# Sophisticated In-situ-technologies to address contaminants in complex geological structures – Remediation in clay structures, layered aquifers, and fractured bedrock


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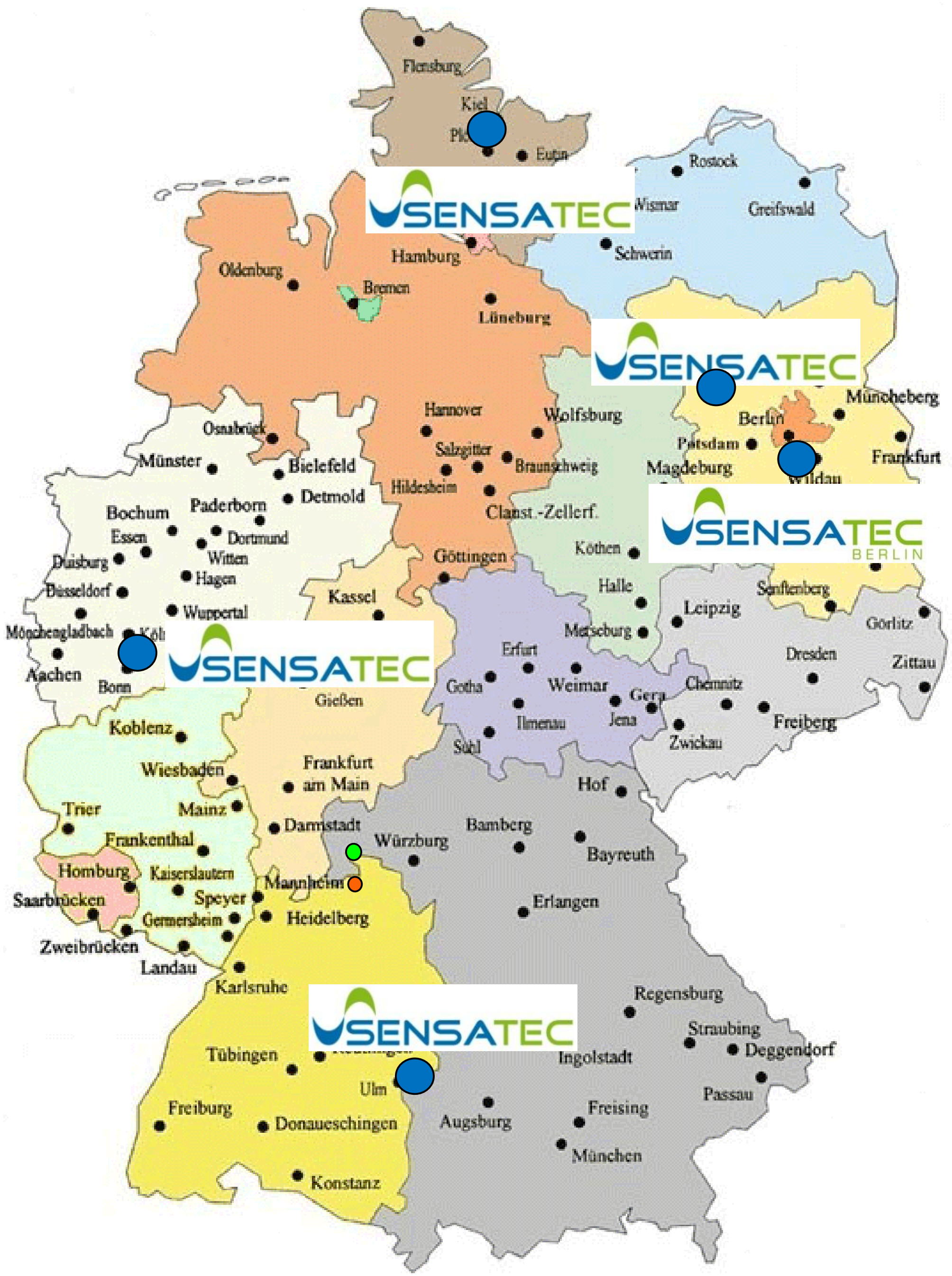
Remtech, Ferrara, 2019

1. Targeted Solids Emplacement in Clay Structures
2. Hydraulic Cycles in Fractured Bedrock

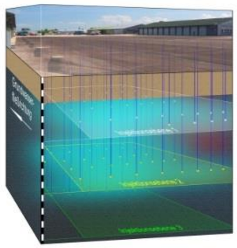
# Sensatec GmbH




| | |
|---|---|
| Headquarter: | Kiel, Germany |
| Founding: | 1.05.2005 |
| Offices: | Berlin<br>Brandenburg<br>Cologne<br>Ulm |
| International Partners/ Representations: | Shenfu, Shanghai/ Beijing<br>BAW, Saluzzo, Italy<br>Remea, Paris, France<br>Aquamatters, South Africa/Namibia |
| Remediation projects completed: | Approx. 500 |
| Ongoing projects: | Approx. 150 |
| Active in countries | Central Europe<br>Scandinavia<br>UK, Italy<br>Northern Africa<br>Asia (China, Kazakh.) |

# Sensatec - Range of Services

## Innovative Technologies for Soil and Water Decontamination



## Process Laboratory for Feasibility Studies and Molecular Biology

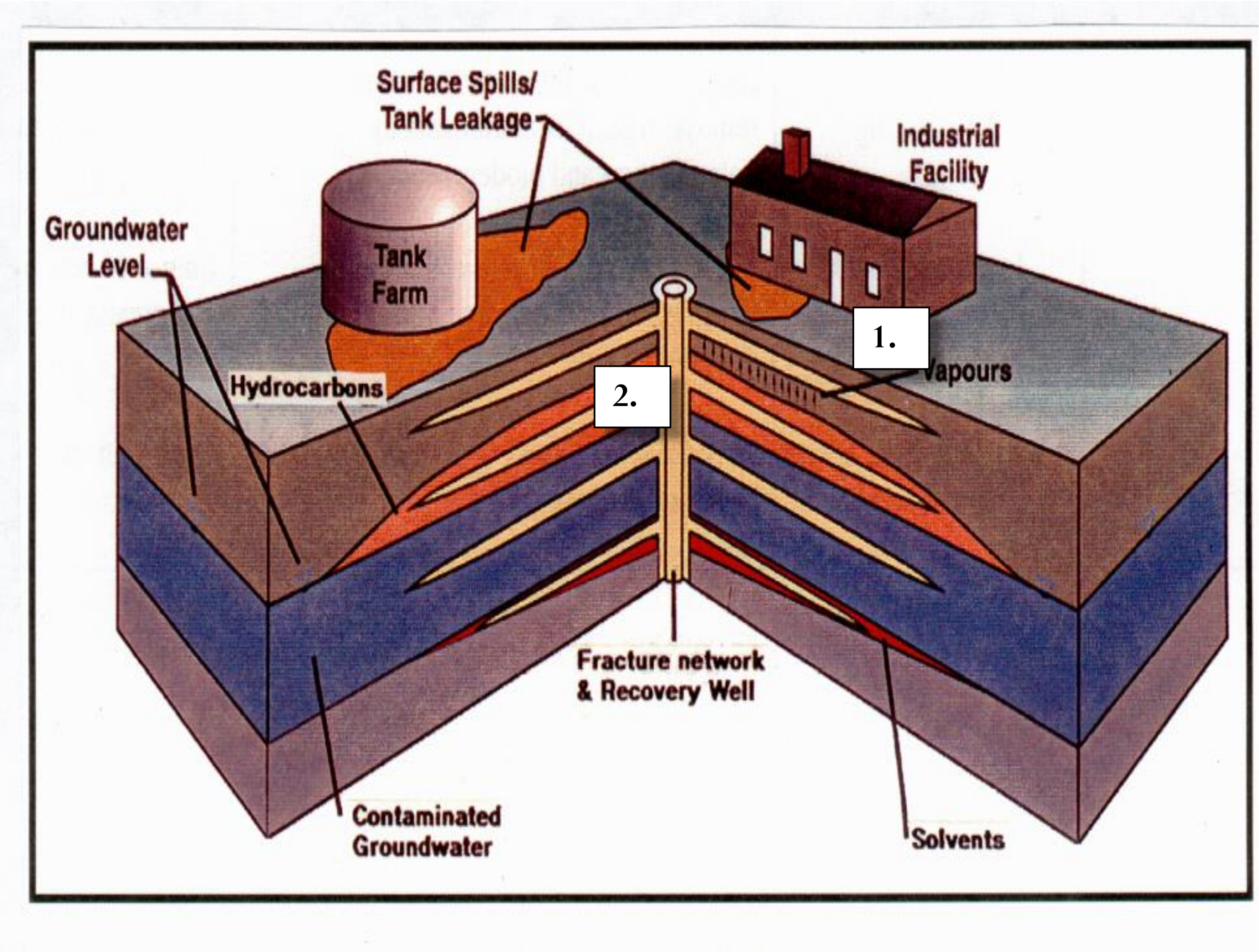
## Environmental Sensors and Remotely Operated Systems

## Environmental Biotechnology and Production of Microbial Cultures

## Innovative drilling technologies

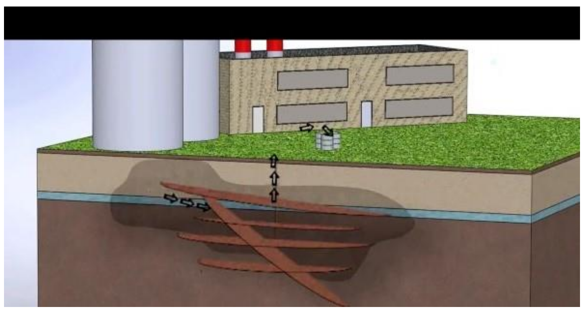
# Technical solution:
# TSE – Targeted Solids Emplacement

TSE is a process where a suspension or highly viscous fluid is injected into geological structures under high pressure which leads to a controlled creation of a network of passageways through an impermeable geological structure for reagent distribution purposes.



