Transport of Carbo-Iron® in porous media: Optimization based on cascading column experiments

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

Motivation

- The NanoRem research project aims at **directly injecting reactive compounds into a contamination source** for faster treatment of the pollution.
- Carbo-Iron® are particles composed of 80 wt% activated carbon and 20 wt% nZVI. Carboxymethyl cellulose (CMC) is added to the suspension to facilitate transport.
- The **stoichiometrically required mass** for remediation of 1g PCE is 1.3g nZVI. With a safety addition 5g nZVI are required.

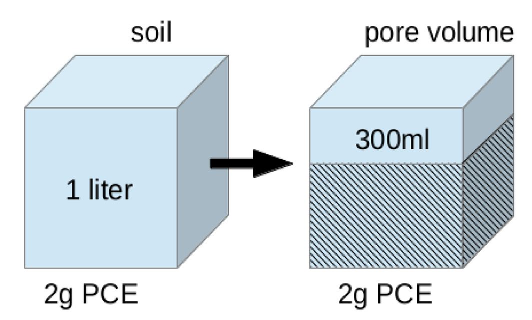


Illustration of soil and porosity n=0.3

- Assuming there is a 20kg PCE contamination in 10m³ of soil, with 2g PCE per liter of soil, or rather 2g PCE per 300ml of pore volume (PV), then 10g ZVI per 300ml PV are required for the remediation.

Goal

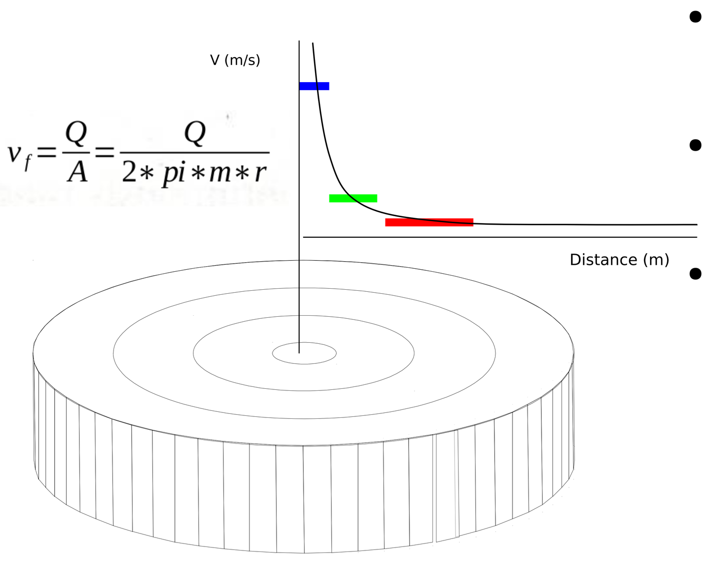
- A slurry of 20g/L Carbo-Iron® contains 4g/L ZVI (20wt%), i.e. there are 1.3g nZVI in 300ml of slurry. With regard to the assumption above, 10g nZVI are needed.
- There are two options to deposit the required mass:

a) Multiple injections, if the mass is not provided with one injection

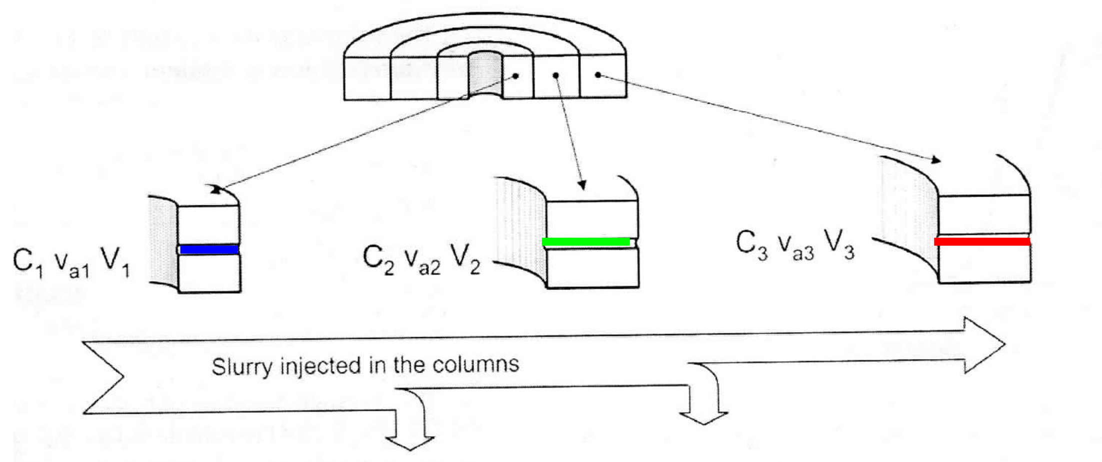
b) higher Carbo-Iron® concentrations in the slurry to achieve a better deposition with only one injection

- This study aims at **optimizing the transport behaviour** of Carbo-Iron® to achieve **maximal deposition** of the particles in the subsurface using cascading columns (CC).

