In situ Bioremediation of Aged Low-K DNAPL Source Zone in Complex Geological Settings by Groundwater Circulation Wells for Efficient Amendment Delivery and Contaminant Mobilization

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Soil & Groundwater Remediation Technologies

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BATTELLE
It can be done

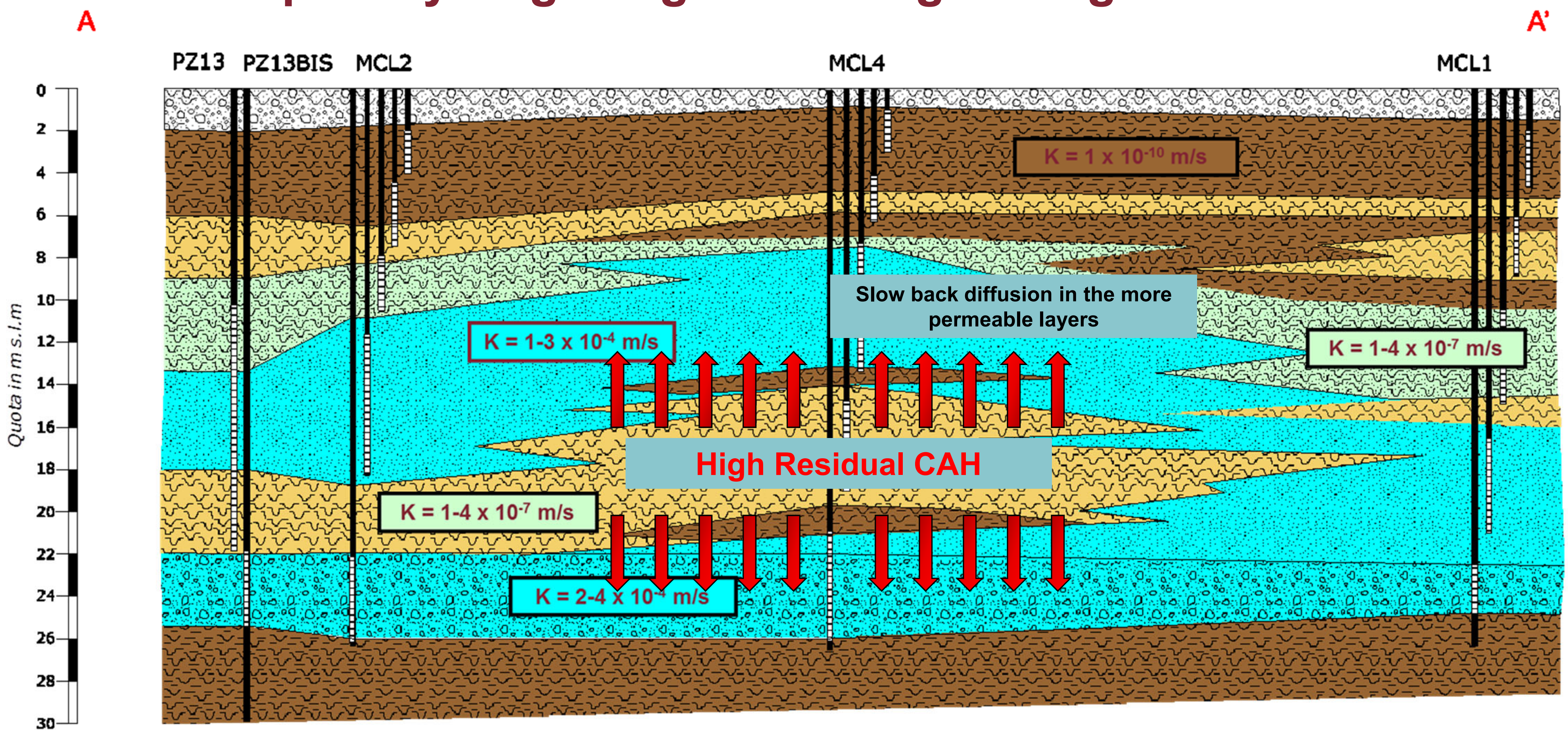
The Site

- A large operative industrial site in Northern Italy historically affected by a heavy chlorinated aliphatic hydrocarbons contamination due to past uncontrolled industrial degreasing activities
- In the central portion of the plant, a building housed in the past two industrial washing machines for the degreasing of mechanical parts produced in the plant

Intense Pump&Treat activity (35 wells)

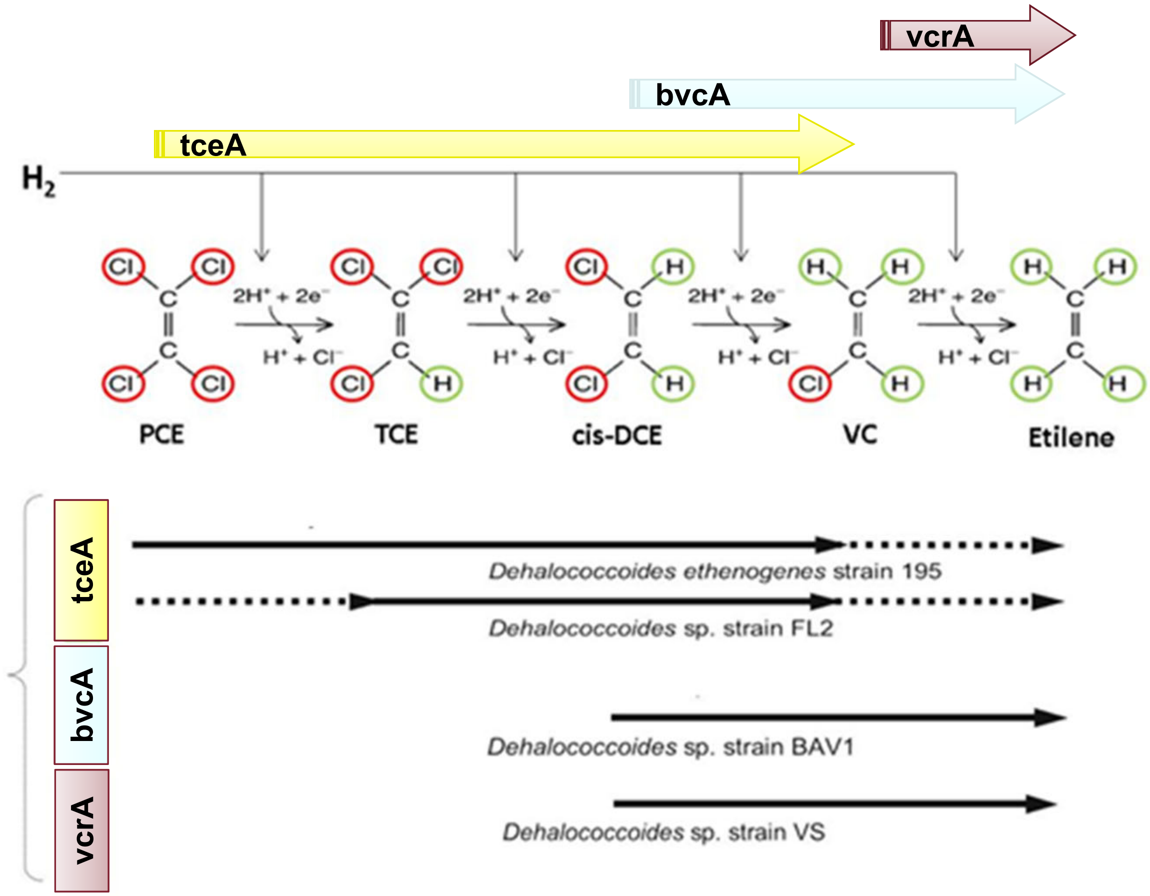
- Hydraulic barrier (downgradient)
- Localized pumping wells
- ≈ 70 $m^3\ h^{-1}$
- More than 10 tons of dissolved CAH removed
- Stable total CAH dissolved concentration at around 500 $\mu g\ L^{-1}$

