

# **Biological investigation and monitoring tools used at a site with chlorinated ethylenes**

## **Cost effective remediation strategies based on biological monitoring**

**NICOLE conference “In situ measuring and  
monitoring: innovations and practical experiences  
for a cost effective approach”**

***Carcassonne, 10-12 May 2006***

**Ir. Maurice Henssen  
Bioclear, The Netherlands**

**Statement:**

**Conceptual site model**



**Conceptual site remediation model**



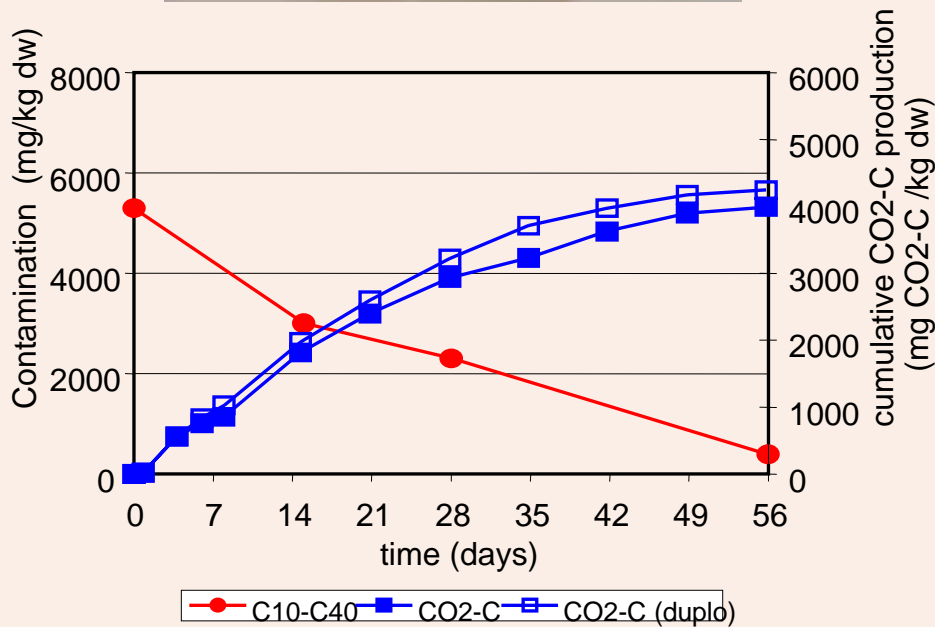
**Data acquisition  
Cost effectiveness**

## **Overview of presentation**

- **Monitoring tools focussed on biological processes**
- **Cases**
- **Conclusions**

# Tools (1)

## 1. Degradation tests



## 2. Groundwater characterisation

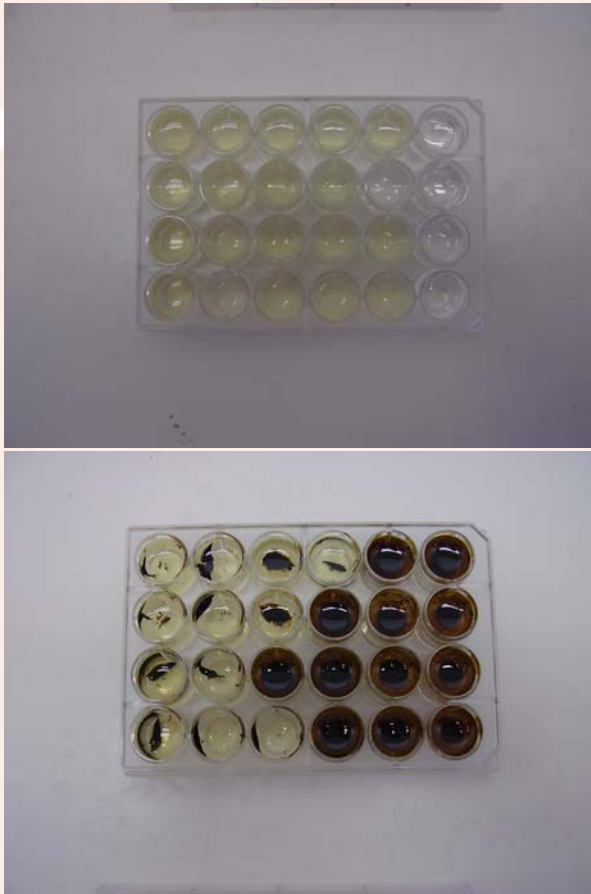


# Parameters in GWC:

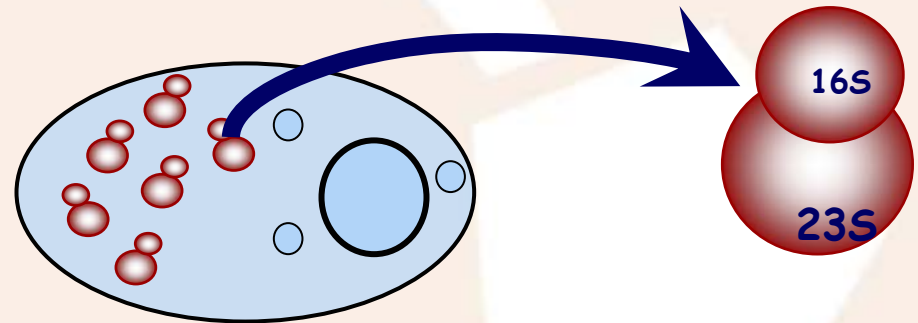
	BTEX Oil	PCE		BTEX Oil	PCE
<b>Redox parameters</b>			<b>Environmental parameters</b>		
Oxygen	+	+	Acidity (pH)	+	+
Nitrate	+	+	Conductivity	+	+
Iron	+	+			
Sulfate and sulfide	+	+	<b>Degradation products</b>		
Methane	+	+	TCE, DCE, VC, ethylene	-	+
Redox potential	+	+	Chloride	-	(+)
Hydrogen analysis	(+)	(+)	Phenols, benzoates	+	-
			Alkalinity (carbon dioxide)	+	-
<b>Carbon source</b>			Isotope analysis	+	+
DOC/TOC	-	+			
			<b>Bacteria</b>	-	+
<b>Nutrients</b>					
Ammonium	+	+			
Phosphate	+	+			

# Tools (2)

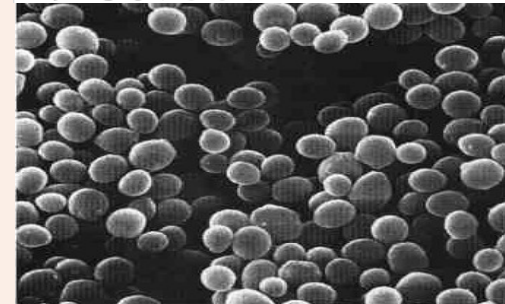
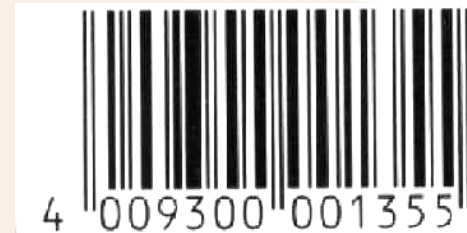
## 3. Microbial analyses (MPN)



