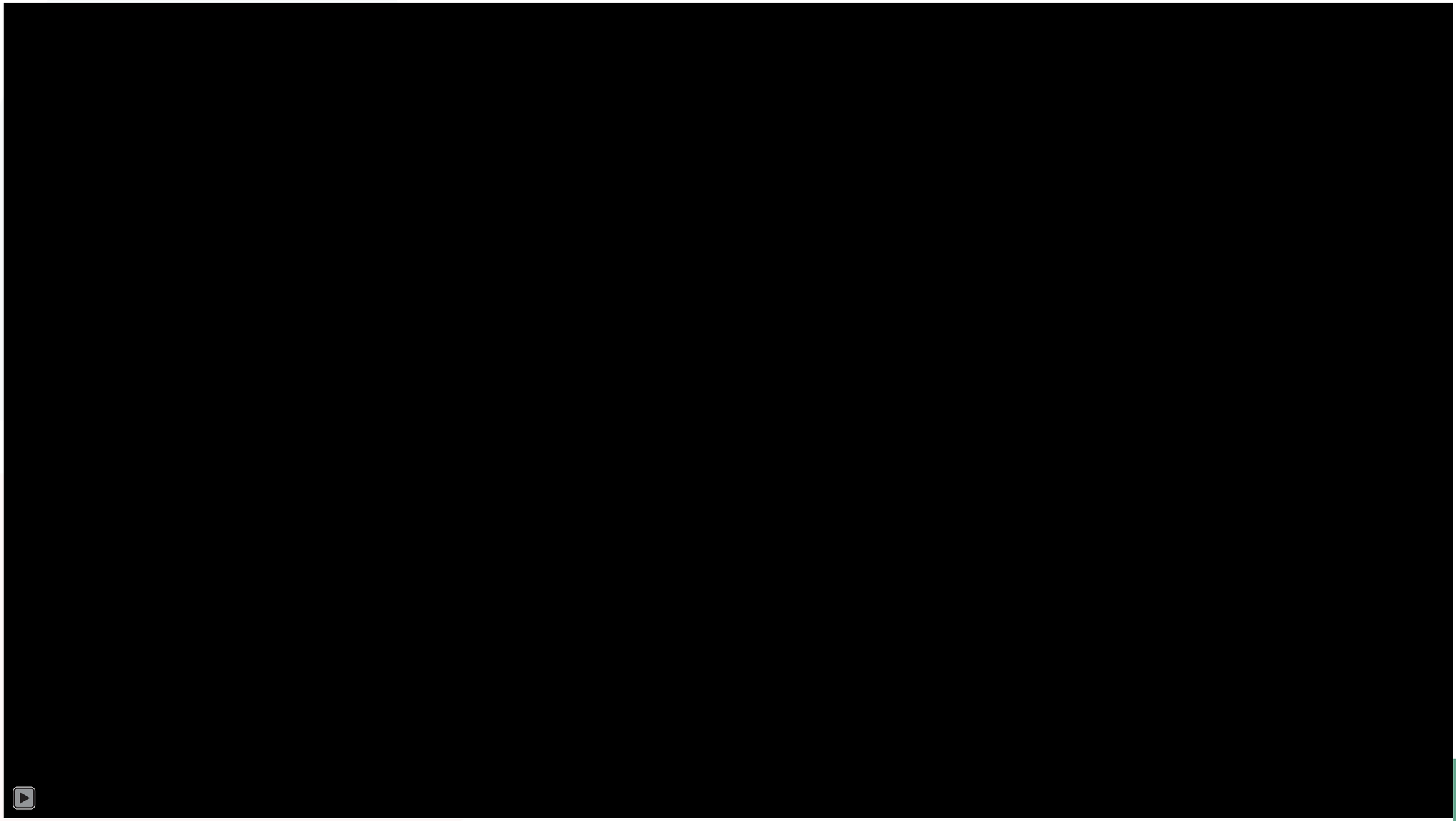
FRAC-IN

In-situ soil remediation at lowpermeability sites using the hydraulic/pneumatic fracturing (FRACIN) approach

