Biological in situ remediation

- Aleida de Vos van Steenwijk,
  RemTech 2011 (Banff, Canada)

Presentation overview

- The companies
- A short introduction
- Case study: remediation in an urban area
- Innovation and development

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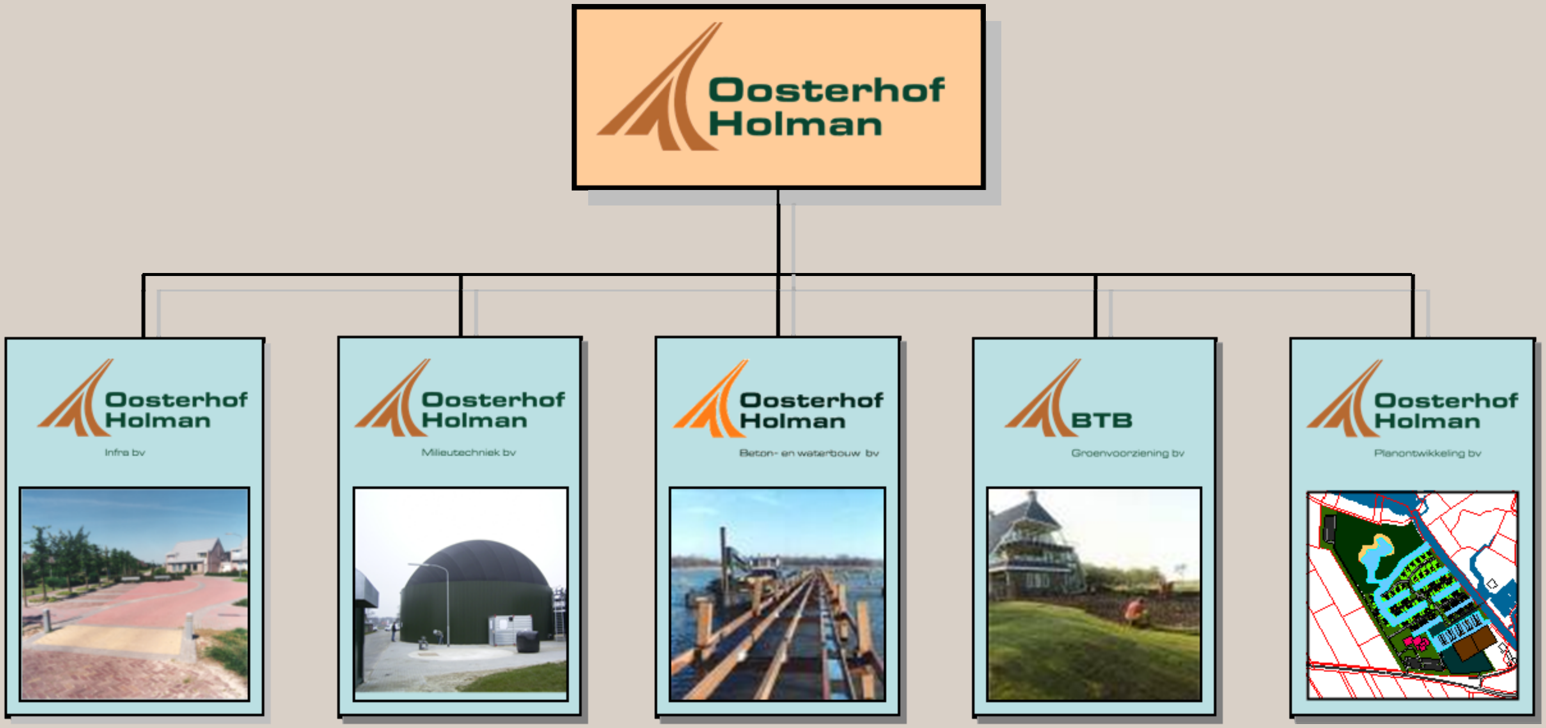

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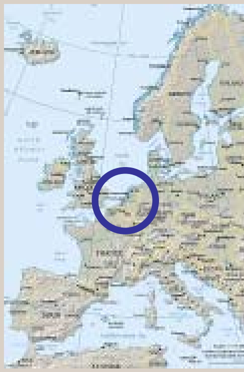
Locations



Grijpskerk
Groningen
Kootstertille
Giekerk
Harlingen
Arnhem

Environmental Technology

- Soil and Groundwater Remediation
- Dredging
- Water Purfication Plants
  - Conventional systems
  - Membrane systems
- Renewabele Energy
  - Biogas
  - Wind
  - Biofuels
- Special Projects
  - “Sustainable Living”

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Bioclear bv

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Bioclear bv

- Consultancy and Innovation office for environment and sustainable production
- To make the world clean, sustainable and safe using biological processes
- 30 employees, multidisciplinary, teamwork
- A large knowledge network
- Offices in Groningen en Geertruidenberg (NL)

