In-situ Groundwater Remediation Using Carbo-Iron®: Upscaling to Large Scale Flume Experiment to Investigate Transport and Reactivity in a Source Treatment approach

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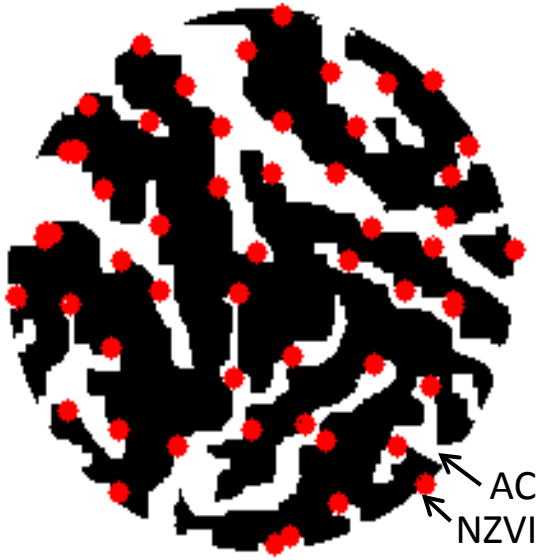
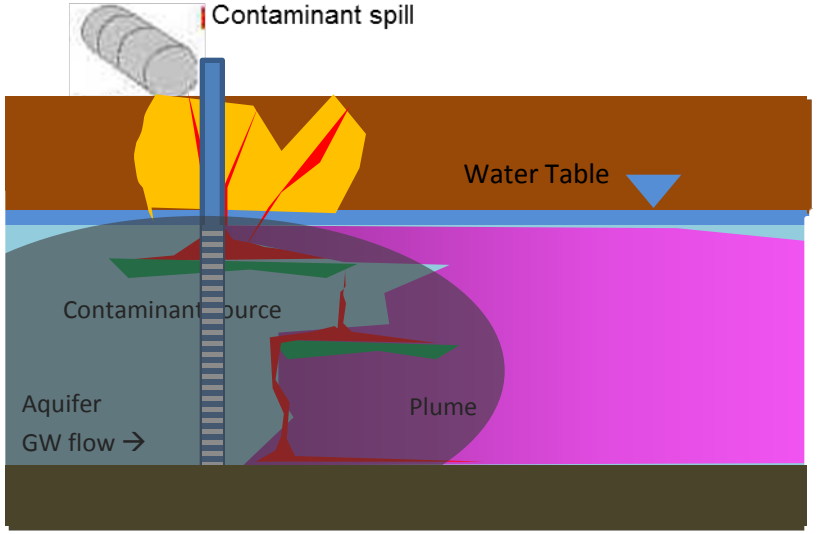
Carbo-Iron®

- New injectable **composite** material to remediate both **chlorinated solvents plumes and sources:**
  - Carbo-Iron particles **consist of clusters of nZVI embedded in colloidal activated carbon (AC) particles**
  - The AC framework functions as a spacer between the NZVI structures lowering their agglomeration tendency which leads to better transport
  - The addition of the environmentally benign stabilizer **CMC** further enhances suspension stability and mobility by electrosteric stabilization



(*Source: UFZ*)

Using Carbo-Iron® for Contaminant (PCE) Source Remediation



Concept:
Injection of Carbo-Iron into contaminant source zone to treat contaminant source directly, consequently plume will also disappear

