



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

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Atmos'Fair 2012



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Lyon 1



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

VOCs

NO_x

CO₂

Particulate

CONSEQUENCES

Environmental effects

↳ O₃

↳ 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

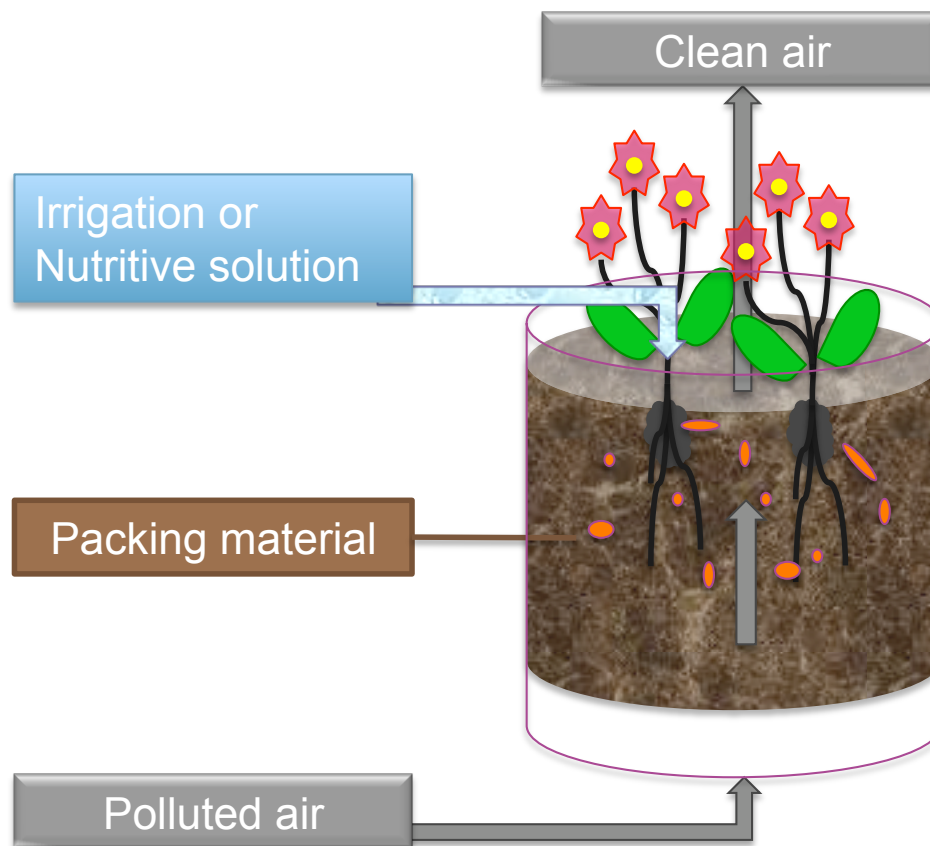
- Large flow rate
- Complex mixture of pollutants
- Low concentrations
 - CO
 - NO_x (100 – 300 $\mu\text{g.m}^{-3}$)
 - BTEX (400 – 600 $\mu\text{g.m}^{-3}$)

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
- CO₂ 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 : 100m.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)

