

Alette Langenhoff

Bioremediation of areas polluted with chlorinated and non-chlorinated hydrocarbons

TNO Built Environment and Geosciences



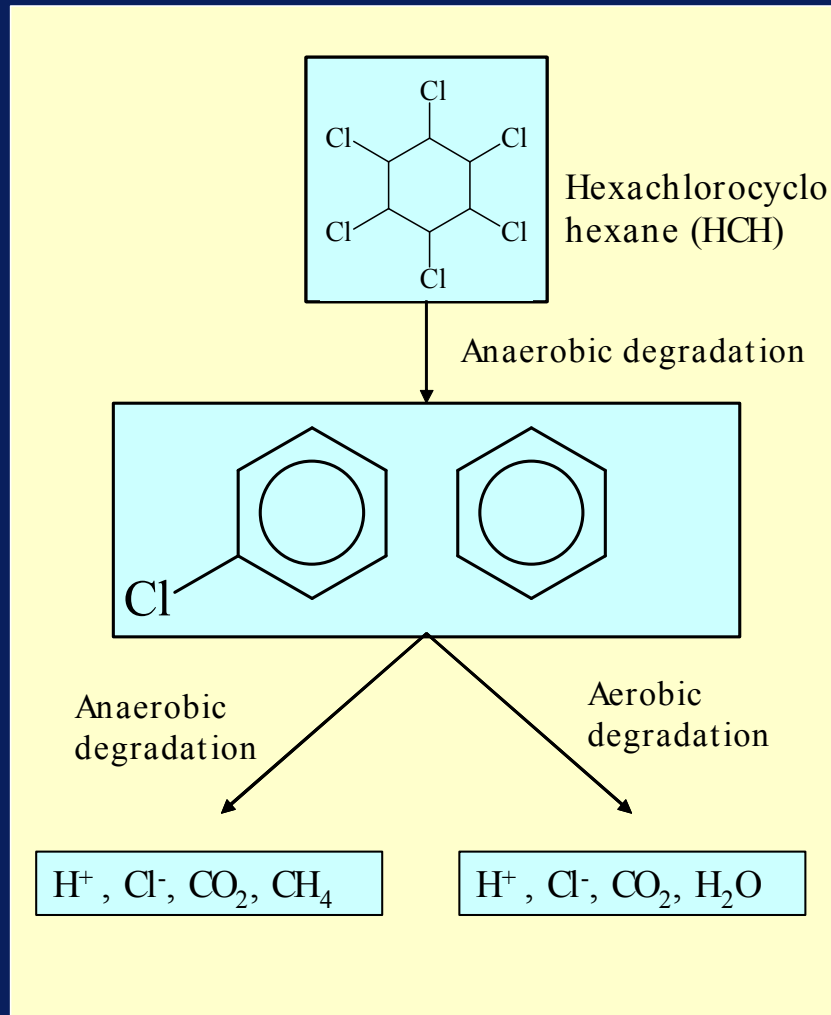
Bioremediation at various Dutch sites

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

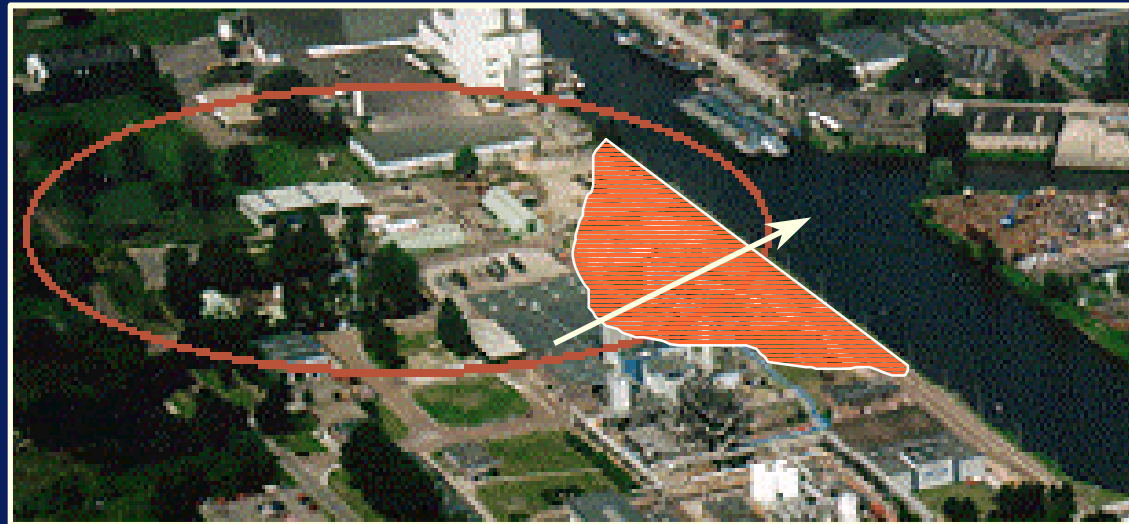


Middeldorp, 1996, ES&T

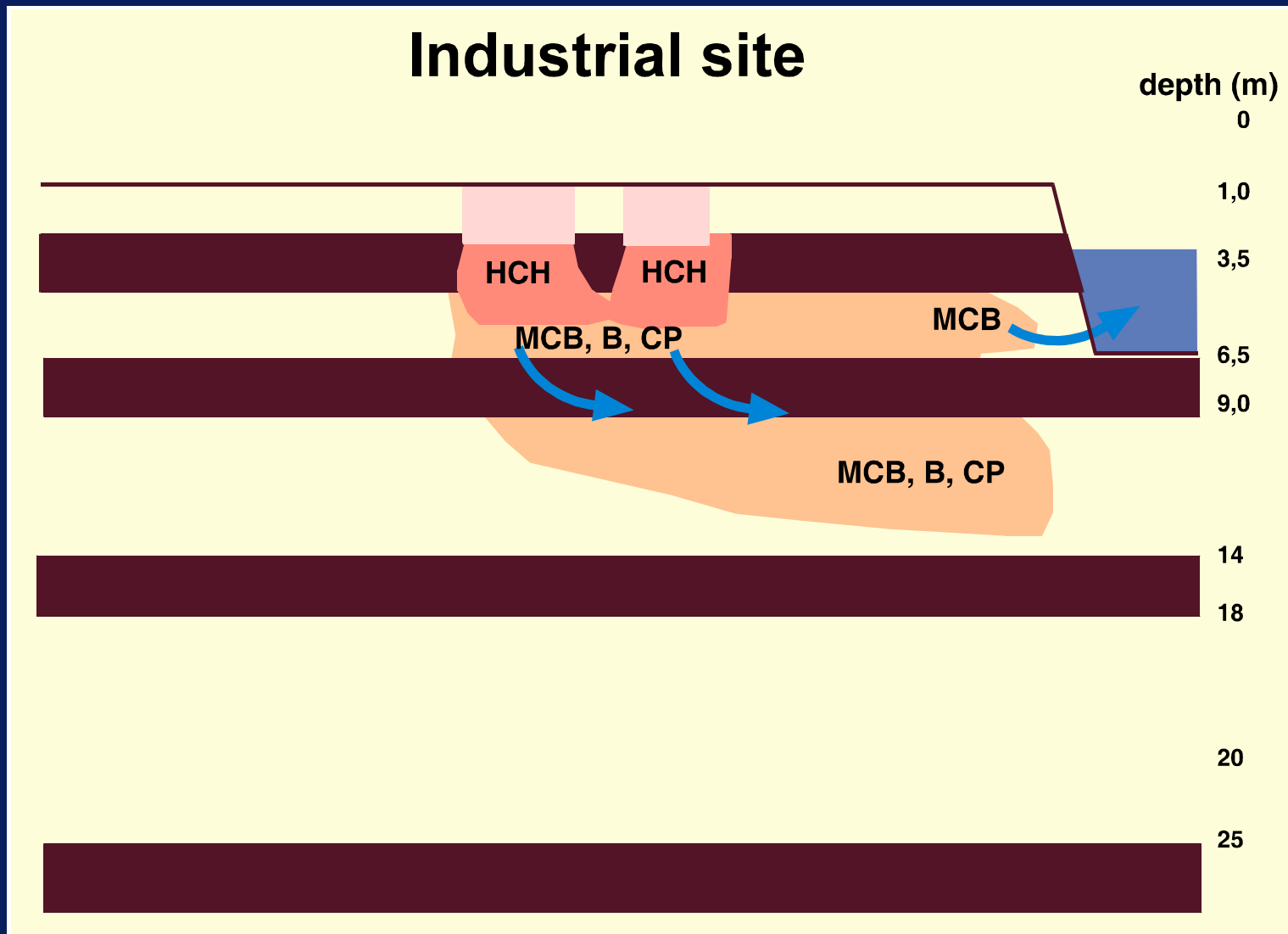
Van Eekert, 1998, ES&T

Industrial site

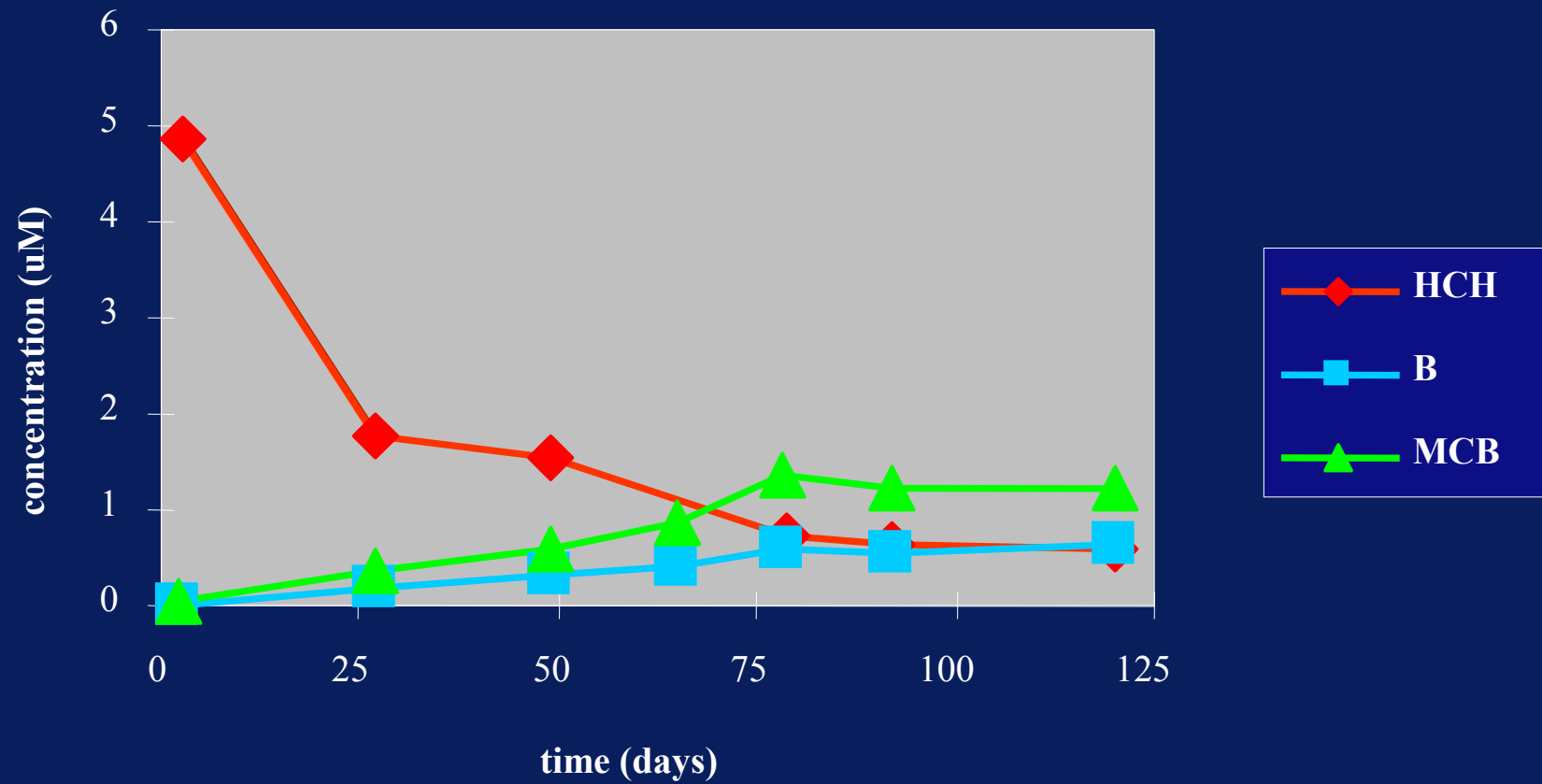
- Site description
 - industrial site situated near canal
 - contaminants: hexachlorocyclohexane (HCH, lindane)
monochlorobenzene (MCB), benzene (B)
 - >250 m plume up to depth of 18 m



