Monitoring enhanced anaerobic bioremediation at contaminated sites in the Netherlands

The use of specific monitoring tools

TNO | Knowledge for business

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- Field characterisation
- Enhanced bioremediation system
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- ??

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Objectives

- Treatment of contaminated area
- Focus on source zone, plume will be treated afterwards
- Use of specific monitoring tools to demonstrate Enhanced Natural Attenuation
  - Hydrogen measurements at the site
  - Compound Specific Stable Isotope Analyses
  - Molecular analyses (DNA)

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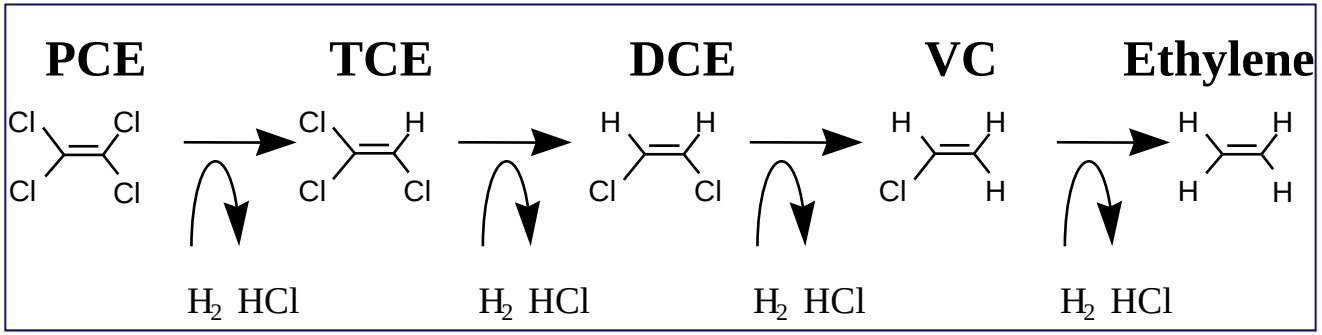
Field characterisation

- Former dry cleaning in the city of the Hague, the Netherlands
- Contamination with PCE from 1975-1983,
  due to leaking sewage system
- At present; mainly DCE and VC



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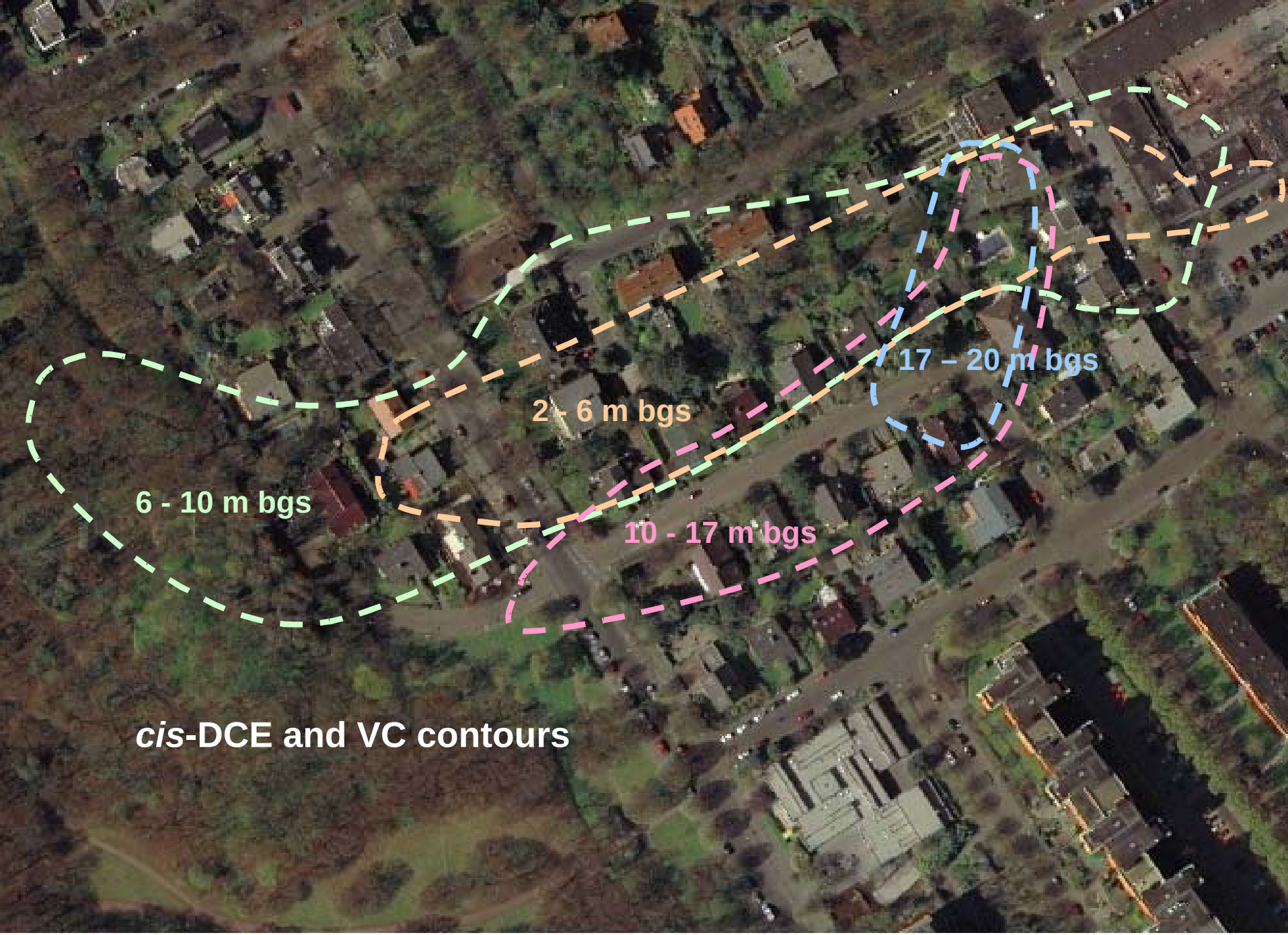
17 – 20 m bgs
2 - 6 m bgs
6 - 10 m bgs
10 - 17 m bgs
cis-DCE and VC contours

Field characterisation

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Field characterisation

Source zone

- Max. concentrations DCE 8,000 µg/l
  VC 5,700 µg/l
- Contaminated soil volume 35,000 m^3

Boundary conditions

- Decrease in groundwater table max 0.3 m NAP (draught damage)
- Reach target value of 2.5 µg/l VC within 10 years

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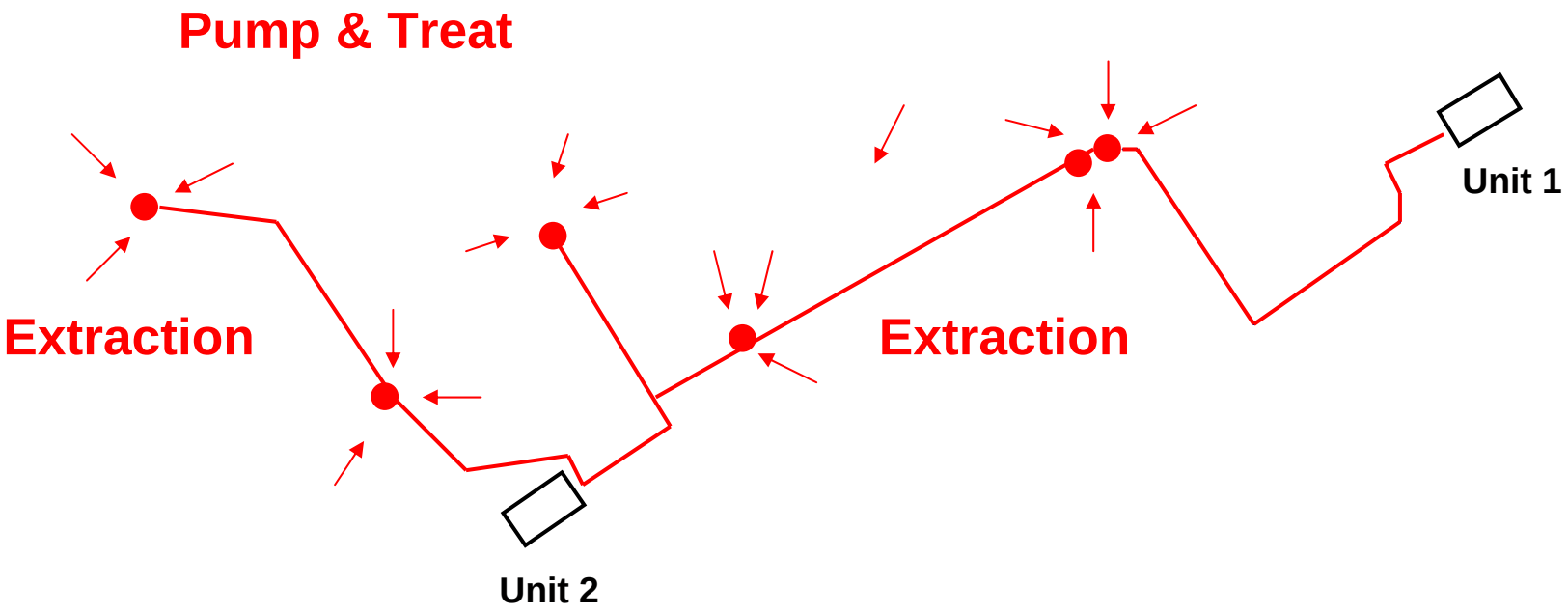
Enhanced bioremediation system