Ondřej Lhotský

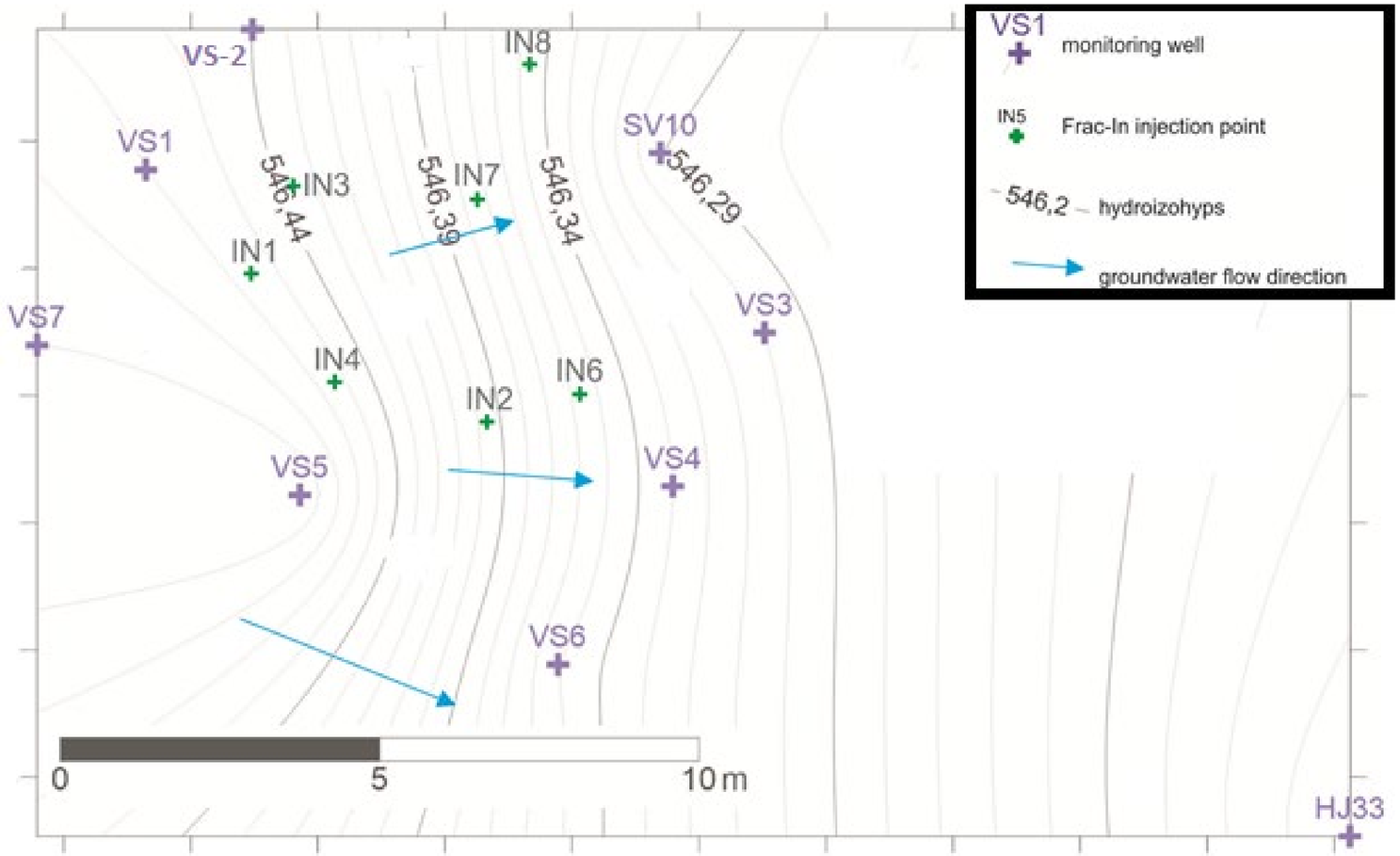
FRAC-IN Concept



FRAC IN Injections – Pilot test on the site in Western Czechia

Pilot test of the Frac -In on the site in Western Czechia - The Site

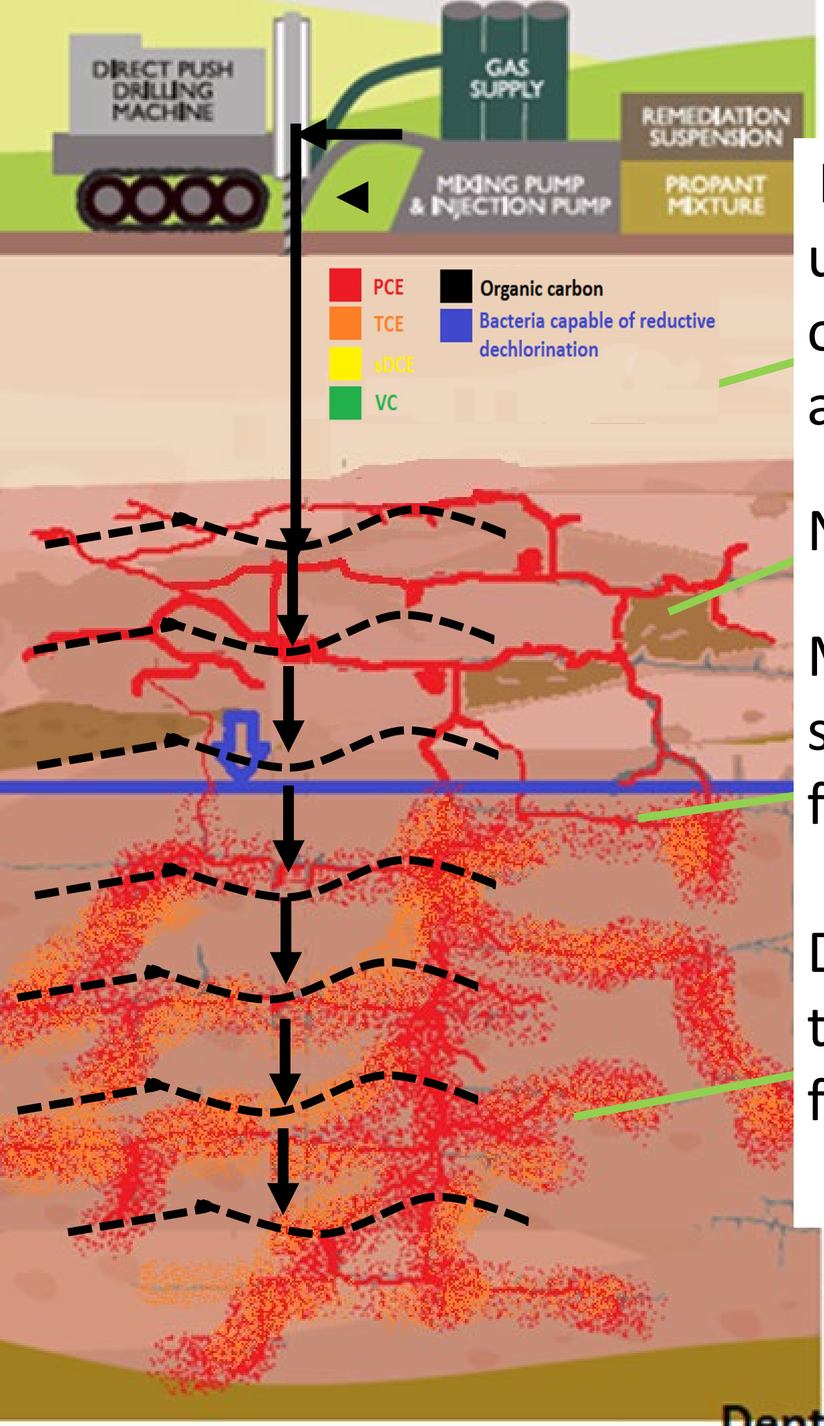
- Old metalworks with chlorinated ethenes (**PCE** is dominant) contamination in both unsaturated and saturated zone
- **Complex geology** – quaternary deposits formed by a mixture of loamy to sandy clays with a significant amount of existing preferential flow paths with the **permeability in range of 10^{-5} to 10^{-6} m/s**



- Pilot spot selected and monitoring system (consisting of 9 wells) installed based on previous MIP survey and other works

Conceptual site model

Typical MIP profile (XSD)