Complex hydrogeological setting and aged source zone



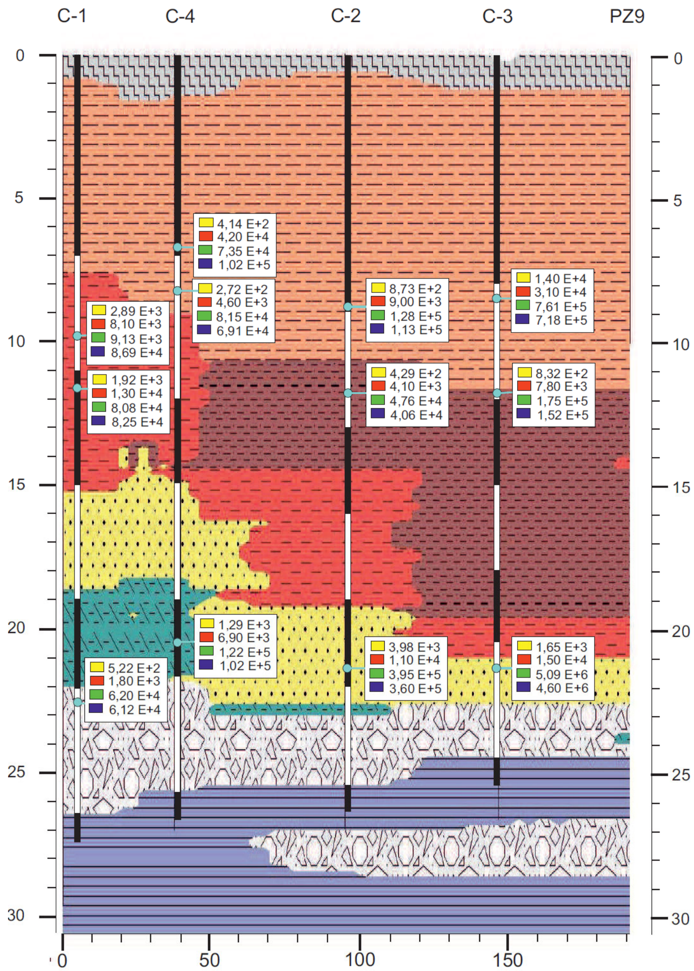
Active Biological Reductive Dechlorination

Most of the contamination is due to less chlorinated compounds with *cis* 1,2-DCE and VC found at concentration often exceeding 100 mg/L, whereas most of the parent compounds occurs at negligible concentration

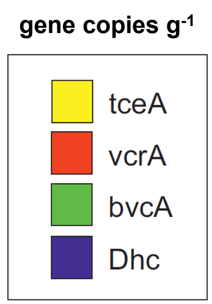


Metabolic

Co-Metabolic



Dehalococcoides mccartyi **and functional genes tceA, bvcA e vcrA in soil samples at different dephts**



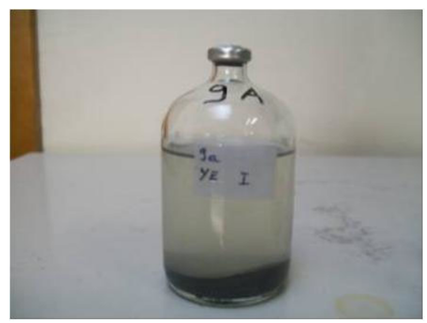
Although at concentrations lower than 10^{-6} gene copies g^{-1}, the occurrence of different *Dehalococcoides mccartyi* strains suggested a strong Reductive Dechlorination potential

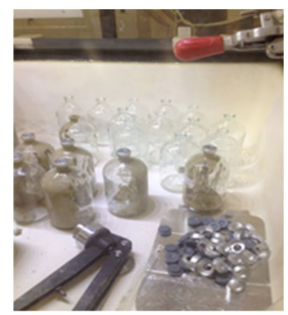
Particularly, higher amount of the functional genes vcrA and bvcA suggested the possibility to stimulate the metabolic reduction of *cis*-DCE and VC to ethene

Samples in 5 liters bottles used for aquifer sampling

Anaerobic glove box for microcosm preparation.

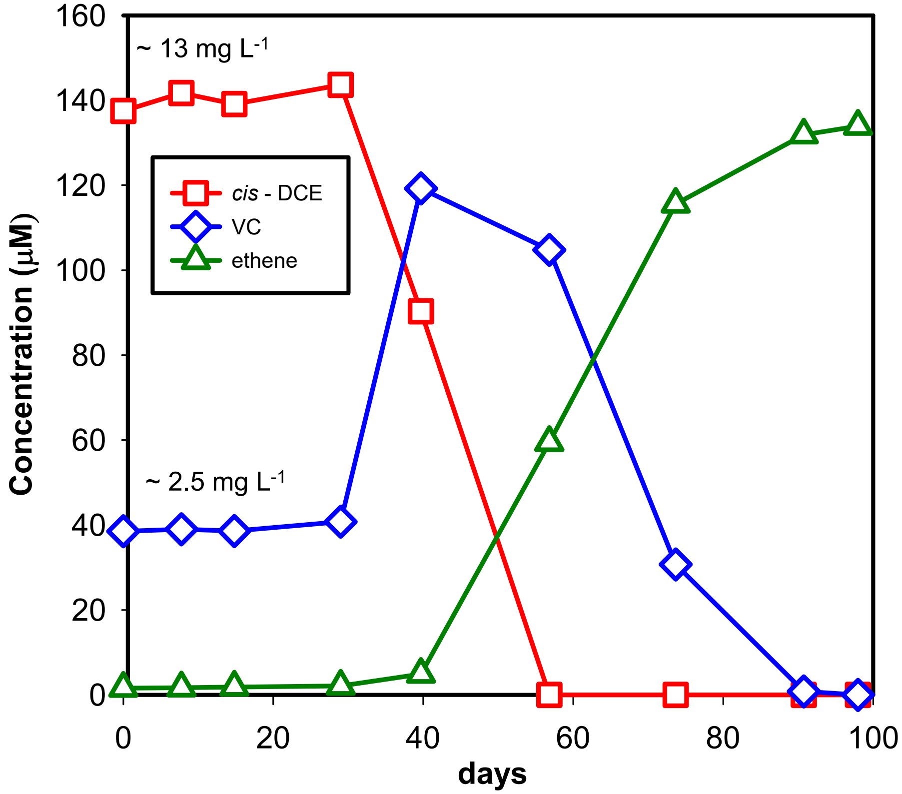
One of the 30 microcosms





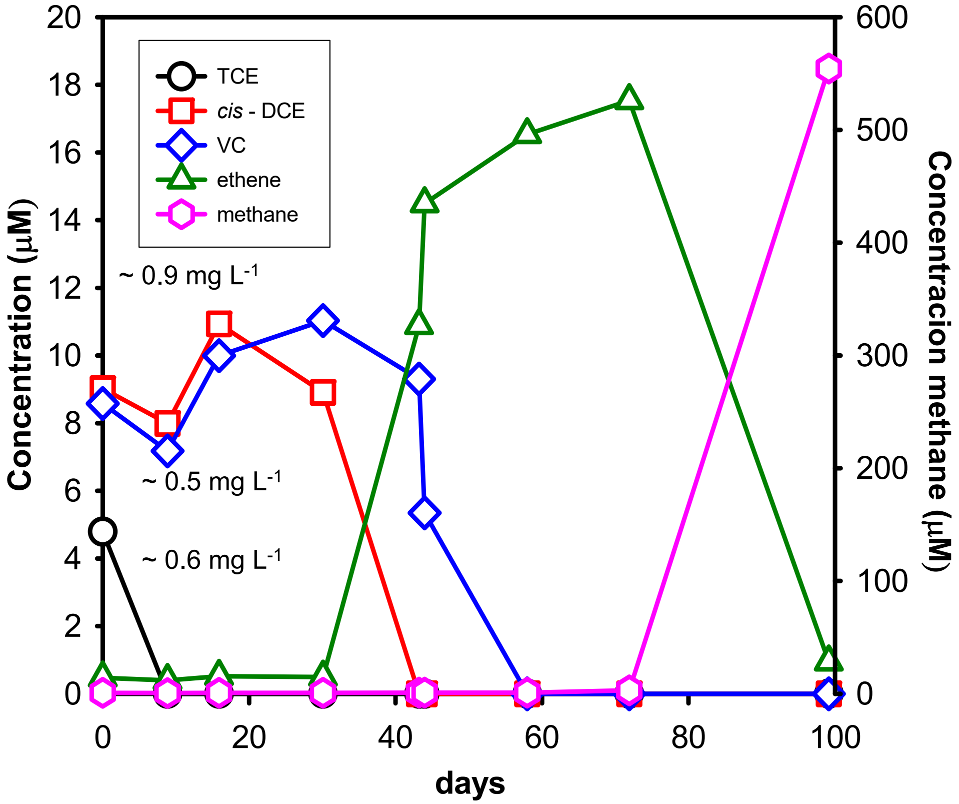
Selected microcosm results

source zone



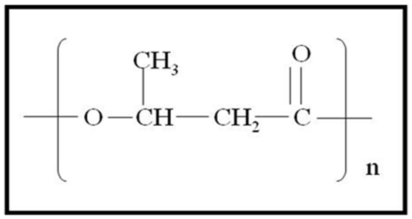
Selected microcosm results

site boundary



The Electron Donor Source (Slow Releasing)

