Cascading Column System: Improved Measurement Technology

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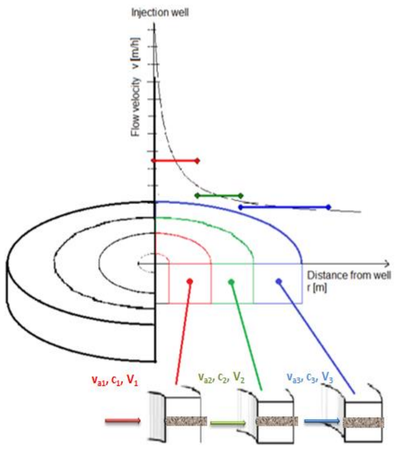
Cascading Column System

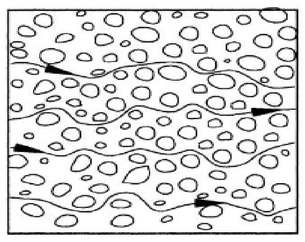


- Discretization of 3D flow domain into shells (columns represent shells)
- Each shell/column is characterized by seepage velocity, volume of slurry and concentration of slurry
- The radial flow field is represented by reinjecting the outflow of one column into the next with a decreased flow rate

Challenge of nZVI Transport

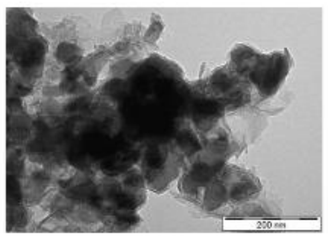
Transport distance is function of

Aquifer properties



Motion path in porous media (Rausch et.al 2002)

Particle properties



TEM images of NANOFER 25S (NANO IRON s.r.o.)