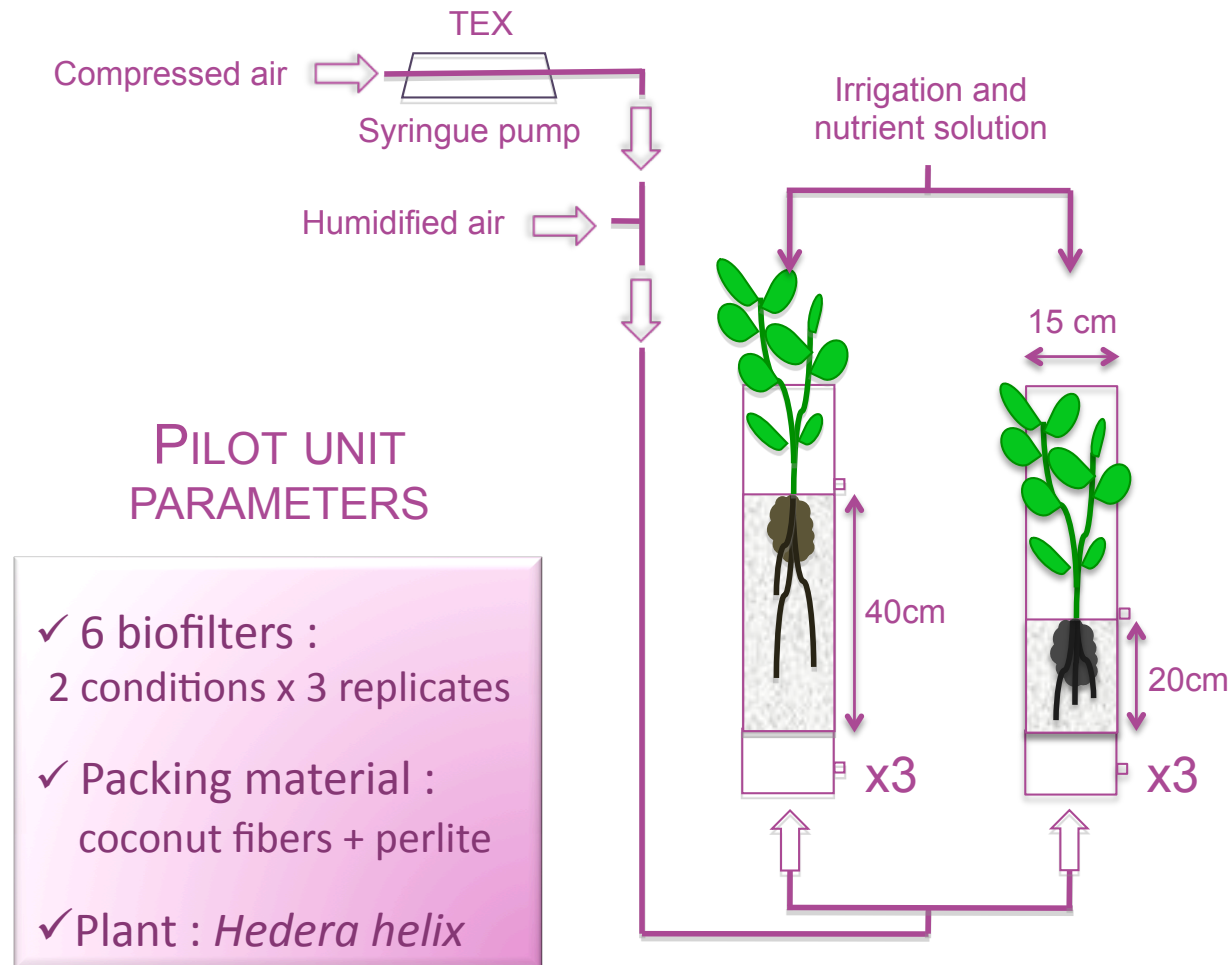
OBJECTIVES

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



OPERATING PARAMETERS

- ✓ 50 days
- ✓ Mixed flow of TEX
- ✓ $200\mu\text{g.m}^{-3}$ / compound

- ✓ Gas velocity : 200m.h^{-1}

- ✓ EBRT : 7s (40cm)
3.5s (20cm)

MATERIALS AND METHODS

ANALYSIS METHOD

CHEMICAL ANALYSIS

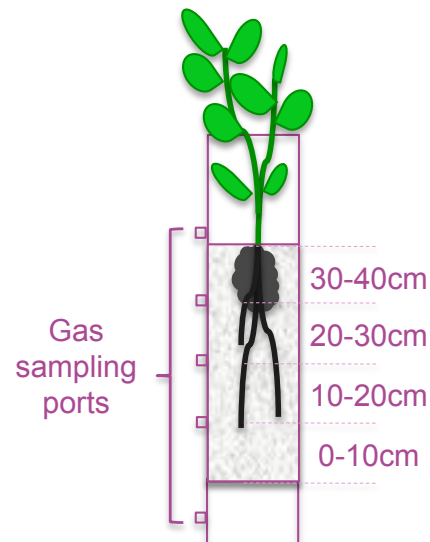
- Analysis of TEX concentration by GC – FID

