



# TREATMENT OF LOW CONCENTRATIONS OF TEX THROUGH A PLANTED BIOFILTER : REMOVAL EFFICIENCY AND ROLES OF INDIGENOUS BACTERIA

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## PARTNERS INDUSTRIAL PHD

CANEVAFLOR®



↳ R&D

*Technical and  
financial support  
Patents owner*



**Planted biofilter**

LABORATOIRE D'ÉCOLOGIE MICROBIENNE

UMR CNRS – INRA



↳ Équipe Groupes Fonctionnels Microbiens  
Et Cycle de l'Azote

*Microbiology – Molecular Biology*

ÉCOLE DES MINES D'ALÈS



↳ Équipe Odeurs et COV

*Process Engineering*

# CONTEXT

## ATMOSPHERIC POLLUTION IN TOWN : A MAJOR PROBLEM

### ANTHROPICS SOURCES

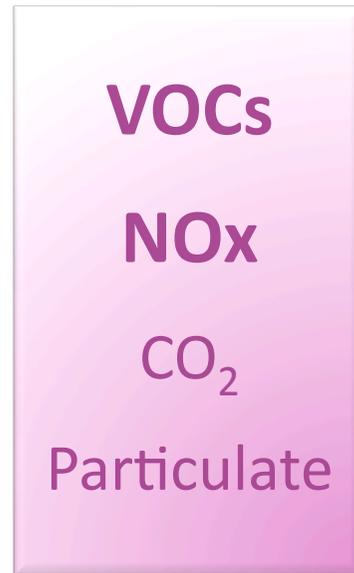
#### traffic



#### Industries



### POLLUTANTS



### CONSEQUENCIES

#### Environmental effects

- ↳ O<sub>3</sub>
- ↳ Global warming

#### Health effects

- ↳ Chronic respiratory diseases
- ↳ SNC cardiac
- ↳ Life expectancy



2 solutions to limit pollution : reduce emission and treatment of air

## CONTEXT

### PROBLEM OF AIR QUALITY IN UNDERGROUND CAR PARCS



## CHARACTERISTICS

### Confined space + Traffic

- Pollution concentration

### Pollution

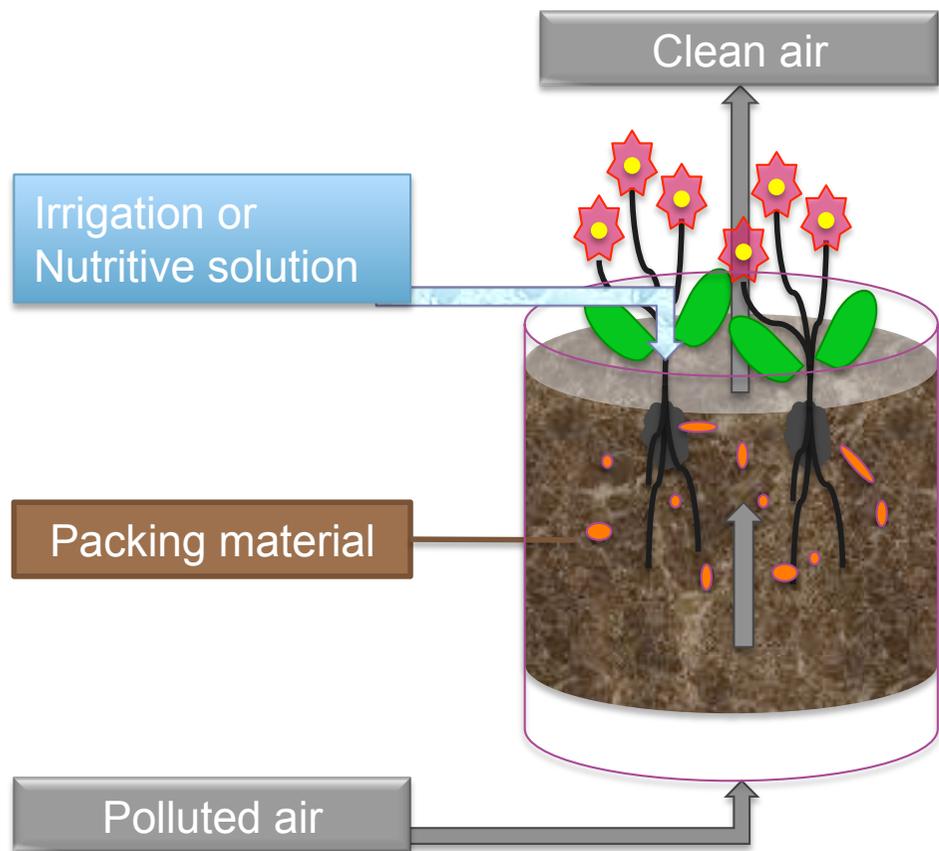
- Large flow rate
- Complex mixture of pollutants
- Low concentrations
  - CO
  - NO<sub>x</sub> (100 – 300 µg.m<sup>-3</sup>)
  - BTEX (400 – 600µg.m<sup>-3</sup>)

