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Bioremediation of areas polluted with chlorinated and non-chlorinated hydrocarbons

TNO Built Environment and Geosciences

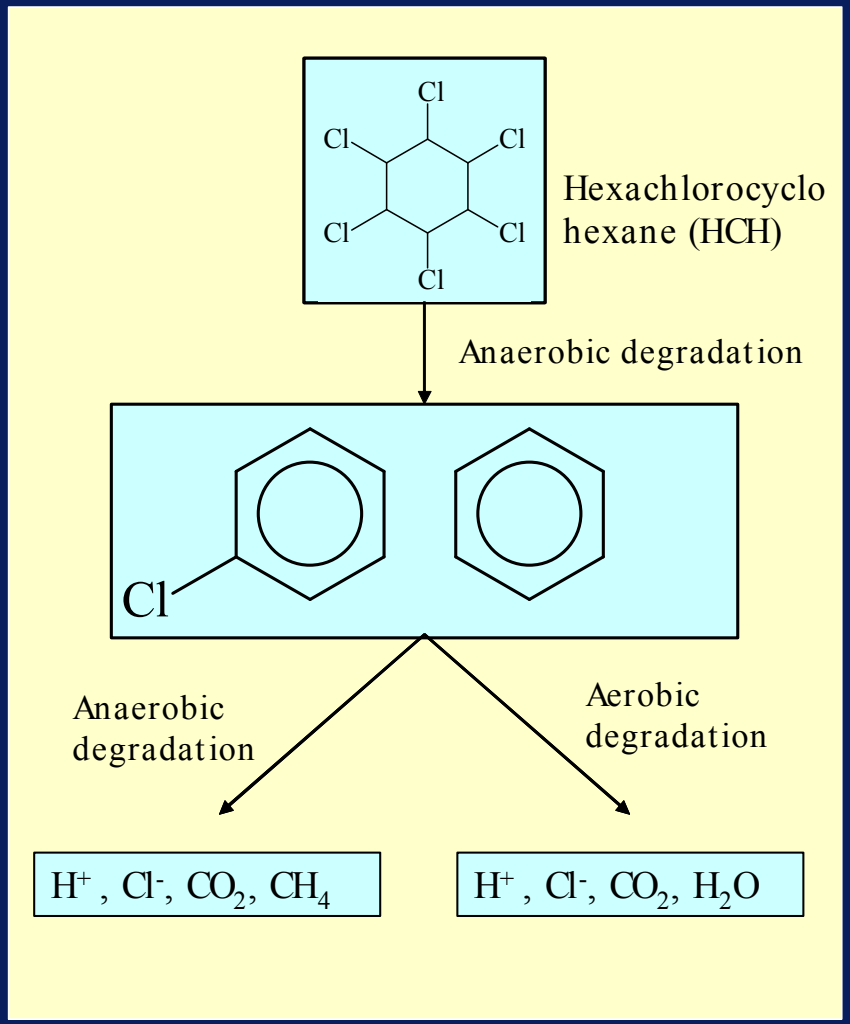
Bioremediation at various Dutch sites

1. Stimulated HCH degradation
2. Stimulated benzene degradation
3. Natural attenuation at interface groundwater – surfacewater

1. Stimulated *in situ* biodegradation of HCH at an industrial site

- Field characterisation
- Batch experiments
- Design and implementation bioscreen
- Infiltration
- Results
- Conclusions

