Control of landfill leachates contaminated groundwater by a MULTIBARRIER approach

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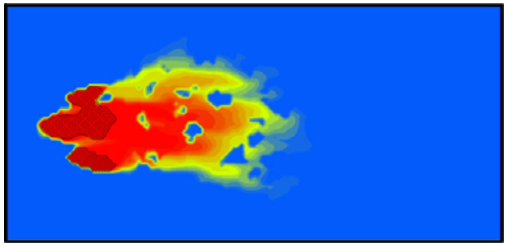
NATO-CCMS Pilot Study

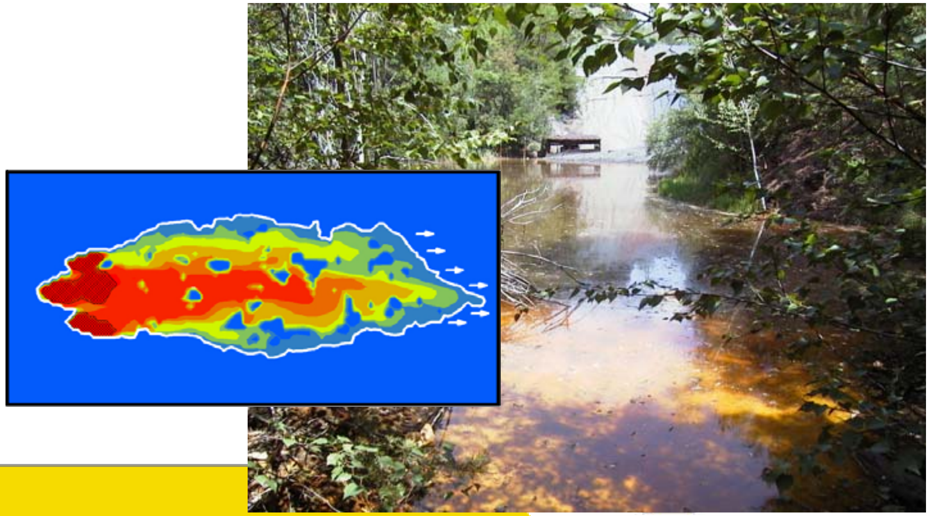
Prevention and Remediation in Selected Industrial Sectors:

Rehabilitation of old landfills

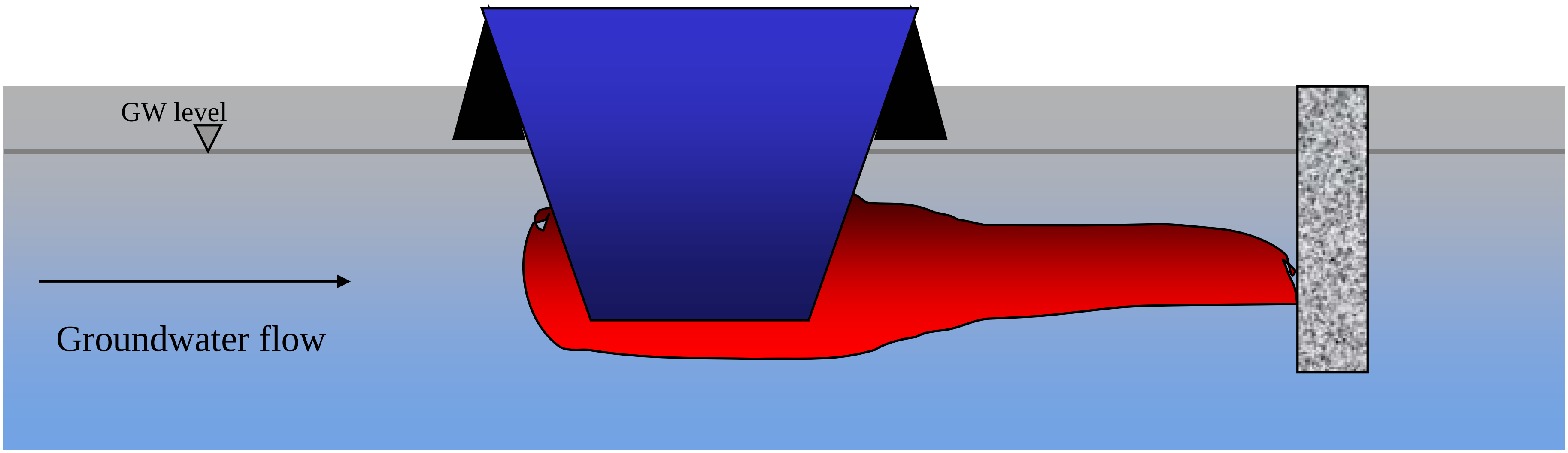
Cardiff, May 23 – 26, 2004



No measures



Landfill leakage: Multifunctional treatment zone or Multibarrier for removal of mixed pollutants



Evaluation of several combinations

- Chemical transformation (Fe°),
- Biotransformation (aerobic/anaerobic),
- Bioprecipitation
- Sorption

Two solutions:

-Installation of a new landfill (20 – 40 million EURO)

-Installation of a MULTIBARRIER (2 - 4 million EURO)

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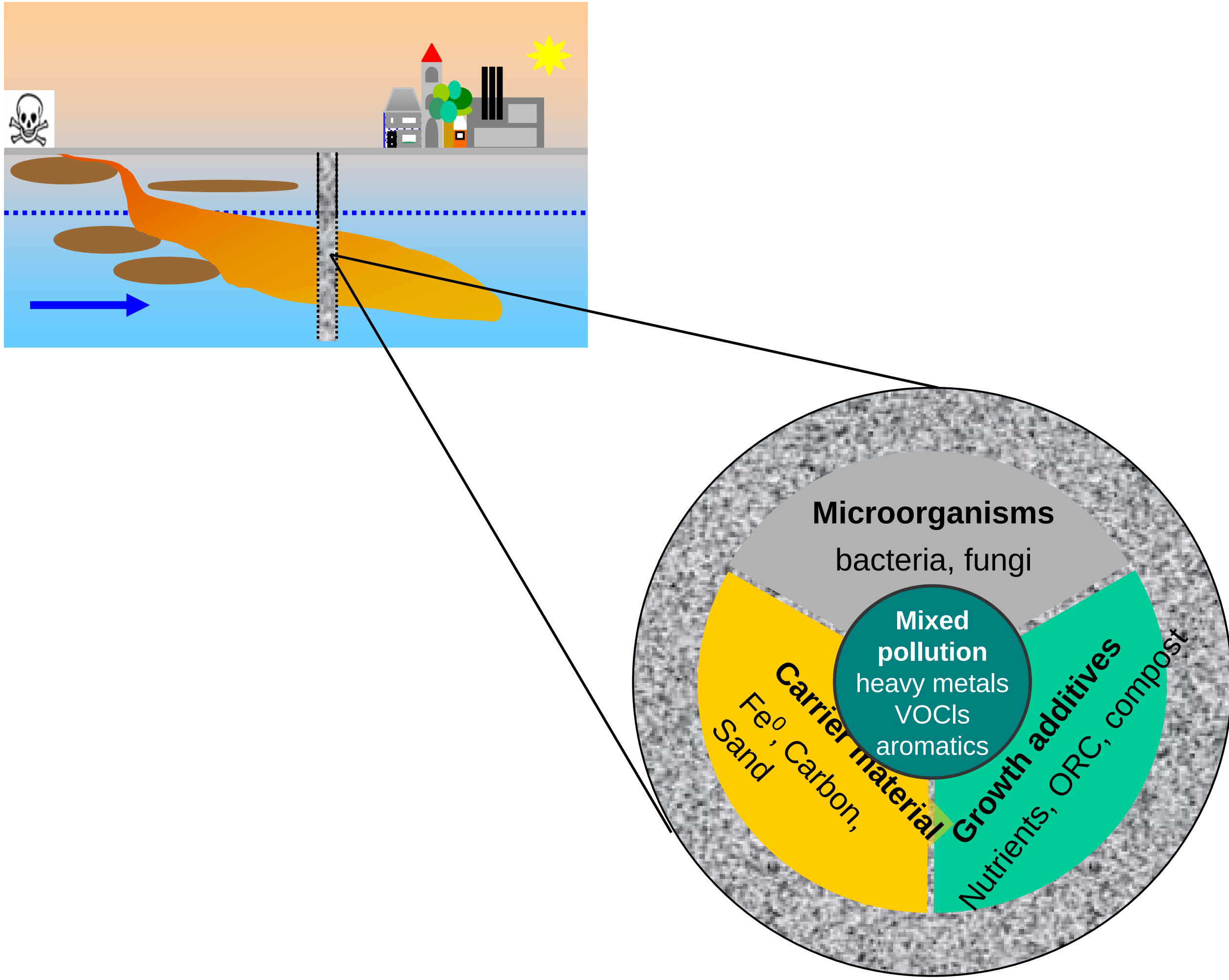
EU-project MULTIBARRIER



PARTNERS:

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ENDORSERS:
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Intercommunale Hooge Maey, Antwerp

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Mixed contamination plumes

- Mixed contamination plumes require:
  - a combination of different pollutant removal processes (biotic & physico-chemical)
  - a combination of barrier types = MULTIBARRIER

- Design and optimisation of multibarriers is more complex than single-barriers
  - Concept: sequential or mixed multibarrier?
  - Effect of the pollutants on the removal process (inhibition, stimulation or no effect)?
  - Effect of one pollutant removal process on an other one?

