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UNIVERSITÉ PARIS-EST CRÉTEIL

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VILLE DE PARIS

Life
LIFE17 ENV/FR/000398

ICWS 2022 LYON FRANCE

Accumulation of organic and metallic micropollutants over time and space in a Reed bed filter for urban runoff

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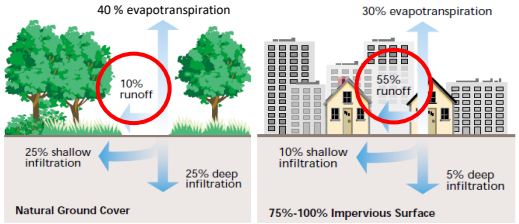
[2] Team Unit, CEREMA
[3] STEA - Ville de Paris

IWA the international water association

6 – 10 November 2022 | Lyon, France

INTRODUCTION

Context



Relationship between impermeable cover and surface runoff - FISRWG, 1998

- Urban zones: **quantity** / **quality** of runoff water (Miller and al. 2014; Gasperi and al. 2010)
  - *Metallic and organic compounds*

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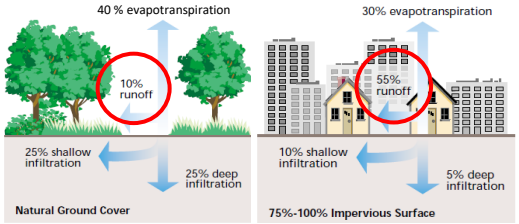

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Infiltration pond (Tedoldi, 2017)

Biofiltration swale (Roux, 2019)

- **Management of runoff (end of 20e c): Sustainable Drainage Systems (SuDS)**
  - ➔ Collect and treat runoff at the source

Vegetative filter strips	Green roof	Infiltration pond	Biofilter, Bioretention cell	...

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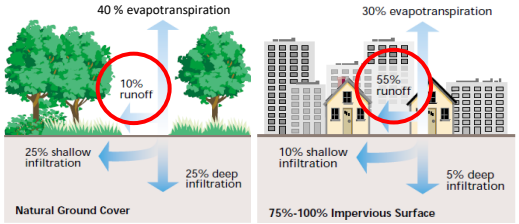

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➔ But also: **Reed Bed Filter** for urban runoff
  - ➔ Recent application

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Context: Bibliography

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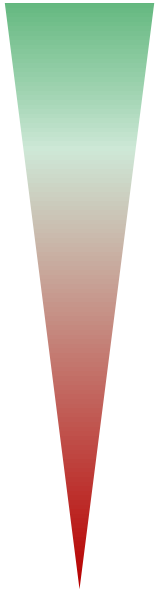

TSS = Total Suspended Solid / N = Nitrogen / P = Phosphorus

PAH = Polycyclic aromatic hydrocarbons / THC = Total Hydrocarbons / AP = Alkylphenols / PAE = Phthalates / BPA = Bisphenol-A

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Reed Bed Filter for urban runoff

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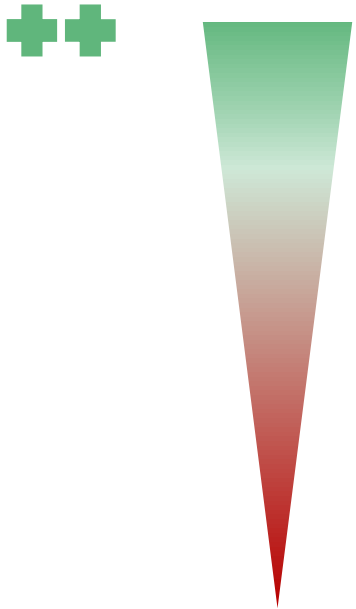

- Water treatment efficiency (TSS, N, P, metals, PAH/THC) (Walaszek et al. 2018, Mangangka et al. 2015)
- **Dissolved** pollutants less retained than particulate (LeFevre et al. 2015, Flanagan et al. 2018)

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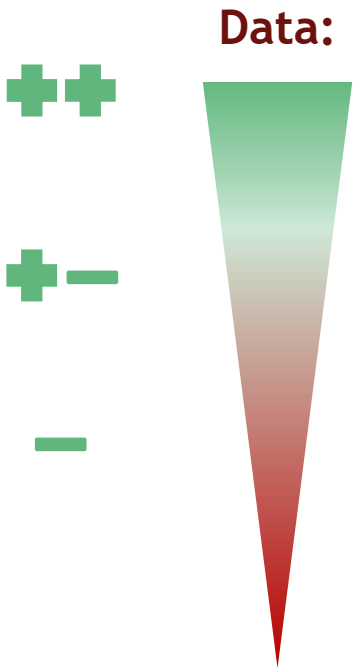

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- Fate of **metallic** micropollutants (MPs) (Dechesne et al. 2004, Gill et al. 2014, Walaszek et al. 2018)
- Process and operation of this filter for **runoff water** (Molle et al. 2013, Branchu et al. 2018)