Degradation pathways

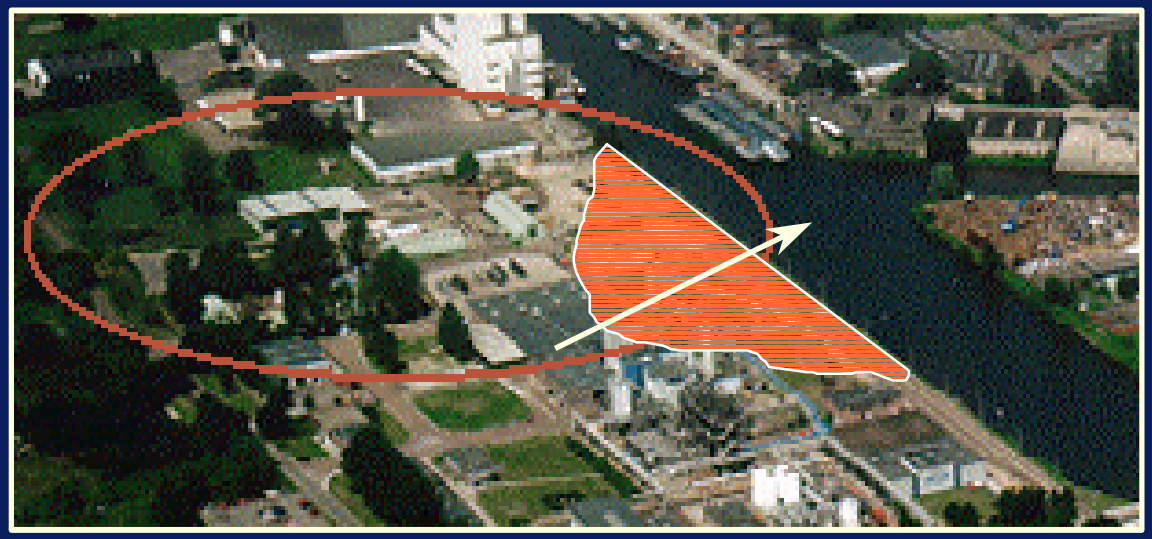


Middeldorp, 1996, ES&T

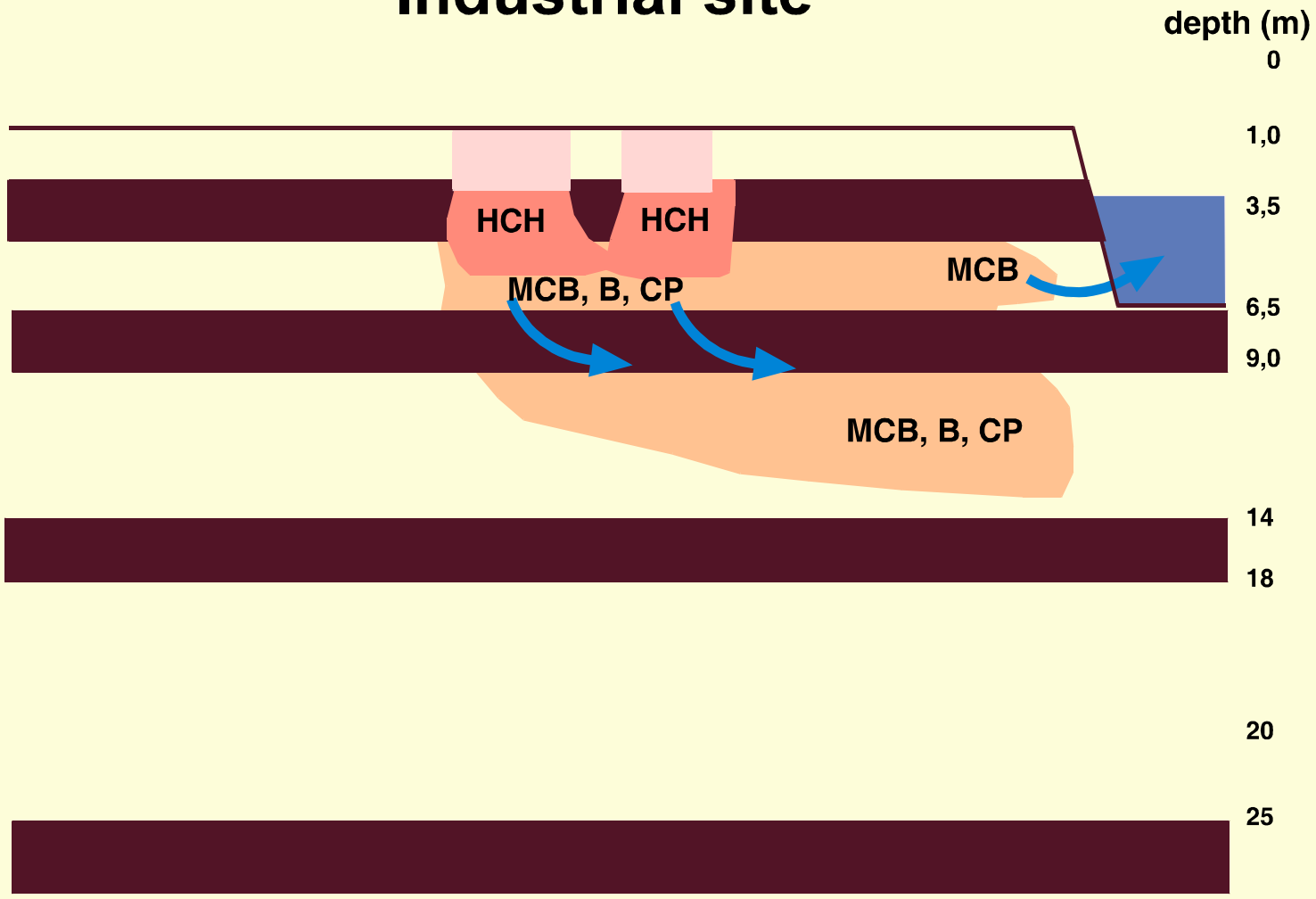
Van Eekert, 1998, ES&T

Industrial site

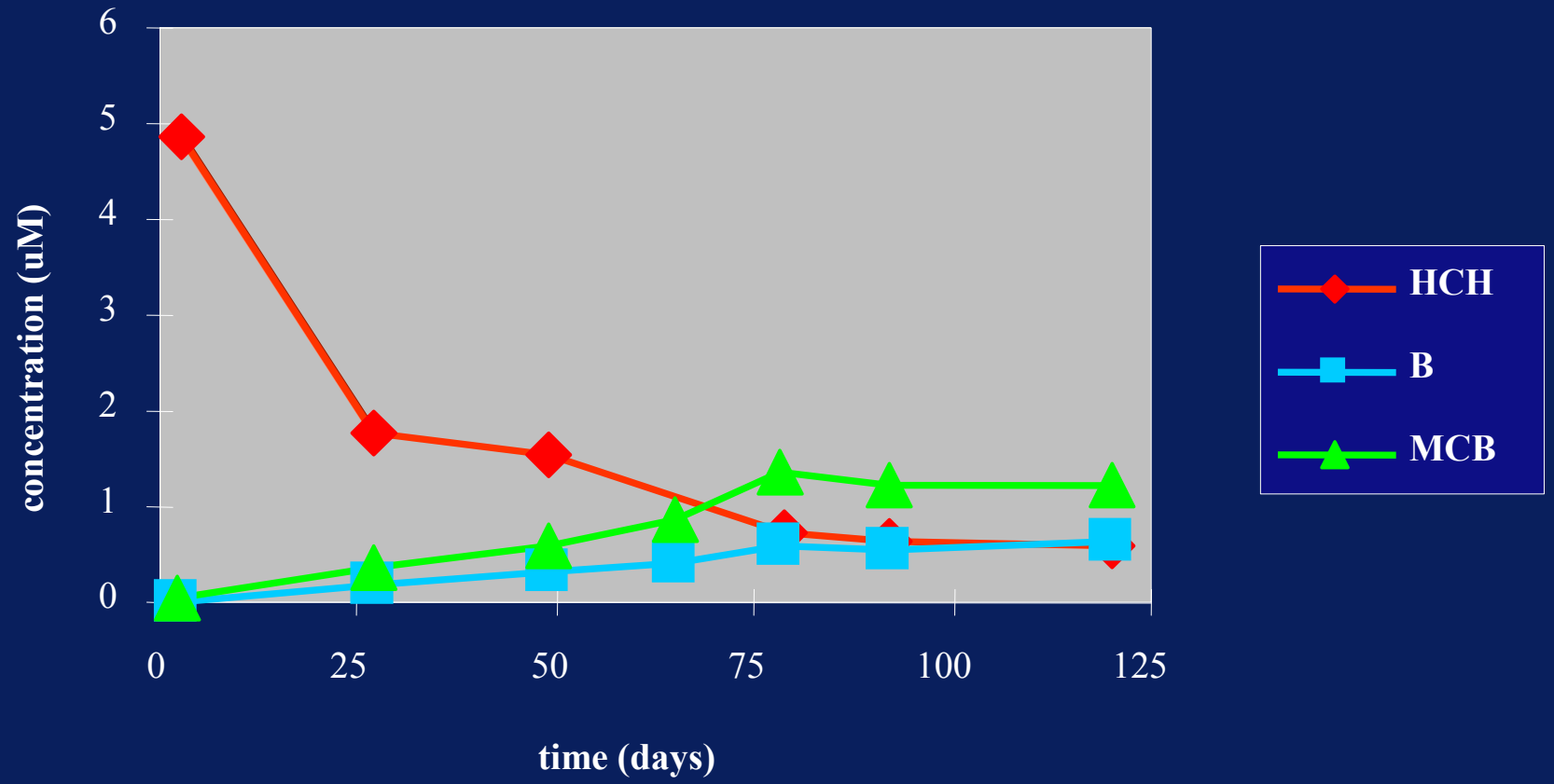
- Site description
  - industrial site situated near canal
  - contaminants: hexachlorocyclohexane (HCH, lindane)
    monochlorobenzene (MCB), benzene (B)
  - >250 m plume up to depth of 18 m



Industrial site

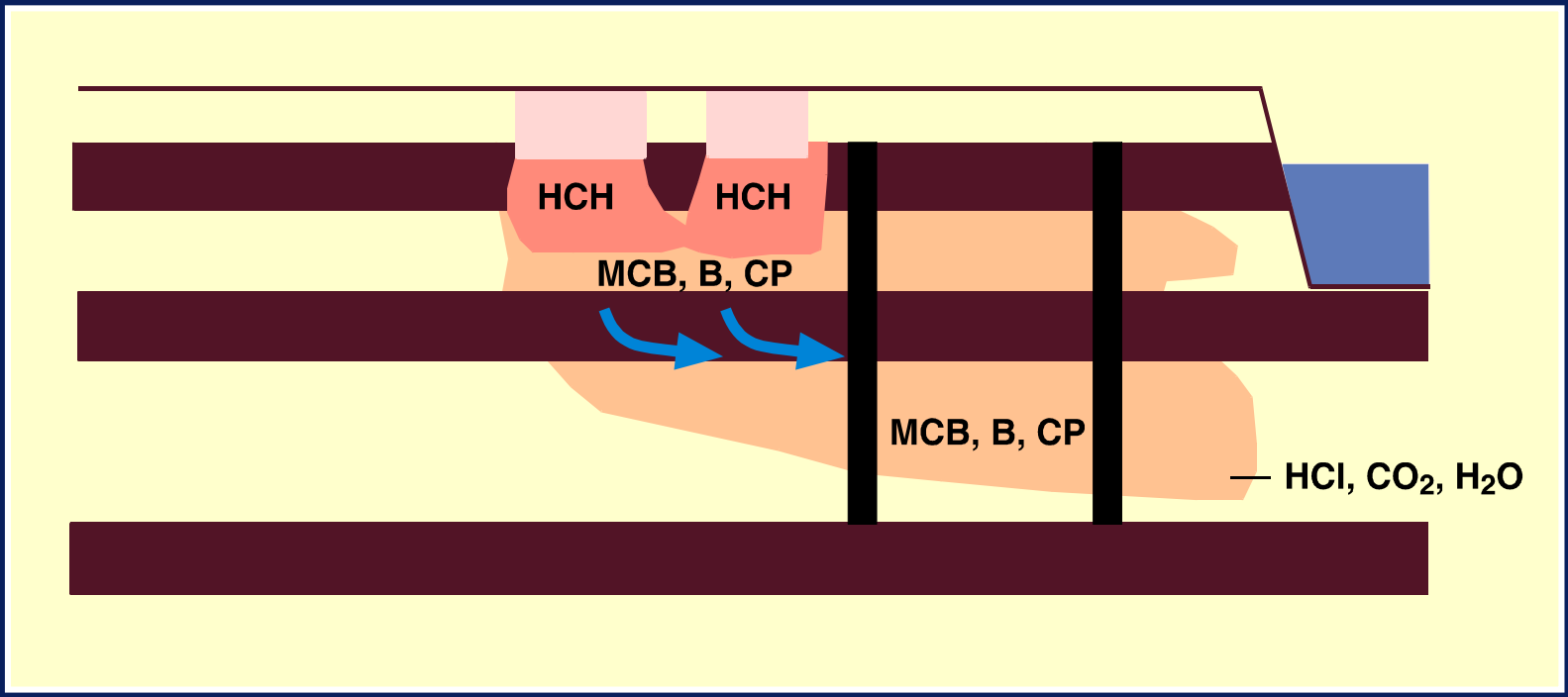


Anaerobic HCH degradation



Industrial site

2 bioscreens: anaerobic and aerobic



Implementation at Industrial Site

Redevelopment of site :

