Cerema
Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement
Direction territoriale
Ile-de-France

# BIOTAIR

## Biofiltration for AIR Treatment

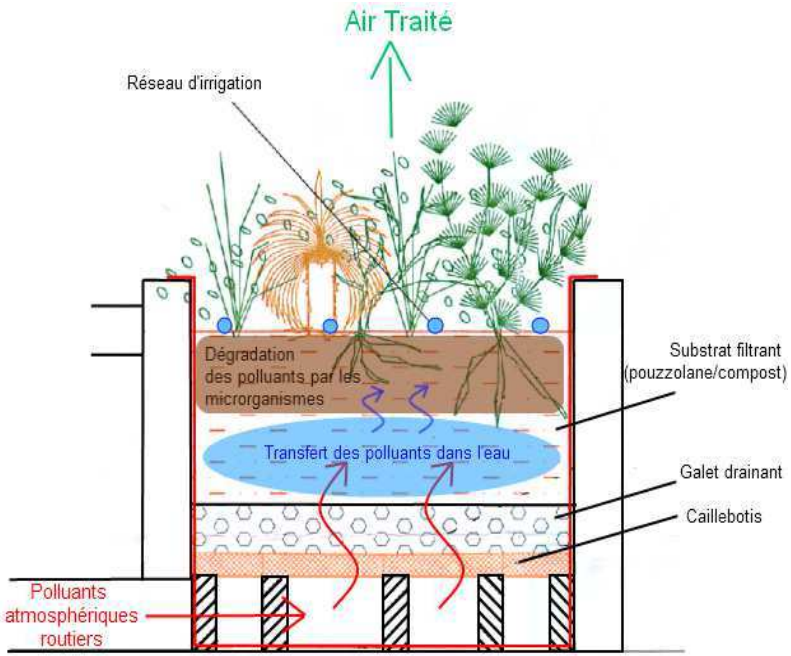
J-F PETIT

# Context

Experimentation of biofiltration for the treatment of stale air in a road tunnel

Presentation of results after 18 months of operation including 4 measurement campaigns

A multi-parameter approach (Air, water, soils, microbiology, LCA)




ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

Project supported by ADEME 210 k Euros
APR CORTEA

Total budget 450 k euros

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# Partnership

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Coordination and leadership
Environmental parameter measurement and LCA skills

CETU

Tunnel skills (ventilation) and specific regulations (air quality)

phytorestore
UN JARDIN FILTRANT EST UN ESPACE PAYSAGER QUI DEPOLLUE L'EAU, L'AIR ET LES SOLS

Biofiltration skills (engineering, installation, operation)

Ecologie microbienne Lyon

Microbiology skills (analysis and expertise)

AXIMA SEITHA
GDF SUEZ

Ventilation skills (engineering and installation)

# Objectives

**Evaluate the feasibility and potential of biofiltration to treat stale air in road tunnels**

- Design, construction and then operation of a pilot plant capable of treating up to 3 $m^3/s$
- Design of civil engineering, ventilation and the filtering installation aspects (plants and substrate)
- Quantification of inputs and maintenance constraints, etc.
- Study of the environmental impact by LCA
- Estimate of the performances of such biofilters with the development of an appropriate metrology

> reduction of pollutants

> durability

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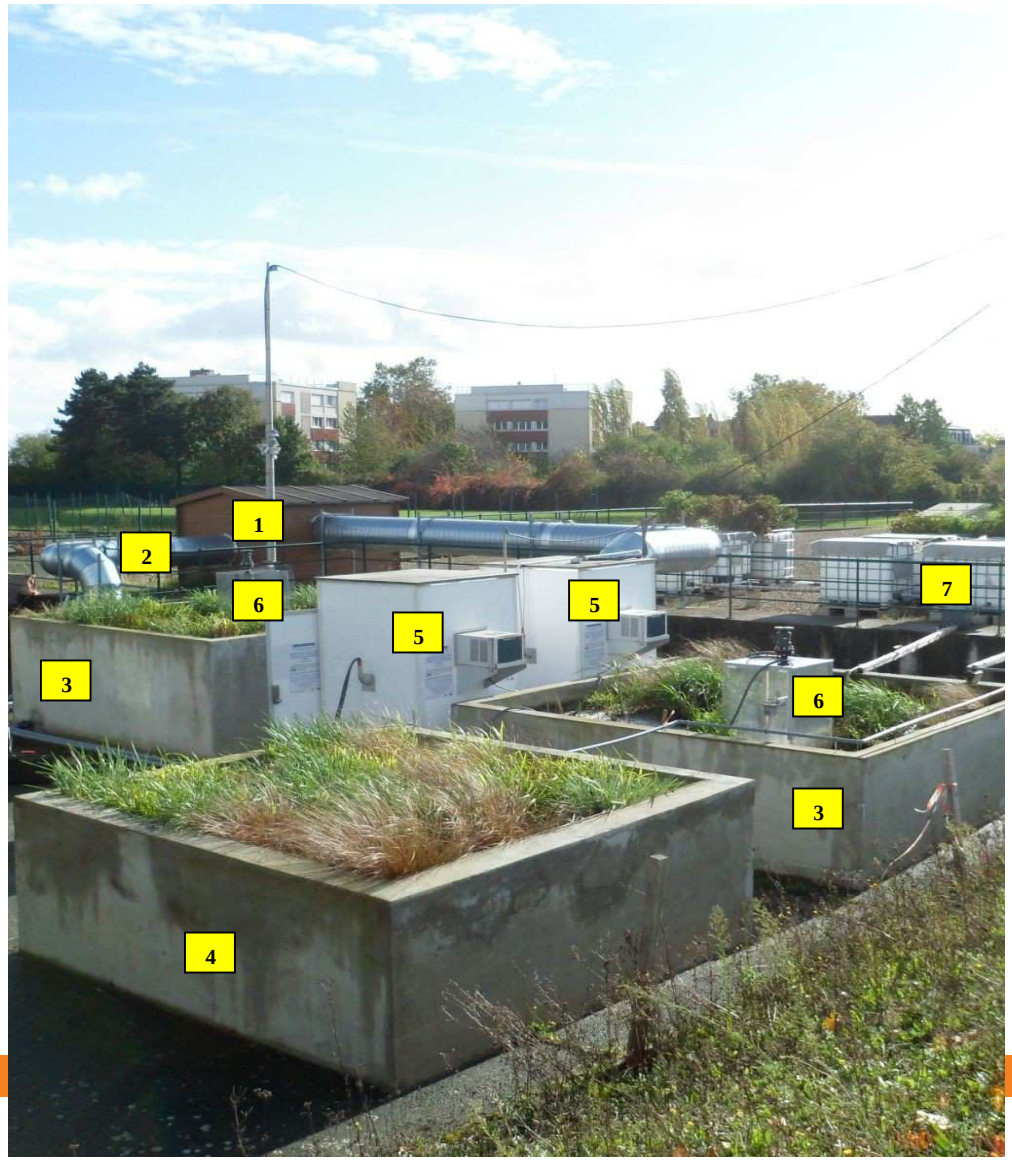
# The site: platform above the Guy Môquet Tunnel, A86, Thiais




1: Fan shelter

2: Extraction duct

3 : Two 50 and 100 cm thick biofilters $BF_{50}$ and $BF_{100}$ respectively

4 : control biofilter

5 : Shelters containing measurement instruments

6 : Air sampling « chambers »

