



European Remediation Technologies

*Let us do it
together!*

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CAPISCOTM



TOPICS

- What is the CAPISCO™ process
- Technologies used
- Reference project

What is the CAPISCO™ process

- Turn key project for VOC pollution
- Fixed price
- Payments coupled with achieved results
- Condition :
 - Bench scales and pilots performed by ourselves

- In Situ Chemical Oxidation(=ISCO) :
 - Fenton's
 - Permanganate
- Anaerobic bioremediation :
 - CAP18[®] and/or CAP18-ME[®]

What are ISCO and BIO?

ISCO

- Deliver strong chemical oxidants to subsurface
- Chemical reaction destroys pollution, not biological reaction
- Fenton's reagent, permanganate, ozone, persulfate

BIO

- Deliver a carbon source to the subsurface
- Stimulate bacteria to destroy the pollution
- May also inject the bacteria (bioaugmentation)

ISCO

- Types of oxidants
- Basic chemistry involved
- Advantages & disadvantages

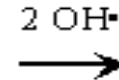
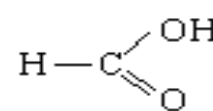
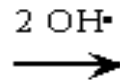
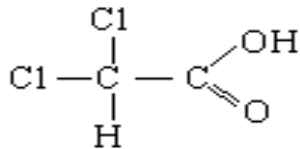
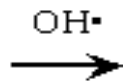
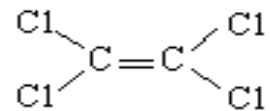
FENTON'S REAGENT

Key Reaction

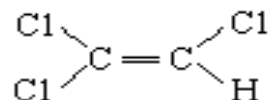


Tetrachloroethene and Trichloroethene Oxidation Pathway

Tetrachloroethene



Trichloroethene



Dichloroacetic Acid

Formic Acid

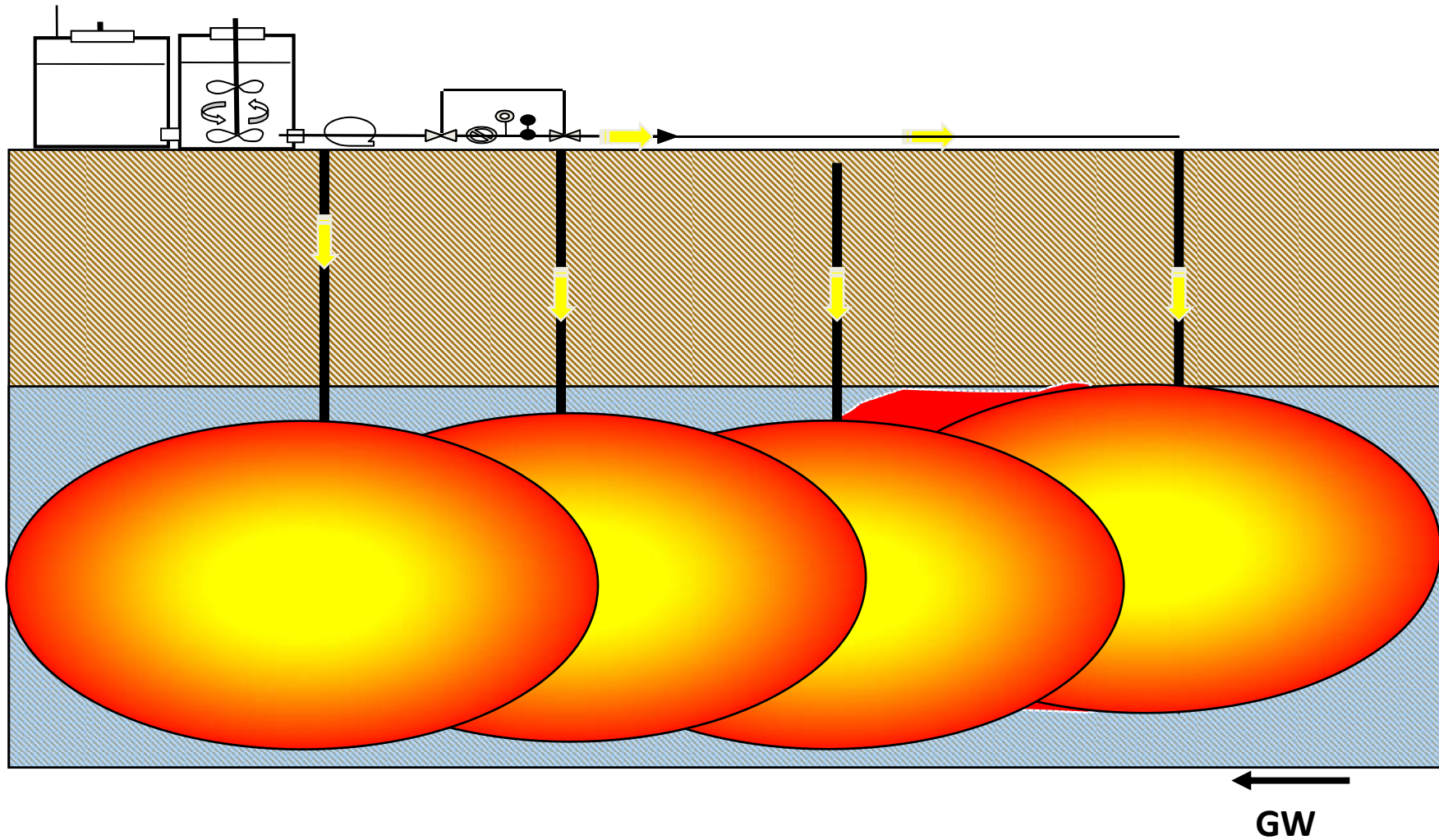
Carbon Dioxide

Does not generate DCE or vinyl chloride

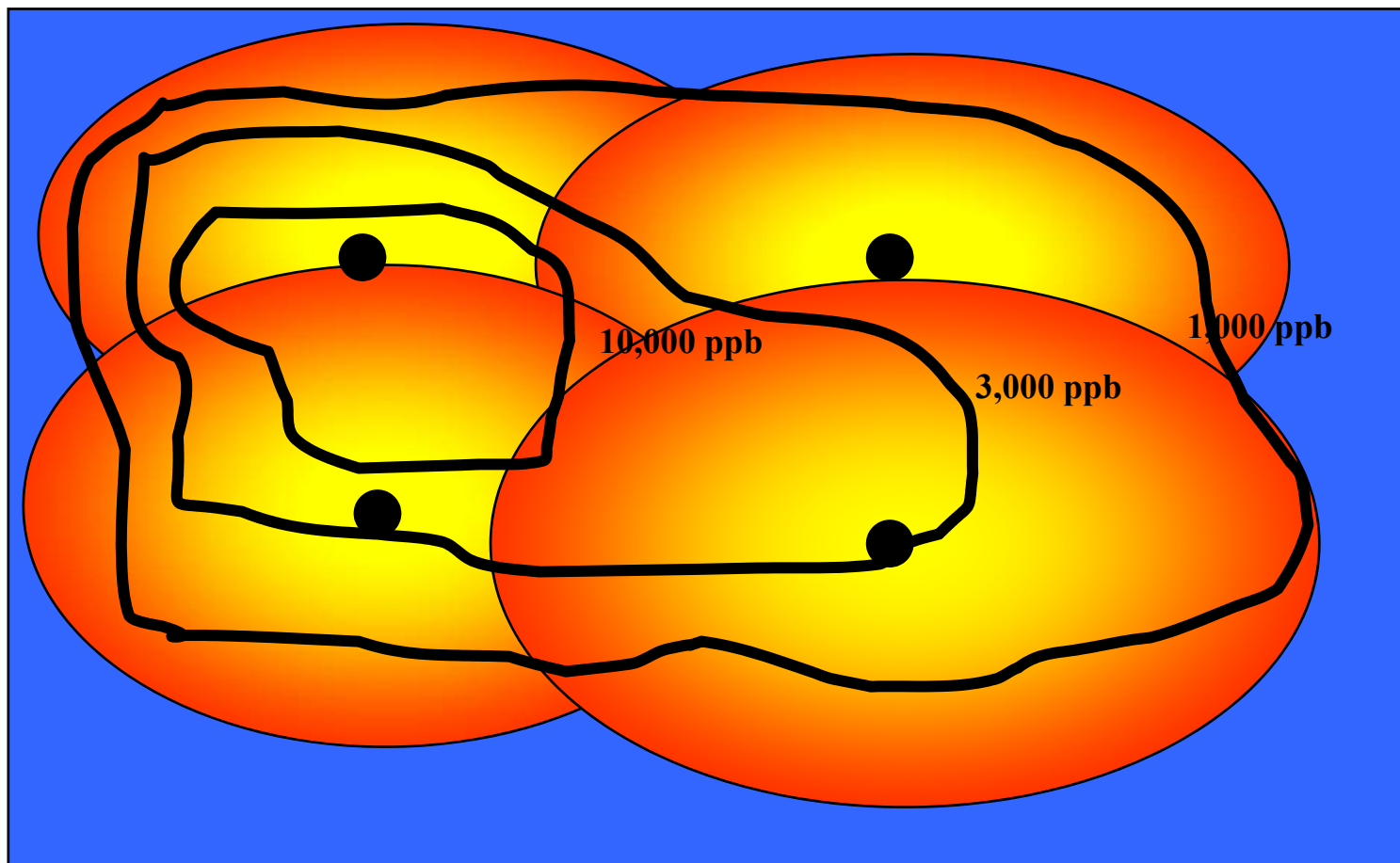
Fenton's Reagent Advantages

- Most powerful chemical oxidant for remediation
 - Chlorinated ethenes and ethanes
 - BTEX
 - MO
 - Explosives
- Source reduction
 - Destroys DNAPL and LNAPL
 - 75-90% mass reduction in short time period (weeks-months)
- No “residual” solids

Example Fenton's injection



View from above Fenton's injection



Fenton's Reagent Disadvantages

- Requires simultaneous presence of 3 reagents
 - pH <6, prefer <5
 - Iron 10-15 mg/L, prefer >25 mg/L
 - Peroxide detection, prefer >100 mg/L
- Sensitive to groundwater chemistry
 - Carbonate
- Very short lifetime – days to a week
- Gas production, elevated temperature