PHB (Poly 3-hydroxybutyrate)

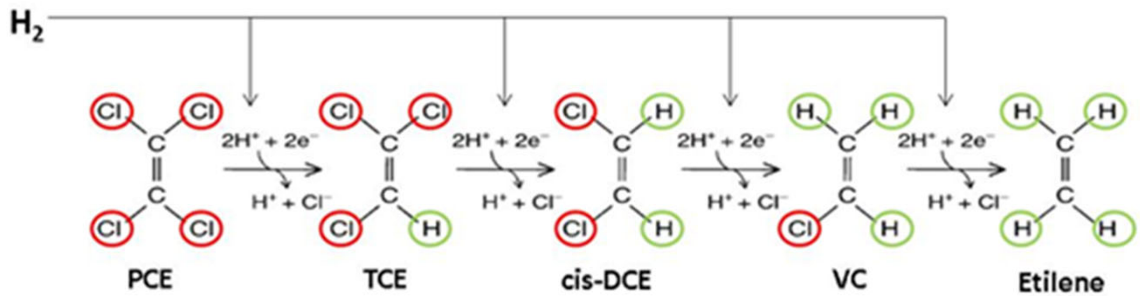


Hydrolysis

3 – hydroxy butyrate

hydrogenation → Butyrate

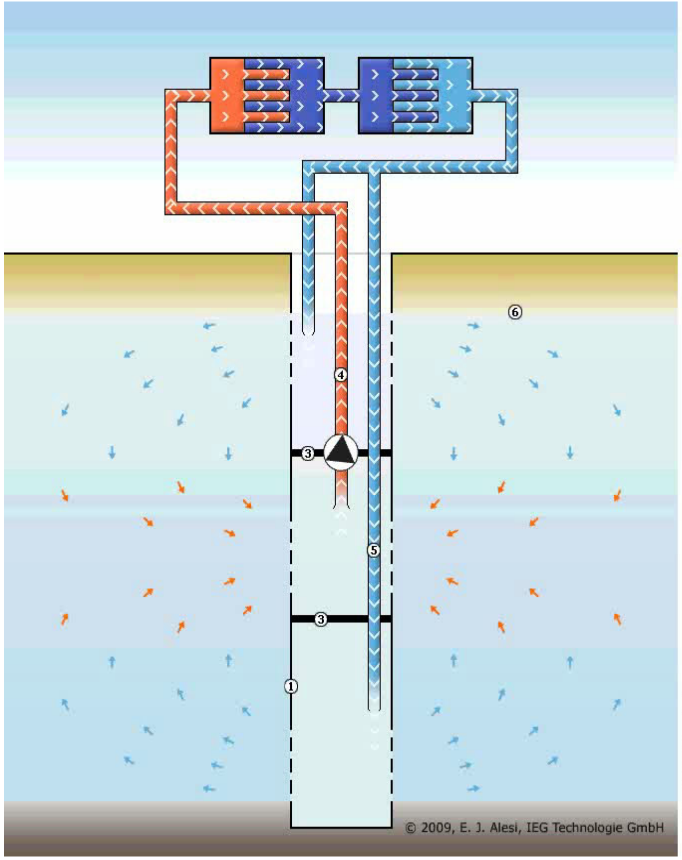
β-oxidation → Acetate, hydrogen



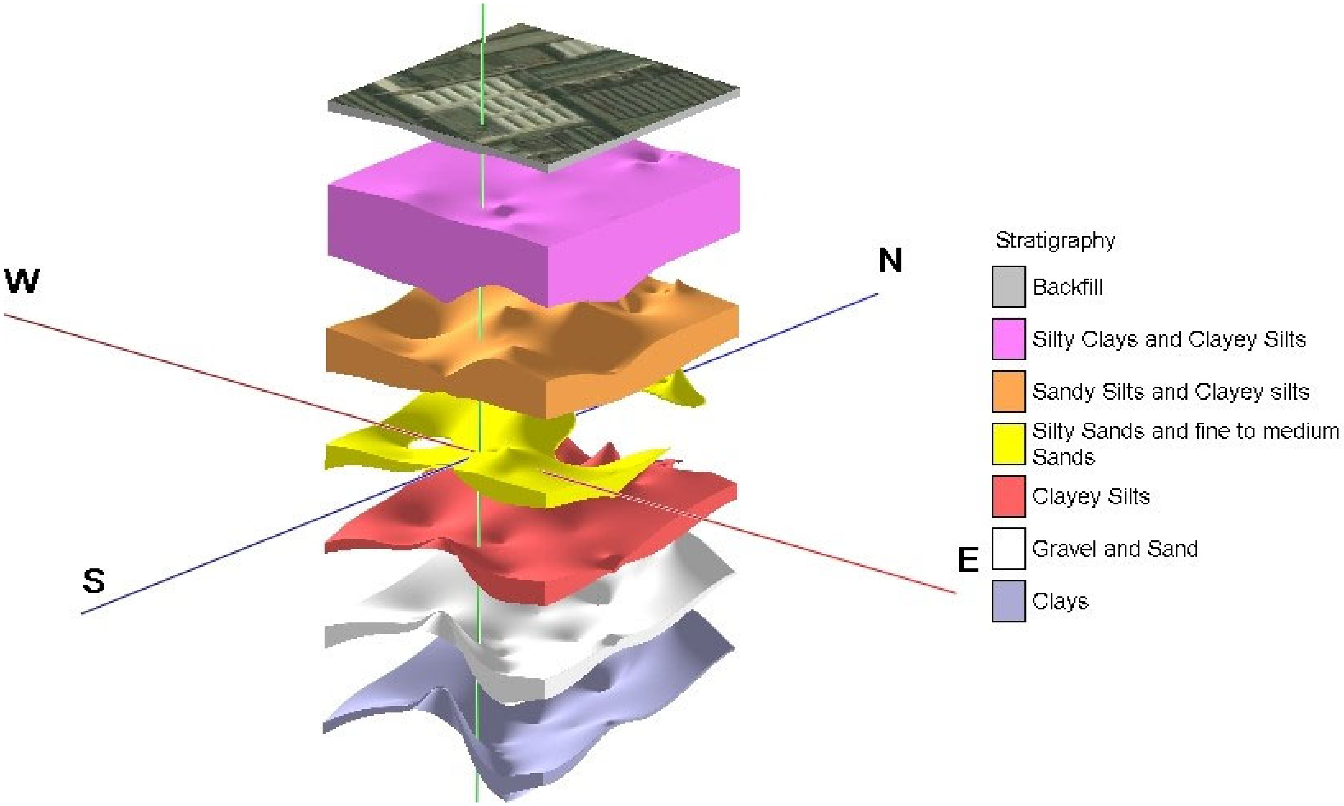
Electron donors for biological reductive dechlorination

Remediation strategy definition

- strategy for the progressive source zone reduction has been identified in the use of **Groundwater Circulation Wells** to mobilize residual contamination and delivery dissolved electron donors through the less permeable layer (to enhance *in situ* BRD).