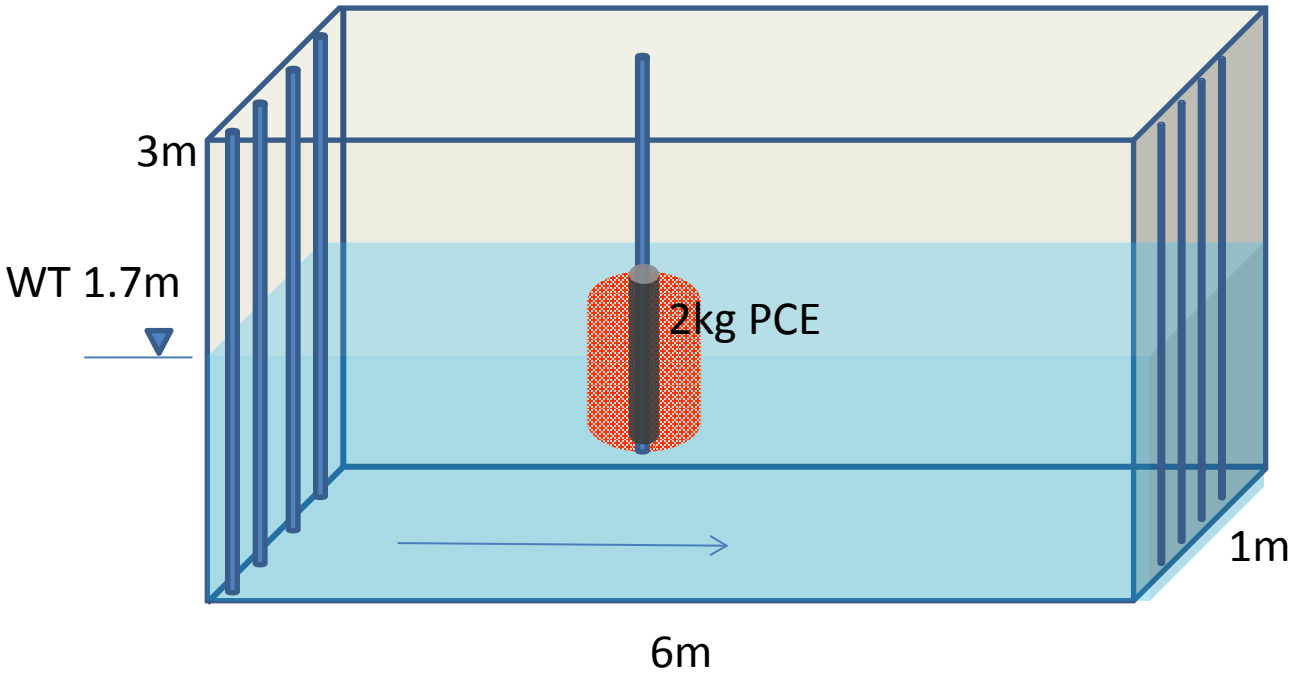
Advantage:
Low cost for installation
Source zone treatment
Possible under buildings
No limit to depth of injection (except economic)
After nZVI depletion, new injection possible

Challenges:
Reactivity
Deposition of Carbo-Iron in target zone

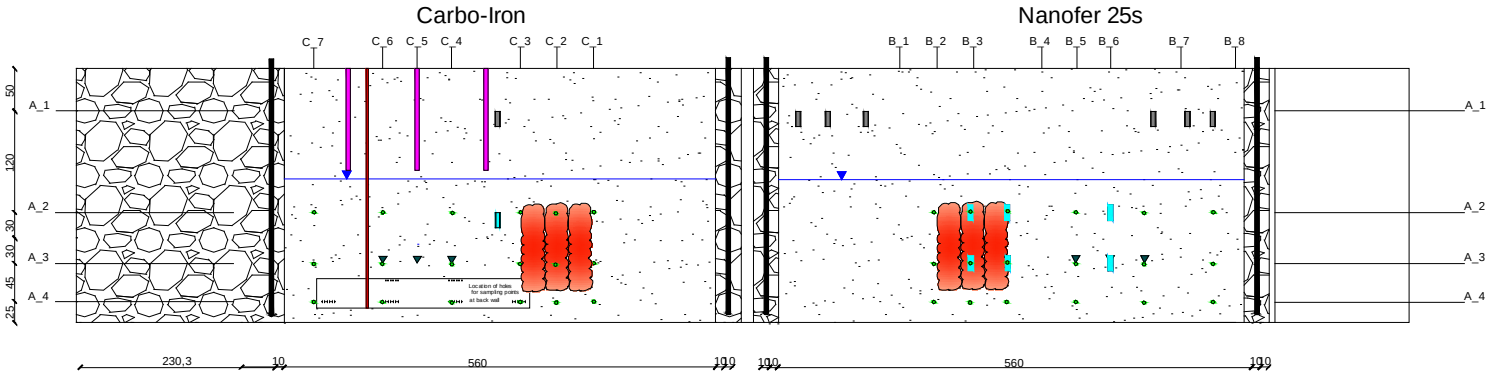
Goal of Large Scale Experiment

Contaminant Source Remediation (PCE) using Carbo-Iron®

- Emplacement of PCE source in large scale experiment
- Injection and emplacement of sufficient nZVI into PCE source zone