Building of Container terminal

Implementation of bioremediation system :

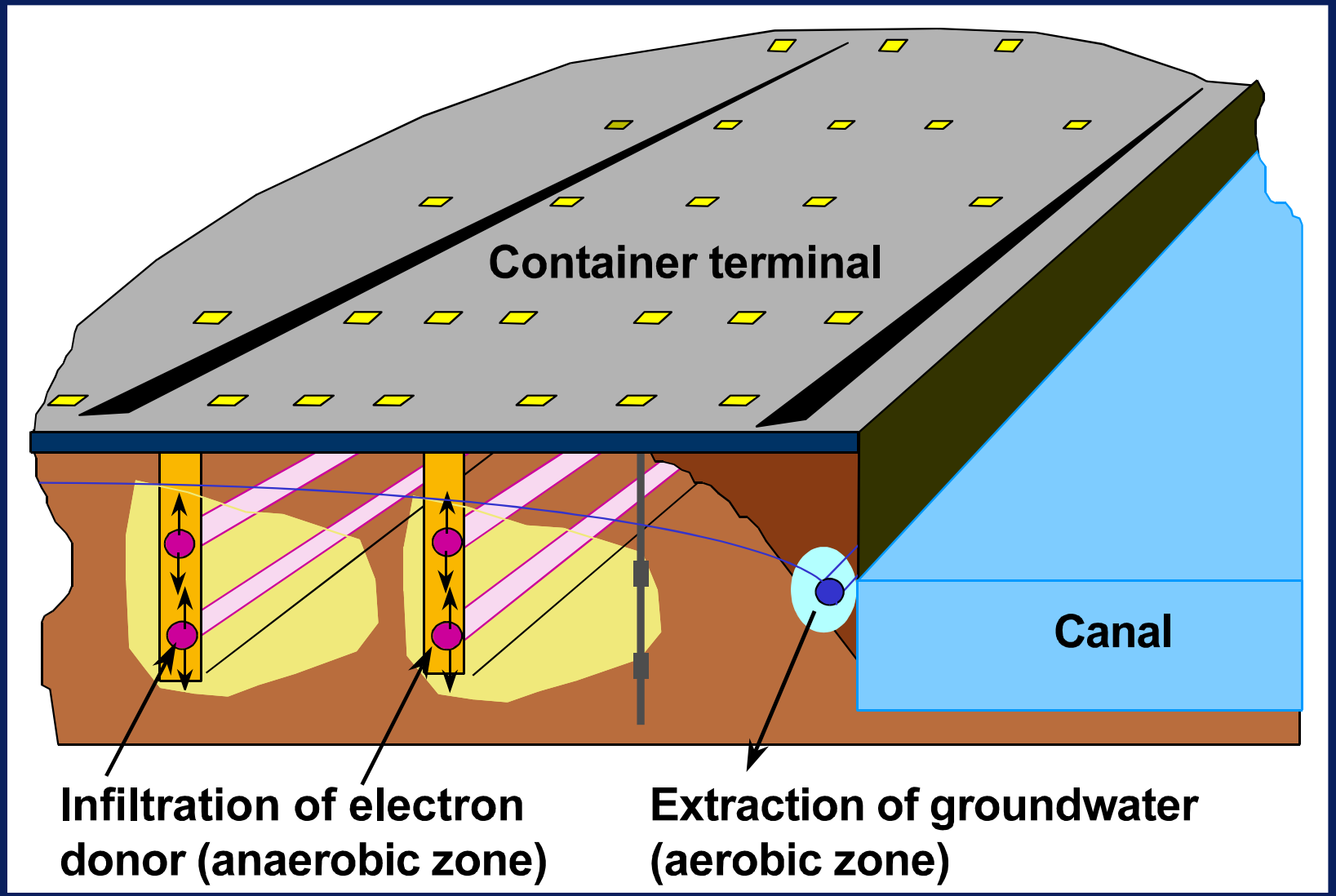
Anaerobic phase

Aerobic phase

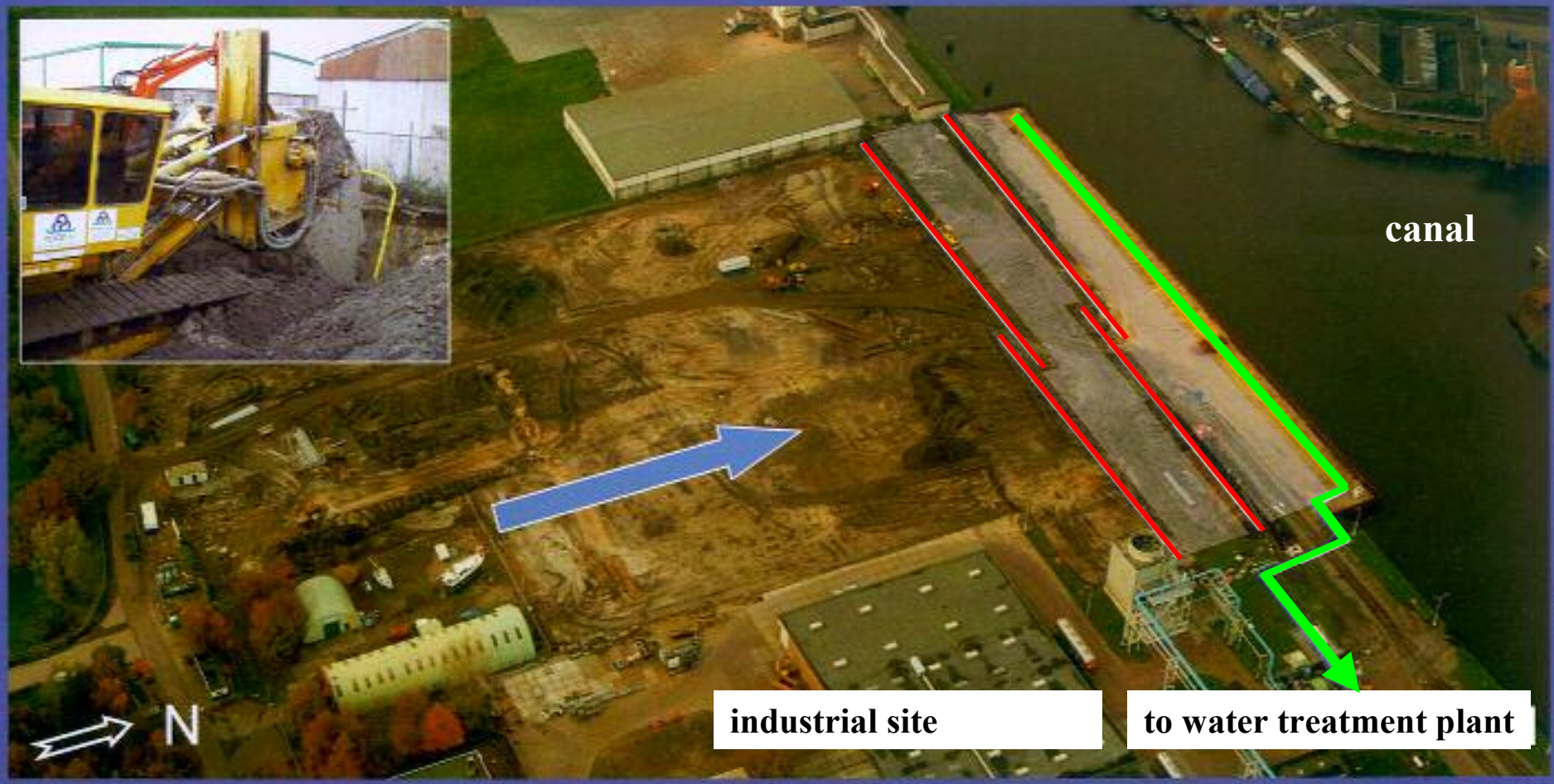
Phases

- System design
- Installation of system
- Analyses of starting point (before injection)
- 0 to 6 months: Geohydrological characterisation with tracer injection and conductivity measurements
- 7 to 24 months: Infiltration of electron donor and monitoring
- Evaluation pilot