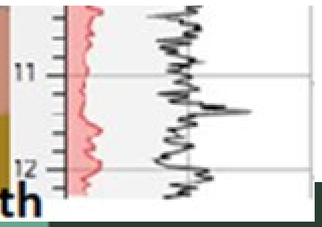


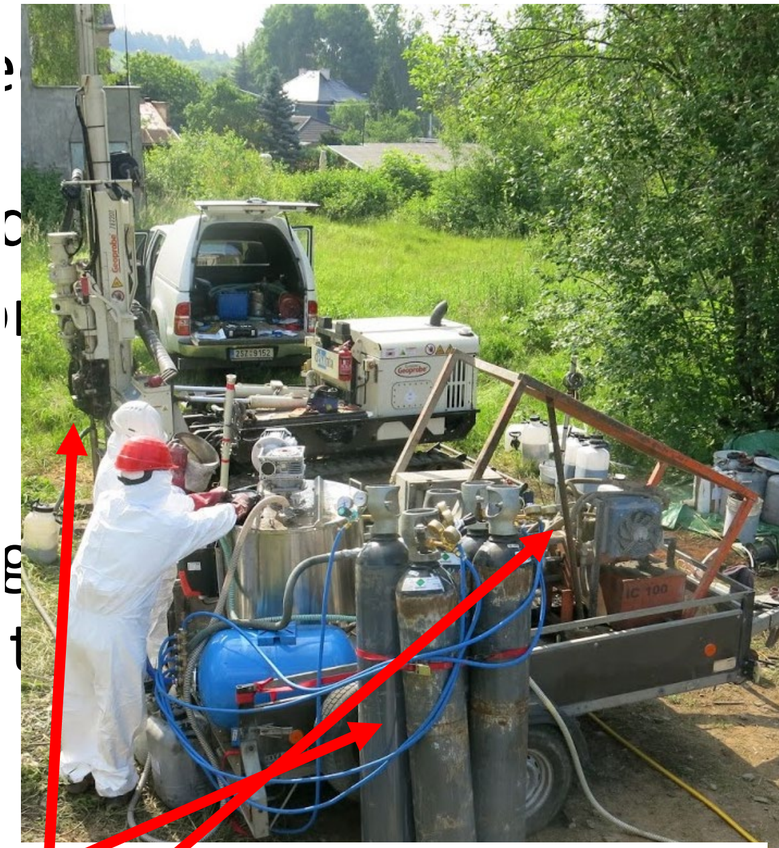
Frac In injections in to both unsaturated and saturated zone in order to widen current fracture system and fill it with reactive materials

Nitrogen used for pneumatic fracturing

Mixture of sand, milled iron and sulfidized nZVI used to fill the fractures

Dried whey injected afterwards in to the fractures to provide carbon source for bacteria