nZVI Suspension

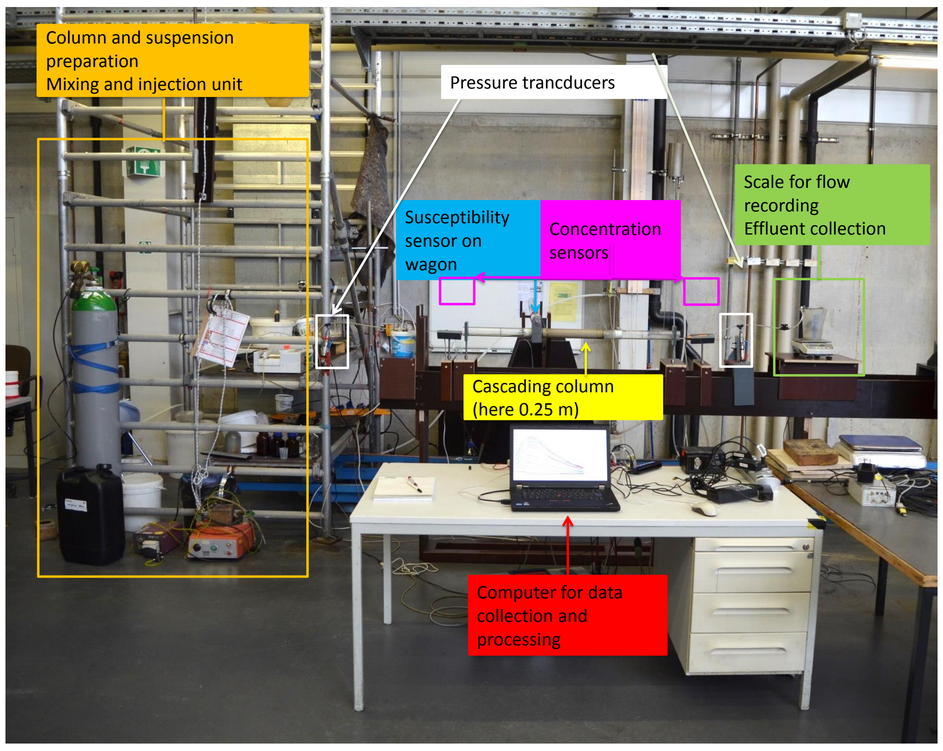
Suspension properties

Experimental Inclusion of Influencing Factors

Influencing factors	Parameter	Methods
aquifer/ porous media	Darcy flux, $q_{aquifer}$	flushing column with water $q_{aquifer}$ after NP–injection → remobilization of deposited NP?
	Porosity, n	filling columns with porous media from aquifer
	Hydraulic conductivity, K	constant and falling head permeability tests before and after each measurement
	Dispersitvity	tracer test
	number of columns, length of each column	adaption of number and length according to radius of interest and required discretization
nano particles	shape, size, density, agglomeration	manufacturer information
suspension	temperature	PT100 in injection vessel
	differential pressure	pressure transducer inflow and outflow
	viscosity	rotational viscometer
	nanoparticle concentration	stoichiometric equations empirical determination
	addition of stabilizer	empirical determination
	NP– transport and sedimentation 1.Fe^0 2. Al/Mg, Ferrate	1.) nondestructive measurement via specially developed susceptibility method: induced voltage ~ c(Fe^0) 2.) mass balances by analyzing NP-concentrations of liquid and soil samples

Set-up

- preparation of suspension: disperser to prevent agglomeration, argon to prevent oxidation
- pump to adjust inflow flux (velocity) to radial flow field, pressure, flow and temperature control
- column and susceptibility equipment to measure time and space dependent NP distribution in flow field
- inflow and outflow sample valves, additionally, soil samples may be taken after the experiments
- injection in next column with reduced concentration (outflow concentration of column i-1)



Determination of nZVI in columns using susceptibility sensor

During injection a mobile sensor moves along the column and measures the magentic susceptibility with repeated scans in high spatial and temporal resolution.

In order to get an quantitative concentration of iron inside of the porous media several steps of data processing are required.

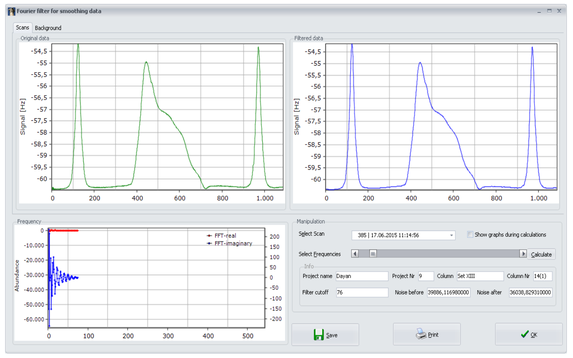
Evaluated data can be linked with iron concentration analyzed in the lab („hydrogen method“).

After calibration (Fe(0) [g] ~ Fe(0) [mm*mV]) a quantitative and qualitative determination of Fe(0) distribution in the porous media is possible.

The measurement system can also be used for reactivity columns, where the reaction kinetics is studied for several months.