Set-up of Large Scale Experiment



- Stainless steel walls
- Glass front
- Size (L/W/H): 6.0/1.0/3.0m
- 32 sampling and measurement ports

Soil: Medium sand ($K = 4*10^{-4}$ m/s)

BC: Const. flux (inflow) / const. head (outflow)

Flow: controlled by pump 5.2L/h (v = 0.2 m/d)

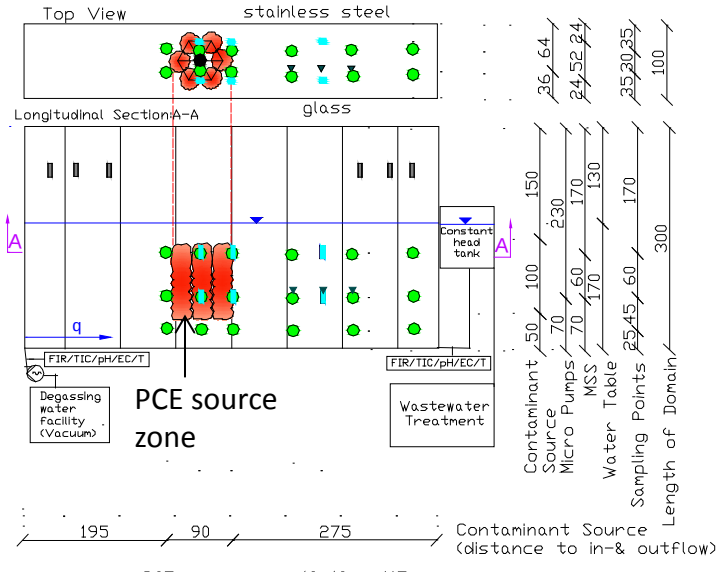
Water table: 1.7m

Emplacement PCE Source in LSE

Emplacement

- Injecting pure PCE with syringe and long rod
- At 2m from inflow BC
- 2kg PCE in 60 locations

  (6 positions x 10 depth: 33.3g each)



PCE Source Zone

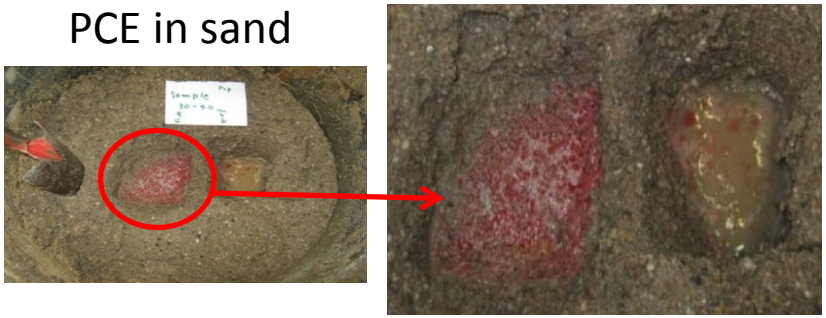
$V = 0.64\ m^3$

($PV \approx 0.2\ m^3$, r = 0.45m , h = 1m)