7 : Water supply for biofilters

Commissioning in October 2012

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# Methodology

-Traffic conditions monitoring

- Weather monitoring

- Air and water flow measurements

- Air quality monitoring

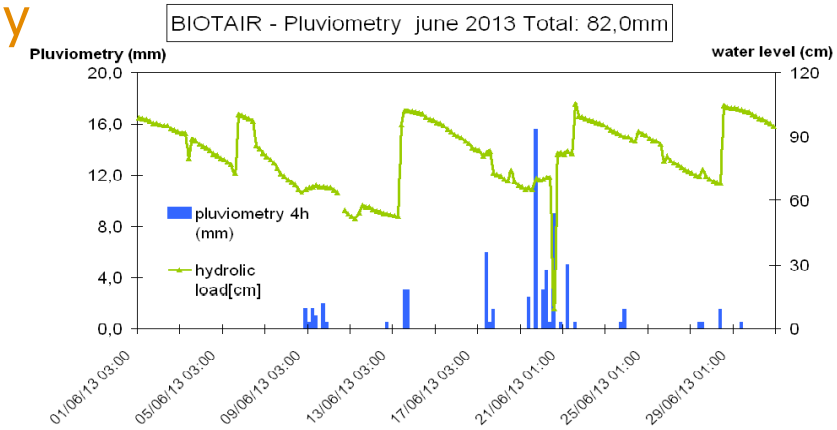
- Condition and growth of the flora monitoring

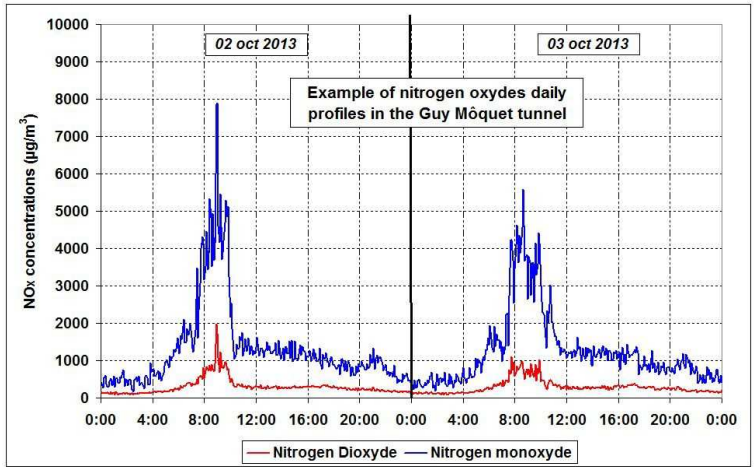
-Water quality monitoring (pH, Suspended Matters and all nitrogen parameters)

- Soils quality monitoring (total hydrocarbons, metals, PAH)

-Development of micro-organisms monitoring in biofilters by DNA sequencing and statistical approach

- Measure or estimate inputs (construction elements, electricity, water, etc.) for the LCA




# Methodology – AIR compartment

Purification performance : comparison of pollutant concentrations between the inlet and outlet sides of the biofilters

4 measurement campaigns over 18 months
November - December 2012
May - July 2013
October 2013
March - April 2014

Monitored atmospheric parameters:

nitrogen oxides : continuous measurement with chimiluminescent analysers,

Particles : PM 10, 2.5 and 1 (TEOM + impactors)

$NH_3$ and BTEX by tubes, PAH on particles

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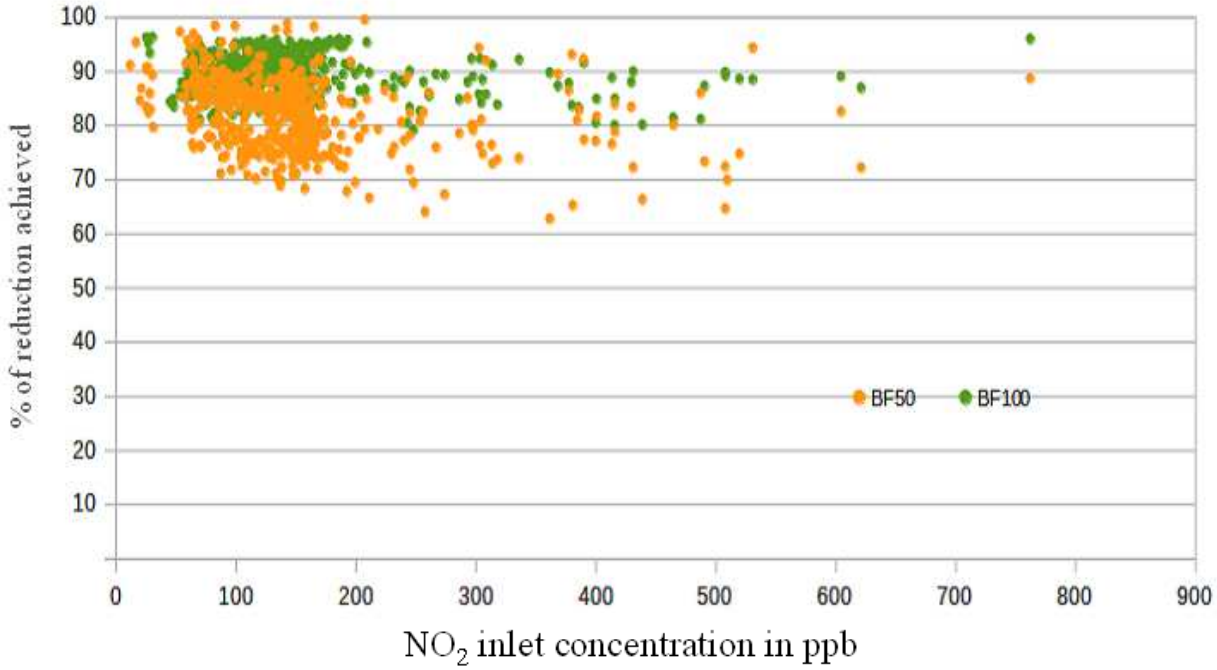
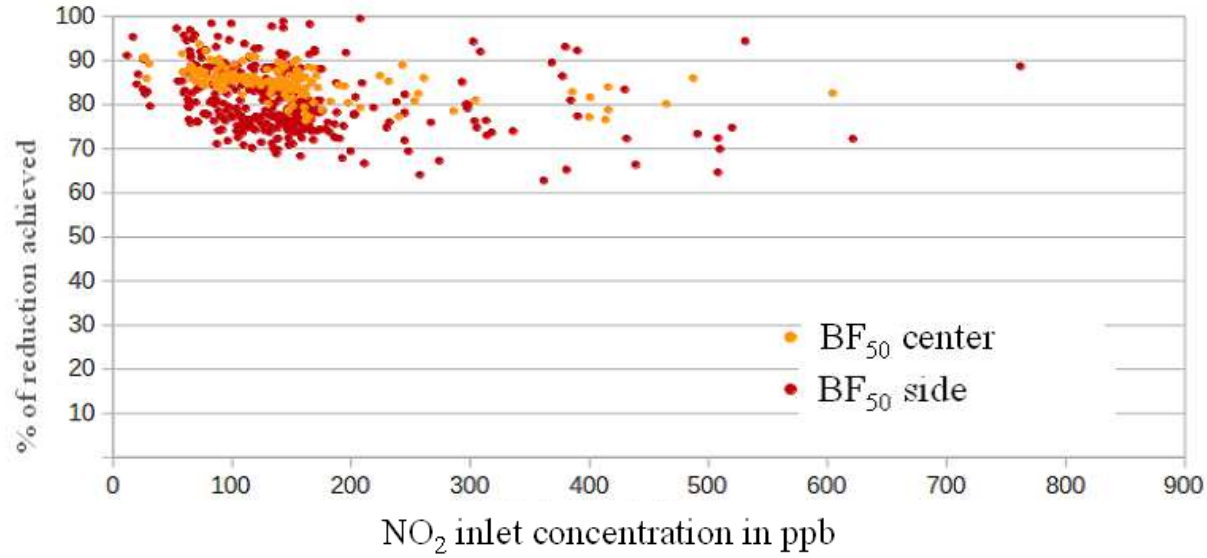
# Methodology : interpretation of results, Nox