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Areas of expertise

Soil & Water

Hygiene & Safety

Biobased Society

Bioclear Laboratories

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Soil & Water

Soil & Water

- In situ bioremendation
  - Natural attenuation
  - Feasibility and design of bioremediation concepts
  - Performance and supervision of biological soil remediation
  - Sustainable use of soil / cycling
  - Buffering capacity of soil (ETS)
- Ecosystem services
- Ecological quality and risk assessments
- Knowledge and technology development
- Monitoring and control of biological processes

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Hygiene & Safety

Hygiene & Safety

- Prevent unwanted processes (detection, monitoring and control)
  - biofouling
  - biocorrosion / MIC
  - Pathogens
- Monitoring and control biological processes
  - development custom made analyses
  - sampling strategies
  - interpretation
  - risk-assessments
  - preventative strategies

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Biobased society

Biobased Society

- Monitoring and control biological processes
- Valorisation of wastes and residues
  - biogas
  - green chemicals
  - fertilisers
  - market research
- Recycling of nutrients (NPK)
- Chain development
- Knowledge and technology development

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Bioclear laboratories

Bioclear Laboratories

- Routine analyses for monitoring and control
- Analyses for ecological and soil quality
- Analyses for product quality / safety
- Development of custom-made analyses
- Validation and implementation
- Courses and workshops
- Contract research

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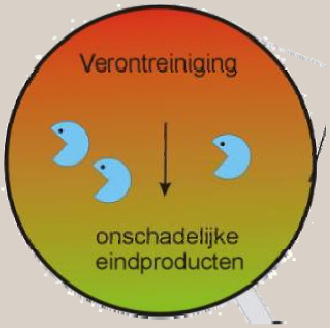
Short introduction

In situ bioremediation

Biological degradation of CVOC is possible?



In the nineties:

Biodegradation is difficult and slow

From 1997:

Dehalococcoides bacterium (Maymo-Gatell *et. al.*)

Research into optimum conditions for biodegradation

Now:

Biological in situ remediation is proven technology

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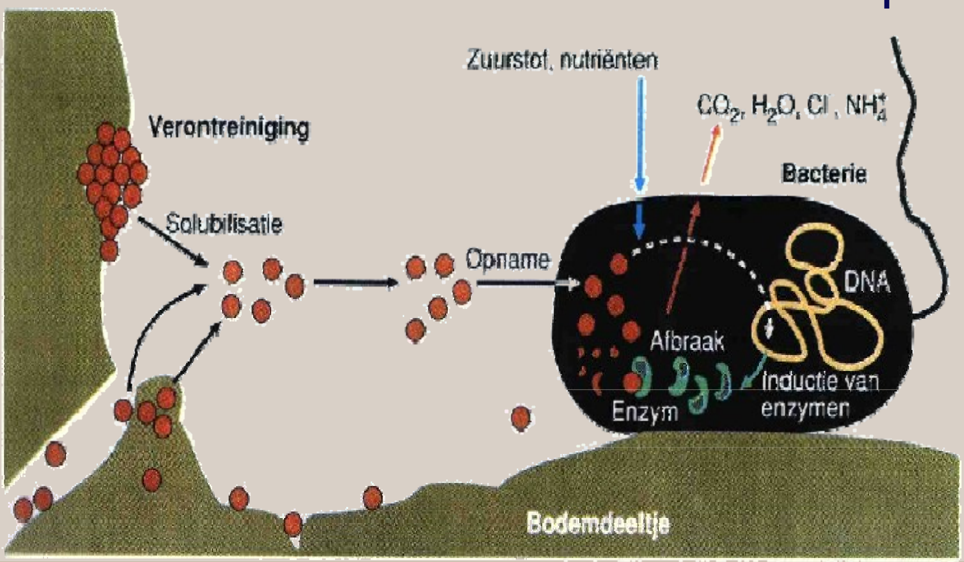
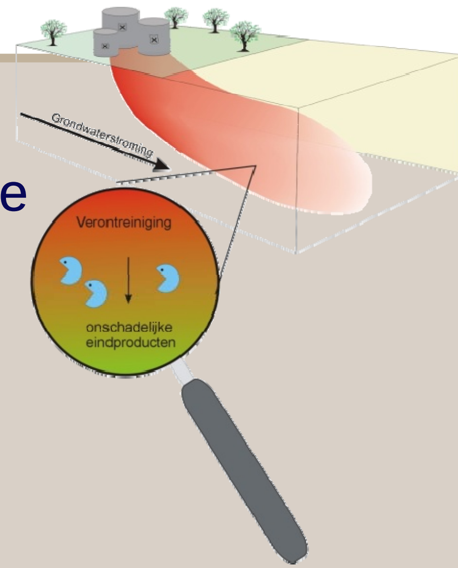
Optimal conditions