→ $S_{PCE} \approx 3.4\%$

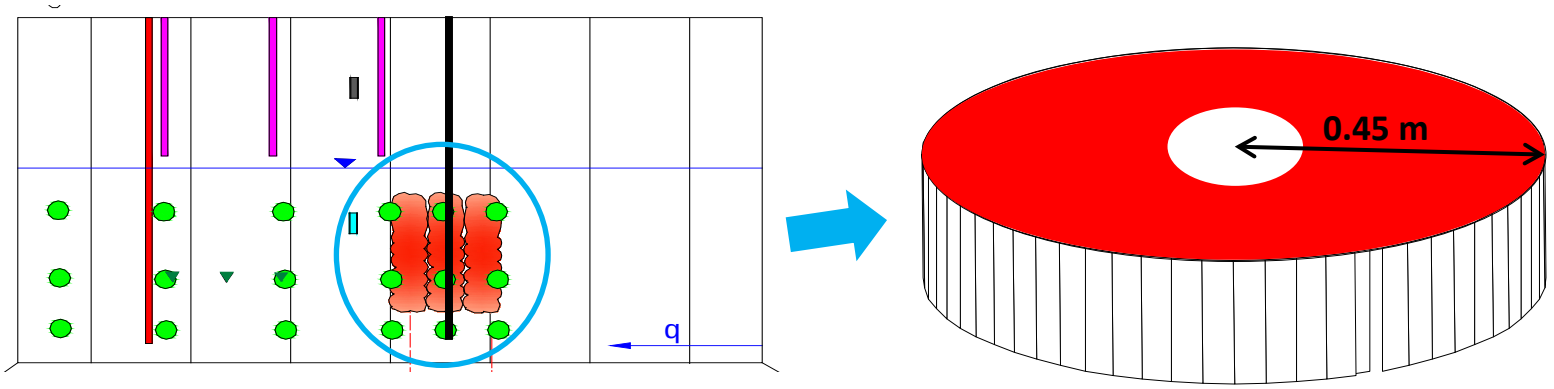
$S_{PCE} < S_{PCE,res}$ → Stable source zone

PCE in sand



Goal of Carbo-Iron®
Transport and Deposition in LSE

PCE source zone in LSE (2 kg PCE in 0.64 m³ aquifer)

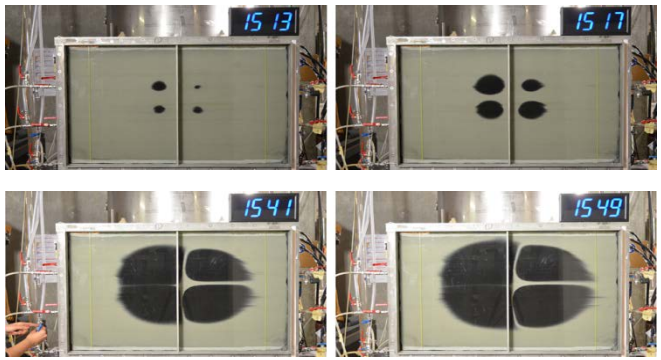


1. Distance of deposition of Carbo-Iron®
   → r = 0.5m
2. Mass of deposition of Carbo-Iron®
   → At least 13 kg Carbo-Iron® (2.6 kg nZVI) to treat 2 kg PCE
3. Max injection rate of Carbo-Iron®
   → Q_{max}: ~ 1.0 m³/h (Unconfined aquifer)