- 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

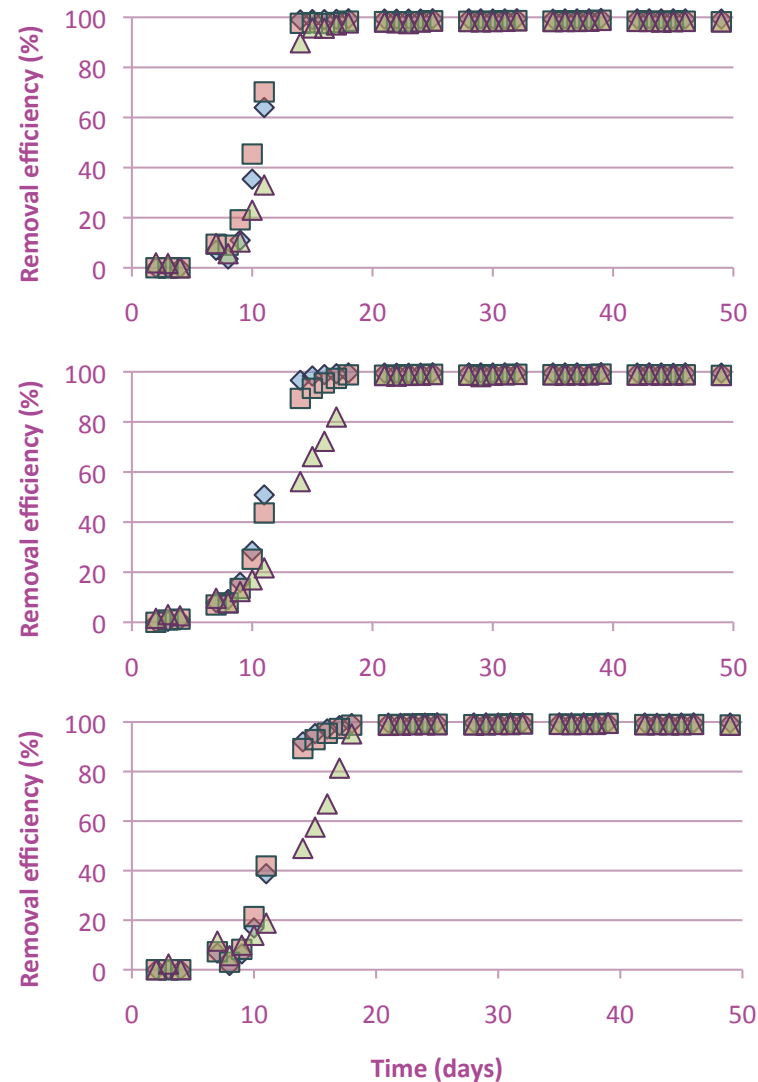
(Zouache *et al.*, 2011)

- 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)

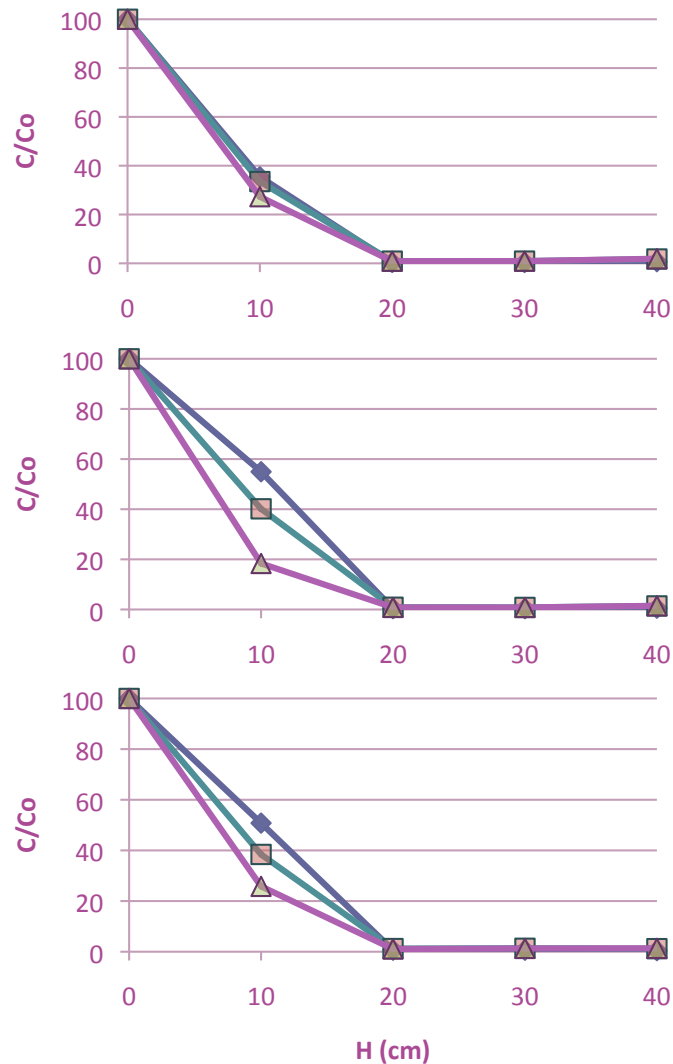
➡ Total removal efficiency of TEX
in 40cm at 200m.h⁻¹