Industrial site

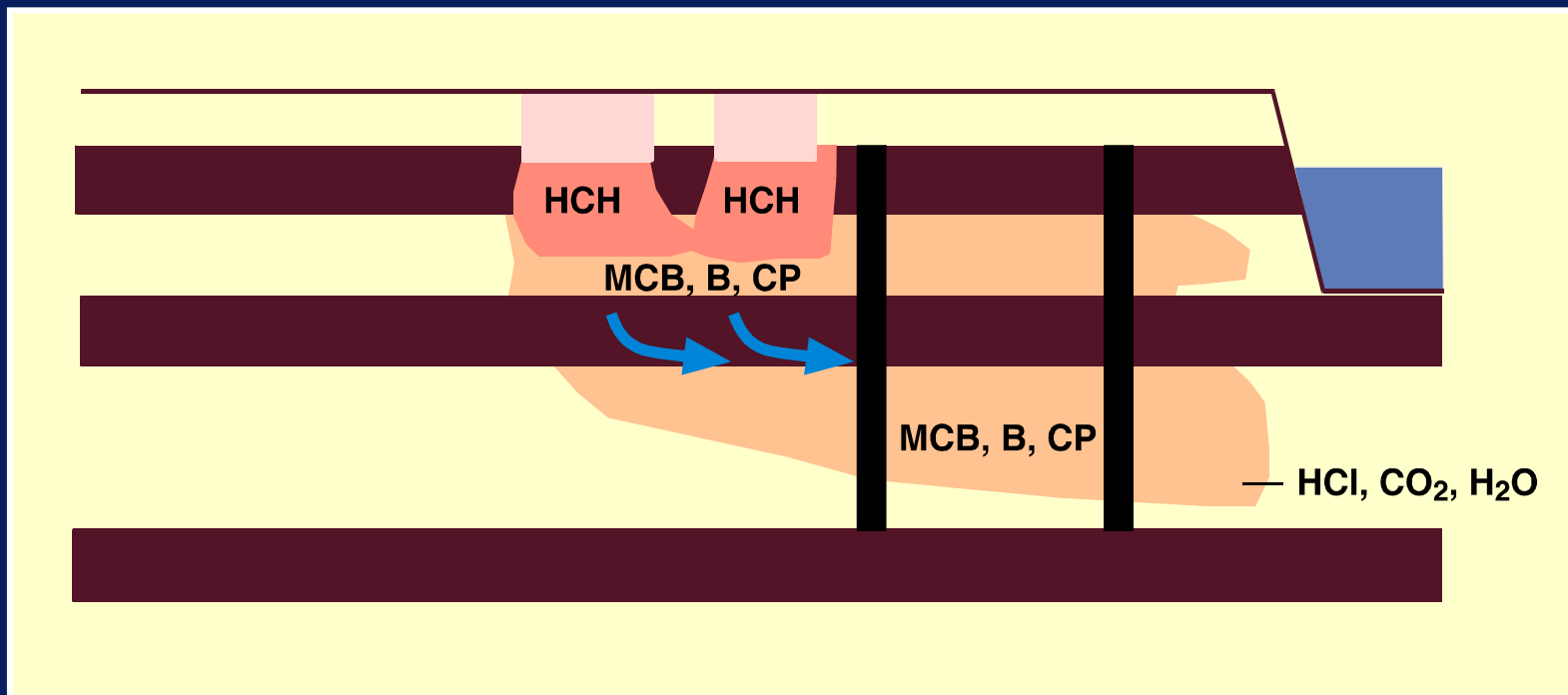


Anaerobic HCH degradation



Industrial site

2 bioscreens: anaerobic and aerobic



Implementation at Industrial Site

Redevelopment of site :

Building of Container terminal

Implementation of bioremediation system :