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MULTIBARRIER Key-components

- **Groundwater:**
  - **0.5 mM $NaHCO_3$**
  - **0.5 mM $KHCO_3$**
  - **0.5 mM $CaCl_2.2H_2O$**
  - **0.5 mM $MgCl_2.6H_2O$**
  - **+ growth supporting additives (Nutrients, O_2, compost,..)**

- **Carrier materials:**
  - **Filter sand (1-2 mm)**
  - **Zerovalent iron FeA4 (0.3-2 mm)**
  - **Activated carbon**
    - **GAC F400**
    - **GAC Ind. React. (landfills)**
  - **(Aquifer material)**
  - **Metasorb**
  - **Zeolites**
  - **Wood chips**

- **Mixed pollution:**

VOCls:	**2 mg/l PCE**
	5 mg/l TCE
Metals:	**5 mg/l Zn as $ZnCl_2$**
	0.2 mg/l As(V) as Na_2HAsO_4
BTEX:	**2 mg/l benzene**
	2 mg/l toluene
	2 mg/l *m*-xylene
Extra:	**AOX (LFU)**
	DCM, 11 DCA (UW)
	Ni, Cr (Vito)
	o-xylene, p-xylene,
	Ethylbenzene (Vito)

- **Micro-organisms**:
  - **Aquifer material**
  - **Enrichment cultures**
  - **Axenic strains**

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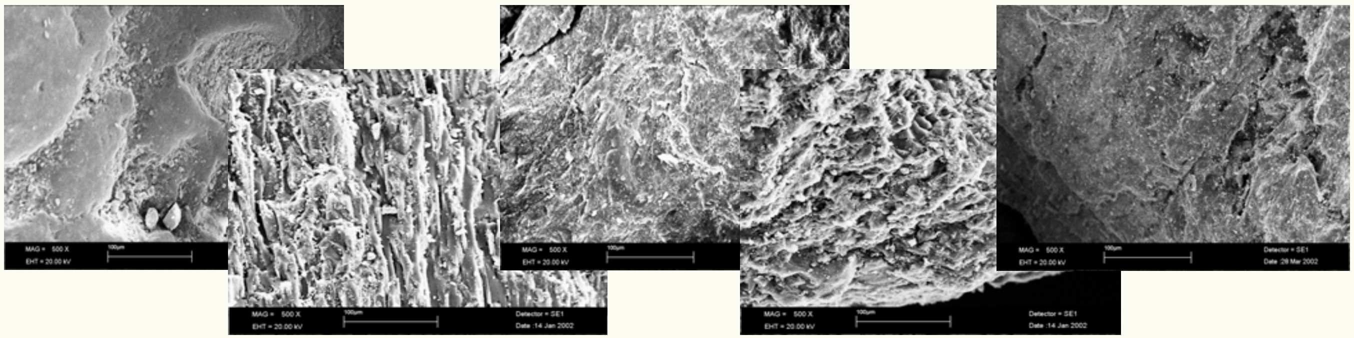
MULTIBARRIER materials

magnitude: 500x



Filtersand Everzit Metasorb GAC F400 Zero Valent Iron

Specific surface [m^2/g] (measured)

Filtersand	1,9
Everzit	294,1
Metasorb	3,0
GAC F400	764,4
Zerovalent Iron	1,0

+ Aquifer as source of micro-organisms

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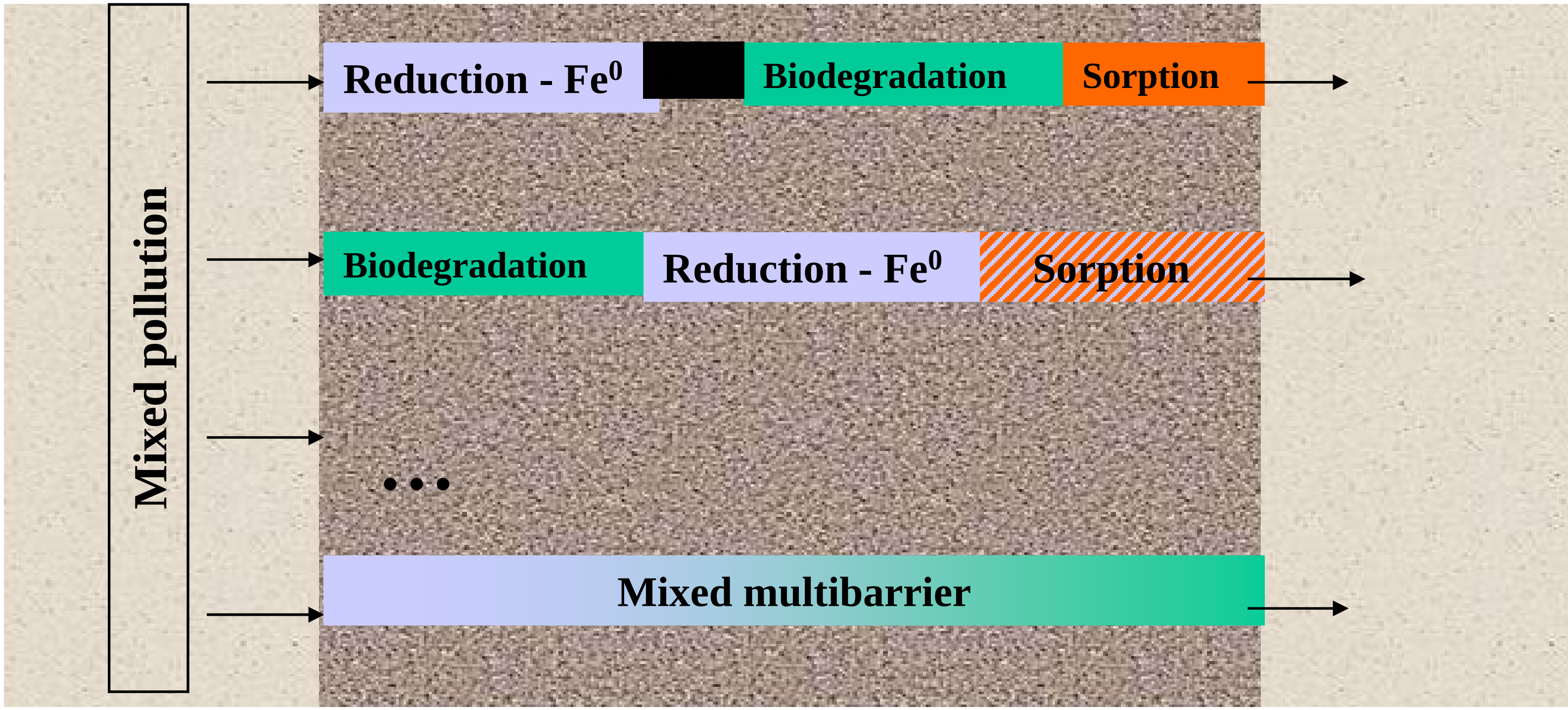
Design of multibarriers

- Different multibarrier concepts:



- Concept = Site specific and depending on the pollutants present
- Sorption barrier = polishing step

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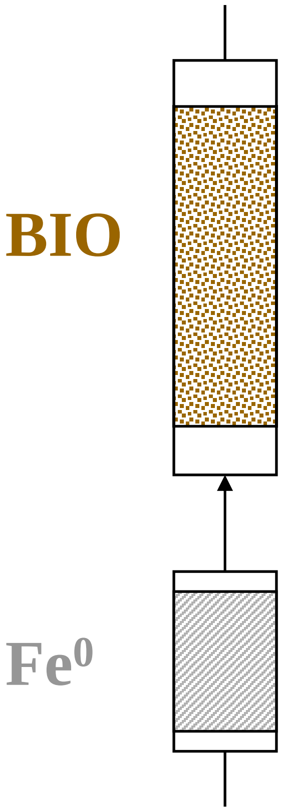
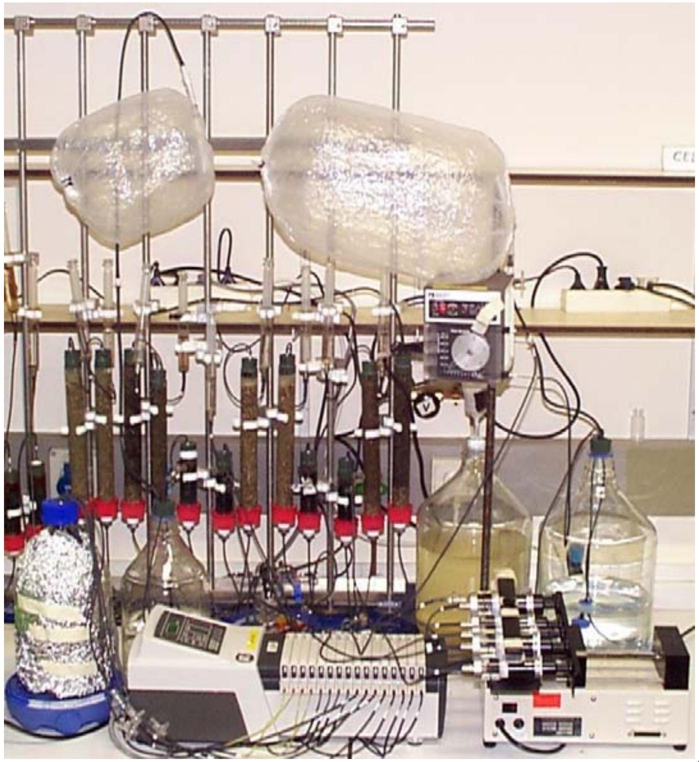
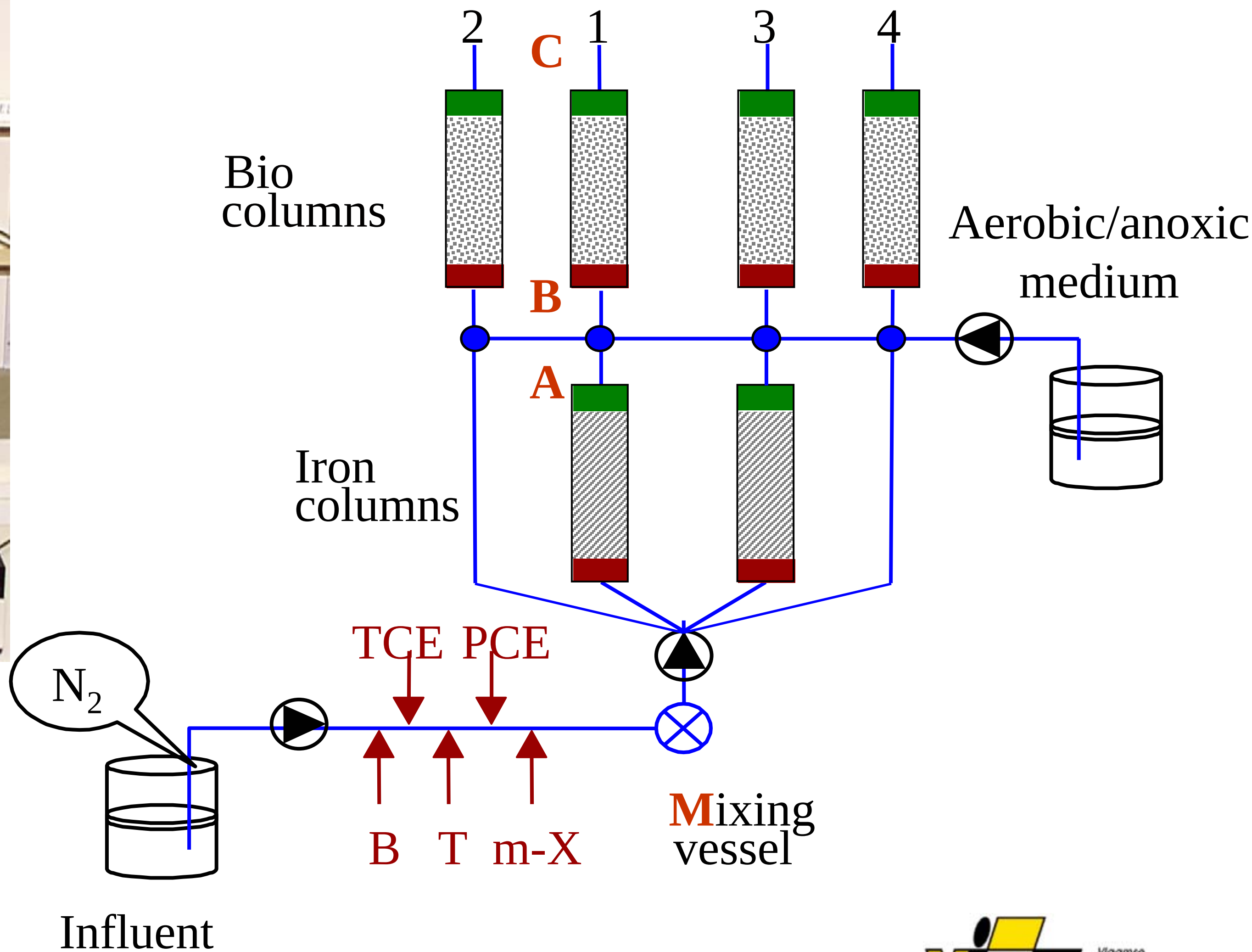
MULTIBARRIER concepts: Sequential vs mixed