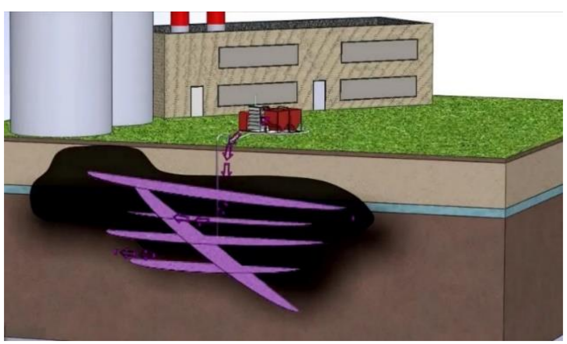
# Different strategic options for TSE applications

The TSE©-technology enables intensified contact and significantly better distribution of injected reagents, especially in soils with low hydraulic permeability (e.g.  Kf < 1 x $10^{-6}$ m/s)



1. Formation of a network of permeable layers (using sand as supporting element) for the supplemented extraction or in-situ-degradation of pollutants

**Option 1**: Increased extraction rates (for pump and treat or soil vapor extraction) due to placement of sandy structures for improved conductivtiy



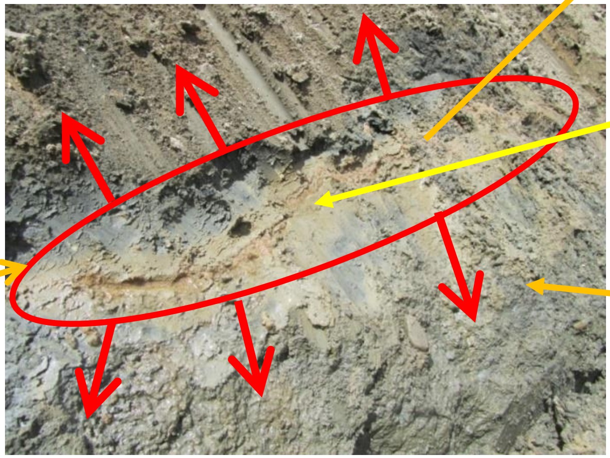
2. Highly concentrated micro-iron distributed as solid substrate in layers in clayey core drilling

**Option 2**: Controlled distribution of solid reagents in suspension, e.g. micro iron, Permanganate, Chitin for the formation of a reagent depot for long lasting remediation effect

# Option 1: Increase of soil permeability by TSE

Fracture filled with sand for remediation in clay structures

Horizontally oriented drainage channels for the distribution of reagents



Spreading of reagents due to accelerated diffusion, approx. ± 15 cm in 2 months

**kf-value in sand:**
**1 x $10^{-4}$ m/s**

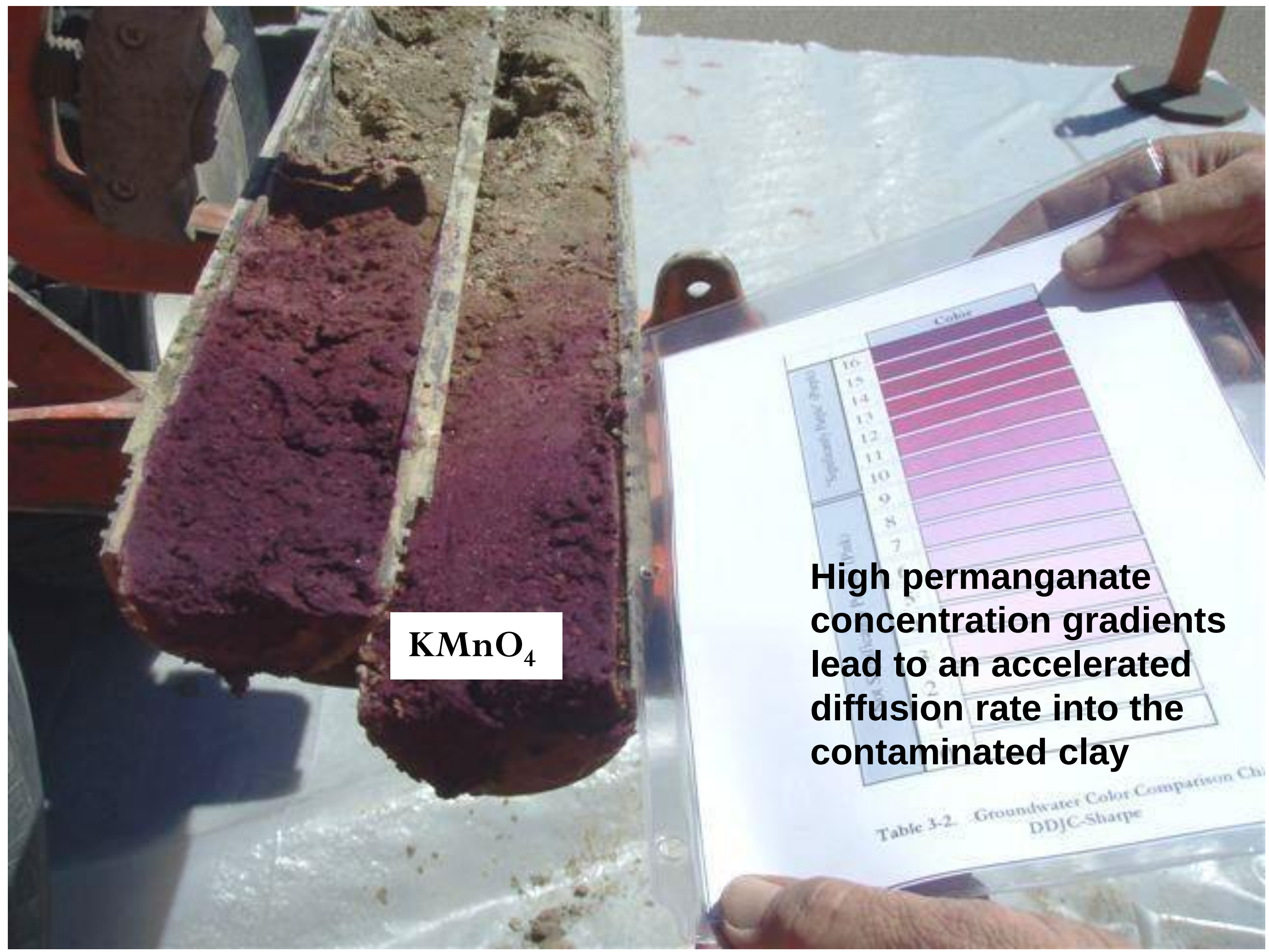
**kf-value in clay:**
**3 x $10^{-8}$ m/s**

# Option 2: Direct injection of highly concentrated reagents (as a slurry) for increased contact between contaminants and reagents

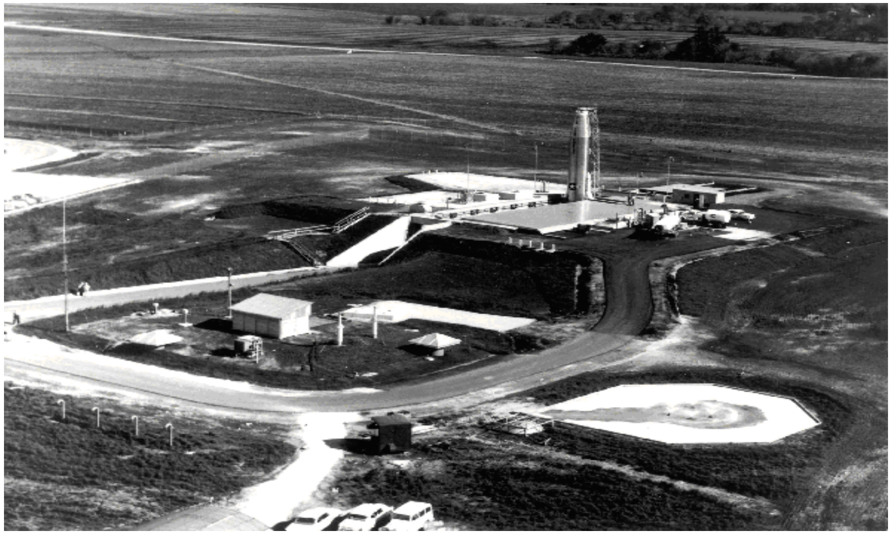
Potassium Permanganate injected as a liquid:
Max. 4% concentration will be further diluted in the groundwater