## REGLEMENTATION

### IN FRANCE

- Mechanical ventilation
- Partial supervision of air quality (CO)
- **No obligation on the quality of air released into the atmosphere**

# PLANTED BIOFILTER AN INNOVATIVE PROCESS



## ROLES

### PLANTS

- aesthetic
- VOCs fixation
- CO<sub>2</sub> absorption

### MOUND OF SOIL

- contribution of rhizospheric microorganisms

### PACKING MATERIAL

- adsorption
- contribution of indigenous microorganisms

### MICROORGANISMS

- biodegradation

## PLANTED BIOFILTER PRELIMINARY RESULTS

- Planted biofilter can treat a low concentrations of TEX
  - Removal efficiency : 99%
  - Standard superficial gas velocity :  $100\text{m}\cdot\text{h}^{-1}$  (EBRT = 14s)
  - Addition of nutrient solution
  
- Plants can grow in this system (Ivy : *Hedera helix*)
  - No Impact if nitrogen is not limited
  - Negative impact in absence of nutrient solution (nitrogen competition)
  
- Microorganisms can grow and colonize the packing material
  - Low TEX concentrations and short EBRT are sufficient to induce the microorganisms activities
  - good potential capacity for NOx biodegradation



(Rondeau *et al.*, 2012)

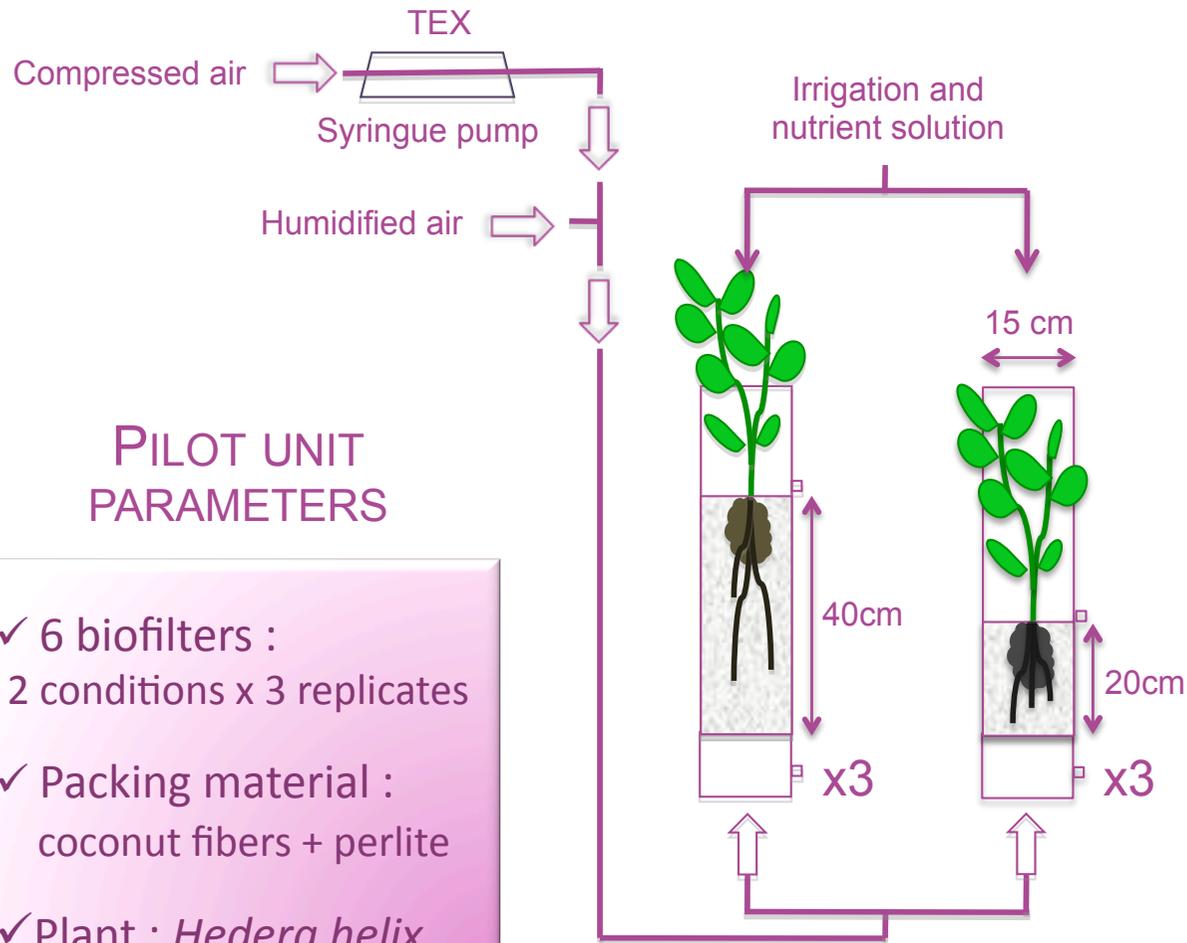
## OBJECTIVES

### OPERATIONAL CONTROL

- Treatment of larger volume of air contaminated with low concentrations of TEX ?
  - Possibility to reduce the footprint of biofilters ?
    - Increasing the superficial gas velocity :  $100\text{m.h}^{-1} \rightarrow 200\text{m.h}^{-1}$
    - Reducing packing material height :  $40\text{cm} \rightarrow 20\text{cm}$
- } ⇒ Reduction of EBRT
- Compatibility very short EBRT vs biological degradation compounds ?
    - Roles of indigenous bacteria ?
    - Density and diversity of total bacterial community ?

# MATERIALS AND METHODS

## PILOT SCALE UNIT



### PILOT UNIT PARAMETERS

- ✓ 6 biofilters :  
2 conditions x 3 replicates
- ✓ Packing material :  
coconut fibers + perlite
- ✓ Plant : *Hedera helix*

### OPERATING PARAMETERS

- ✓ 50 days
- ✓ Mixed flow of TEX
- ✓  $200\mu\text{g}\cdot\text{m}^{-3}$  / compound
- ✓ Gas velocity :  $200\text{m}\cdot\text{h}^{-1}$
- ✓ EBRT : 7s (40cm)  
3.5s (20cm)

# MATERIALS AND METHODS

## ANALYSIS METHOD

### CHEMICAL ANALYSIS

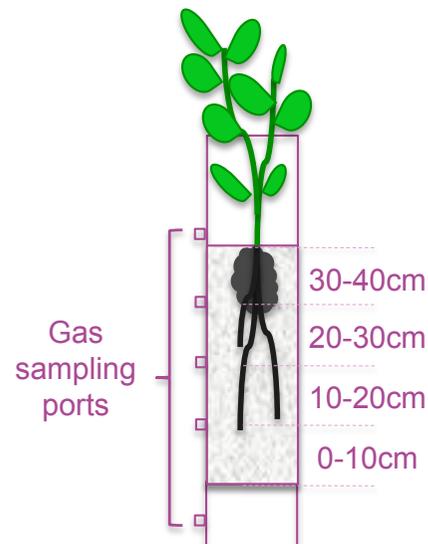
- Analysis of TEX concentration by GC – FID