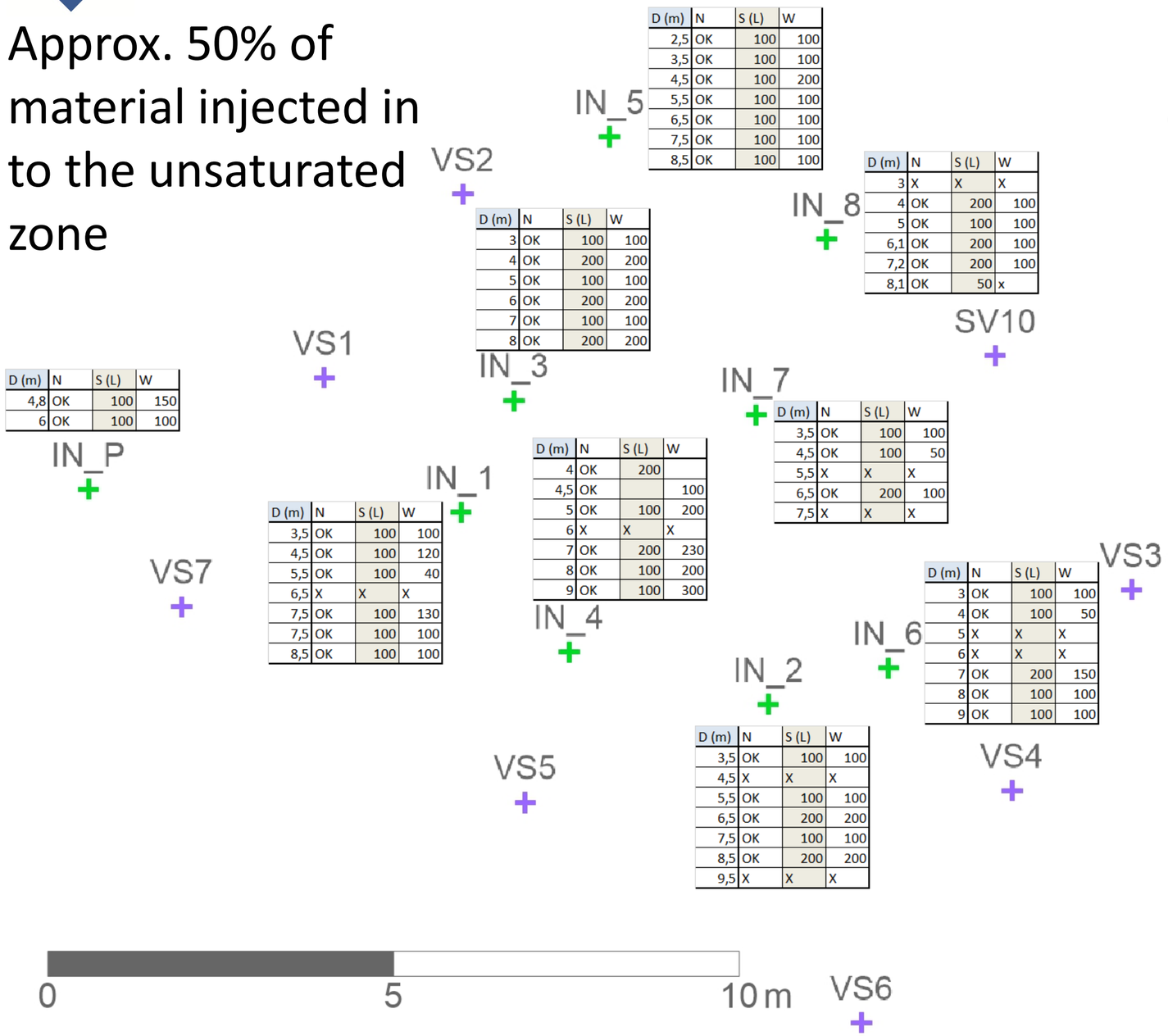
Pneumatic system with nitrogen

Injection pump

Injection hose connected to the injection rods

FRAC IN Injections

Approx. 50% of material injected in to the unsaturated zone

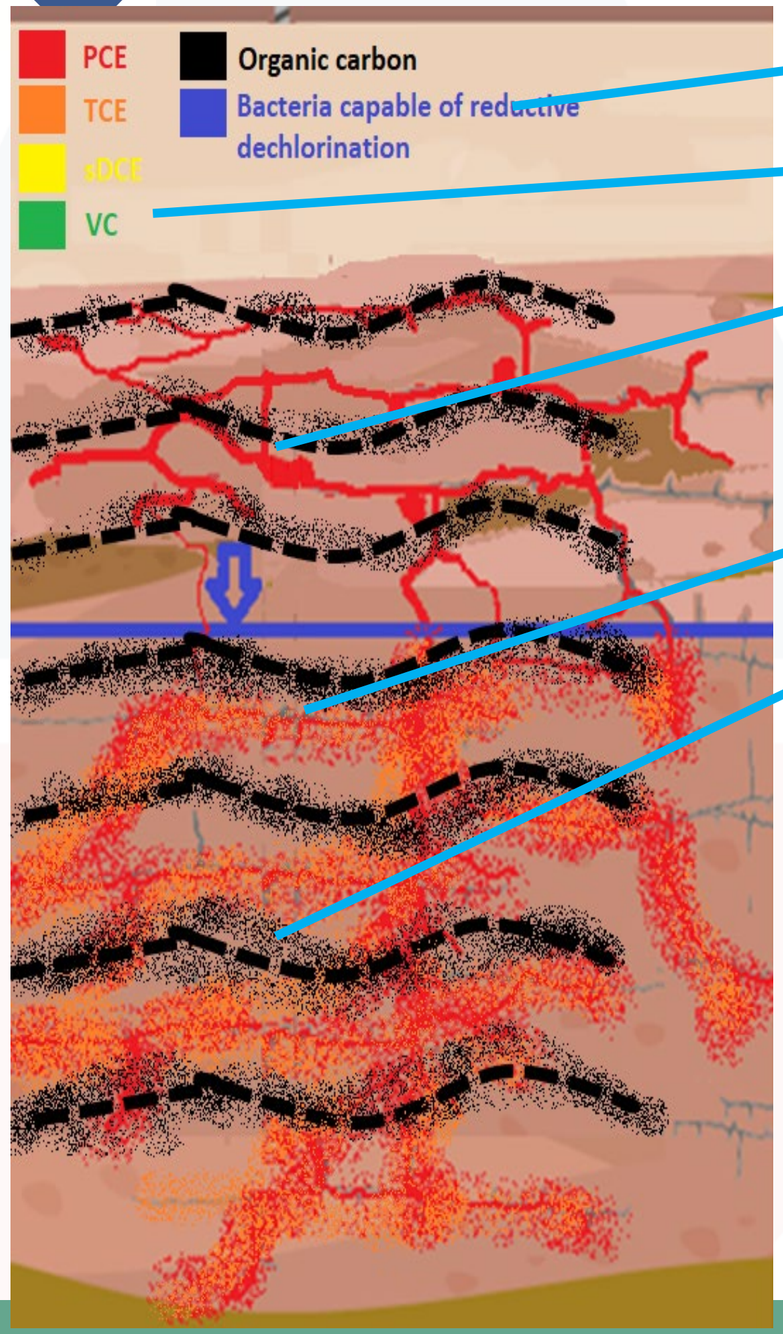


- In total:

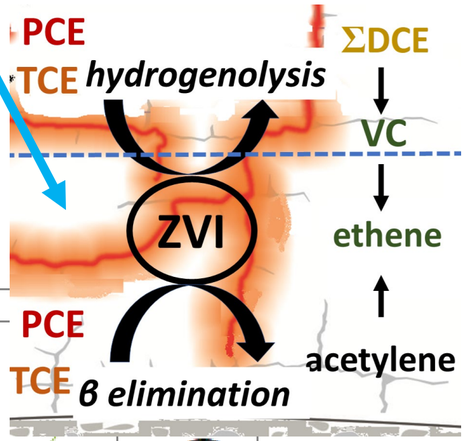
9 injection points
45 successful injection horizons
5,5 m³ of suspension
1700 Kg of milled Fe and sand
35 Kg of SnZVI
5,5 m³ of hydraulic/rinse fluid
300 kg of dried whey with pH stabiliser

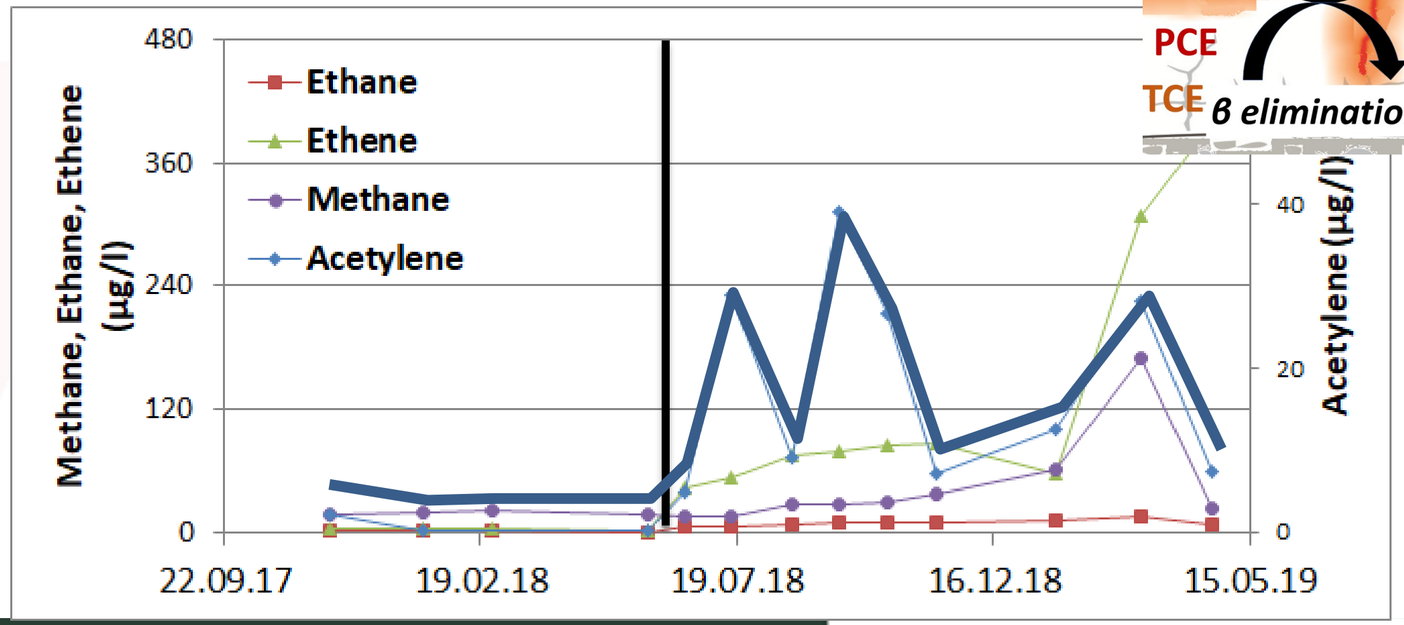
- Based on the results the radius of influence varied from 2 to 6 m, with typical **ROI around 4 m**

Results – Conceptual site model few months after the injection



- Low bacterial abundance
- DCE and VC in low concentrations
- Existing network of cracks widen and partly filled with iron which reacted with PCE to generate acetylene (abiotic processes were dominant)
- High organic carbon concentration
- PCE mobilized and partly dechlorinated