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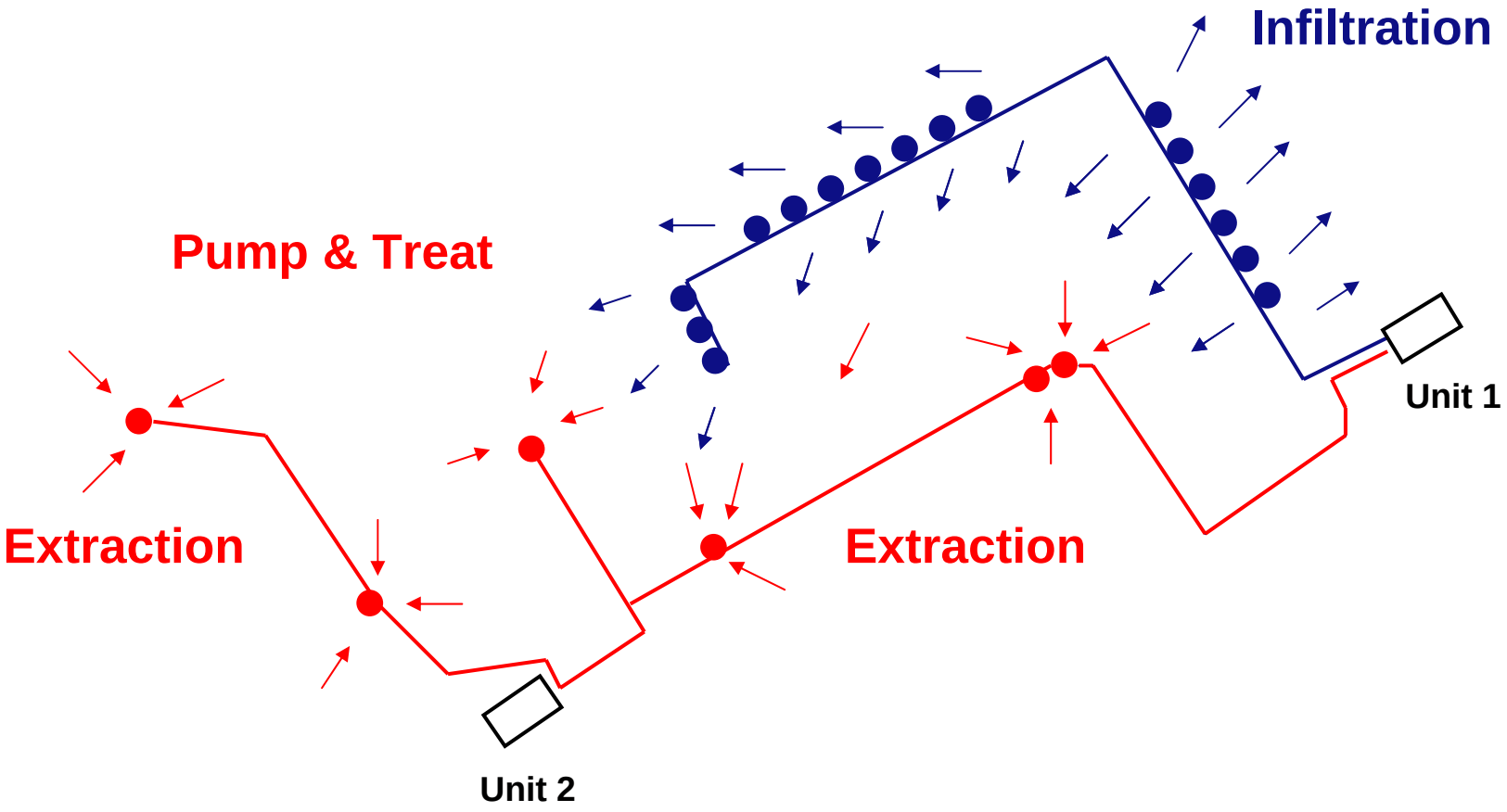
Enhanced bioremediation system