## 4. Molecular microbial analyses



**Specific DNA**



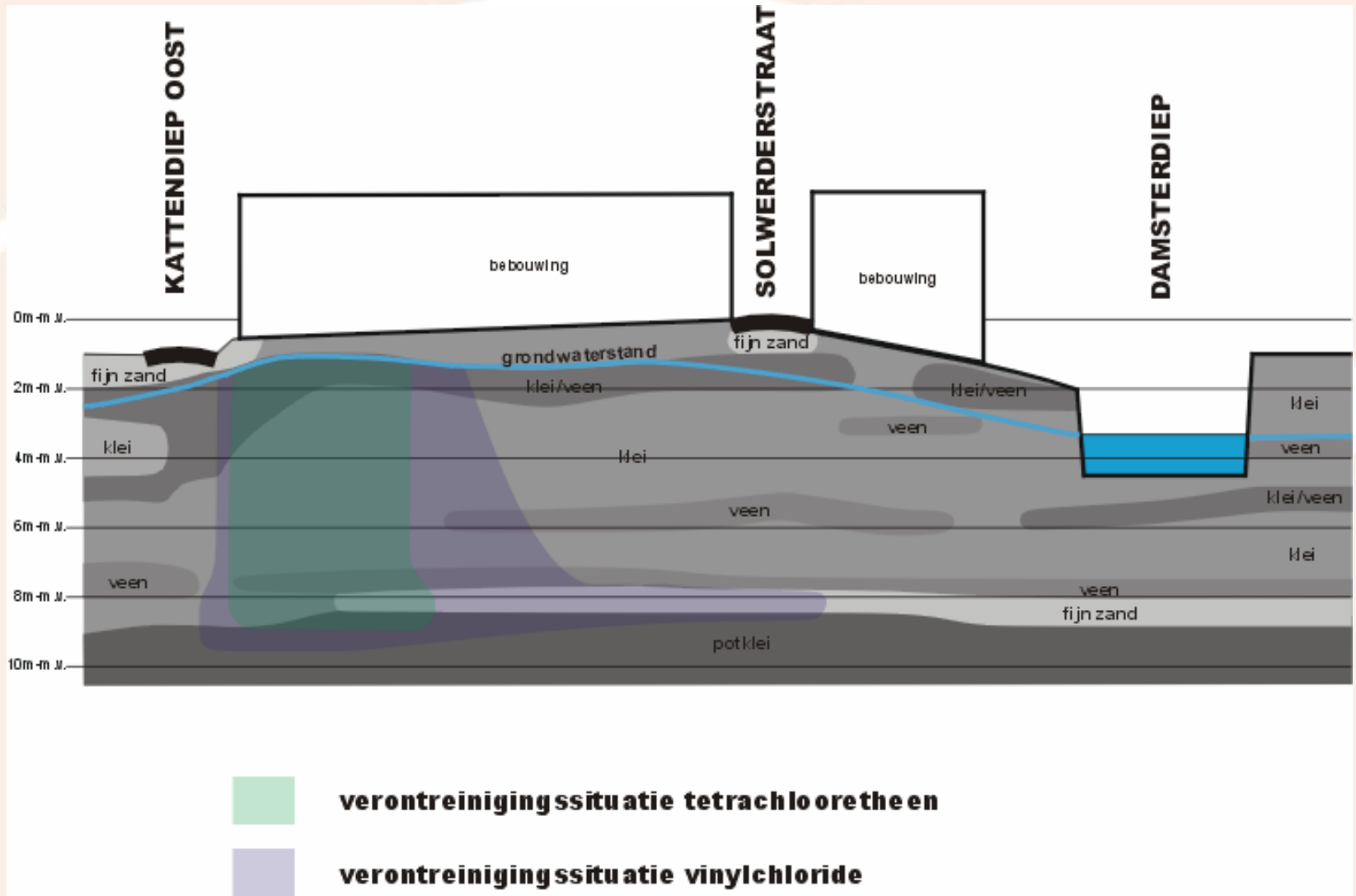
## **Aims**

- **Early insight of cost effective solutions !**
- **Effective monitoring !**

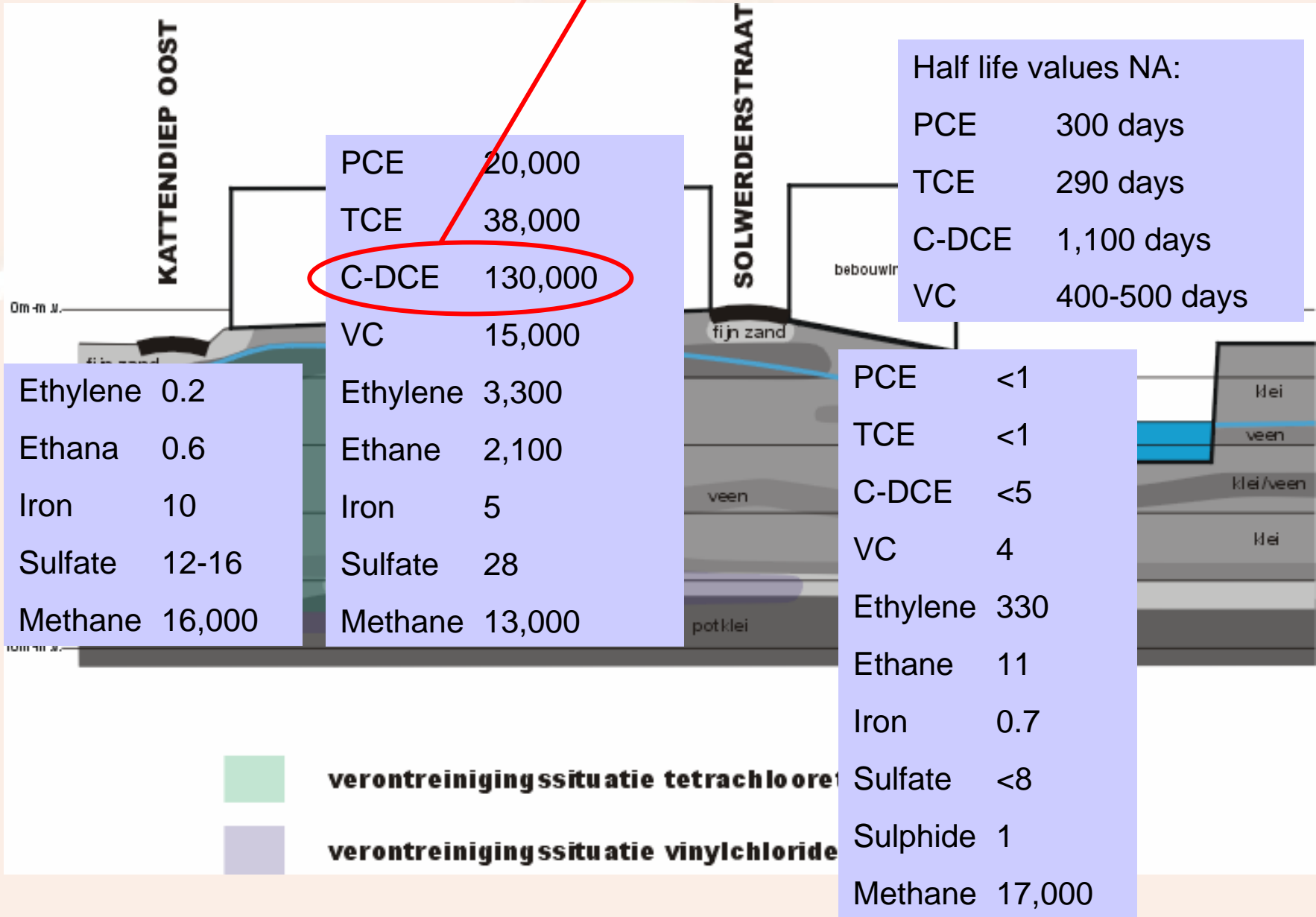
# Case Appingedam (VOC)