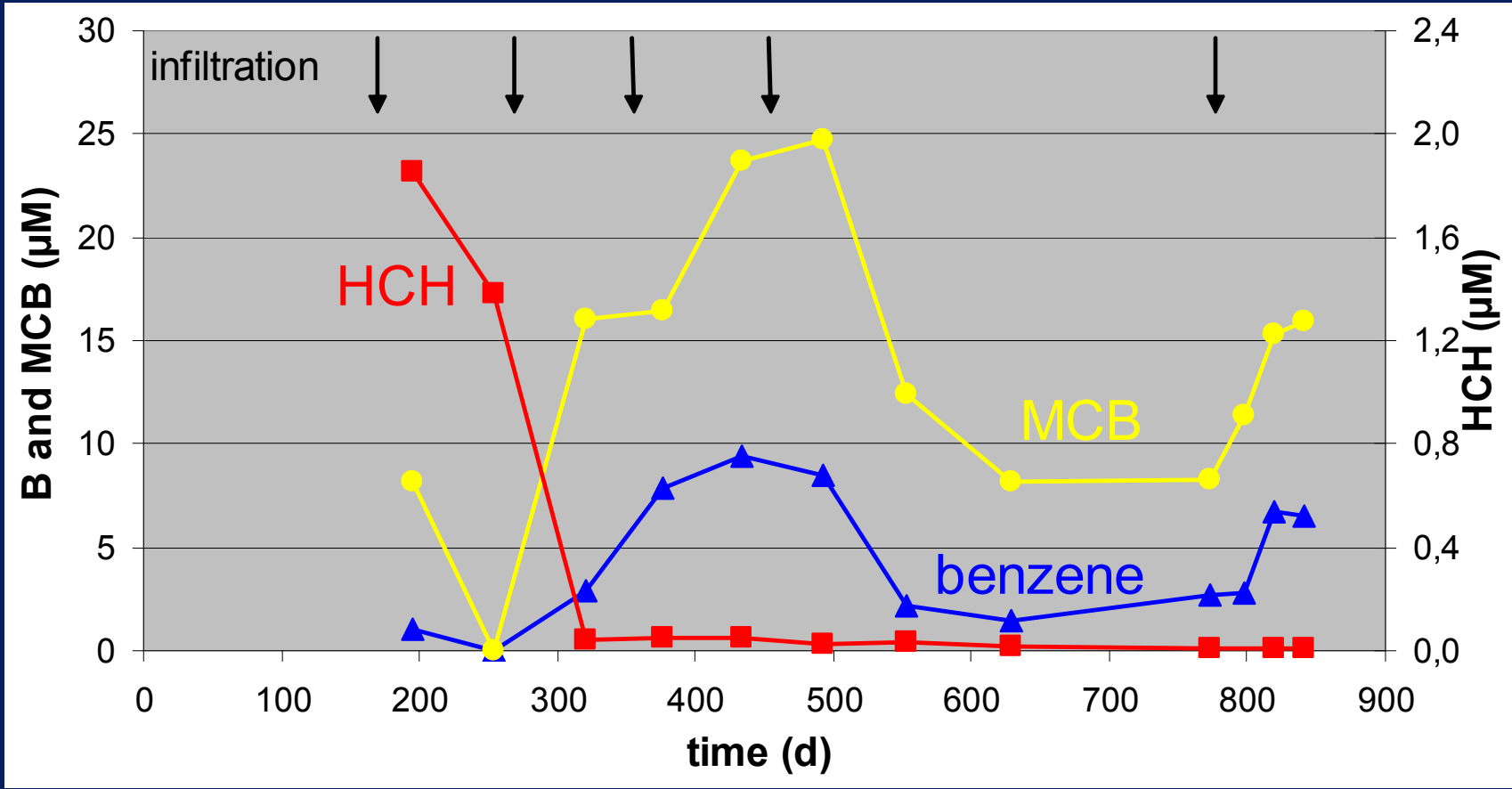
Industrial Site, cross section



Installation of system Top view



Concentrations in well 24-2

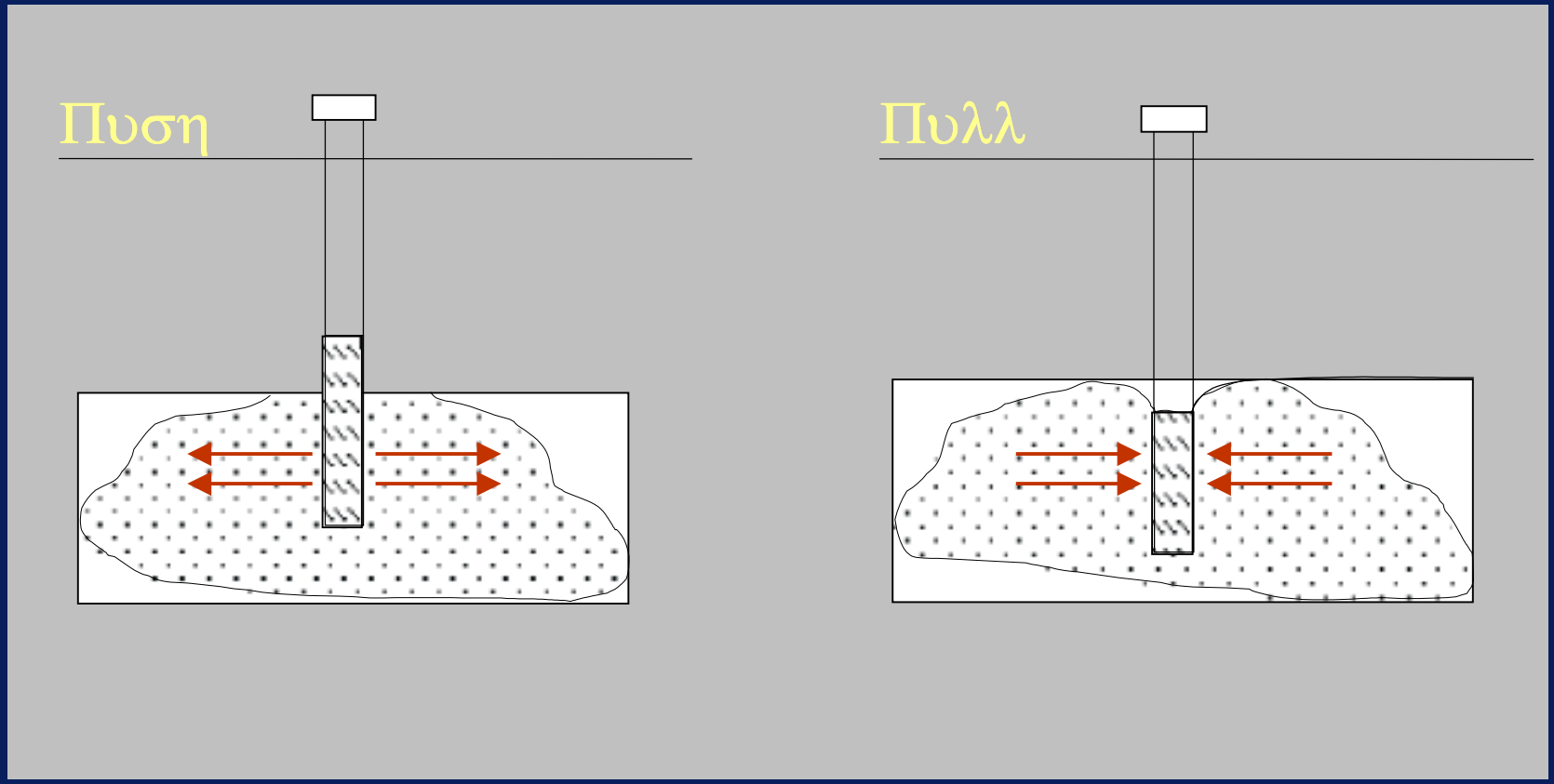



C.T.T.