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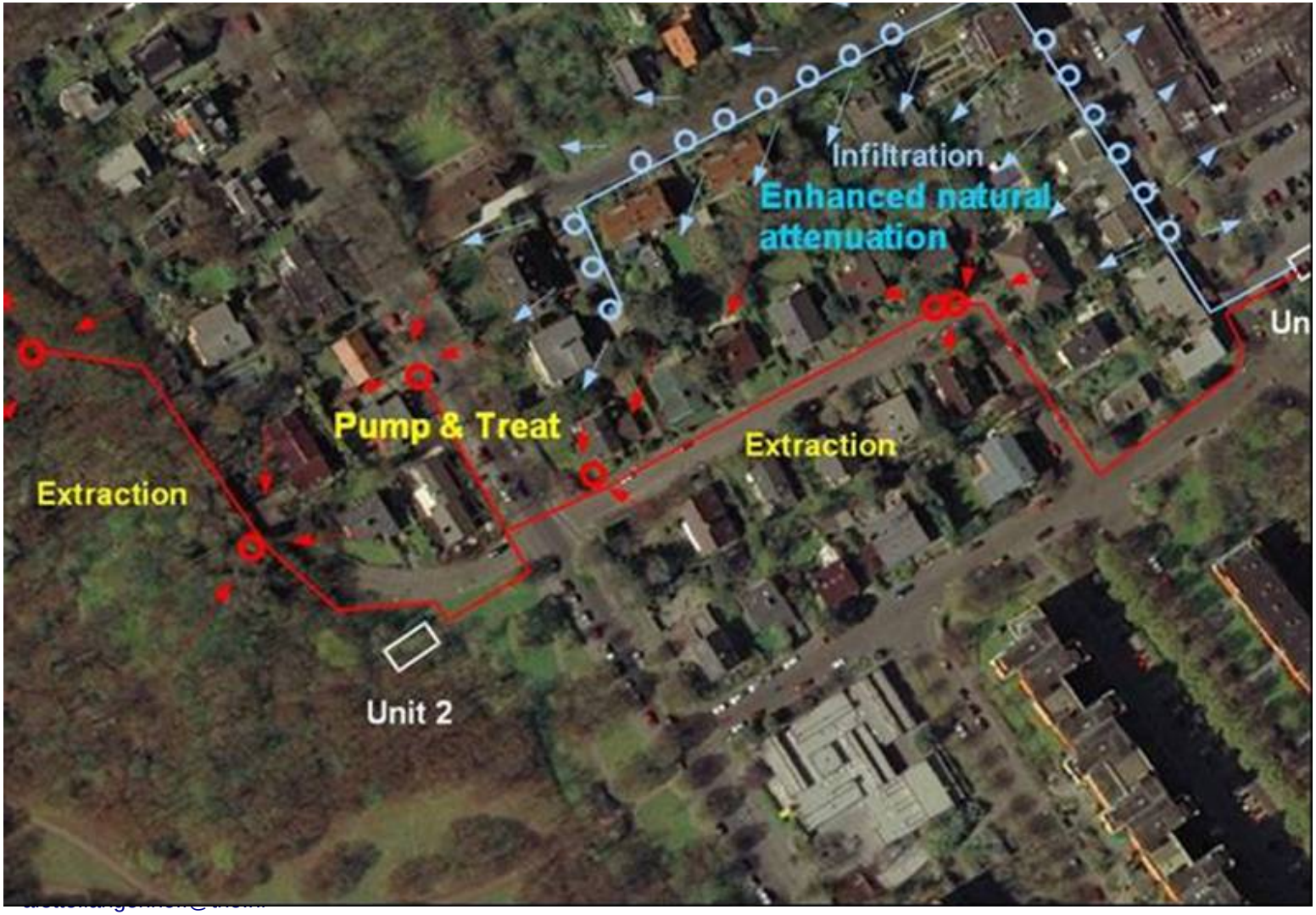
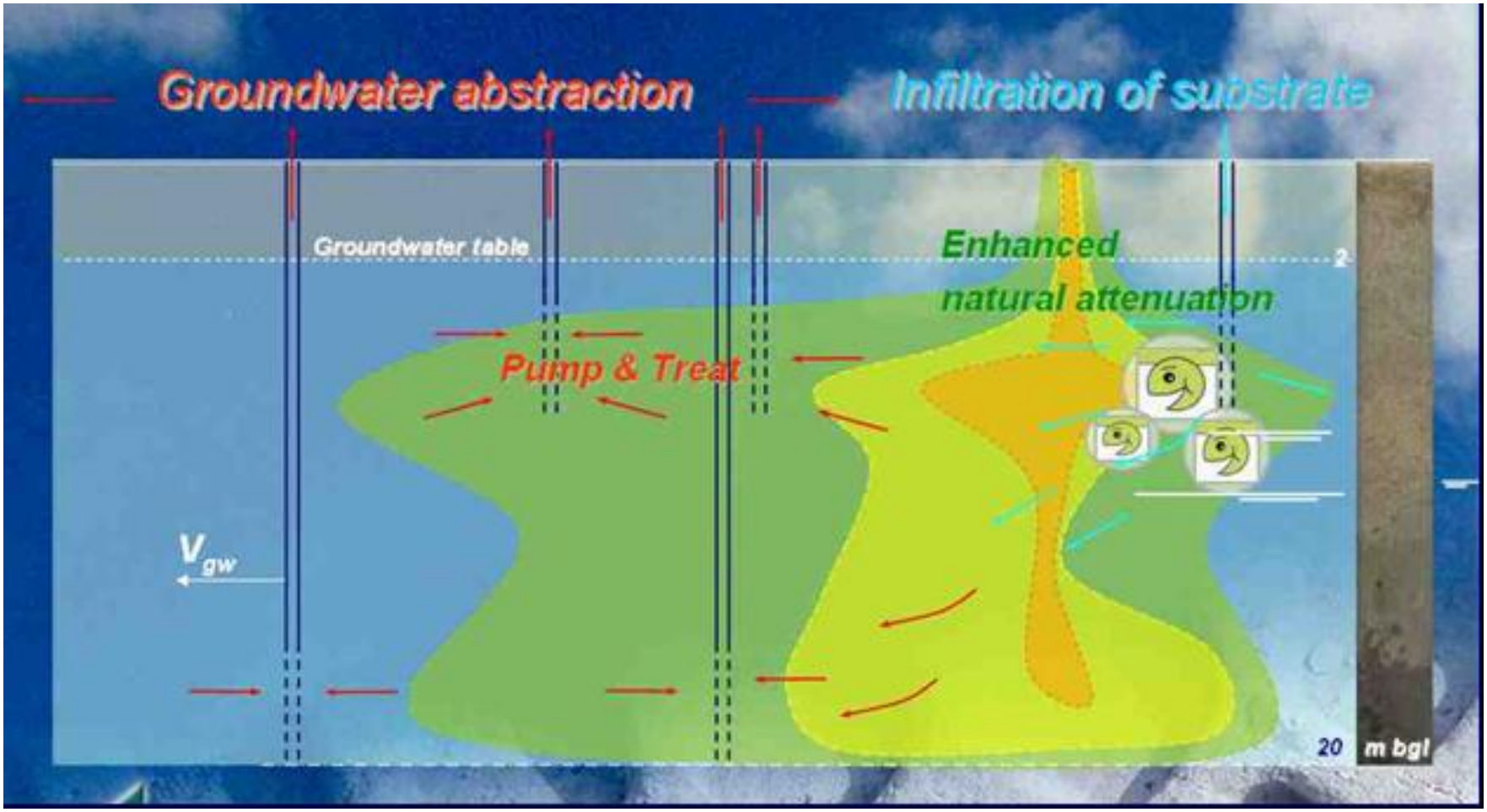
Enhanced bioremediation system



Enhanced bioremediation system



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Enhanced bioremediation system; installation

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Enhanced bioremediation system; installation

Unit 1; Infiltration

Unit 2; Air stripper

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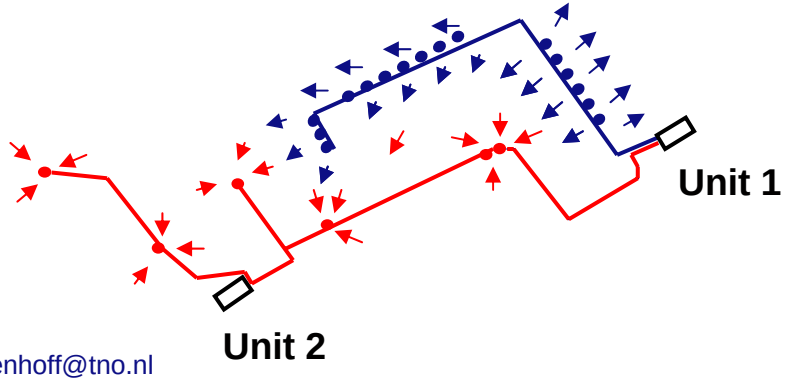
Enhanced bioremediation system; installation

Unit 1; Infiltration



Unit 2; Air stripper

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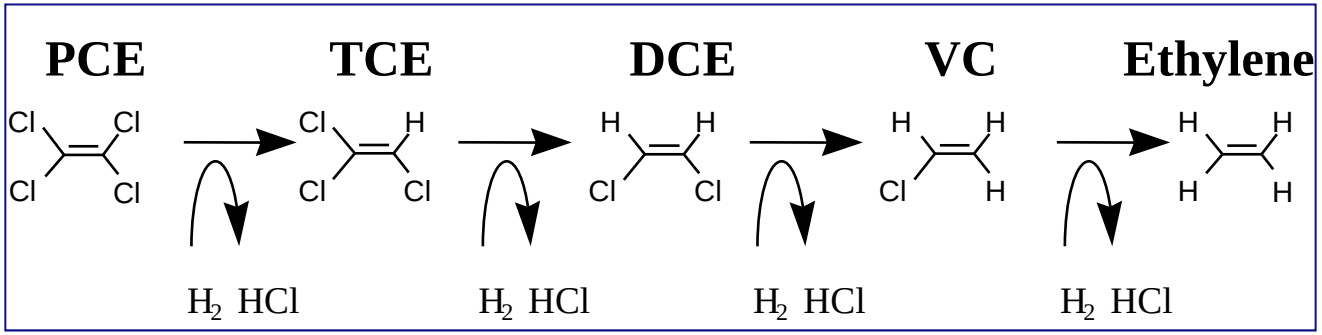
Enhanced bioremediation system

- Combination of Pump & Treat, and Infiltration
- Source zone
- Reductive dechlorination by addition of electron donor
  - Acetic acid
  - Lactic acid