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

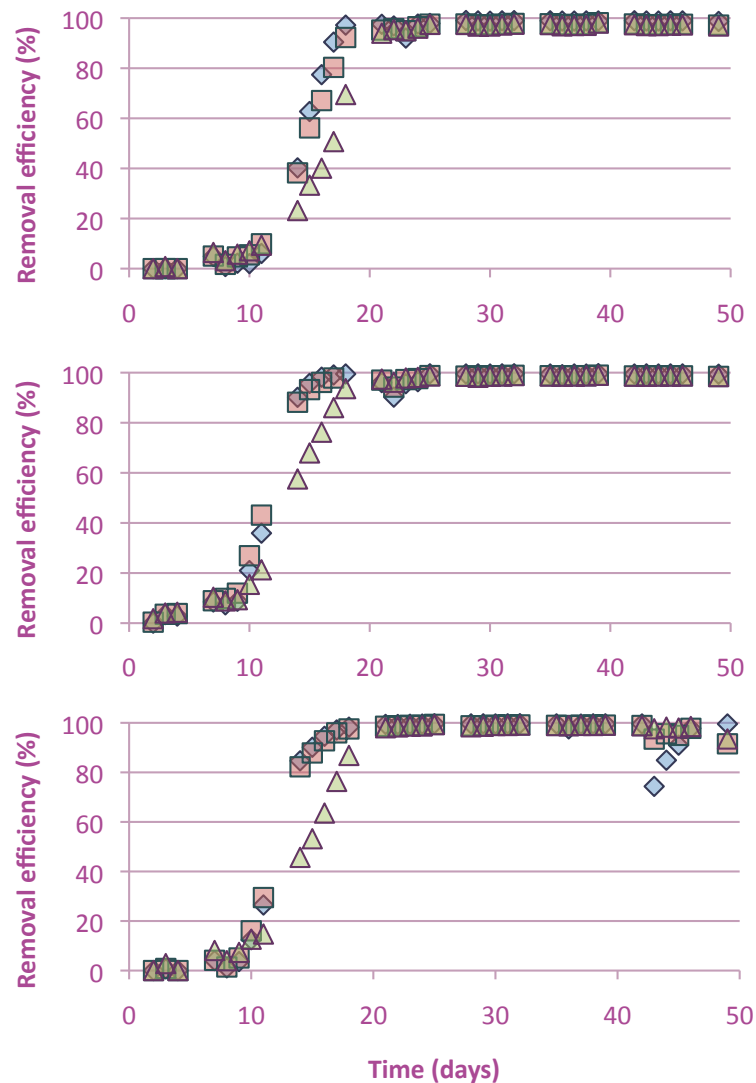
✓ biodegradation activity in
0 – 20cm stratum