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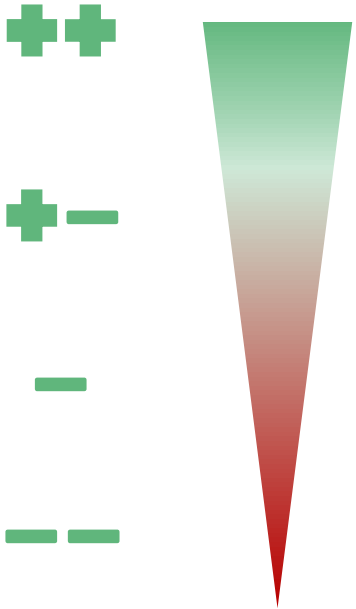

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- Fate of **organic** MP (PAH/THC…) (Zhou et al. 2005, Leroy et al. 2015, Walaszek et al. 2018)

- Fate of **emerging** organic MP (**AP**, **BPA**, PAE)
- Caracterization of **microbial communities** and their **roles** in the filter

➔ **No data** in Reed Bed Filter (few in other types of filtration systems)

TSS = Total Suspended Solid / N = Nitrogen / P = Phosphorus

PAH = Polycyclic aromatic hydrocarbons / THC = Total Hydrocarbons / AP = Alkylphenols / PAE = Phthalates / BPA = Bisphenol-A

INTRODUCTION

Context: European LIFE ADSORB Project

LIFE17 ENV/FR/000398
Life Adsorb

Construction of a **vertical flow reed bed filter** to treat **road** runoff = RBF
Built in 2019-2020

Life Adsorb RBF (2020)

INTRODUCTION

Context: European LIFE ADSORB Project

LIFE17 ENV/FR/000398
Life Adsorb

Construction of a **vertical flow reed bed filter** to treat **road** runoff = **RBF**
Built in 2019-2020

1 **conventional** RBF

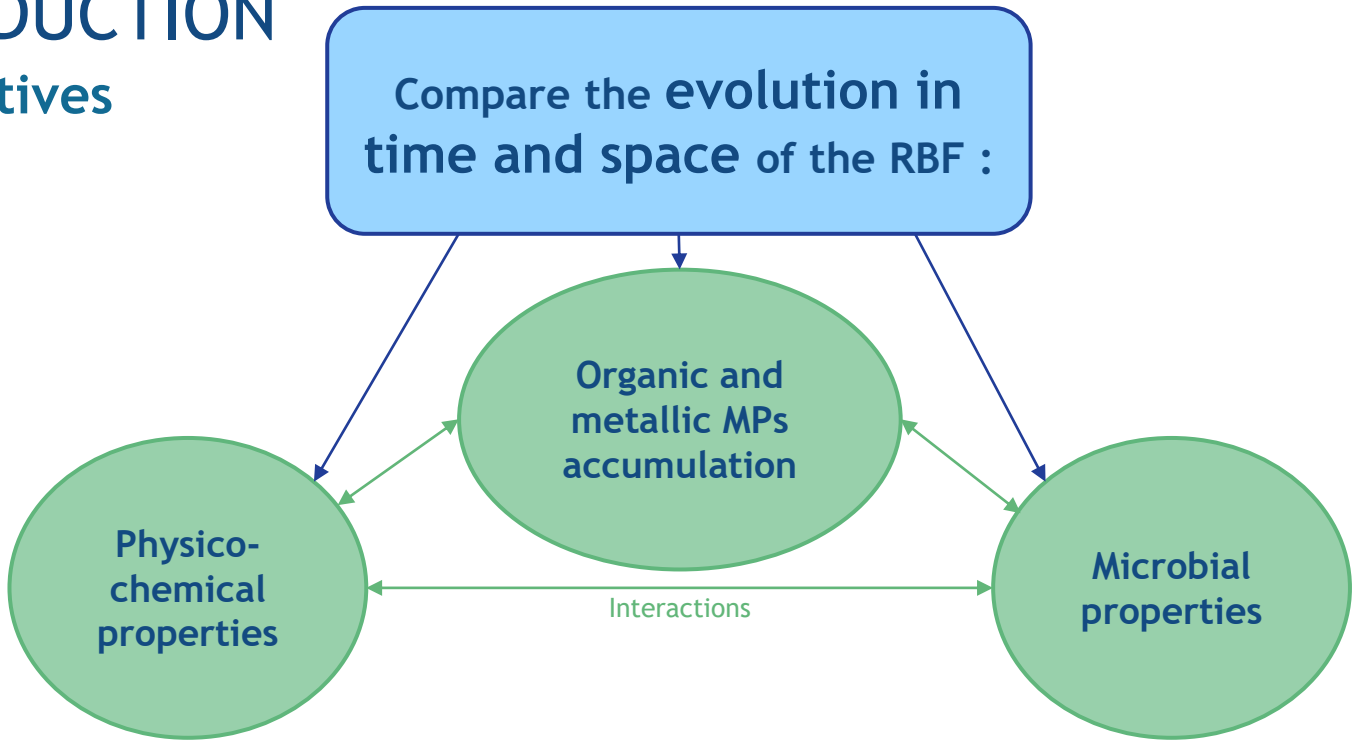
1 **innovative** RBF
→ **Dissolved pollution**

Life Adsorb RBF (2020)

Better uderstand processes involved during filtration
➔ Fate of organic and metallic MPs