- Removal efficiency : RE

$$RE = \left[ 1 - \frac{C_o}{C_i} \right] \times 100$$

$C_o$  : TEX concentration outlet

$C_i$  : TEX concentration inlet



### MICROBIOLOGICAL ANALYSIS

- Sampling strategy stratum

- $T_0$  : before operation

- After operation (50 days)

- Molecular approach of the total bacterial community

Target : 16S rDNA

- Density of bacteria

qPCR

(Zouache *et al.*, 2011)

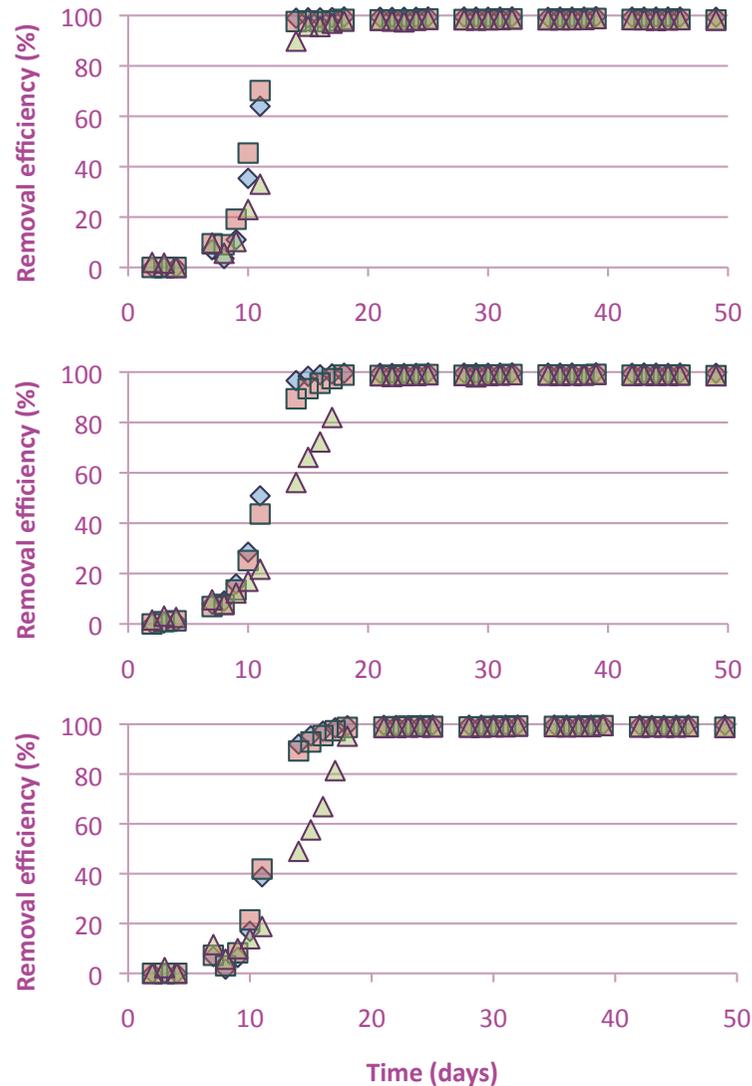
- Diversity analysis

Pyrosequencing

(iBio, Ecologie Microbienne)

# RESULTS

## BIOFILTERS 40CM : TEX REMOVAL EFFICIENCY



➔ Similar trend for 3 pollutants

➔ Same evolution for 3 biofilters

➔ 2 periods :