Performances independent of inlet concentrations




Performances independent of the position of sampling points

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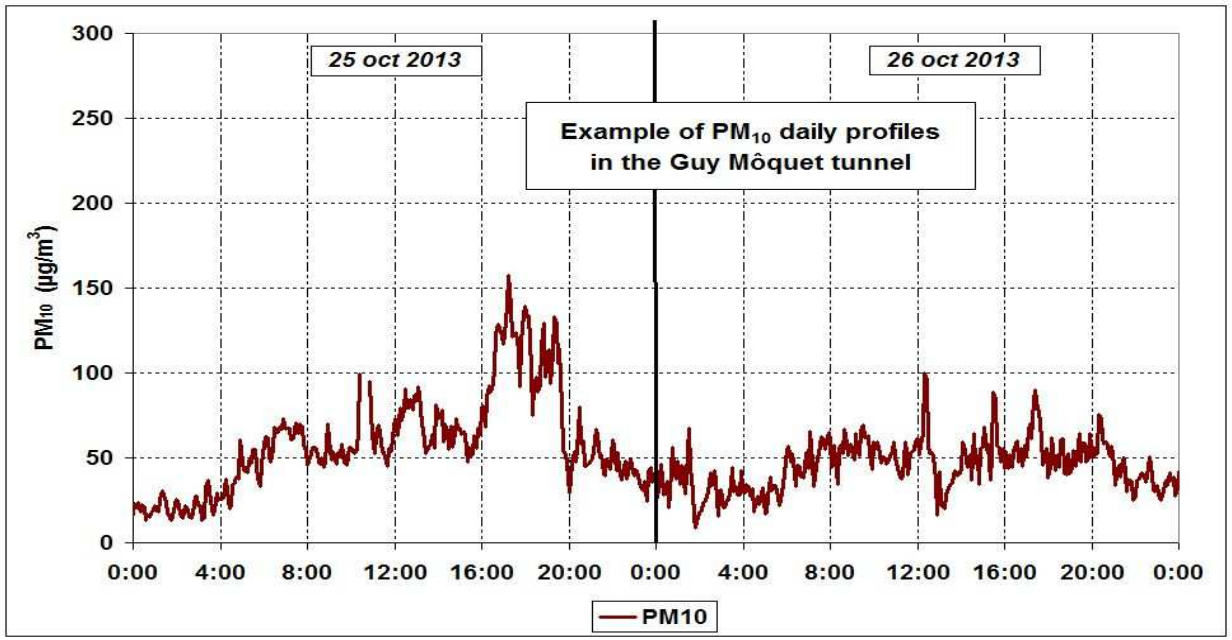
# Methodology: interpretation of results, PMs




Good correlation between continuous measurement and the impactors

Calculation of performances on measurements by impaction

| Time of sampling | TEOM (en µg/m3) | Impactor (en µg/m3) | Deviation measurement |
|---|---|---|---|
| 8 au 12 nov | 64,65 | 58,67 | 9,3 % |
| 12 au 15 nov | 65,83 | 66,35 | -0,8 % |
| 15 au 19nov | 70,55 | 65,48 | 7,2 % |
| 22 au 26 nov | 57,30 | 55,71 | 2,8 % |
| 26 au 29 nov | 60,50 | 60,22 | 0,5 % |

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# Results: formulation of the biofilter, qualitative monitoring

9 different plant species installed for each biofilter

Qualitative monitoring with a first report in june 2013

+ replanting

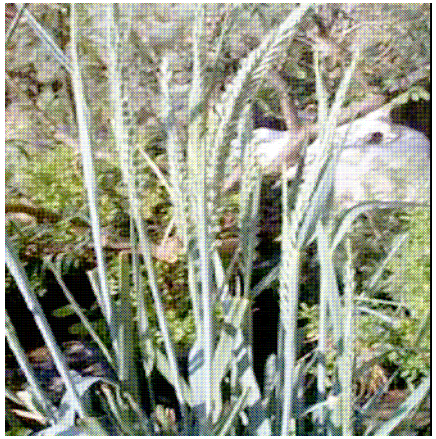
Final report after the experimentation in june 2014

# Results: formulation of the biofilter, qualitative monitoring

4 preferred species (carex comans - carex pendula - leymus arenarius - miscanthus) survival rate from 53 to 76% in $BF_{100}$

These species provide a good compromise between growth, spreading, resistance to the weather and pollutants






An improved composition on which experiments are being conducted to improve microbial activity + structure

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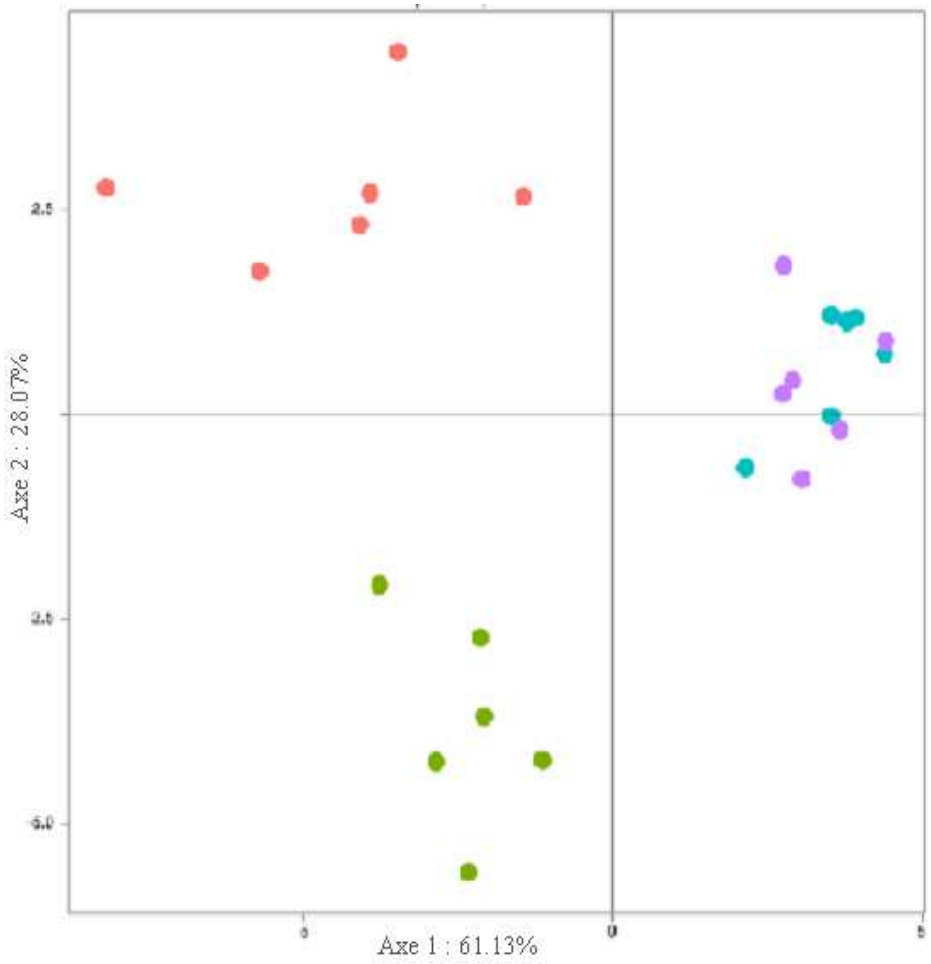
# Results: the microbiology

An approach by Principal Component Analysis (PCA) “differentiate biofilters”




Control (20 cm)