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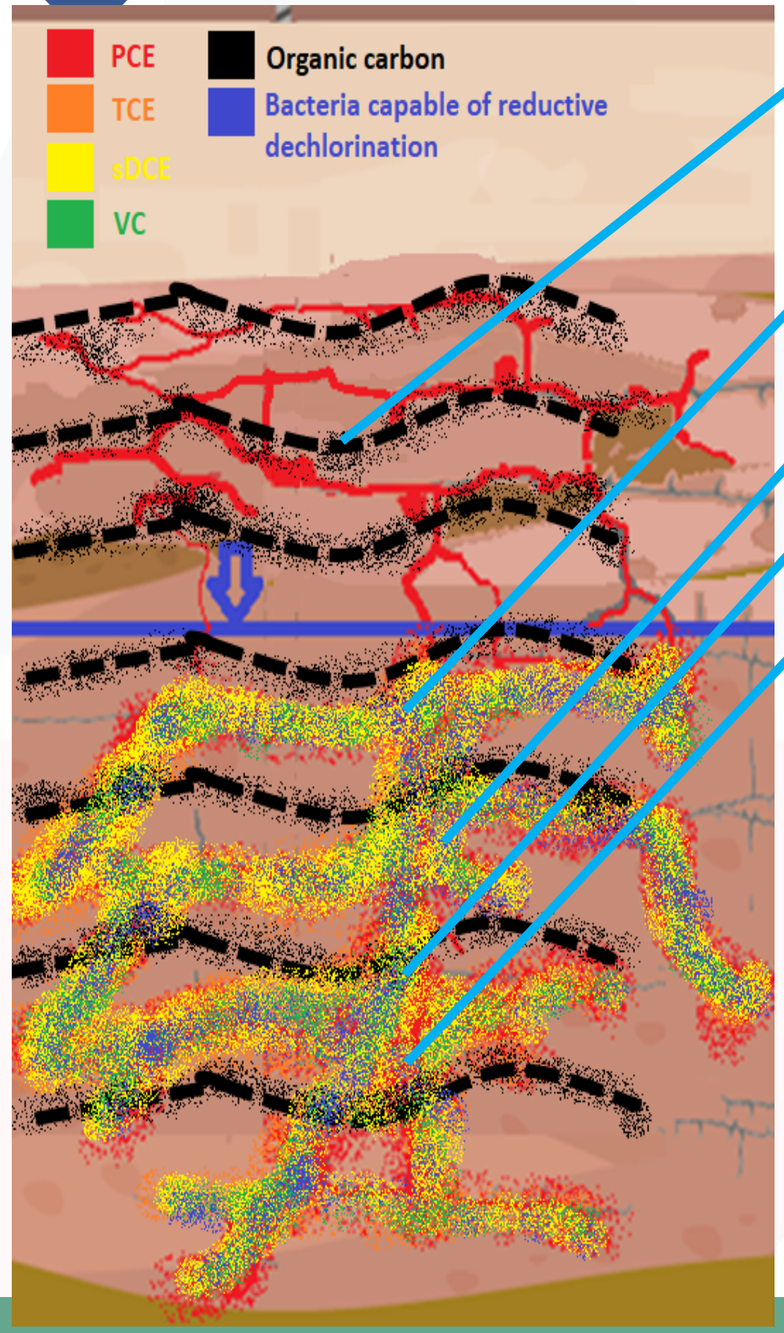
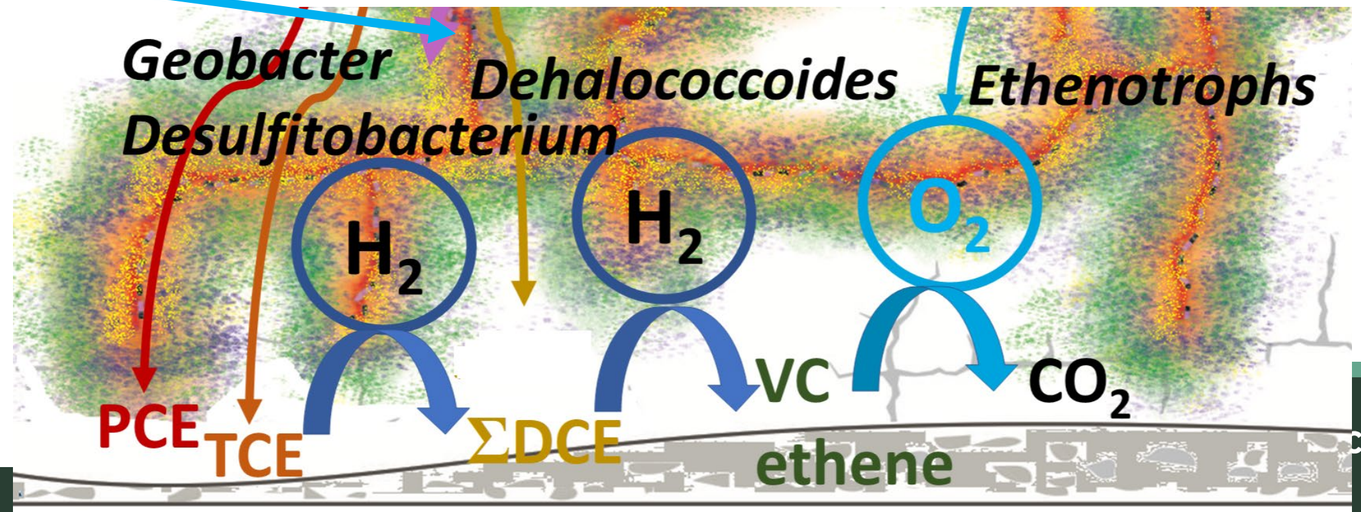
Results – Conceptual site 2.5 years after the injection



- Precipitation seeps into treated fractures→ significant decrease in unsaturated zone contamination → most of the PCE phase reduced to DCE → runoff to groundwater
- High activity of anaerobic and aerobic CVOCs degrading bacteria in groundwater
- A significant decrease in PCE and TCE conc. in groundwater
- DCE dominant CVOC→ concentrations gradually decrease
- VC is not accumulated probably due to the activity of ethenotrophic bacteria
- Biotic degradation of the CVOCs is a dominant process



FRAC IN Injections pilot – Results

- The performed injections led to an increase in the permeability of the site
- In the first phase after the injections, the abiotic reduction of ClE on the supplied iron particles dominated
- Successive increases of dechlorinating bacteria → removal of accumulated DCE
- 2.5 years after the injections, a significant decrease in the mass of ClE present and dechlorination of most of the PCE
- The triggered processes will continue → significant improvement in the condition of the site

