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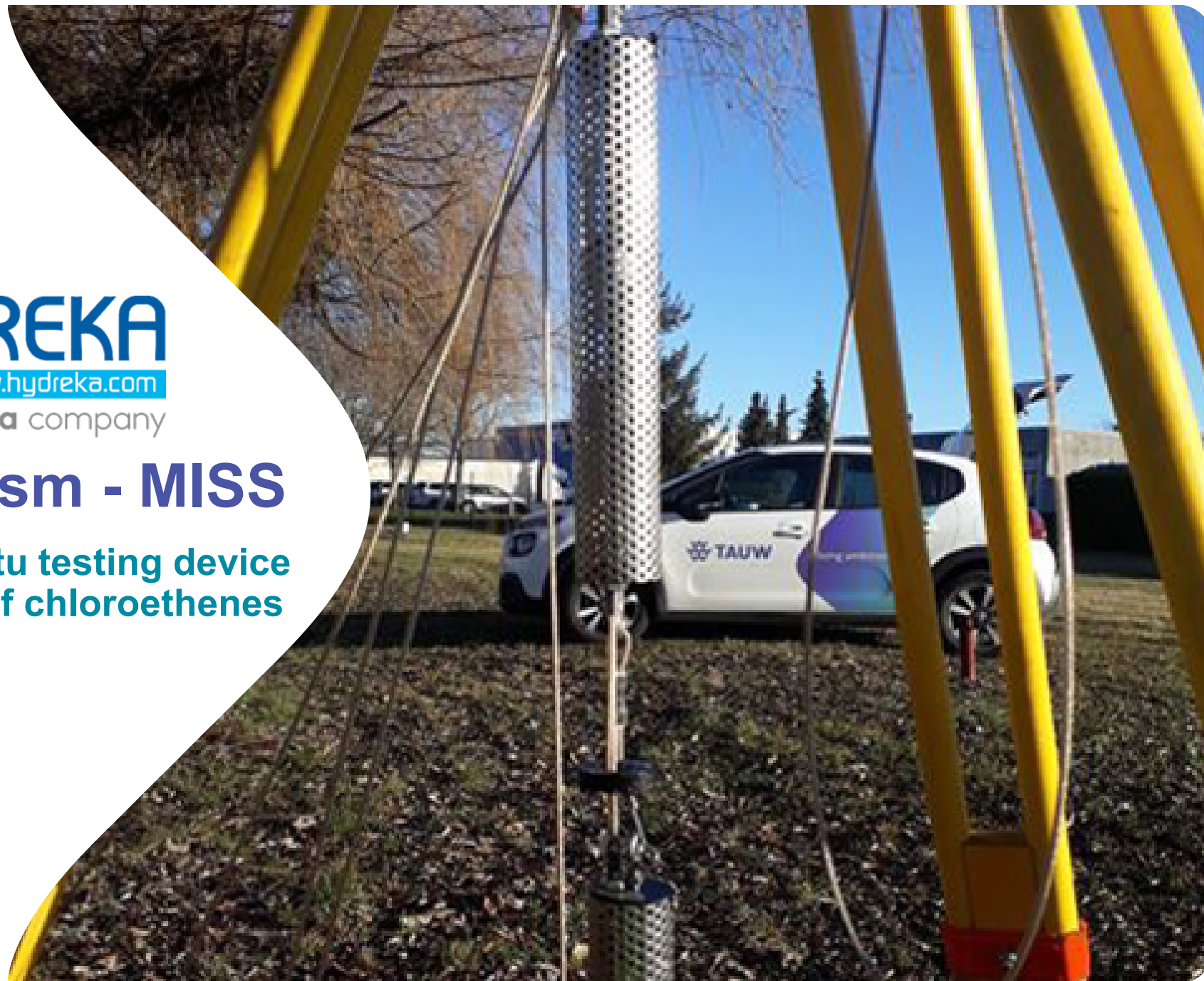
## *In situ* microcosm - MISS

Development of an in-situ testing device  
for the biodegradation of chloroethenes

30/03/2023

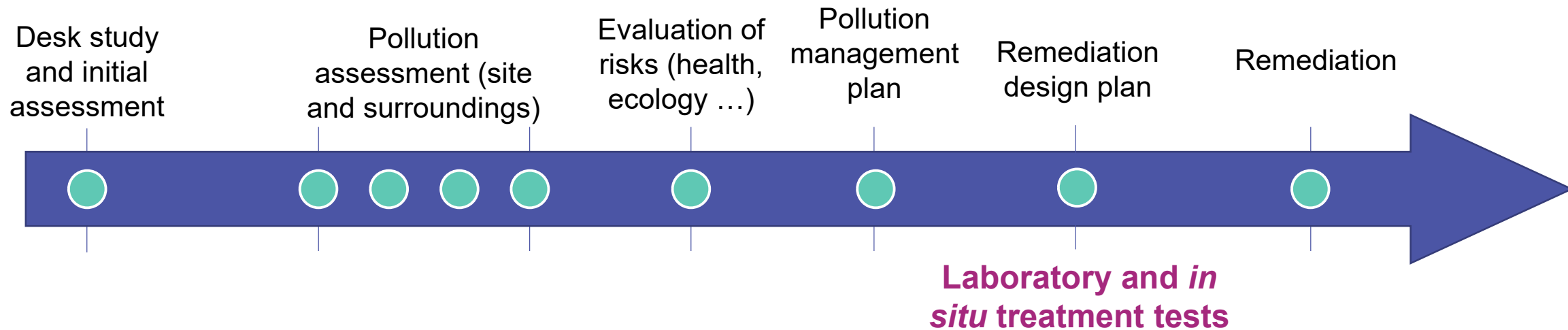
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C. Malandain - HYDREKA