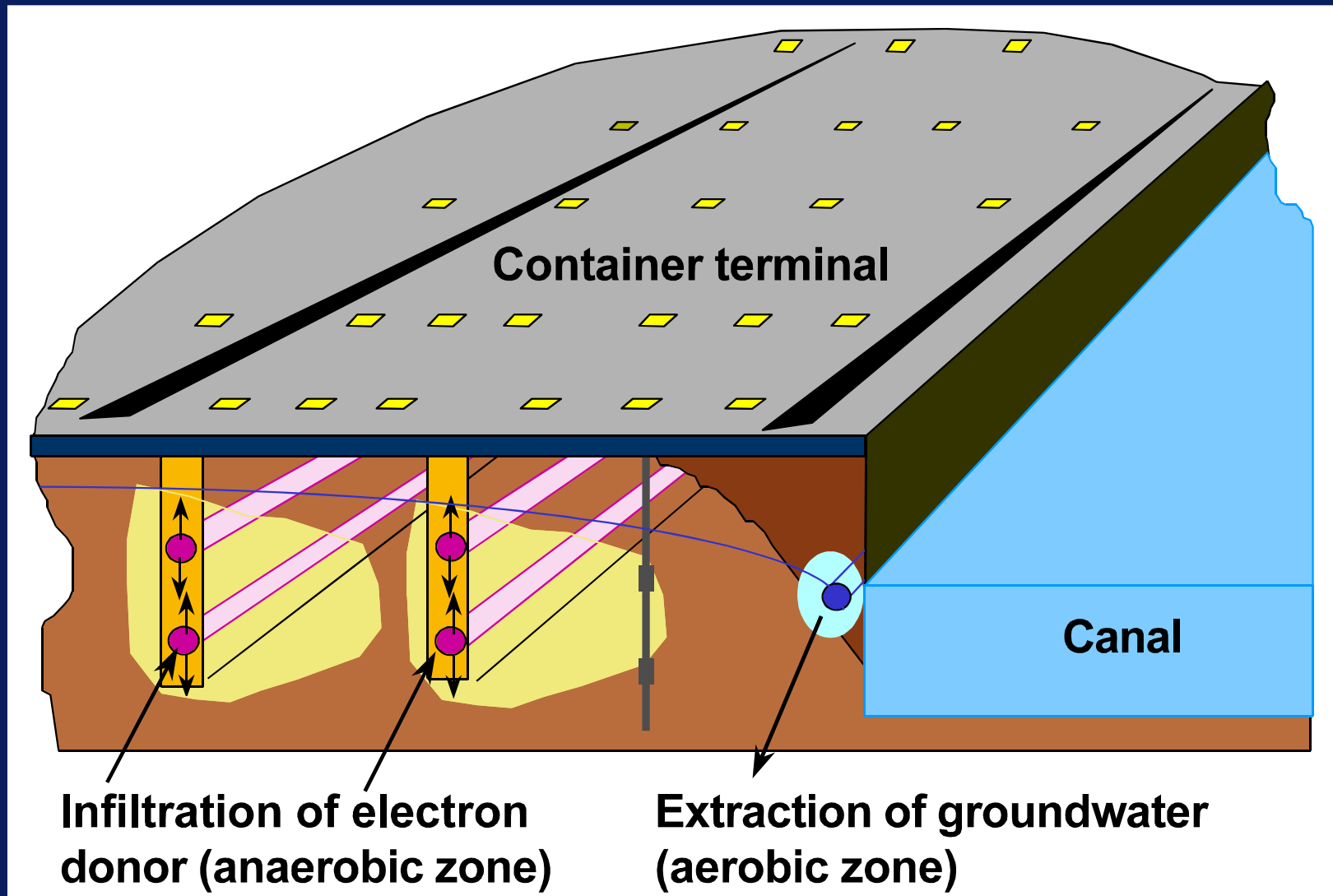
Anaerobic phase

Aerobic phase

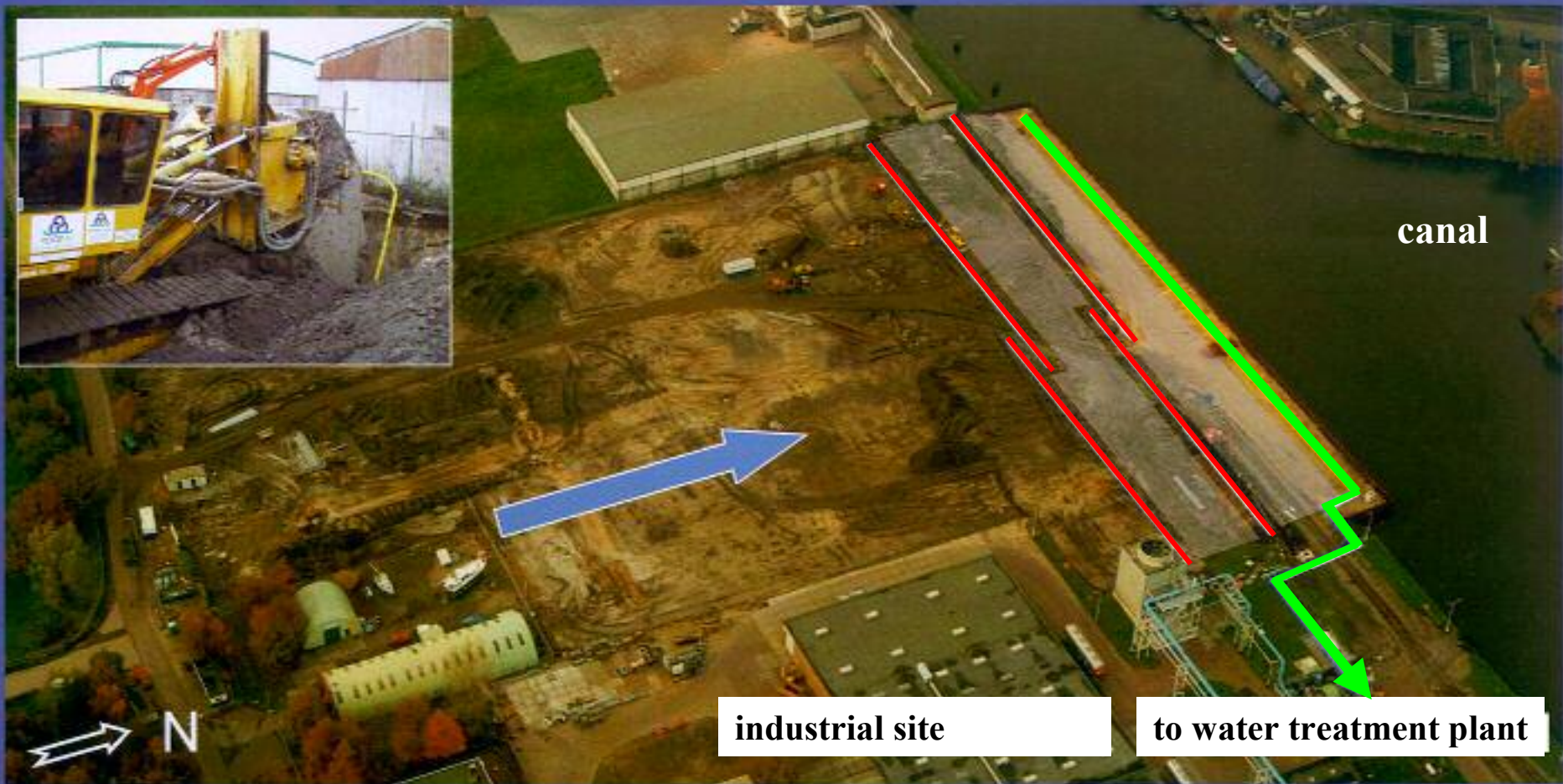
Phases

- **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

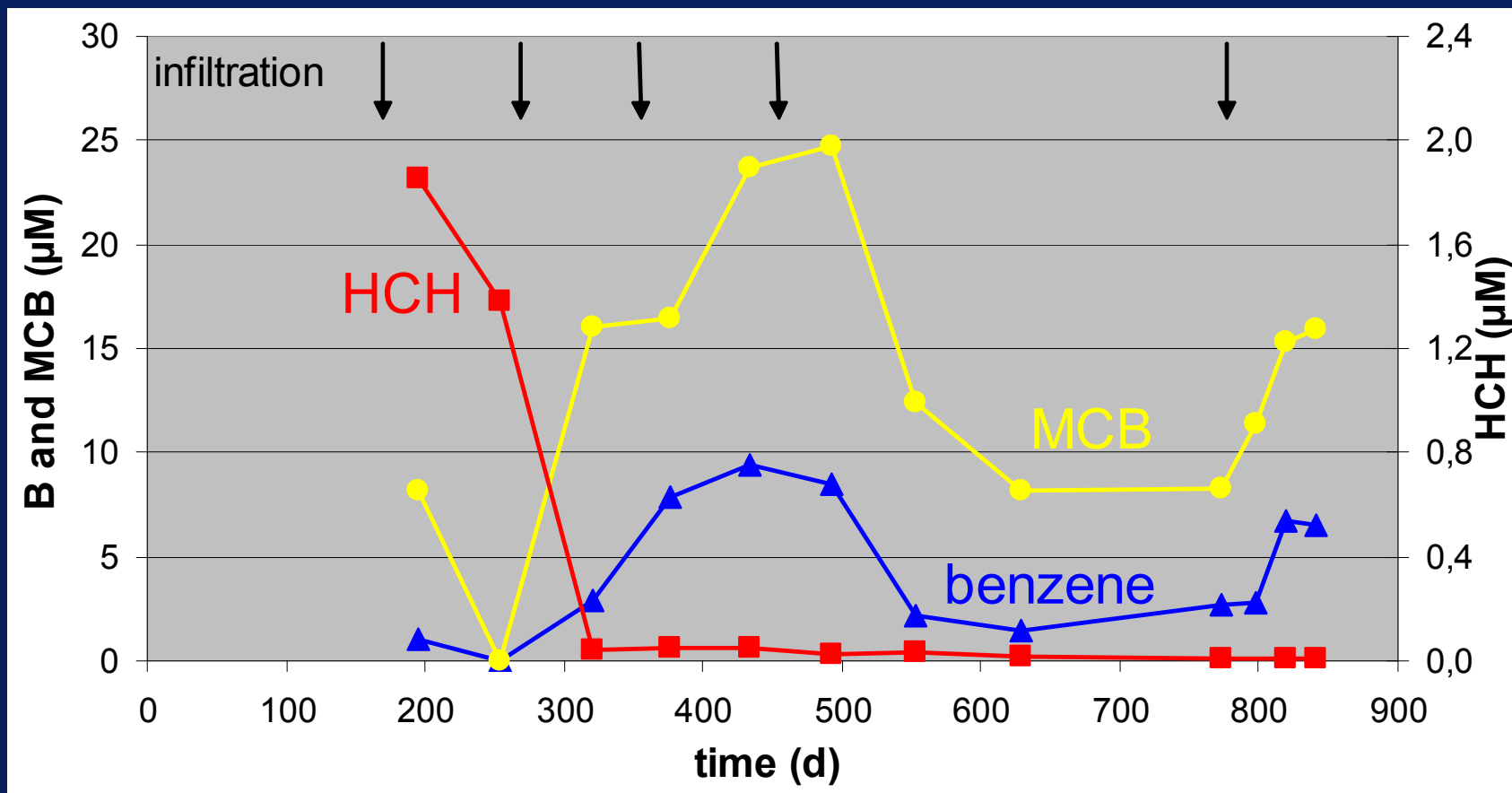


— infiltration drain
— extraction drain

■ stimulated zone (0 - 6m - mv)
→ groundwater flow