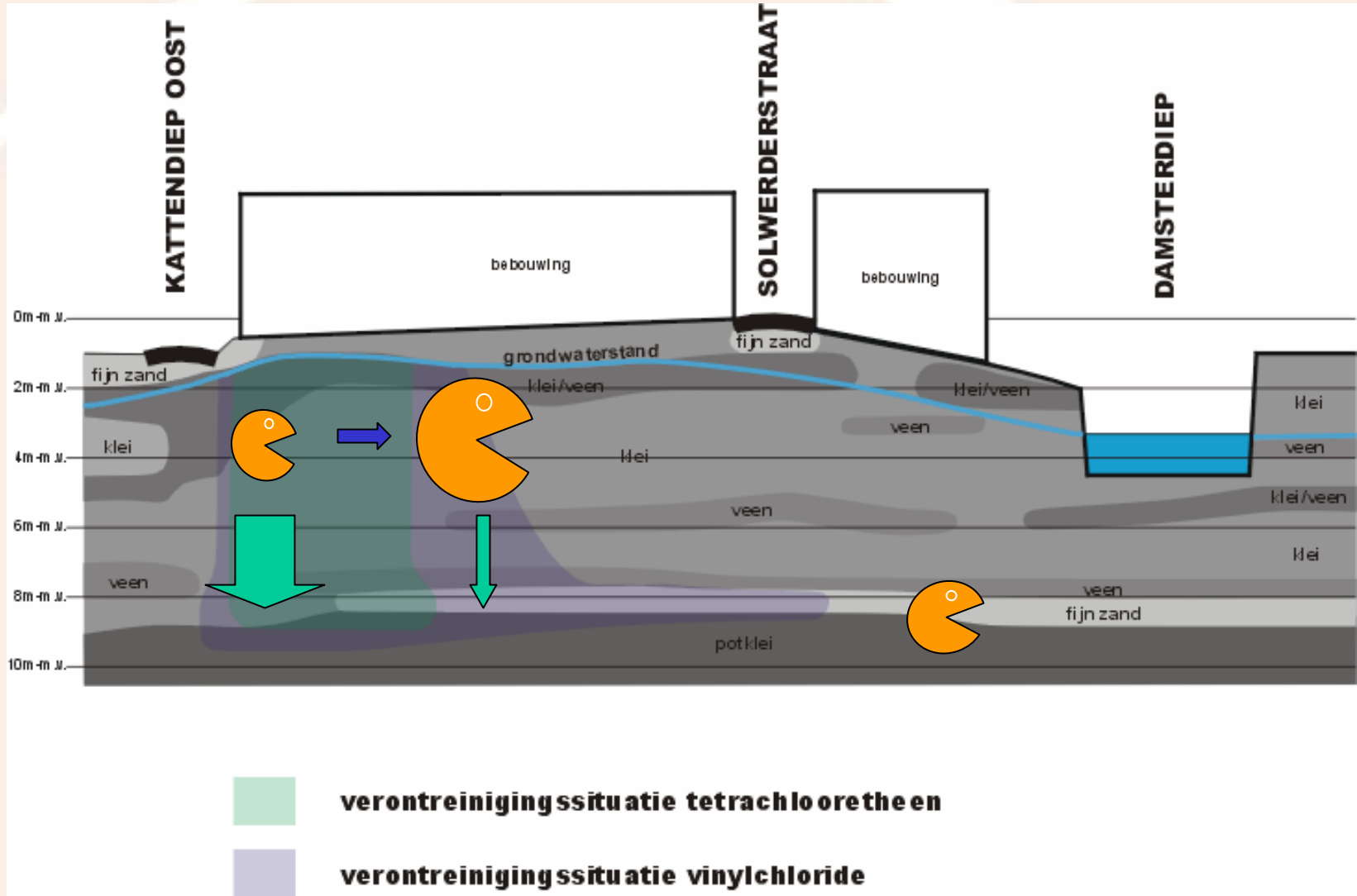
**Estimation source zone:  
500 – 600 kg PCE**

