Biodegradation kinetics of organic micropollutants (OMPs) in planted or unplanted columns simulating an innovative reed bed filter treating runoff water.

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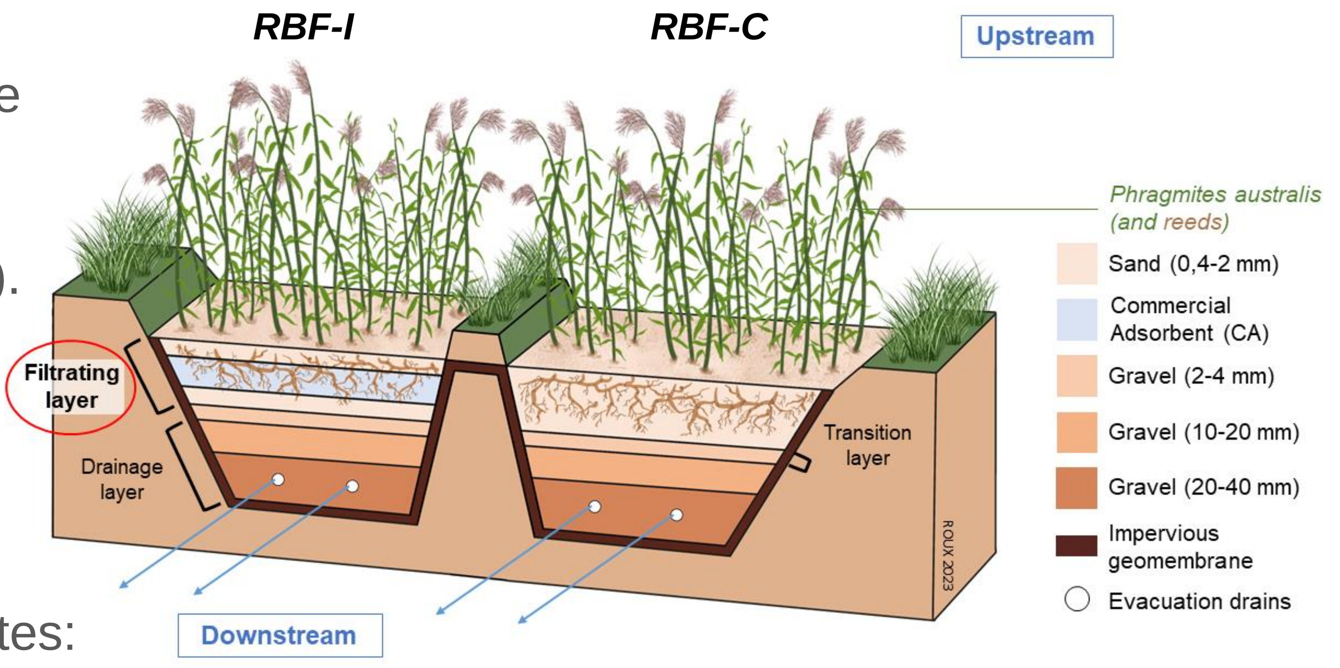
Context

Road runoff: contamination with **metallic** and **organic** compounds [(1)] ➔ **Reed Bed Filters** (RBF) are Constructed Wetlands used worldwide to manage urban runoff issues [(2)].
Life Adsorb project: construction of an innovative RBF in 2020 to treat a part of road runoff in Paris.
2 RBFs : a conventional one (**sand**) and an innovative one (**sand** + **Commercial Adsorbent** (**CA**)).
Sediment accumulates at the surface of the RBF with time.

Objectives of the project: monitor the evolution of the RBF efficiency and understand the **fate** of contaminants within the substrates. This requires the study of their **degradation**.

Objectives of this work:

- Evaluate biodegradation of three emerging organic micropollutants (**OMPs**) within the substrates: bisphenol-A (**BPA**), and two alkylphenols, 4-nonylphenol and 4-t-octylphenol (**NP**, **OP**).
- Elucidate the role of autochthonous **microorganisms** of substrates and **vegetation** in biodegradation