BF 50 (20cm)

BF 100 depth 1 (20 cm)

BF 100 depth 2 (50 cm)

Populations specific to depollution

Clearly different microbial communities between each biofilter (by spring 2013)

E.g. in BF 100: Chara corallina (eukaryote micro-algae) known to degrade BTEXs

E.g. in BF 50: Arthrobacter sp. (Species known to degrade polycyclic aromatic hydrocarbons)

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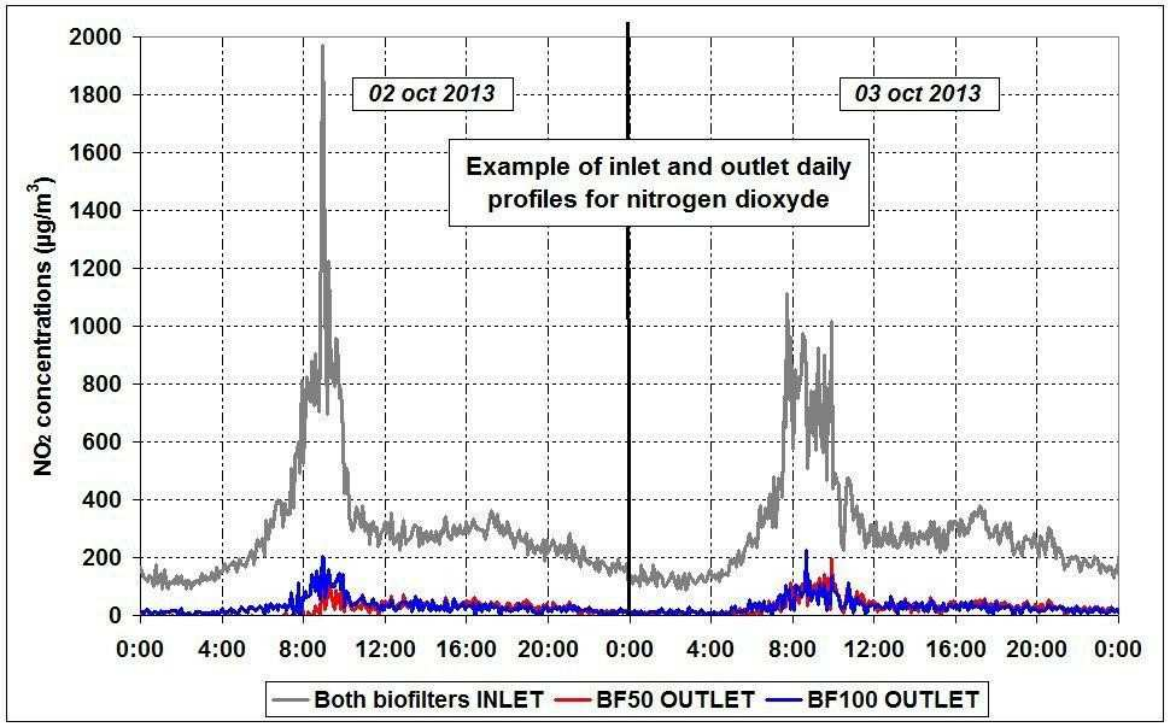
# Results: Nitrogen oxide removal efficiencies General averages




A negligible effect on NO

A major effect on $NO_2$, result of dissolution of $NO_2$

High efficiencies throughout the experiment

Technology adapted to $NO_2$

| | NO | $NO_2$ |
|---|---|---|
| $BF_{50}$ reduction in center | -3.1% | 58.3% |
| $BF_{100}$ reduction in center | 3.7% | 86.2% |

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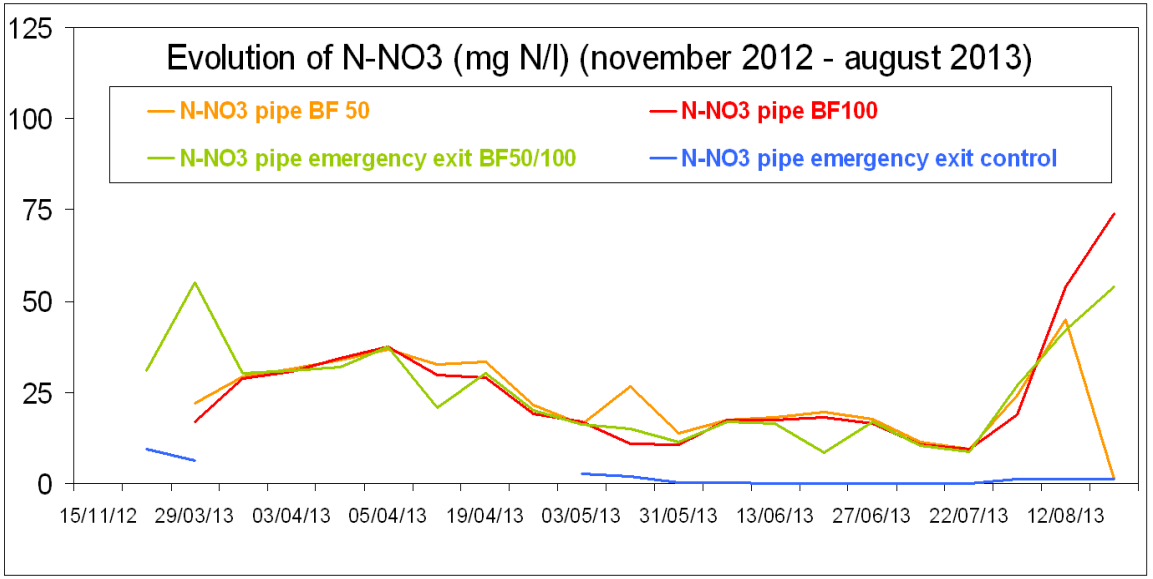
# Results: Nitrogen oxide removal efficiencies, aqueous phase nitrification?



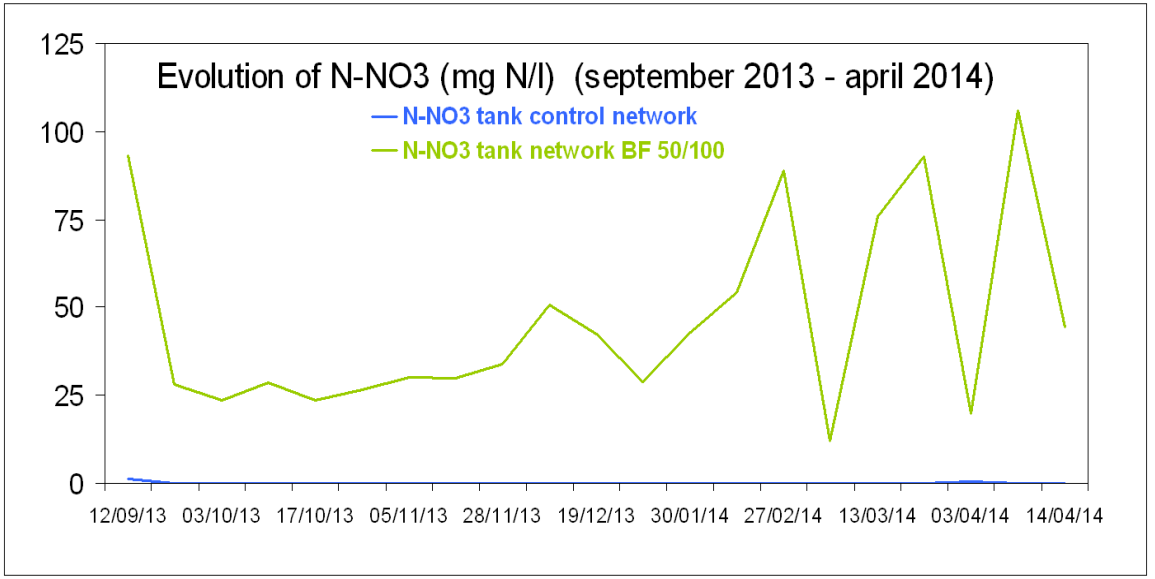

A clear difference between the two networks

There is no nitrification on the control biofilter

Acceptable values at all points in the water network regarding:

- the concentration

- volumes considered (150 $m^3$ over 18 months)

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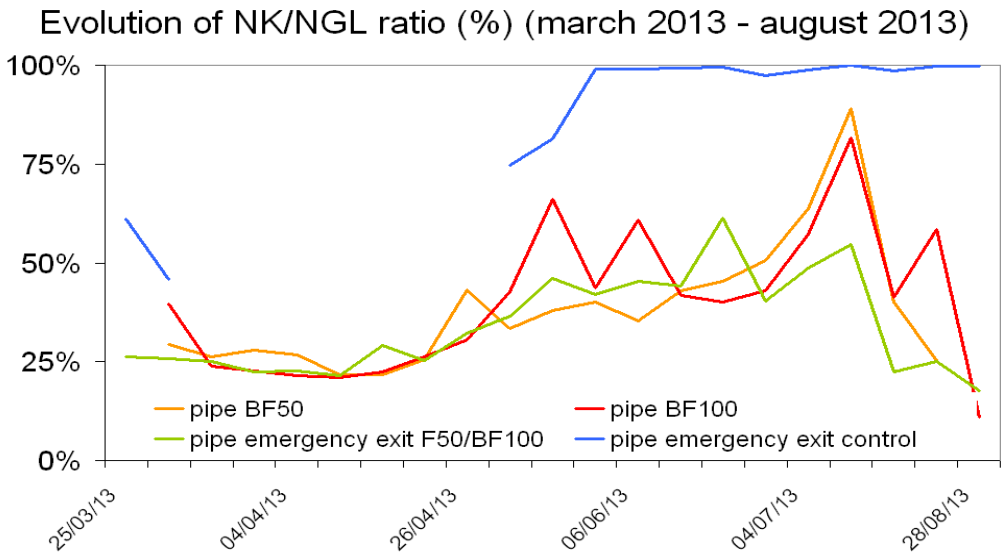
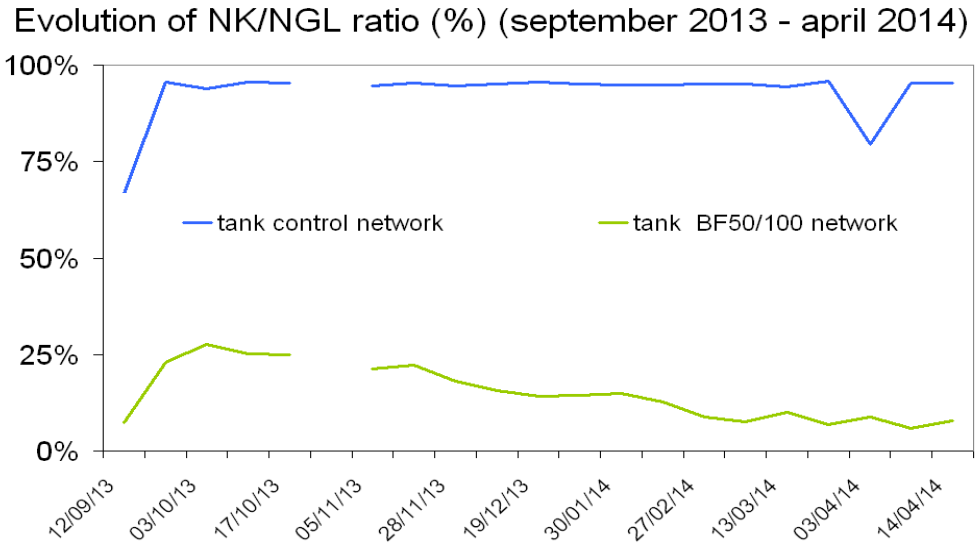
# Results : nitrogen in aqueous phase monitoring




The NK/NGL ratio indicates a singular behaviour of treatment biofilters / at control

The addition of oxygen in the treatment biofilters network prevents any type of fermentation

Water network plays a induced role of particle settlement tank

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# Removal efficiencies on particles – General averages

| Size of particles | [0-1µm[ | | [1-2,5µm[ | | [2,5-10µm[ | | PM10 | |
|---|---|---|---|---|---|---|---|---|
| | average | Standard deviation | average | Standard deviation | average | Standard deviation | average | Standard deviation |
| purifying rate $BF_{50}$ | 29 % | 39 % | 77 % | 12 % | 84 % | 12 % | 36 % | 33 % |
| Purifying rate $BF_{100}$ | 61 % | 27 % | 93 % | 7 % | 91 % | 21 % | 66 % | 23 % |

Very good efficiency on PM, **mechanical effect of the filter.**

# Particular episode: Particles pollution peak March 2014

| Time of sampling 10/03/2014-24/03/2014 | | Average | Standard-deviation |
|---|---|---|---|
| $PM_{10}$ | Inlet µg/m3 | 169 | 18 |
| | Purifying rate BF50 | 81% | 2 |
| | Purifying rate BF100 | 86% | 2 |

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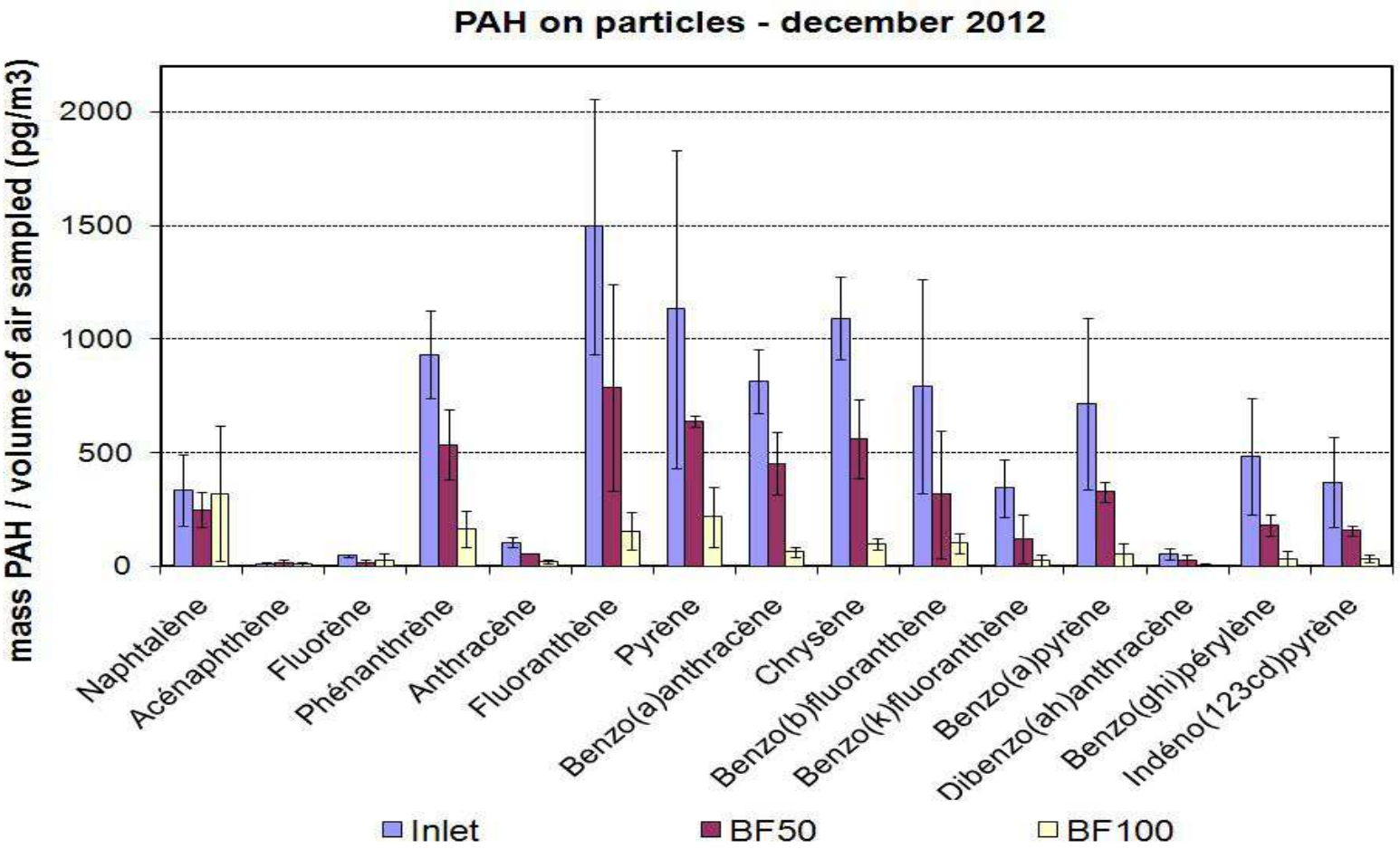
# Purifying efficiencies: PAH on particles