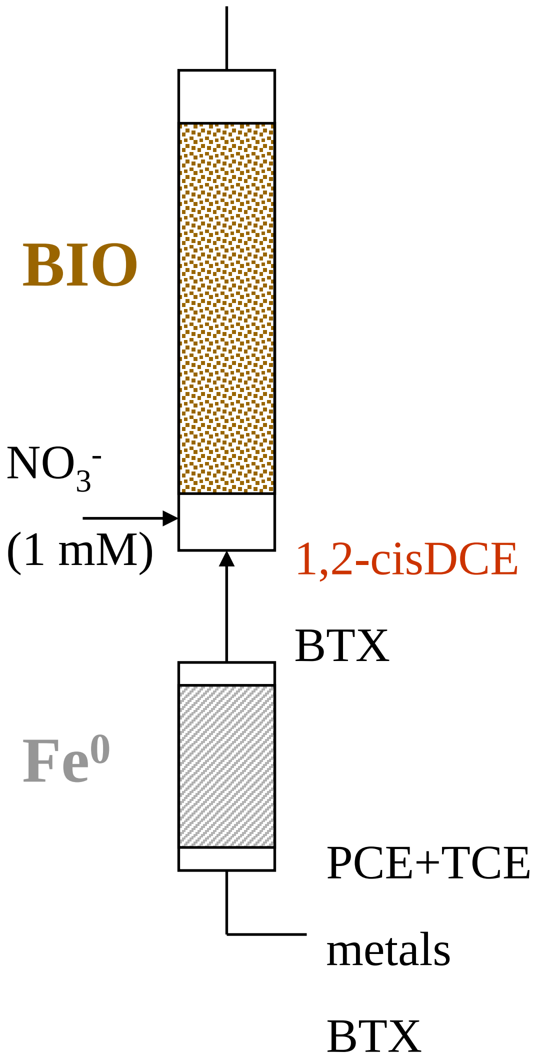
TEA	SEQUENTIAL	MIXED
O_2	+	
NO_3^-	+	
SO_4^{2-}	+	+
Fe^{3+}	+	+
CO_2	+	+
As	+	
VOCls	+	+

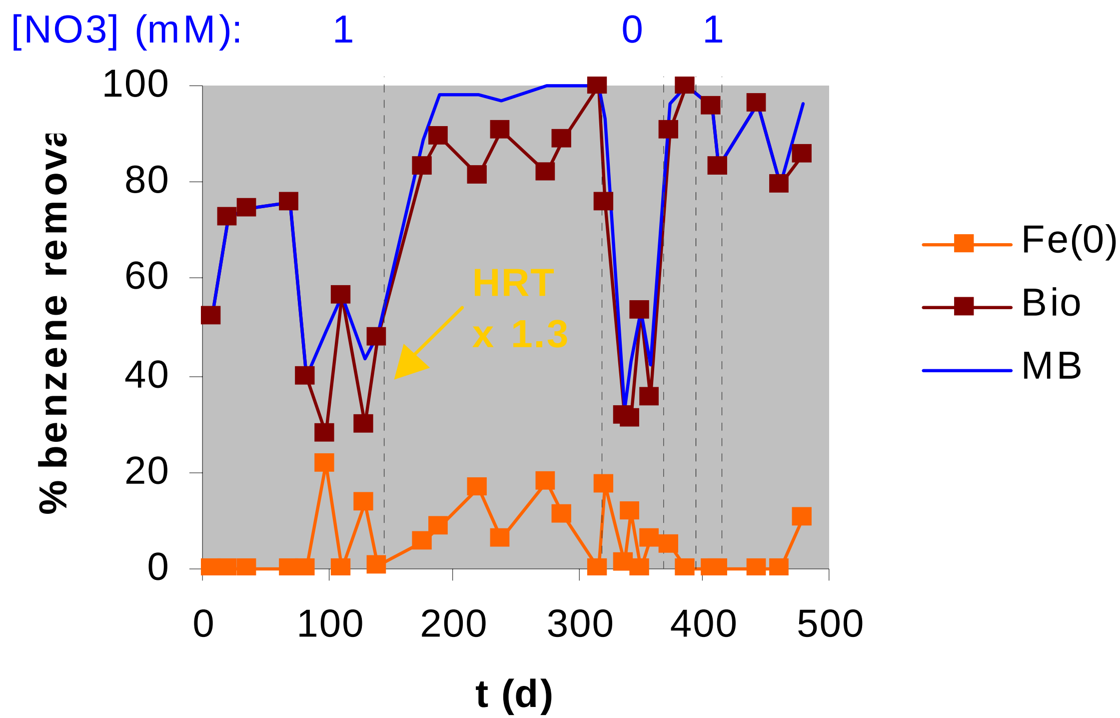
System A (O_2) & System B (NO_3)



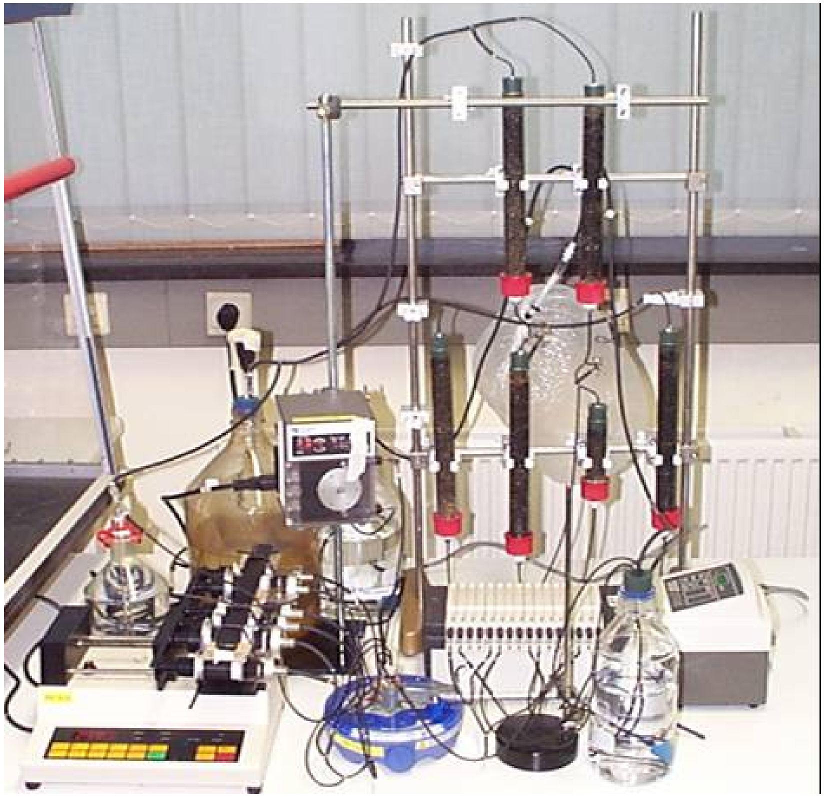


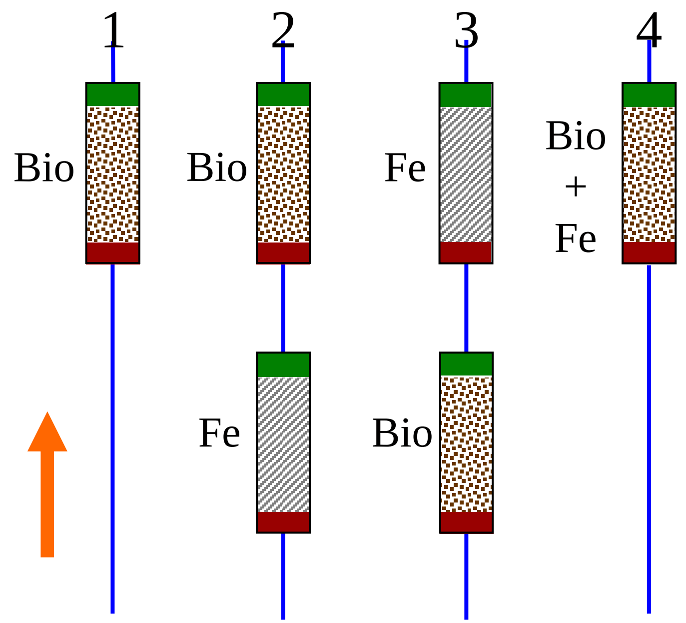
Benzene removal in a denitrifying sequential system