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Field results, source zone

- 22,500 m^3 of groundwater infiltrated during 6 months;
- 19 ton of electron donor added; mix of lactate and acetate (4,500 kg DOC, 185 mg/l)

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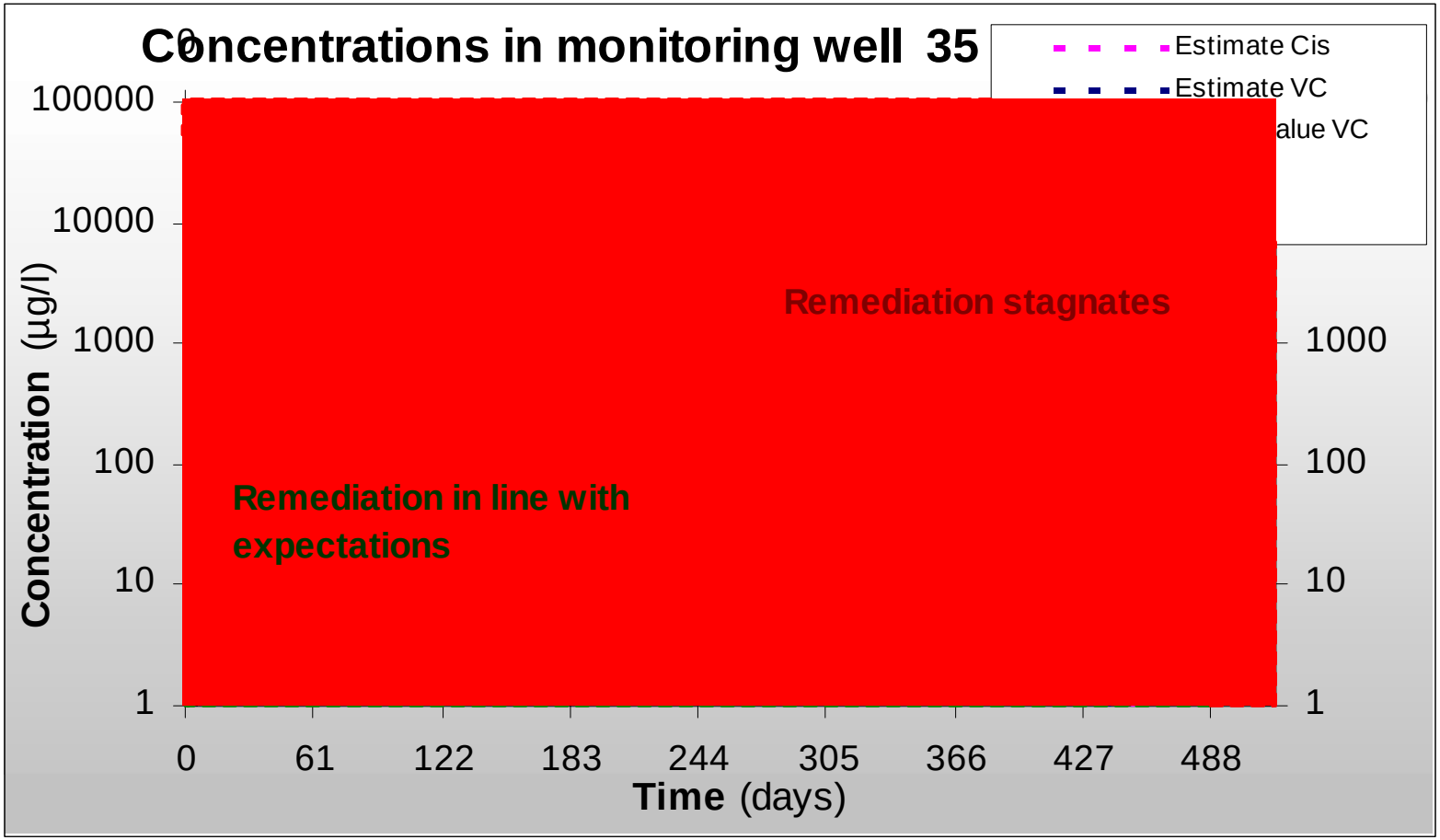
Field results, source zone



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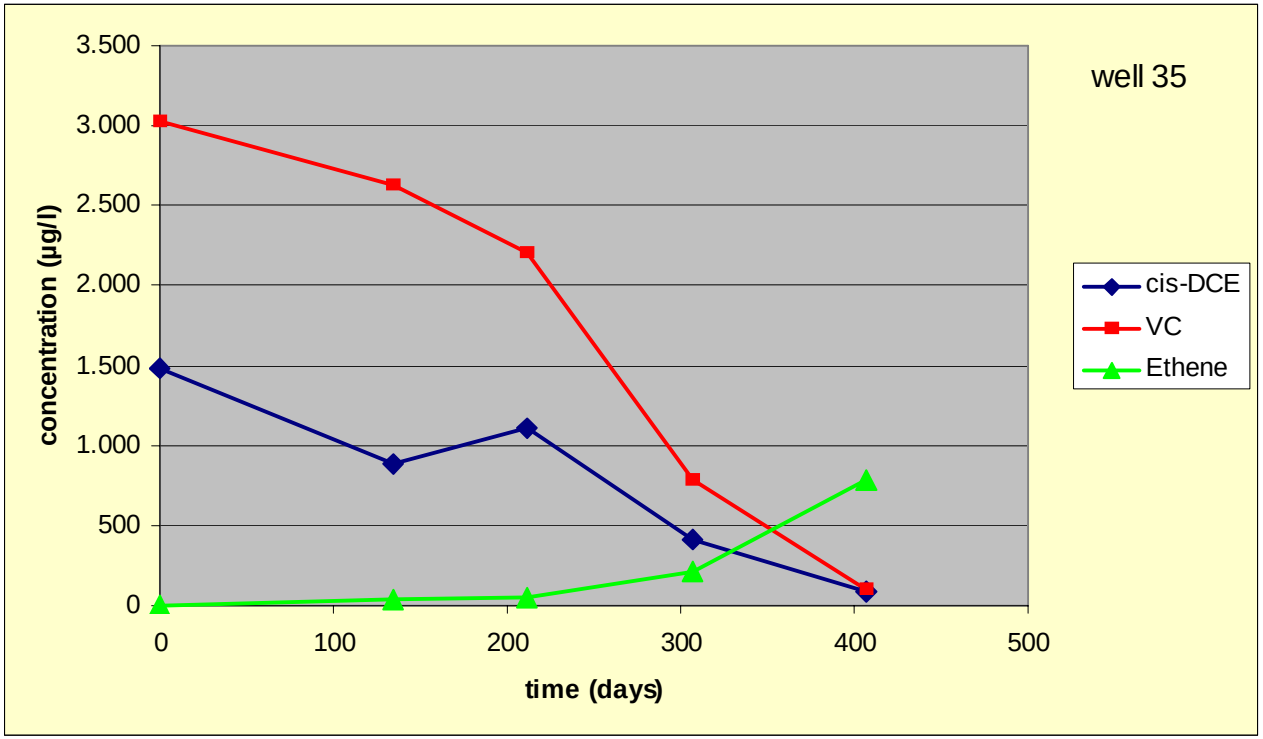
Field results, source