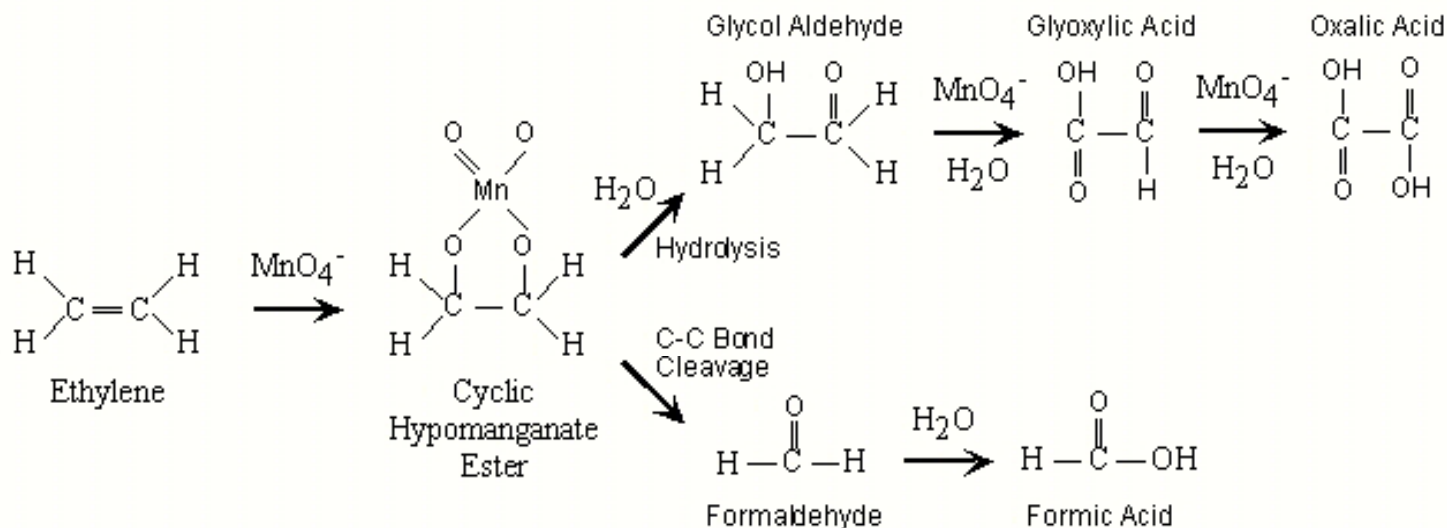
Requires a lot of experience for success!



Permanganate

Sodium (NaMnO_4) or Potassium (KMnO_4) Salts

Key Reaction



Does not generate DCE or vinyl chloride

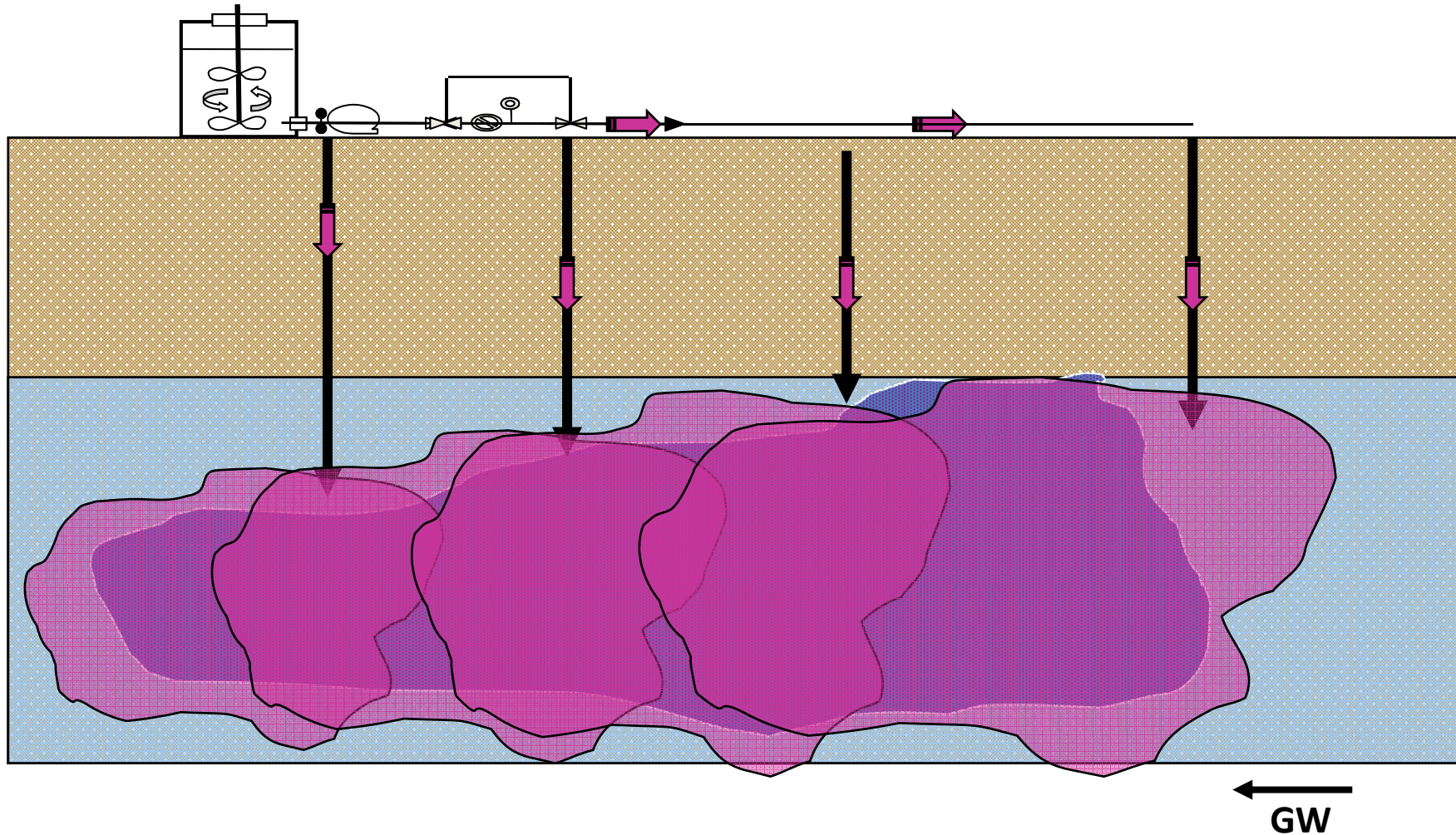


Permanganate Advantages

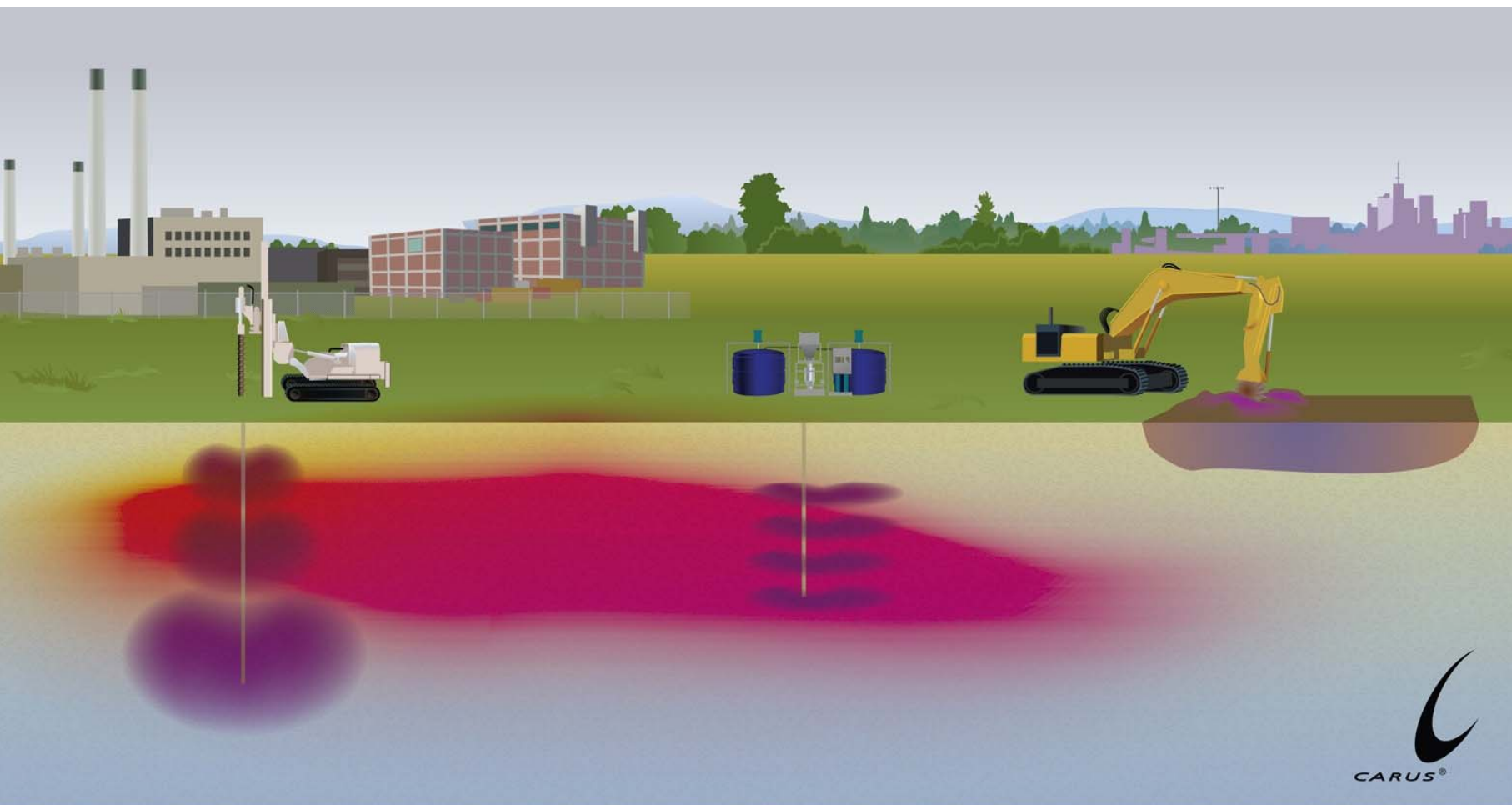
- Easier to apply
 - Prepare one solution
 - More application methods
- Not as reactive
 - No offgas or elevated temperature
- Longer lifetime
 - Weeks to months
 - Diffuse into fine-grained soil
- Purple color
- Not as sensitive to water chemistry
- Wider range of concentrations



Example permanganate injection



Voorbeeld permanganaatinjectie



Permanganate Disadvantages

- Not as powerful
 - Limited to “ethenes”: PCE, TCE, DCE, VC
- Precipitates MnO_2 solid
 - Clogged injection wells
- Not as good for DNAPL
 - Large volume of permanganate – MnO_2
- Purple color