Systems D & E: Strictly anaerobic systems





SR: 0.5 mM SO_4^{2-}

IR: 2.5 mM Fe(III)EDTA

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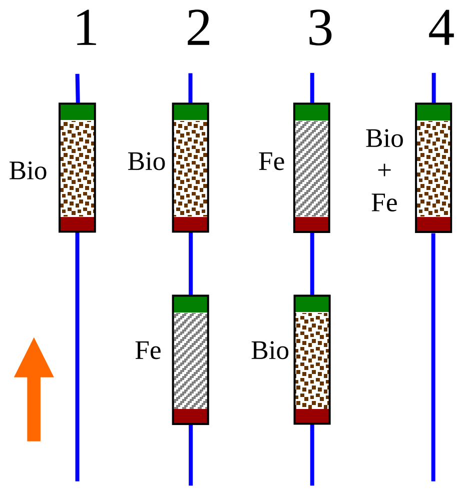
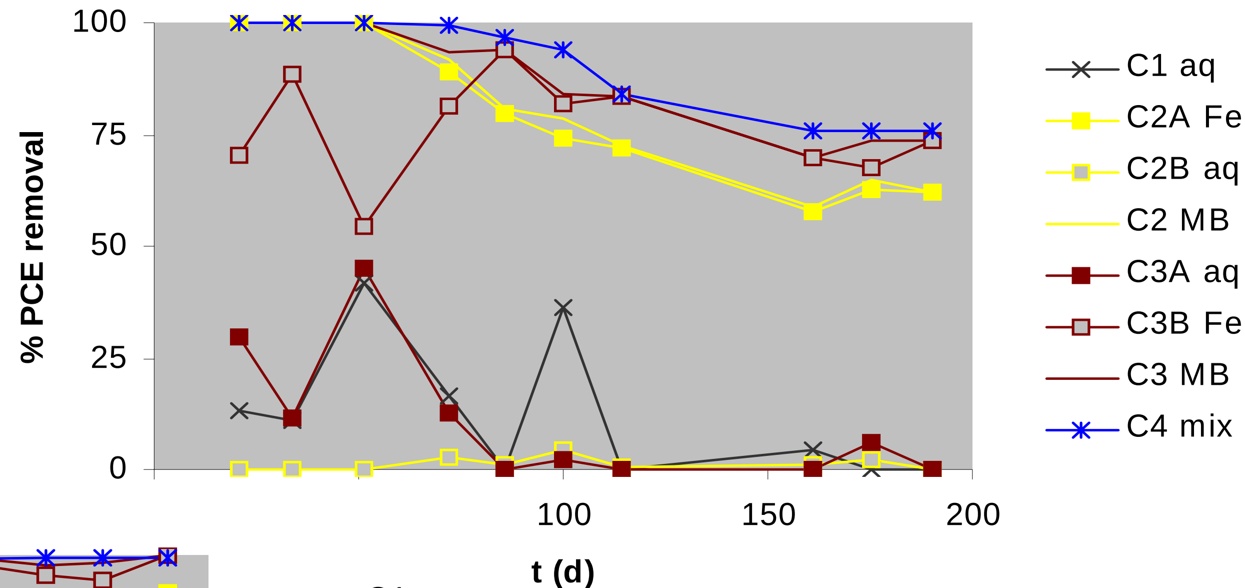
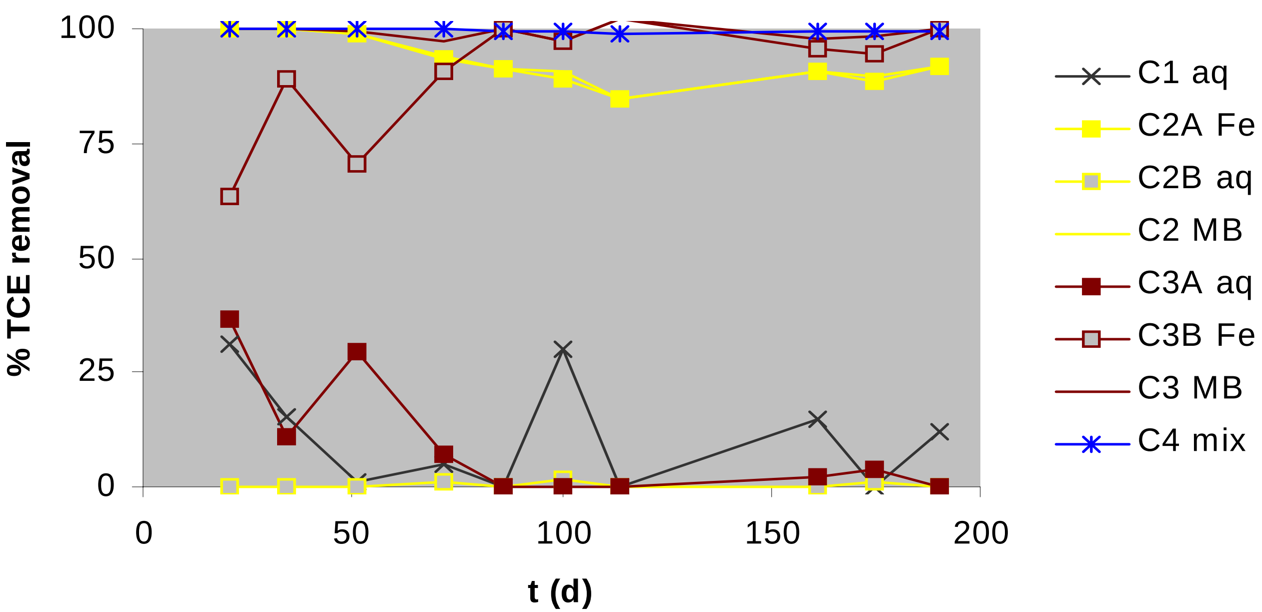
System D: PCE & TCE degradation (SR columns)