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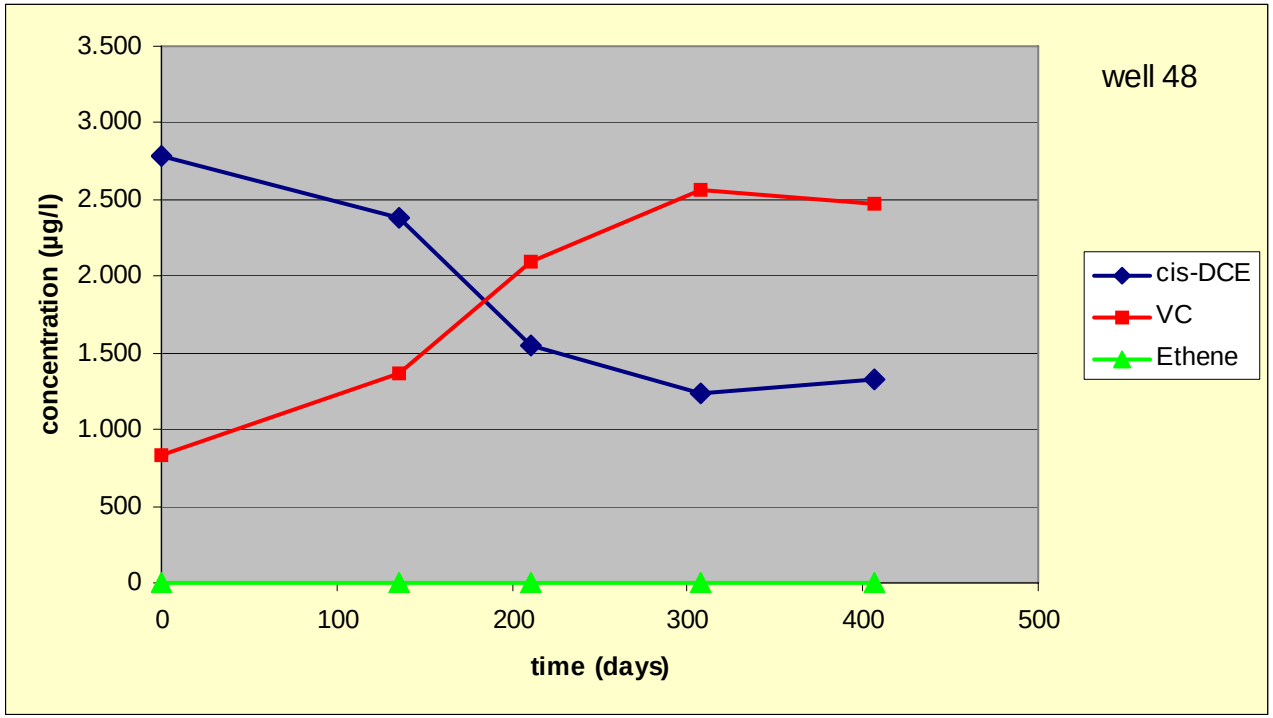
Field results, plume



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Field results, percentage of dechlorination

- Good indication for dechlorination process
- Based on the ratio between parent and daughter compound
- To be calculated as follows (PCE as parent compound)

$$\frac{[TCE]+2[DCE]+3[VC]+4[Ethylene]+4[Ethane]}{4\cdot([PCE]+[TCE]+[DCE]+[VC]+[Ethylene]+[Ethane]}\cdot 100\%$$

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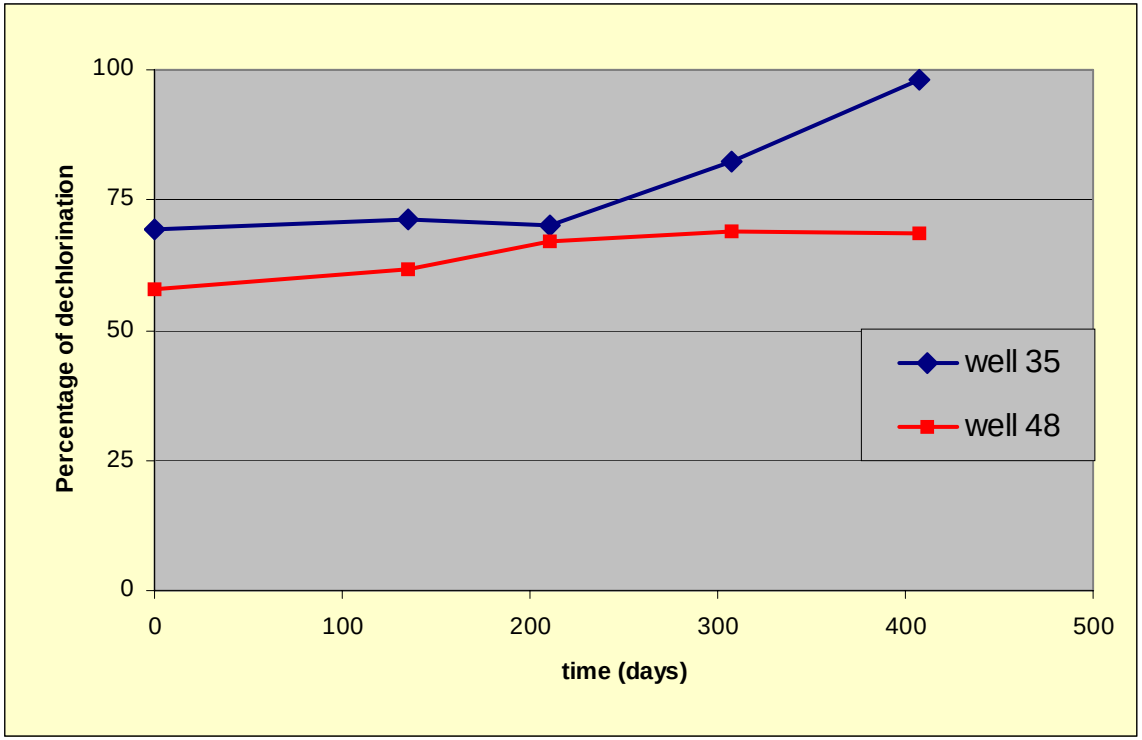
Field results, percentage of dechlorination



$$\frac{[TCE]+2[DCE]+3[VC]+4[Ethylene]+4[Ethane]}{4\cdot([PCE]+[TCE]+[DCE]+[VC]+[Ethylene]+[Ethane]}\cdot 100\%$$

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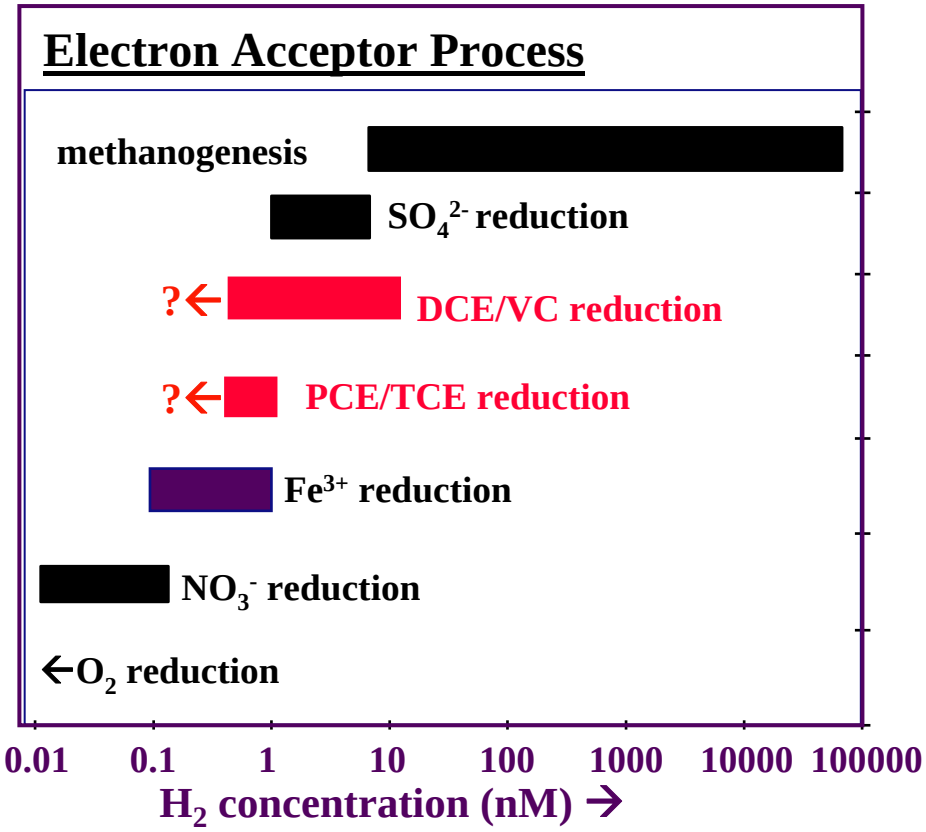
Field results, Hydrogen (H_2)

Conditions suitable for dechlorination?