Good degradation of PAHs present on particles
(fluoranthene, pyrene, benzo(a) anthracene, chrysene, etc.)

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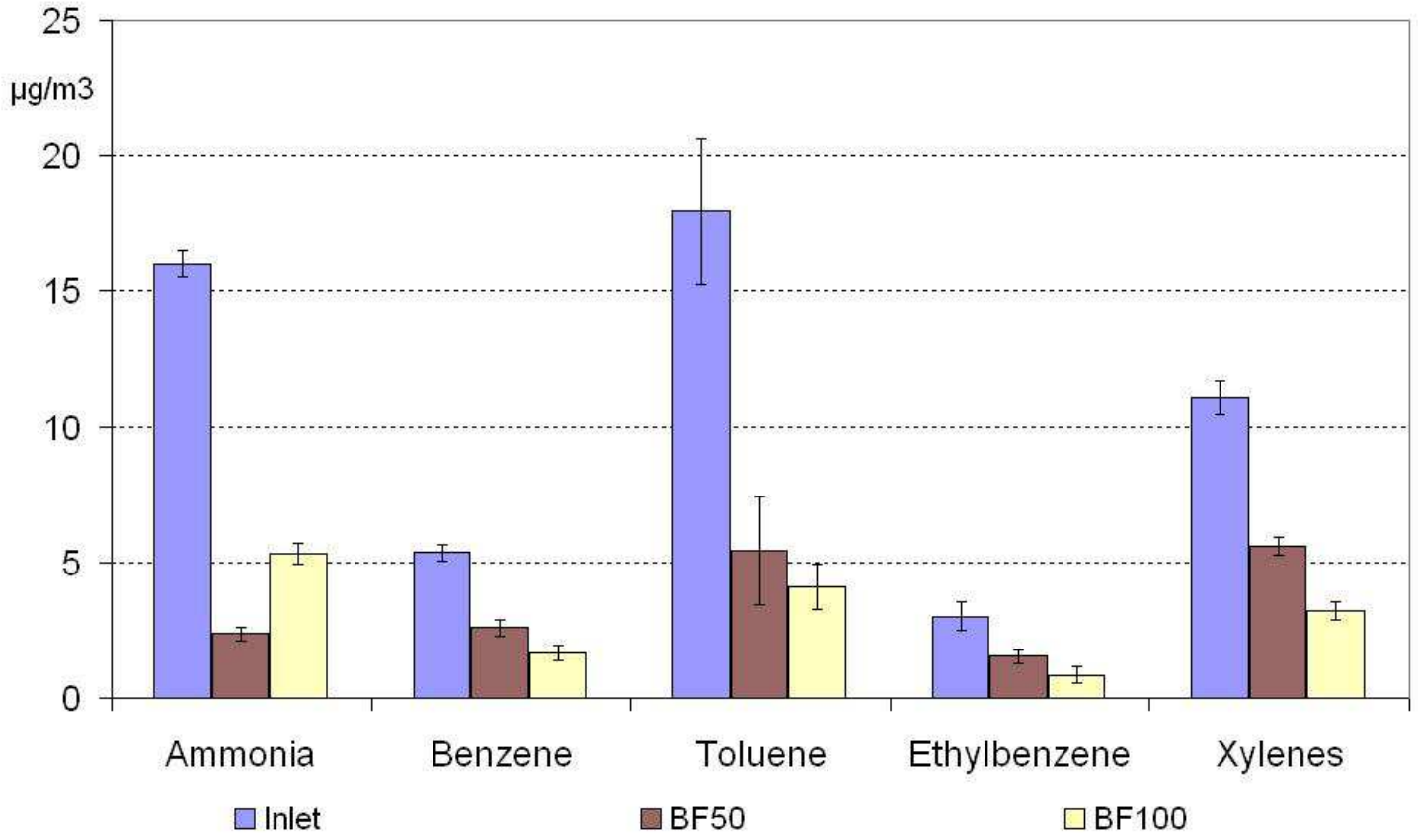
# Results: removal efficiencies on gas pollutants – General averages