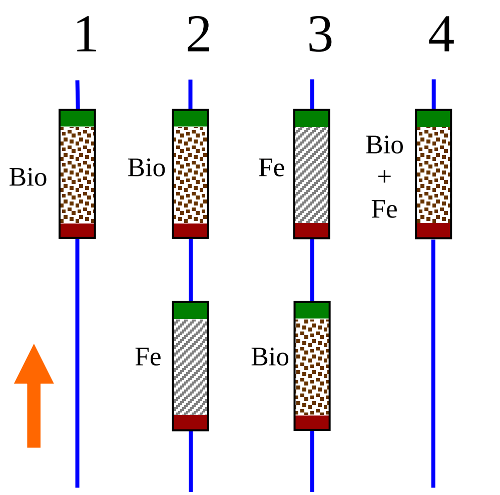


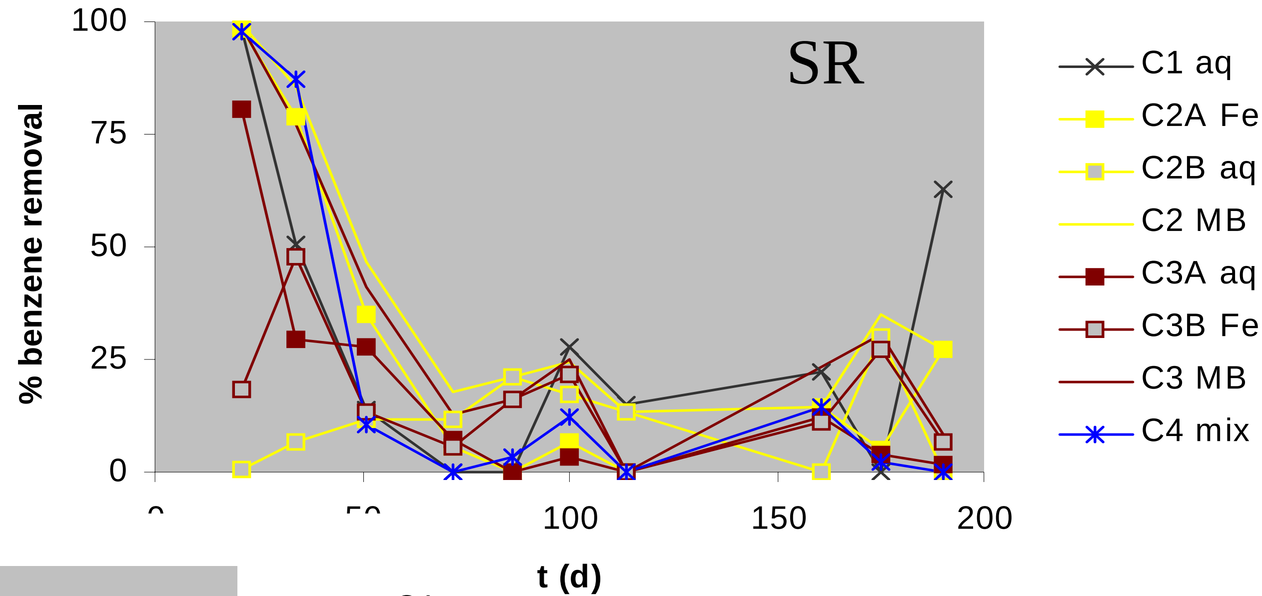


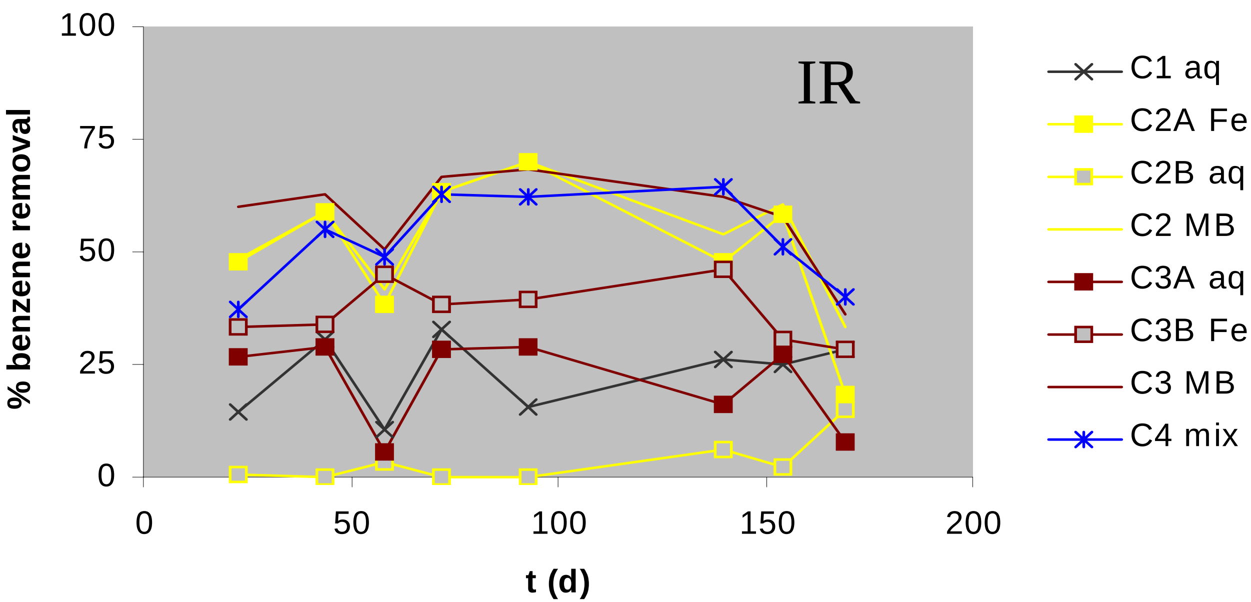


- initial sorption
- incomplete PCE degradation
- complete TCE degradation

System D & E: Benzene removal

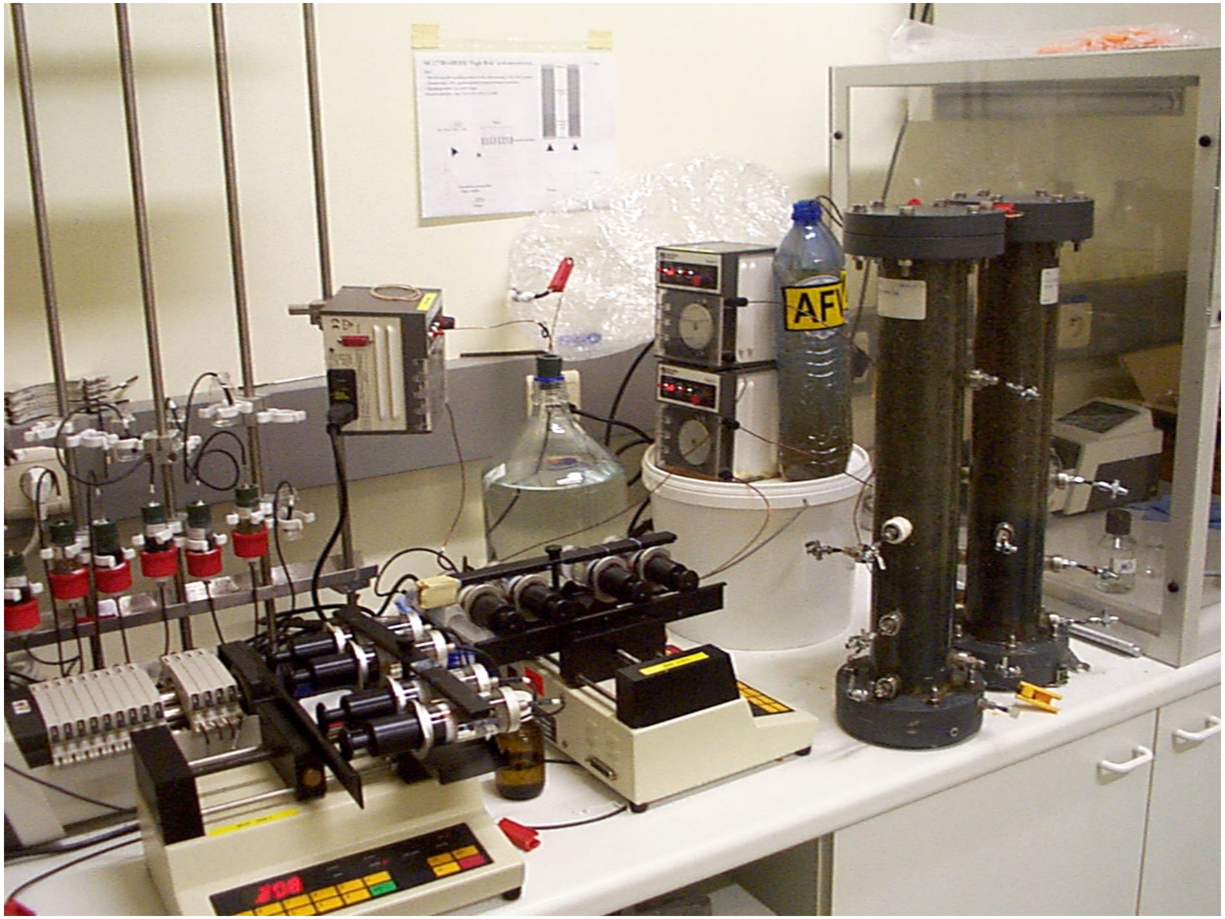






- SR: no degradation
- IR:
  - all MB
  - not in C2aq

System C: Partially mixed MB system



Columns (L = 50 cm)
K1: test column
K2: abiotic control

Layers:
L1: FS/Aq/Fe0 = 60/20/20 (W)
L2:FS/Aq = 78/22 (W)

Monitoring:
chemical analyses
microbial ecology

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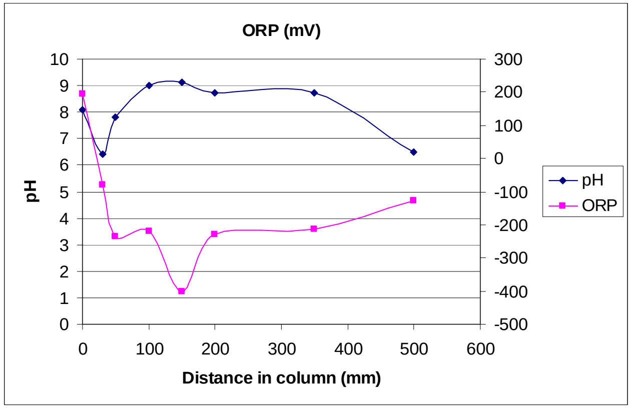
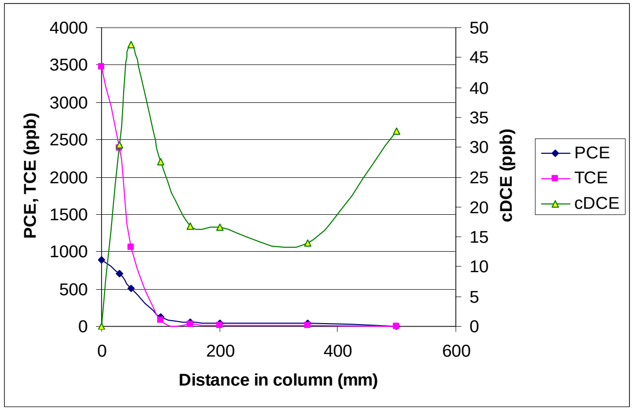
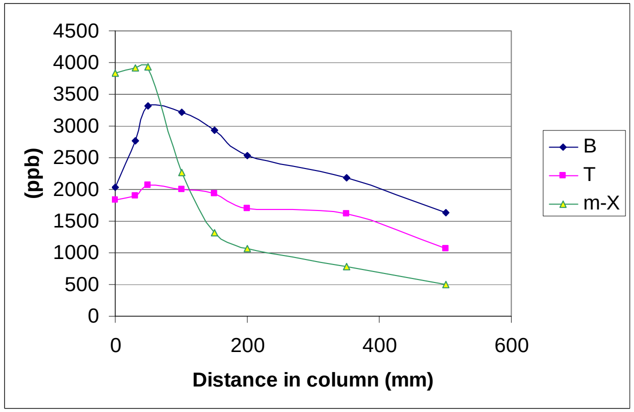
Partially mixed MULTIBARRIER: results







System 1-5: Results DCM &11DCA

Fe(0)			
100%		No	No
50%	redox conditioning electron donor	Complete	50%
10%	redox conditioning electron donor	Complete	No
0%		>50%	No and 50% (2nd)

Results (% removal)

Column trains	Characteristics (TEA)	Acro-nym	PCE	TCE	Benzene	Toluene	m-xylene
System A: Zerovalent iron wall followed by a micro-aerobic biobarrier [1]							
A1	1 – Fe(0)column	A1-1	60-80	90-99	4-13	10-53	NA
	2 – Bio column (O_2)	A1-2	80-100	92-100	99-100	99-100	> 90
System B: Zerovalent iron wall followed by a denitrifying biobarrier [1]							
B1	1 – Fe(0)column	B1-1	66-99	97-100	6-18	16-54	NA
	2 – Bio column (NO_3^-)	B1-2	80-93	97-100	89-100	99-100	> 90
System C: Partially mixed Fe(0)/biowall followed by anaerobic biowall [2, 1]							
C1	1 – mixed zone	C1-1	95-100 [1]	95-100 [1]	20 [2]	30 [2]	40 [2]
	2 – bio zone	C1-2	95-100 [1]	95-100 [1]	20 [2]	30 [2]	50 [2]
System D: sequential and mixed barriers under sulfate reducing conditions [1]							
D1	1 – Bio column (SO_4^{2-})	D1-1	0-11	0-15	11-44	97-100	NA
D2	1 – Fe(0)column	D2-1	55-71	88-98	4-54	0-36	NA
	2 – Bio column (SO_4^{2-})	D2-2	55-78	89-98	23-67	12-36	< 25
D4	1 – Mixed column (SO_4^{2-})	D4-1	76-89	99-100	18-62	7-23	> 90
System E: sequential and mixed barriers under iron reducing conditions [1]							
E1	1 – bio column (Fe^{3+})	E1-1	0-11	9-18	24-29	100	NA
E2	1 – Fe(0)column	E2-1	53-67	85-92	50-68	72-91	NA
	2 – Bio column (Fe^{3+})	E2-2	54-67	86-92	52-71	77-90	> 90
E4	1 – Mixed column (Fe^{3+})	E4-1	58-73	94-97	55-64	94-98	> 90

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Conclusions

- Mixed contamination plumes are omnipresent.
- Remediation of mixed contamination plumes using barriers

  → MULTIBARRIERs are required
- Fungi do not play a big role in a Multibarrier
- In lab-scale columns different Multibarrier-concepts have been shown to be effective for the remediation of a mixed plume (PCE, TCE, BTmX, Zn, As).
- Behaviour of AOX in a Multibarrier is under study
- No toxicity detected in effluent (toxicity reduction)
- The design and optimisation of multibarriers is more complex in comparison with 'single barriers'

  → Many influencing parameters have to be taken into account

  → Mixed Multibarrier under iron or sulfate reducing conditions

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Conclusions

- Sequential Multibarrier: **ZVI** + **Micro-aerofilic biobarrier**
  - PCE, TCE dehalogenation in ZVI
  - Zn, As removal in ZVI
  - BTX degradation in biobarrier
  - No degradation of cDCE
- Sequential Multibarrier: **ZVI** + **Anaerobic biobarrier (denitrifying)**
  - PCE, TCE dehalogenation in ZVI
  - Zn, As removal in ZVI
  - T, X degradation in biobarrier
  - B partially degraded in biobarrier
  - No degradation of cDCE
- Mixed Multibarrier: **filtersand, aquifer materiaal, ZVI** + Anaerobic biobarrier in aquifer
  - PCE, TCE dehalogenation
  - Zn, As removal in ZVI
  - BTX degradation in mixed zone
  - No formation of cDCE or VC