Concentrations in well 24-2





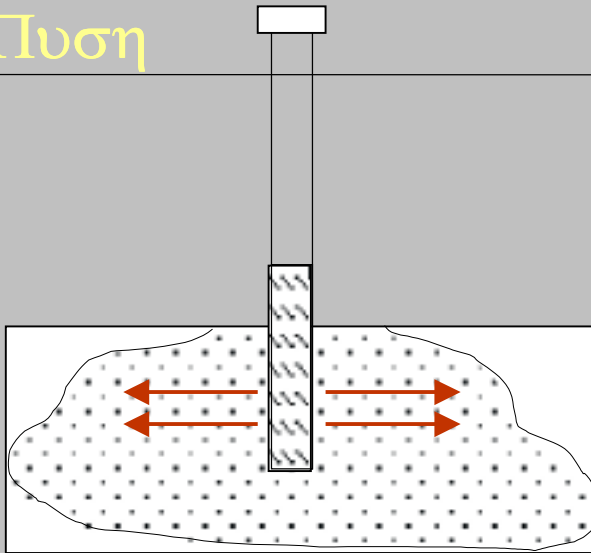
Conclusions HCH study

- 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

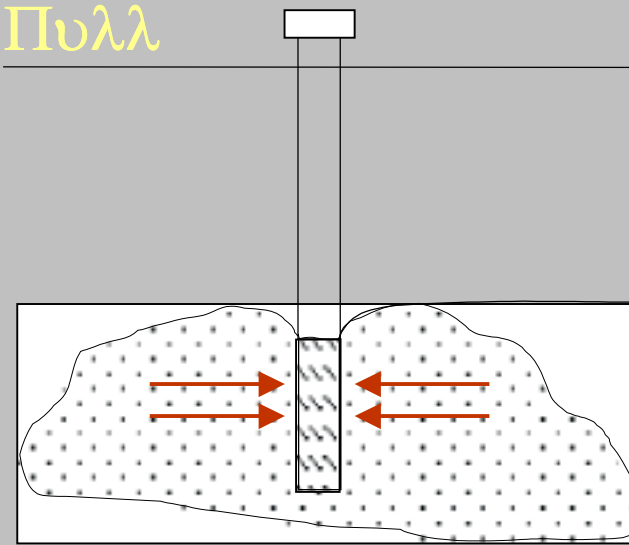
2. Anaerobic degradation of benzene

Field study, Push Pull with nitrate

Πυση



Πυλλ