PCE → TCE → DCE → VC → ethene → (ethane) (reductive dechlorination)

- Presence of *Dehalococcoides* bacteria
- Right conditions in soil
- Adequate nutrients and carbon source

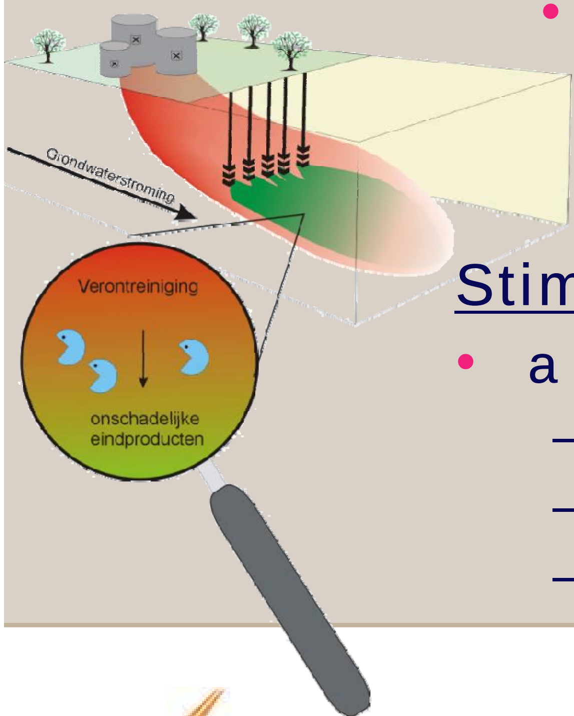


Natural or a helping hand?



Natural Attenuation (NA)

- naturally occuring conditions are suitable
- no active measures required
- this situation is rare!



Stimulated degradation

- a limitation inhibits natural attenuation
  - create optimal conditions
  - add nutrients and/or carbon source
  - add bacteria → bioaugmentation

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Case Study

TCE concept in centre of
The Hague, the Netherlands

Background information location

- Urban area (houses and shops)
- Renovated and protected buildings
- Contamination with chlorinated solvents (PCE and TCE)
- Likely cause: sewer leak containing waste from dry cleaners

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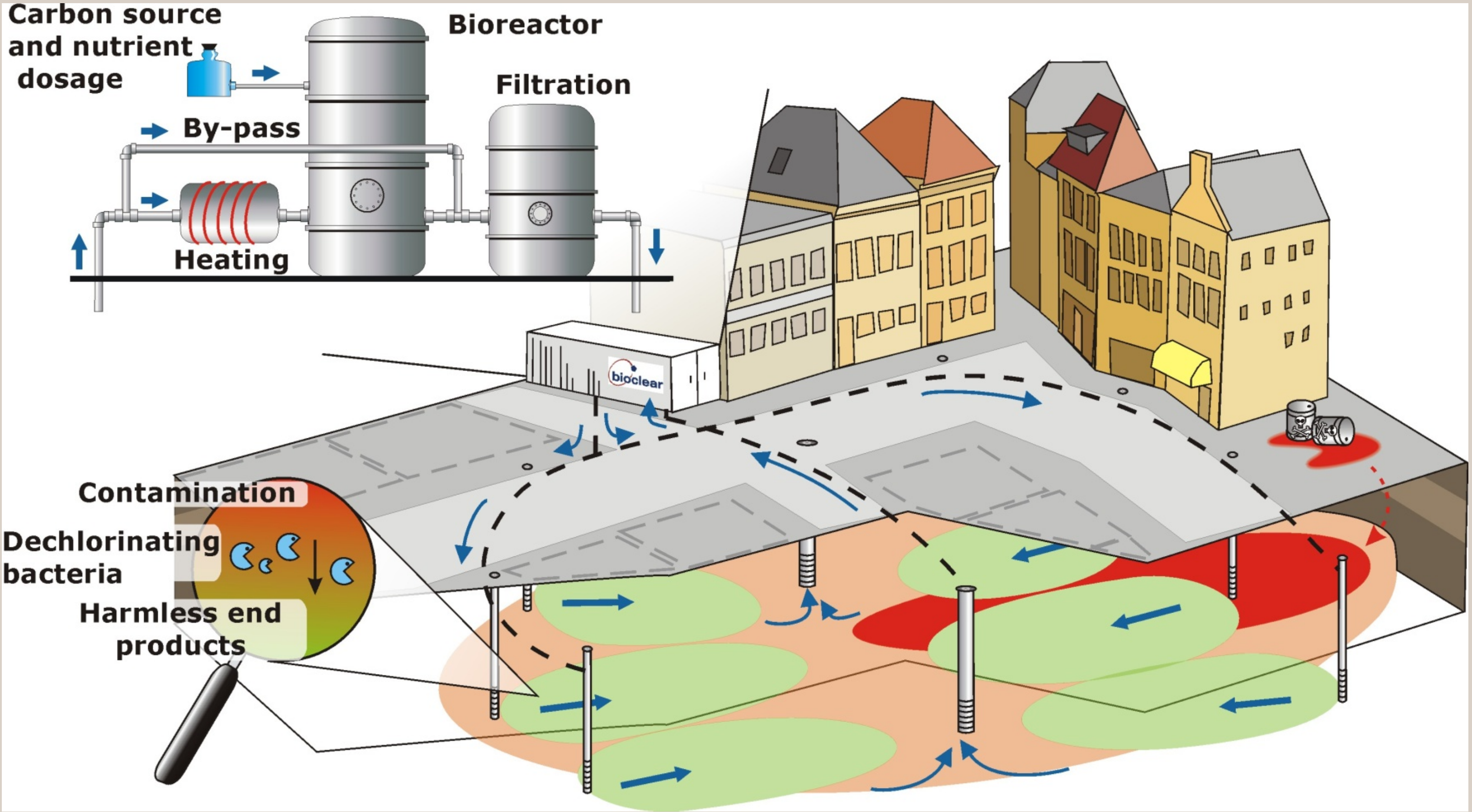
TCE concept (bio-augmentation)