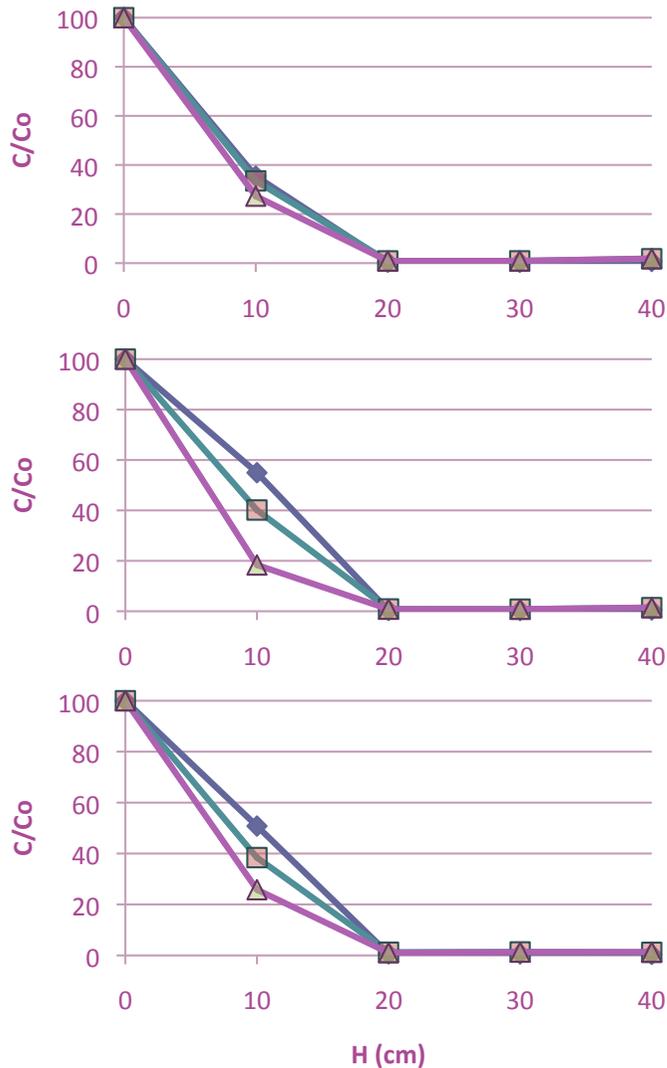
- ✓ 1 : acclimatization (20 days)
- ✓ 2 : stationary (30 days)

➔ **Total removal efficiency of TEX in 40cm at 200m.h<sup>-1</sup>**

↳ **EBRT of 7 s compatible with biological degradation of low concentrations of TEX**

# RESULTS

## BIOFILTERS 40CM : LONGITUDINAL PROFILES OF DEGRADATION



➔ Similar trend for 3 pollutants

➔ Same profil for 3 biofilters

➔ Total removal of TEX at 20cm

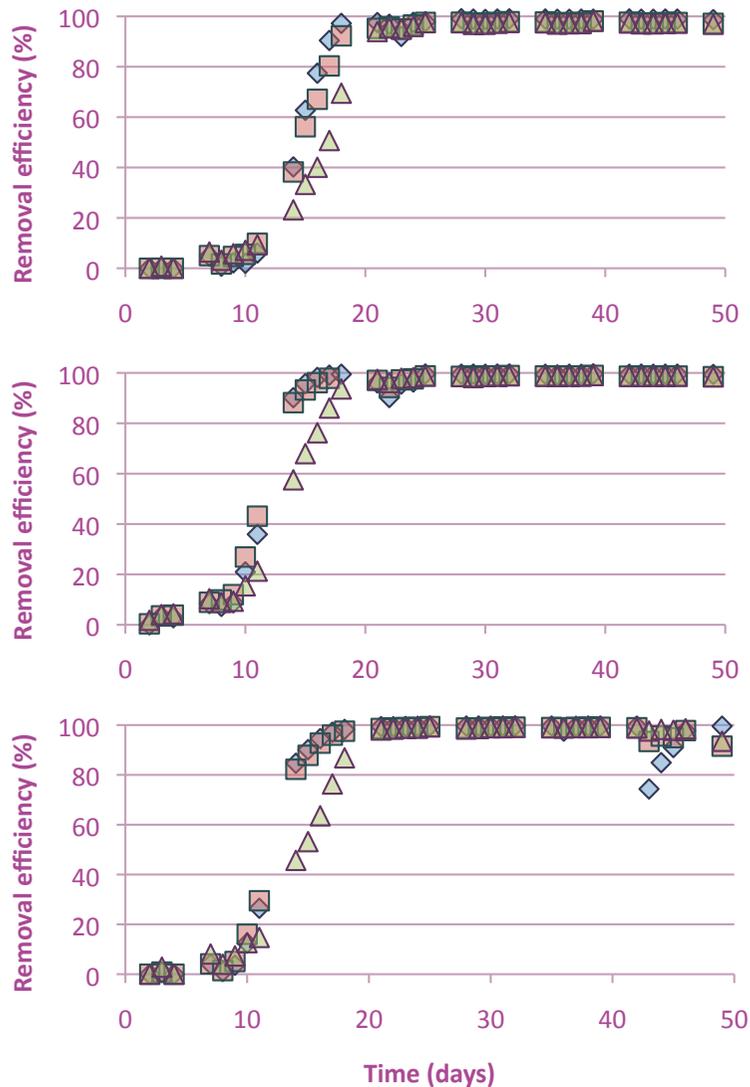
✓ biodegradation activity in  
0 – 20cm stratum