**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

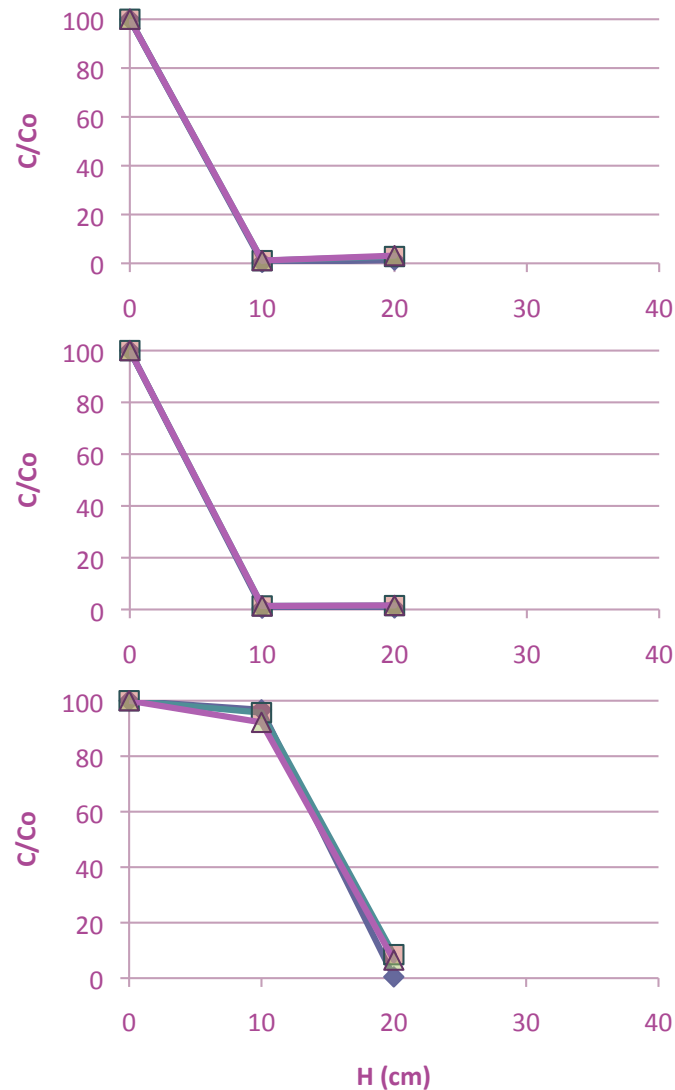
In 20cm at 200m.h⁻¹



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 :

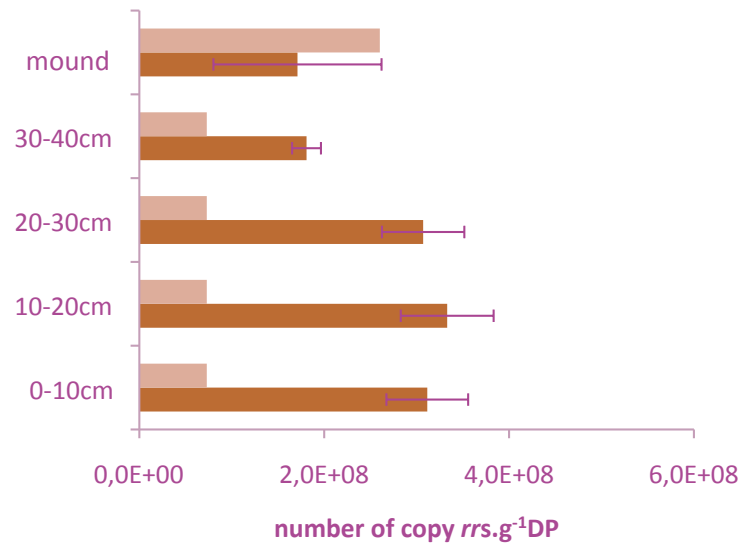
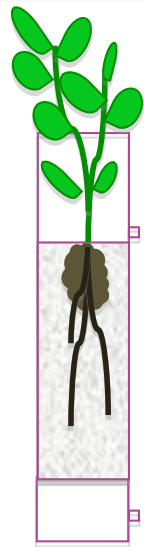
Total removal of TEX at 20cm

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

What happens about microorganisms ?