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Remediation approach

- Active phase
  - Create right conditions in soil
  - Sufficient carbon source for reductive dechlorination
  - Sufficient and active dechlorinating population
- Passive phase
  - In situ reductive dechlorination until remediation aim is achieved
- Monitoring phase
  - Has a stabile end situation been achieved...?

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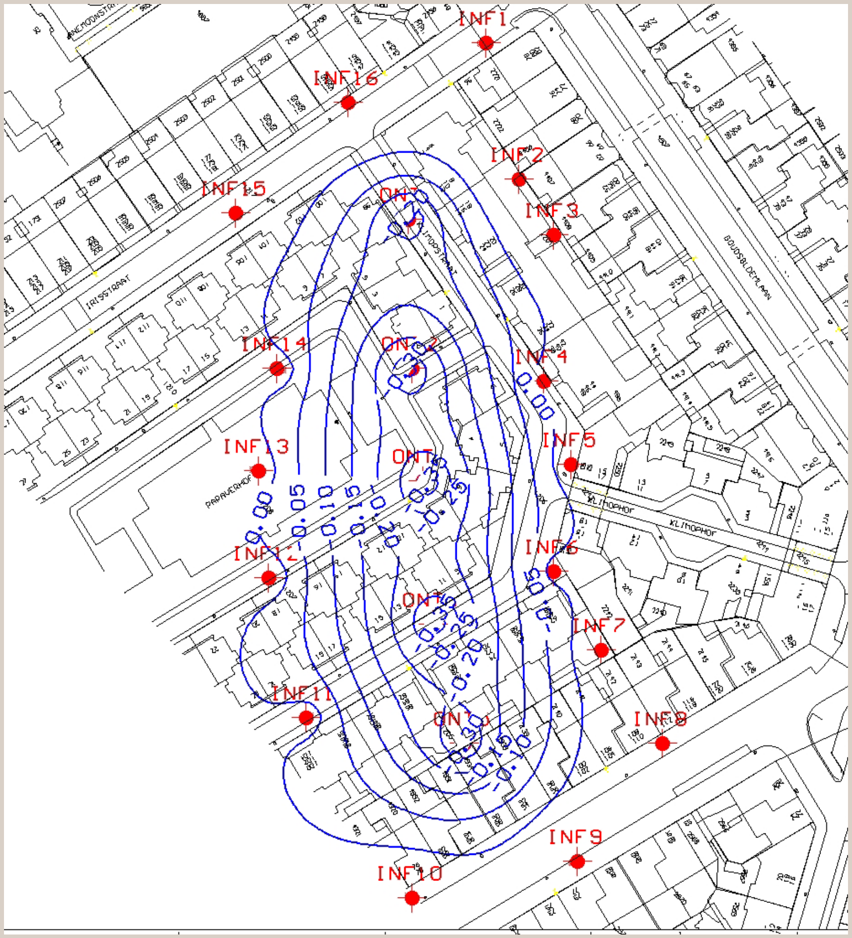
Remediation design



- 80.000 m³ > I-value
- Up to 1.000 µg/l
- 10 m-sl
- Medium-grained sand
- 5 Extraction wells
- 16 Infiltration wells
- Closed water balance
- Water table change < 42 cm
- 10 m³/hour ext/inf

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Remediation Phases

- Active Phase: Dec. 2007 – Sept. 2008
- Passive Phase: 2 Years,
  goal: PCE=20 µg/l; TCE=262 µg/l; DCE=10 µg/l; VC=2,5 µg/l