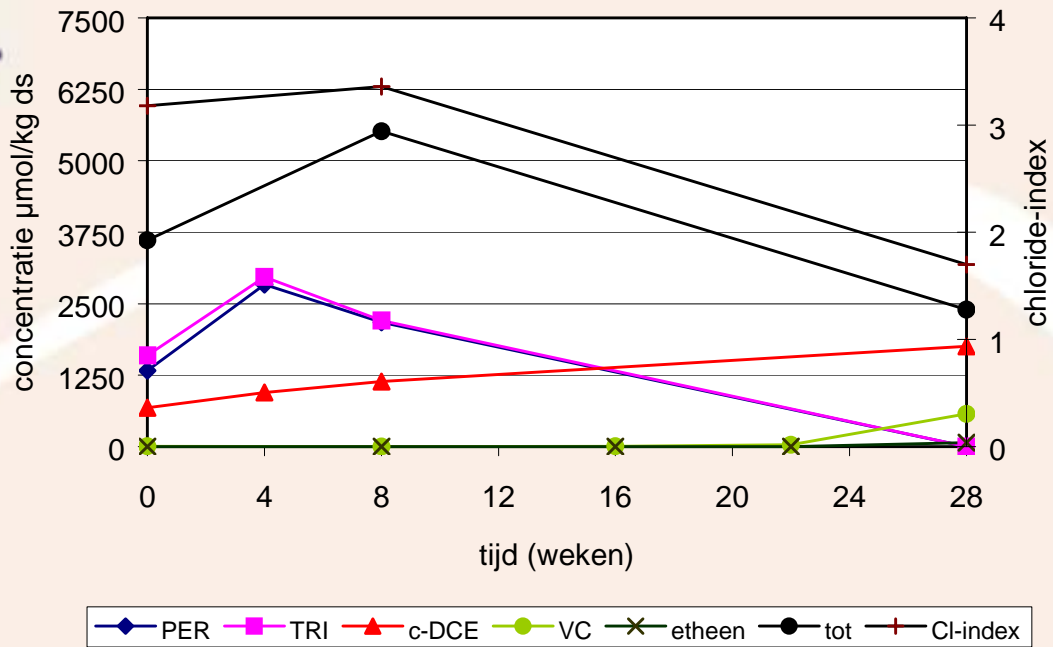


# Degradation high concentrations PCE

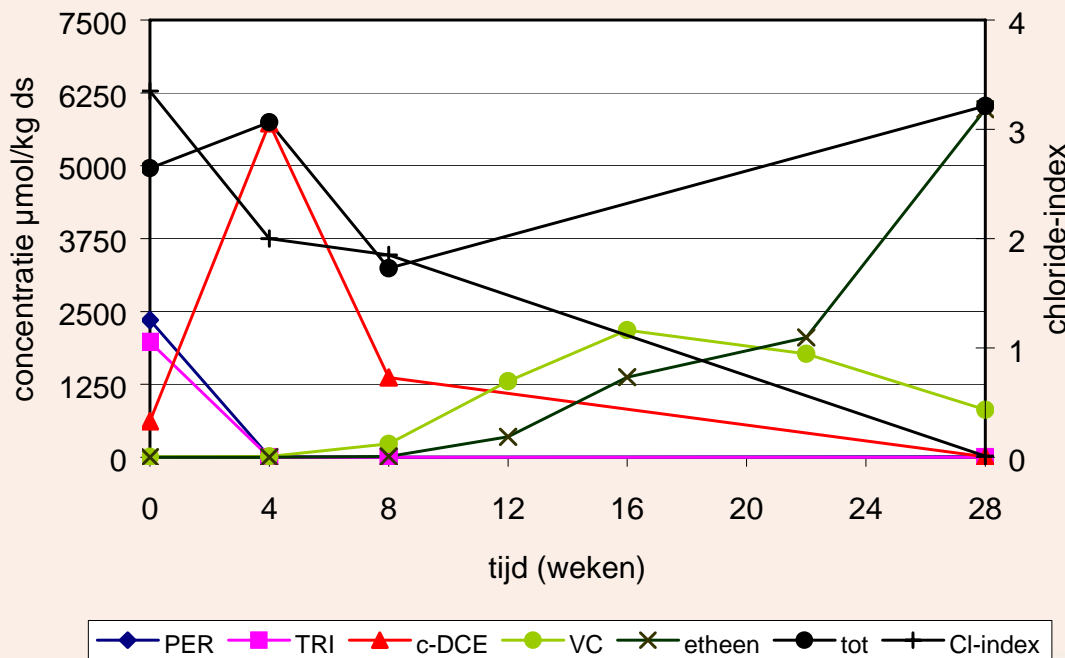


# Conceptual model: lower flux to sandlayer by increasing biodegradation in source zone





**Acceleration enhanced vs NA:  
Lab factor 20,  
Field factor 4-5**



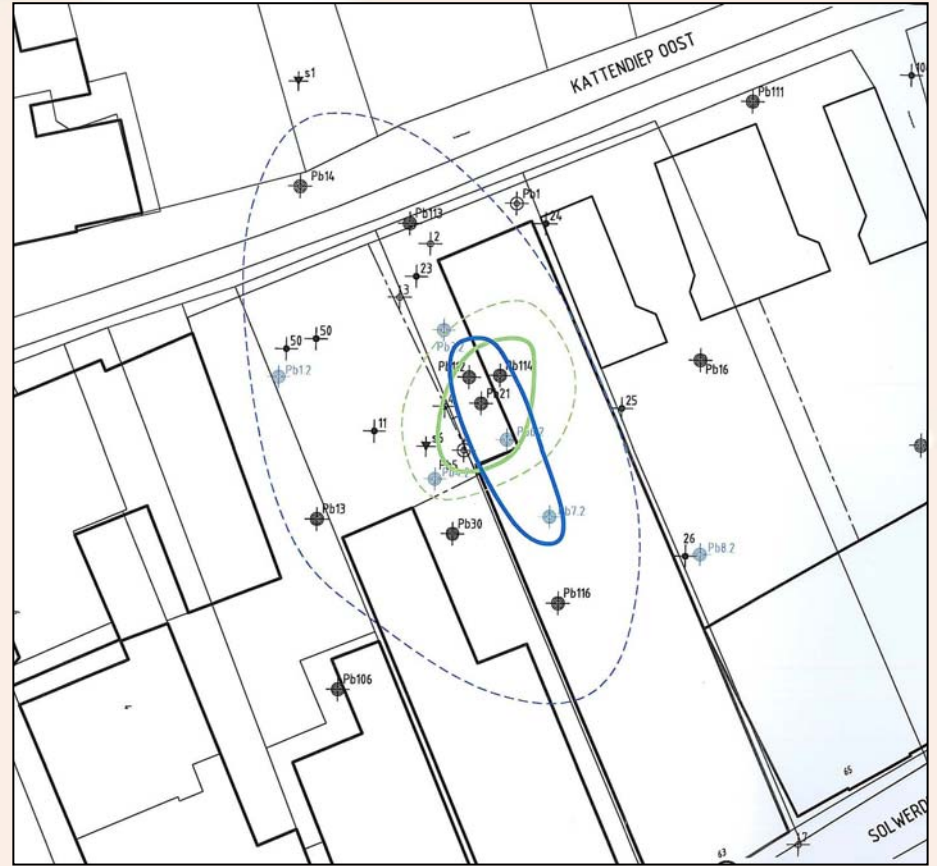
# Cost effective remediation: Enhanced degradation PCE in source zone



**Direct injection  
of carbon source  
(lactate and molasses)  
and nutrients**



1998



2003

- globale interventiewaardecontour tetrachlooretheen
- globale streefwaardecontour tetrachlooretheen
- globale interventiewaardecontour vinylchloride
- globale streefwaardecontour vinylchloride