The Second Piece of the Puzzle

Adding Bioremediation to Complete
the Cleanup

Types of Carbon Substrates



Soluble Substrates

• Examples

- Molasses
- Sugars
- Lactate

• Advantages & Disadvantages

- Easy to inject
- Requires reinjection

Insoluble Substrates

• Examples

- Polylactates
- Chitin

• Advantages & Disadvantages

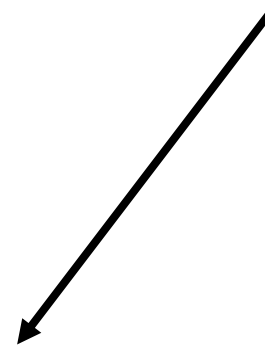
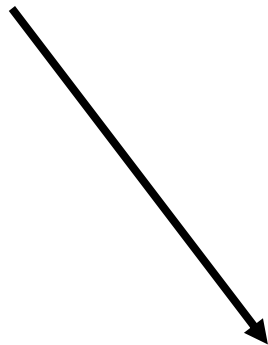
- Difficult to inject
- Expensive
- One injection

Types of Carbon Substrates



Soluble Substrates

Insoluble Substrates



Vegetable Oils

- Insoluble substrate
- Easy to inject
- Low cost

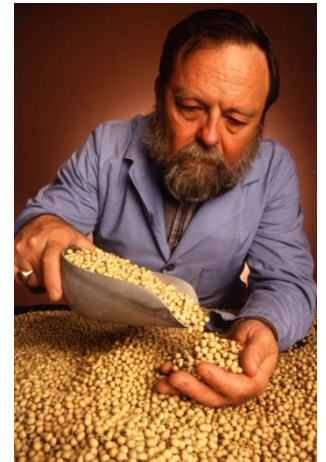


CAP18TM

CAP18TM
ME

What are CAP18[®] and CAP18-ME[®]?

- Food-grade, slightly viscous liquids
- Refined from natural vegetable oil
- Specifically designed for bioremediation
 - Chlorinated solvents (PCE, TCE, TCA)
 - Nitrate, Explosives & Perchlorate
- Concentrates the C18 unsaturated fatty acids



CAP18[®] and CAP18-ME[®] Advantages

- Easier application
- Lower cost
- Better hydrogen efficiency
- Very long lifetime – onetime injection



EVV215 60

MIL LABO EVV LA2

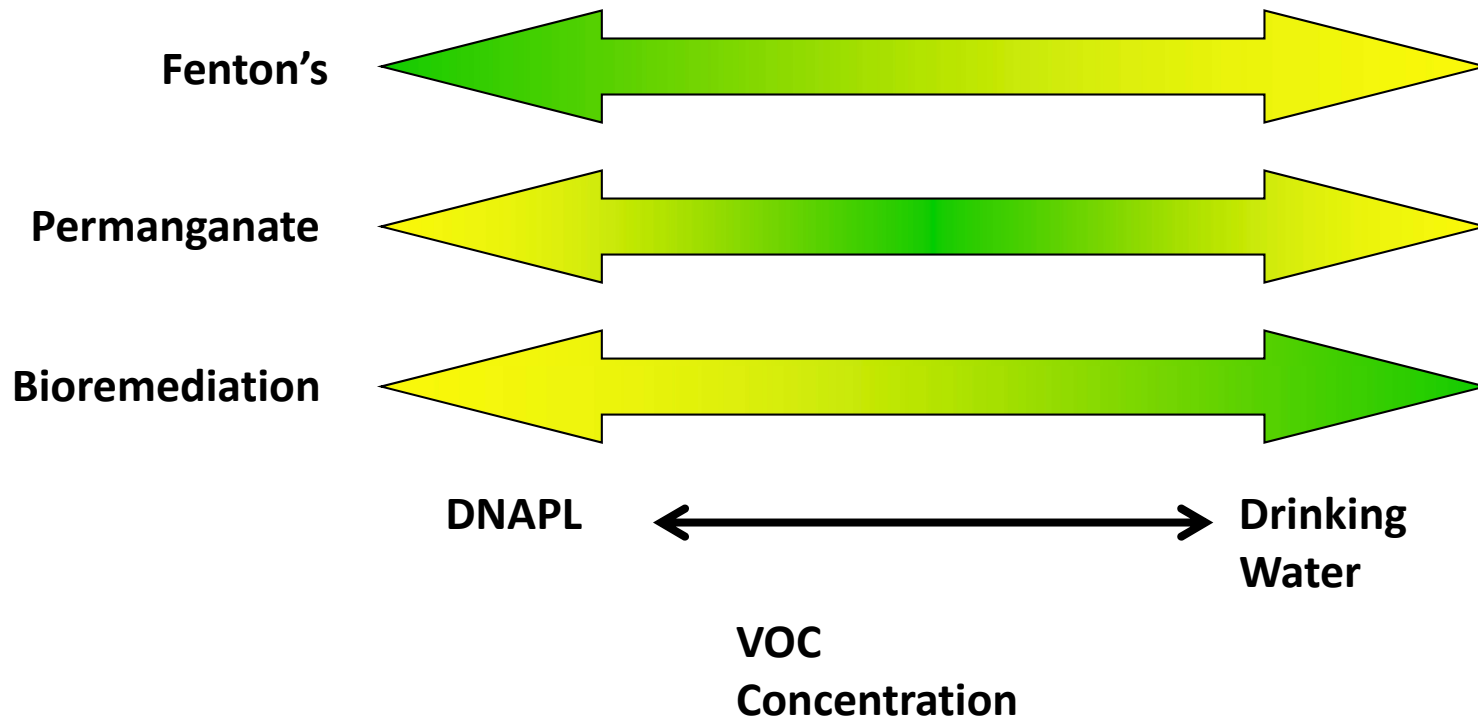
Cap18
DIB



ISCO AND BIO ARE COMPLIMENTARY TECHNOLOGIES

Each can work over a wide range of concentrations

Each has advantages & disadvantages



Reference project

**CAPISCO™-project region Antwerp
BELGIUM**

TOPICS

- Site specific conditions
- Bench tests and pilots
- Full scale
- Conclusions

Site specific conditions :

- **Former dry cleaner**
- **Pollution** : VOCs, maximum concentrations :
 - PCE = 49.100 µg/L
 - TCE = 19.300 µg/L
 - CIS = 117.000 µg/L
 - VC = 46.100 µg/L
- **Geology** : sand
- **Aquitard** : clay layer at circa 3 m-bg
- **Groundwater level**: circa 1 m-bg
- **Groundwater velocity** : circa 20 m/year
- **Groundwater flow** : S – SE
- **Bail to the government** : circa 700.000 €
- **Initial remediation technology** : reactive barrier downstream(30 years)
- **Payment terms** : fixed price coupled to different stages of the project

TOPICS

- Site specific conditions
- **Bench tests and pilots**
- Full scale
- Conclusions

CAPISCO™-project region Antwerp

1. ISCO bench tests :

- *PSOD-tests* : 2,38 en 2,39 g NaMnO₄/kg

2. ISCO pilot with NaMnO₄ :

- *1 point injection via direct push(into two different zones)*
- *Injection of ca.200 L NaMnO₄ 40%, diluted till 7 to 10 %*
- *Permanganate worked for ca.16 weeks*
- *ROI* : > 3 m
- *Final conclusion* : effective technology

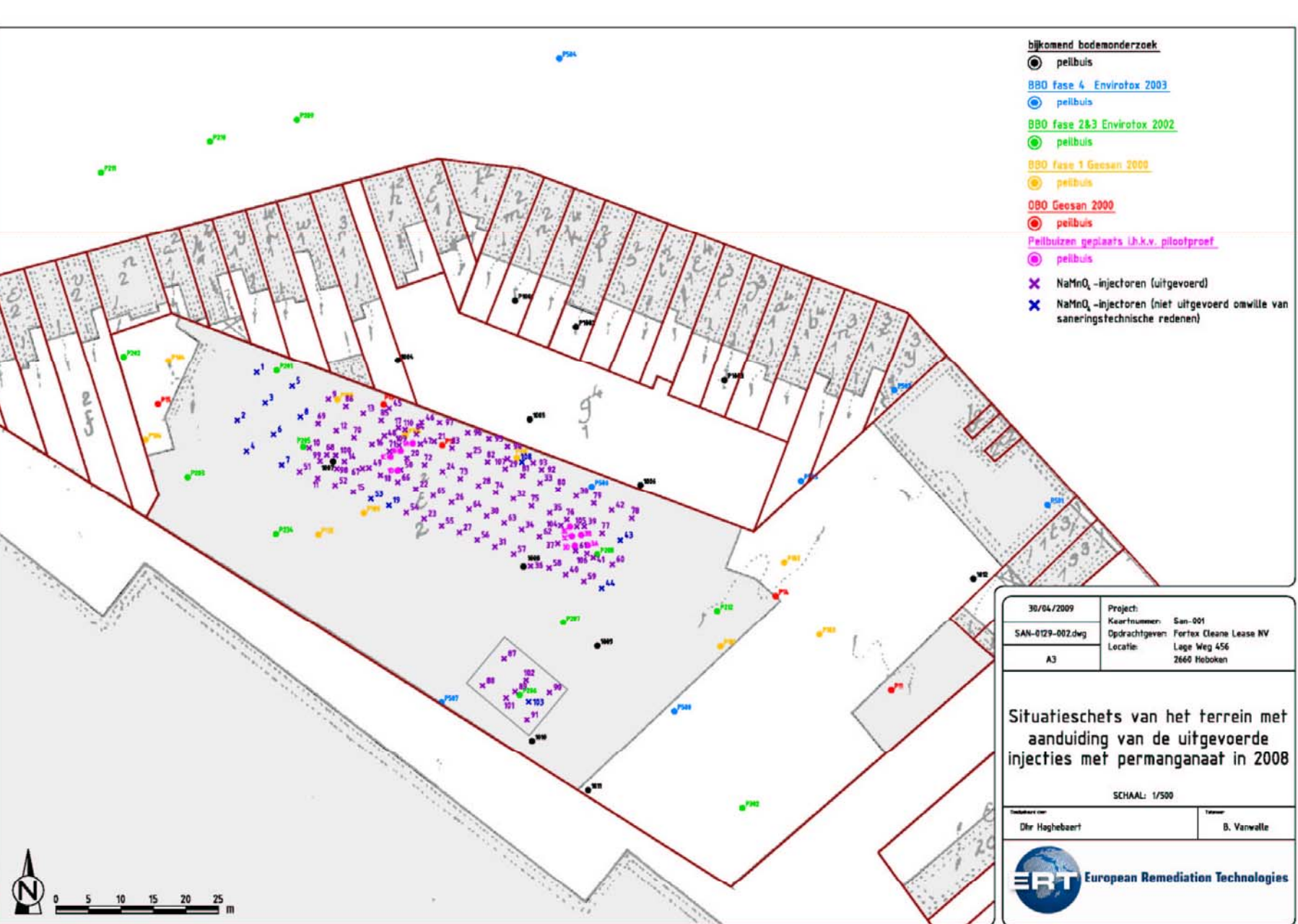
3. Molasse and CAP18® pilot test

TOPICS

- Site specific conditions
- Bench tests and pilots
- **Full scale**
- Conclusions