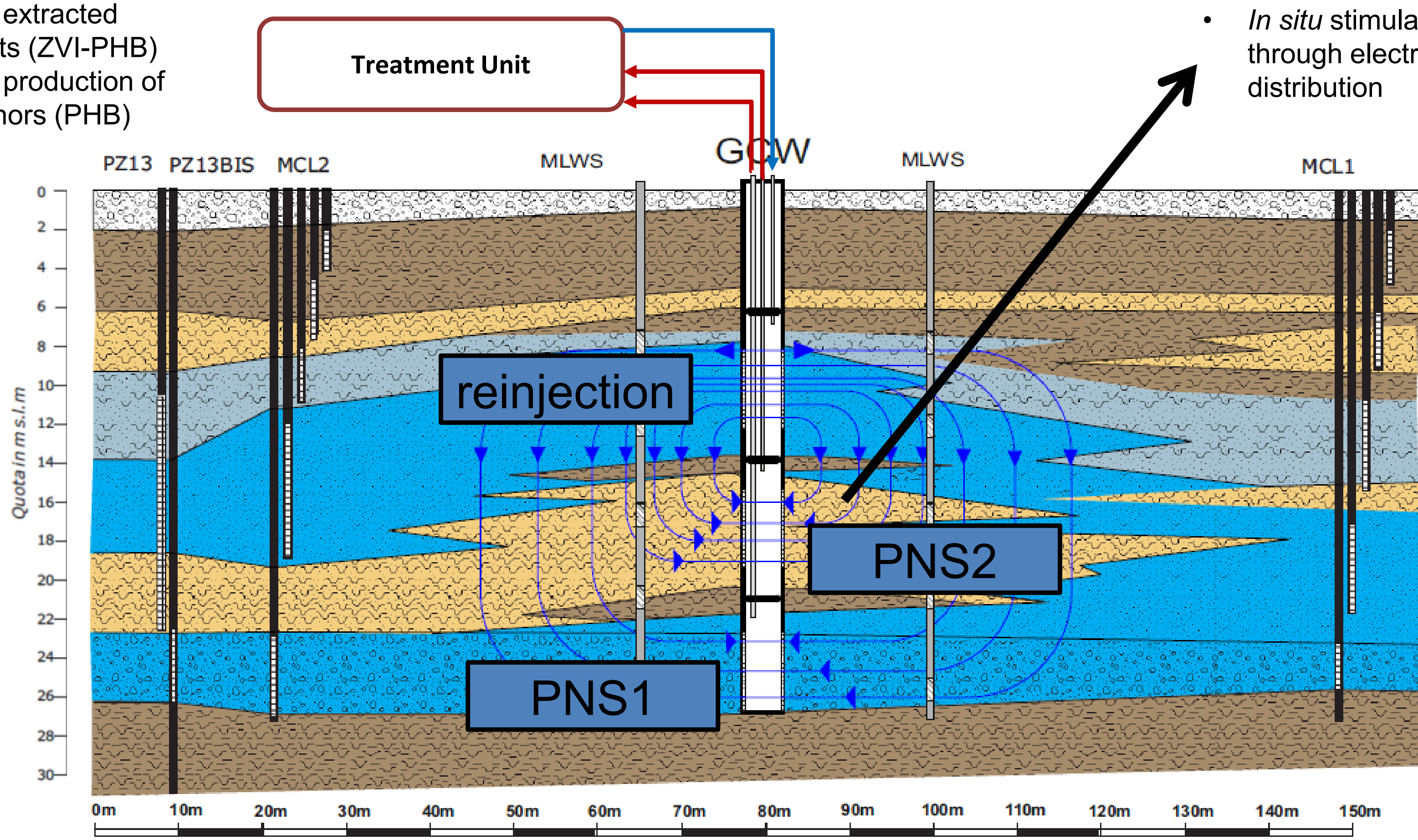
Pilot Test Area



Configuration of the pilot test

- Removal of extracted contaminants (ZVI-PHB)
- Continuous production of electron donors (PHB)

- Mobilization of contaminants
- *In situ* stimulation of BRD through electron donor distribution



Configuration of the pilot test

The external treatment unit consists of:

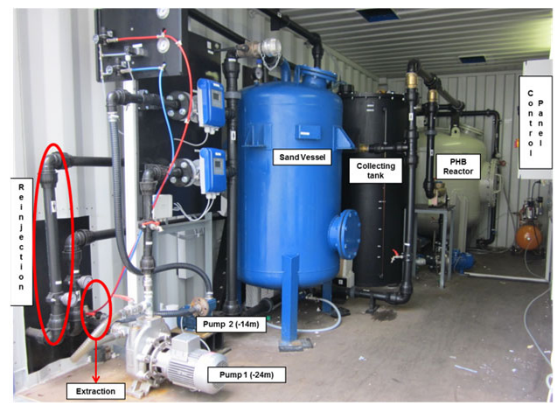
1) A sand filter for the removal of suspended solids in the groundwater stream pumped before the passage through the successive stages of the treatment;

2) A reactor containing poly-3-hydroxybutyrate (PHB) for the continuous production of electron donor dissolved in the recirculated water stream;

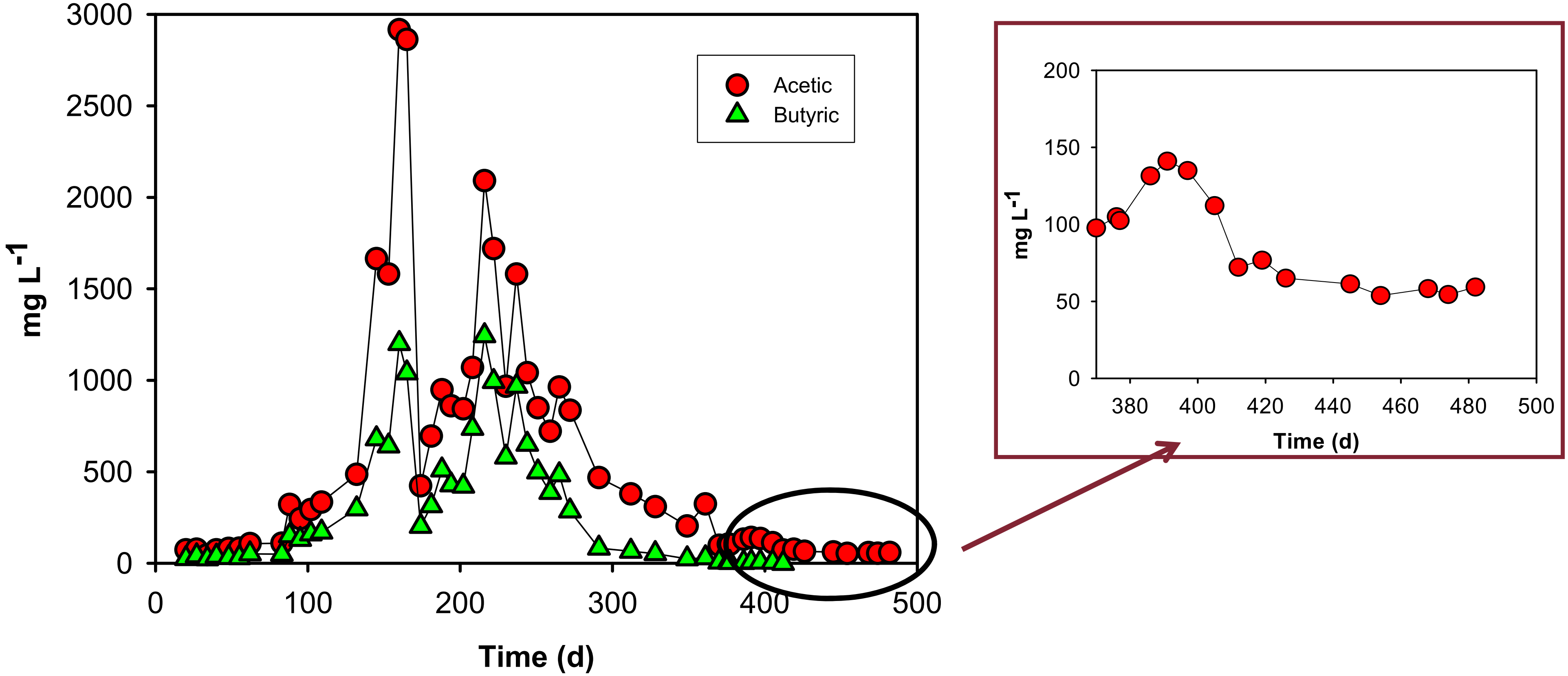
3) A reactor containing ZVI/Fe to perform abiotic reductive dechlorination of chlorinated solvents;

4) Relaunch tank where the treated water is collected and re-injected into the most superficial part of the aquifer (8-12 m), thus closing the circulation circuit.