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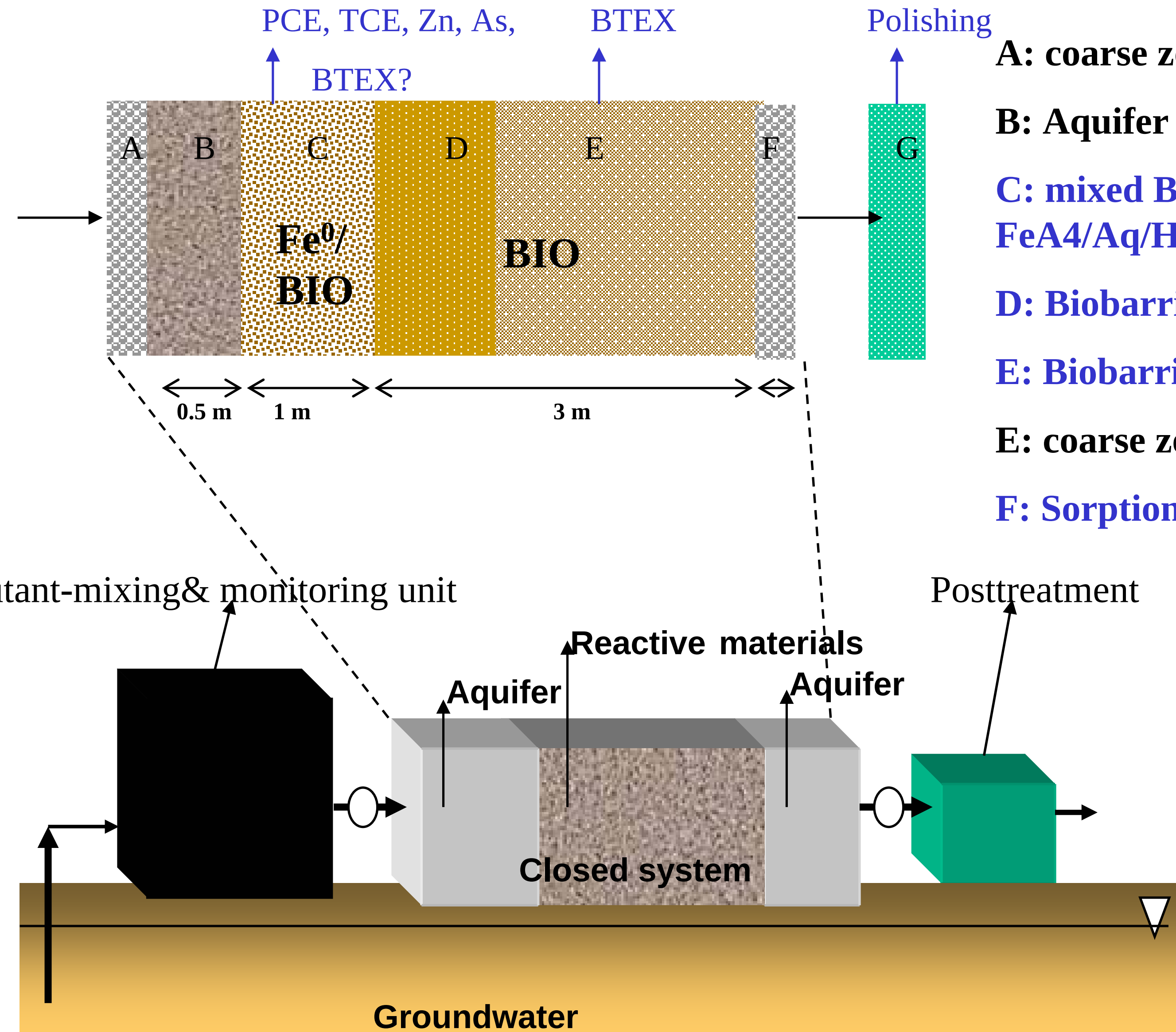
Upscaling promising multibarrier concept



A: coarse zone (25 cm)

B: Aquifer material

C: mixed Bio/Fe^0 barrier : FeA4/Aq/HM = 30/60/10

D: Biobarrier Aq/ HM (90/10)

E: Biobarrier Aq

E: coarse zone (25 cm)

F: Sorption barrier

Set-up of MB on pilot scale

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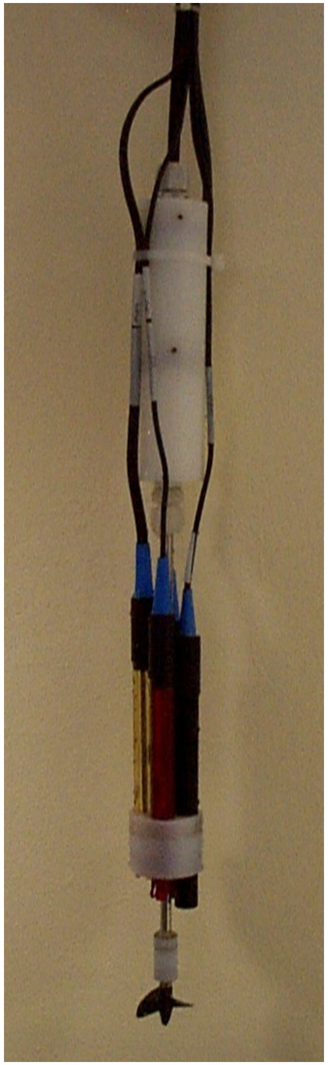
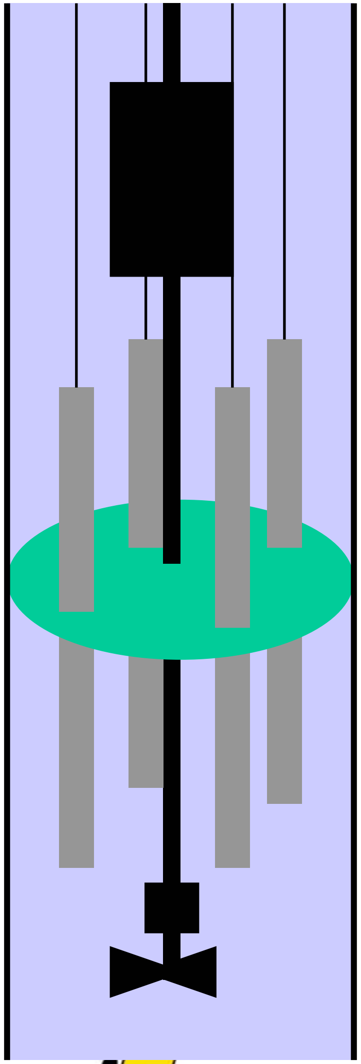
MULTIBARRIER Monitoring System (MMS)

- On-line measuring and logging system pH, T, ORP, conductivity, O_2 and pressure :
  - Tested in the pilot system
  - Focus on EC-measurement

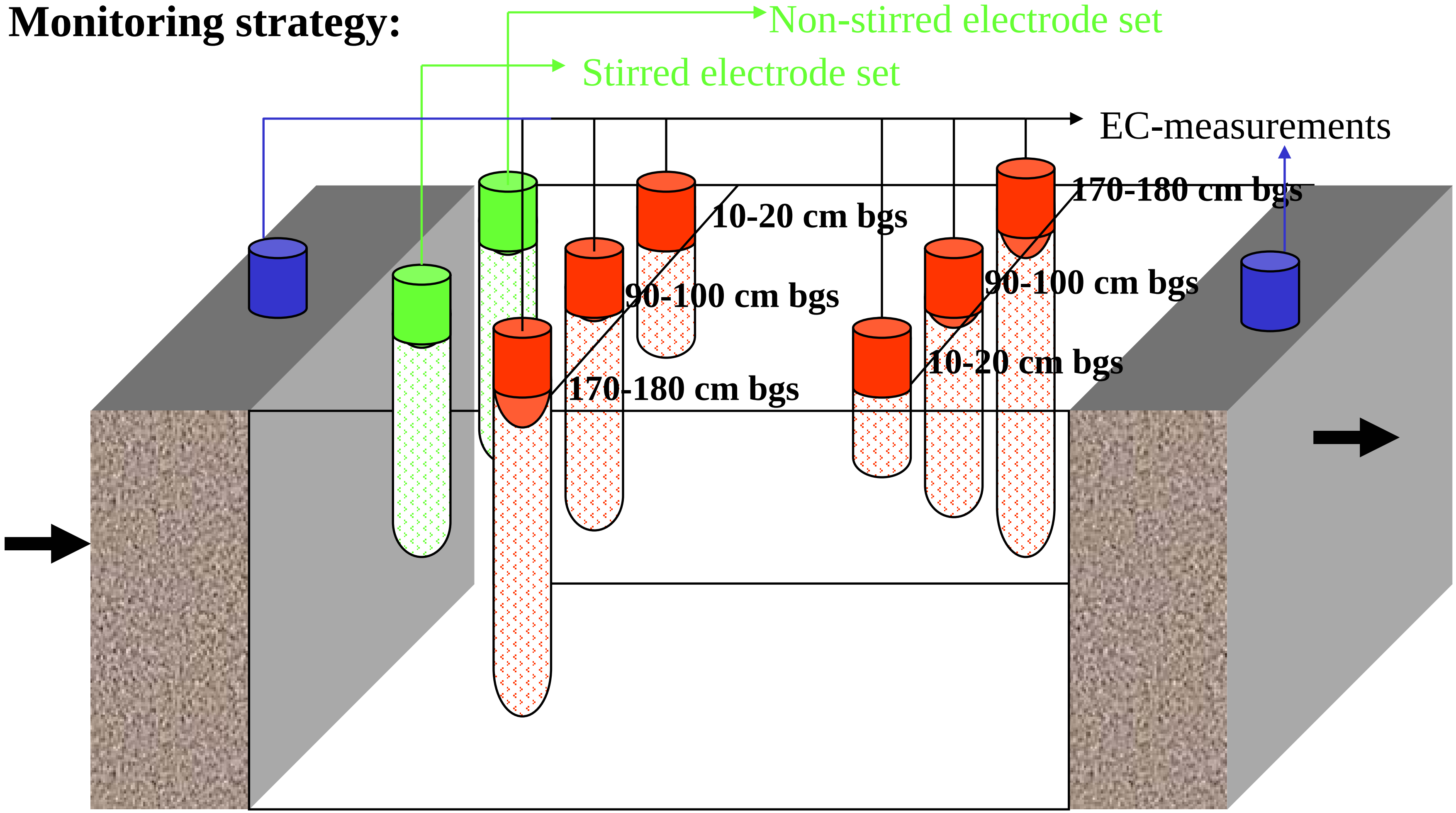
- in-well mixing system has been tested:
  - Works very well