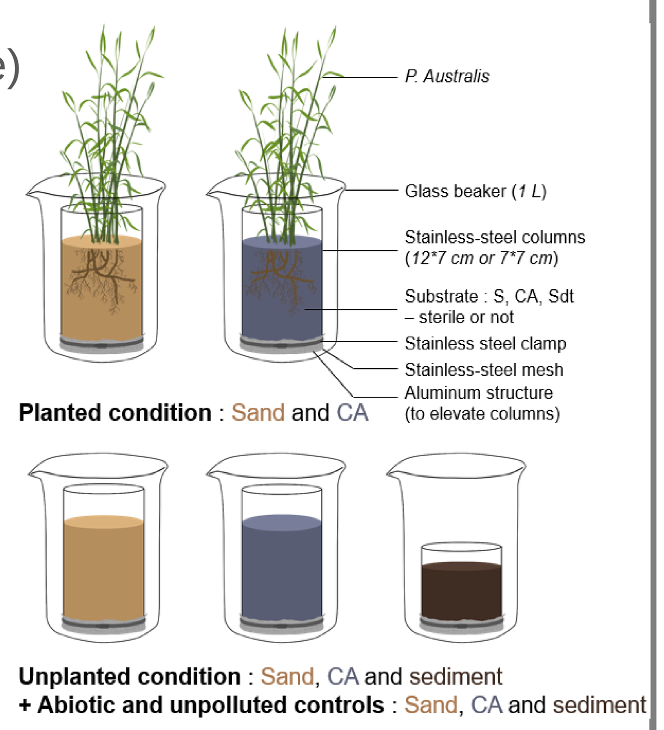


The Reed bed filter (RBF). RBF-C: Conventional RBF ; RBF-I : Innovative filter

Material and methods for aerobic biodegradation experiments

① Columns set-up (triplicate)

- 3 substrates studied: **sand**, **CA** and **sediment**
- 2 OMPs exposition: **planted** (*Phragmites australis*) and **unplanted**.
- 2 controls: **Abiotic** and **Unpolluted** (all unplanted)



Substrate	TOC g/kg	TN g/kg	pH	CEC me/kg
Sand	1.57	0.53	8.62	22.0
CA	27.5	0.37	8.79	374
Sediment	104	5.46	7.87	198

② Preincubation of 2 weeks

- 16h light ; 8h dark
- 20°C day ; 15°C night
- 60% humidity; Watering / 2 days

➔ Growth chamber

③ Contamination of columns by saturating with water

Concentration (mg/L) [(3)]:
- BPA : 2,57
- 4-NP : 3,5
- 4-OP : 1

④ Incubation of 30 days, Column sampling at **0 ; 1 ; 4 ; 7 ; 14 ; 30** days

⑤ Analysis

Substrates OMPs contents (µg/g)	Bacterial **genetic** diversity	Overall **enzymatic** activity	Microbial **functional** diversity
UPLC-MS/MS	*Illumina* DNA sequencing (V3-V4)	Fluorescein diacetate (FDA) hydrolysis	Biolog EcoPlates™

Modelling of OMPs (bio)degradation kinetics [(4)] — *Gmkin software package (R)*

4 kinetic models used: Single First-Order (SFO), First-order multi-compartment (FOMC), Hockey-Stick (HS)

Conclusion

Our work is the **first to demonstrate the laboratory efficiency** of BPA, NP and OP **biodegradation** in the context of RBF treating runoff water. A publication is in preparation.

While the 3 substrates and their different bacterial communities showed ability to **rapidly biodegrade** the 3 OMPs studied, **CA** and **sediment** still showed high % **residual OMPs** (related to their adsorbing properties) which may lead to their accumulation over time.

P. australis and OMPs **promoted OMPs-degrading genera** in the 3 substrates, demonstrating the **adaptation** of bacterial communities to the contaminated water received.