Pilot Plant Installation

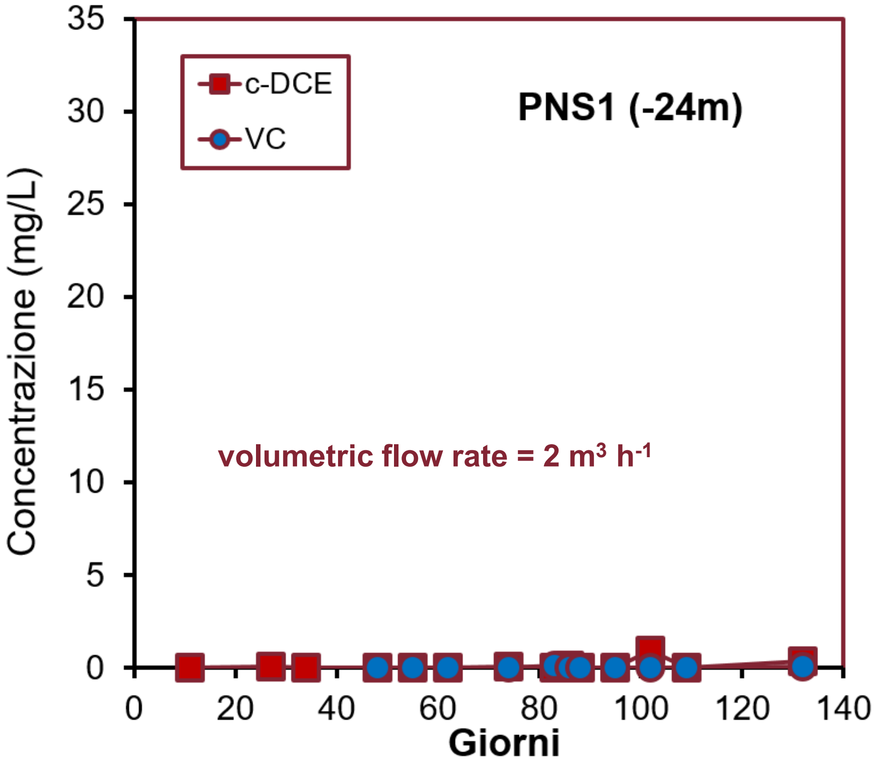


Production of dissolved electron donors in the PHB reactor

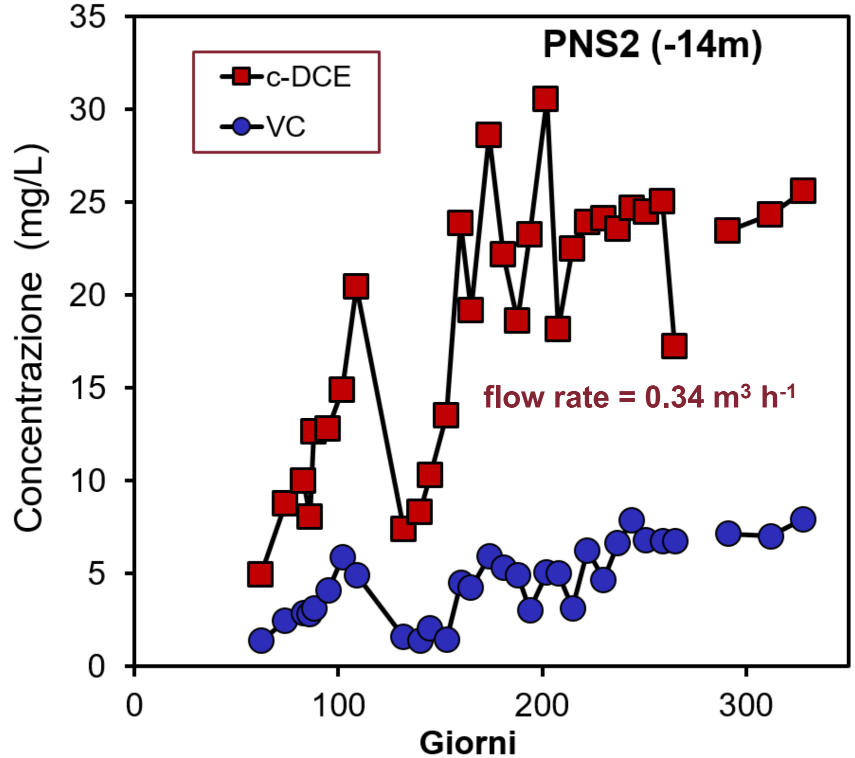


Mobilization of contaminants from layers at different permeability

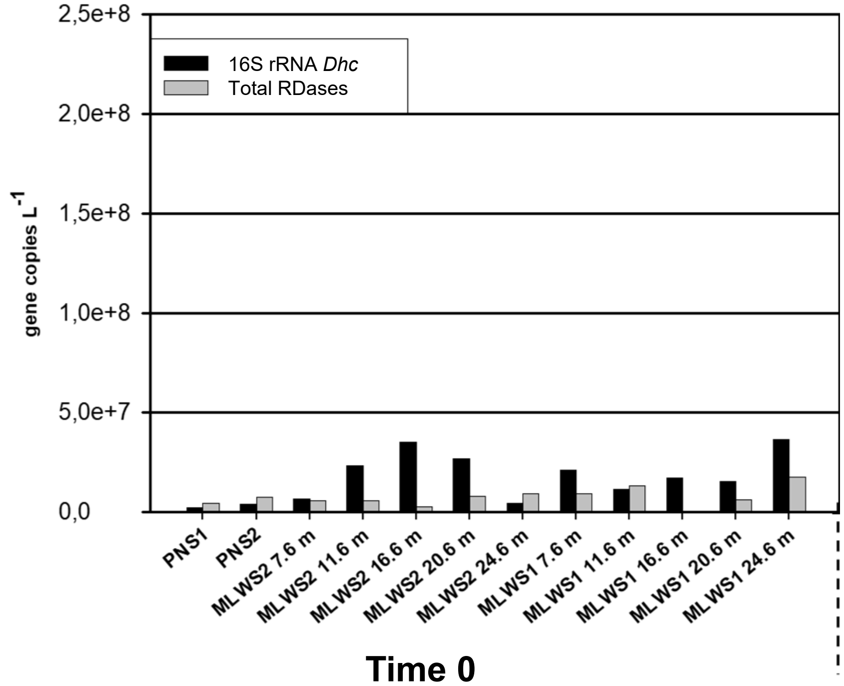
high permeability layer



low permeability layer



Effect of recirculation on microorganism population