Conclusions HCH study

- Complete degradation HCH feasible
- First performed and successful HCH field study
- Perspective biological treatment
  - intrinsic and stimulated degradation
  - combination anaerobic / aerobic stimulation
  - translation to other contaminated sites
- Successful combination bioremediation and redevelopment

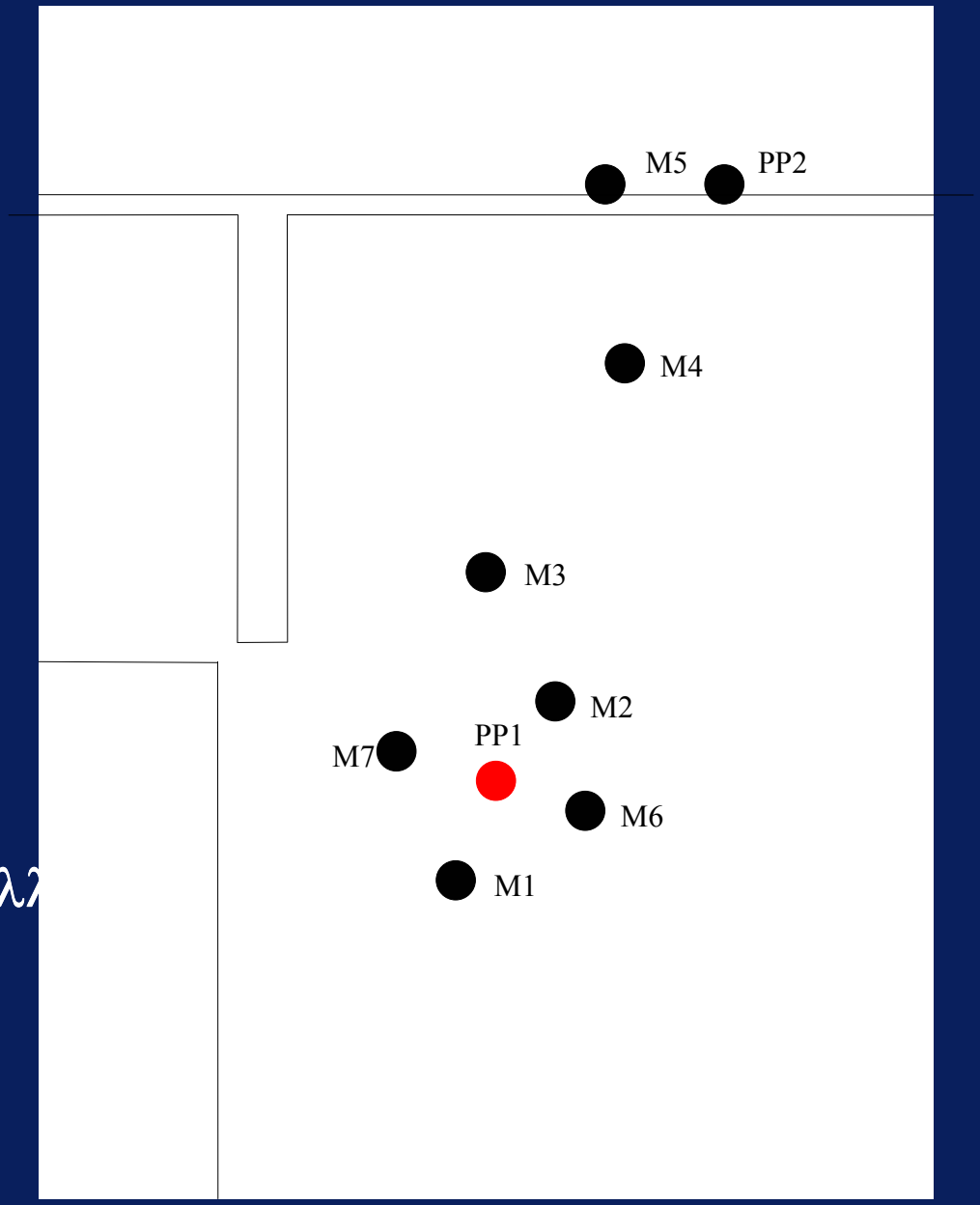
2. Anaerobic degradation of benzene
Field study, Push Pull with nitrate



Phases Push Pull experiment

- Push phase (2 days)
- Intermediate phase (6 ½ weeks)
- Pull phase (4 days)