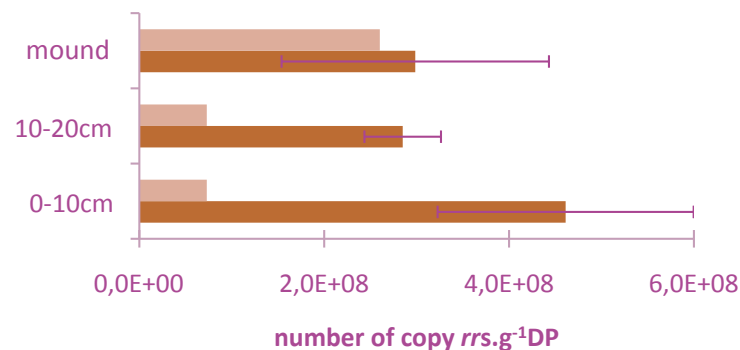
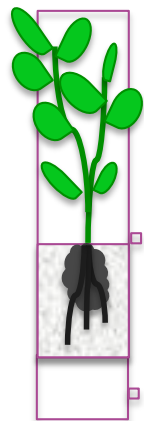
RESULTS

DENSITY OF TOTAL BACTERIA



→ T₀ : before operation

- ✓ mound = 2.7.10⁸ bacteria.g⁻¹ DP
- ✓ packing = 0.8.10⁸ bacteria.g⁻¹ DP



→ After operation :

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

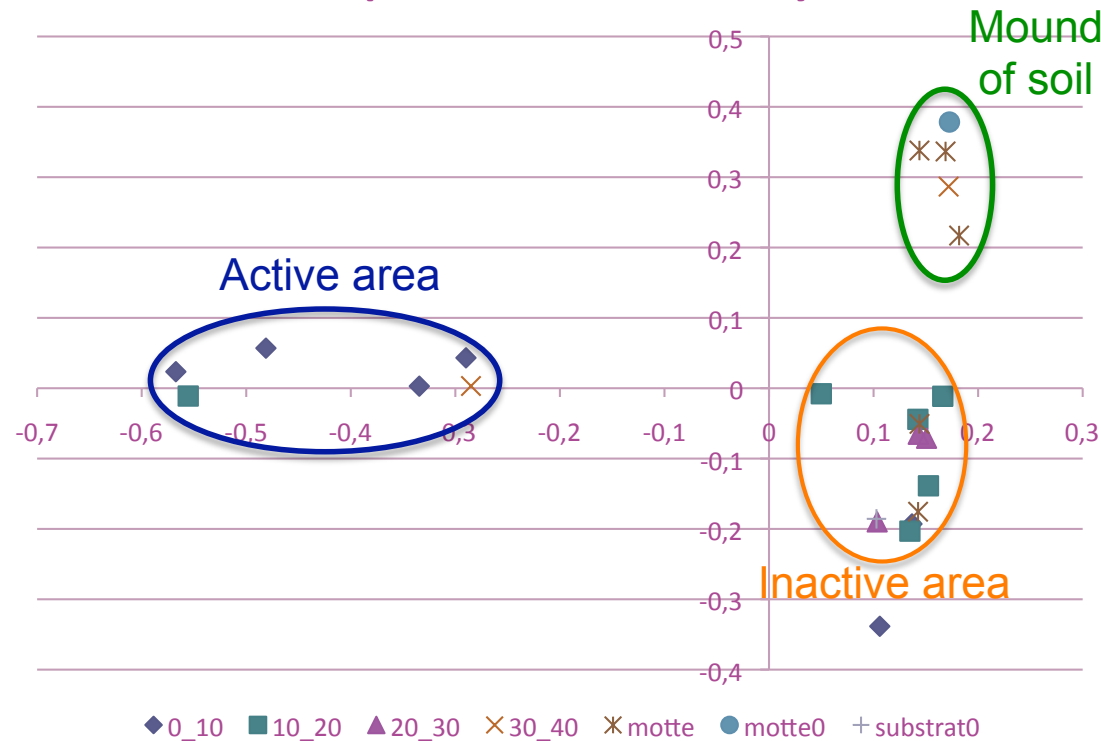


**Increase bacterial density
in the active areas**

RESULTS

DIVERSITY OF TOTAL BACTERIA : STATISTICAL ANALYSIS

Principal Coordinates Analysis



→ T_0 : before operation

✓ Structural diversity :
mound \neq 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^{-1}
 - 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_x)
 - 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_x biodegradation

Thanks for your attention



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