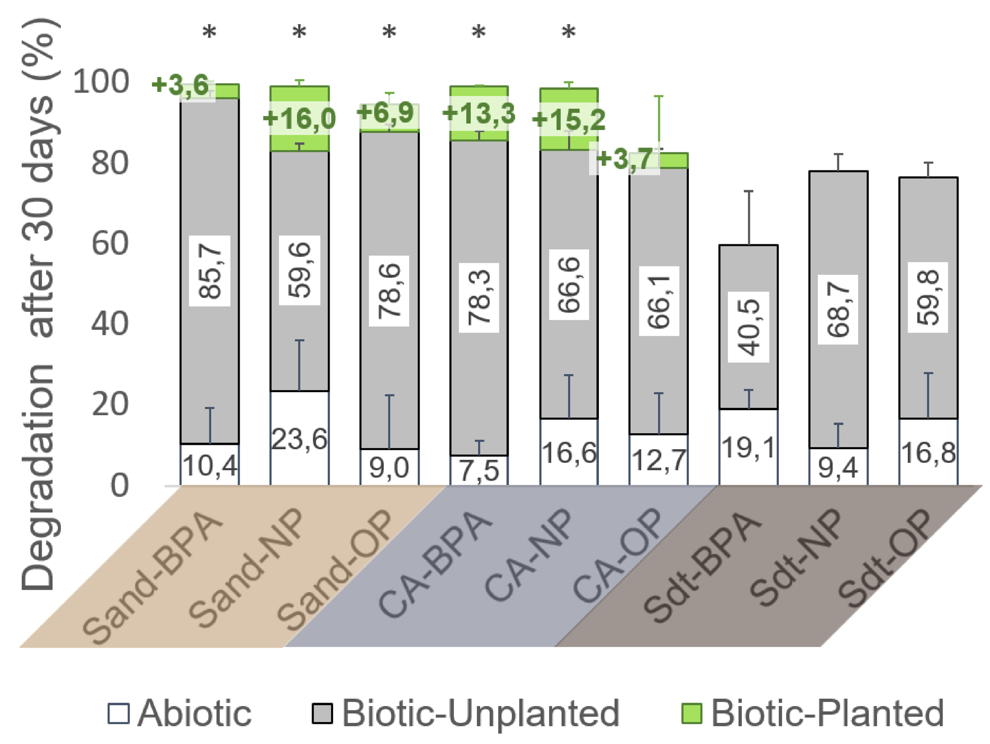
Results

(* significant difference between % degradation of planted and unplanted condition, p-value KW test < 0.05)

• (Bio)degradation of OMPs : impact of substrates and vegetation

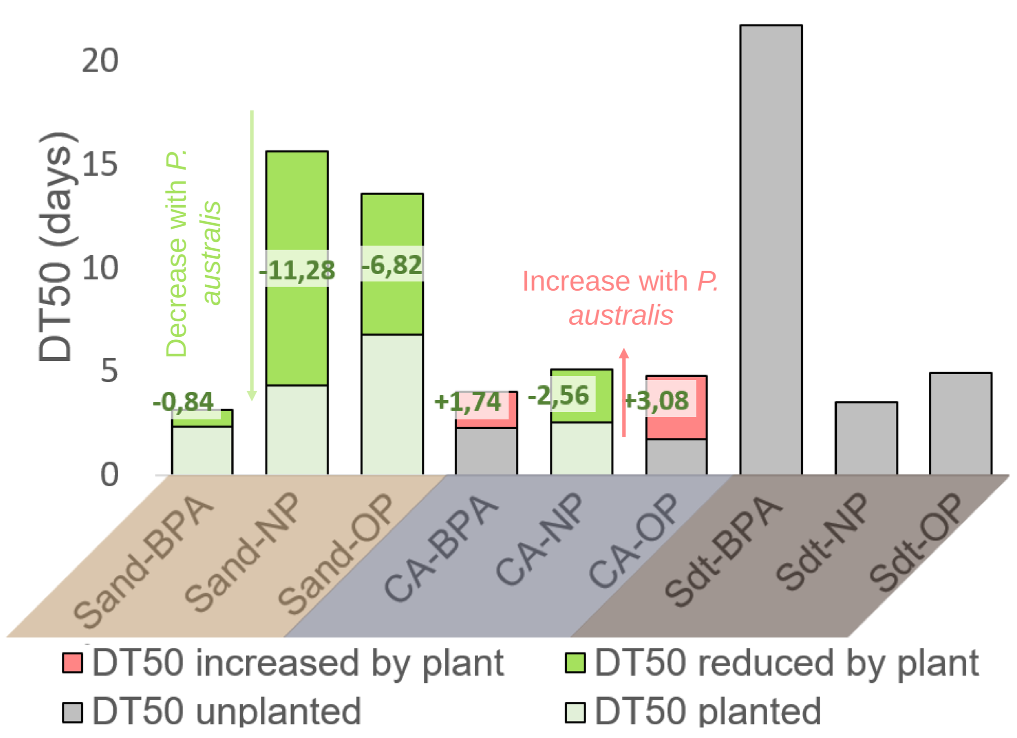
% of OMPs degradation

Efficiency: Planted > Unplanted (except OP in CA)



Rate of degradation: modeled DT50

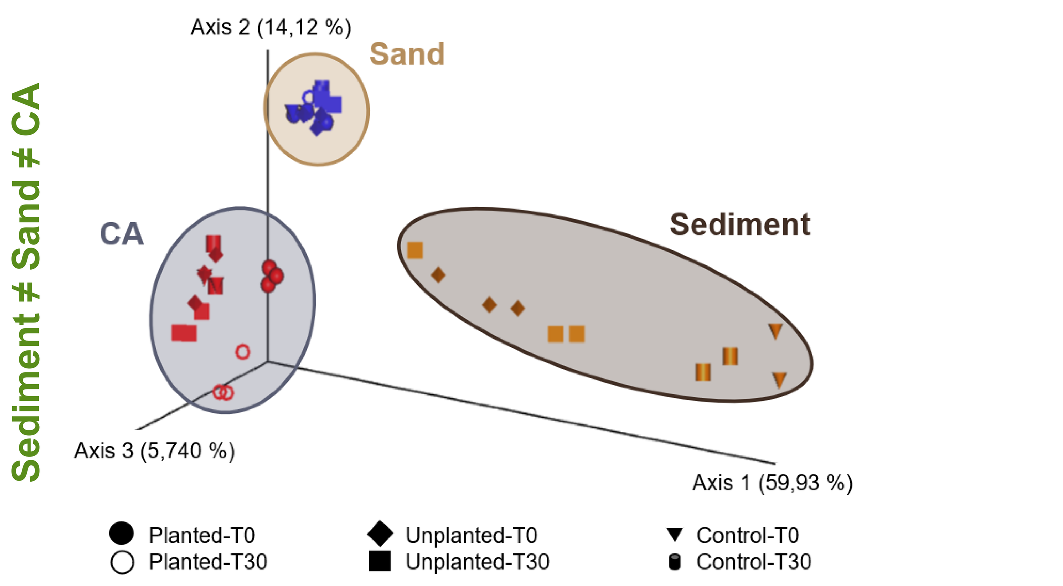
Efficiency: Planted < Unplanted in sand
No relation in CA