FRAC IN Publicity

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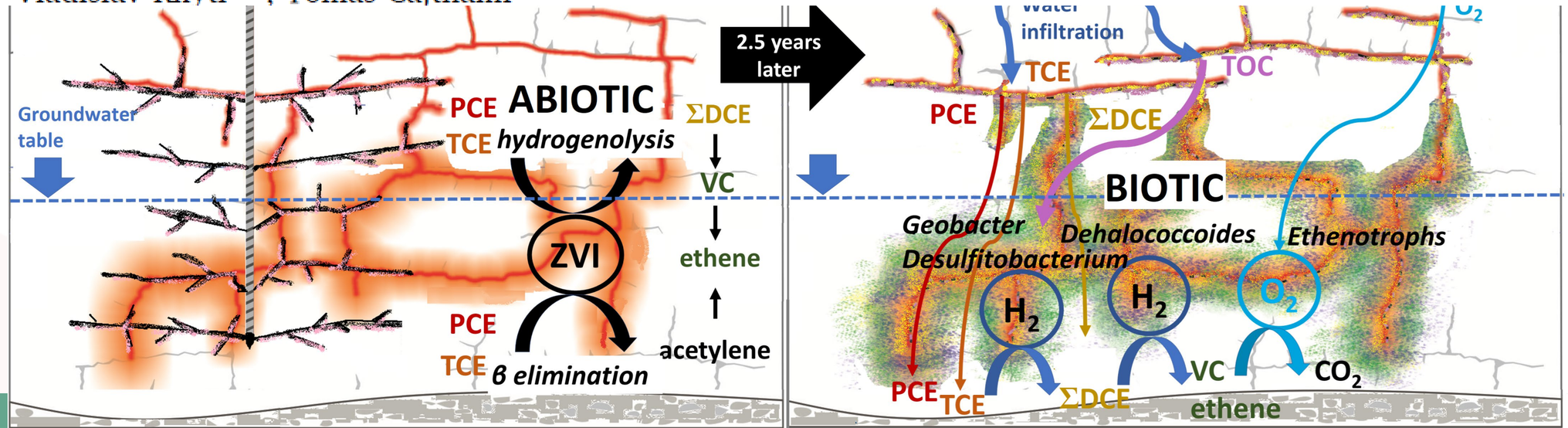
The effects of hydraulic/pneumatic fracturing-enhanced remediation (FRAC-IN) at a site contaminated by chlorinated ethenes: A case study

Ondřej Lhotský [a,b], Jan Kukačka [a], Jan Slunský [c], Kristýna Marková [d], Jan Němeček [d], Vladislav Knytl [a,b], Tomáš Cajthaml [b,e,*]



FRAC-IN

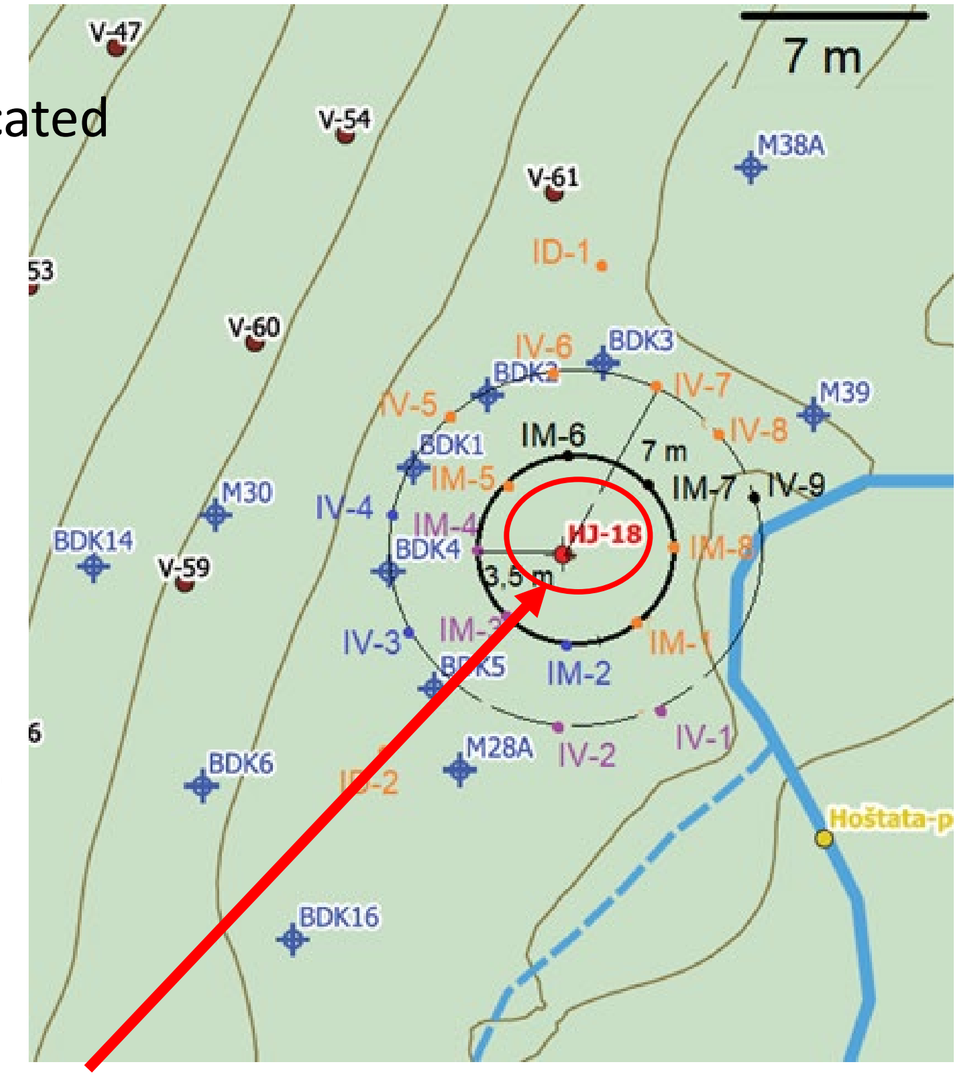
Development of FRAC-IN-OX technology and pilot test on the Březinka site in Silesia

Frac-In-Ox upgrade

- Frac-In-Ox technology combines direct-push drilling with pneumatic fracturing and the subsequent hydraulic emplacement of **strong oxidation agents**
- The technology is suitable for treating poorly permeable or heterogeneous sites contaminated with organic contaminants that are treatable **via in-situ chemical oxidation (ISCO)**
- The technology enables the injection of highly-concentrated and, thus, **highly-corrosive solutions** of strong oxidation agents
- The upgraded Frac-In-Ox set up provides allows for the remote operation of the system, thus significantly **enhancing the safety** of the procedure