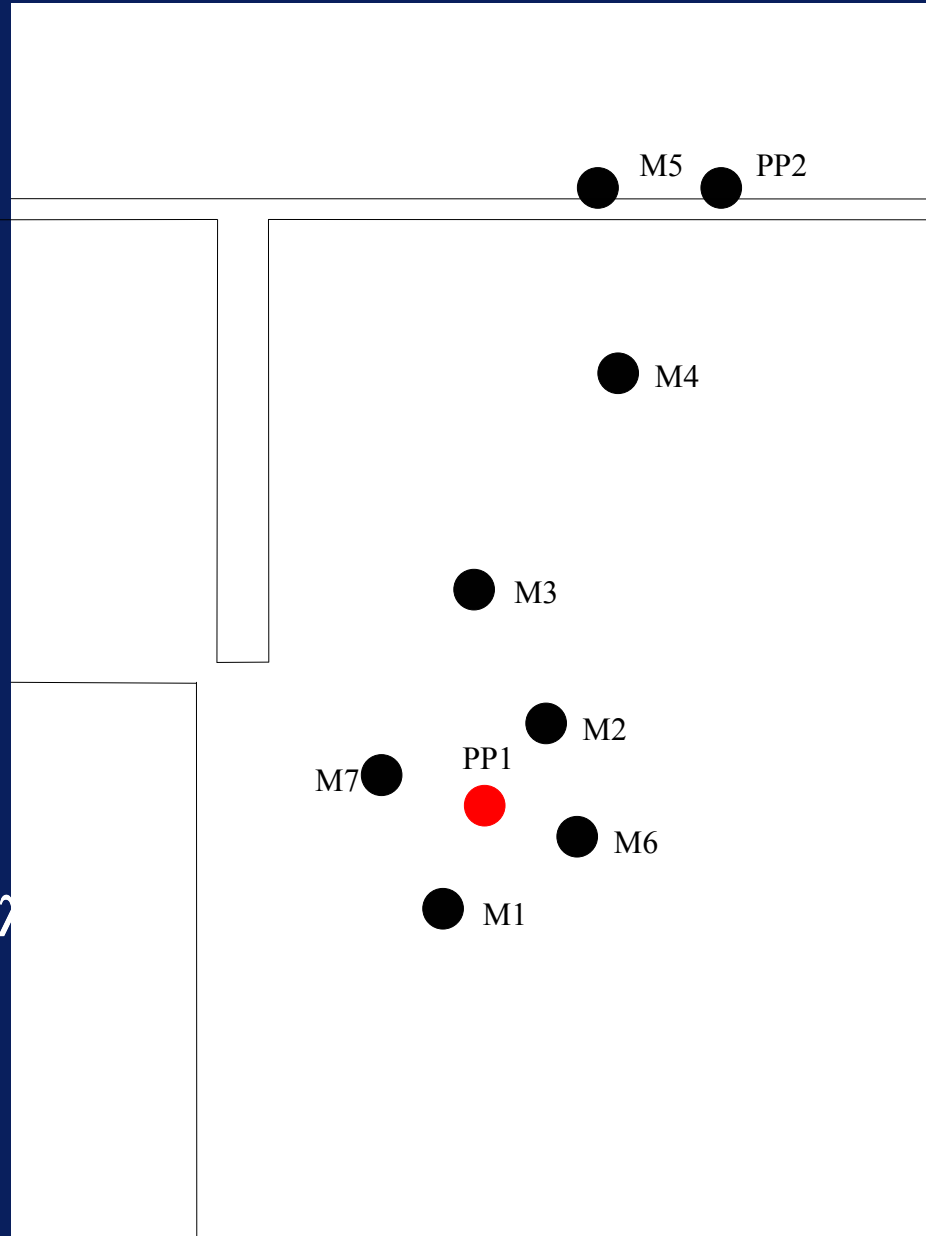
Phases Push Pull experiment

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

Location



Ινφιλτρατιον ωελ



Proof degradation of benzene

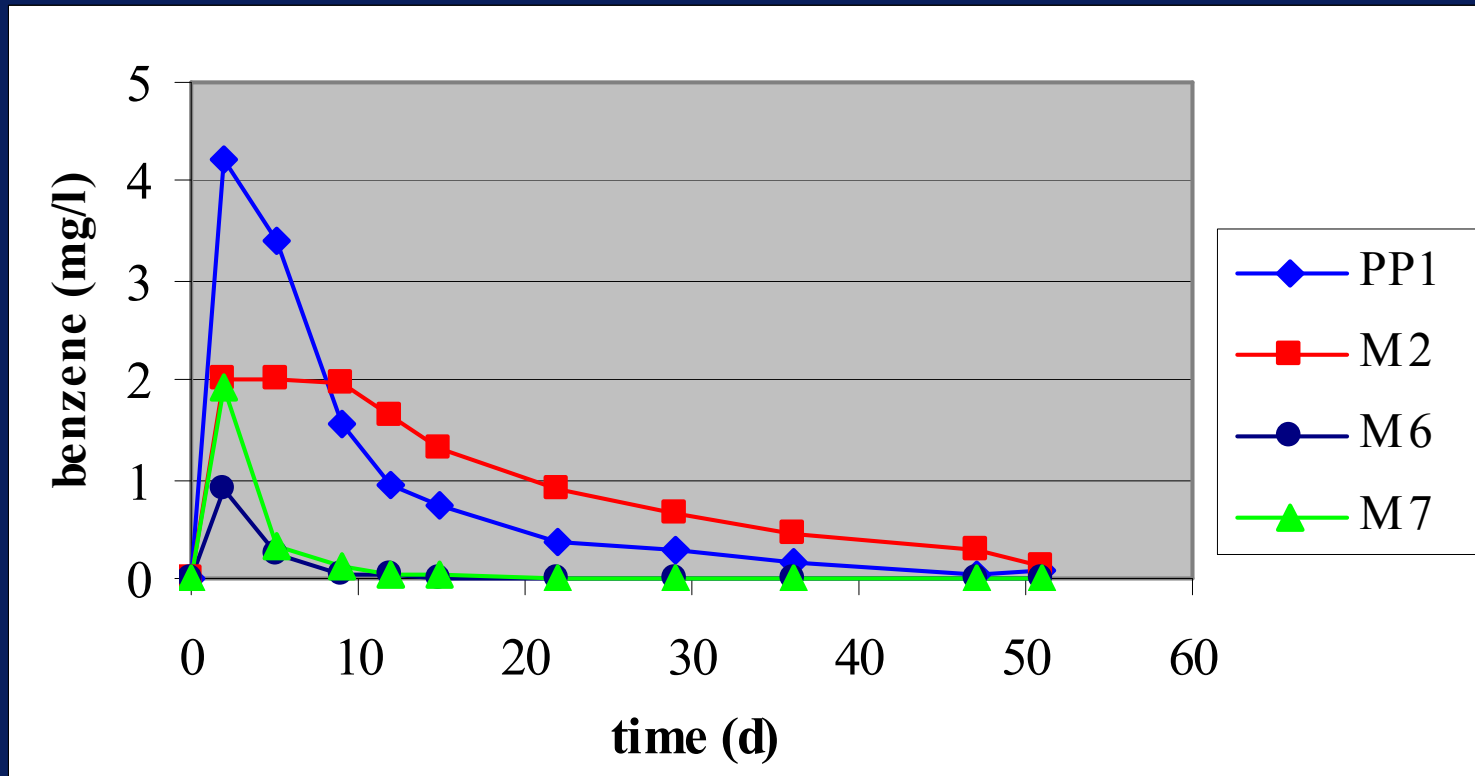
- **Mass balance**
- **Comparison with previous runs**
- **Modeling**
- **Isotope analyses**