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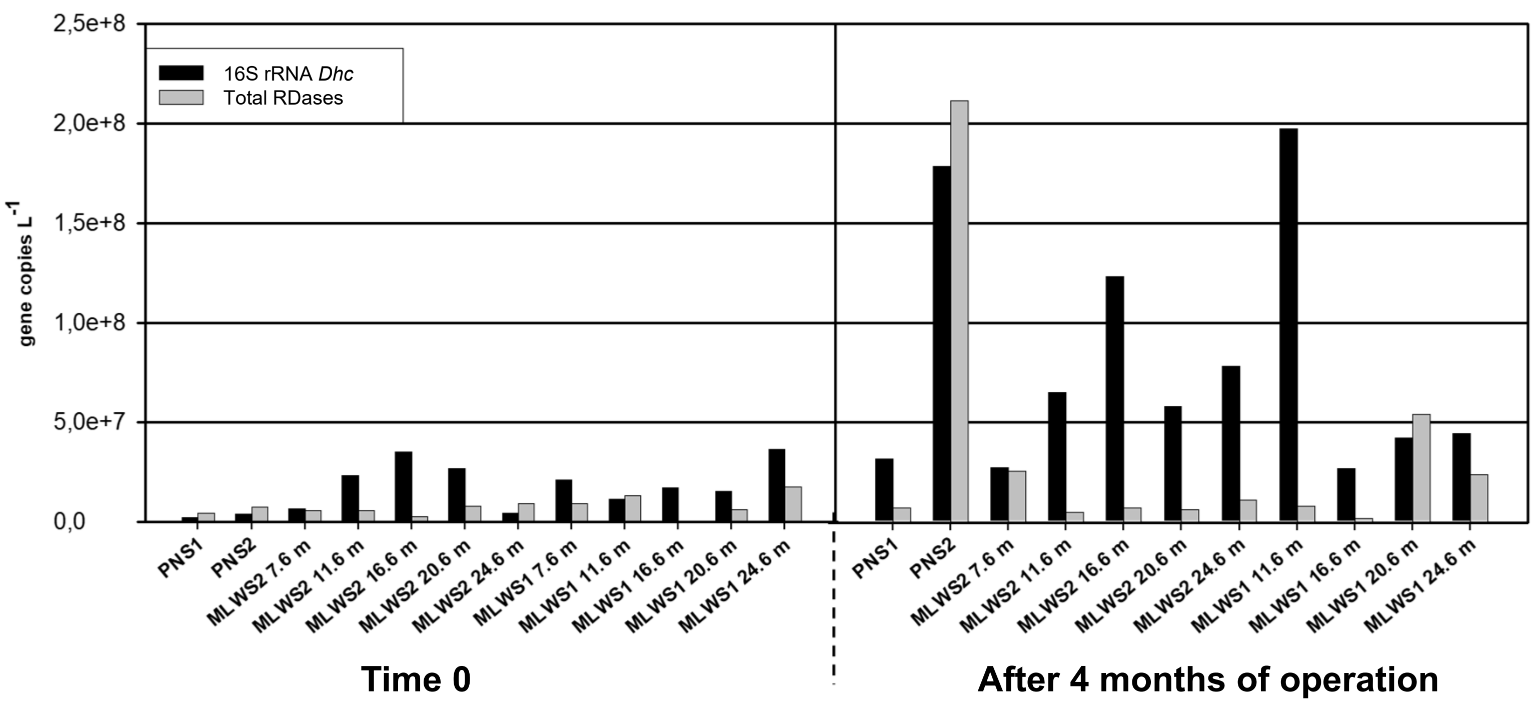
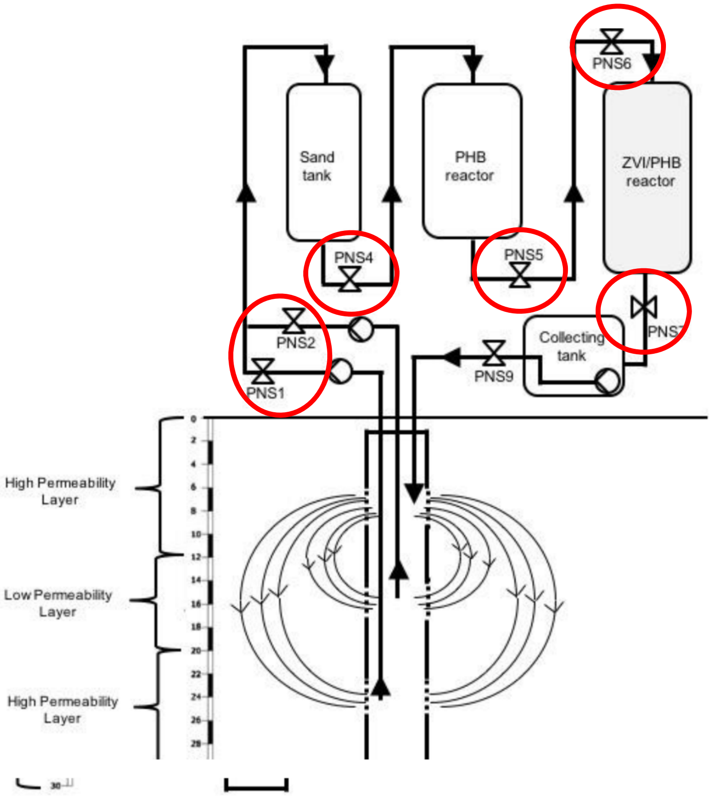
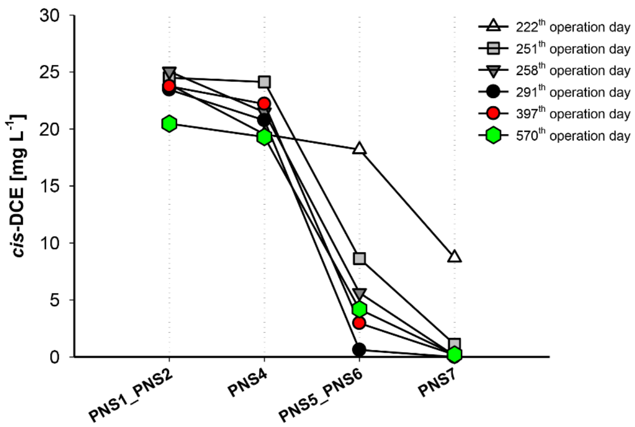
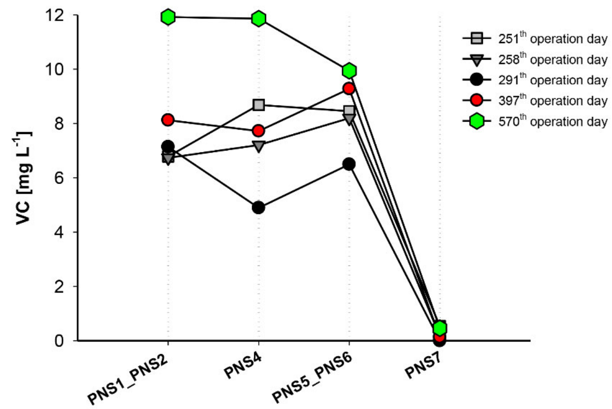
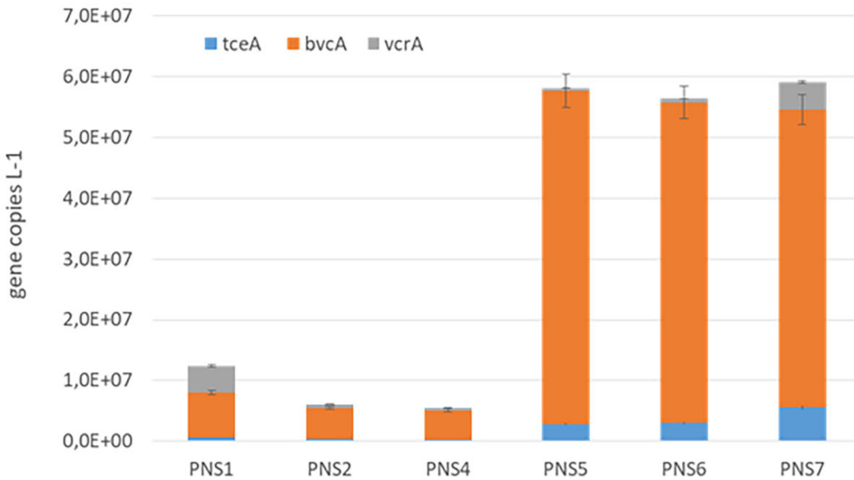


Unexpected colonization of the external PHB reactor by dechlorinating bacteria









Full scale design and installation (August 2019)