INTRODUCTION

Objectives



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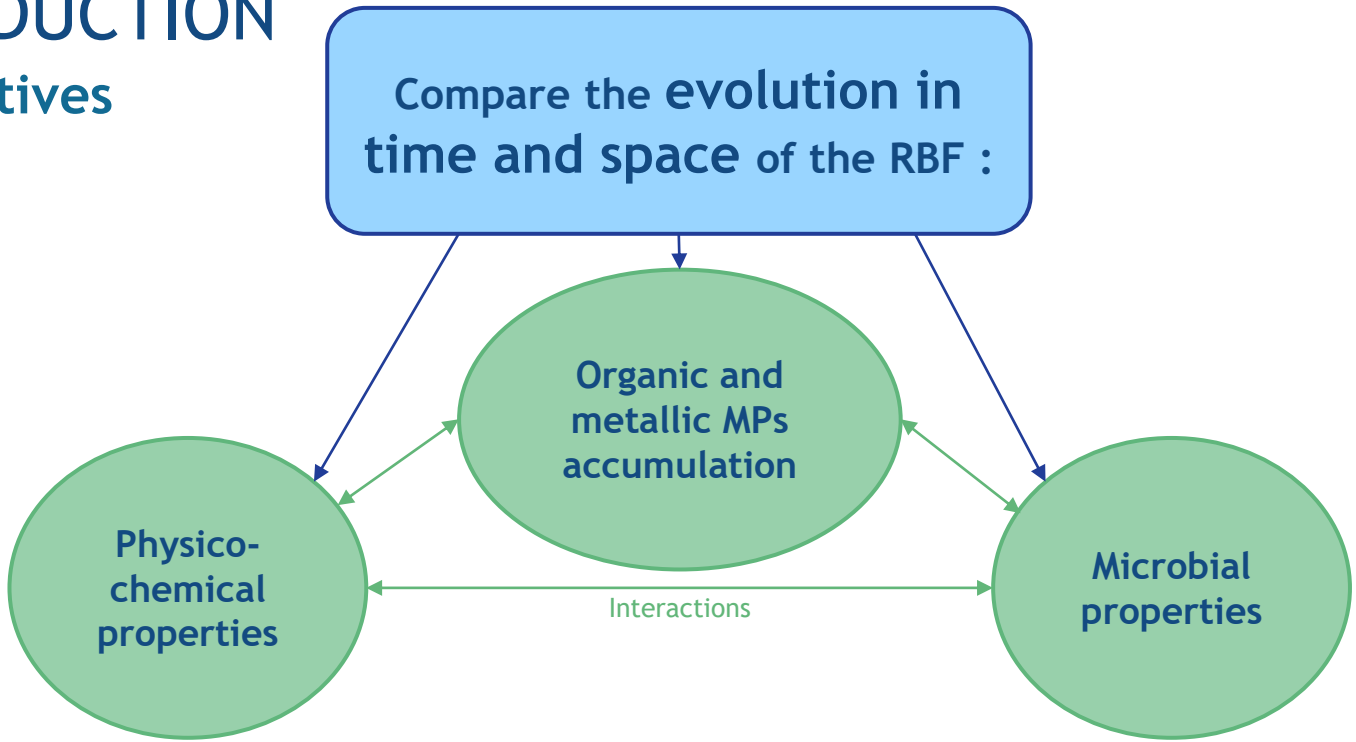


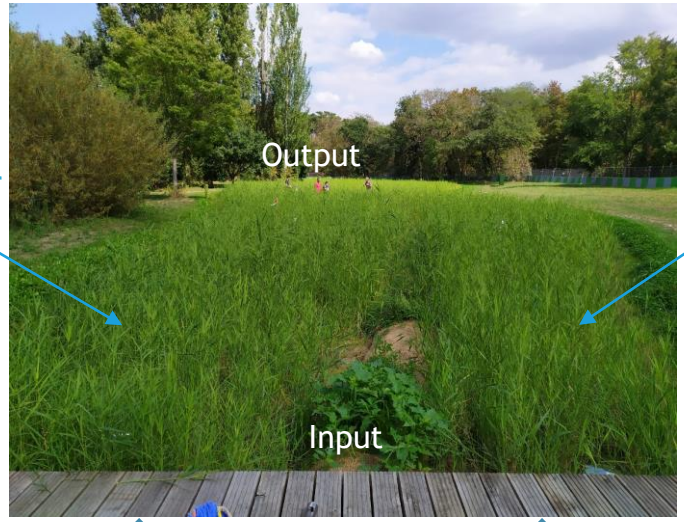
➔ Explain the accumulation of metallic and organic MPs

➔ Differences between the 2 RBF ?