Upscaling Carbo-Iron® Transport

1D: Column experiment to optimize Carbo-Iron® suspension

2D: Small Flume to test applicability of optimized suspension for 2/3D



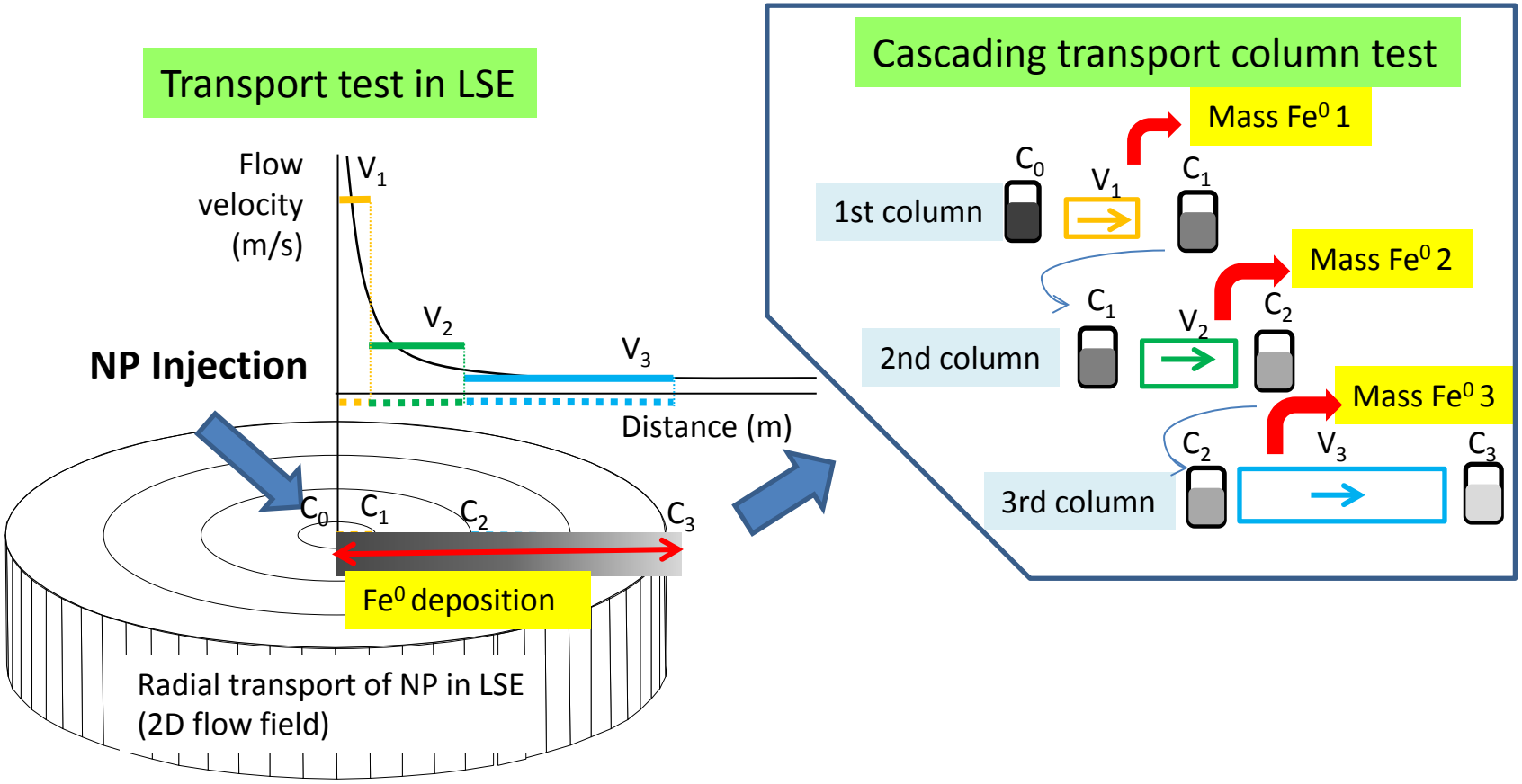
Carbo-Iron®: 20g/L
CMC: 4g/L

Suspension was optimized for transport

- no retardation
- Injected particle flushed with subsequent injection /baseflow
- Downward displacement due to gravity

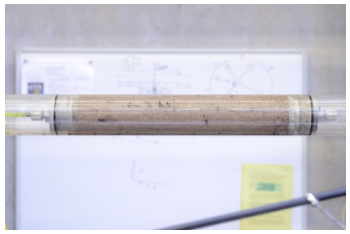
→ **Optimization for targeted Carbo-Iron® deposition necessary**