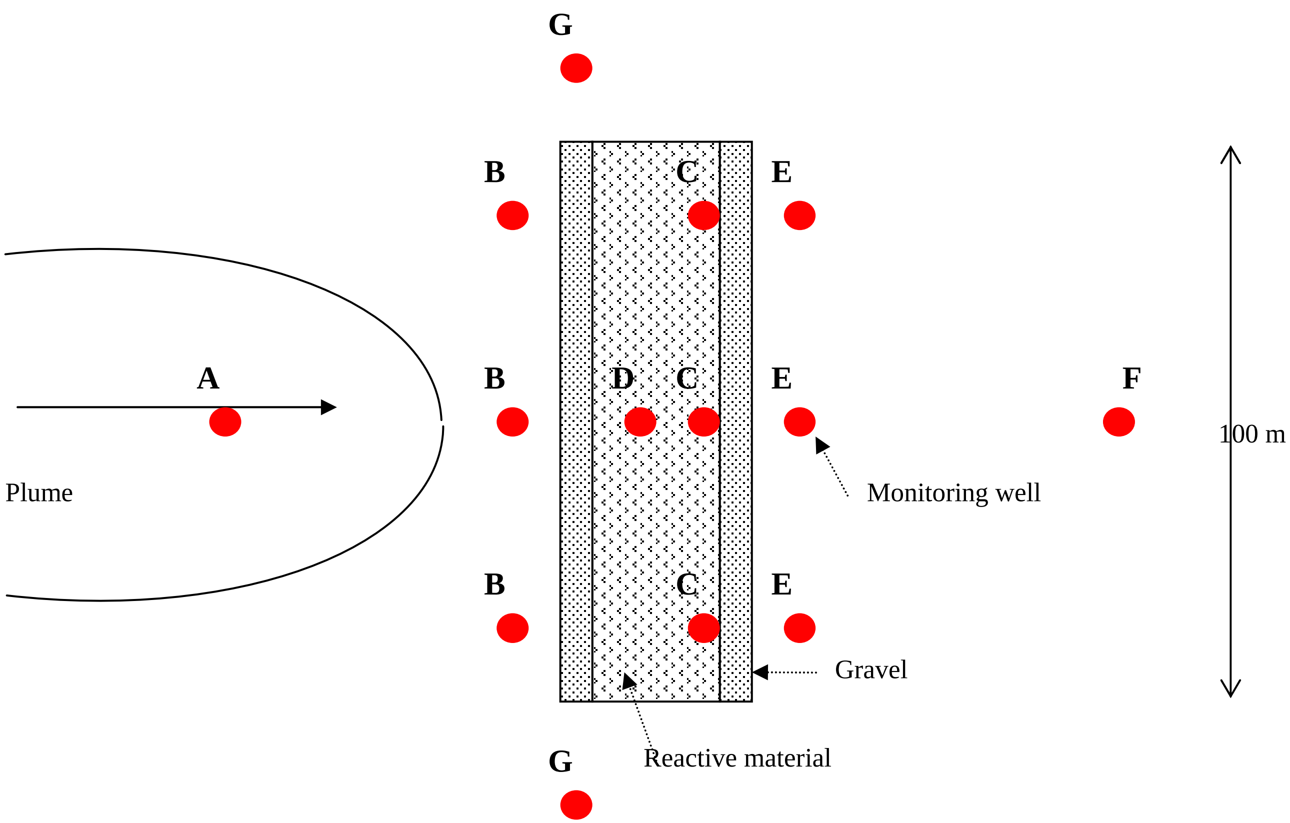
Pilot MULTIBARRIER system: First experiment

- **Monitoring strategy:**



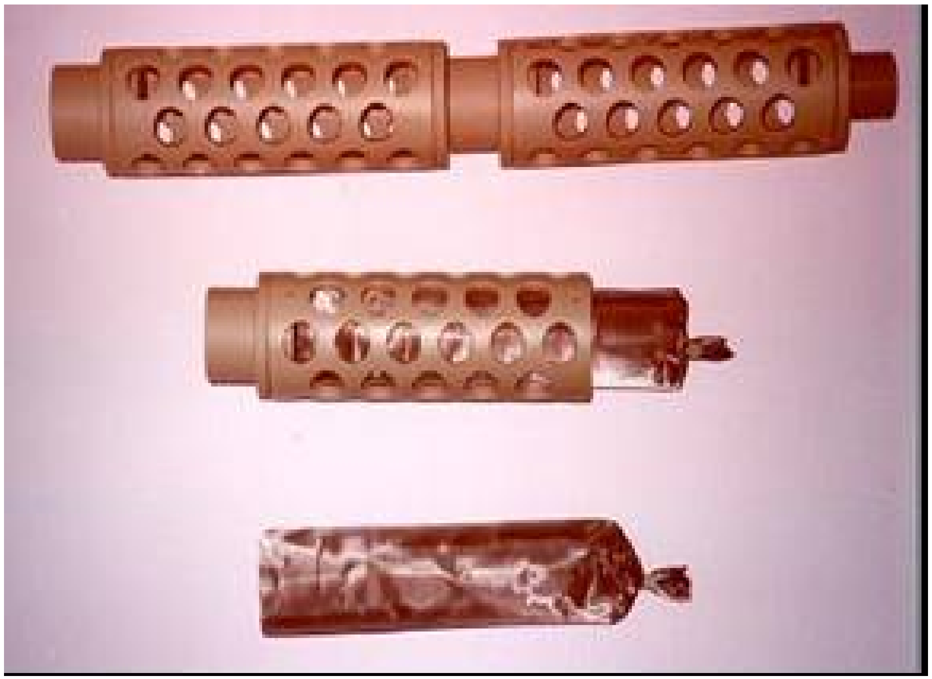
Monitoring of PRBs

- UK guidelines
- US EPA guidelines
- Flanders (OVAM) guidelines
- Germany (in preparation?)

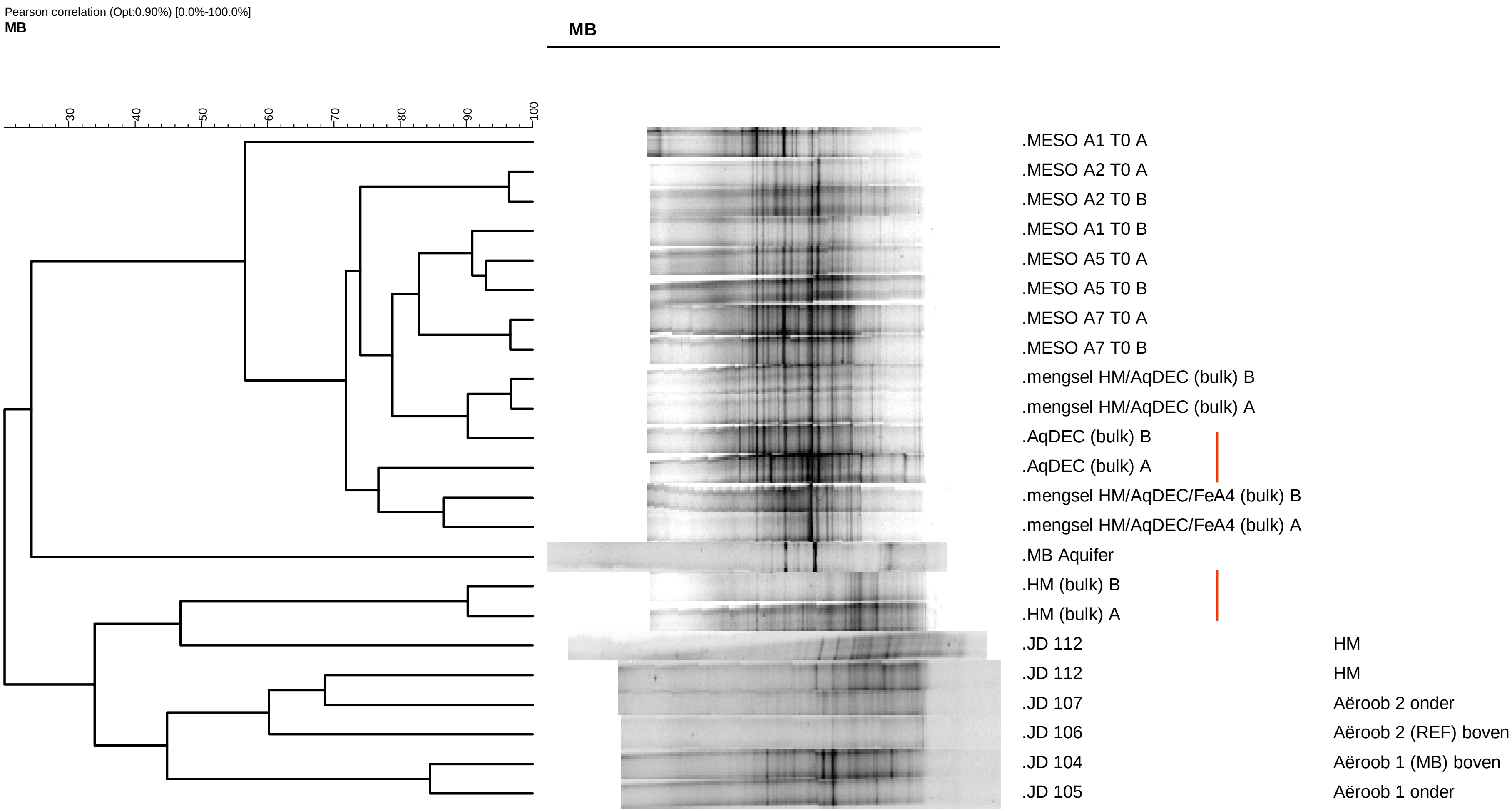


In situ mesocosm-systems

Monitoring of microbiology (molecular biology)



WP3: HM + Mesocosms container



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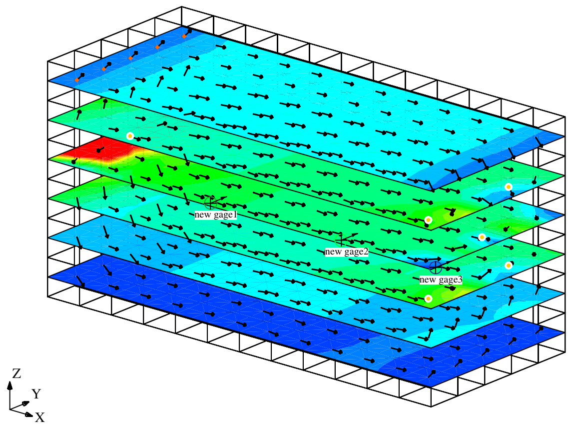
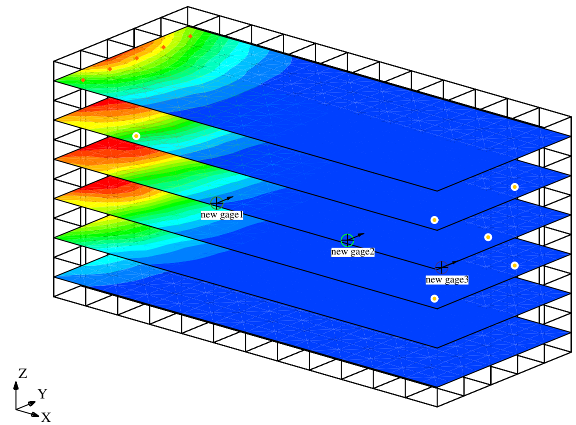
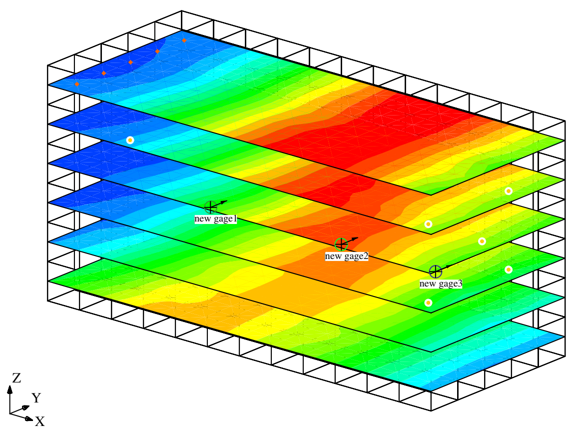
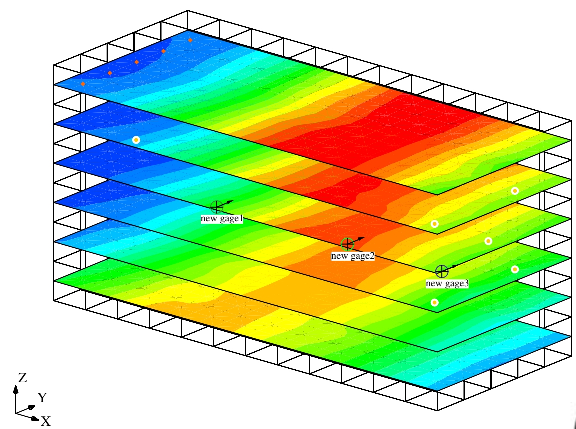
MULTIBARRIER Modelling System: salt injection