# Introduction

## Continuity of steps from initial study to remediation works



### Remediation design plan is a crucial milestone especially for biotic processes

- Ensures the ability of remediation strategies to achieve objectives / time / costs
- Requires the implementation of lab. Tests & field pilots
  - ➔ **representativeness of site conditions vs. biases during treatment tests?**
  - ➔ **cost / duration vs. lessons learned for design?**

# Objectives of the MISS project

## Lab. tests - Microcosms

### Pros:

- **Test under various conditions** (O<sub>2</sub>, redox, substrate, ...)
- Better understanding of the biotic processes
- **Shorter duration ~ 3 to 6 months**
- **Lower overall cost ~ 10 to 20 k€**



### Cons:

- Batch mode = **no flow & by-product accumulation**
- Product in excess
- Time is not relevant → **prediction?**

## Field pilot

### Pros:

- **Representative field conditions:** natural TOC, EA-ED balance, need for pH control, GW flow ...
- Test injection parameters (soil stratigraphy)
- **Better prediction of performances:** concentrations reduction vs. time & distance



### Cons:

- **Longer duration >6 to 9 months**
- **Higher overall cost >50 to 100 K€**
- 1 testing zone = 1 set of conditions (redox)

→ **Need to fill the gaps, reduce design uncertainties and costs**



# The MISS project

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**Development of an in-situ microcosm device (MISS) installed in existing monitoring wells for the prediction of biostimulation performances**

**Academic research lab**



ÉCOLE  
CENTRALE LYON

Research on microbial  
genomic and ecology

**Water monitoring tools  
and services**



Development of new technology  
related to environmental  
microbiology

**Environmental  
engineering group**



Field implementation of new  
technology and development of  
remediation design strategies



**French environmental agency**

# MISS project working program

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## Lab tests

- Substrate formulations & release with time
- Passive samplers for pollutants, TOC and microbial indicators
- Effect of substrate on microbial populations

## Prototype design

- Dimensions and architecture
- Materials and costs

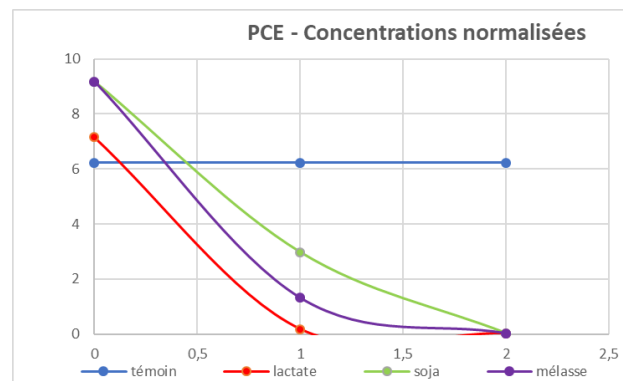
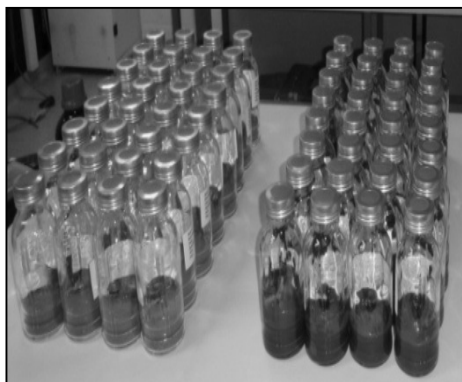
## Field tests

- Testing protocols: installation, retrieval, sampling
- MISS field implementation → 2 zones tested
- Comparison of MISS results to real field remediation