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**

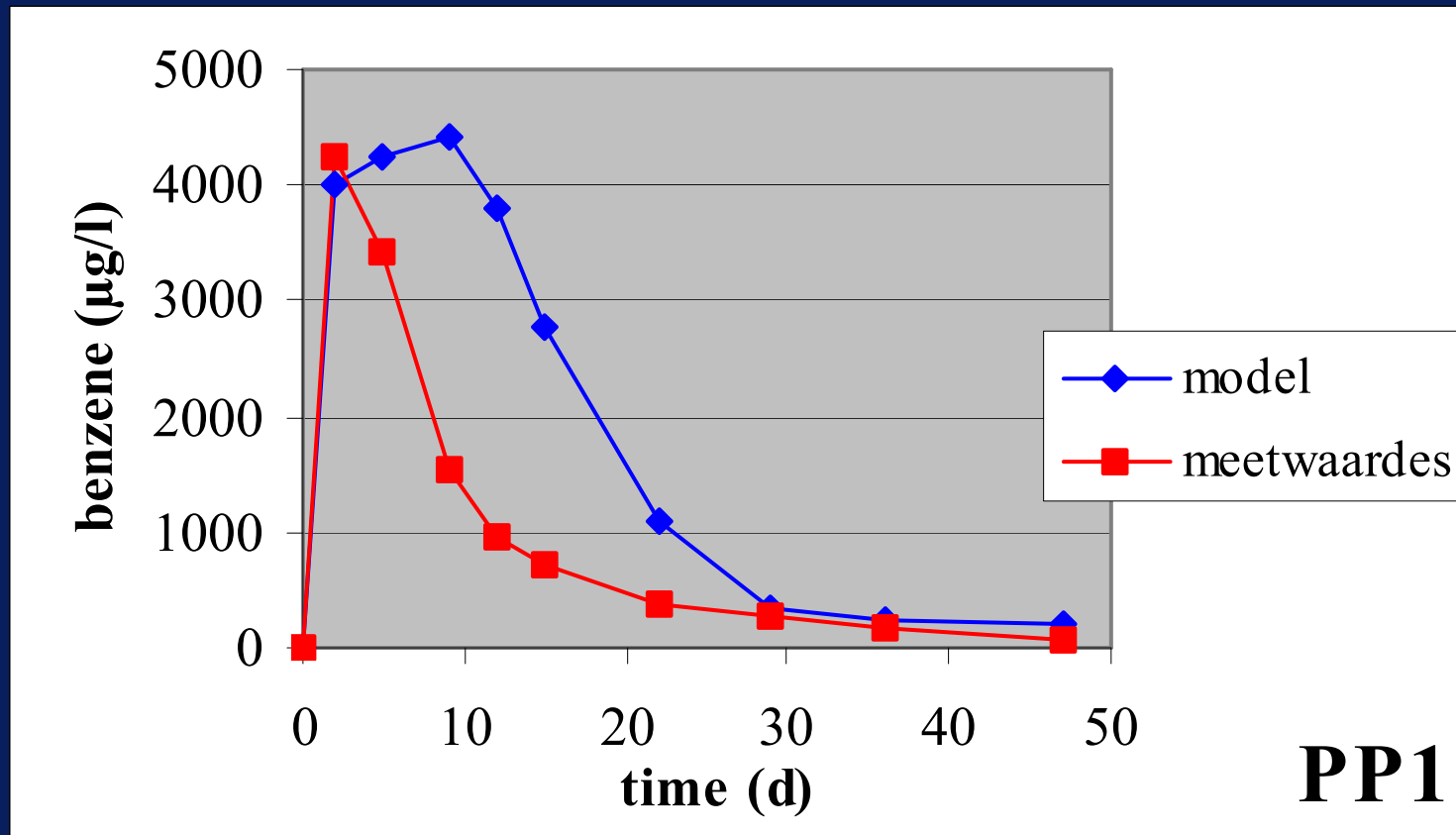
Pushpull; Benzene and nitrate

Benzene concentrations



Pushpull; Benzene and nitrate

Modeled benzene concentrations



Pushpull; Benzene and nitrate

Benzene concentrations

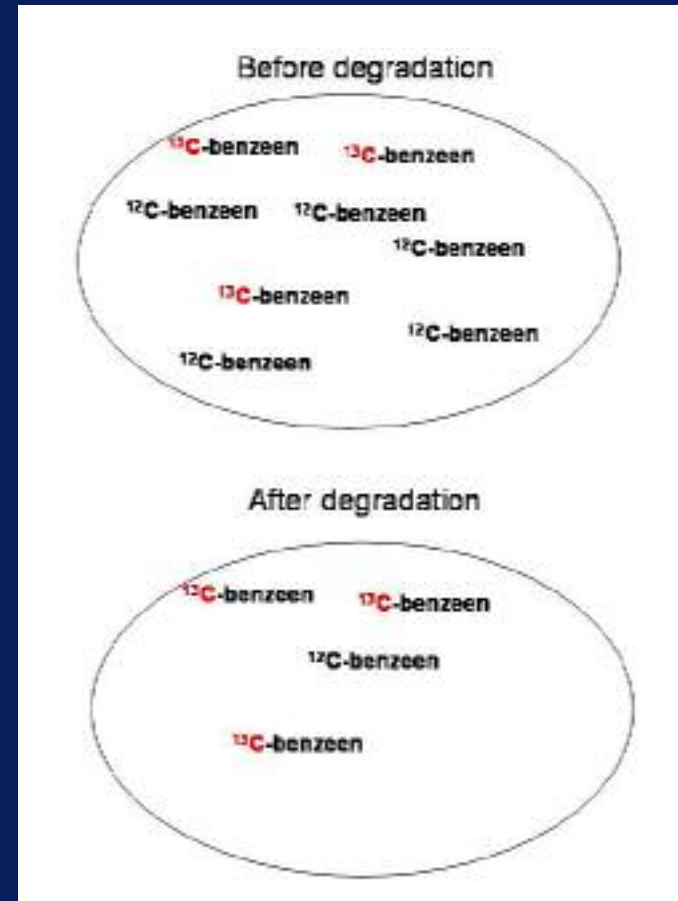
- **No mass balance possible**
- **Lower benzene concentrations as predicted by model suggest biodegradation**
- **Isotope analysis !!**