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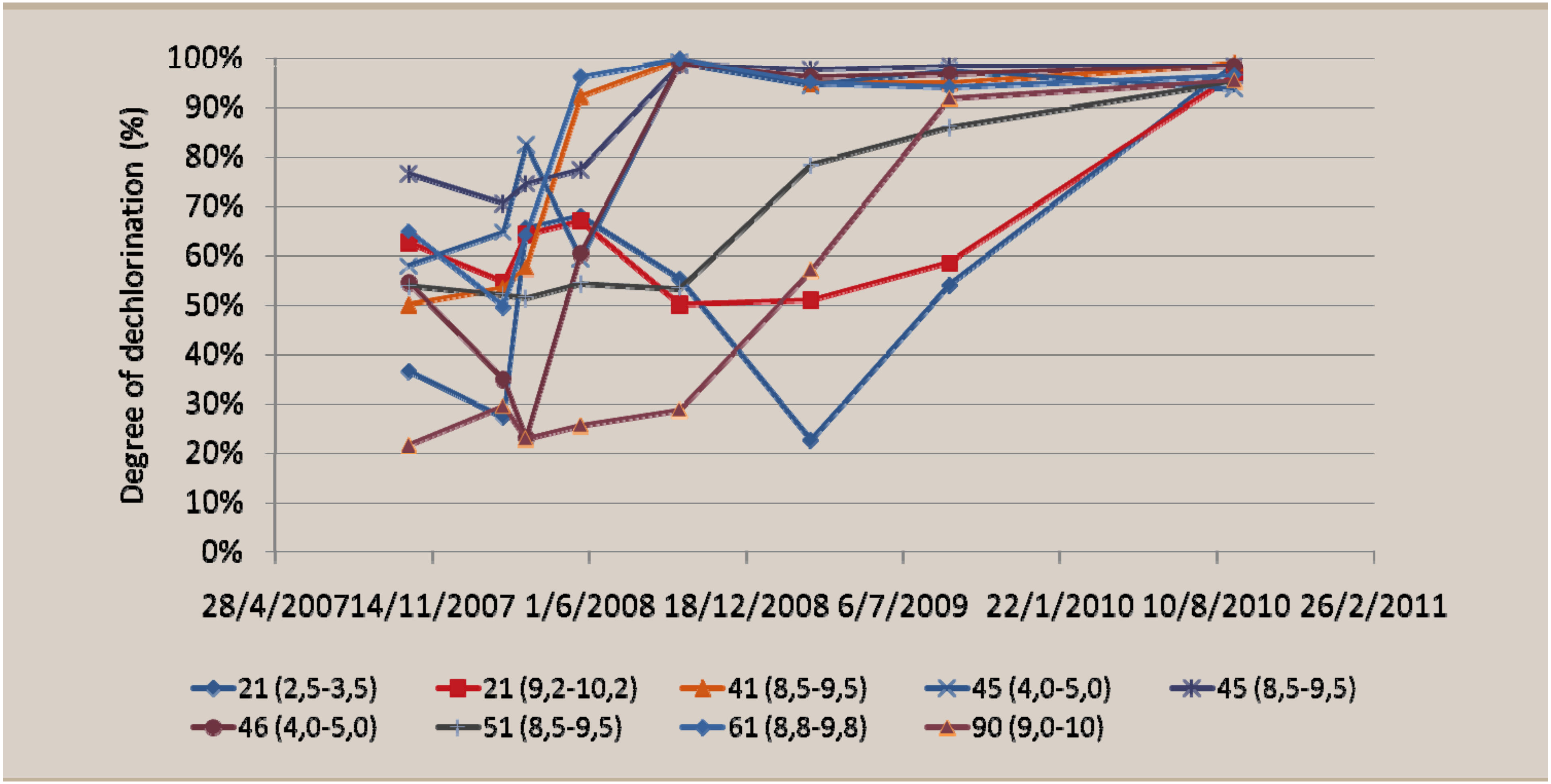
Results



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Results

- After 1 year: 6 out of 9 wells < remediation target
- After 2 years: 8 out of 9 wells < remediation target
- Sept. 2010: Site closure
- In-situ treatment of TCE plume within 3 years
- 80.000 m^3 soil volume remediated
- Total actual costs € 441.000 (= 5,51 euro / m^3)

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Sustainability

- *TCE concept (as performed)*
- *Pump & Treat (hypothetical)*
- *ISCO using Ozone (hypothetical)*

Alternative 1. Pump & Treat

- 17 Infiltration wells
- 13 Extraction wells
- 10 m^3/hour
- Closed water balance
- Stripping system 8 KW
- Duration 10 years
- Costs est. € 900.000