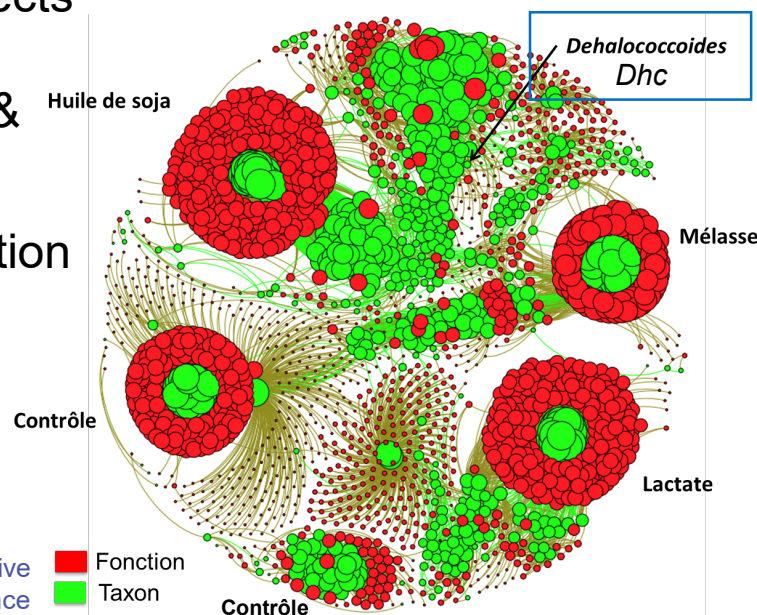


# Effect of substrate on microbial populations & functions

## Lab. tests - Microcosms



- Substrate selects the microbial communities & functions
- Better correlation of *DHC* with Molasse or Soybean substrates



Taille ronds : prop. Abondance relative  
Long. Liens : inv. Prop. Co-occurrence

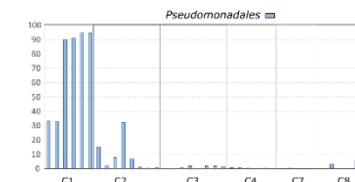
■ Fonction  
■ Taxon

## Field pilot

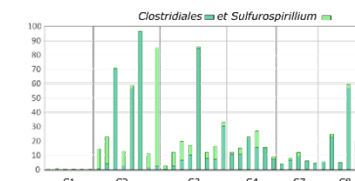


GW flow

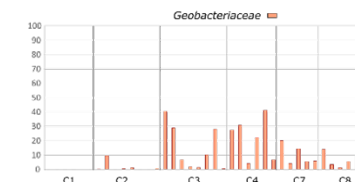
Shift of microbial populations & functions



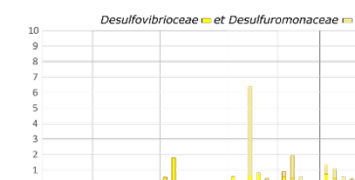
Hydrolyse enzymatique



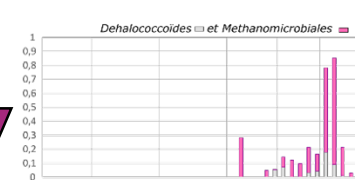
Fermentation



Réduction des métaux



Sulfato-réduction



Dehalorespiration  
Méthanogénèse

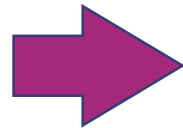
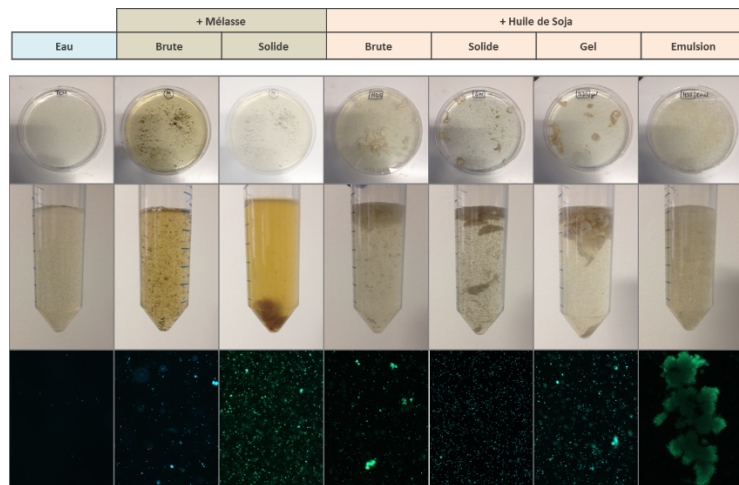
Time



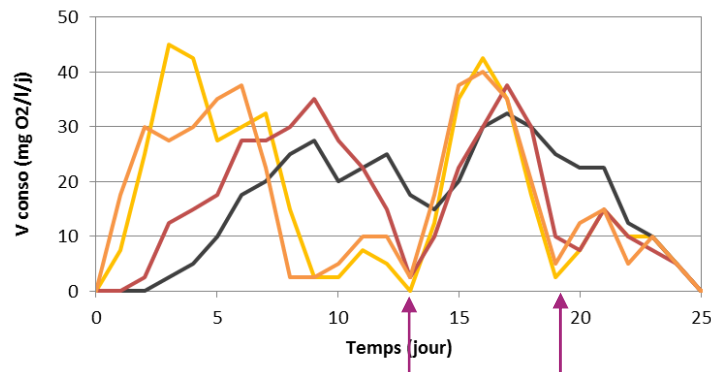
# Substrate formulations and TOC release with time