- Between **60-99,6 % of degradation.** The majority was due to **microorganisms** (40-92 % of **bio**degradation). **Residual phase** of all OMPs in unplanted CA and sediment (~20 %) were observed due to adsorption properties of substrates.
- **Sand and CA**: Ability to faster degrade OMPs in the RBF and better biodegradation if planted (rate and % of biodegradation). **Sediment**: fast biodegradation except for BPA, and highest residual phases.
- Significant effect of ***P. australis*** and more plant effect in NP and OP than BPA were observed.

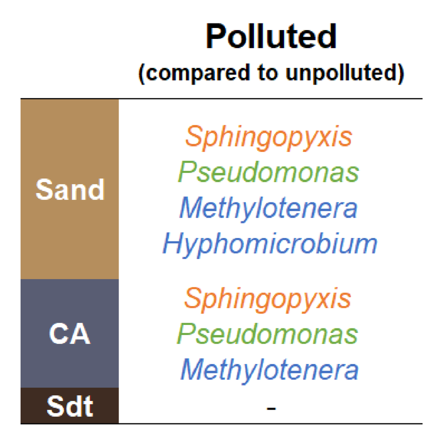
• Microbial communities

1- Genetic diversity (Beta-diversity, PCoA)



- Communities structure were **different** in the three substrates.
- OMPs impacted communities in **sediment.**
- *P. australis* impacted communities in **CA.**
- Limited impact in **sand** during de period studied.

2- Genetic diversity (OMPs-degrading bacteria) : LEFSe analysis to assess bacterial genera with **significantly higher abundances** ➔ Focus on OMPs-degrading genera [(5,6)]



LEfSe = linear discriminant analysis effect size : comparison of bacterial taxa between planted and unplanted and between polluted and unpolluted conditions for each substrate at T30.

OMPs concerned: BPA; NP/OP; BPA/NP/OP

- Genera with differential abundance in polluted conditions ➔ OMPs-degrading genera **found**.
- **More** OMP-degrading genera in planted (not shown) and polluted than unplanted and unpolluted conditions for sand and CA, no difference in Sediment.

➔ ***P. australis*** and **OMPs promote** OMPs-degrading genera development in sand and CA

3- Functional diversity (EcoPlates) ▲

Sediment > Sand > CA

Sample	AWCD T0	AWCD T30	Catabolic richness T0	Catabolic richness T30
Planted-S	1.12 (0.13) b	0.99 (0.13) b	82.8 (7.45) b	66.1 (2,28) a *
Unplanted-S	1.11 (0.23) b	0.72 (0.08) a *	82.8 (7.45) b	53.8 (3.72) b *
Control-S	0.62 (0.02) c	0.33 (0.17) d *	54.8 (4.56) c	30.1 (8.12) e *
Planted-RC	0.83 (0.13) a	0.68 (0.16) a	68.8 (7.45) a	57.0 (9.86) ab
Unplanted-RC	0.65 (0.19) c	0.49 (0.10) cd	56.5 (15.97) c	41.9 (9.12) c
Control-RC	0.69 (0.16) ac	0.51 (0.21) c	55.9 (8.12) c	39.8 (9.86) ce
Unplanted-Sdt	2.16 (0.02) d	1.91 (0.08) e *	100 (0) d	96.8 (0.01) d *
Control-Sdt	2.10 (0.04) d	1.81 (0.03) e *	100 (0) d	97.8 (1.86) d *

ACWD = Average Well Color Development

- Significant effect of ***P. australis*** at T0 and T30 for sand and CA
- Significant effect of **OMPs** at T0 and T30 for sand

➔ ***P. australis*** and **OMPs improved** functional diversity (intensity, diversity) of sand and CA during incubation.

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▲ Mean (± SD), n= 3. All data were compared with R software using Kruskal Wallis test . Each different letter means significant difference with p < 0.05. * means significant difference between T0 and T30.

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