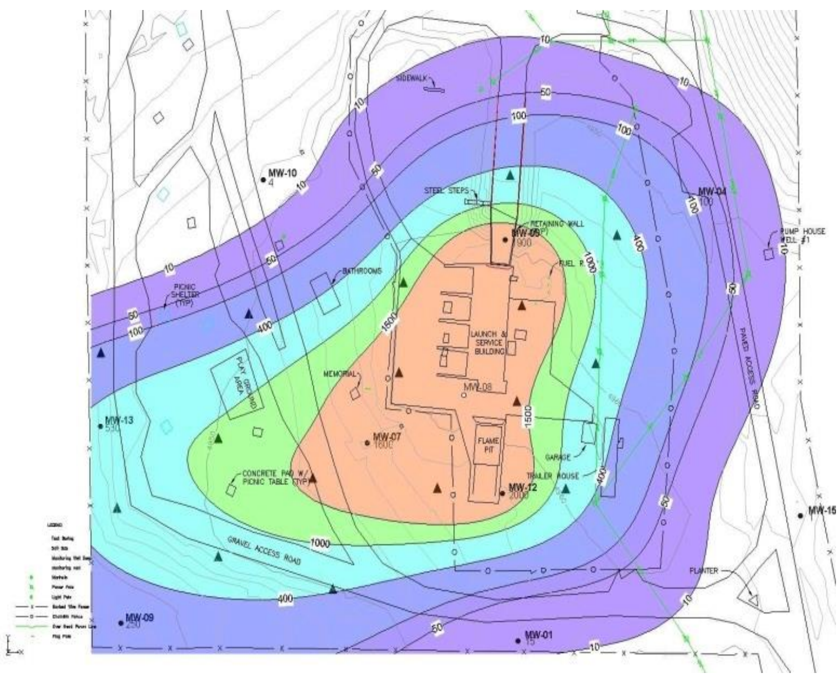
Compared to Potassium Permanganate injection with TSE

Up to **820 kg/m³** as a suspension made possible through the carrier gel



# Case study: Enhanced ISCR in fractured bedrock





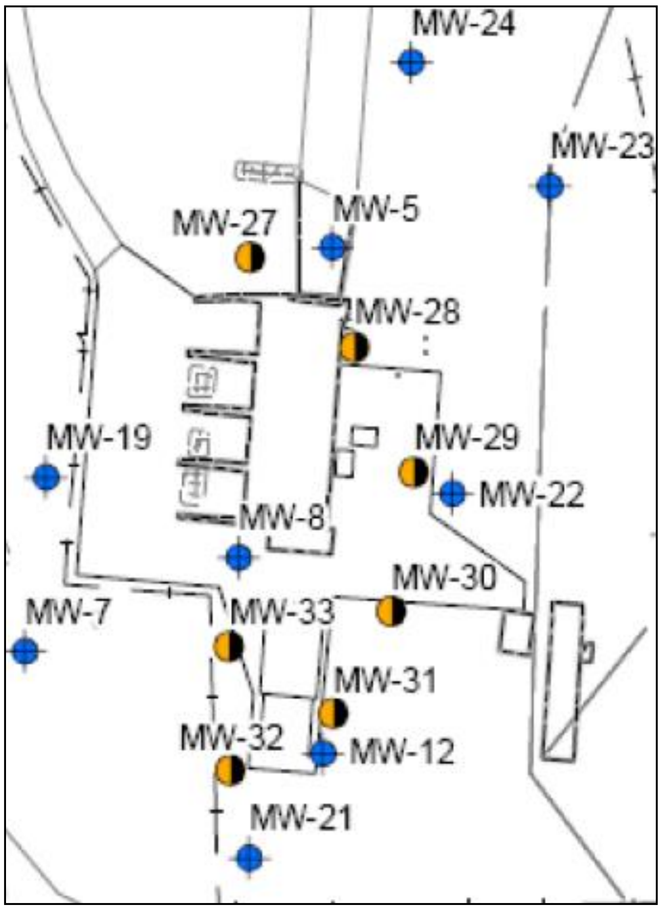

Site characteristics

- Former US Airforce “Atlas 12” rocket launch base
- TCE leakages (1960-1965)
- Contaminant distribution into the “Foxhill Sandstone” aquifer (20m depth)
- Massive TCE contamination
- TCE-concentrations up to 4.000 µg/L

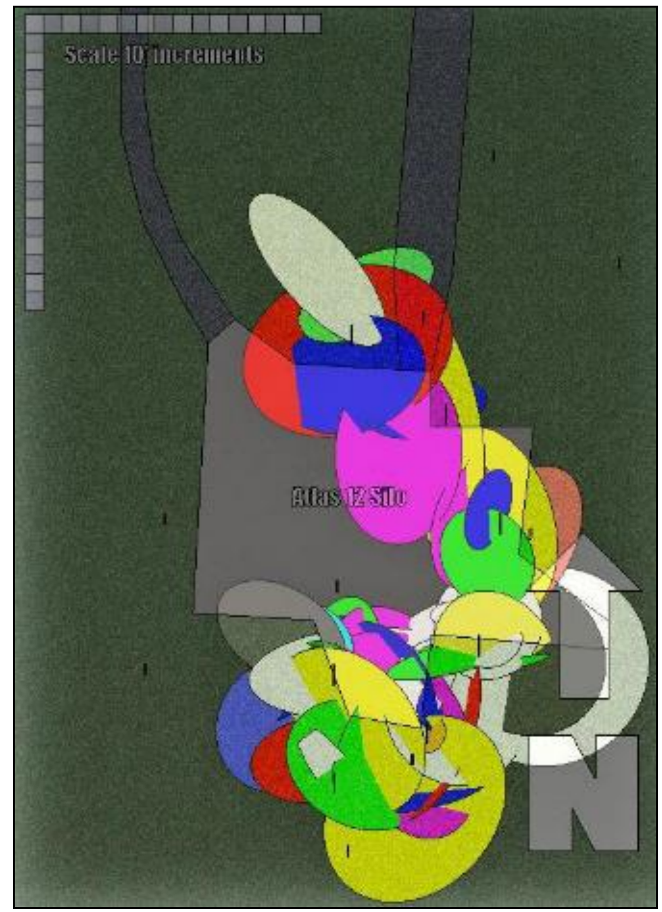
# Case study: Enhanced ISCR in fractured bedrock