NaMnO₄ and CAP18-ME[®]-results (Zone 1)

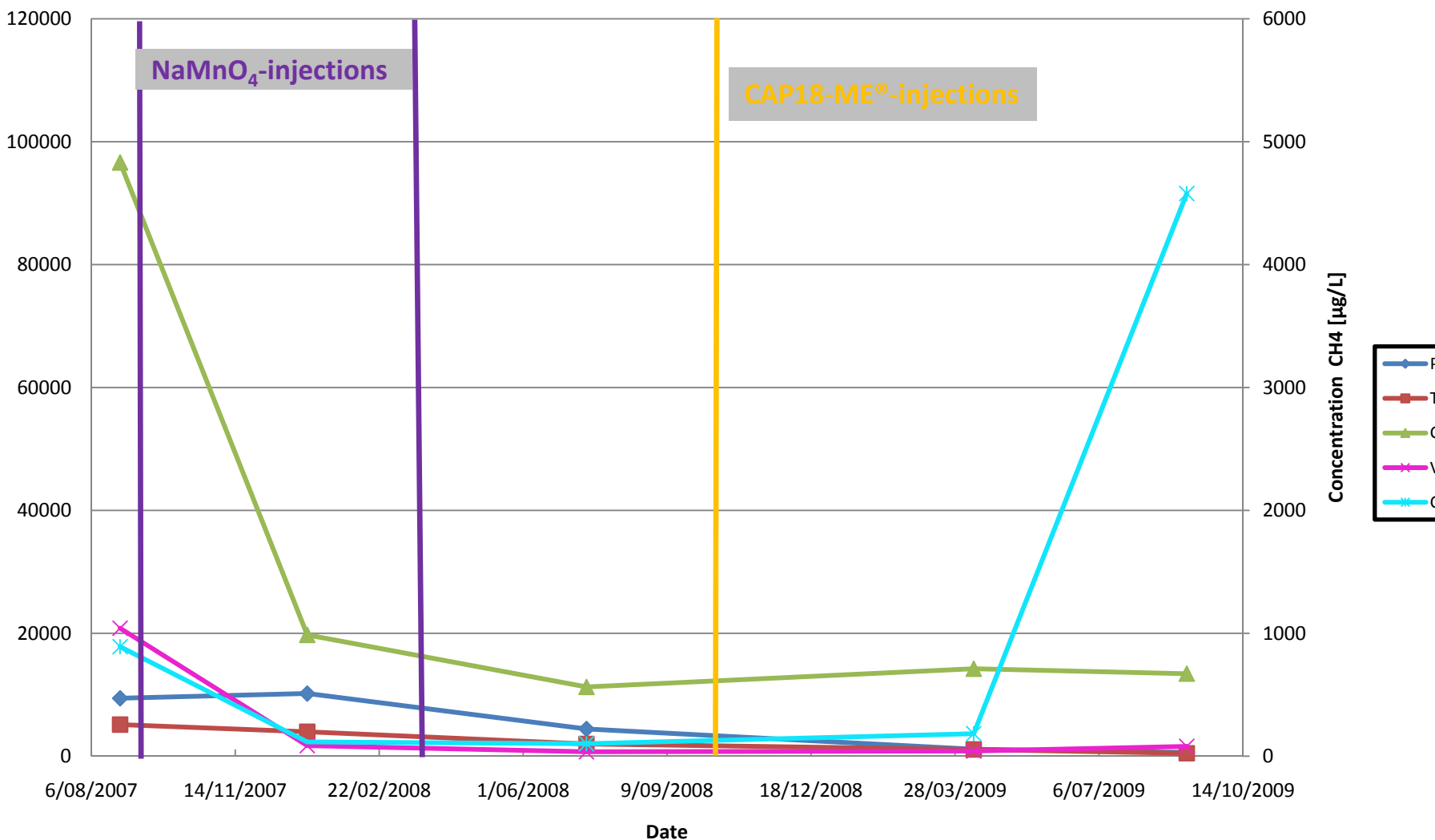
CAPISCO[™]-project region Antwerp



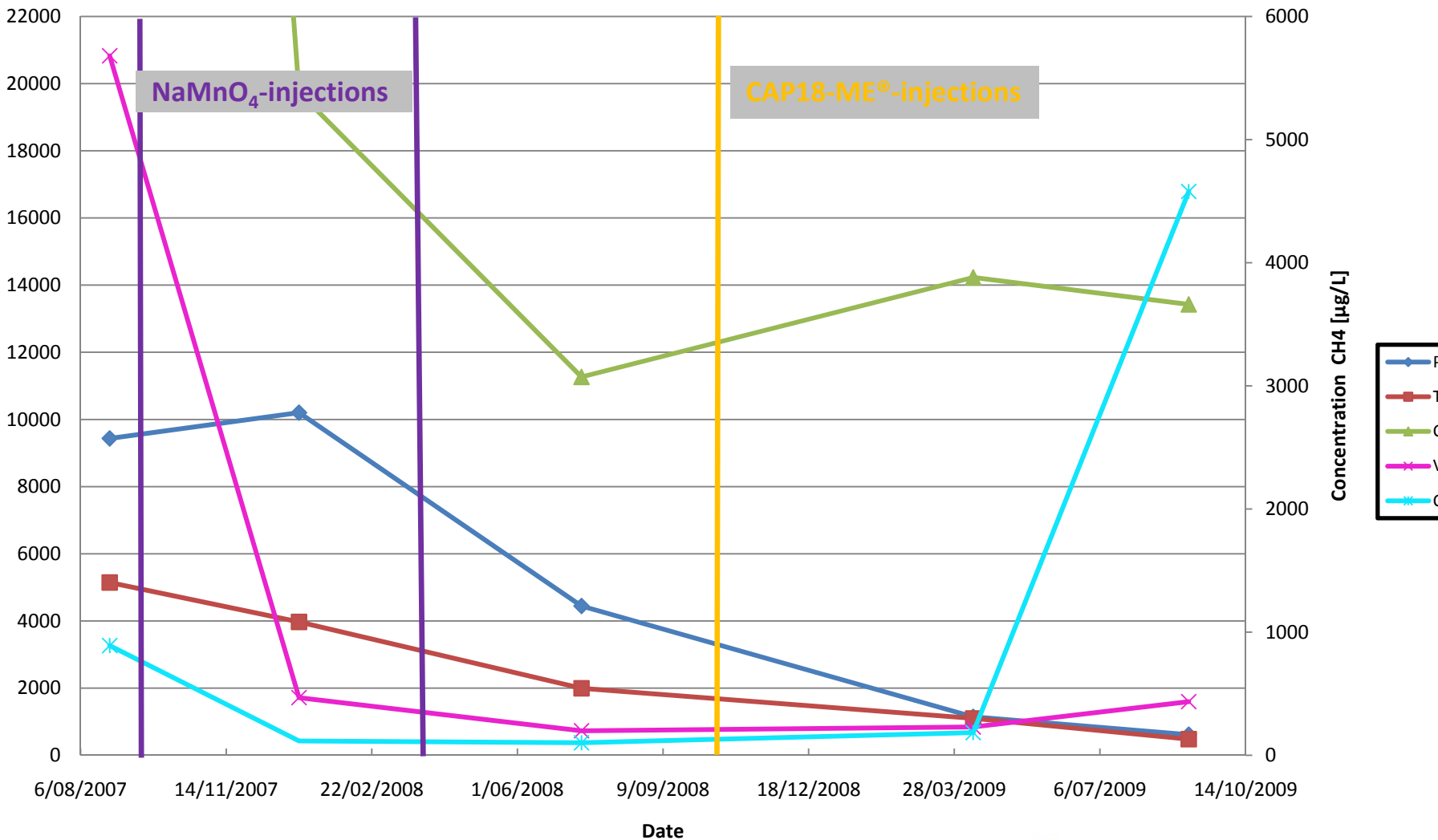
Full scale design :

- ***Injections via 'direct push' :***
 - ✓ *August 2007* : 6.720 kg NaMnO_4 40 % diluted till 8% divided into circa 45 injectors.
 - ✓ *March 2008* : 5.440 kg NaMnO_4 40 % diluted till 4% injected via circa 100 injectors.
 - ✓ *October 2008* : 2.950 kg CAP18-ME[®] injected into 82 injectoren(source).
- ***Conclusion*** : decrease of VOCs is sufficient to justify the after-treatment with CAP18-ME[®] (October 2008).