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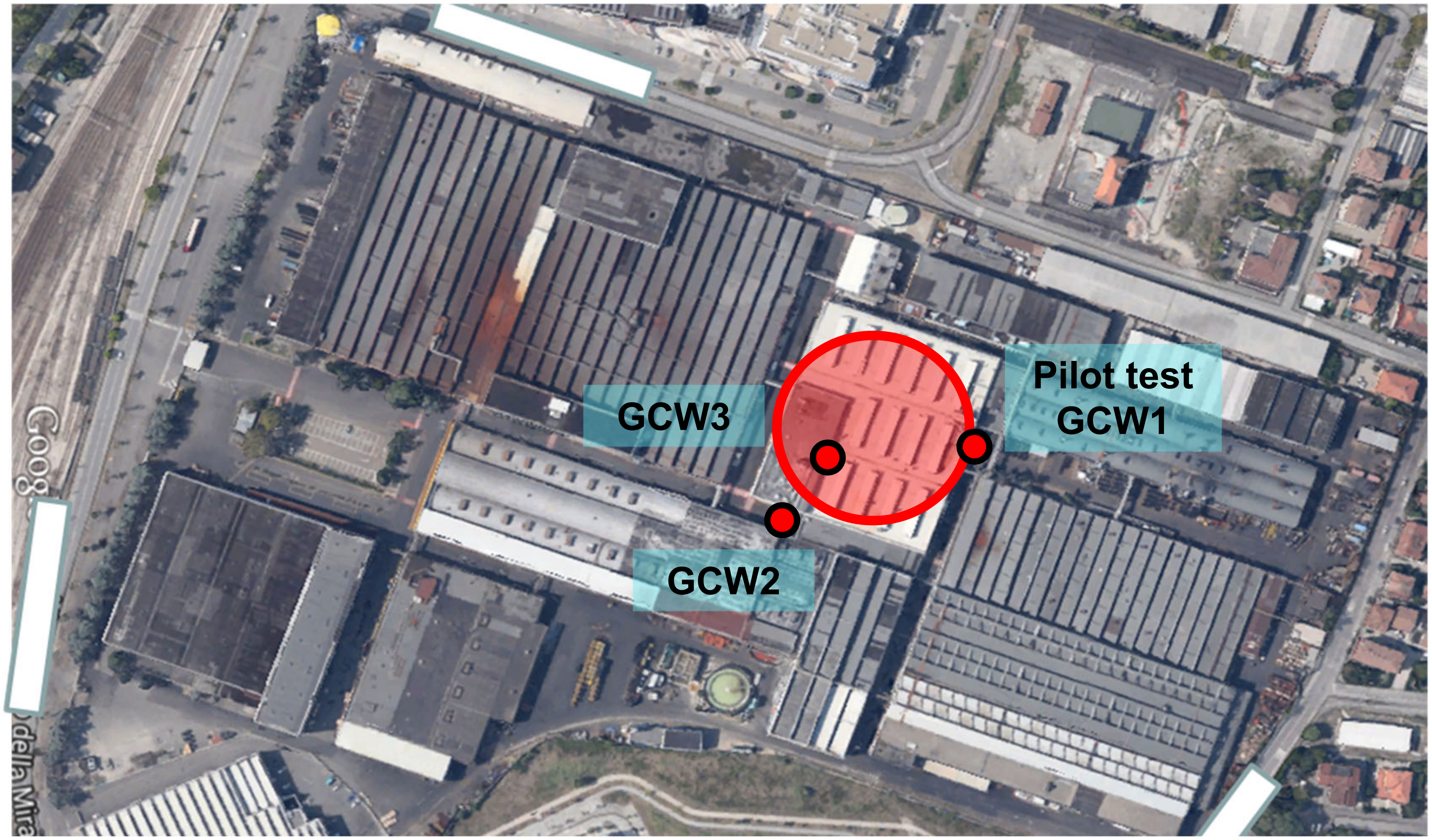

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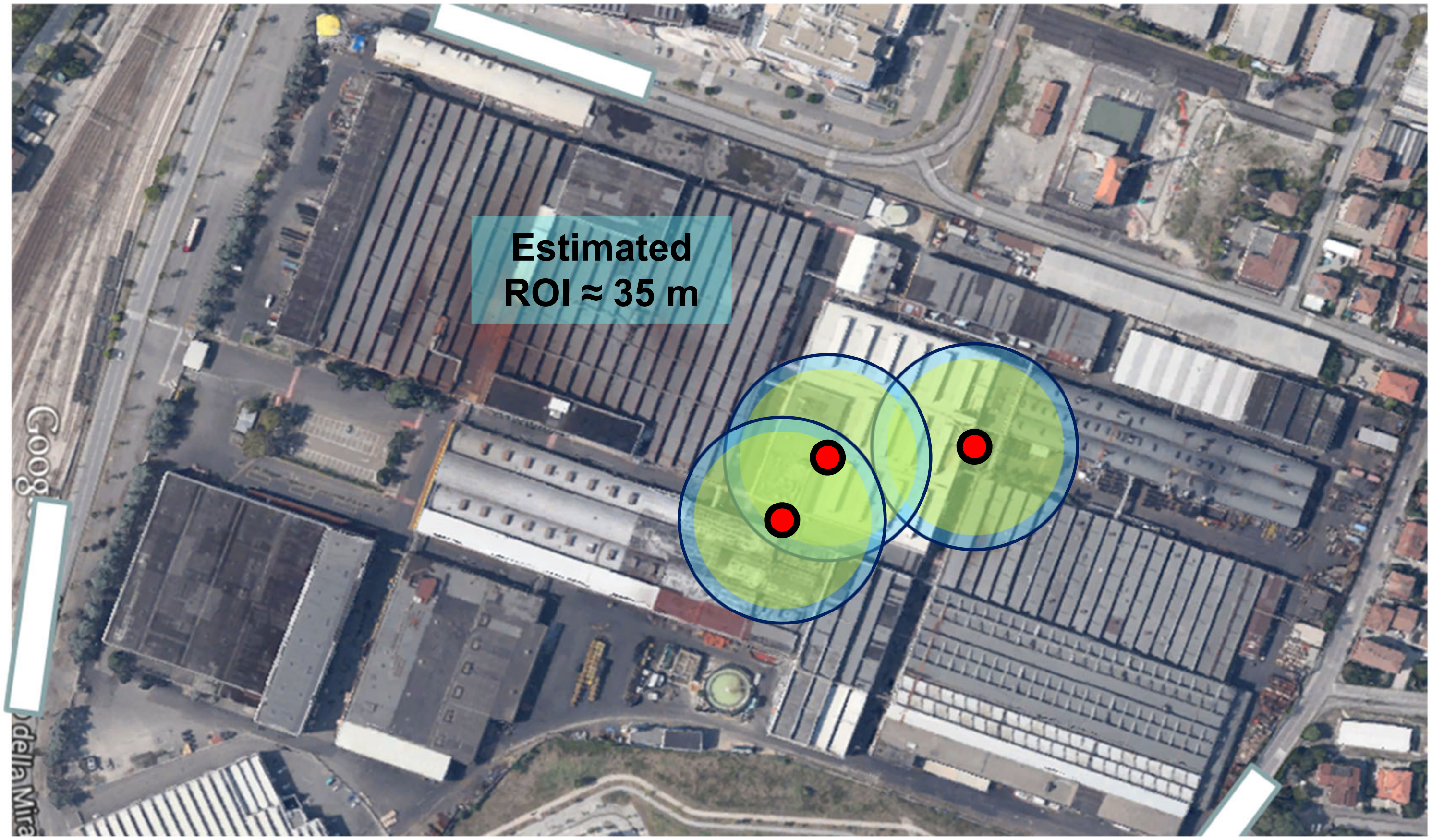

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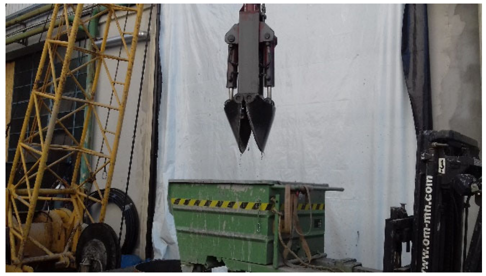