## Mapping of ZVI distribution (bird's - eye view)

7 injection drills with 53 controlled injections in contaminated source zone




= injection drill spots in contamination source zone




Coloured discs = ZVI distribution as measured

# Case study: Enhanced ISCR in fractured bedrock

**TCE-remediation: abiotic and biotic degradation in groundwater**

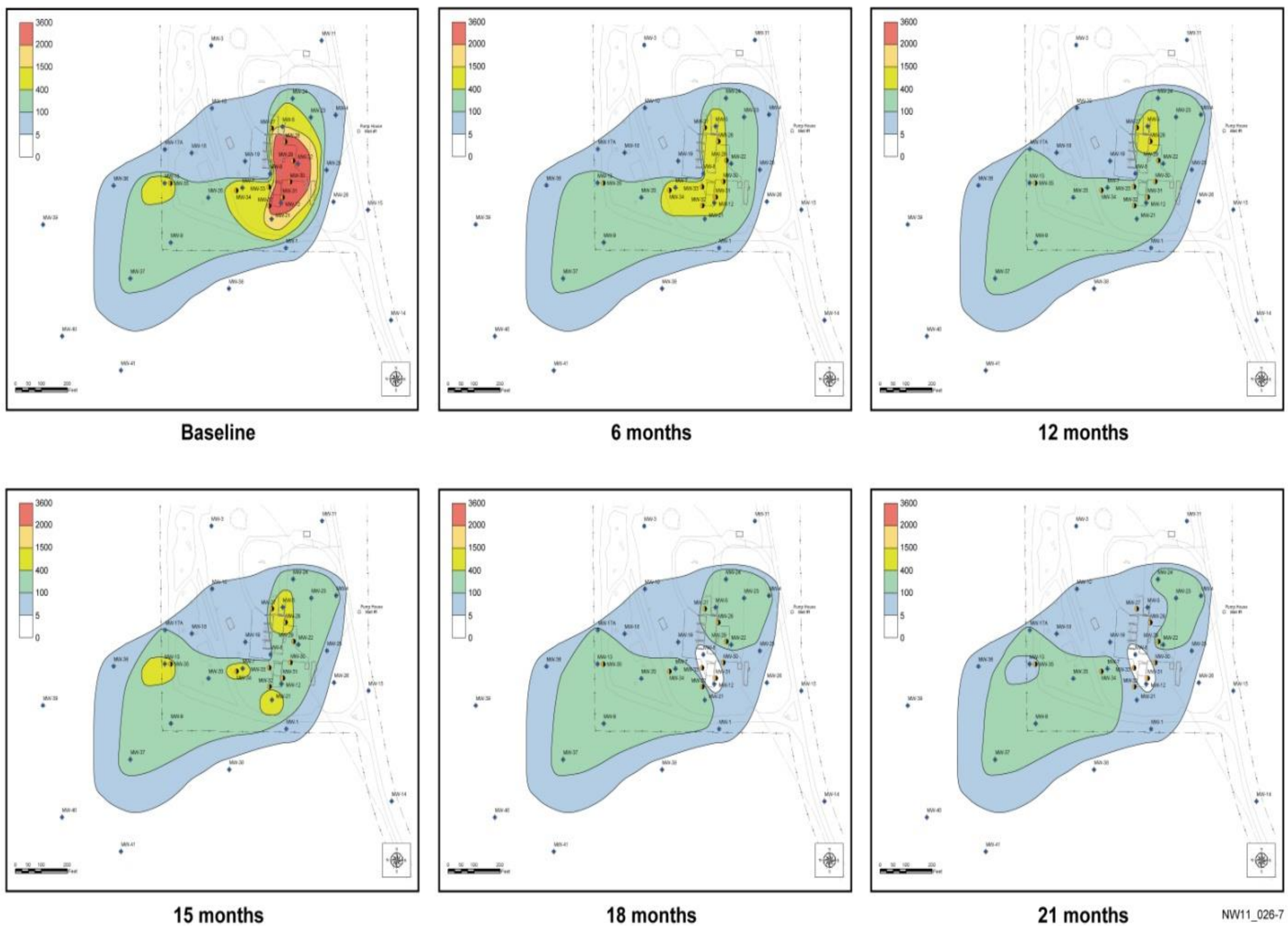
**<u>Source zone:</u>**

- Start TCE-conc.: > 2.000 – 4.000 µg/l
- After 12 months: < 400 µg/l
- After 21 months: <100 µg/l

**<u>Contaminant plume:</u>**

- Start TCE-conc.: 500 - 700 µg/L
- After 21 months: 200 - 400 µg/L

Atlas 12 Post-Pilot Test TCE Concentration Changes



# Case study: Enhanced ISCR in fractured bedrock

- Contaminant source zone:

  94% <  100 ppb TCE (RMC)

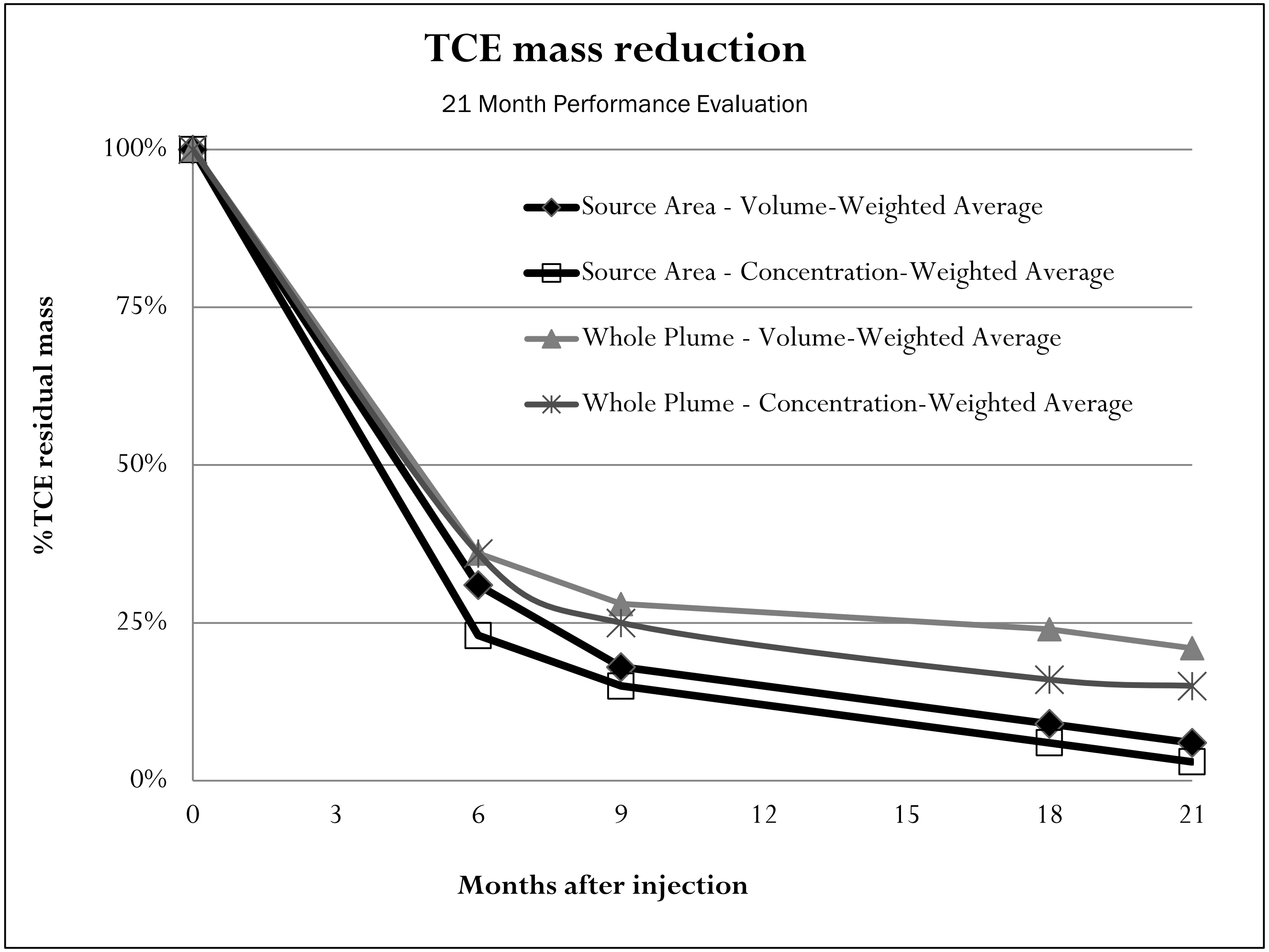
- Plume:

  82% < TCE (RMC)

- Phase 2:
  further 40 t ZVI injected.
  August 2011:
  TCE-Konz. n.n. -100µg/l

- Treatment costs:
  8 $/t

- Registered as new technology for the remediation of rocket launch bases by US Corps of Engineers