Location



Ινφιλτρατιον ωελλ

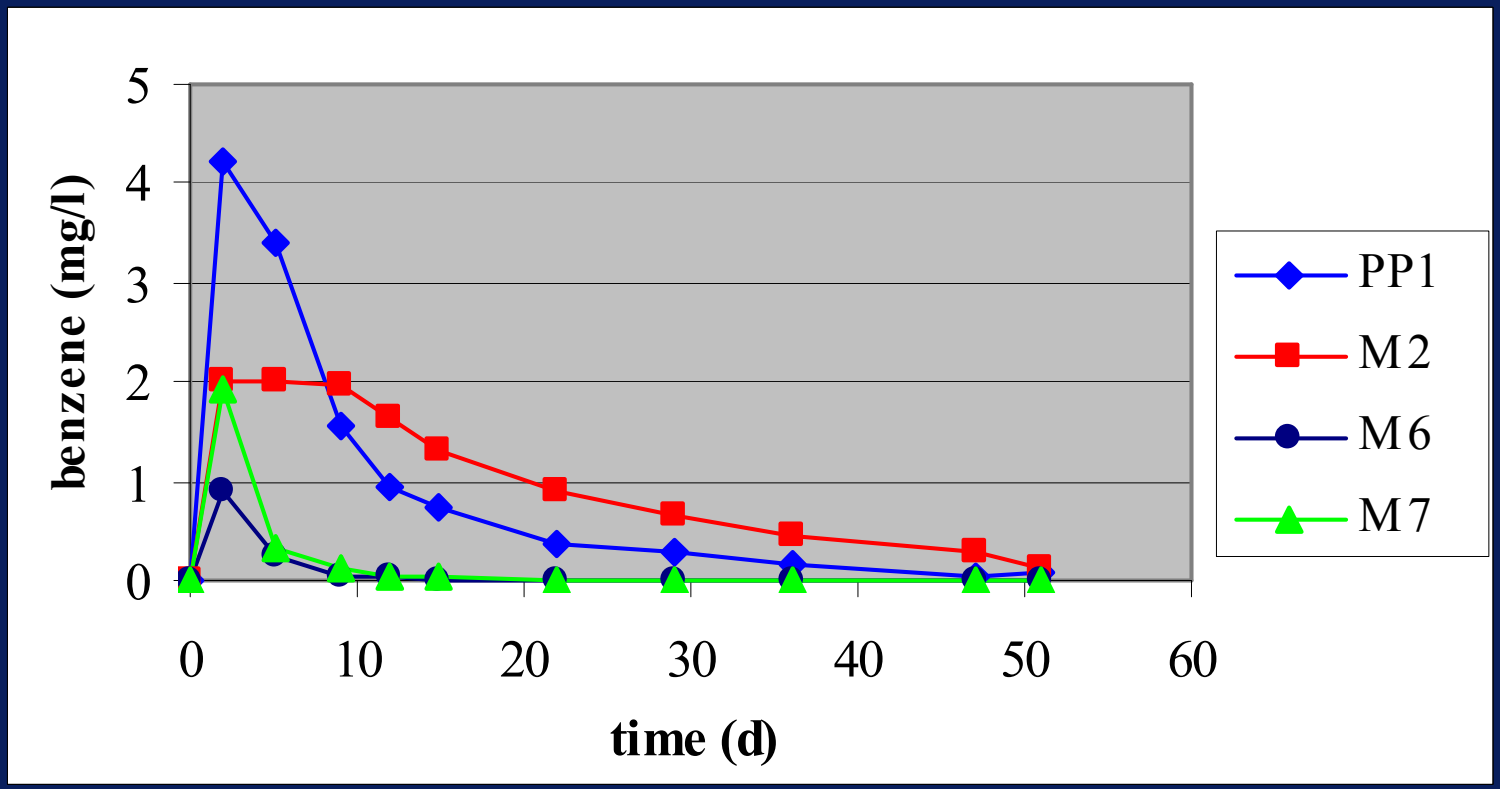
Proof degradation of benzene

- Mass balance
- Comparison with previous runs
- Modeling
- Isotope analyses

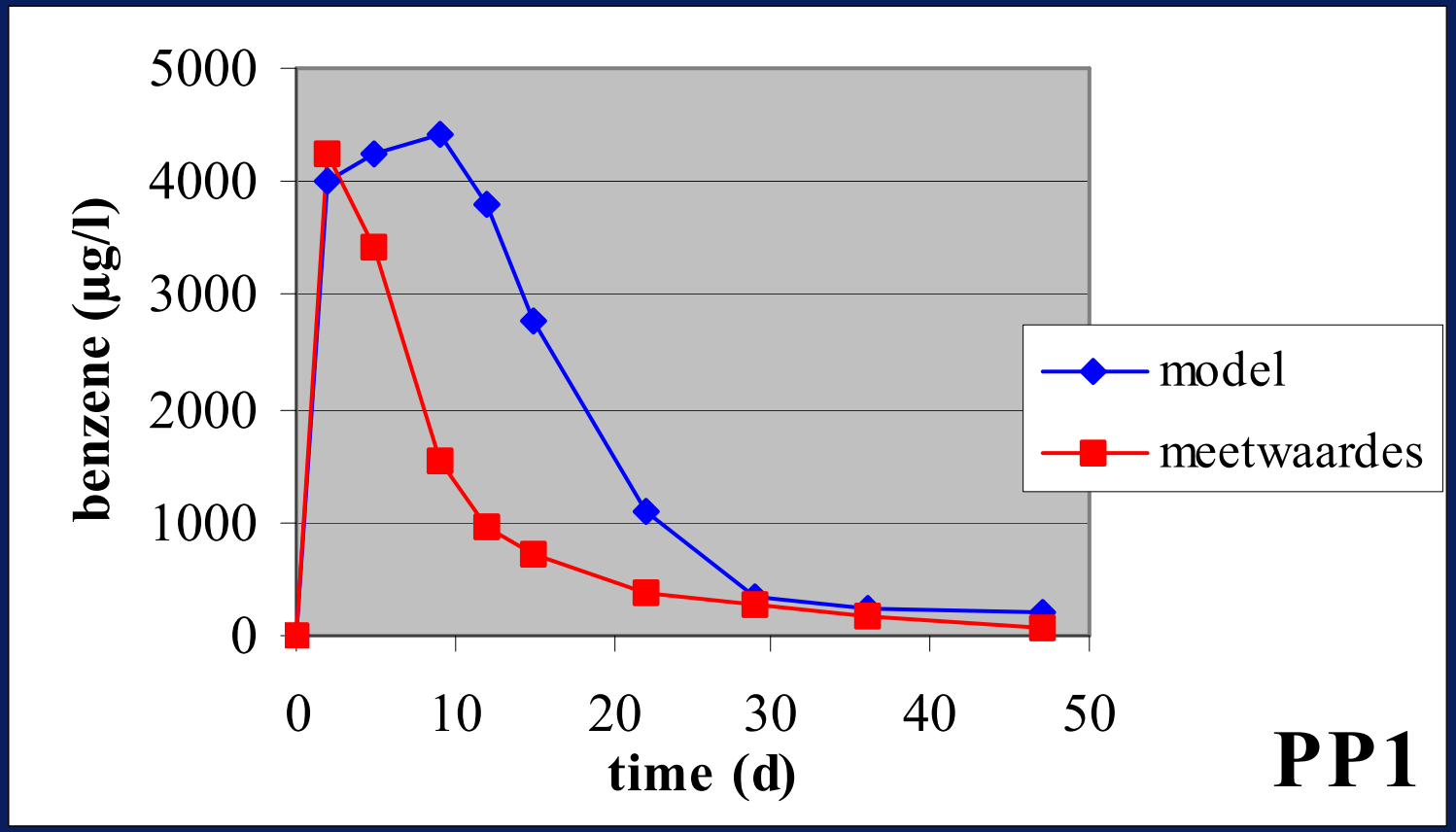
Pushpull experiments

- **Run 1 Benzene**
  - 95 % recovery of benzene
  - 110 % recovery of tracer (bromide)
- **Run 2 Nitrate**
  - Depleted within 10 days
- **Run 3 Benzene and nitrate**

Pushpull; Benzene and nitrate
Benzene concentrations



Pushpull; Benzene and nitrate
Modeled benzene concentrations



Pushpull; Benzene and nitrate
Benzene concentrations

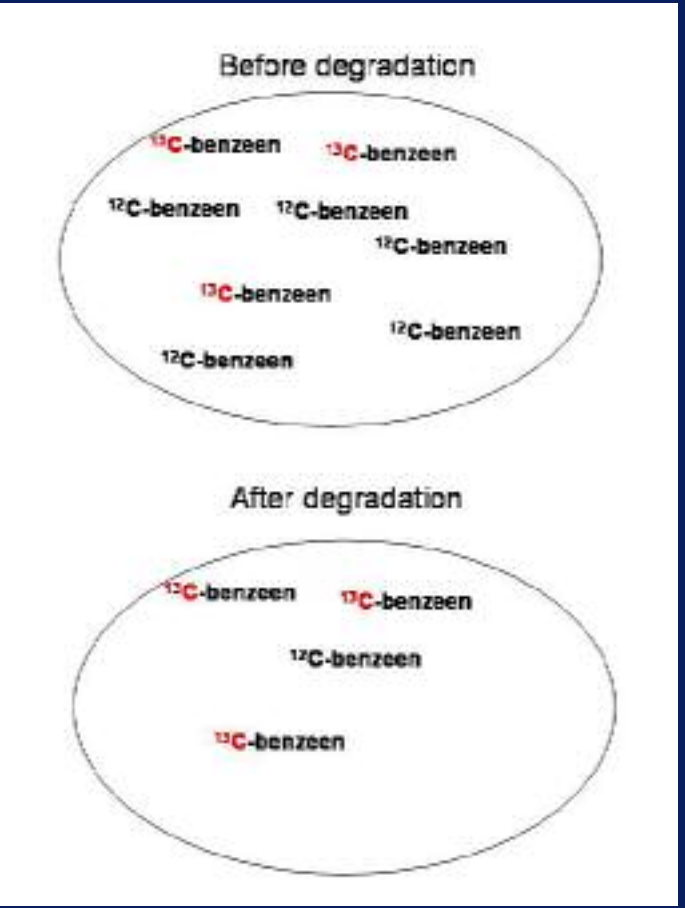
- No mass balance possible
- Lower benzene concentrations as predicted by model suggest biodegradation
- Isotope analysis !!

Compound specific carbon isotope analysis

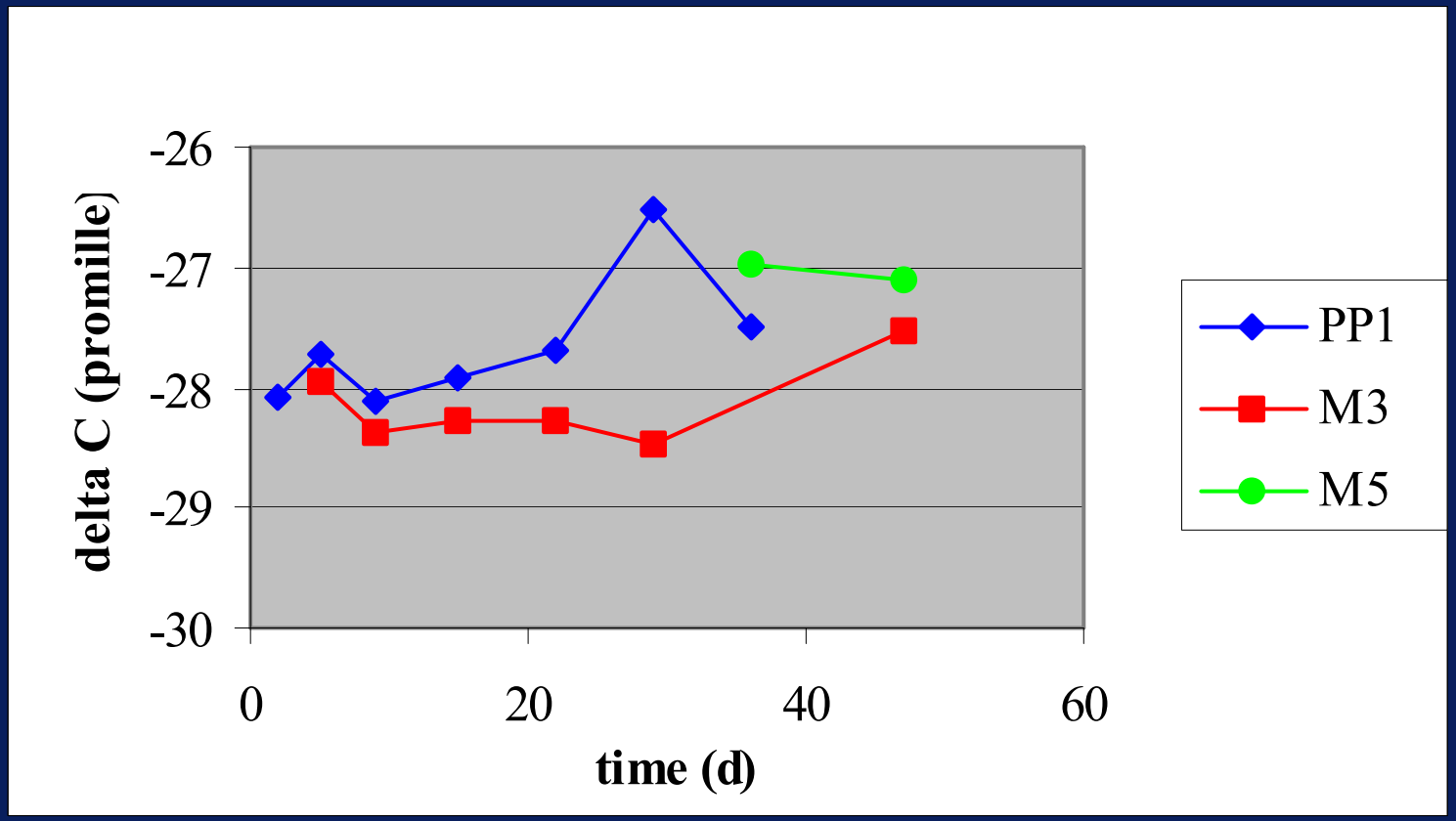
- **Which isotopes ?**
  - **Mainly $^{12}C/^{13}C$ and $^{37}Cl/^{35}Cl$**
  - **Other elements: S, O**
- **Why ?**
  - **Biological degradation; light isotope faster Enrichment of ^{13}C -isotopes in residual benzene (decrease in $\delta\ ^{13}C$)**
  - **Dilution, adsorption and transport; no preference**