**Possibility to reduce the packing material height to 20cm ?**

# RESULTS

## BIOFILTERS 20CM : TEX REMOVAL EFFICIENCY



➔ Similar trend for 3 pollutants

➔ Same evolution for 3 biofilters

➔ 2 periods :

✓ 1 : acclimatization (around 25 days)

✓ 2 : stationary (minimum 21 days)

➔ Total removal efficiency of TEX

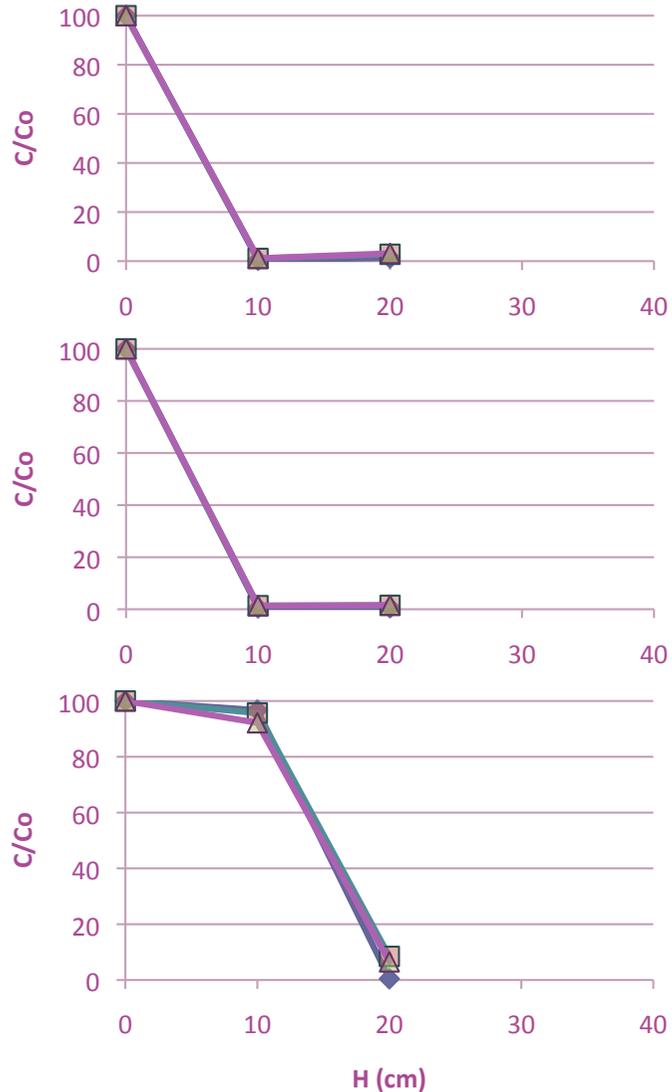
In 20cm at 200m.h<sup>-1</sup>



**EBRT of 3.5 s compatible with biological degradation of low concentrations of TEX**

# RESULTS

## BIOFILTERS 20CM : LONGITUDINAL PROFILES OF DEGRADATION



➔ Similar trend for 3 pollutants

➔ 2 profil types :