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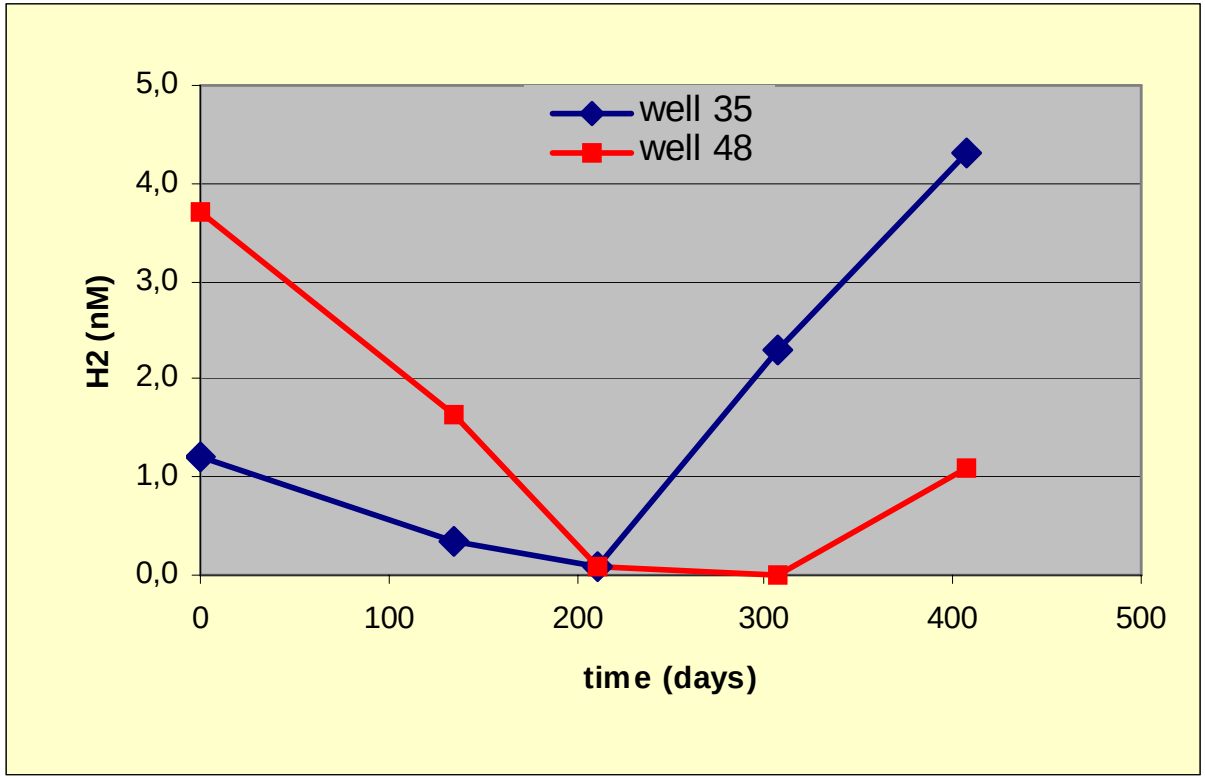
Field results, Hydrogen (H_2)

< 0.1	→	Nitrate reduction
0,2 to 0,8	→	Fe(III)-reduction
1 to 4	→	Sulphate reduction
➢ 1	→	Reductive dechlorination
5 to 20	→	Methanogeneses



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Compound specific stable isotope analyses

- Which isotopes ?
  - Mainly $^{12}C/^{13}C$ and $^{37}Cl/^{35}Cl$
  - Other elements: S, O
- Why ?
  - Biological degradation; light isotope faster
    Enrichment of ^{13}C -isotopes in residual parent compound (decrease in $\delta^{13}C$)
  - Dilution, adsorption and transport; no preference

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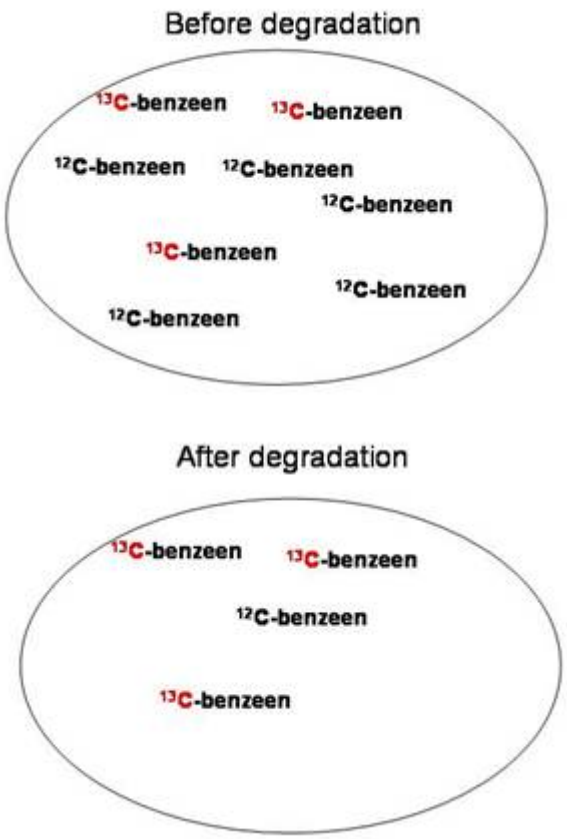
Compound specific stable isotope analyses

- Biological degradation; light isotope faster
- Volatilisation; light isotope faster
- Dilution, adsorption & transport; no effect



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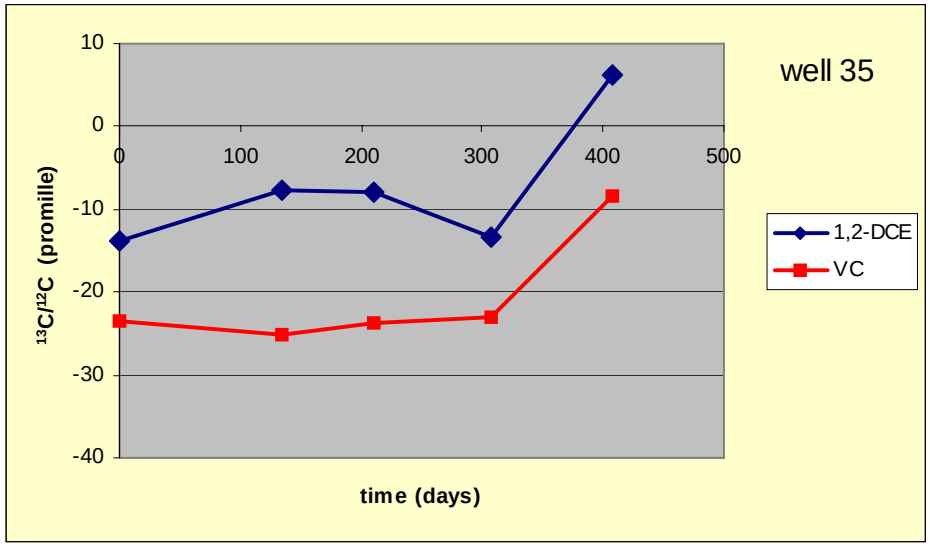
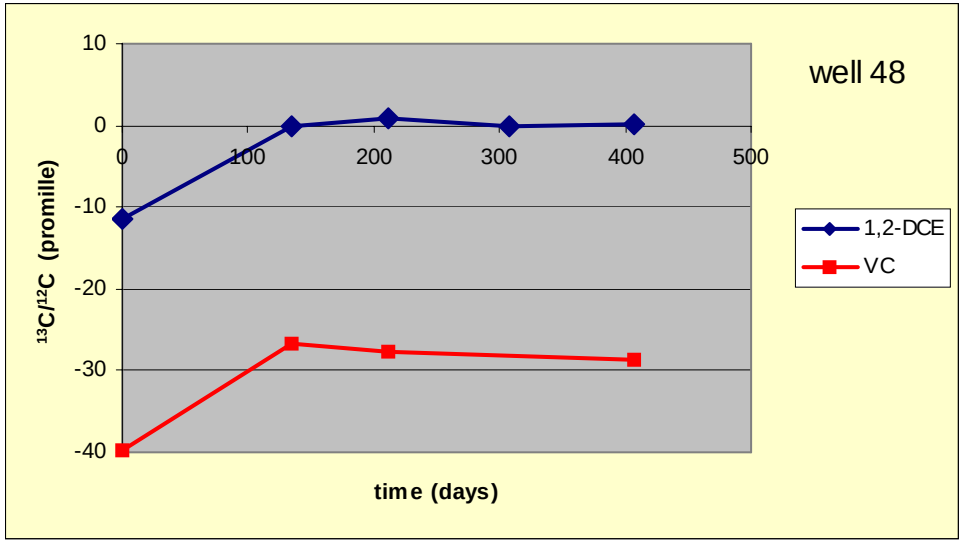
Field results, Stable isotope analyses