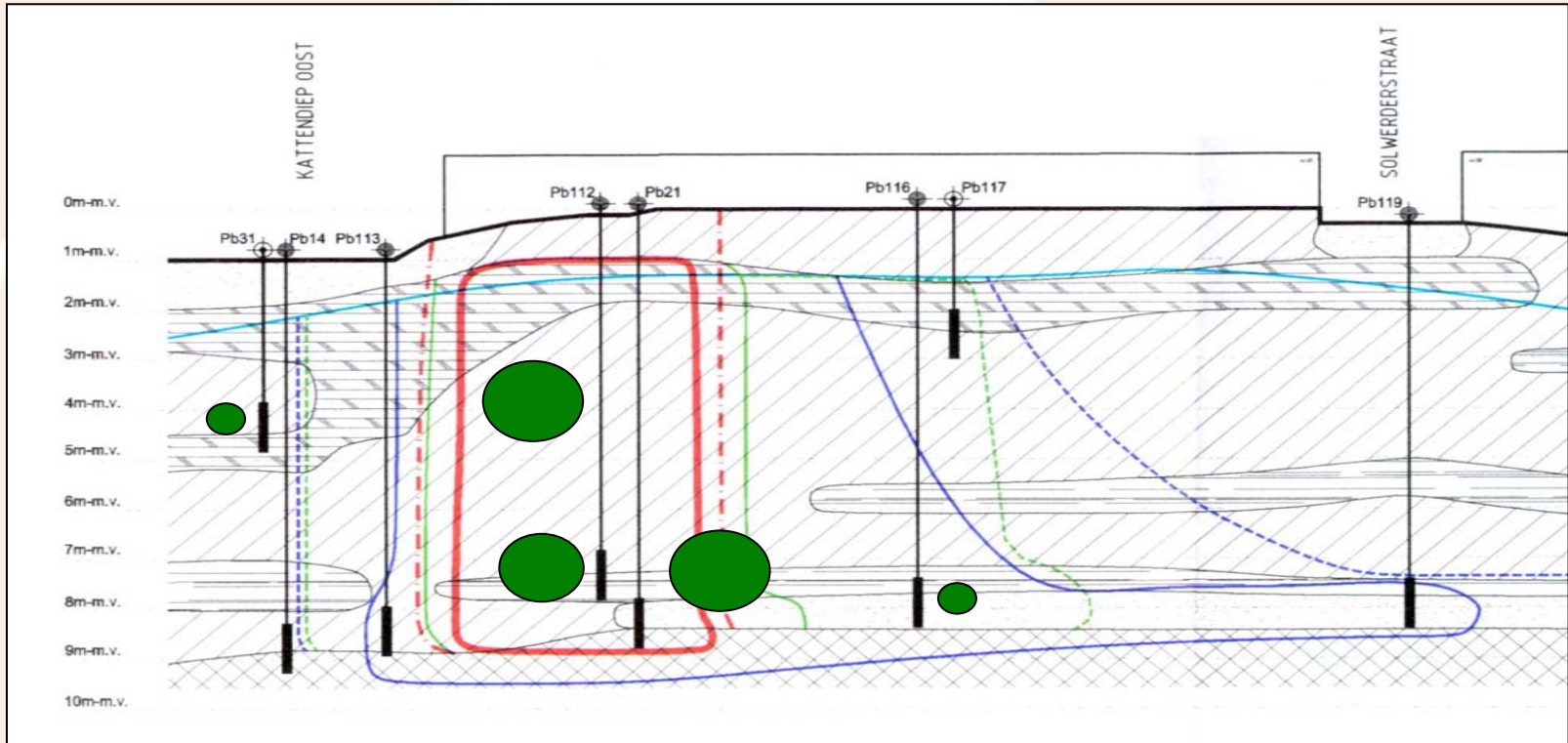


2003

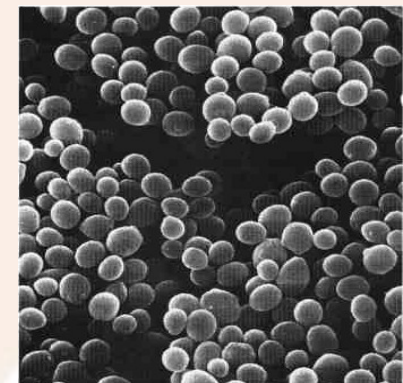
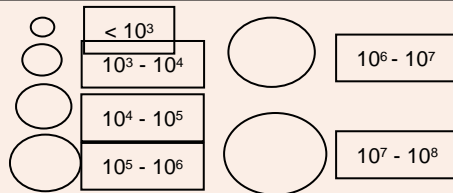
2005

- globale interventiewaardecontour tetrachlooretheen
- globale streefwaardecontour tetrachlooretheen
- globale interventiewaardecontour vinylchloride
- globale streefwaardecontour vinylchloride

# Monitoring: Growth/increase of contaminant degrading organisms



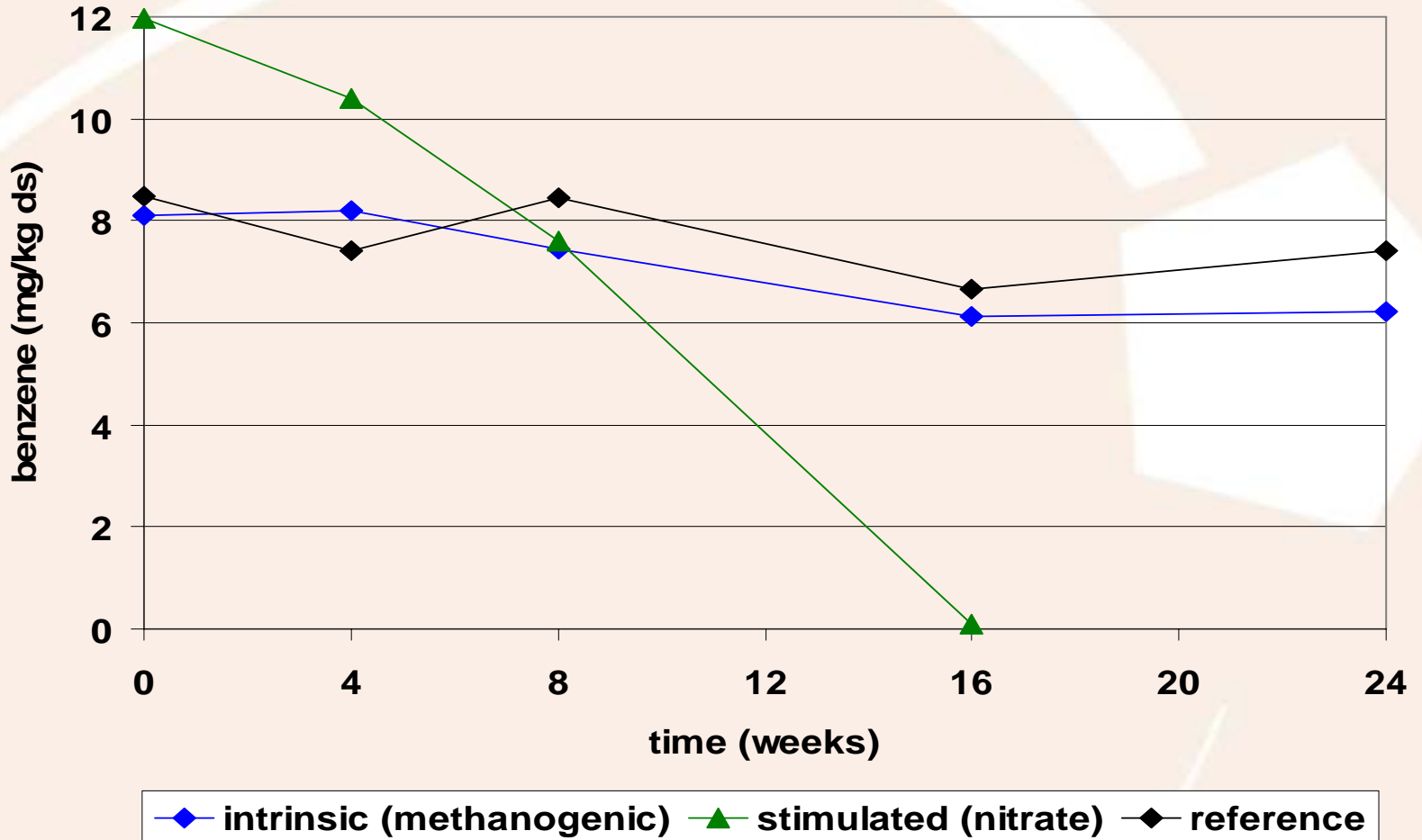
**Aantallen *Dehalococcoides ethenogenes***