✓ 2 profils :

Total removal of TEX at 10cm

✓ 1 profil :

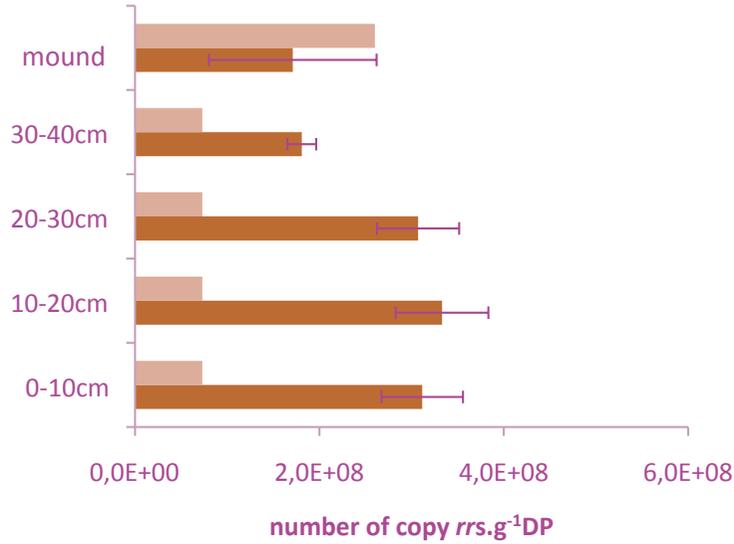
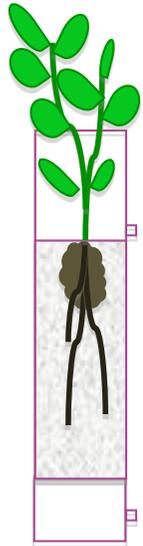
Total removal of TEX at 20cm

➔ **20cm packing material height :**  
**Lower limit to ensure**  
**total removal of TEX**

What happens about microorganisms ?

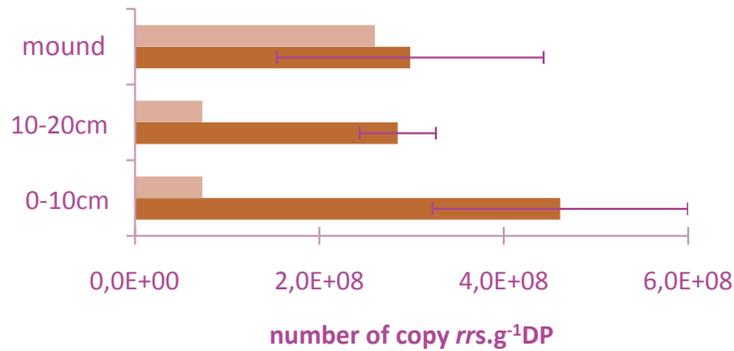
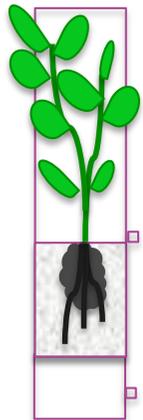
# RESULTS

## DENSITY OF TOTAL BACTERIA



→ T<sub>0</sub> : before operation

- ✓ mound = 2.7.10<sup>8</sup> bacteria.g<sup>-1</sup> DP
- ✓ packing = 0.8.10<sup>8</sup> bacteria.g<sup>-1</sup> DP



→ After operation :