## Formulation testing

- Kinetics of the substrate liberation in static system



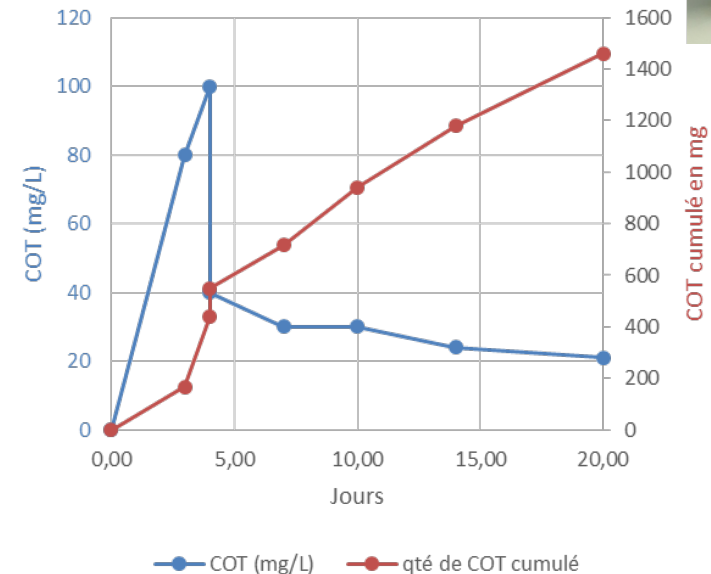
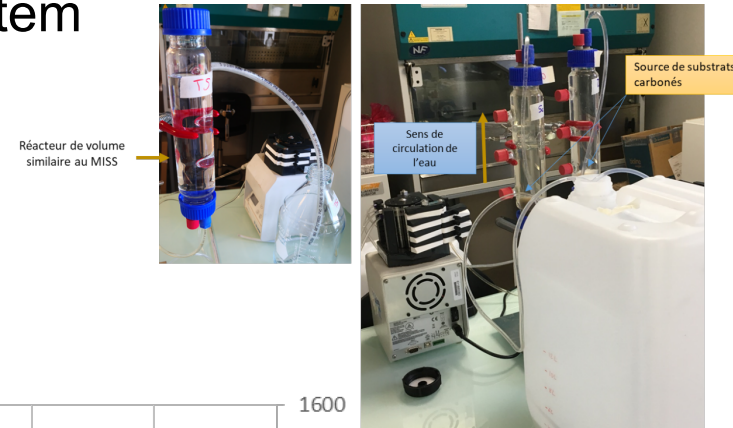
Solidified & customized substrate formulation