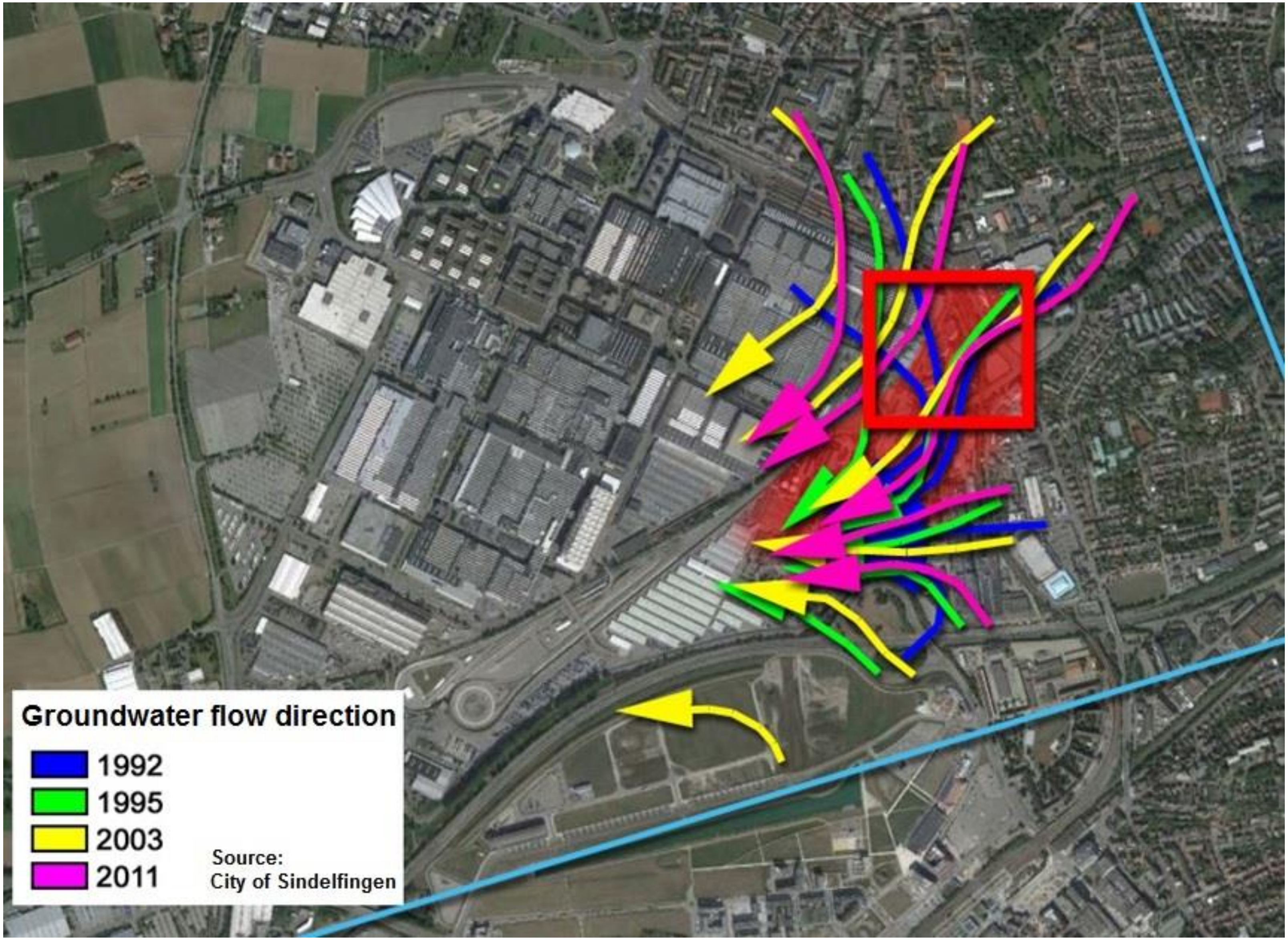



(Source: Journal of Remediation, Spring, 2012)

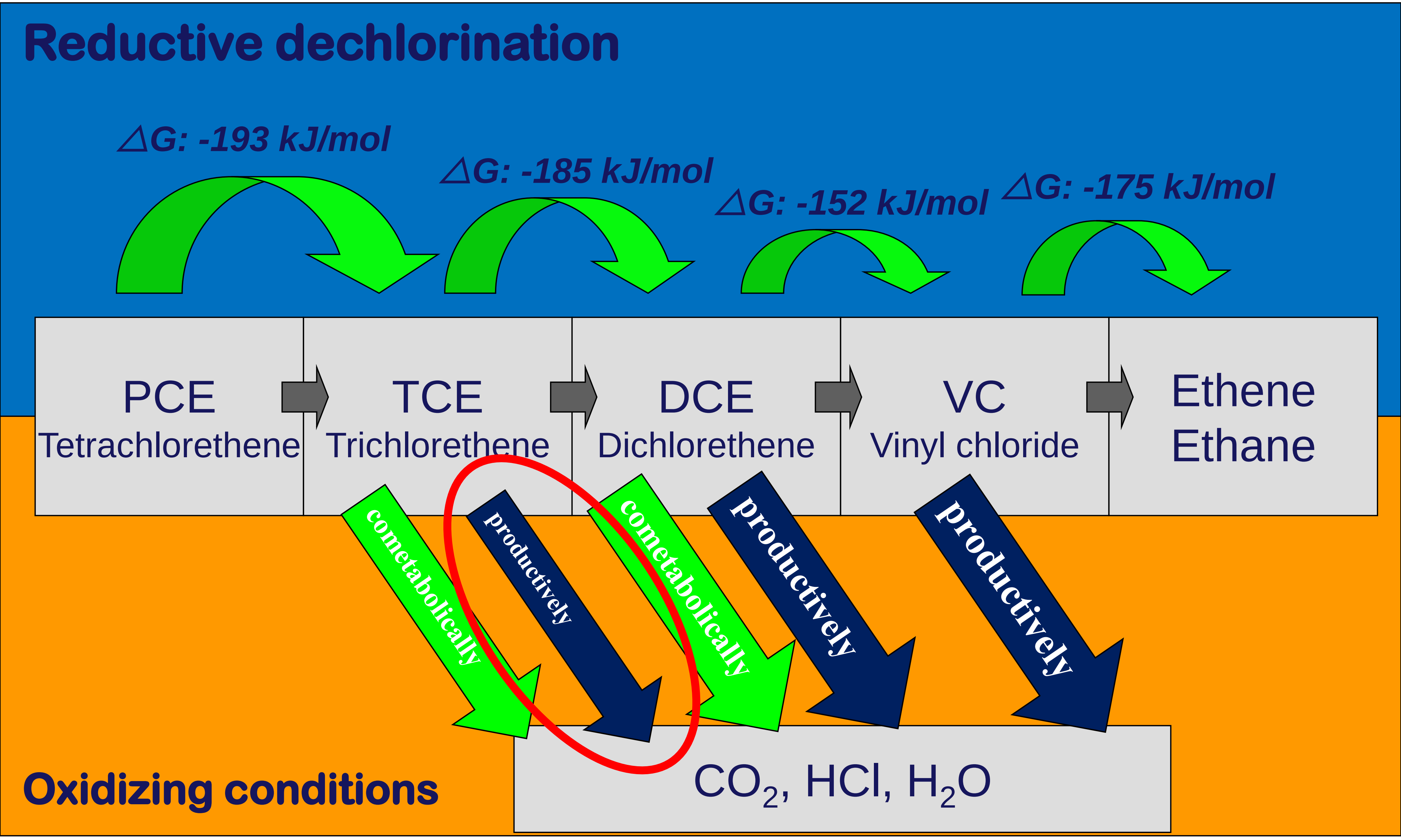
# TSE-application in Italy: Mobile ISCO remediation Autostrada gas station, Italy

SENSATEC

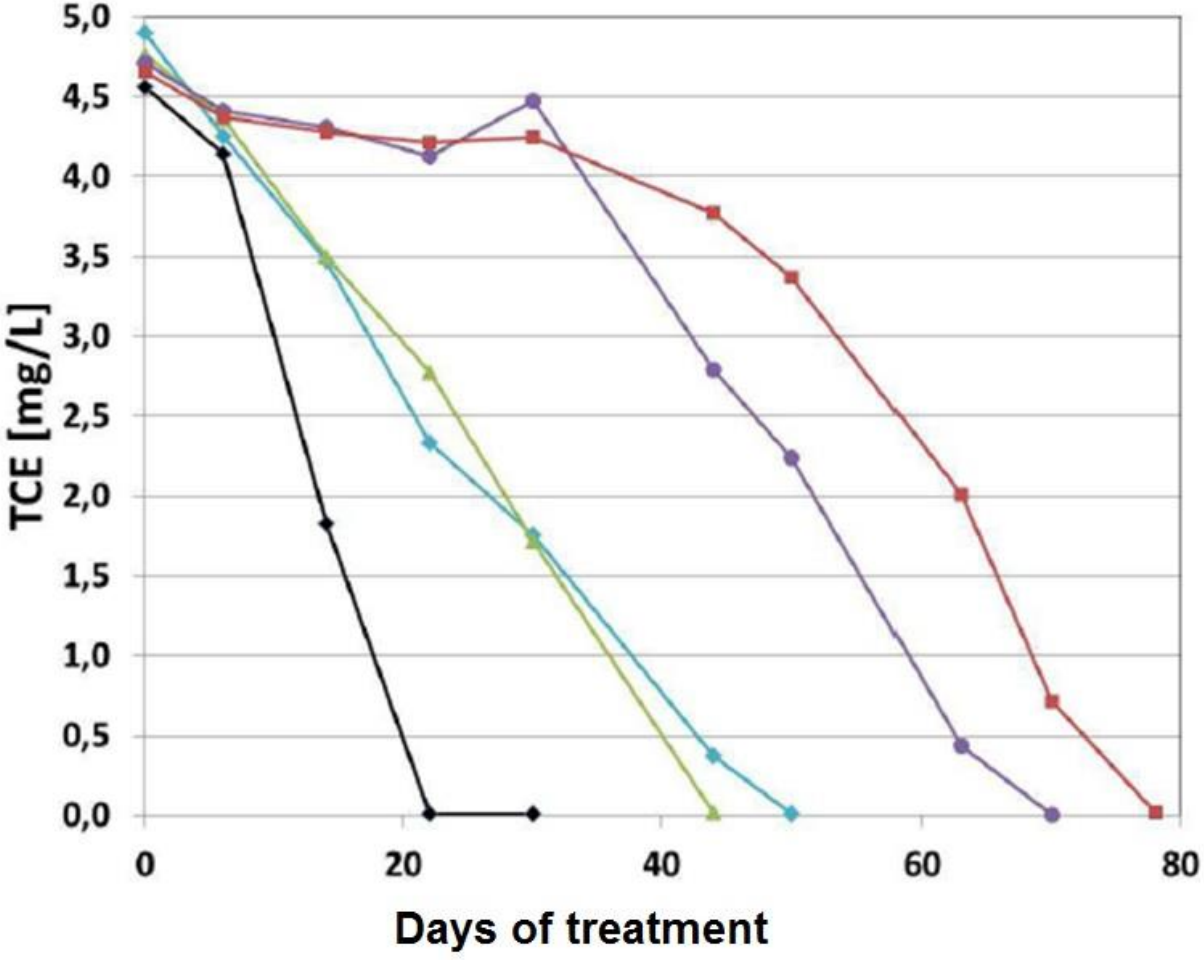
# Aerobic biostimulation project at Mercedes-Benz works, Stuttgart In-situ remediation in fractured bedrock