Compound specific carbon isotope analysis

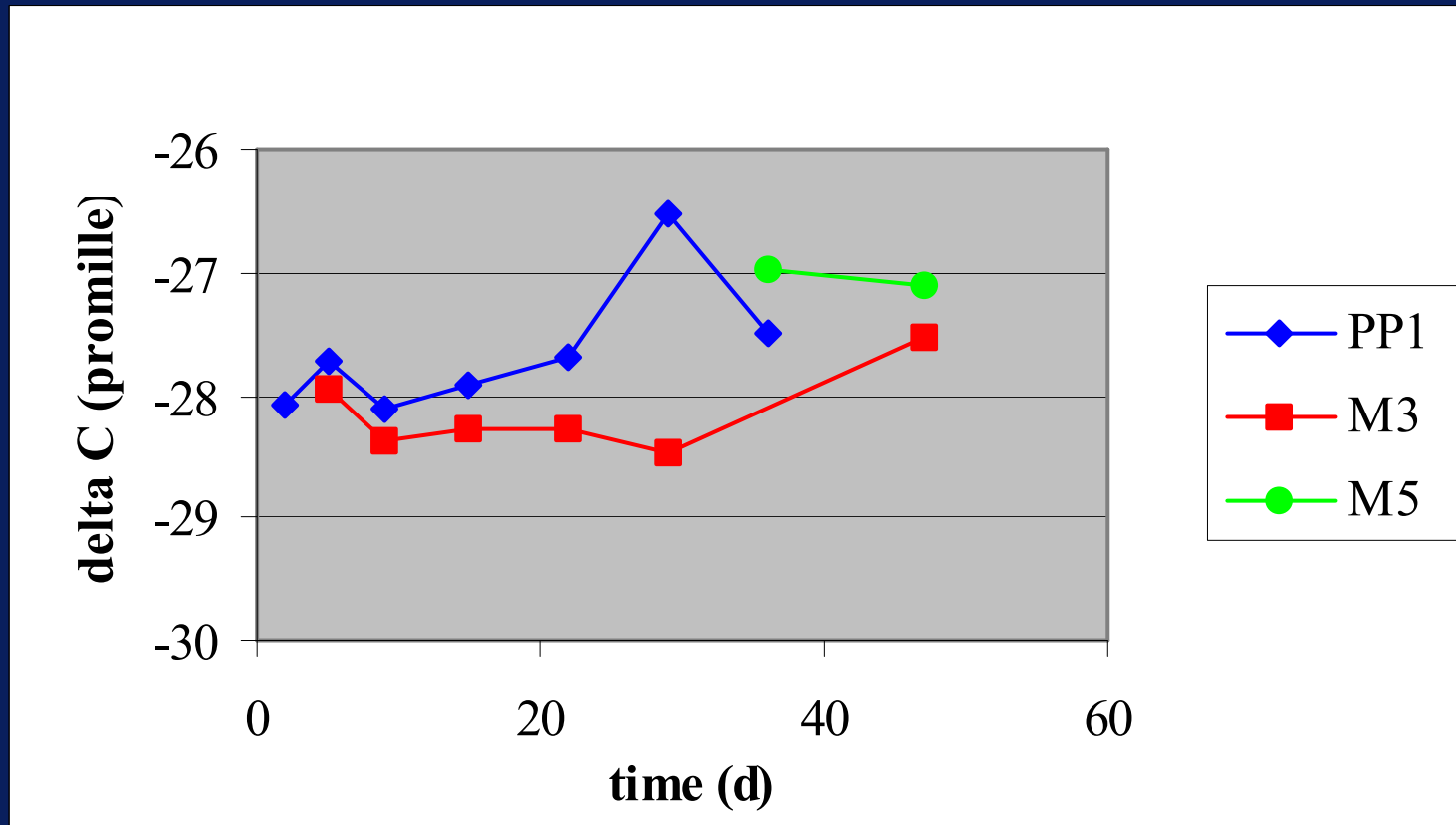
- Which isotopes ?
 - Mainly $^{12}\text{C}/^{13}\text{C}$ and $^{37}\text{Cl}/^{35}\text{Cl}$
 - Other elements: S, O
- Why ?
 - Biological degradation; light isotope faster
Enrichment of ^{13}C -isotopes in residual benzene (decrease in $\delta^{13}\text{C}$)
 - Dilution, adsorption and transport;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

Isotope analysis

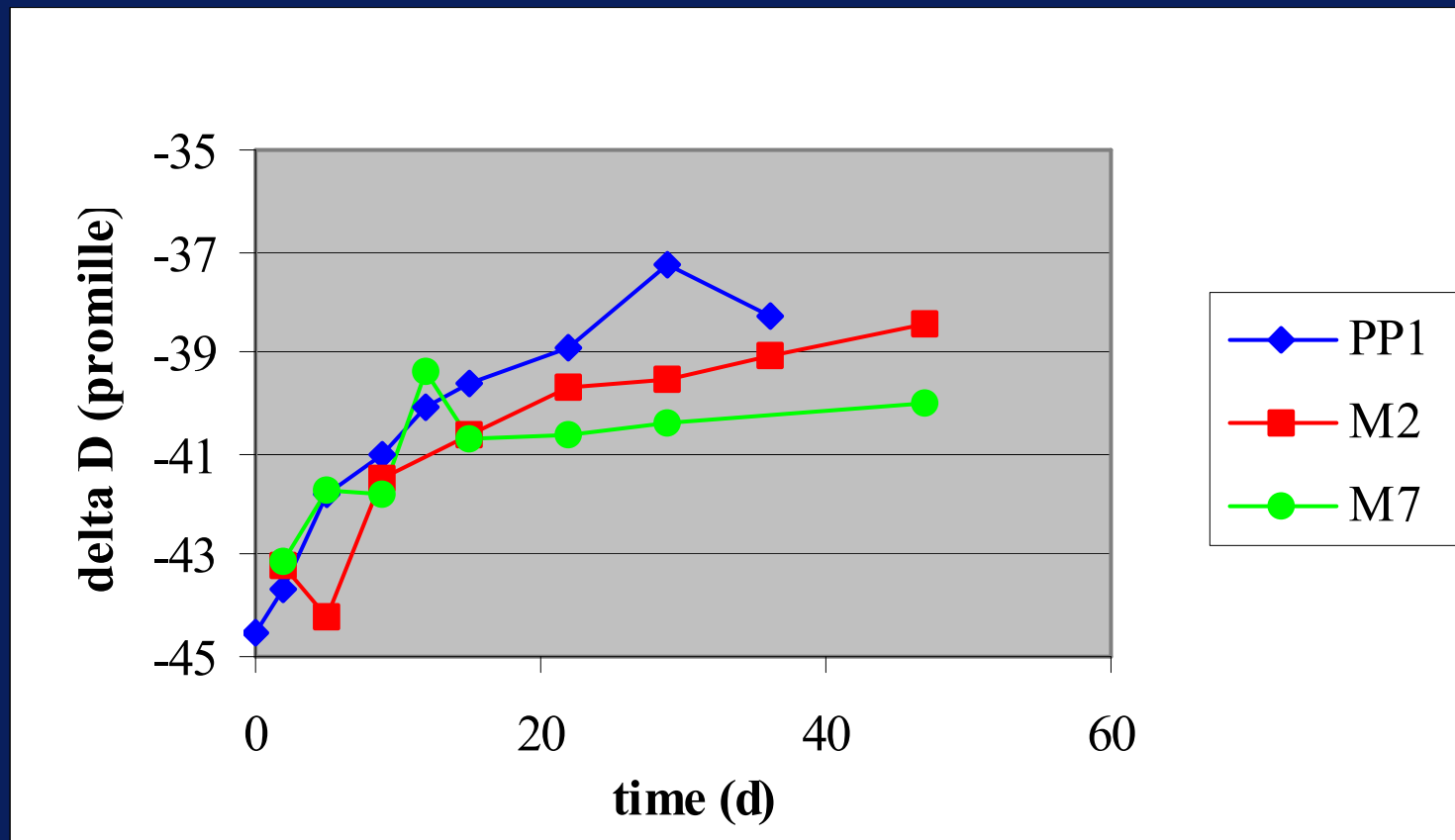
- **Biological degradation;**
light isotope faster
- **Volatilisation;**
light isotope faster
- **Dilution, adsorption &**
transport; no effect