High efficiencies, often more than 50%

variations depending on plant development

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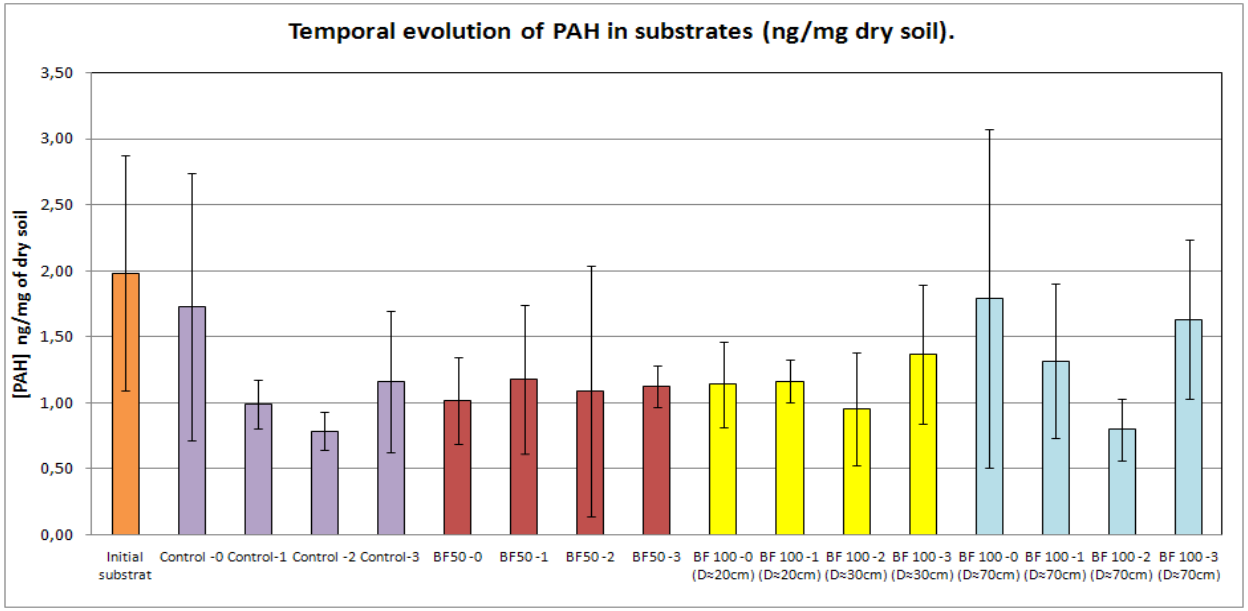
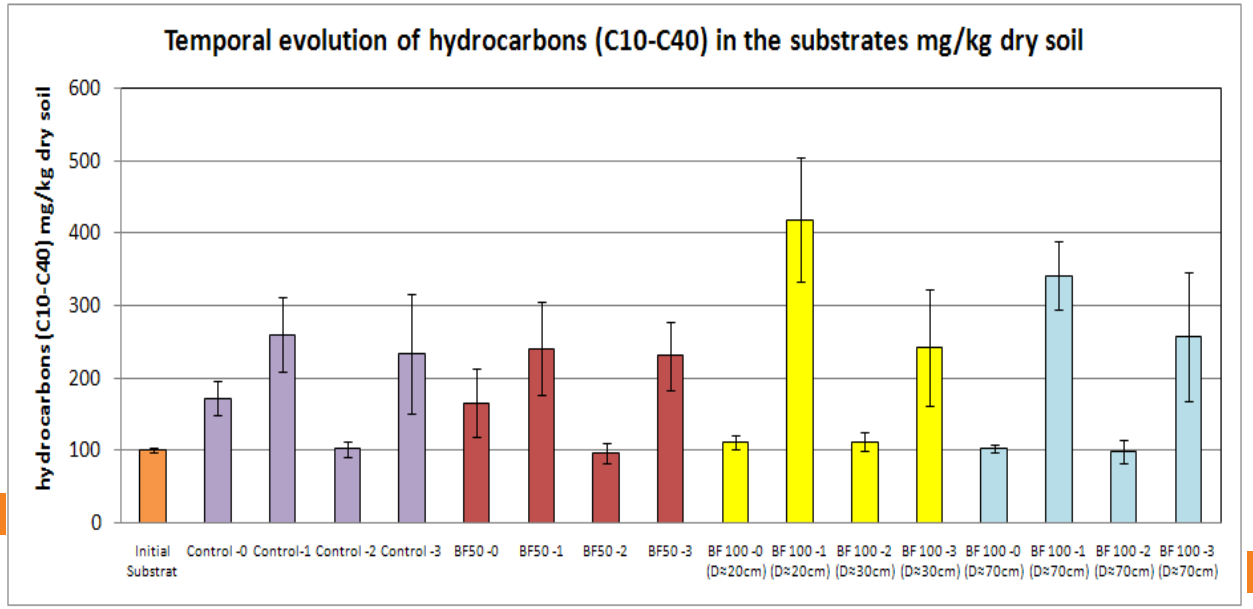
# Results: substrate quality monitoring




No perceptible enrichment in **PAH.**

Low values, of the same order of magnitude as the initial substrate

Seasonal variations in **hydrocarbons**, influence of the atmospheric deposit

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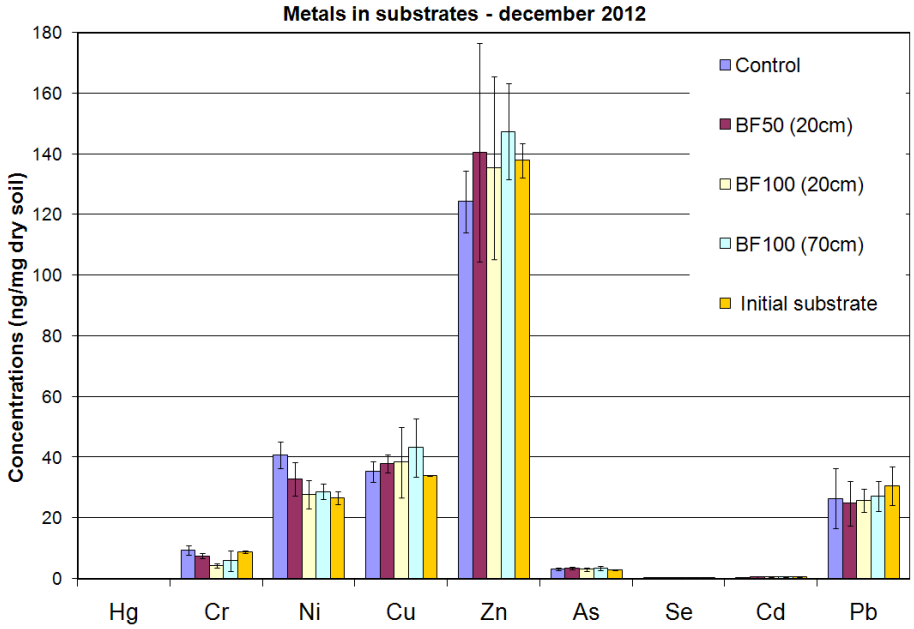
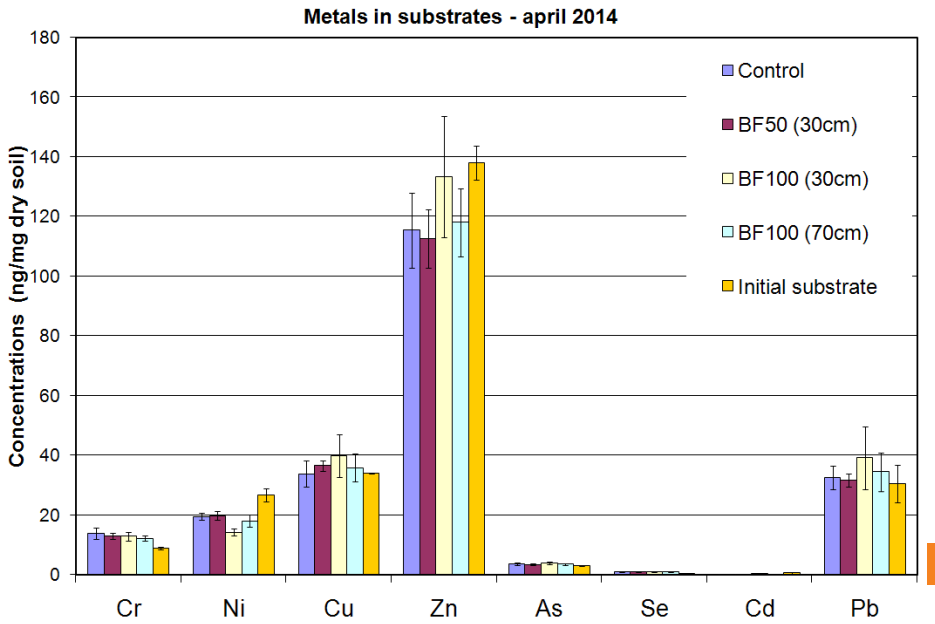
# Results: substrate quality monitoring