**Addition of O<sub>2</sub>: complete consumption after 7 and 12d except for Solidified Soybean Oil**

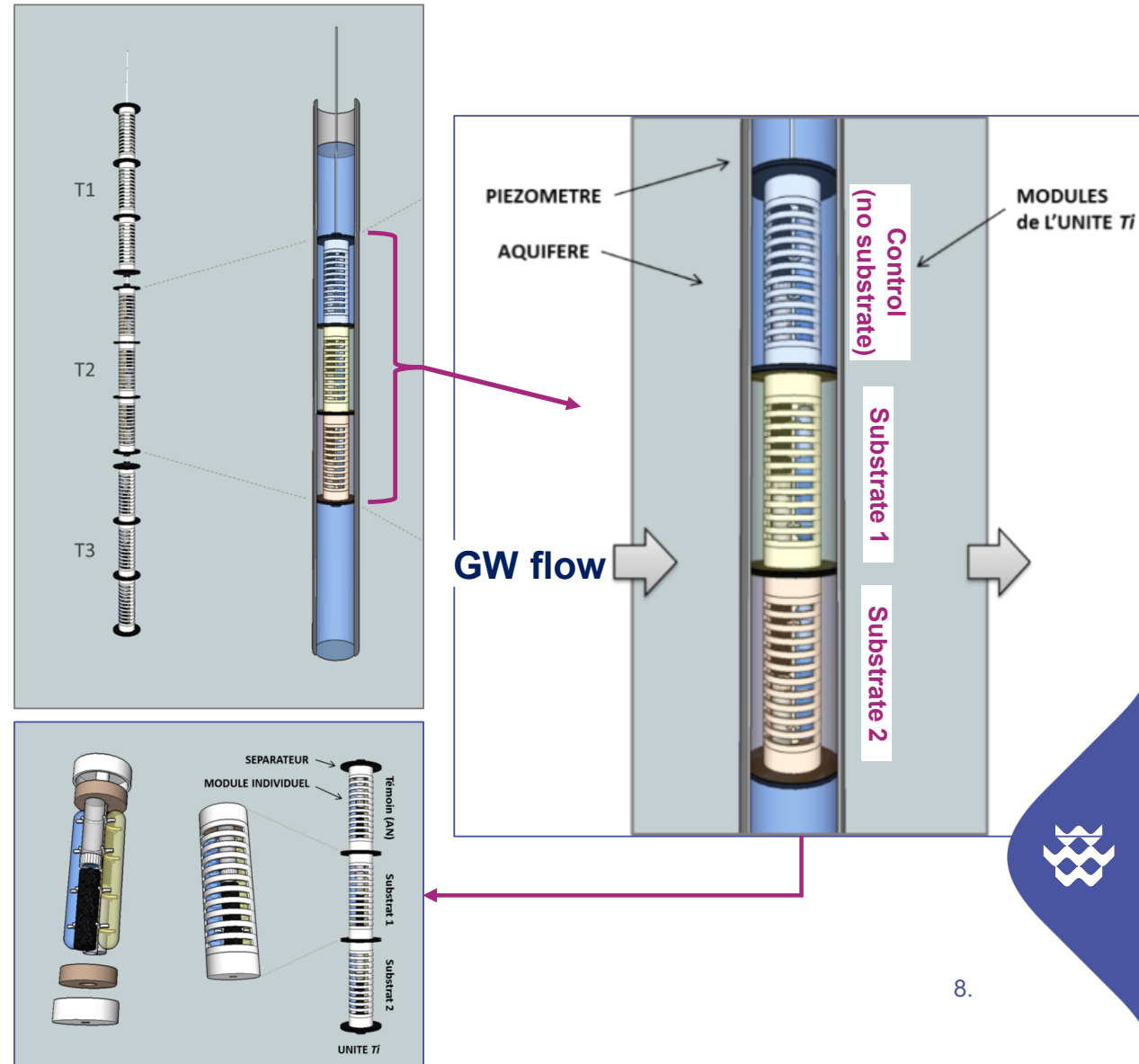
## Flow through columns

- Kinetics of the substrate liberation in dynamic system



# MISS prototype: design & testing protocols

- 1 MISS contains
  - sampling vials for chemical parameters
  - 1 EMP® (HYDREKA) for biofilm growth and microbial analysis
  - 1 carbon source
- GW flow through the MISS device liberates TOC and stimulate local microbes to enhance degradation of contaminants
- 3 MISS = 1 sampling round
  - 1 control
  - 2 substrate formulations
- 9 MISS = 3 sampling rounds
- Each sampling round (T1, T2, T3) can be retrieved independently





# MISS prototype: field implementation

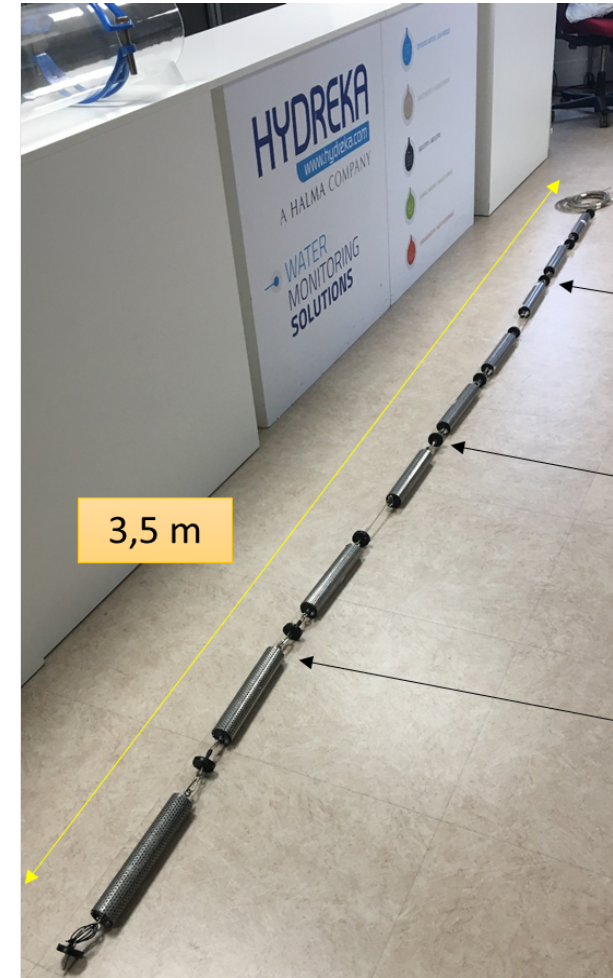


## Site testing:

- Substrate 1: solidified Molasse + Soybean formulation
- Substrate 2: solidified commercial substrate (Tersus®)

## Monitoring:

- Chloroethenes + TOC
- Microbial analysis = qPCR & DNA sequencing
- Initial state = traditional sampling (purge)
- MISS sampling rounds = 16d, 36d, 76d