# Aerobic and anaerobic degradation of chlorinated hydrocarbons (CHC)



# Aerobic degradation of TCE - Sensitivity to high oxygen levels



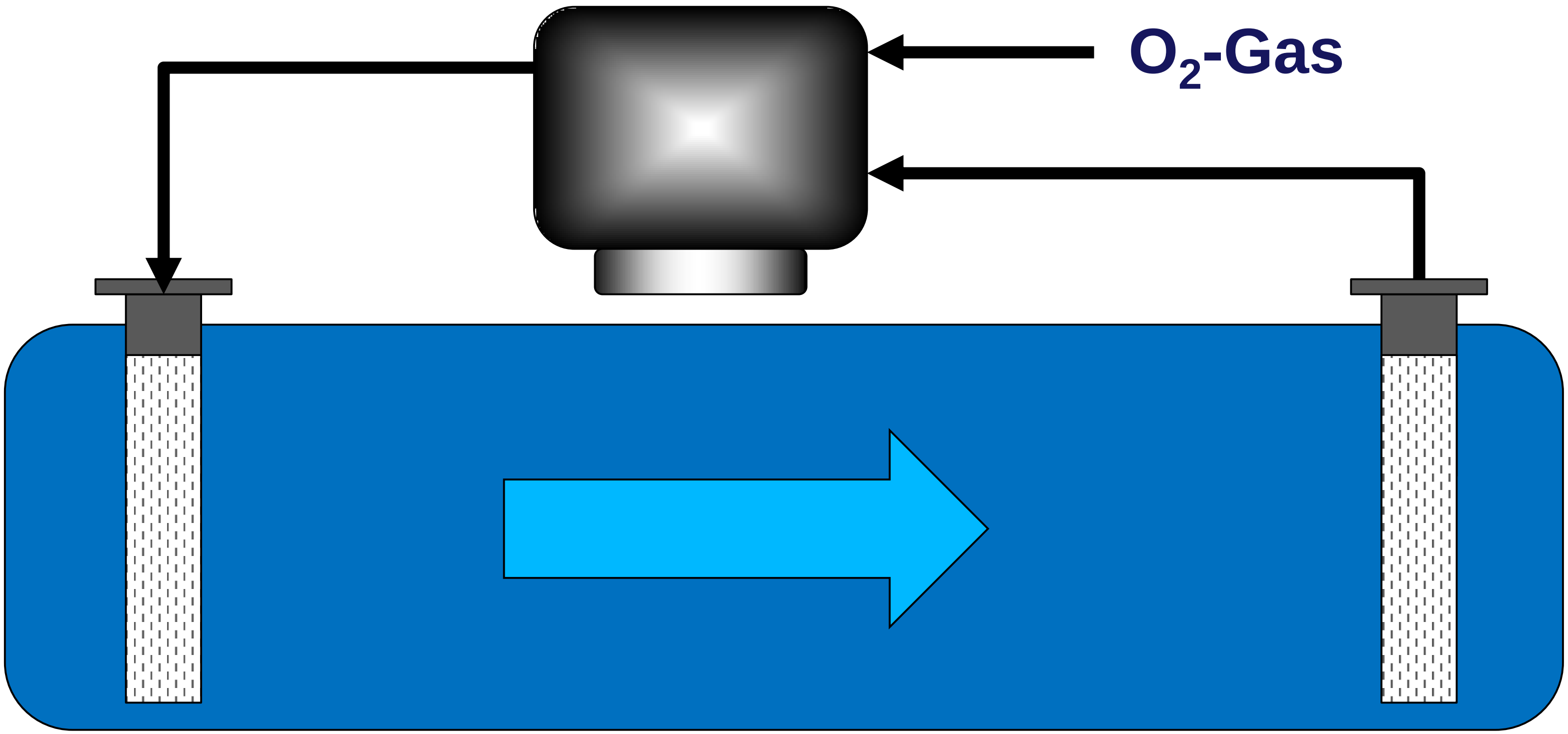

- Microbial mixed culture leads to rapid and complete TCE elimination
- No stable degradation products
- High long term stability
- TCE concentrations up to 50 mg/l are degraded
- Low oxygen levels are sufficient
- High tolerance towards temperature, pH-value, starvation

**Result: reduced degradation at oxygen levels exceeding 14 mg/l**

# In-situ-biotreatment in fractured bedrock – general issues

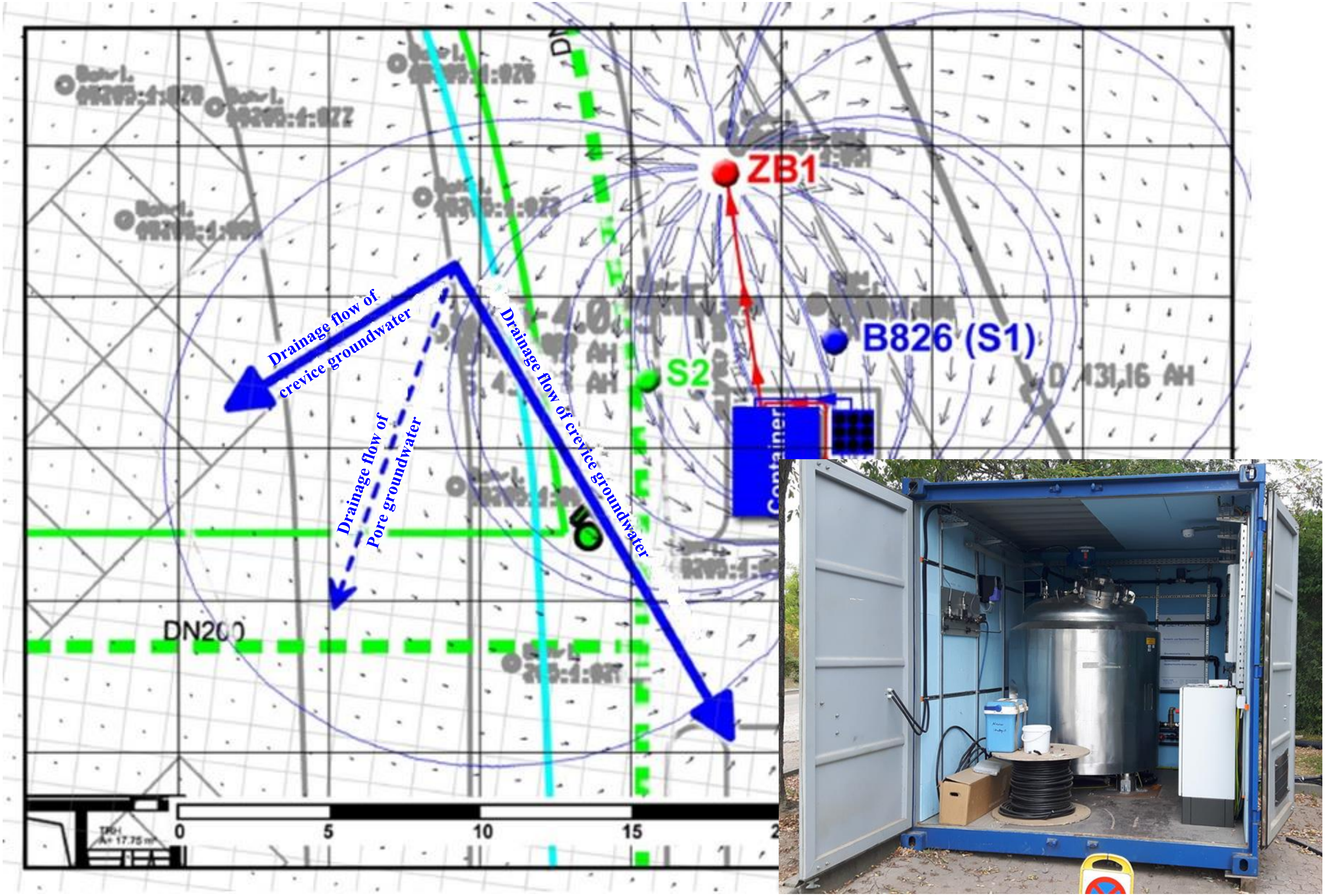
- ❖ Infavourable relation between reactive soil matrix and groundwater flow
- ❖ Potentially high flow velocity, short residence time of water and reagents in bioreaction zone to be established
- ❖ Low surface area for microbial settlement
- ❖ heterogeneous groundwater flow pattern