Cascading Columns



- Around an injection well the **Darcy flux decreases hyperbolically** with r.
- The cascading column scheme **reduces the 3D radial flow to quasi-1D experiments**.
- Column length represents thickness of section area.



- In radial system: v decreases, A increases → Q=const.
- In column: v decreases, A=const. → Q decreases

Migration Properties

- The original Carbo-Iron® slurry was designed for ideal transport, not for controlled deposition.
- The migration properties are influenced by:

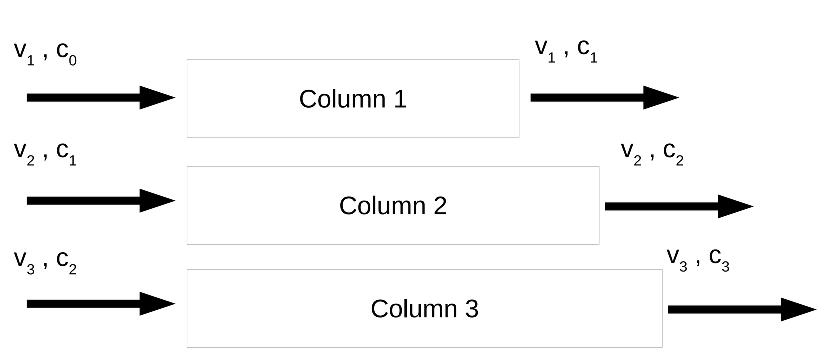
Injected flowrate Q_{inj} → defined by boundary conditions

Carbo-Iron® conc. } base case and variations

CMC concentration

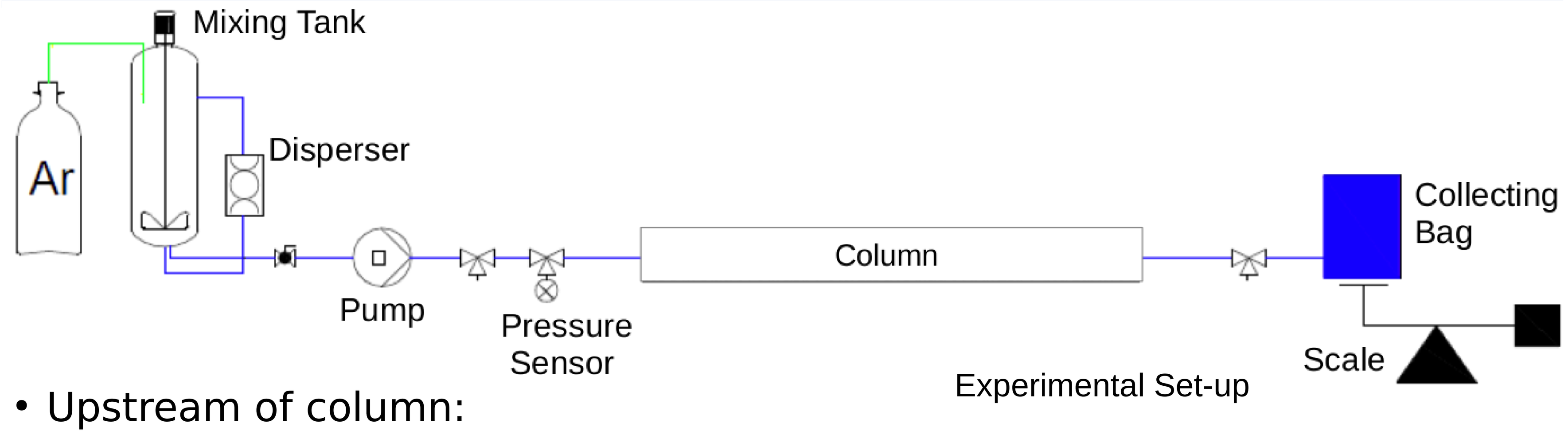
→ Define input parameters for CC: duration, injected volume..