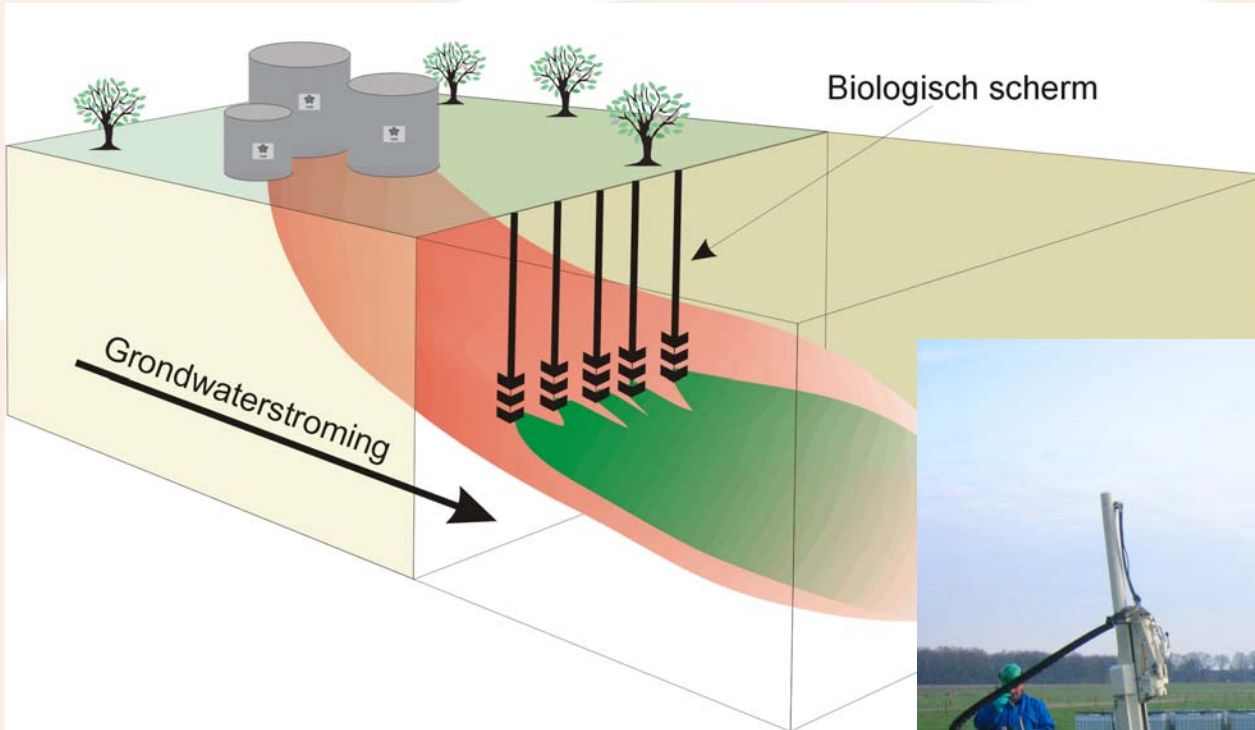


# Case Vries (BTEX)

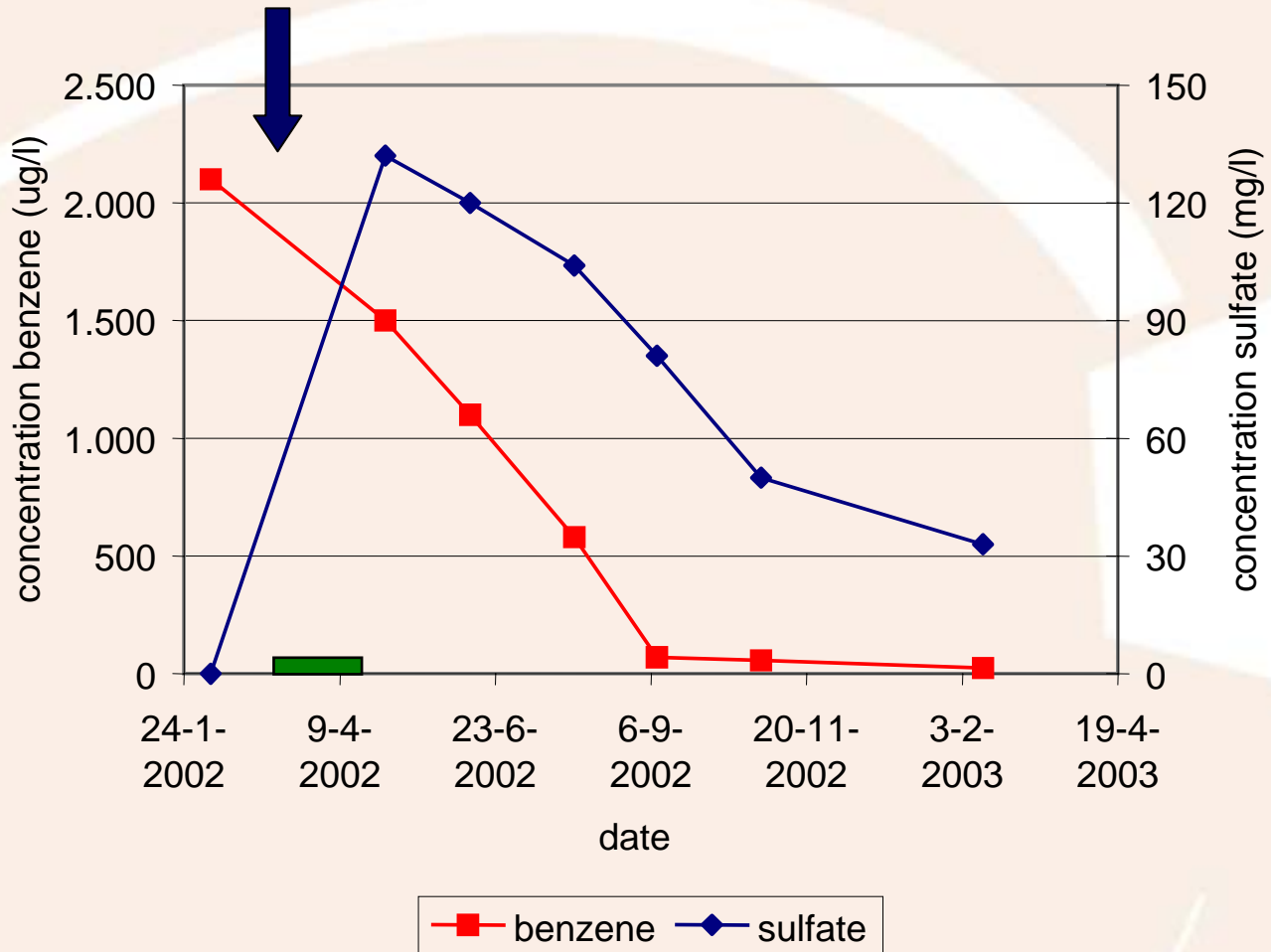
Well		Ref.	Ref.	L. border	L. border	Plume	Plume
Depth	m-gl	6-8	19-20	4-5	11-12	6-8	18-20
NO <sub>3</sub> <sup>-</sup>	mg/l	83	< 1	< 1	< 1	28	< 1
Fe(II)	mg/l	0.1	27	37	54	-	-
SO <sub>4</sub> <sup>2-</sup>	mg/l	22	51	< 8	< 8	59	38
S <sup>2-</sup>	mg/l	< 0.1	< 0.1	1.8	0.4	-	-
CH <sub>4</sub>	mg/l	0.04	0.03	7.7	17.2	6.3	0.9
Benzene	µg/l	< 0.2	< 0.2	110,000	0.9	2,900	210
Tol/Ethylb/Xyl	µg/l	< 0.6	< 0.6	30,000	< 0.6	58	50
Phenols	µg/l	-	-	570	-	-	-
Benzoates	µg/l	-	-	190	-	-	-