# Technical solution: Establishment of a bio-stimulation zone in a water cycle

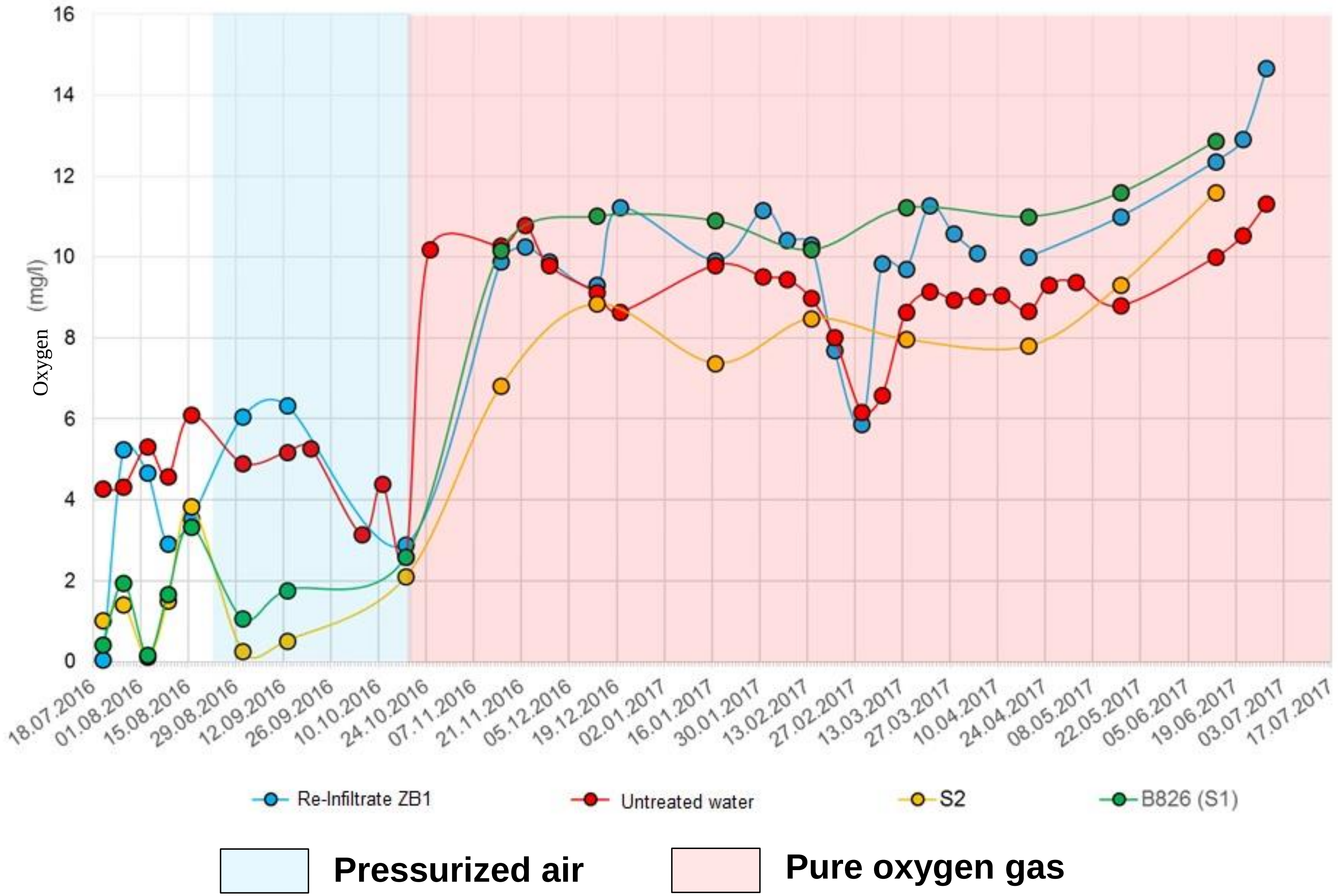



- Re-introduction of microbial biomass
- Reduction of loss of reagents (in this case: $O_2$)
- Longer reaction time of contaminated groundwater in biostimulated zone