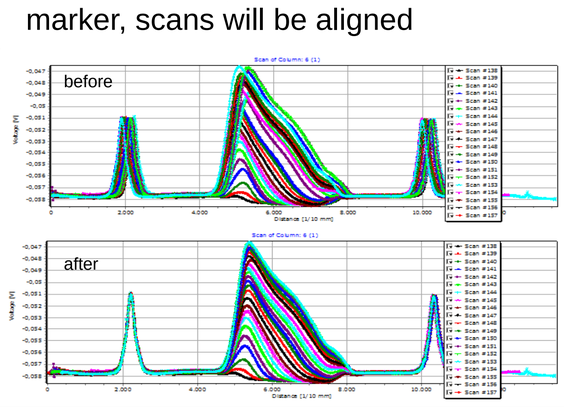
Step 1: Removing noise

- raw scan data smoothing by removing noise



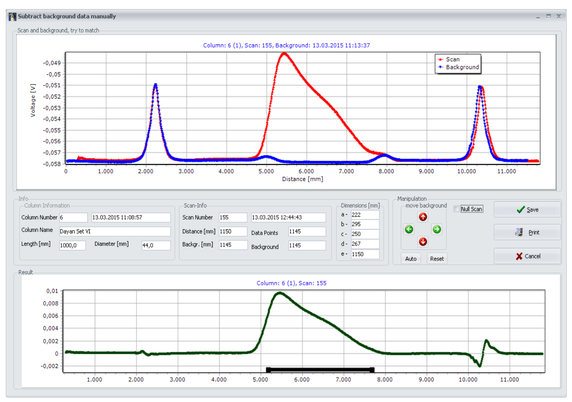
Step 2: Horizontal alignment

- based on fixed positions of iron wire marker, scans will be aligned



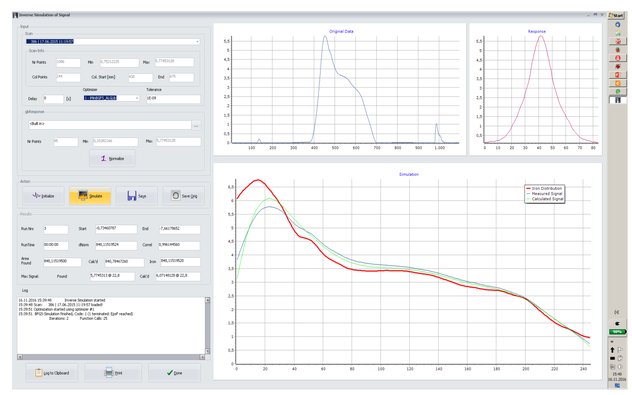
Step 3: Manual subtraction of background

- background scan from pure sand column will be substracted from all nZVI scans



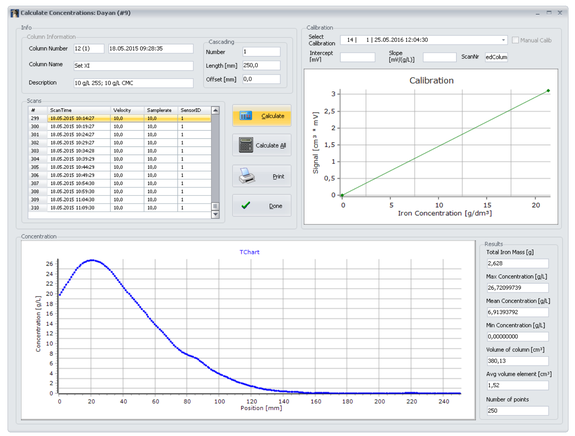
Step 4: Inverse simulation

- optimizing shape of measured scan by adjusting signal with a reference value



Step 5: Calibration

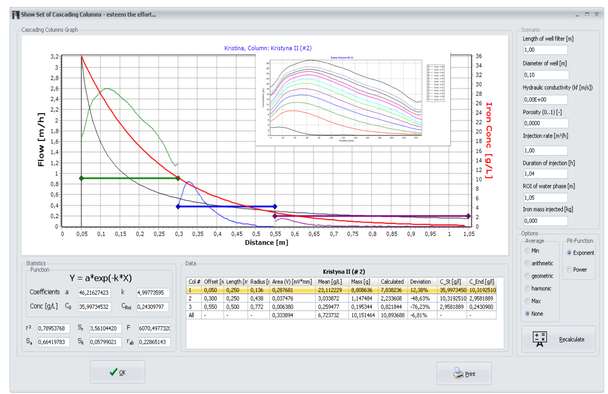
- After calibration signal [mm*mV] ~ $c_{Fe(0)}$ [g/L] iron distribution of each scan will be calculated



Step 6: Results

Transport:

Mean iron concentration profile for whole travel distance calculated from final concentration profiles of each column. Data of different columns is combined predicting the travel distance in a real situation.

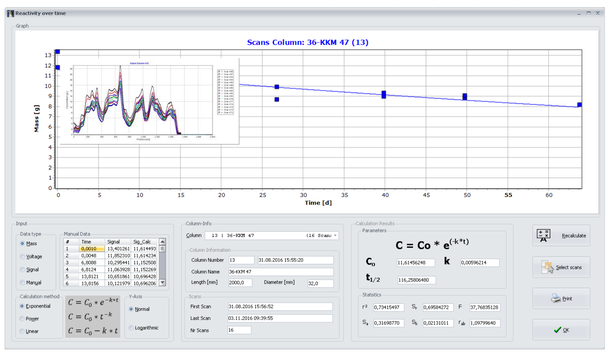


Conclusions

- The setup can be used for a detailed investigation of factors influencing transport and reactivity of nZVI.
- Different particles and conditions can be compared directly.
- Results allow for conclusions and recommendations on upscaling.

Reactivity:

Reaction kinetics calculated from scans showing decreasing iron concentration with increasing time (longevity of particles).



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VEGAS
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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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