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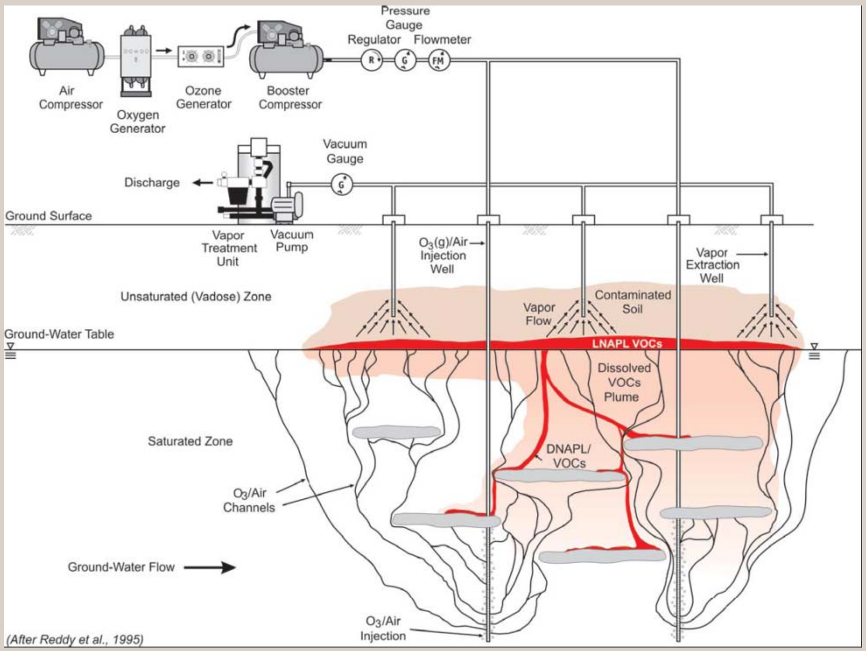
Alternative 2. Ozone



- Ozone sparging
- Analogous to air-sparging
- NOD: 15 g O_3 / m^3 soil
- Sparging efficiency: 5 %
- 24.000 kg ozone
- PLI + SVE system 12 KW
- Duration 1 year
- Costs est. € 800.000

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Method for comparison: MCA

SOCIAL EFFECTS

(smell, noise, hindrance, potential dangers, chance of calamities, chance of damage)

ENVIRONMENTAL EFFECTS

(air, soil, groundwater, ecology, waste production, residual contaminations)

RESOURCES AND MATERIALS

(use and reuse of water, groundwater, energy, fuels (transport), chemicals, materials)

CLIMATE EFFECTS

(Carbon dioxide & methane emissions)

Compare remediation options on these 4 themes

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Summary MCA results

	weight	Alternative 1: Pump&Treat score	Bio-augmentation (TCE concept) score	Alternative 2: Ozone score
Social effects	1	6,1	7,1	6,0
Environmental effects	1	8,7	9,0	9,0
Resources	1	8,0	9,5	8,0
Climate	1	6,0	9,0	6,0
Total		**7,2**	**8,7**	**7,3**

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Innovative developments

Monitoring and control of microbial processes

Monitoring key microbial processes

"A good understanding of the capacity for natural attenuation is the key to feasible and practical bioremediation"

- Sampling
- Analysis

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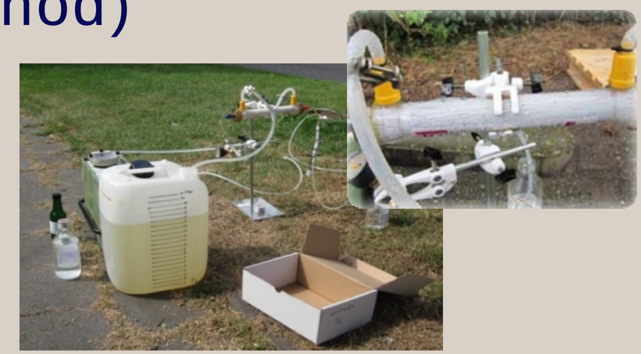
Groundwater sampling

- “Standard method”

- Large volume sampling (dialysis method)



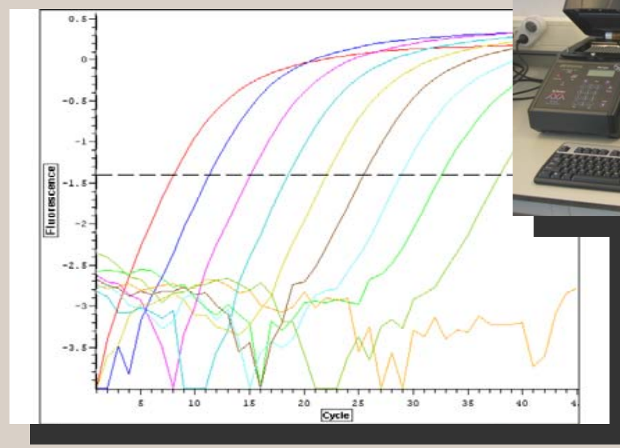
- BACTRAPs©

Who’s there and what are they doing?