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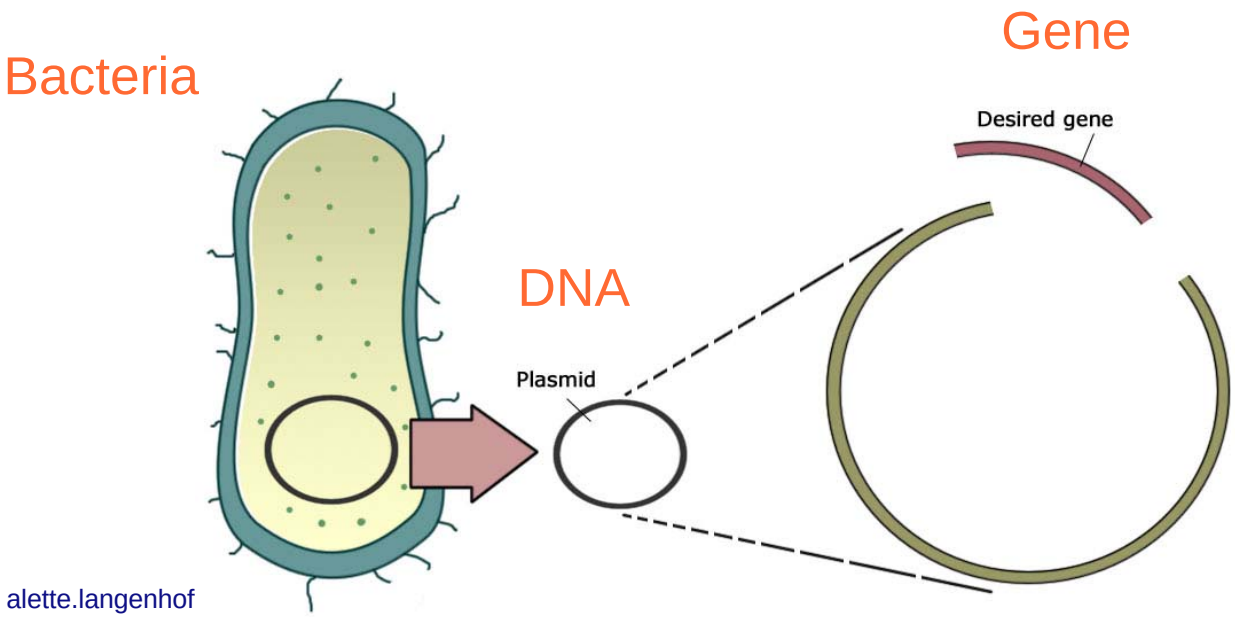
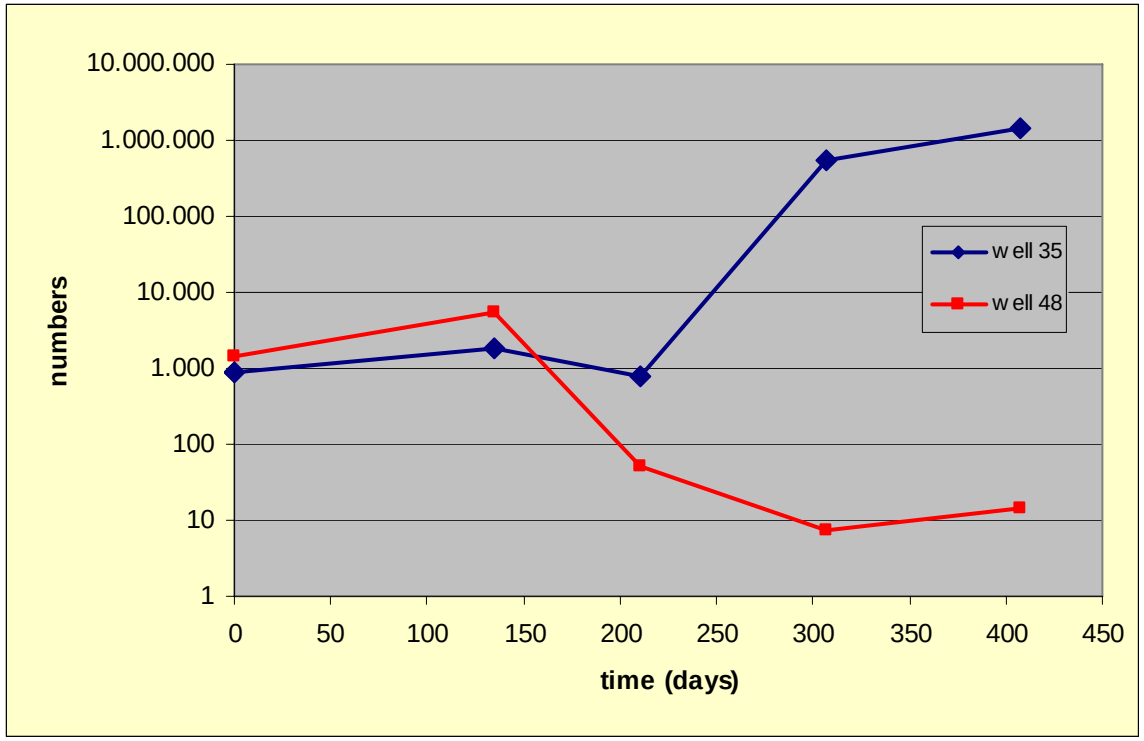
Field results, DNA analyses (molecular detection)

- Detection on molecular level (e.g. DNA or RNA)
- Detection based on specific genes
- Gene: “part of DNA with information of a specific capacity”
  e.g. an enzyme or a type of bacteria