METHODOLOGY

1- The vertical reed bed filter (RBF)

The RBF in September 2020



Bois de Boulogne Park
RBF

- ~600 m² each
- 1 m deep

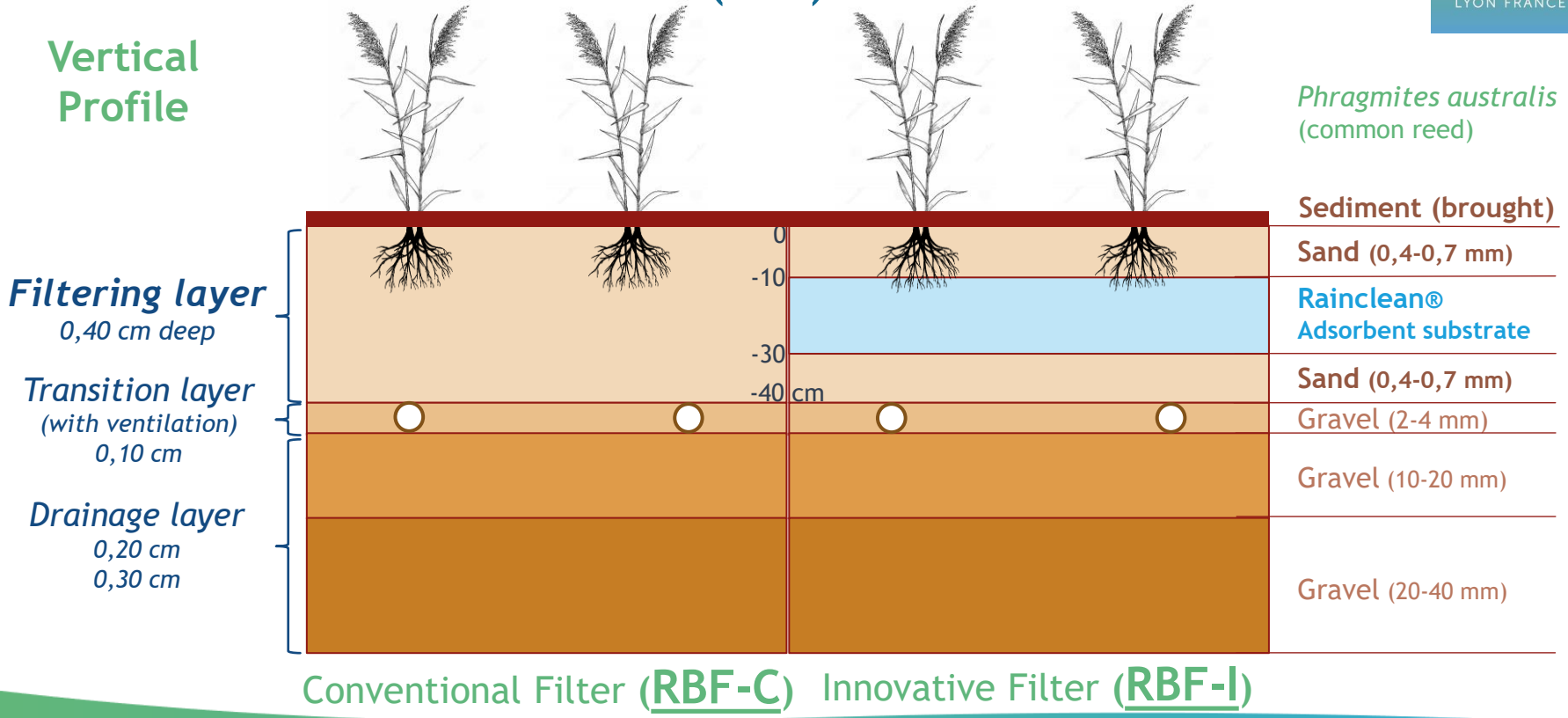
- Fed upstream alternatively

➔ Since february 2021

METHODOLOGY