Quantification of micro-organisms and their activity

Q-PCR: - Flexibility

- Accurate quantification
- Activity measurements
- Sampling
- All sample types
- Objective determination
- Quality control



“Most species cannot be cultured as their growth conditions are unknown or cannot be reproduced in the laboratory. The percentage of cultivable micro-organisms depends on the complexity of the sample and can vary from 90% to as little as 1%. The risk of false negatives therefore is significantly increased.”

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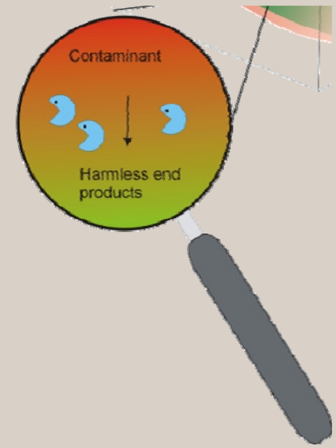
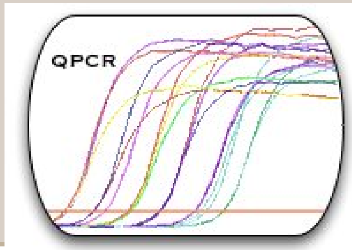
Degradation processes of chlorinated ethenes



- Reductive dechlorination
  - Methanogenic conditions
  - Degradation of PCE, TCE, DCE & VC
  - Bacteria involved: *Dehalococcoides* spp
  - Key enzymes involved: VC-reductase

- Micro-aerophilic oxidation
  - For example Iron reducing conditions, low oxygen (as low as 0,03 mg/l)
  - Degradation of DCE & VC
  - Bacteria involved: *Polaromonas* (*cis-DCE* degradation)
  - Key enzymes involved: *Etn*C & *Etn*E (VC degradation)



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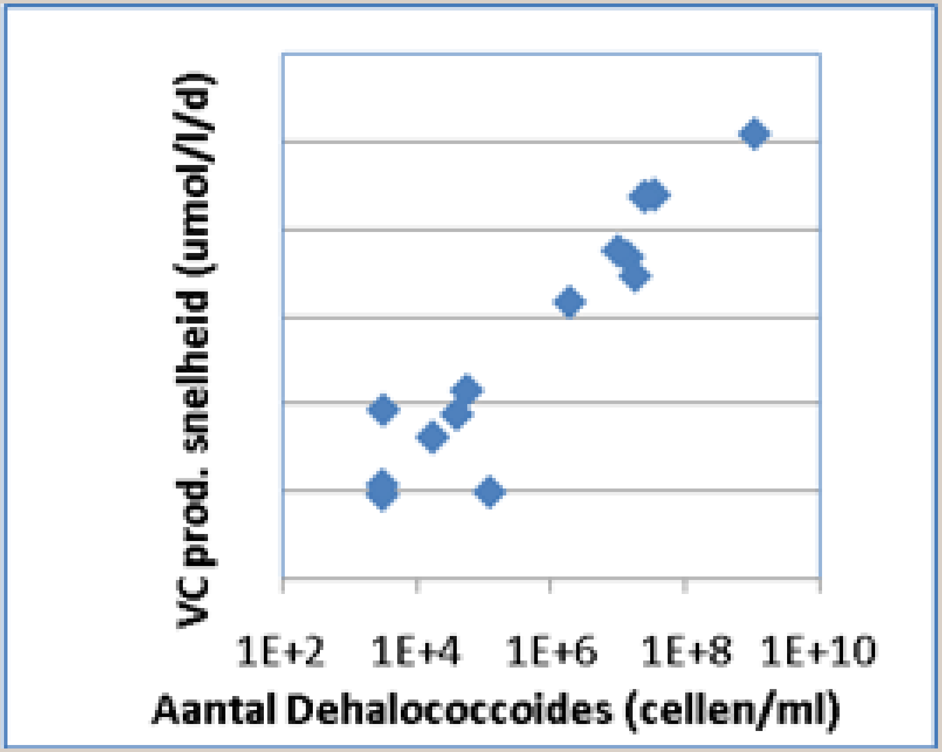
Reductive dechlorination

Correlation between number of *Dehalococcoides* cells and degradation in groundwater per m^3 per day



Micro-aerophilic oxidation

Monitoring well		Pb61-A	Pb53	Pb67	Pb86	Pb86	Pb106	Pb 106
Depth		26 m-mv	38 m-mv	26 m-mv	14 m-mv	24 m-mv	20 m-mv	35 m-mv
Dehalococcoides	cells/ml	<	<	<	<	<	3,9x10^{4}	2,1x10^{5}
*Etn*C	cells/ml	<	7,4x10^{3}	1,6x10^{1}	<	<	<	8,4x10^{2}
*Etn*E	cells/ml	<	9,7x10^{2}	<	<	<	<	1,0x10^{3}
Polaromonas	cells/ml	<	<	<	<	<	<	<