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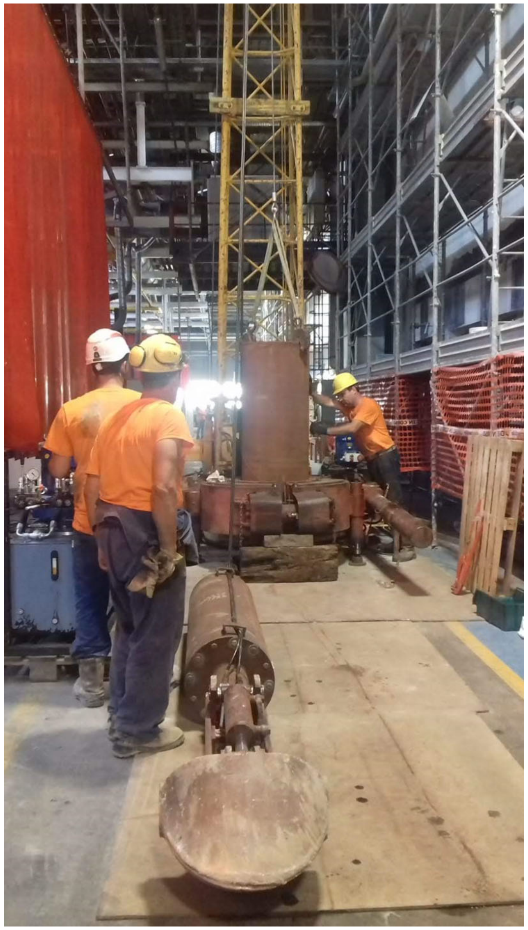

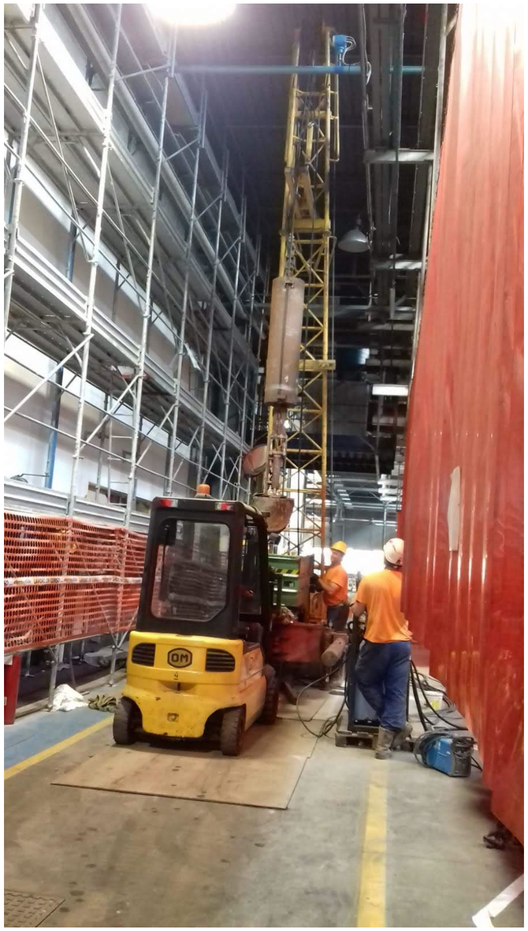

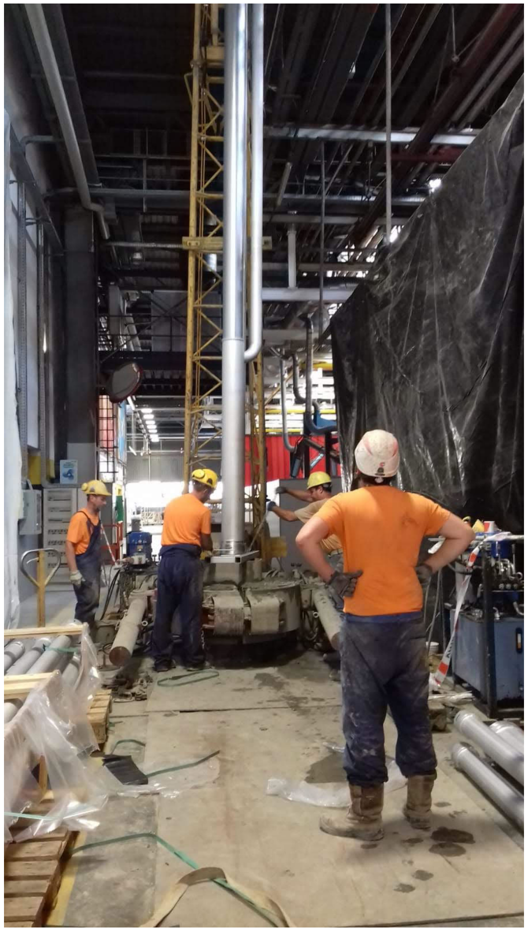

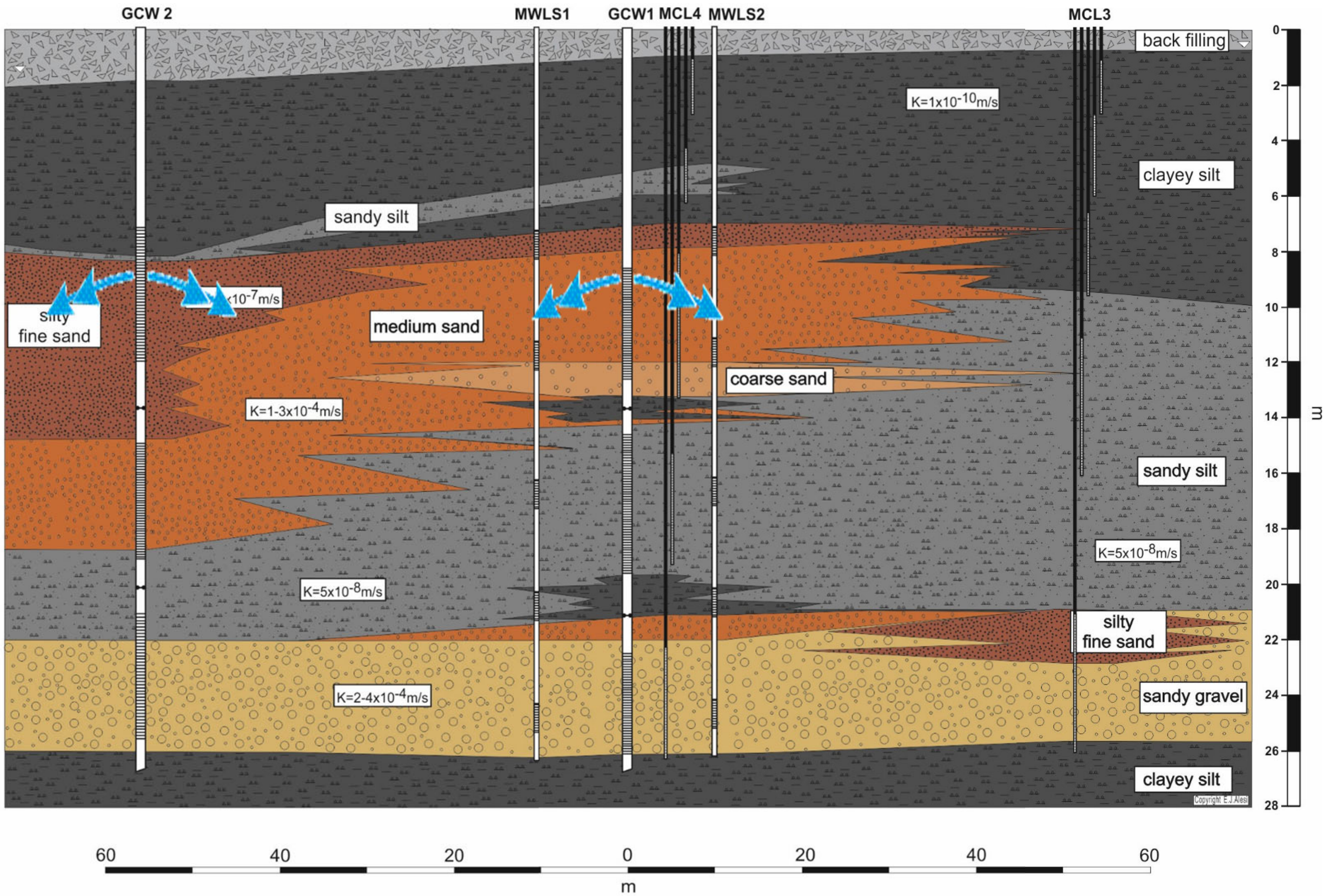

Thanks for your attention