Field results, DNA analyses
Dehalococcoides ethenogenes



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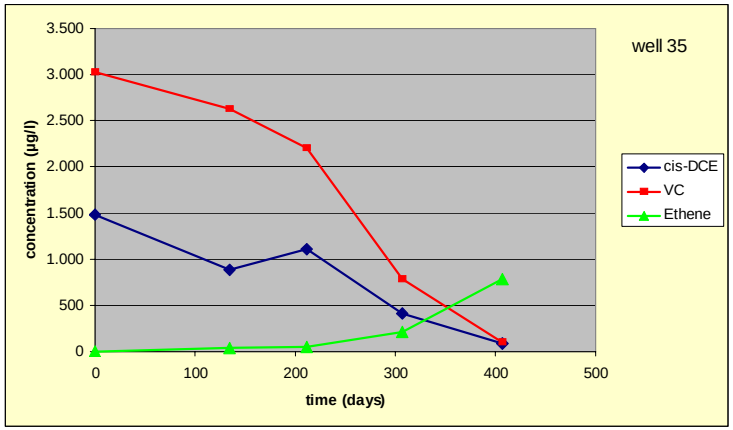
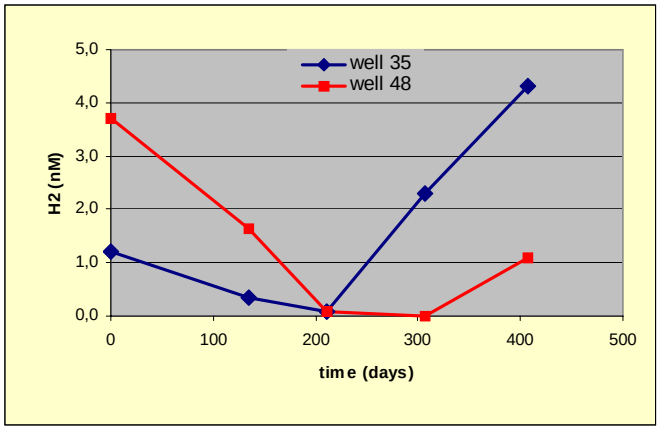
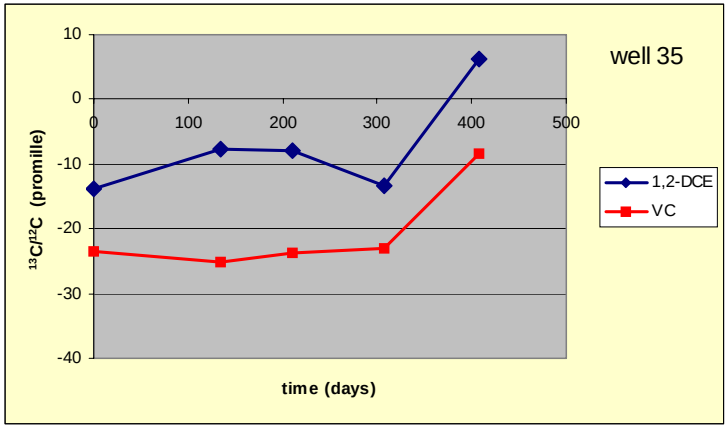
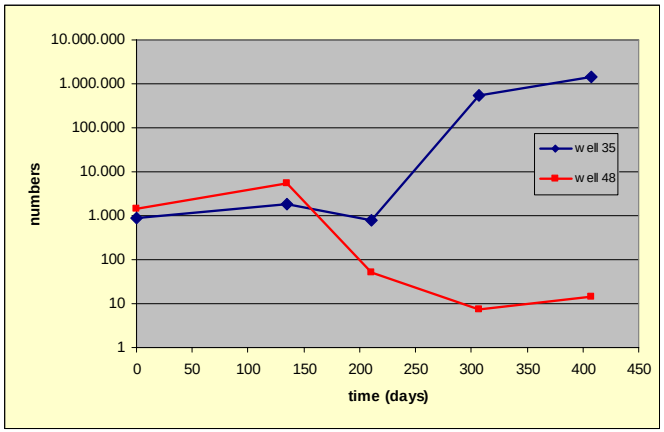
Field results, source









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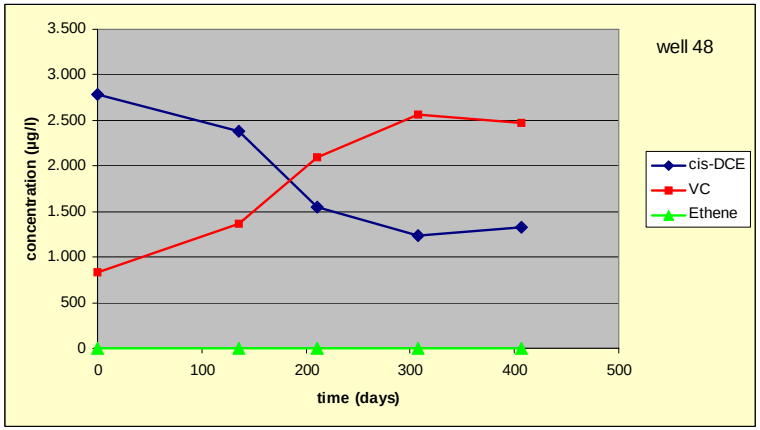
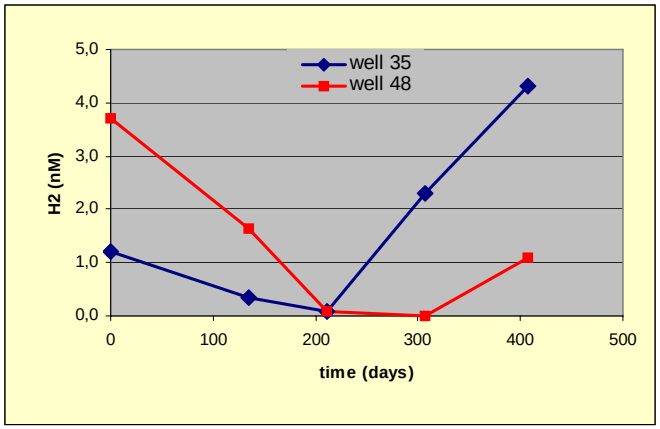
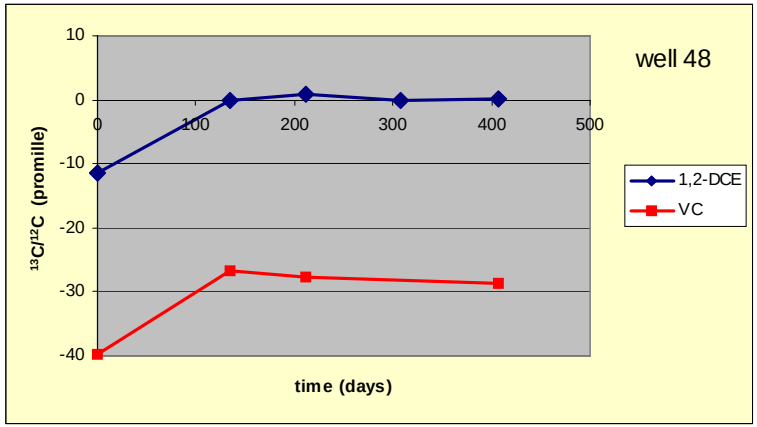
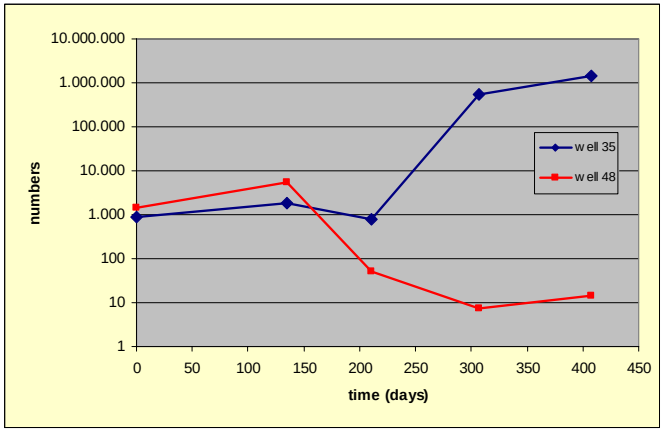
Field results, plume









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Conclusions

System operation:

- Successful infiltration of substrate without clogging (22,500 m^3, 4,500 kg DOC, 185 mg/l)
- Adapted extraction regime, due to restricted groundwater levels and other groundwater extractions in the area;
- Flexible infiltration/extraction regime needed;
- Spreading of electron donor in source zone, except deeper layer in plume.

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Conclusions

<u>Dechlorination takes place in source zone</u>:

- Significant decreases in concentrations of *cis*-DCE (1,485 to 98 µg/l) and VC (3,021 to 55 µg/l);
- Suitable conditions for dechlorination ($0.9 < H_2 < 10.2$ nM and DOC 126 to 170 mg/l);
- Fractionation of *cis*-DCE and VC, 20 and 15 promille;
- Increase of *Dehalococcoides ethenogenes* ($> 10^6$).

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Conclusions

<u>Dechlorination less profound in plume</u>

Initially pump and treat, followed by dechlorination

- Concentrations decrease slightly;
- Major concentrations in deeper aquifer (> 8 m bgs);
- Minor increase of H_2 concentrations (1.1 nM);
- Initial fractionation of *cis*-DCE and VC; but no further fractionation between day 100 – 400
- Decrease of *Dehalococcoides ethenogenes* since start (< 10^3).

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