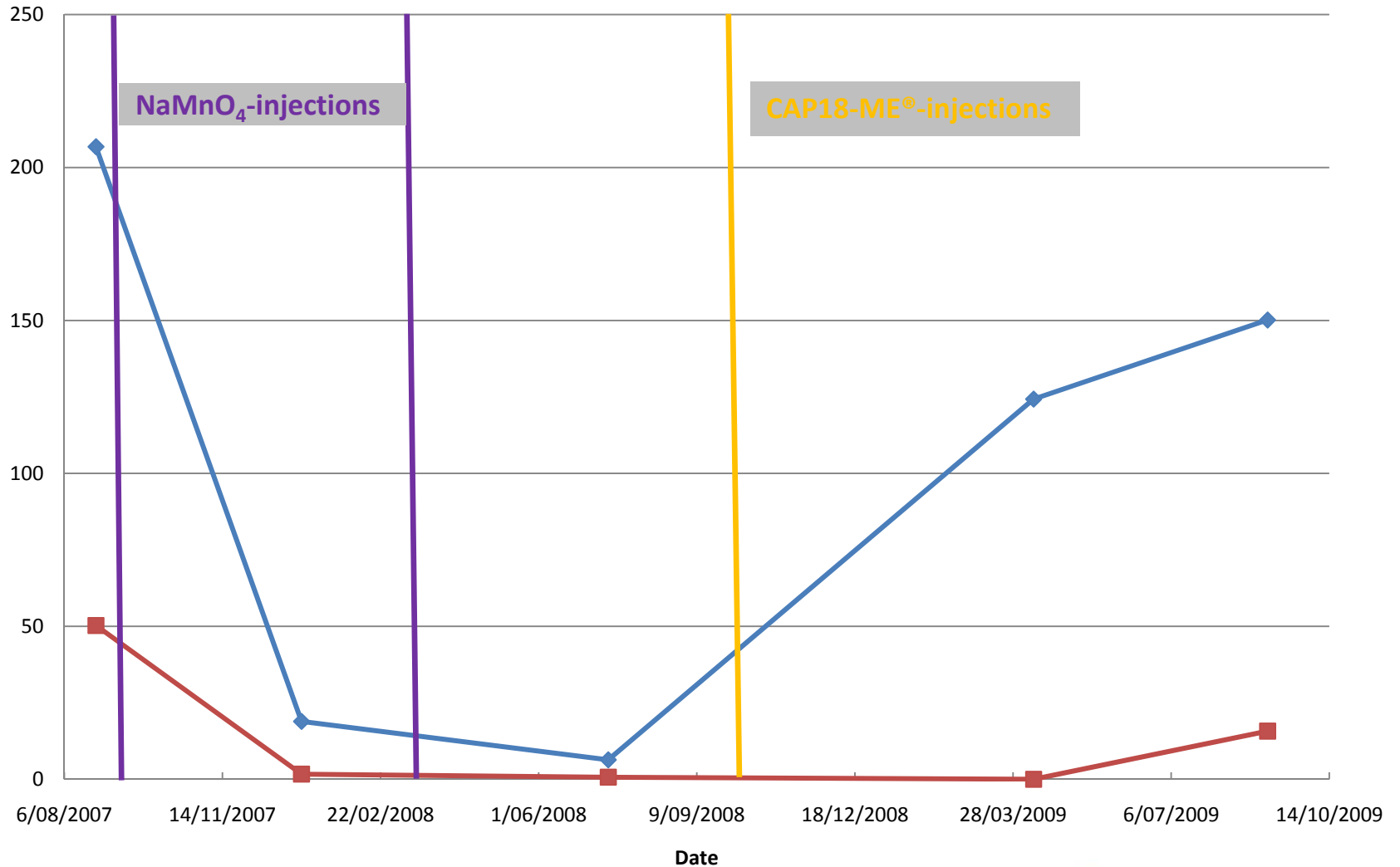
Zone 1 : Average VOC- and CH₄-concentrations



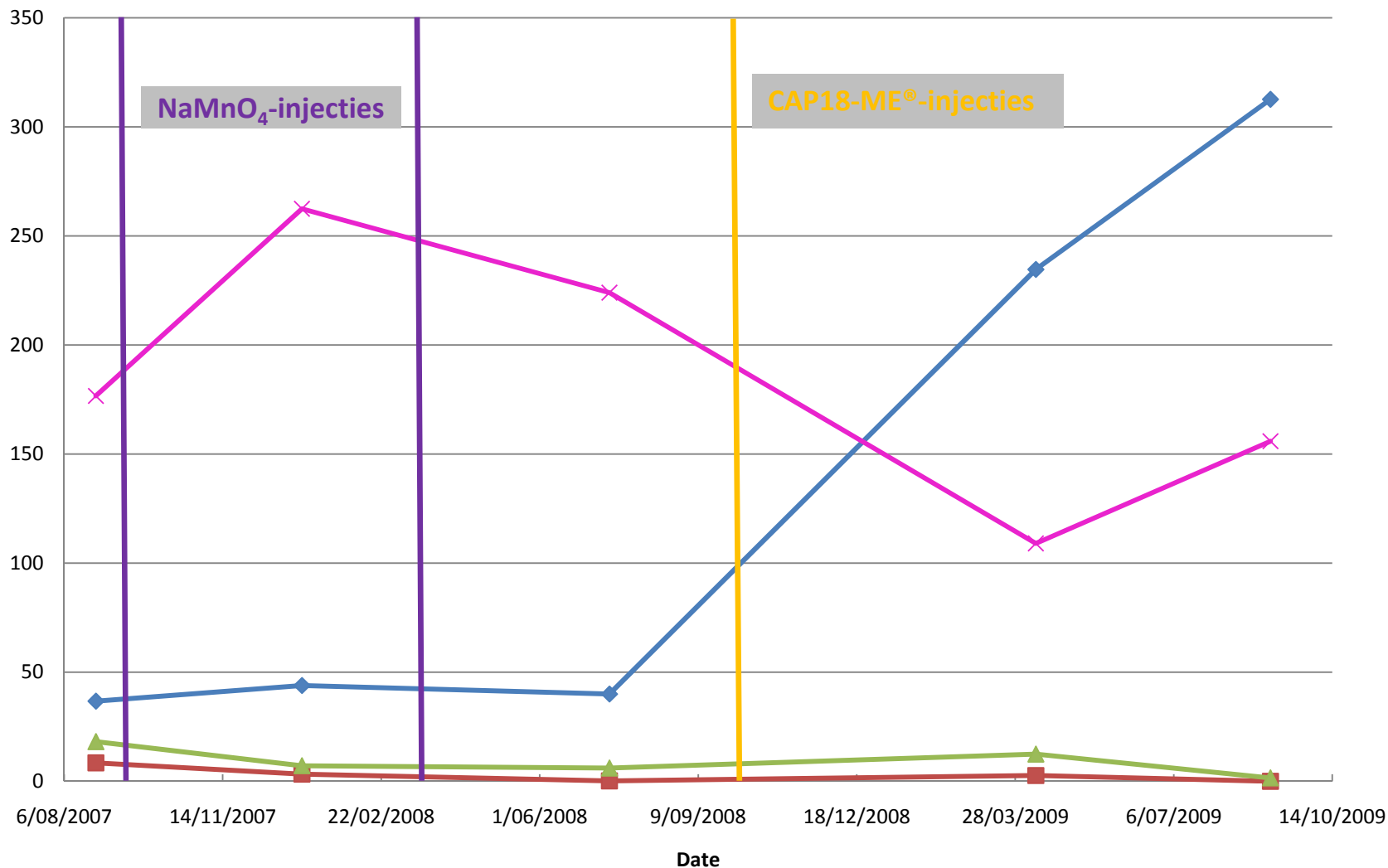
Zone 1 : Average VOC- and CH₄-concentrations



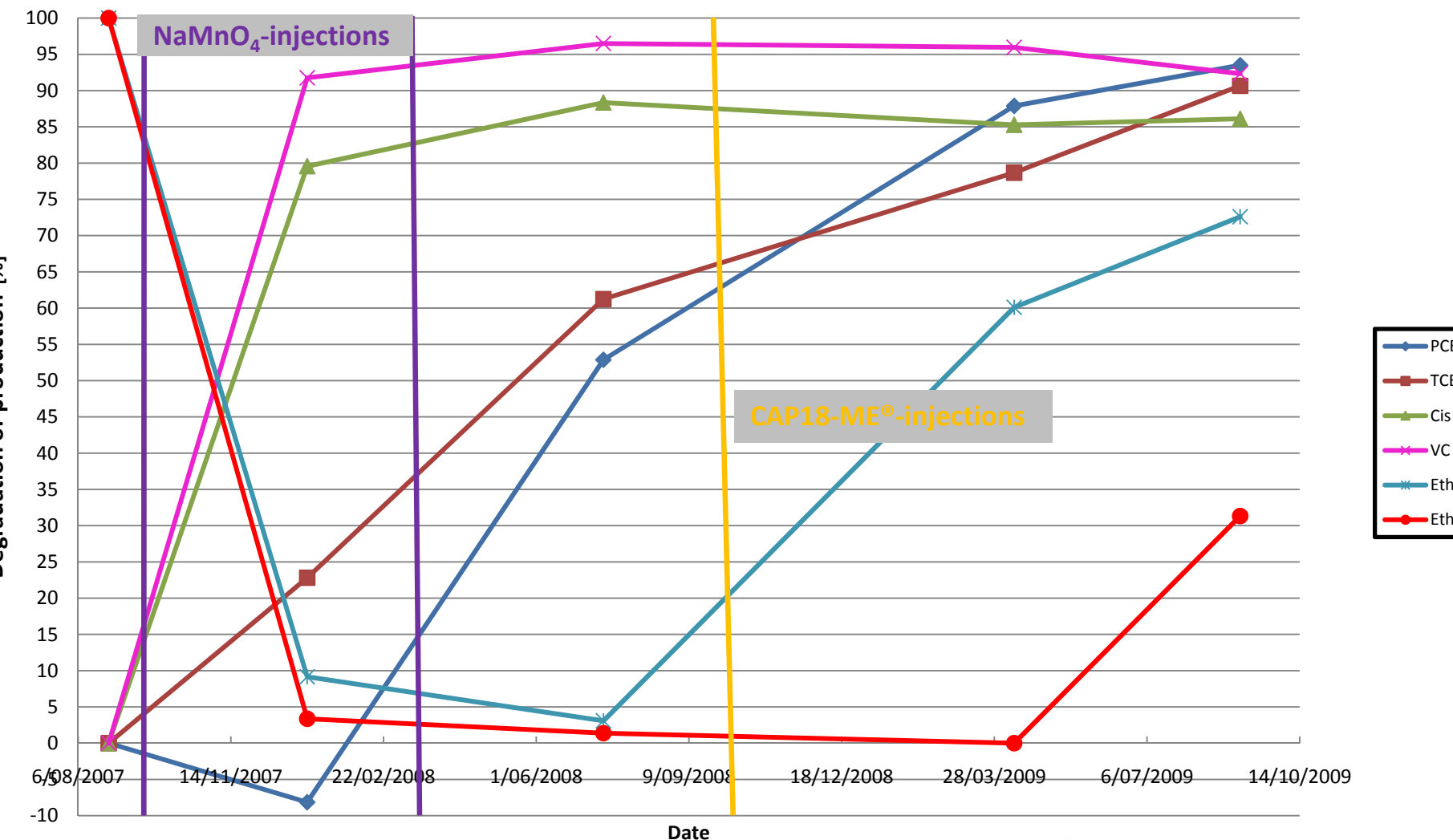
Zone 1 : Average ethene and ethane concentrations