Temps de  
prélèvement T1

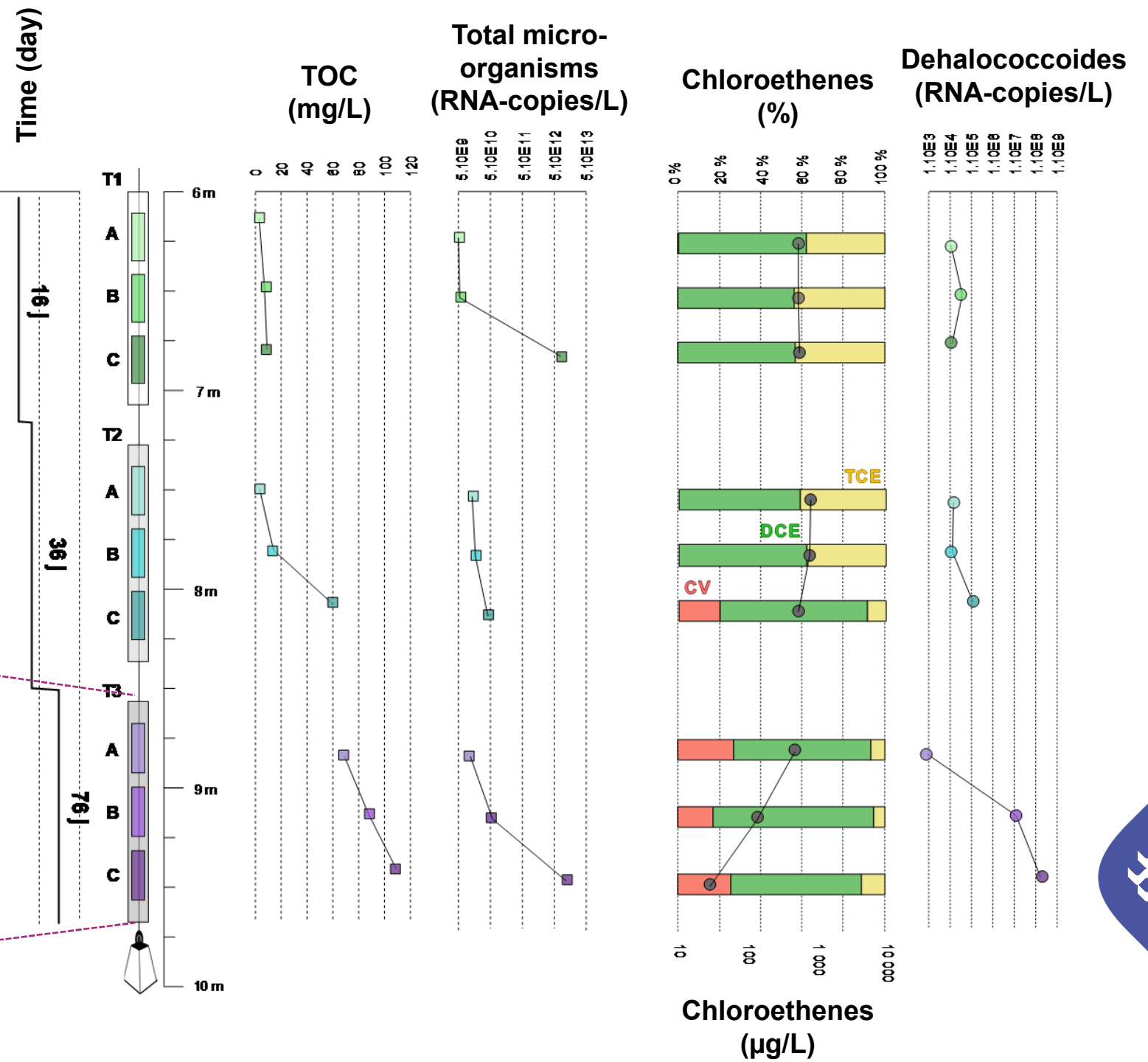
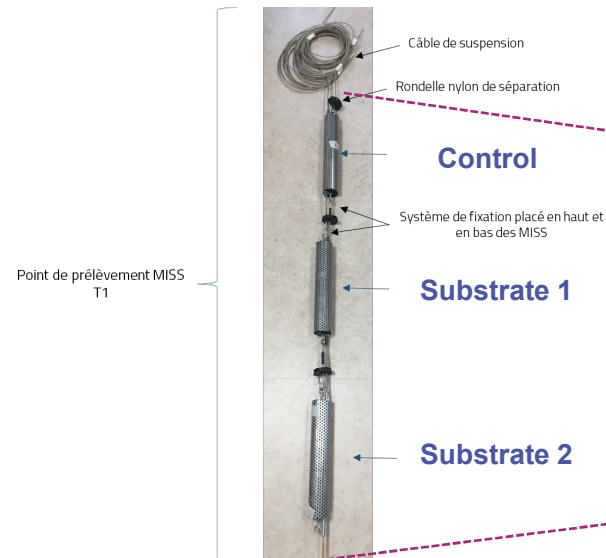
Temps de  
prélèvement T2