Isotope analysis

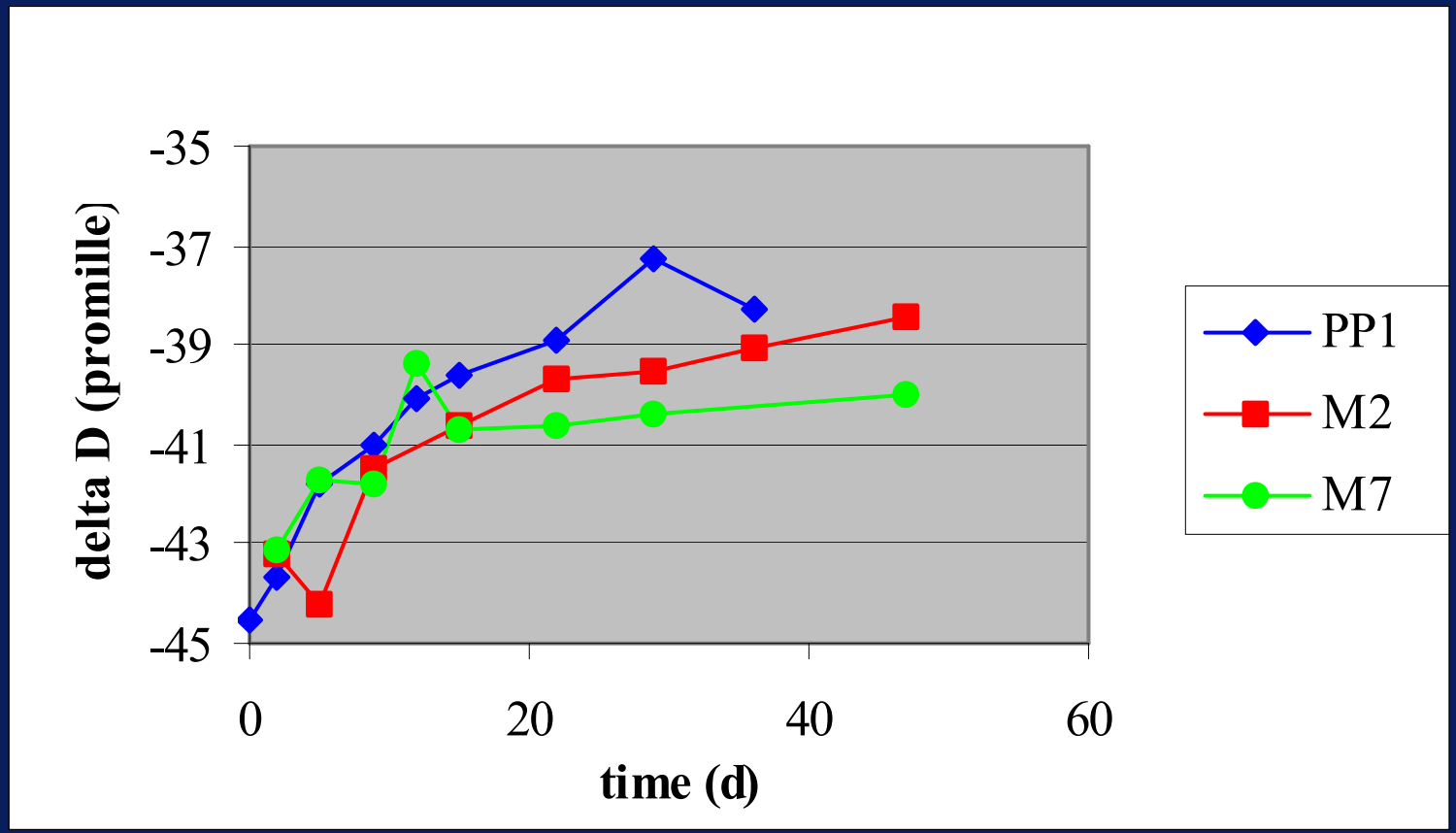
- **Biological degradation; light isotope faster**
- **Volatilisation; light isotope faster**
- **Dilution, adsorption & transport; no effect**



Field experiment; Benzene and nitrate
Stable isotope analyses, C



Field experiment; Benzene and nitrate
Stable isotope analyses, H



Pushpull; Benzene and nitrate
Benzene concentrations

- **No mass balance possible**
- **Lower benzene concentrations as predicted by model suggest biodegradation**
- **Isotope analysis**
  - Small shift in C-fractionation
  - Significant shift in H-fractionation

  - Biodegradation of benzene!!

Conclusions benzene degradation

- **Nitrate has potential for stimulated Natural Attenuation**

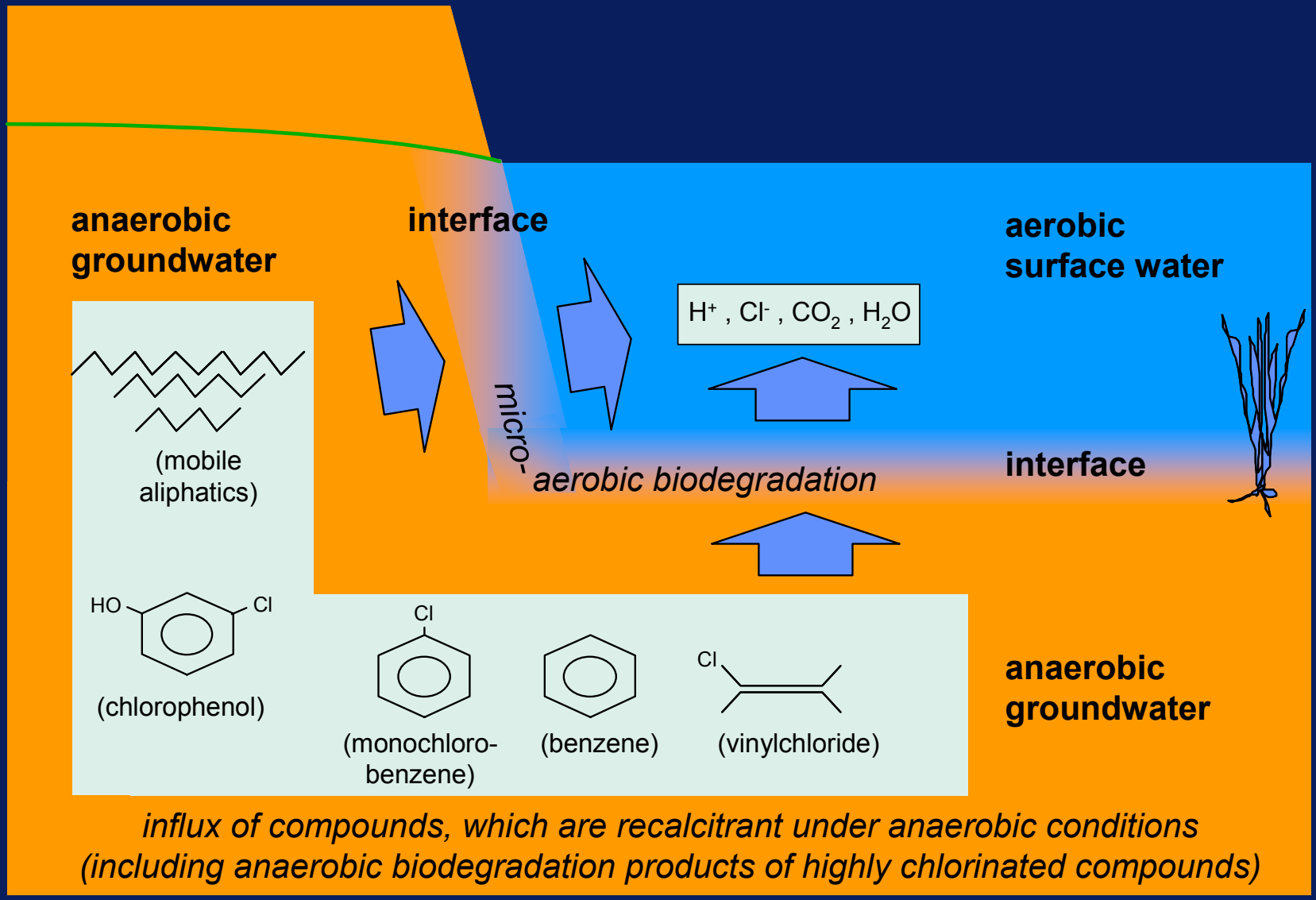
3. Natural attenuation at interface groundwater surfacewater