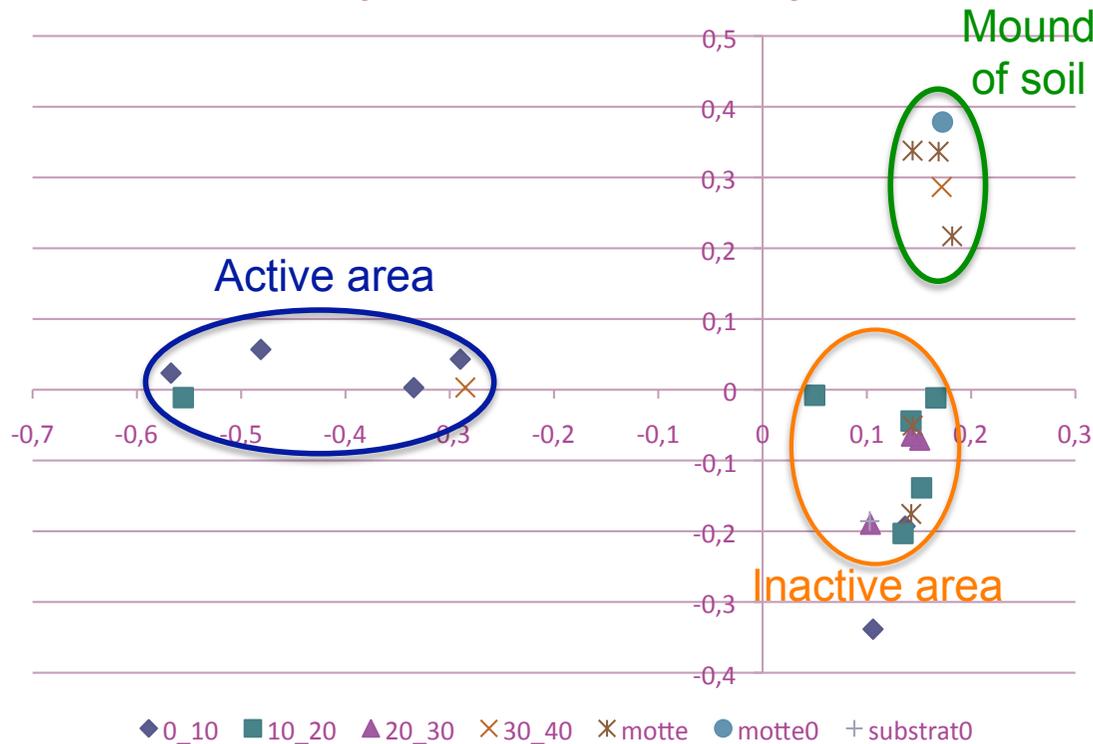
- ✓ mound : no change
- ✓ packing near the mound = mound
- ✓ packing near gas : x 4 for 40cm biofilters  
x 6 for 20cm biofilters

↙ Increase bacterial density  
in the active areas

# RESULTS

## DIVERSITY OF TOTAL BACTERIA : STATISTICAL ANALYSIS

### Principal Coordinates Analysis



➔ T<sub>0</sub> : before operation

✓ Structural diversity :  
mound ≠ packing material

➔ After operation :

✓ Significant variability in biofilters  
 ✓ 3 groups :  
     ➤ mound of soil  
     ➤ active area  
     ➤ inactive area

➤ **Modification of structural diversity of the total bacterial community**

## RESULTS SUMMARY

- Planted biofilter can treat a low concentration of TEX with very short EBRT
  - Total removal efficiency with EBRT of 7 or 3.5s
  - Superficial gas velocity of 200m.h<sup>-1</sup>
  - Reducing packing material height to 20cm
  
- Very short EBRT is compatible with biological degradation compounds :
  - Indigenous bacteria (from the mound or packing material) able to acclimate to the operating conditions
  - Operating conditions increase the density of total bacterial community and modified there diversity

## CONCLUSION AND PERSPECTIVES

- Planted biofilter capacity
  - Real conditions and pollution from underground car parcs (including NO<sub>x</sub>)
  - Warning : 40cm height may provides greater inertia against changes in temperature and an security area may be required for more complex mixture treatment
  
- Plants
  - impact of plant species (roles on microbial diversity)
  - plant impact in the long term
  
- Characterization of active microorganisms
  - quantitative study
  - qualitative study
  - fungi roles ?

} functional genes of TEX and NO<sub>x</sub> biodegradation

Thanks for your attention



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