Upscaling Targeted Carbo-Iron® Deposition

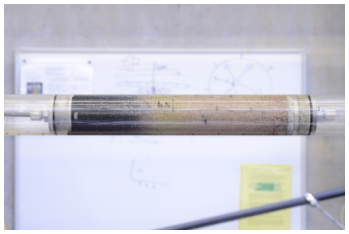


Cascading Column Tests

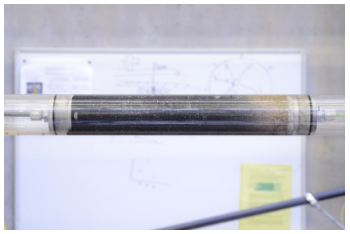
At the beginning



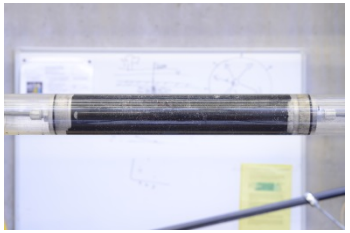
After 0.5 PV



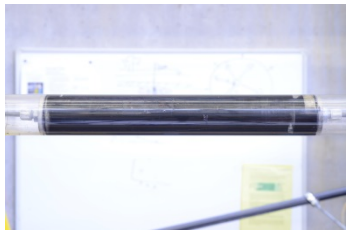
After 1.0 PV

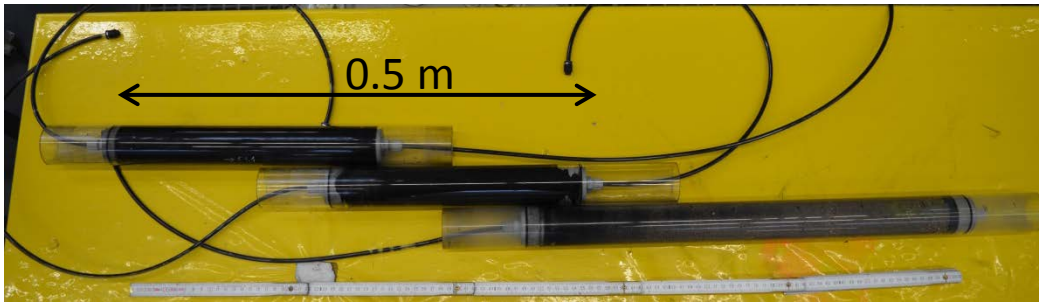


After 1.5 PV



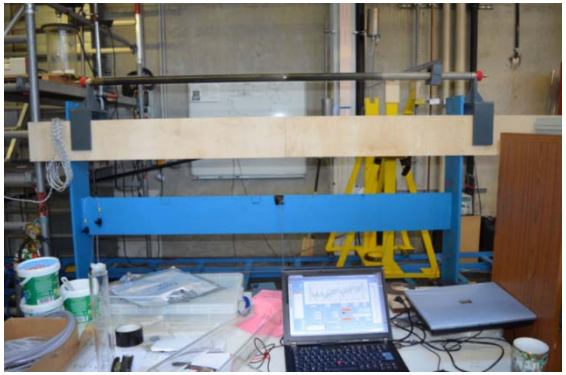
After 3.0 PV





Q_{equiv}	**0.5 m³/h**
Injection Vol	**1 – 3 PV**
$C_{carbo\text{-}Iron®}$	**20 - 40 kg/m³**
C_{CMC}	**0.1 - 2 kg/m³**

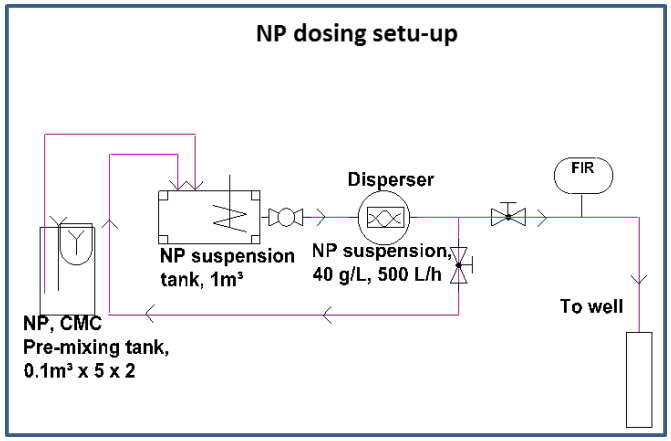
Best Condition of Targeted Carbo-Iron® Deposition for LSE



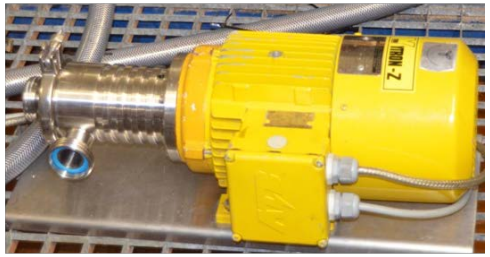
Q	**0.5 $m^3/(h*m)$**
$C_{carbo\text{-}Iron®}$	**20 kg/m^3**
C_{CMC}	**1 kg/m^3**

Carbo-Iron® Injection in Large Scale Experiment

- → Confirmation that targeted deposition of Carbo-Iron® in source zone works
- → Determination how to deposit the **required mass of iron**
  - → one injection only?
  - → Subsequent injections?
  - → Time interval between injections?



Injection will take place in July 2015



Thank you for your attention

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