Anaerobic degradation of aromatic compounds

Degradation of BTEXN

- BcrA enzyme: breaks open ring structure aromates
- BssA enzyme: first steps of degradation of aromates. Adds a molecule (fumarate) to methylated aromatic compounds (toluene en de xylenes). Likely also involved in degradation of benzene.
- NcrC enzyme: only recently discribed in literature. Same function as BcrA enzyme, but then for naphtalene

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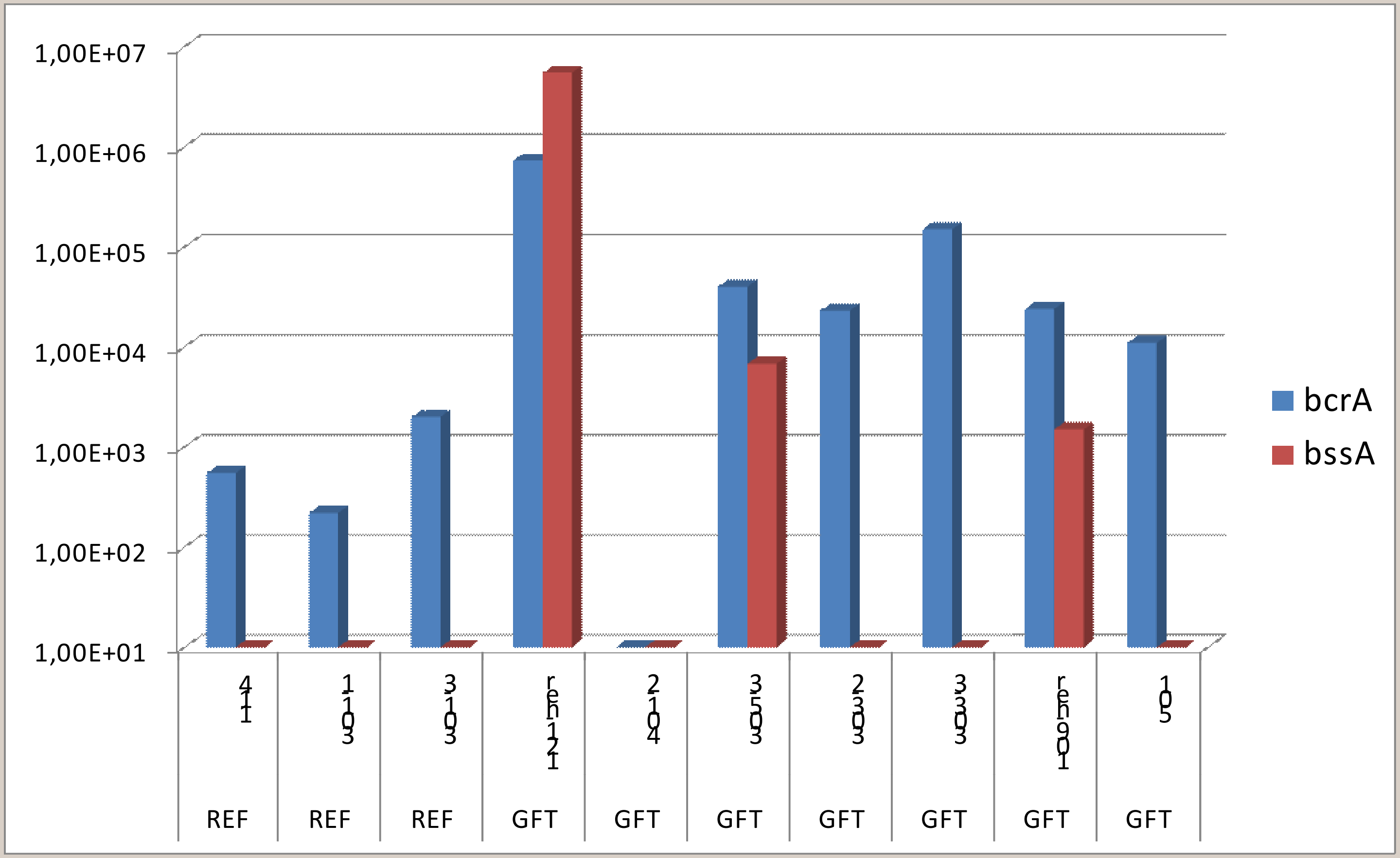
Anaerobic degradation of aromatic compounds



Conclusions

- In situ bioremediation is proven technology
- Bio-augmentation highly sustainable: low energy, low CO_2, low cost & very effective
- Continuing innovation and development to further improve in situ bioremediation

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Thank you for your attention

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