1- The vertical reed bed filter (RBF) : Subdivided in 2 RBF

Vertical Profile



METHODOLOGY

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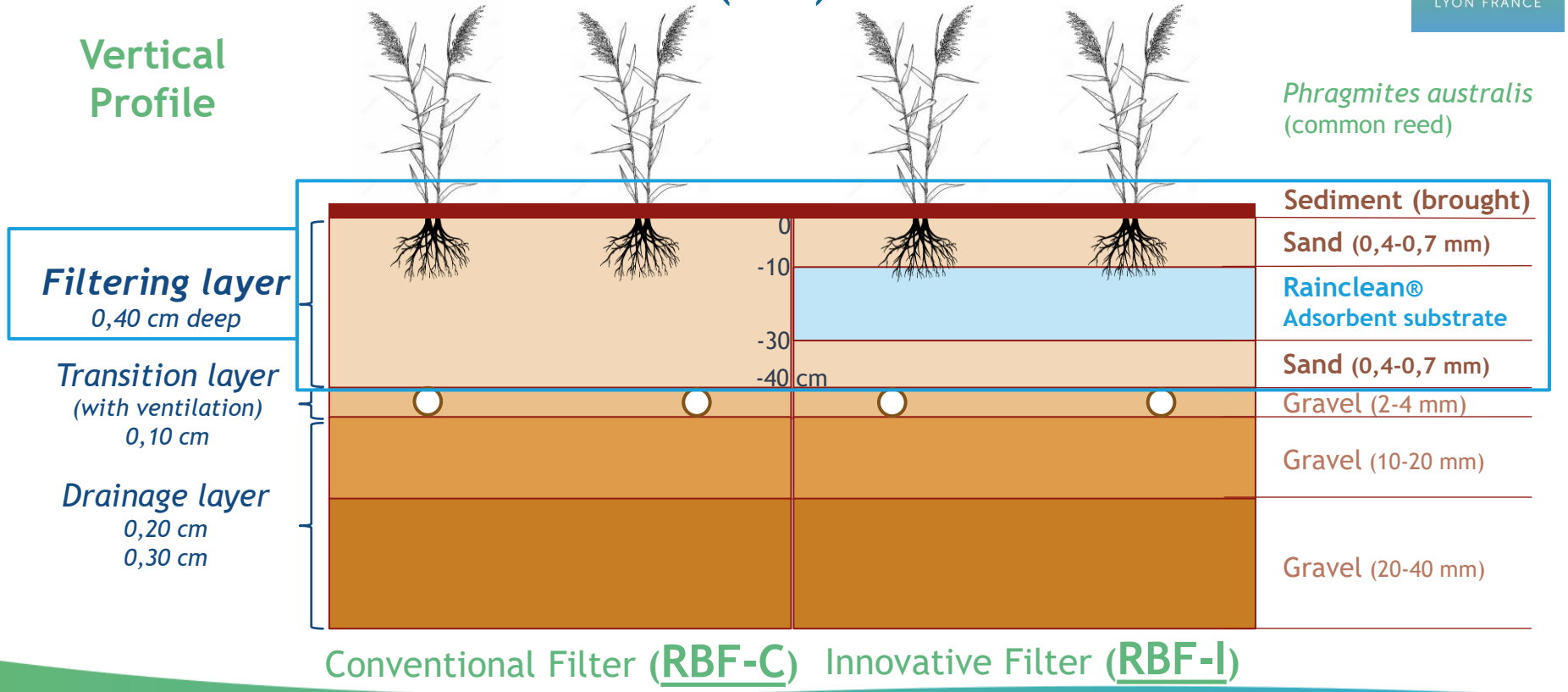
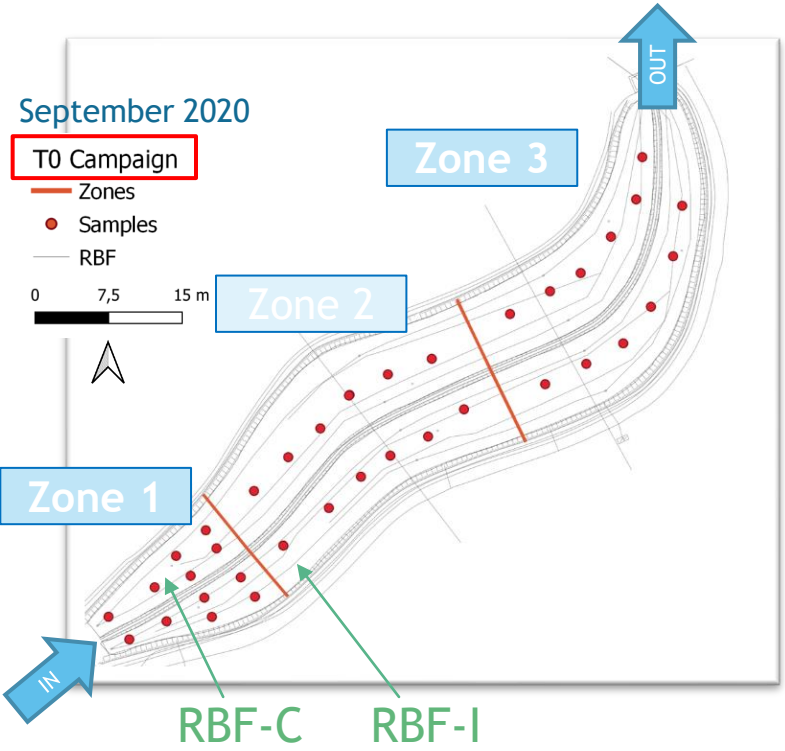