Zone 1 : Average TOC-, NO₃-, Fe(+II)- and SO₄-concentrations

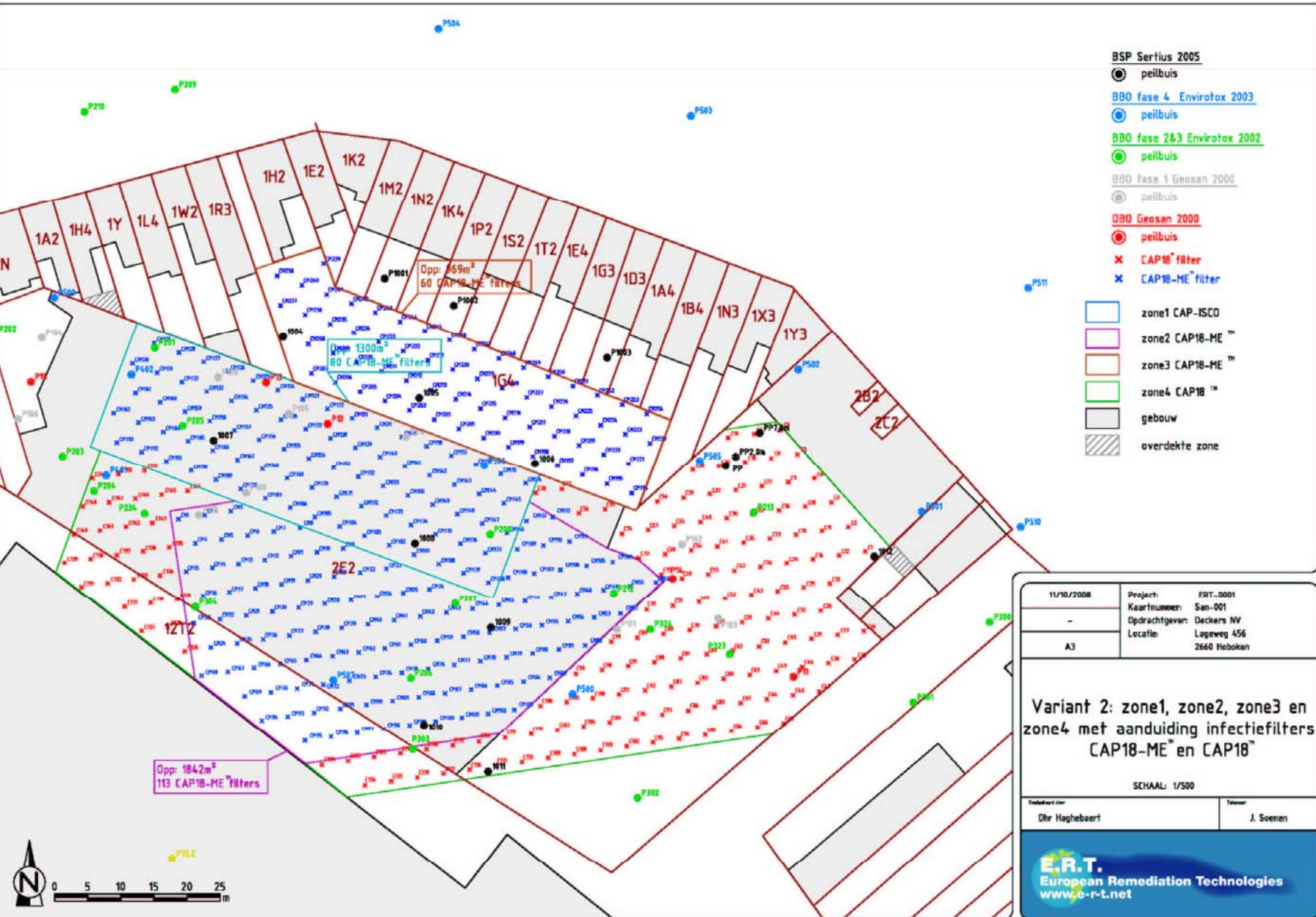


Zone 1 : average %-degradation or %-production VOC-concentrations source



CAP18[®]-results (Zone 4)

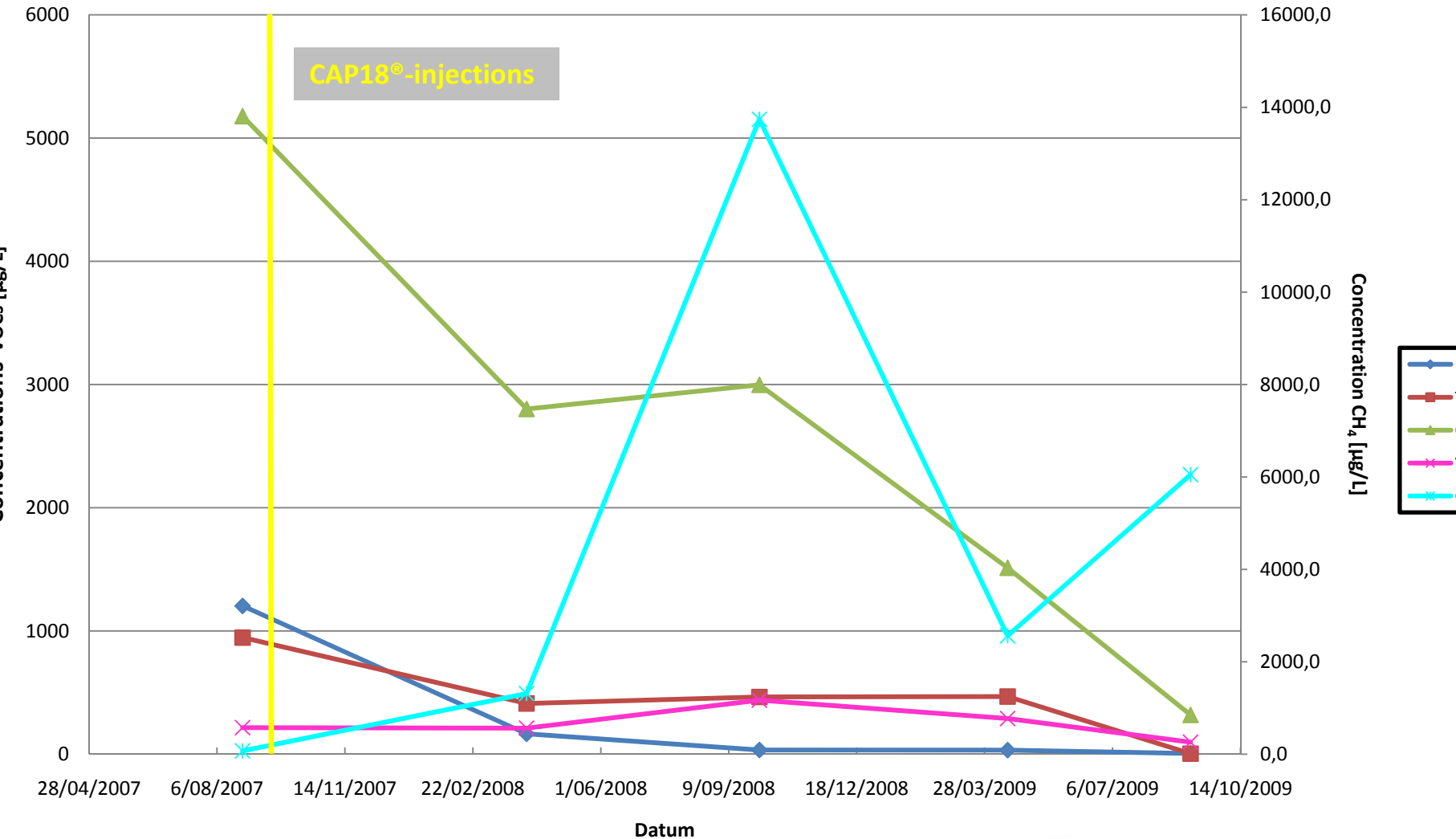
CAPISCO[™]-project region Antwerp



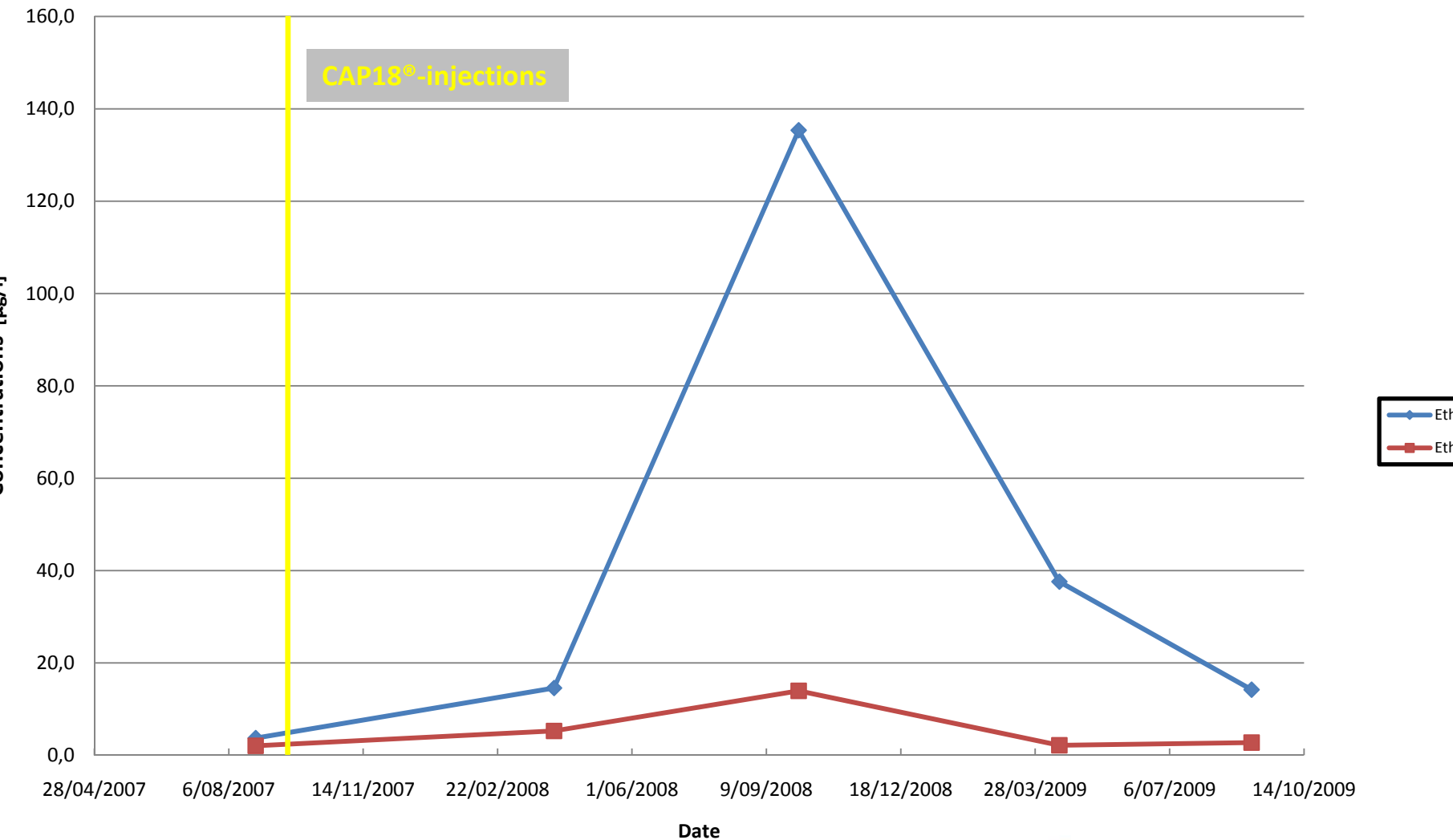
Full scale design :