Temps de  
prélèvement T3



# MISS prototype: results

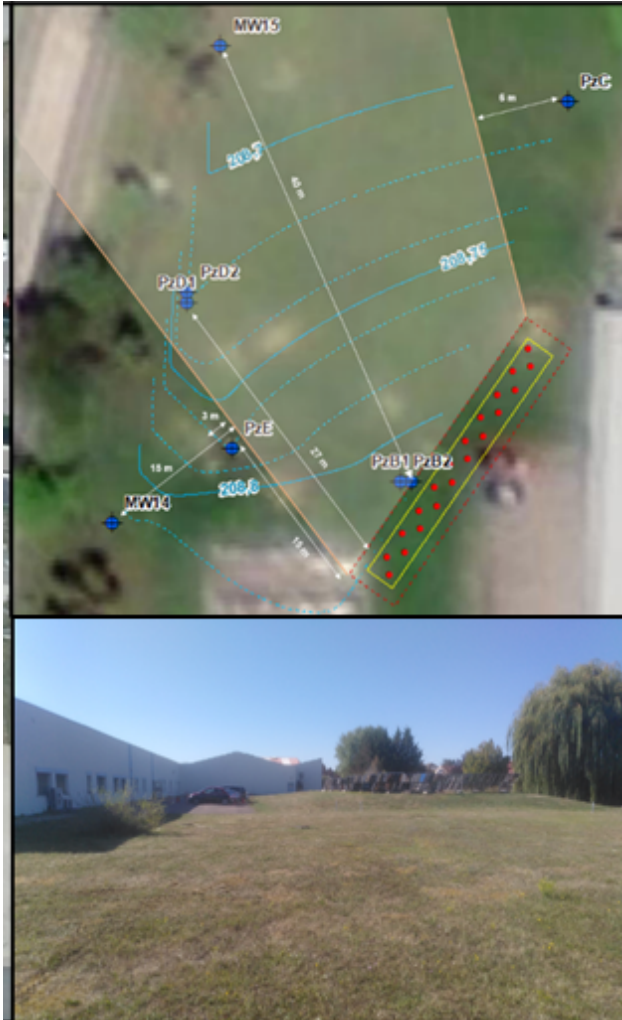
- ➔ Substrate 2 shows early TOC release and biodegradation stimulation (36d)
- ➔ After 76d, TOC is still high and degradation is efficient





# Field scale pilot: biostimulation for Cl-VOCs plume remediation

## Installation of injection zone & monitoring wells



### Substrate Injection:

- Substrate: commercial substrate (Tersus®)
- Injection method: rotary auger – pressurized continuous injection (Injectis®)
- Injection window: depth 2 to 10m, 20 points over 35 m width

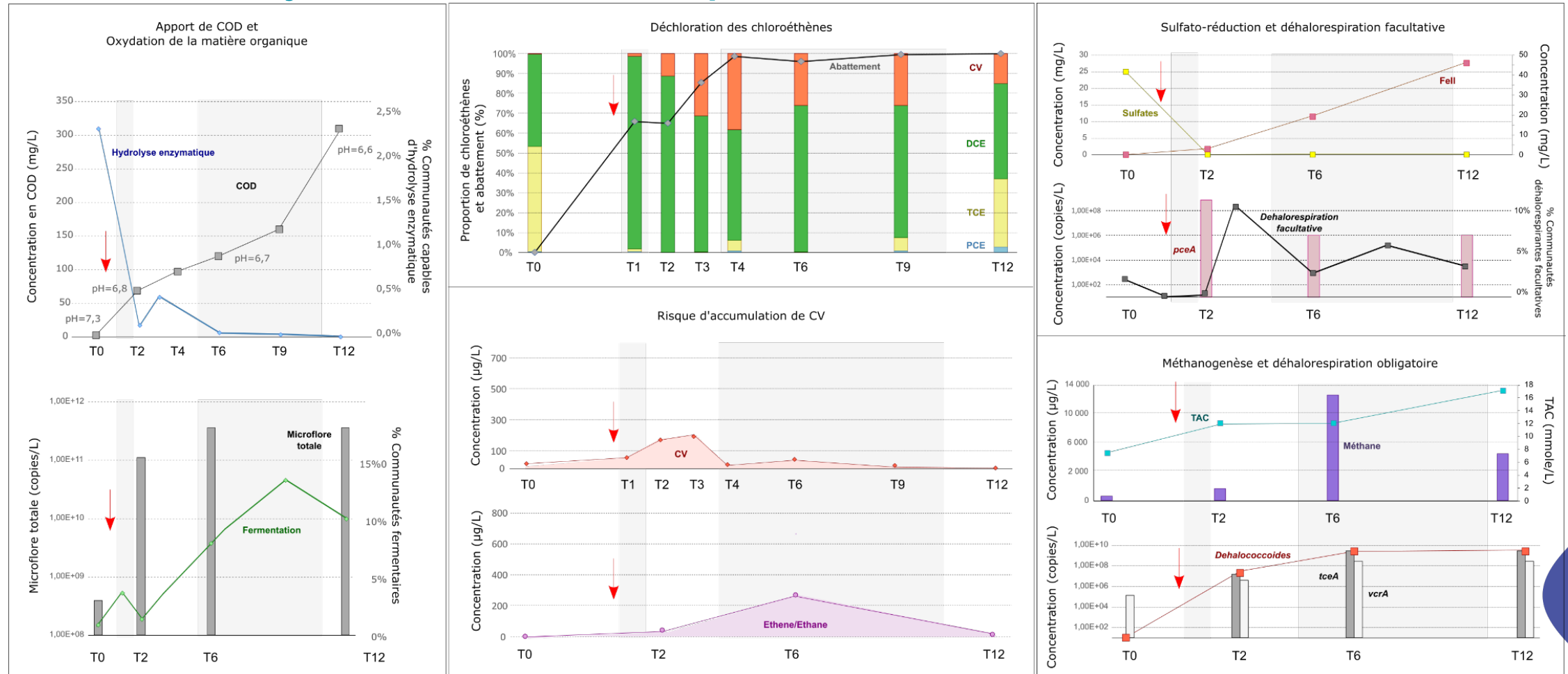
### Monitoring:

- Redox, pH
- Chloroethenes + TOC + EA
- Microbial analysis = qPCR & DNA sequencing
- Traditional sampling method (purge)
- 10+ wells (2 depths)
- 12 months period



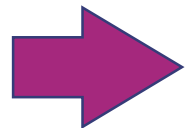
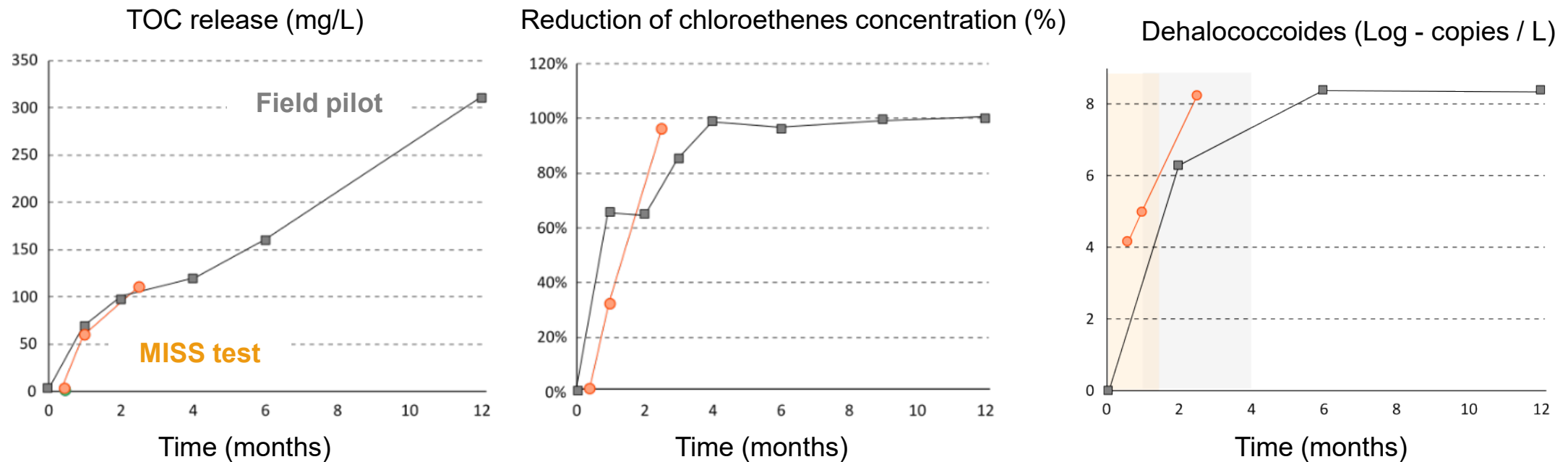
# Field scale pilot: biostimulation for Cl-VOCs plume remediation

## Results near injection : CV and ethene production starts after 3-4 months



# Comparison: MISS device vs. field scale pilot

## Comparison with the same commercial substrate



**The substrate liberation, chloroethene degradation and Dhc numbers are similar between the MISS test and the field scale pilot (near injection wells)**





# Summary and future improvements

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## A new tool for testing bioremediation performances

- No need for energy (passive device), no need for additional wells (can fit existing wells)
- Testing conditions: 4 to 6 months, control (MNA) & 2 carbon custom-made substrate
- Lower costs, better representativeness of existing field conditions
- Good prediction of actual remediation results (substrate release & dechlorination rate)

## Future developments

- Implement the device in different sites: various redox & flowrate conditions
- Test new carbon substrate formulations
- Enhance the design, reduce interferences and adapt monitoring rounds to site conditions
- Allow the MISS device to release Oxygen like compounds for aerobic biostimulation





TAUW

# Thank you for your attention



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## Comments / contacts



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