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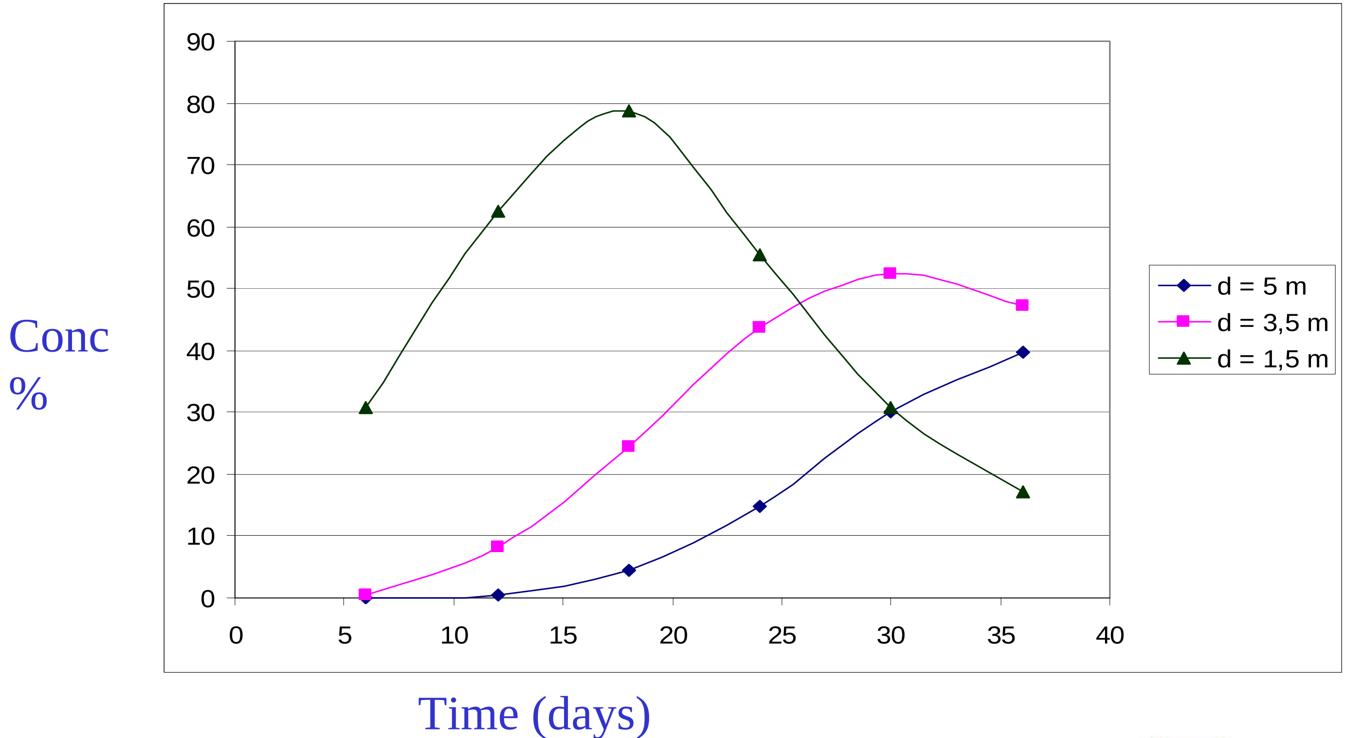
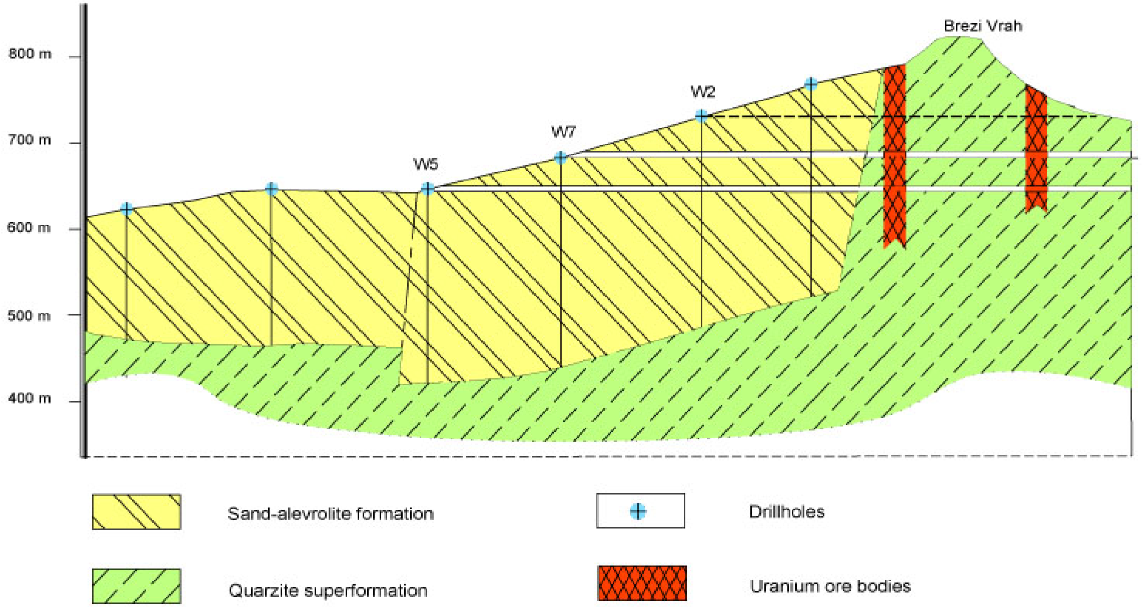
Modelled salt-peaks

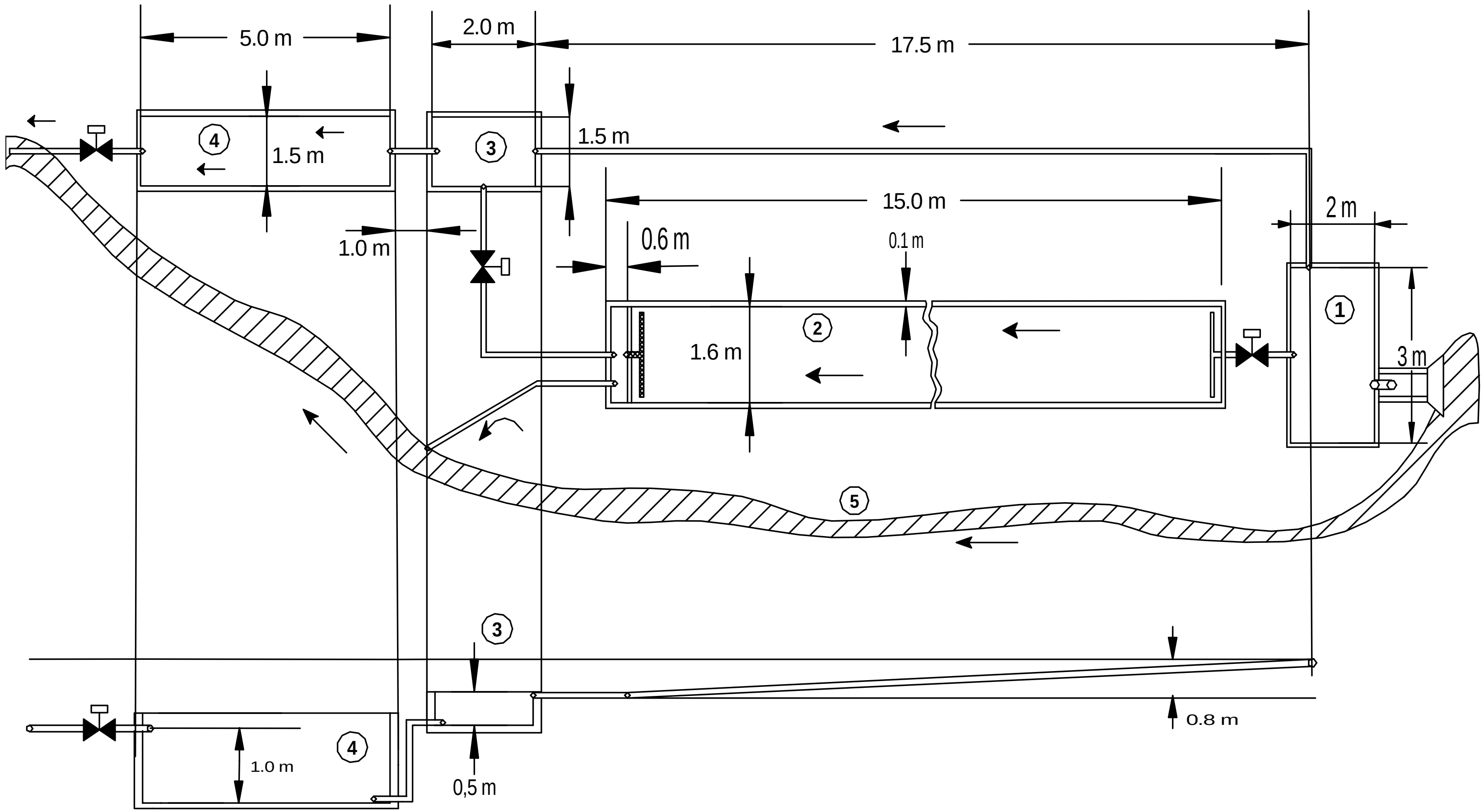
- Permeability: 24.17 m/dag
- Dispersivity: 0.3 m
- Monitoring wells: filter 100 cm bgs,
- Result: migration of pollutant initally faster, afterwards slower in comparsion with measured values



Pilot scale Multibarrier: Curilo deposit



Installation at Curilo deposit



Curilo deposit: constructed wetland + Multibarrier

Thanks to all the partners and the European Commission

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+
QLRT-2001-02916

www.multibarrier.vito.be