- ***CAP18®-injections via 'direct push' :***
 - ✓ *September 2007 : 5.520 kg CAP18® injected into 152 injectors.*

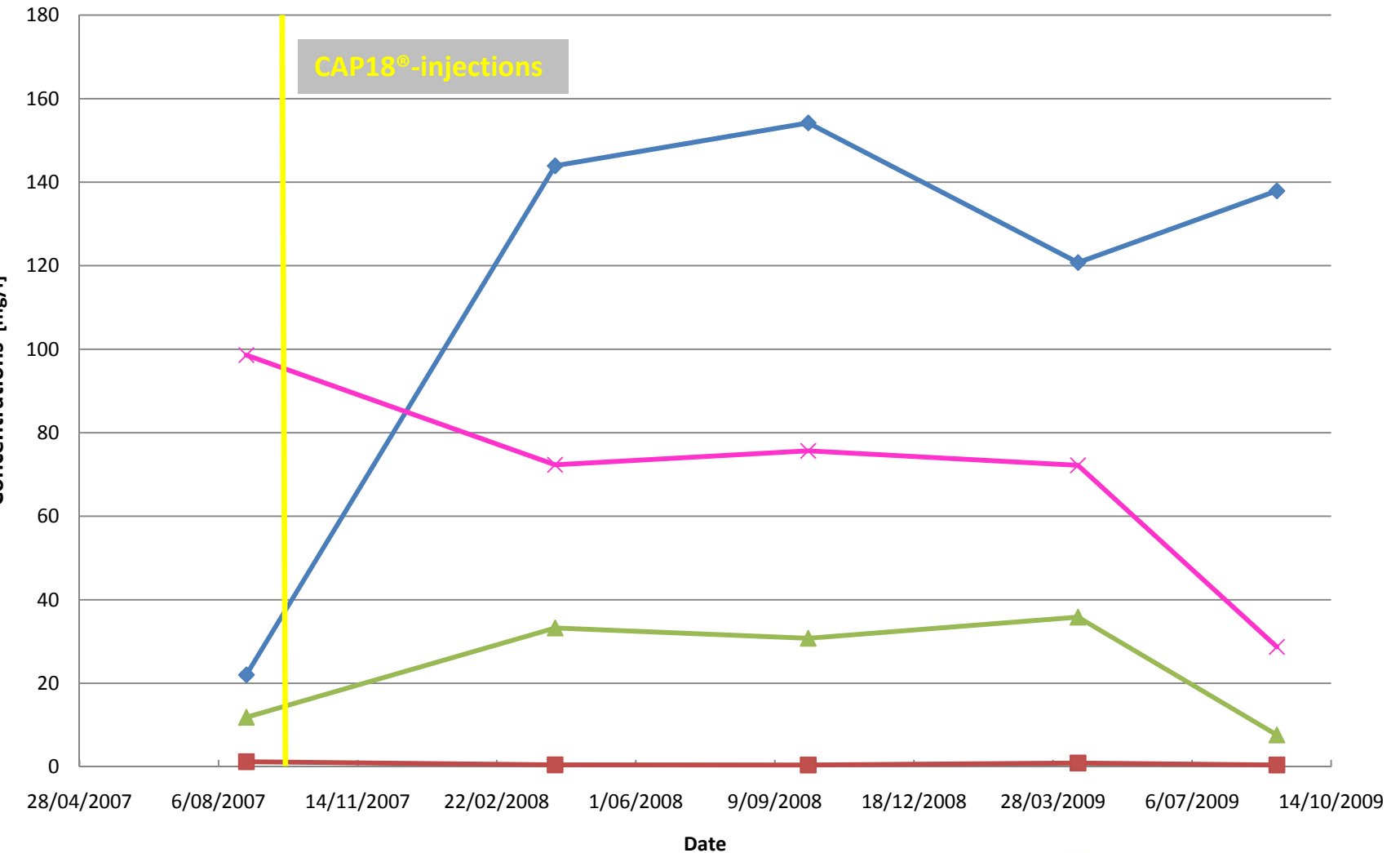
Zone 4 : Average VOC- en CH₄-concentrations



Zone 4 : Average ethene and ethane-concentrations

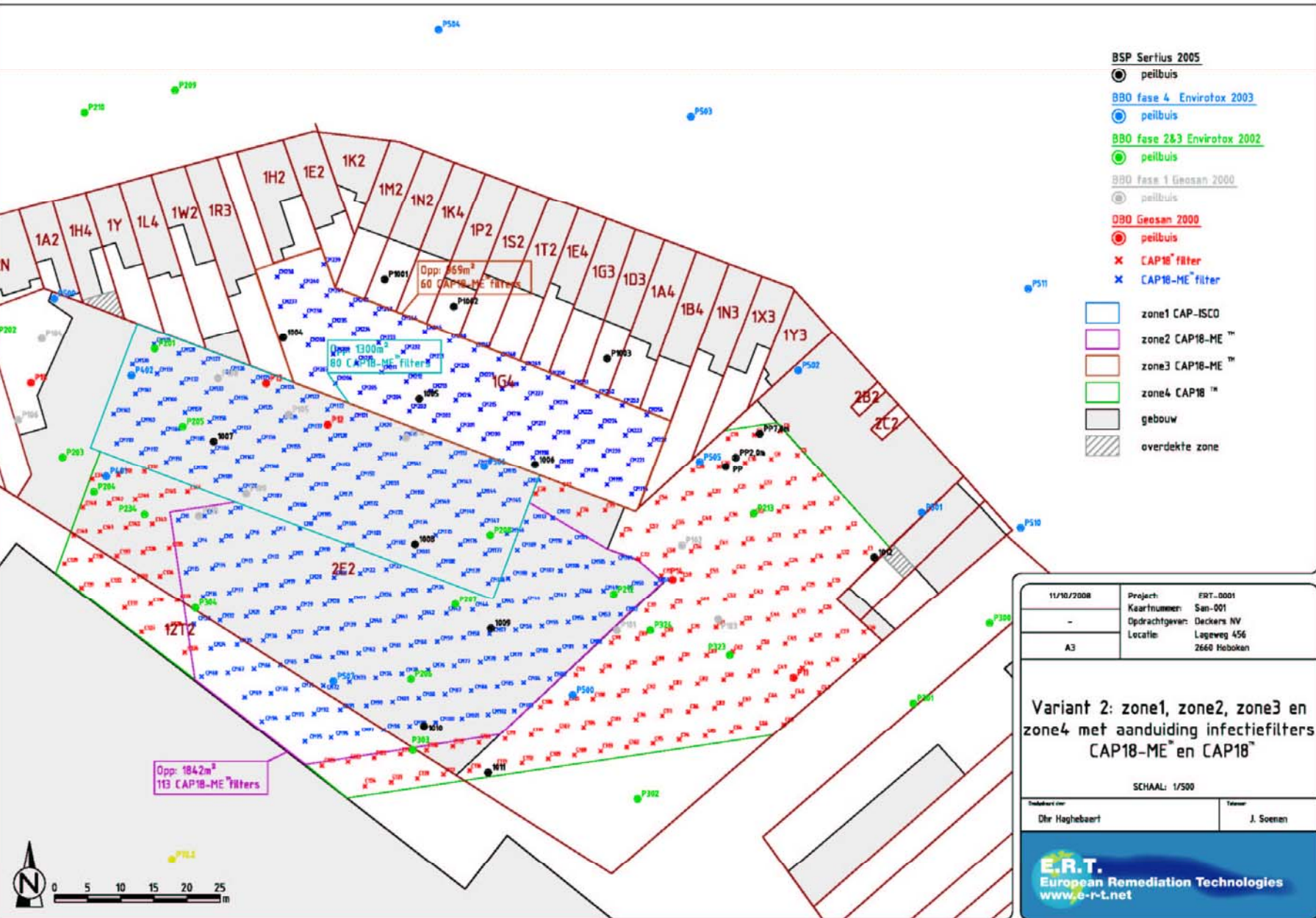


Zone 4 : Average TOC-, NO₃-, Fe(+II)- and SO₄-concentrations



CAP18-ME[®]-results (Zone 2&3)

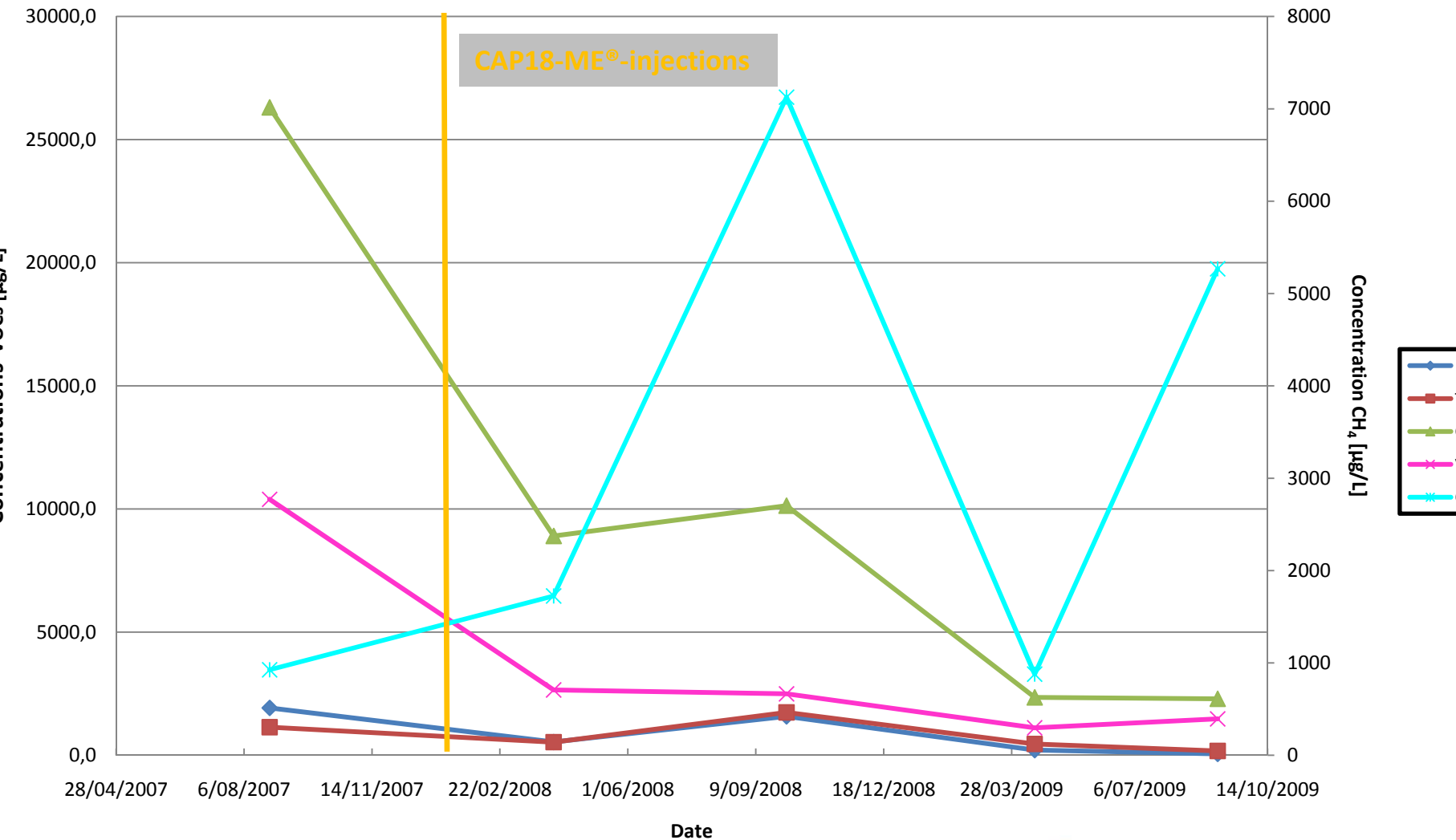
CAPISCO[™]-project region Antwerp(B)