Pilot test of the Frac -In-Ox on the Březinka site - The Locality

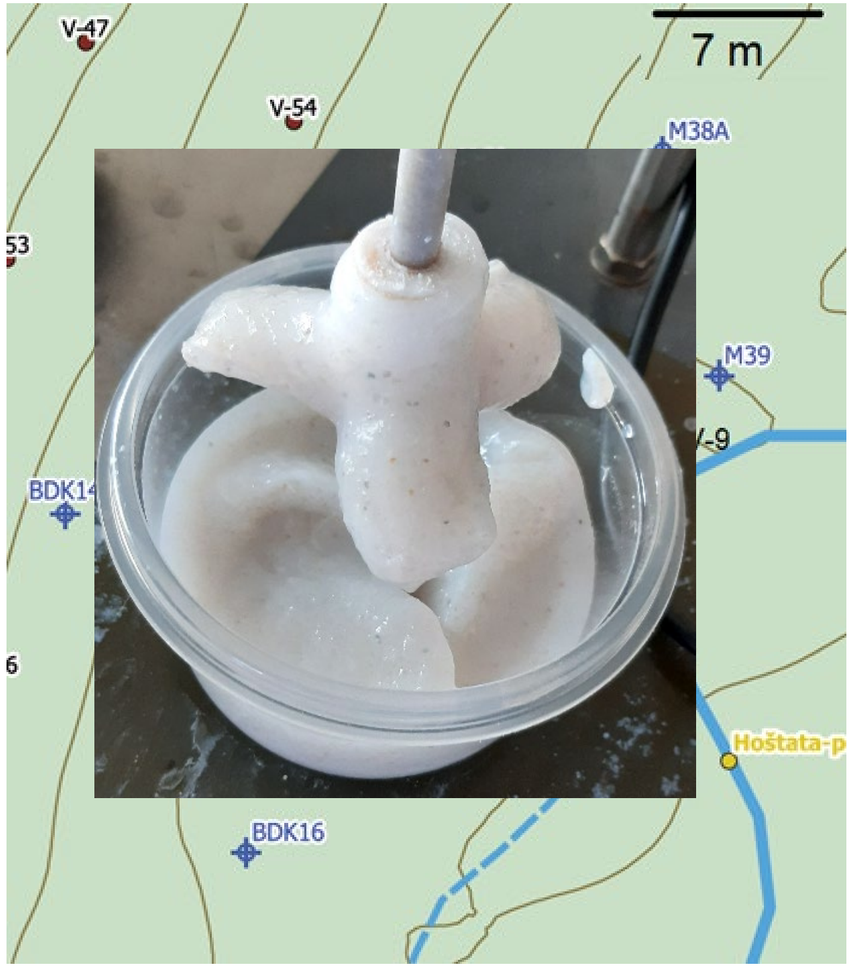
- The former landfill site used for dumping of waste paints, varnishes and solvents from the drug manufacturer located in a former sand quarry.
- Main contaminants are 1,2 dichloroethane, chloroform, dichloromethane, benzene, toluene and trichloroethene.
- The aquifer is composed of fine-grained sands with low permeability → problems injecting remediation as the injected materials tend to migrate upwards to the surface.
- The water table depth round 1 m b.g.l. Aquifer thickness round 4 m



- Main area for Frac-In-Ox injections in the close vicinity of the HJ-18 monitoring well

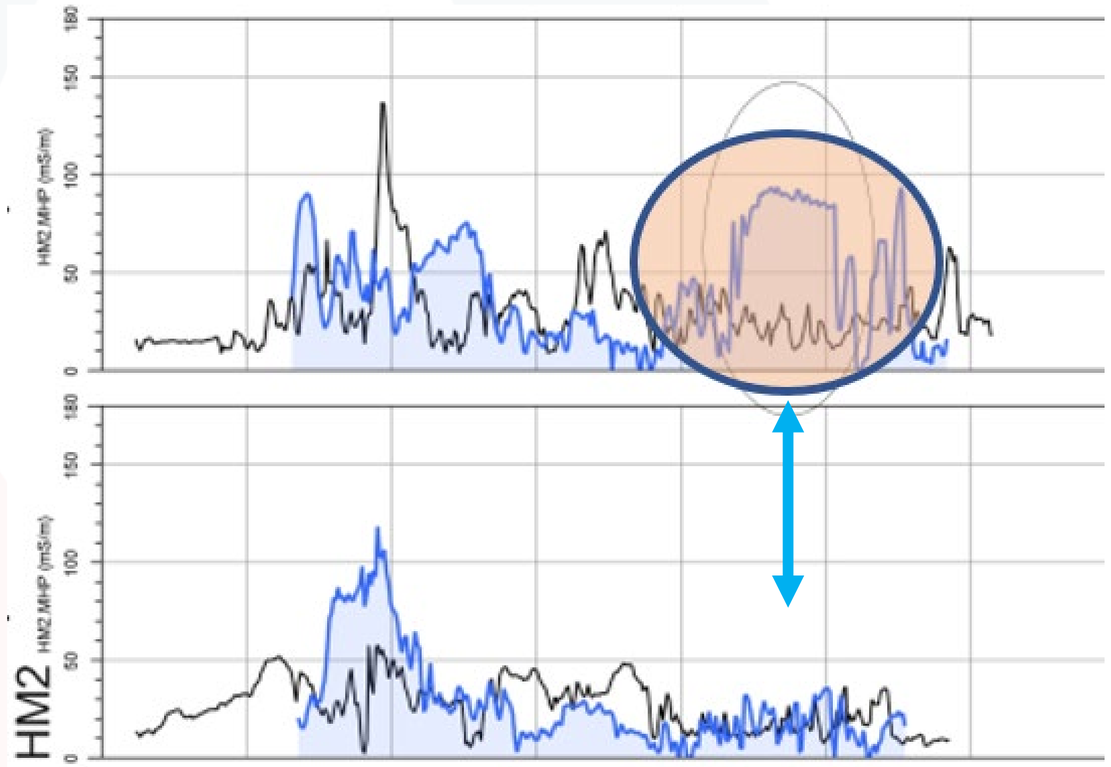
Pilot test of the Frac -In-Ox on the Březinka site – Injections

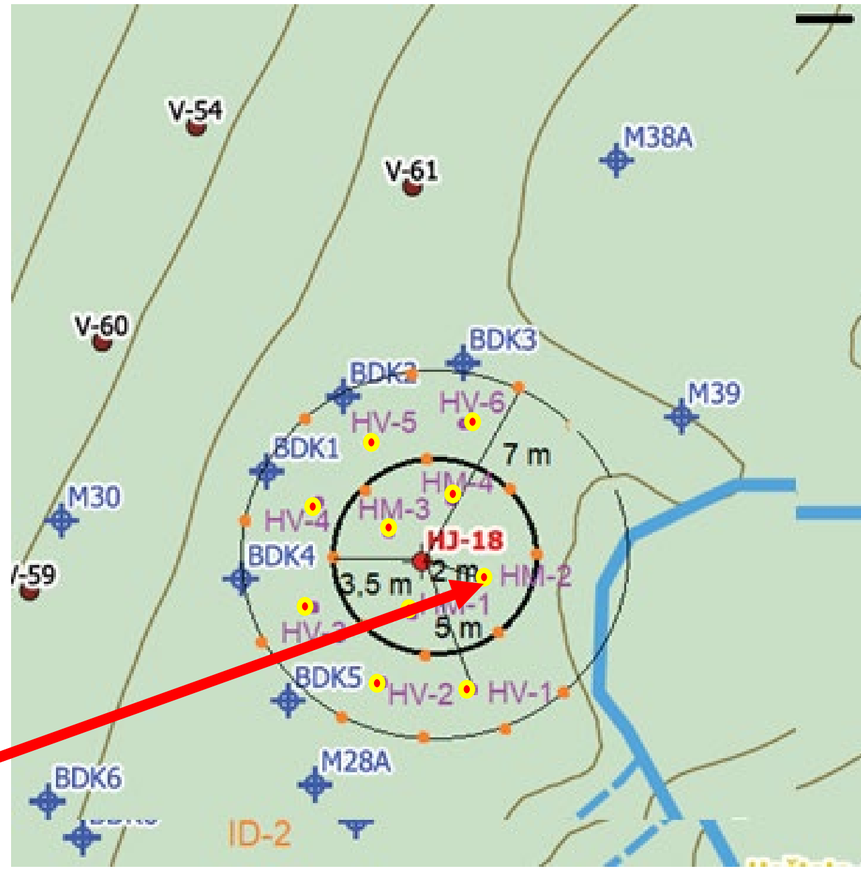
- 16 injection probes at the site were performed within the pilot test and two different remediation mixtures injected:
  a. 9 probes with mixture using guar gum as the thickening agent for transporting sand into the created fractures, with subsequent injection of strong ISCO agents
  b. 7 probes with mixture using hydrophilic fumed silica and calcium peroxide as thickening agent, with subsequent injection of strong ISCO agents
- A total of 1.4 t of sand, 1.4 t of sodium persulphate, 0.95 t of potassium persulphate and 0.56 t of calcium peroxide was injected.



