Injection Method	Gravity Injection
Injection Well	4” ID with 2.2 m full screen
$Q_{injektion}$	0.7 m³/h
$C_{NP(Goethite)}$	20 g/L
Volumne of Injection	6 m³
Mass of NP	120 kg
Depth of Injection	0.8 m – 3.0 m BGL

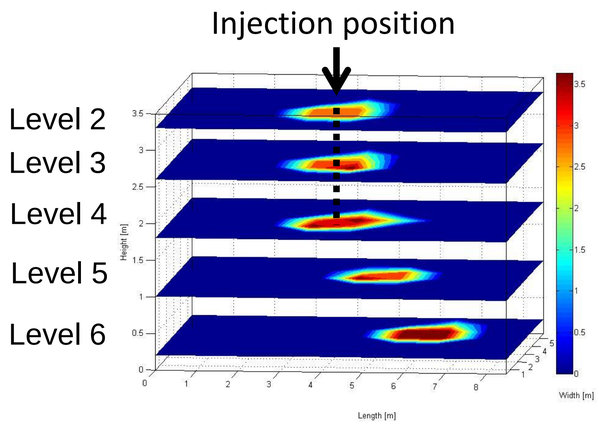


Injection Result



Injected Volume:
6 m³ (120 kg Goethite) in 8.5 h
Injektion Rate:
0.7 m³/h (Goal 0.7 m³/h)
Water Table Rise:
max. 0.72 m

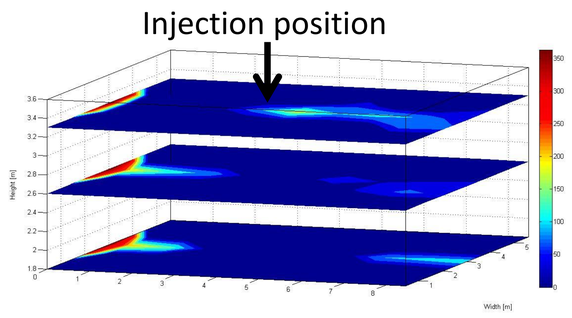
Transport of Particles



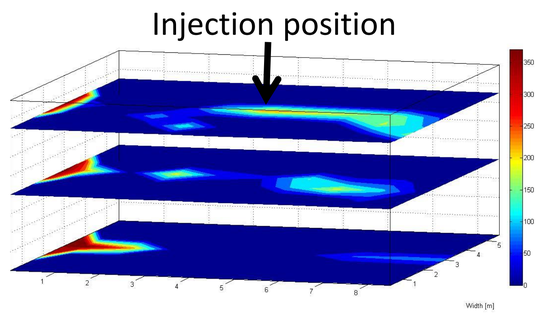
- The final distribution of the particles after injection was confirmed by optical observation of the magnitude of brownish color in the liquid samples. The range of the color was ranked from 0 to 4 (4 darkest).
- Goethite particles were transported in the target zone of ROT 1.5 m with sufficient concentration. From the distribution of the level 5 and 6, the injected particles were transported downward and downstream during and after the injection. Maximum transport distance was observed to be 4.3 m from the injection well.

Toluene Concentration Distribution in LSC

Before the NP injection, most of the toluene was transported in the upper layer; after the injection, plume pathway changed and more toluene was observed in the middle layer.



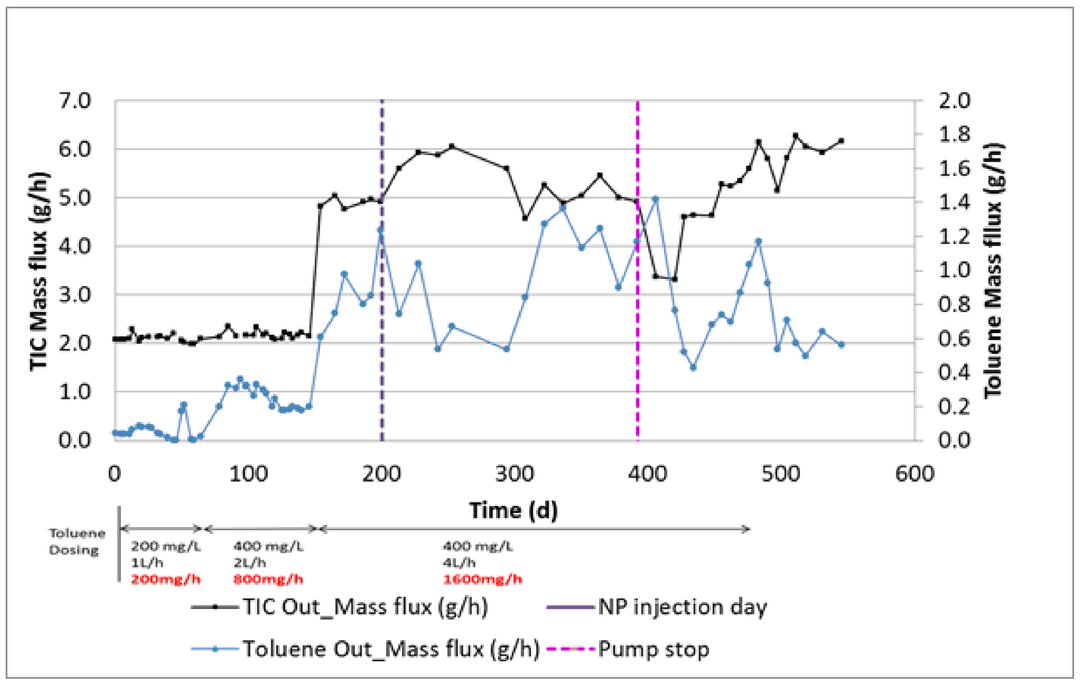
1 month before injection



1 month after injection

Remediation

- After the injection of goethite NP a distinct increase in $\dot{m}_{TIC}$ and decrease of $\dot{m}_{tolu}$, hence increase of biodegradation can be observed. However, this increase in biodegradation lasted for approx. 100 days (or less) only (red line) (between day 200 and day 300 in graph).
- During this time interval, 1394 g of TIC was produced due to toluene degradation. During the same time interval, toluene mass flux in the outflow of the container decreased from 1.2 g/h to 0.6 g/h, hence 1440 g Toluene (15.6 Mol) was degraded.
- 1 Mol Toluene (C_7H_8 = 92.14 g/Mol) needs 36 electrons to be degraded, so 36 x 1440/92.14 = 562 electrons are necessary for the remediation of 1440 g toluene. If these electrons were provided by Goethite only (FeO(OH) = 88.8 g/Mol) then 88.8 * 562 = 49,905 g ~ 50 kg of Goethite was utilized.



[1]Kumiko Miyajima, Pfaffenwaldring 61, Stuttgart, Germany, kumiko.miyajima@iws.uni-stuttgart.de
[1]Jürgen Braun, Pfaffenwaldring 61, Stuttgart, Germany, juergen.braun@iws.uni-stuttgart.de
[2] Rainer Meckenstock, Universitätsstr. 5, Essen, Germany, rainer.meckenstock@uni-due.de

VEGAS Versuchseinrichtung zur Grundwasser- und Altlastensanierung

UNIVERSITÄT DUISBURG ESSEN

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

This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 309517. This poster reflects only the author’s views. The European Union is not liable for any use that may be made of the information contained therein.

www.nanorem.eu