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

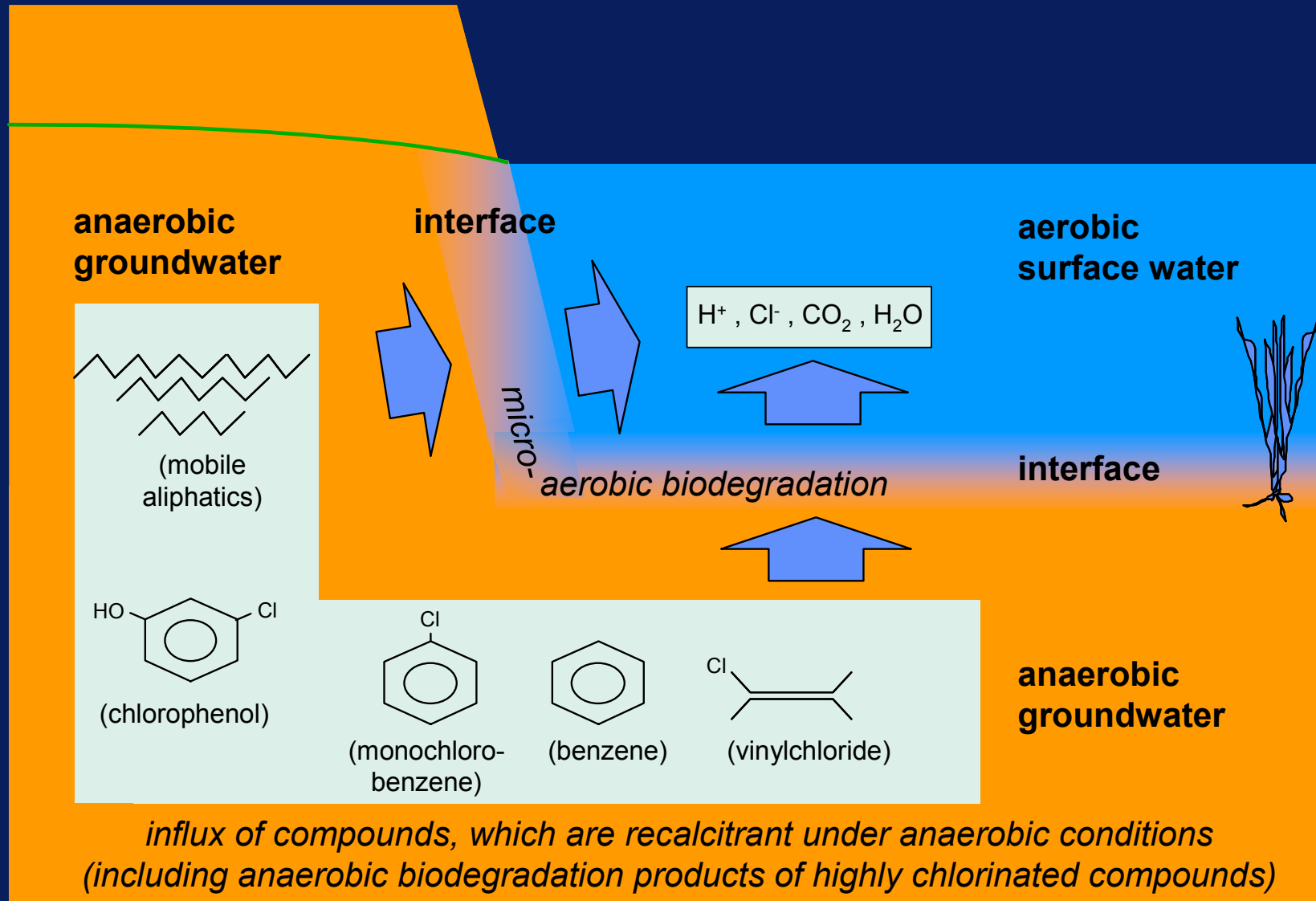
Hypothesis

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)



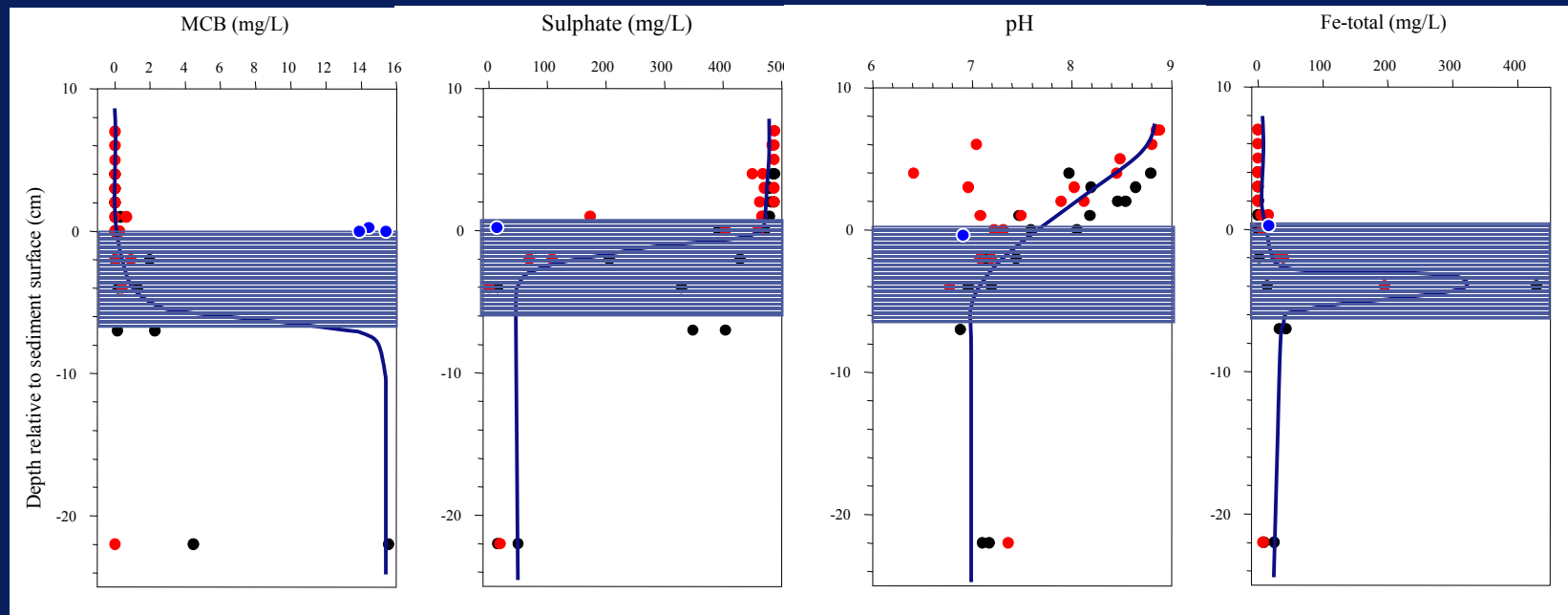
Installation



αναεροβιχ χοντρολ
χομπαρτμεντσ

μυλτιλεσελ
σαμπλιγ
δεσιχεσ

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 O₂ consumption**
- **Differences tidal / steady state (O₂ 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

Huib Rijnaarts

Universities

Companies and sponsors

Microbes