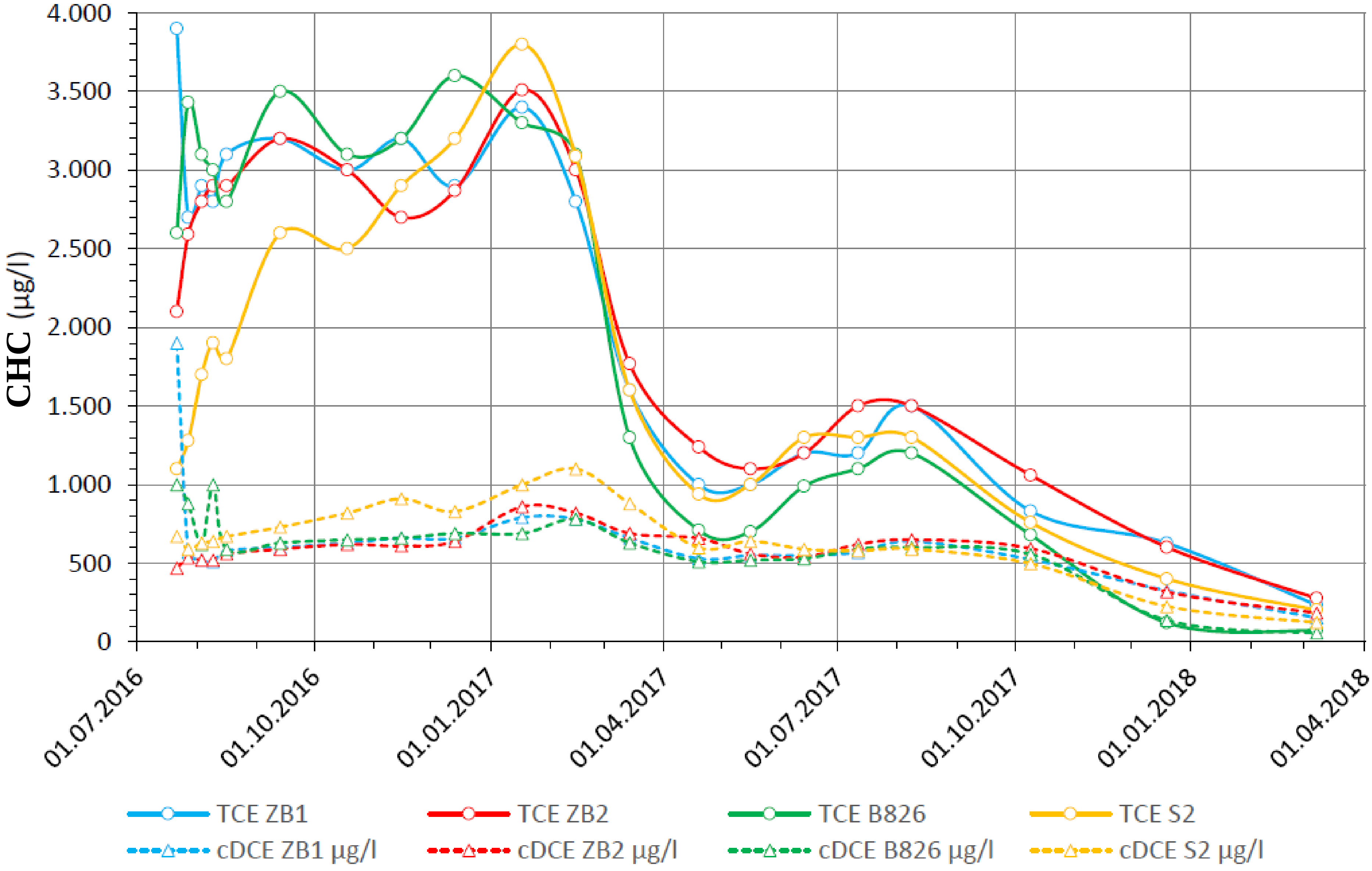
# Technical setup on site



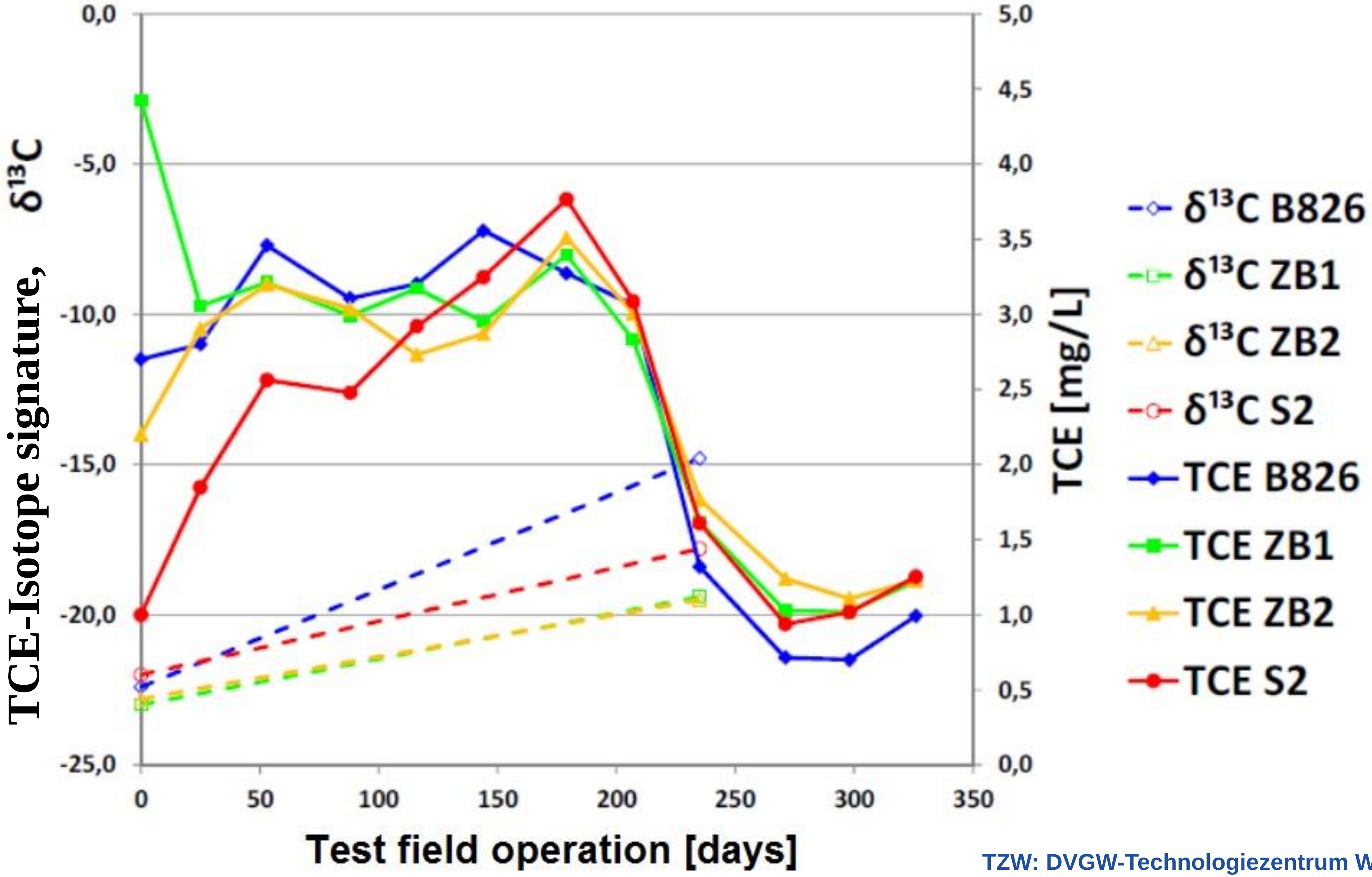
# Oxygen enrichment in groundwater



# TCE-development after start of oxygen injection



# 13C/12C-Isotope development after start of injection

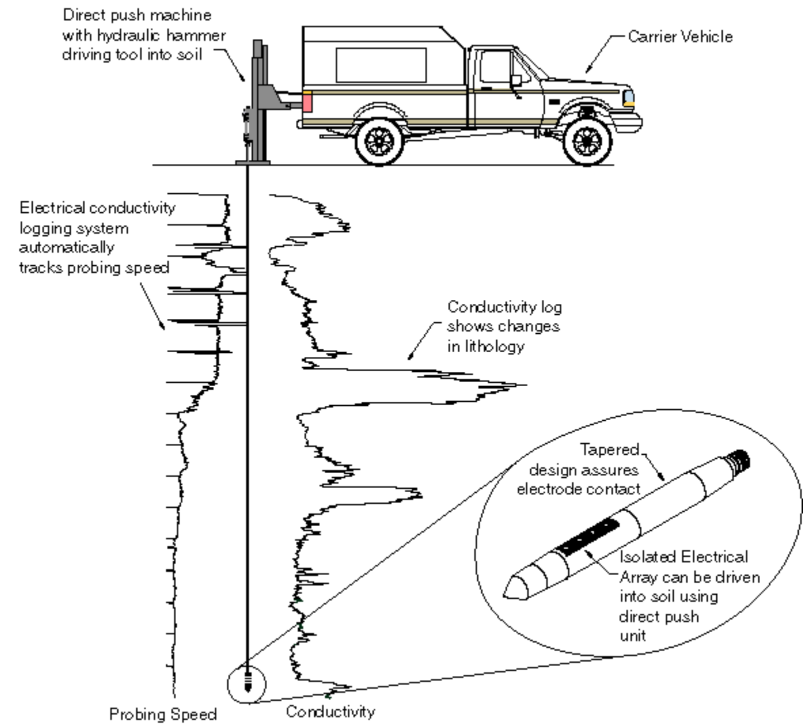



TZW: DVGW-Technologiezentrum Wasser

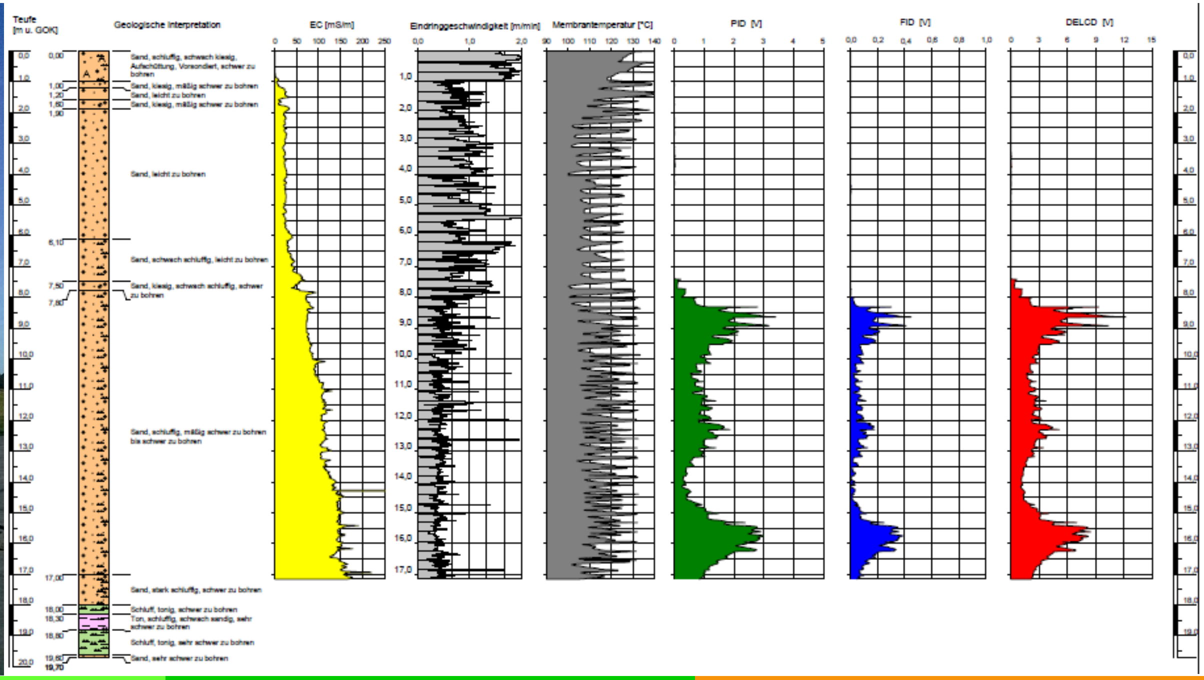
# Conclusions for in-situ treatment in difficult geological structures

- **Fractured bedrock aquifers may be treated successfully by in-situ remediation technology provided that reagents are kept within the reaction zone (e.g. by groundwater circulation). Lag phases and reaction speed may be considerably slower.**
- **Structures with low hydraulic permeability can be made accessible for in-situ remediation by using TSE injection technology which injects sand structures or reagents directly to these layers to address contaminants.**

# Invitation to live demonstration at Remtec fair




1. **Where: outside main entrance of exhibition hall, on greenfield**
2. **When: today, 14.30**
3. **What: Live demonstration of MIP – Membrane Interface Probe Drilling**



# Thank you for your attention!

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