Pilot test of the Frac -In-Ox on the Březinka site - Results

- Surveys of the pilot site using the so-called Hydraulic Profiling Tool (HPT) were performed at the site prior to and following the injections indicated a significant increase in the hydraulic permeability of the aquifer

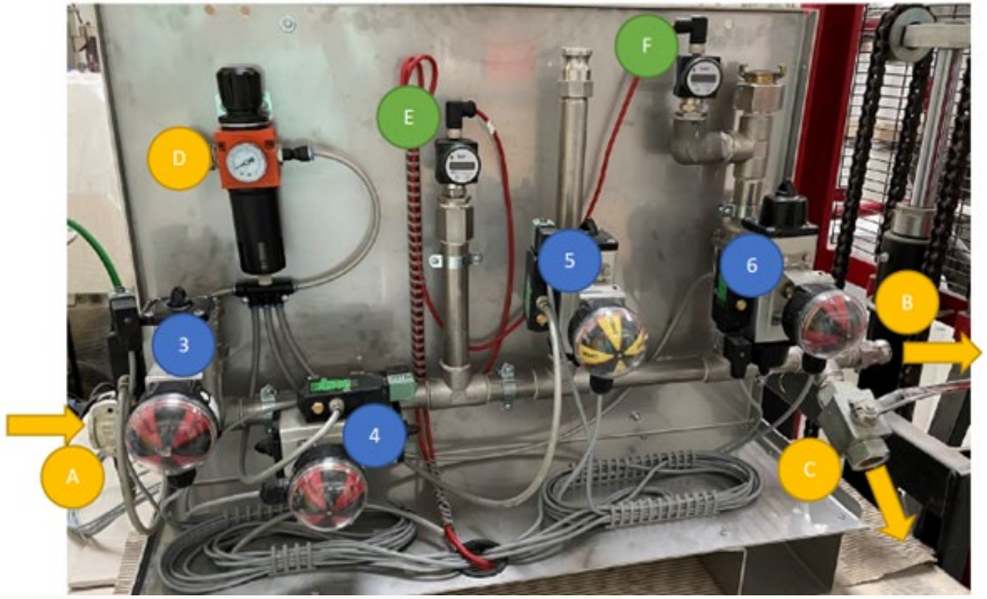


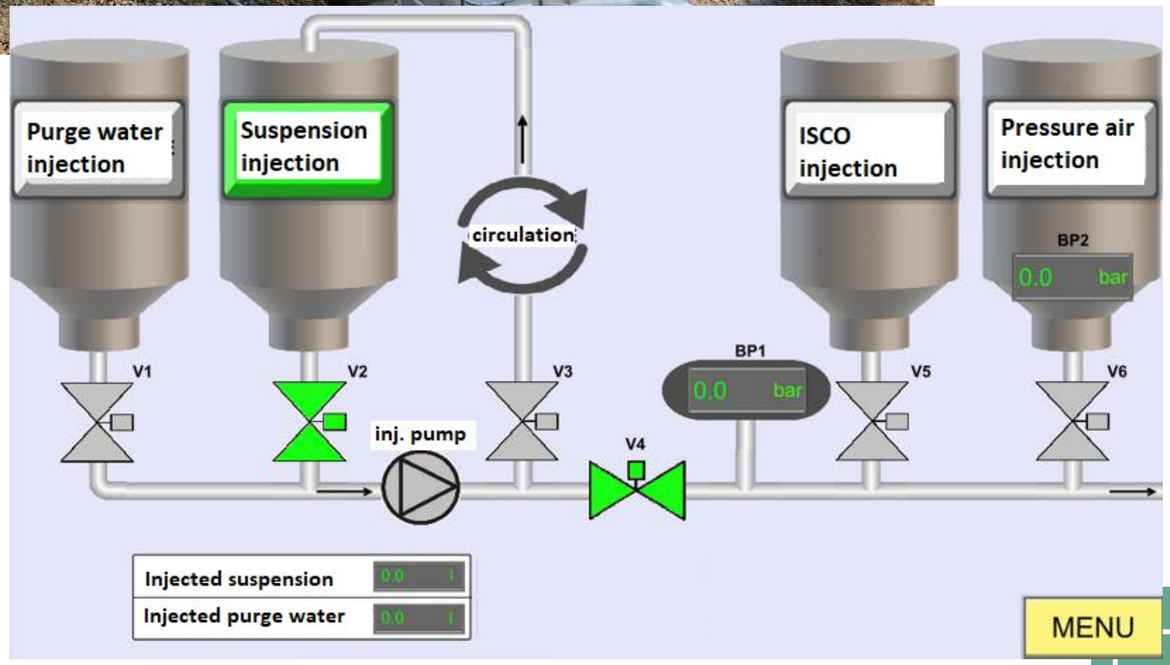


FRAC-IN-Ox Injections – Results

- It was proved it is possible to inject strong oxidizing agents via the upgraded Frac-In-Ox injection system using a remote control valve system enhancing the safety during injections
- The performed injections led to significant increase in the permeability of the site
- The monitoring of the groundwater quality both before and after the pilot testing served to prove the good distribution of the injected remediation agents and their long-lasting presence in the groundwater.
- A mean decrease of 62% in the sum of the volatile organic compound concentration was observed via the monitoring of boreholes 4 months following the injection campaign.

FRAC-IN -Ox Injections – Foto





FRAC-IN

Session 3c6 / Abstract title: The Utilisation of Innovative Site Survey and Remediation Methods at the Duchcov Site with Complex Conditions and Geology

Thursday 14:00-15:30 Room Z-I / 111

Thank you for your attention

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