METHODOLOGY

Space and time evolution

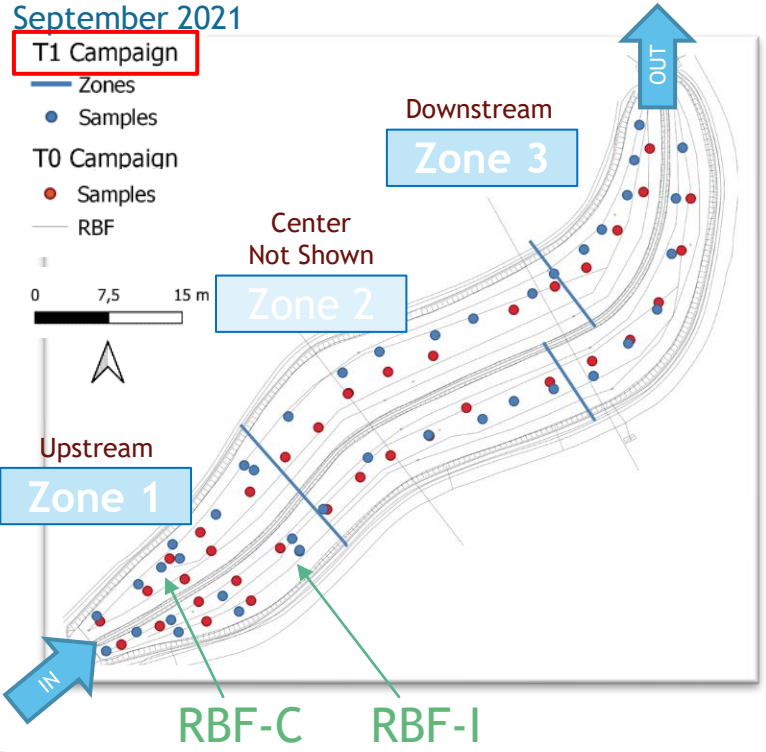
2- Substrates Sampling campaigns



METHODOLOGY

2- Sampling campaigns

Space and time evolution



METHODOLOGY

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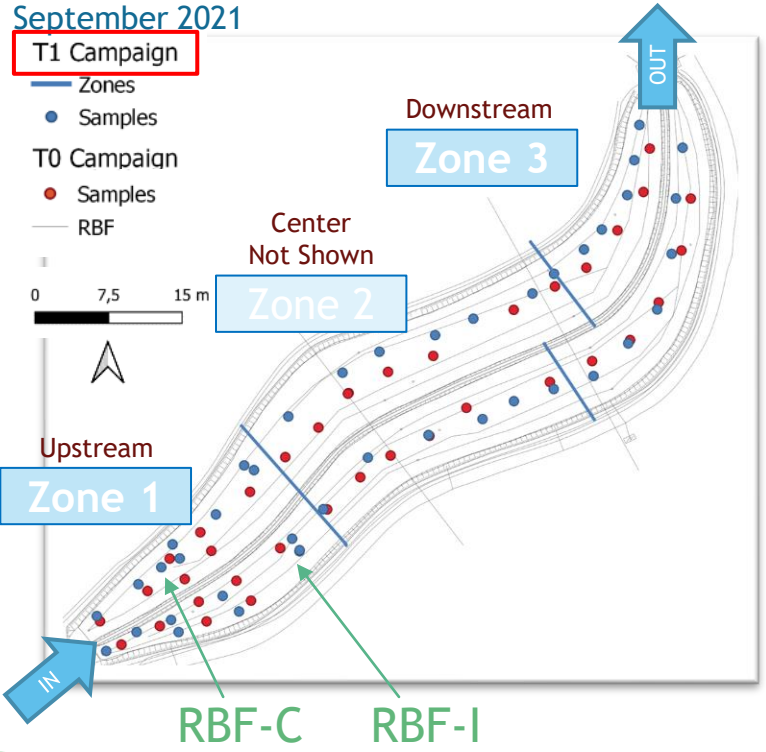


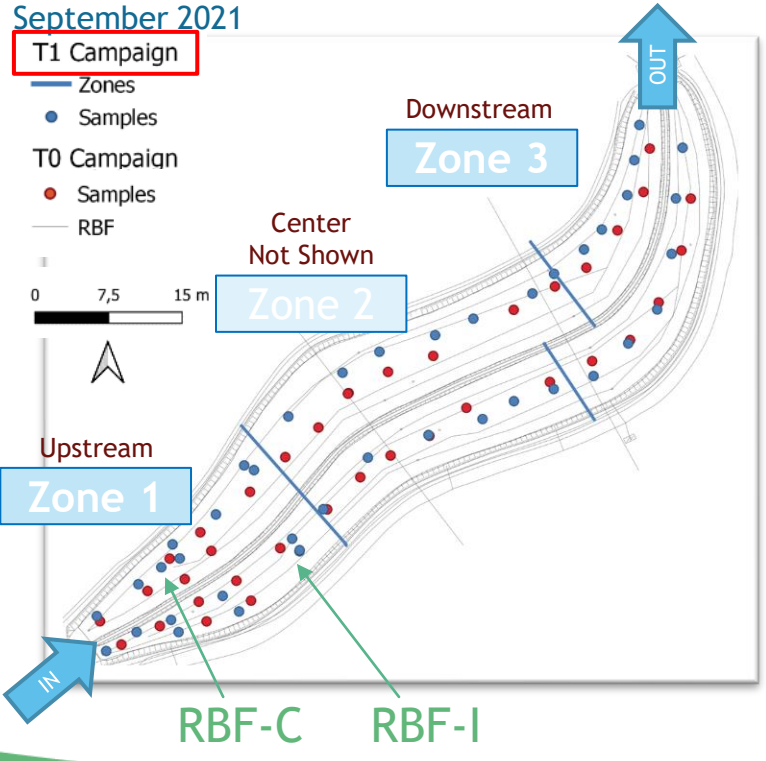
Space and time evolution

= 1 core sample

6 to 8 cores/zone

METHODOLOGY

2- Sampling campaigns



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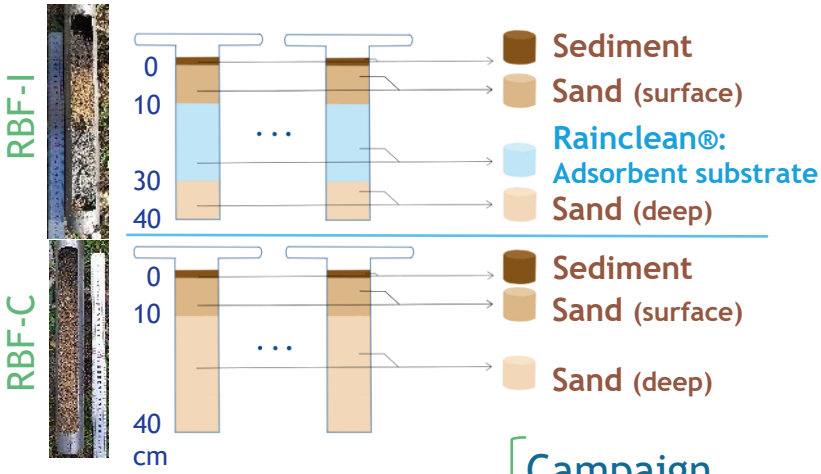