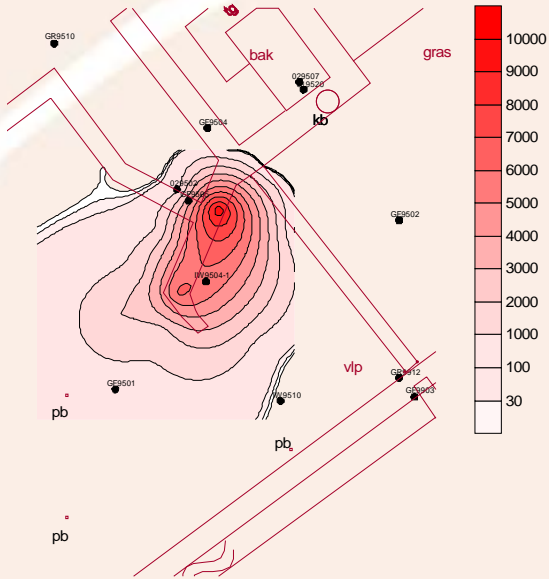
# Degradation test: Additional proof



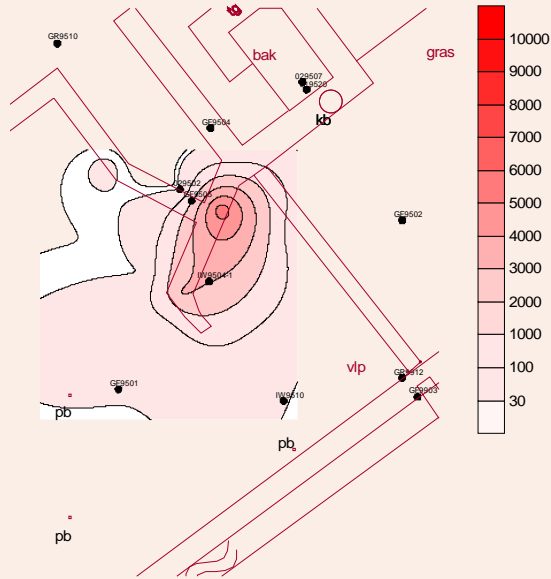


Direct injection of nitrate/sulfate at site

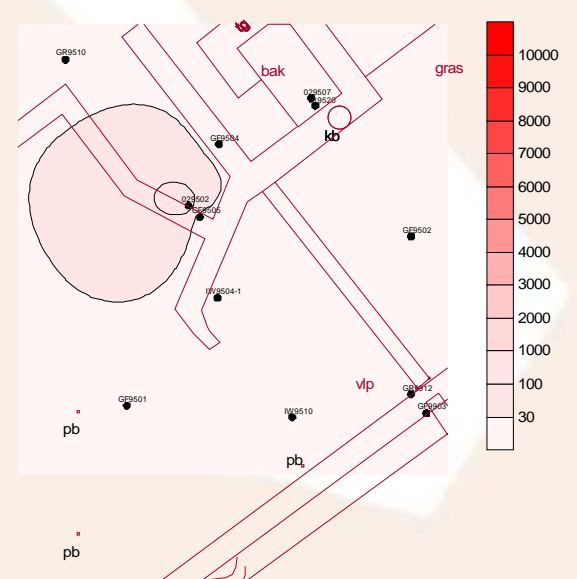




May 2002



February 2003



November 2004

Half life time benzene: 144 days

# Case Almelo (VOC)



T=0:

pH: 6.4-7.0

Sulfate: 75 –130 mg/l

PCE: 15,000 to several hundreds of  $\mu\text{g/l}$

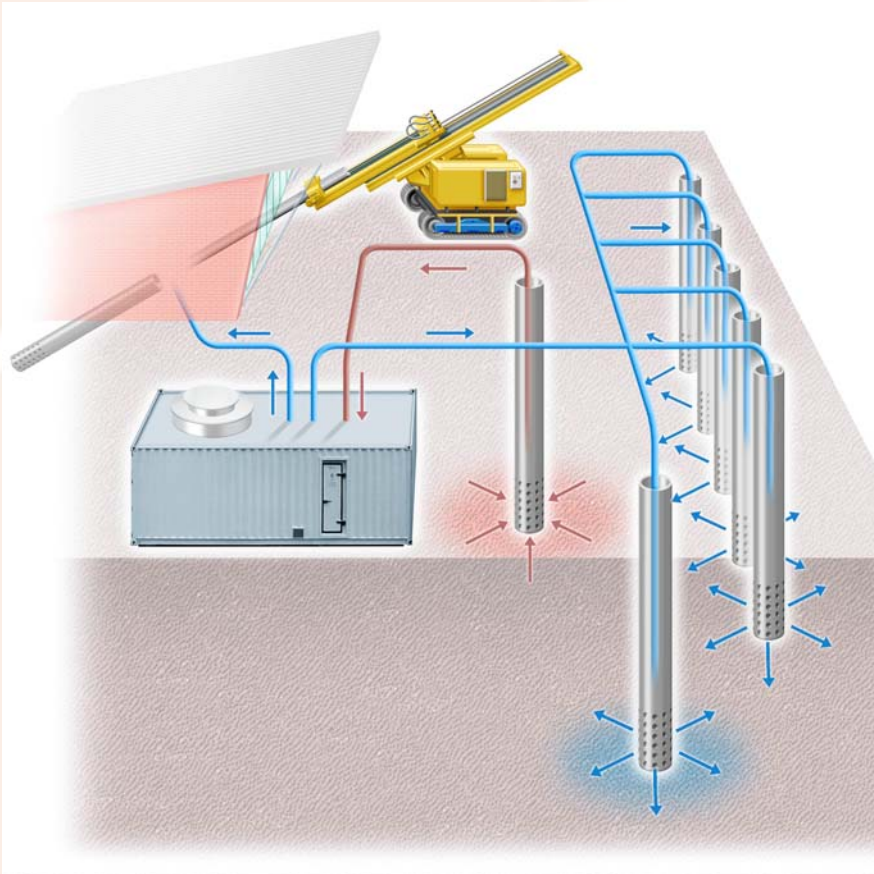
TOC: 14-18 mg/l

No degrading organisms

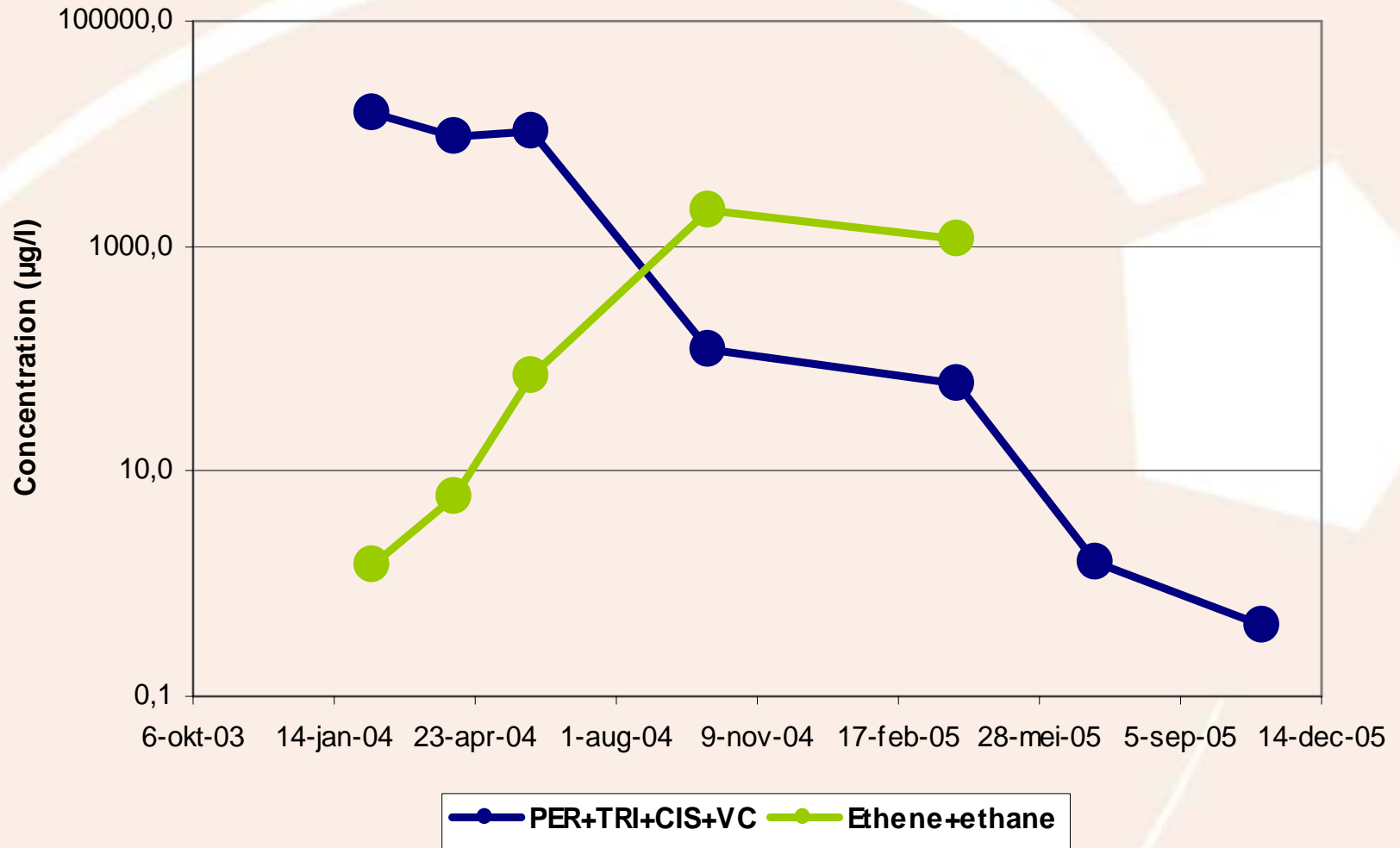
**GWK**

**Molecular  
analysis**

# Technical approach



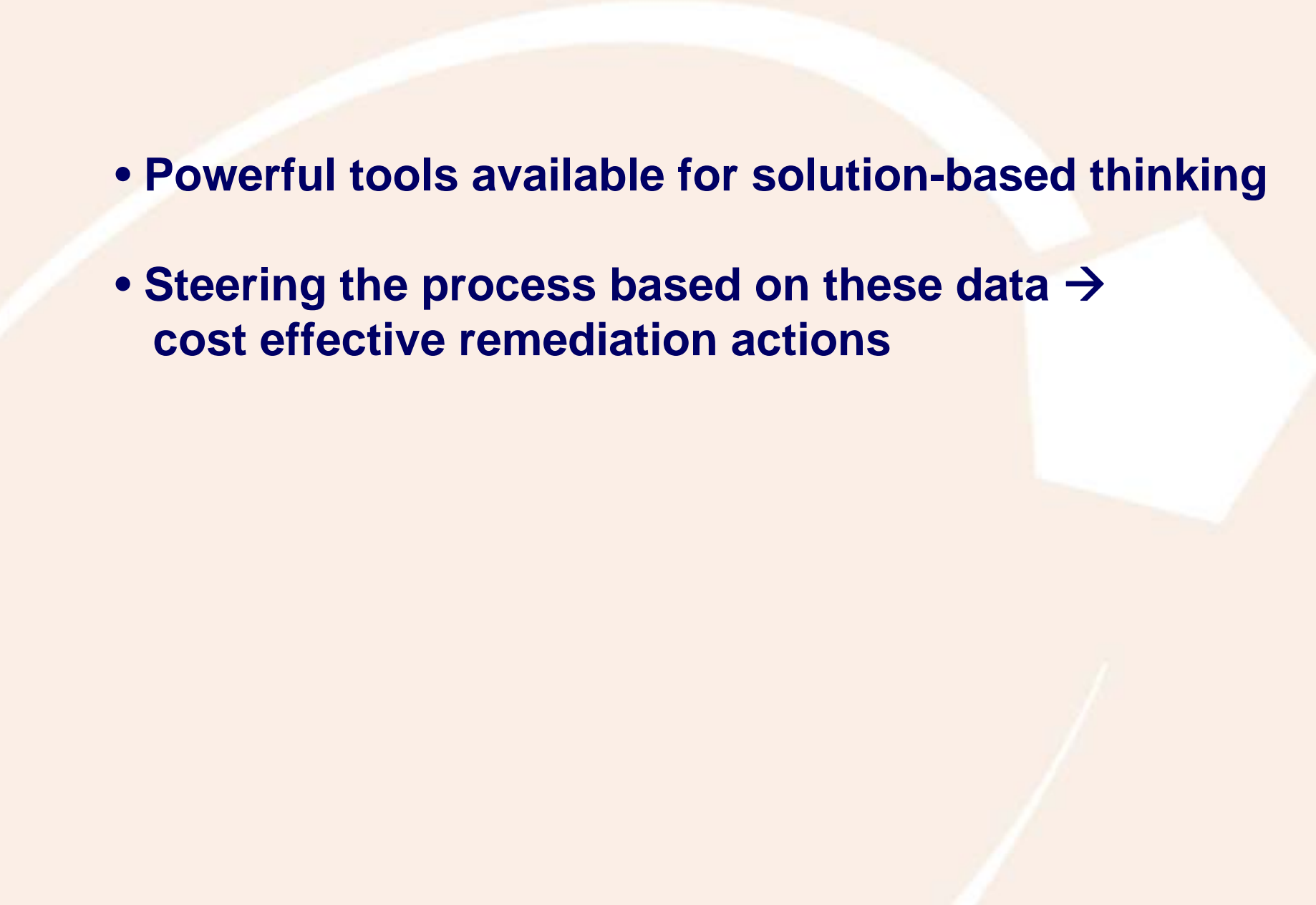
# Dechlorination



# Dechlorination

	February 10, 2004	April 8, 2004	June 2, 2004	October 5, 2004	July 7, 2005	November 3, 2005
PCE (µg/l)	15.000	7.000	< 0,1	0,2	< 0,1	< 0,1
TCE (µg/l)	< 40	1.300	< 0,1	< 0,1	< 0,1	< 0,1
<i>cis</i> DCE (µg/l)	< 40	1.300	10.000	45	0,76	0,3
VC (µg/l)	< 40	NA	NA	23	0,8	0,13
Ethylene (µg/l)	0,2	4	57,9	2.100	NA	NA
Ethane (µg/l)	1,3	2	13,4	6.0	NA	NA

## Conclusions

- **Powerful tools available for solution-based thinking**
  - **Steering the process based on these data → cost effective remediation actions**
- 
- A large, light-colored decorative graphic on the right side of the slide. It consists of a thick white curved line that starts from the left and ends in a white diamond shape pointing to the right. The background is a light beige color.



*"... and we can save 700 lira by not taking soil tests."*