Hypothesis

Organic persistent pollutants (anaerobic)

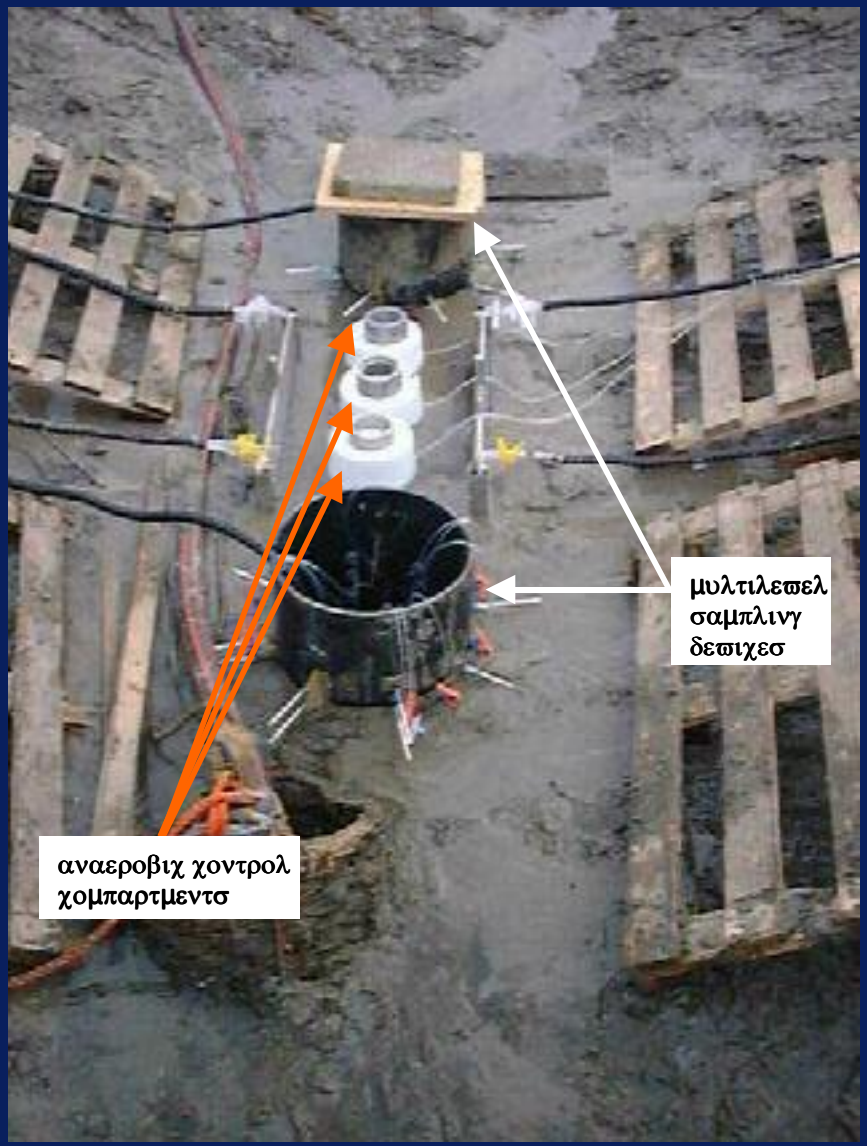
Biological oxidation in the (micro-)aerobic sediment interface between groundwater and surface water

Schematic view of the NA-Interface

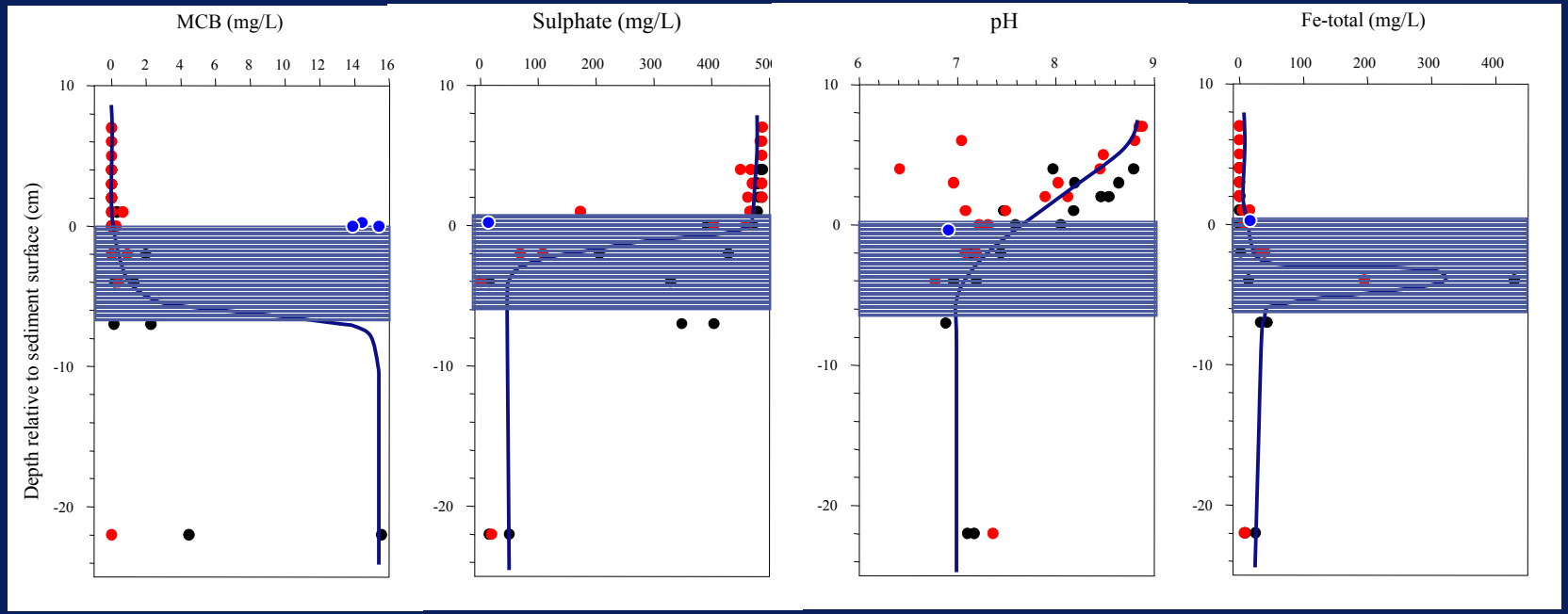


NA research ditch (Amsterdam)

Installation



Measurement results



● = North tube ● = South tube ● = Buckets (controls)

Conclusions NA interface

- NA-interface gradients measured on site
- Diffusion / dispersion determine concentration profile
- Oxygen penetration depth depends on O_2 consumption
- Differences tidal / steady state (O_2 infiltration depth)
- Decrease of flux in interface: 5-70%

Conclusions

In situ **bioremediation technologies depend on**

- **Type of contaminant**
- **Type of location**
- **Can soil be reached**

- **Site specific solutions are needed**

Biodegradation is teamwork

Colleagues

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Jan Gerritse
Alette Langenhoff
Nanne Hoekstra
Peter Middeldorp
Sjef Staps
Huub Rijnaarts

Universities

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