Injection Scheme and Sampling



- The prepared slurry is injected into the first column whose outflow is injected into the subsequent column (at the appropriate velocity) etc.
- Deposition may then be **compared via mass balance.**

Experimental Procedure

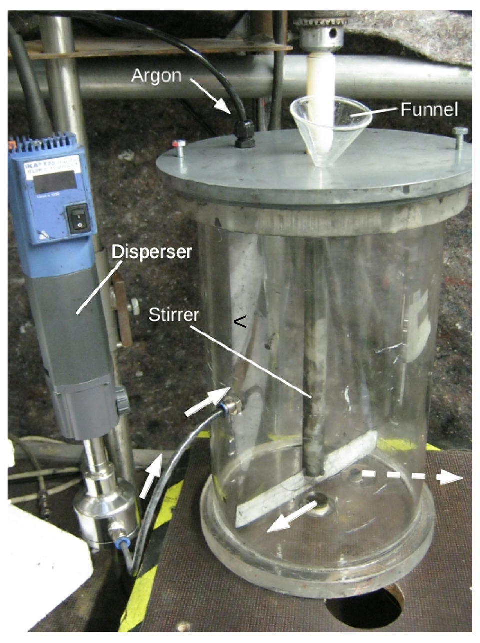


Experimental Set-up

- Upstream of column:

Argon as inert gas, disperser and stirrer to **avoid sedimentation and agglomeration**, peristaltic pumps, pressure sensor for monitoring the pressure, sampling valve for inflow sample.

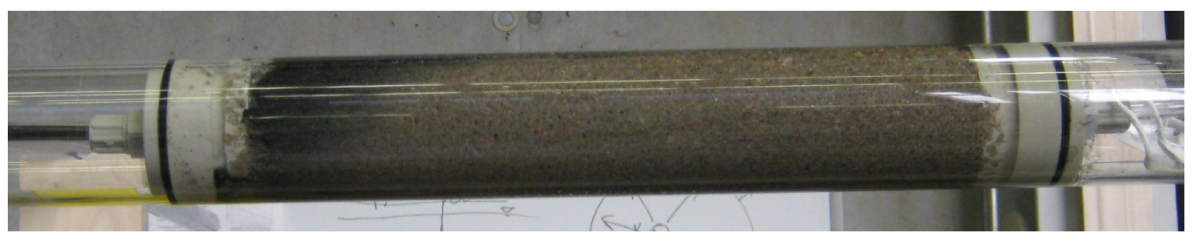
Preparation of slurry: gradually dissolving CMC, slowly mixing in Carbo-Iron®, filling suspension in mixing tank.



Mixing Tank and Disperser

- Column:

Plexiglass column, diameter 44mm, variable filter head with mesh screen to adjust length and detain sand.



Injection of CI slurry into a column

Preparation of columns: filled with sand, flushed with argon, saturated with degassed water → **bottom-up method**, check porosity and hydraulic conductivity (goal: n=0.3 and K=4*10⁻⁴m/s).

- Downstream of column:

Bag for collection of outflow, sampling valve, scale to monitor the flow.

Collection bag and scale

Results

Column	Initial slurry	Iron_in [g/L]	Iron_out [g/L]	Deposition within a radius of 1m [%]
S1.1	20g/L Carbo-Iron 2g/L CMC	2.4	0.86	> 90.8 (iron analysis)
S1.2		0.86	0.22	
S1.3		0.22	-	
S2.1	20g/L Carbo-Iron 1g/L CMC	1.29	0.47	96.9 (iron analysis)
S2.2		0.47	0.26	
S2.3		0.26	0.04	
S3.1	40g/L Carbo-Iron 2g/L CMC	4.5	4.7	88.9 (TOC analysis)
S3.2		4.6	3.5	
S3.3		2.6	0.5	
S4.1	40g/L Carbo-Iron no CMC	4.6	-	clogged at 17.5cm
S5.1	20g/L Carbo-Iron no CMC	2.3	-	clogged at 8cm
S6.1	40g/L Carbo-Iron 0.5g/L CMC	5	1.8	100 (TOC analysis)
S6.2		2.3	0.6	
S6.3		0.8	-	

- Nomenclature: Sx.y is column y of set x.

Conclusion and Outlook

- The initial composition of 20g/L Carbo-Iron® and 2g/L CMC was adjusted to 40g/L Carbo-Iron® and 0.5g/L CMC. Given this concentration, a **total deposition within 0.75m** was achieved.
- Additional experiments investigating slightly higher CMC concentrations between 0.5g/L and 1.0g/L to reach an economically more feasible radius are recommended.

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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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