No increase in metals

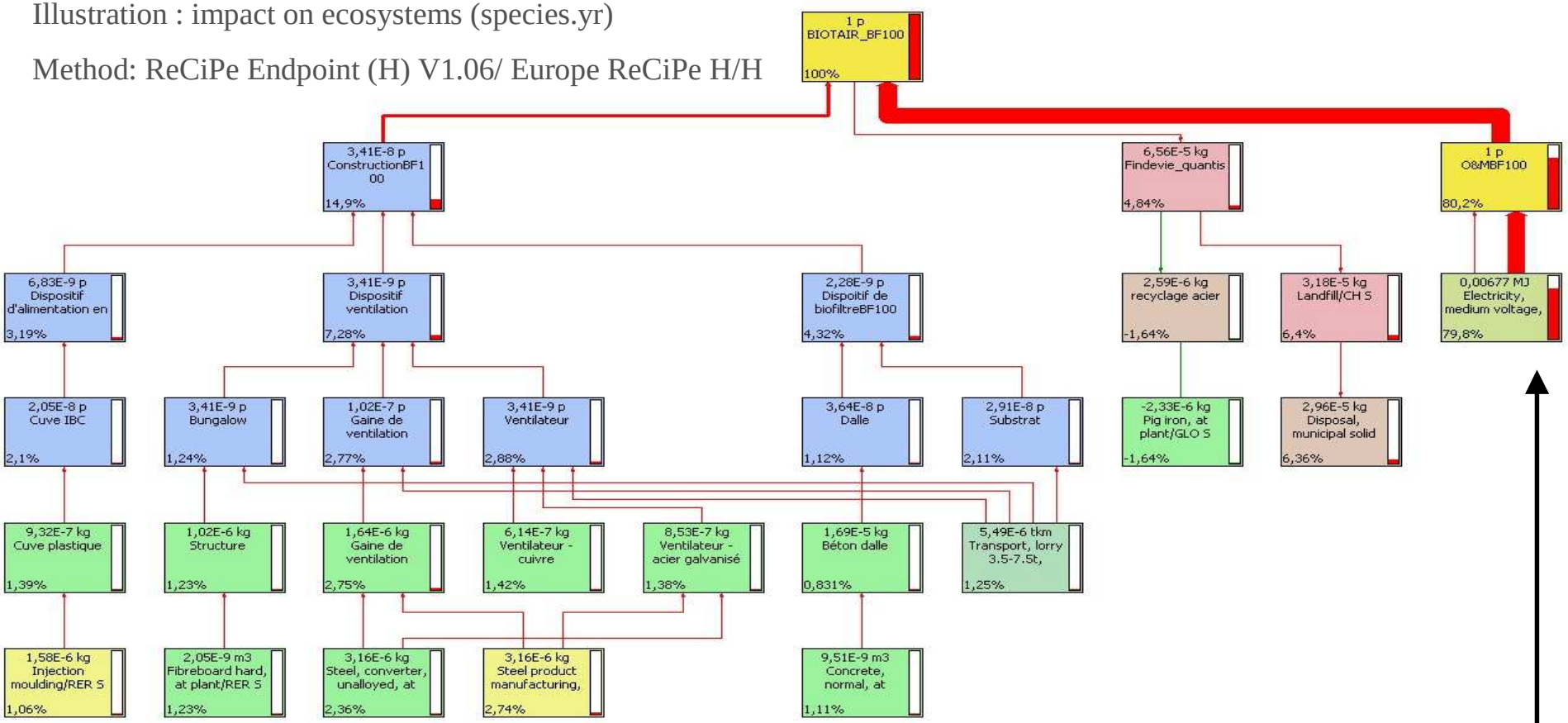
Substrate not altered – good durability predicted



# Global LCA for a biofilter, summary of the different imputs taken into account

Illustration : impact on ecosystems (species.yr)

Method: ReCiPe Endpoint (H) V1.06/ Europe ReCiPe H/H




Low impact of assembly phase (always less than < 15%) and end of life, on every damages gategories (human health, ressources, ecosystems) (minimised because no construction of an extraction shaft)

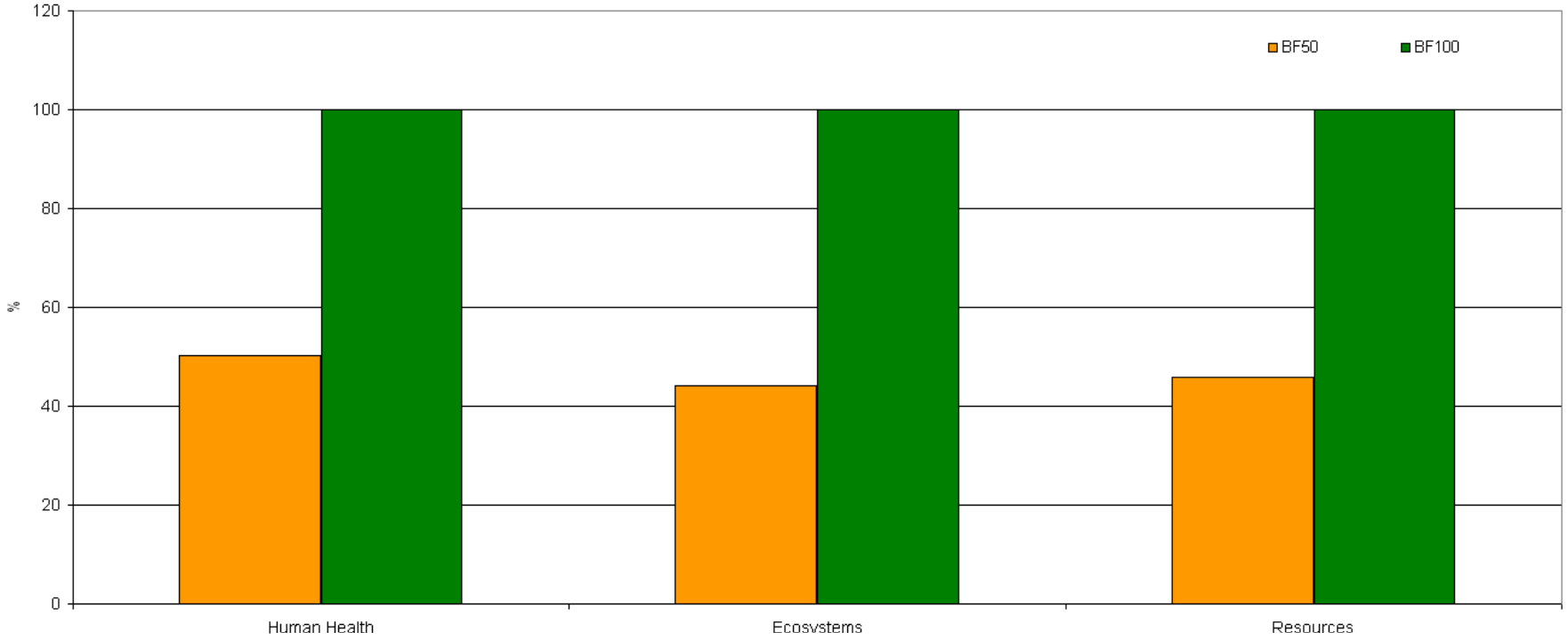
High impact of use phase :

Electricity : predominant impact > 80%

Water : < 1% (operation in closed circuit)

Improvement system:  reduce this item by taking combined action on the ventilation / pressure loss

# LCA results: difference between the two biofilters




The $BF_{100}$ has a twice impact than the $BF_{50}$ for three major damages categories (pressure loss)

Optimisation between performance and impact to be determined

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# Main conclusions

## Efficient treatment:

- a technique capable of treating the principal road pollutants
- good capability of « treating » high quantity of pollutants

## Complementary observed treatment processes:

- dissolution in aqueous phase
- mechanical filtration
- microbiological activity

## An improved formulation (choice of plants)

Good durability (substrate not degraded, removal efficiency maintained over an 18 month period) which promises a long life

No by-products detected

Large influence of electrical consumption demonstrated by the LCA

# Follow up to this experiment

## Future actions for research and improvement:

- get a better understanding of the impact of each medium (water, substrate, bacteria)
- reduce pressure losses by optimising the water inlet and formulation of the substrate composition
- optimise properties of the biofilter : air flow, thickness and surface area of the biofilters

## Develop a full scale prototype, by extrapolating:

- energy needs for extraction of air from the tunnel
- the volume of civil works
- operations and maintenance constraints