Composite samples for each:

- Campaign
- Filters
- Substrates/Depth
- Localisation

METHODOLOGY

3- Analysis

METHODOLOGY

3- Analysis

Substrates physico-chemistry :

pH, CEC, particule size distribution, TOC, N, CaC03 …

Substrates microbial communities

Abondance of bacteria and fungi (MNP method)

Genetic diversity (Next Generation Sequencing)

Functional diversity (Enzymatic assays and EcoPlates ®)

METHODOLOGY

3- Analysis

Substrates physico-chemistry :

pH, CEC, particule size distribution, TOC, N, CaC03 …

Metallic micropollutants (MPs)

Contents of : **Cd, Cr, Cu, Ni, Pb, Zn**
Aqua regia + ICP-AES

+ fine mapping of Metals in sediments

Organic micropollutants (MPs)

Contents of : **Polycyclic Aromatic Hydrocarbons** (PAH), **Total Hydrocarbons** (THC), **Bisphenol-A** (BPA), **Alkylphenols** (AP: OP, NP, …) and **Phthalates** (DEHP, …)
Solvent extraction + GC-MS or UPLC-MS-MS

Substrates microbial communities

Abondance of bacteria and fungi (MNP method)

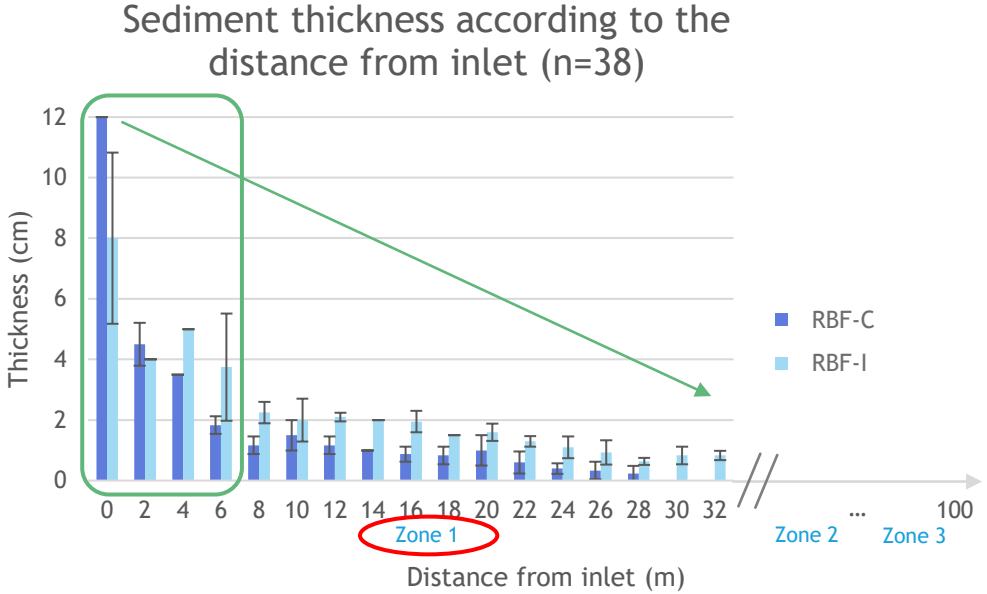
Genetic diversity (Next Generation Sequencing)

Functional diversity (Enzymatic assays and EcoPlates ®)

RESULTS 1) Sediment distribution

- **Thickness of sediment**

  Zone 1 : Thickness every 2m (T1 campaign)



Only in zone 1

↘ with distance from inlet

<2cm after 6m from input

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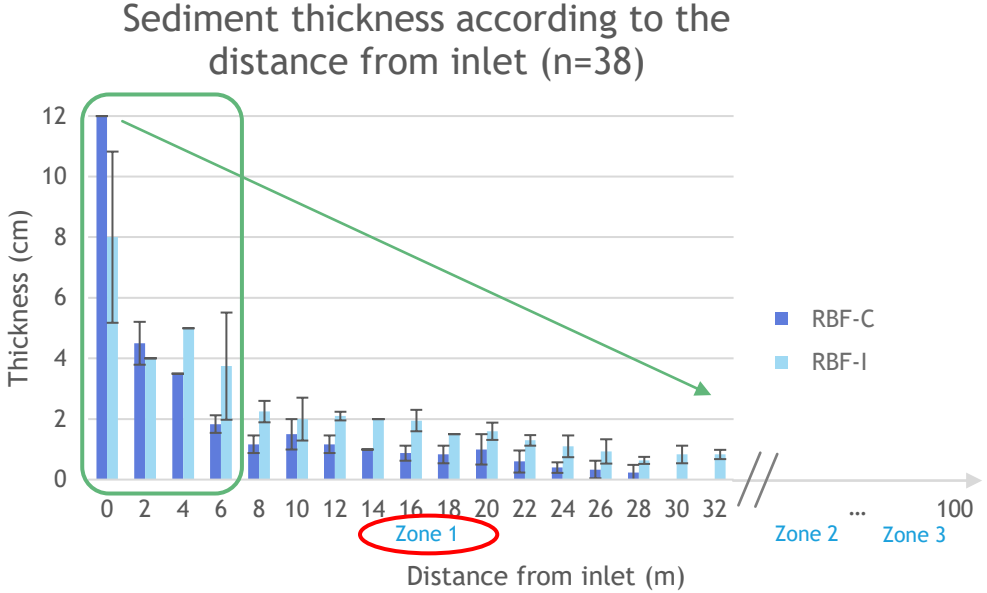
Water inlet