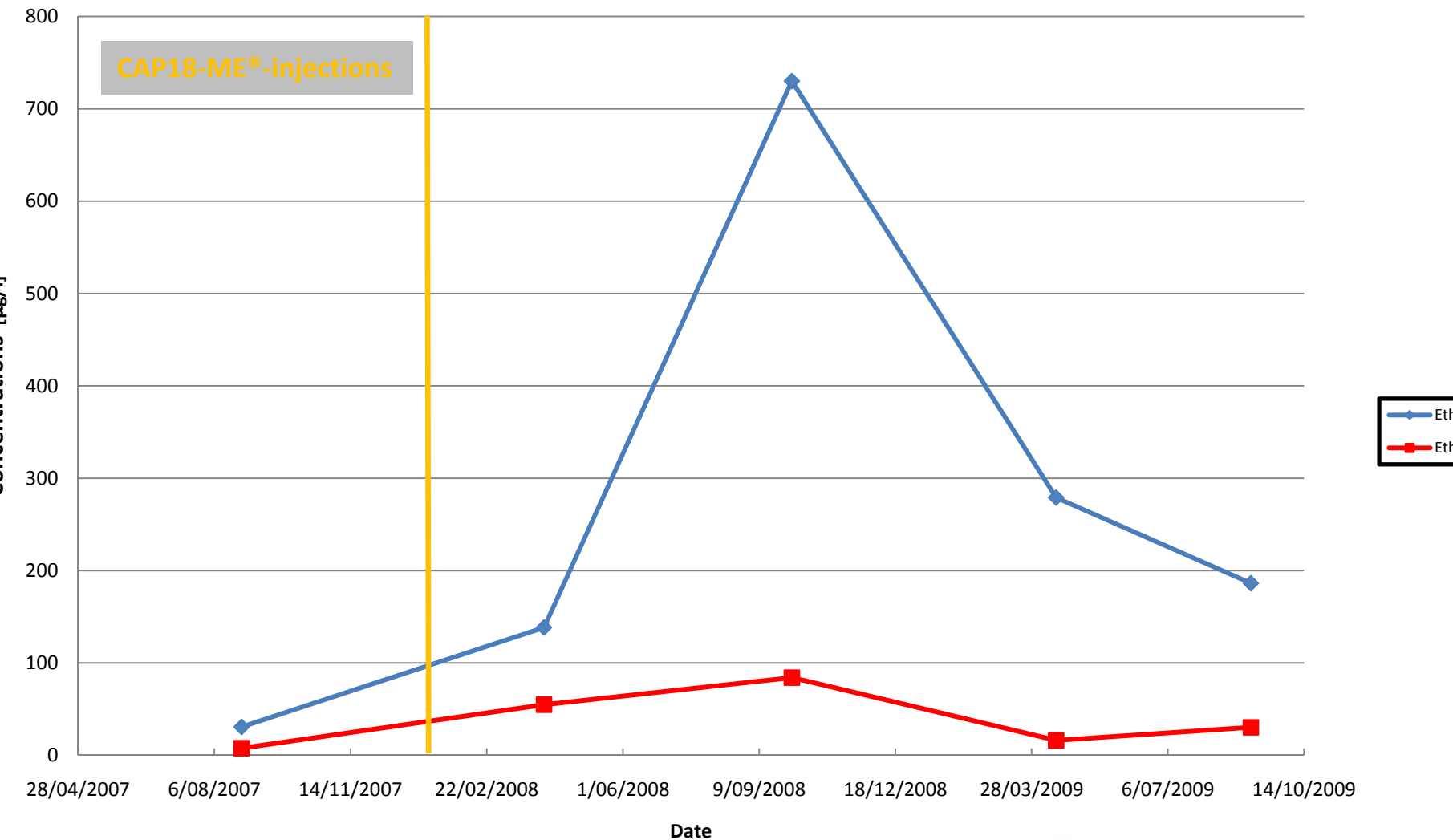
Full scale design :

- ***CAP18-ME®-injections via 'direct push' :***
 - *January 2008 : 10.170 kg CAP18-ME® divided 254 injectors.*

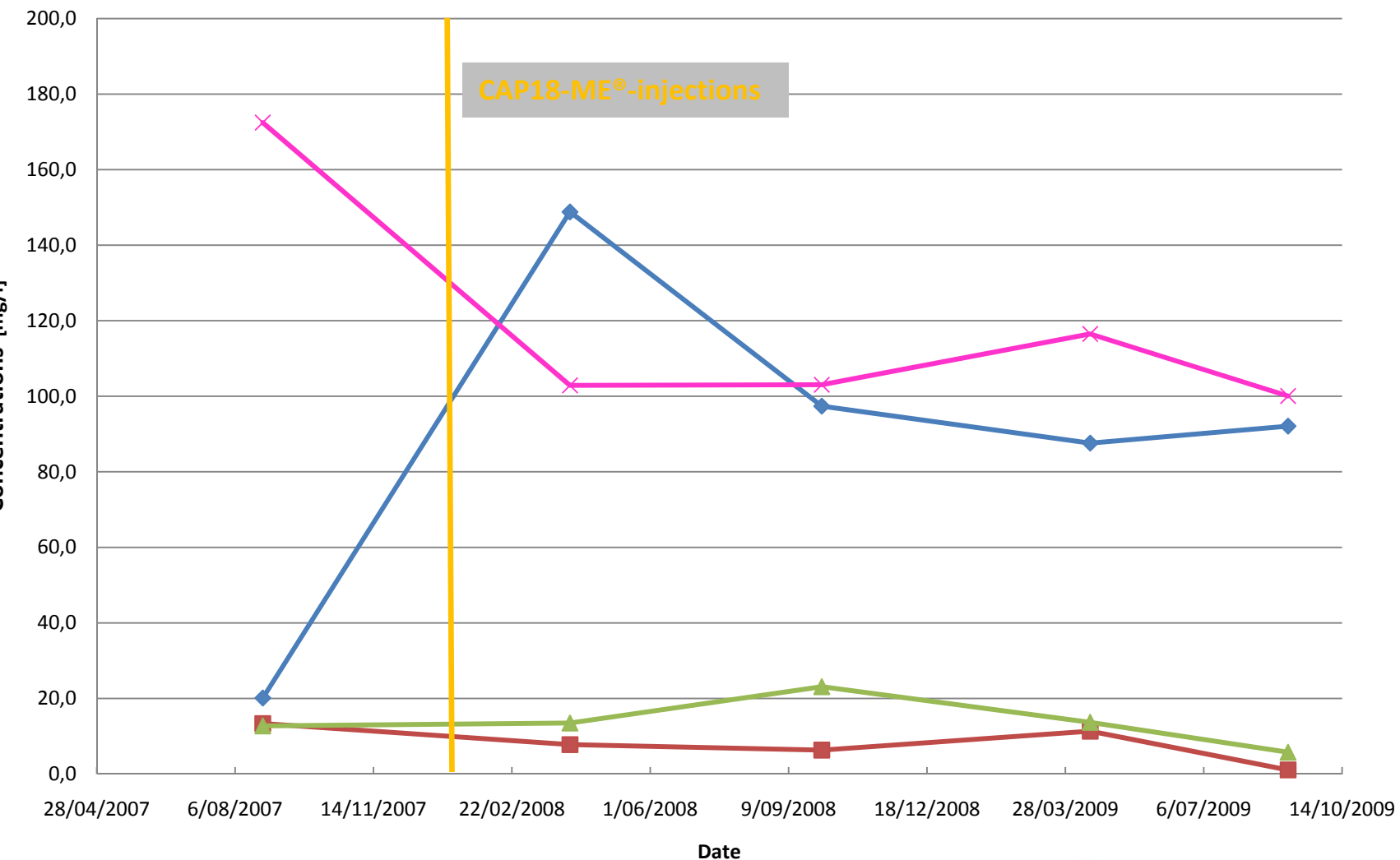
Zone 2&3 : Average VOC- en CH₄-concentrations



Zone 2&3 : Average ethene- and ethane-concentrations



Zone 2&3 : Average TOC-, NO₃-, Fe(+II)- en SO₄-concentrations



CONCLUSIONS :

- **Source :**
 - ISCO with permanganate was succesfull, at present 95% reduction of PCE!
 - After-treatment with CAP18-ME® already working after 6 months
- **Plume :** Good reductive dechlorination with CAP18® and CAP18-ME®
- **Payment evolution :**
 - 95% of the budget is already paid;
 - 97% of the bail is paid back to the client;
 - Last slice when the site is delivered up by the government
- **General CAP18® and/or CAP18-ME® cost :** 5 to 8 €/m³
- **Only monitoring needed anymore, other activities possible on site.**

Before



After





Before



After



Before



After



Questions?



ERT **European Remediation Technologies**

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together!*

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