Only in zone 1

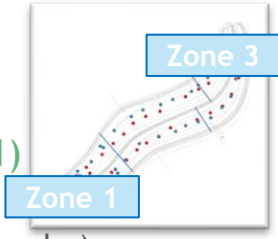
↘ with distance from inlet

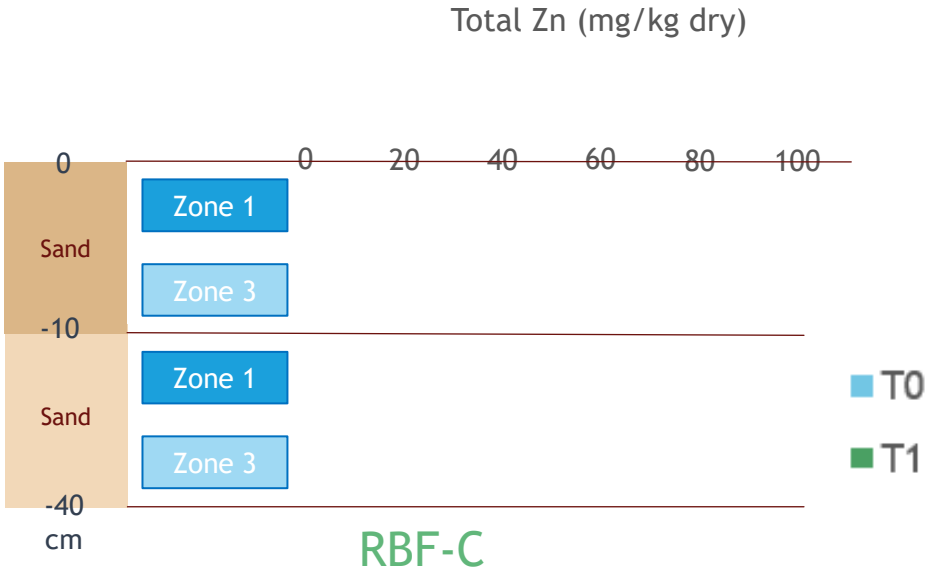
<2cm after 6m from input

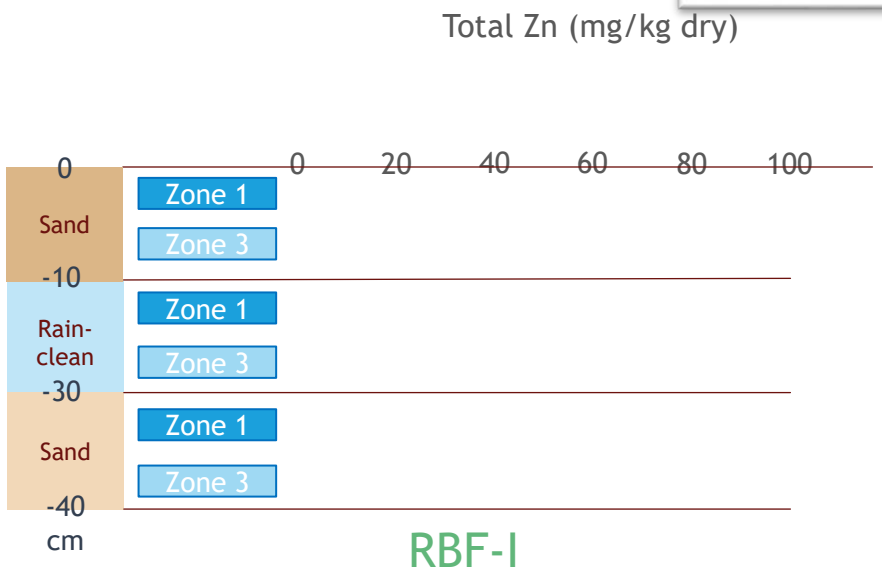
➔ Runoff particulate mater directly filtered in surface by sand

RESULTS 2) Space-time evolution of Metals

- **Vertical profile of Zinc** content in RBF-C and RBF-I between T0/T1 and zone 1/3 (n=1)







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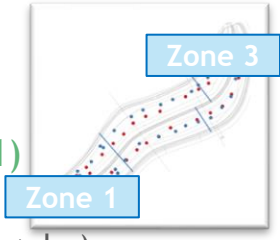
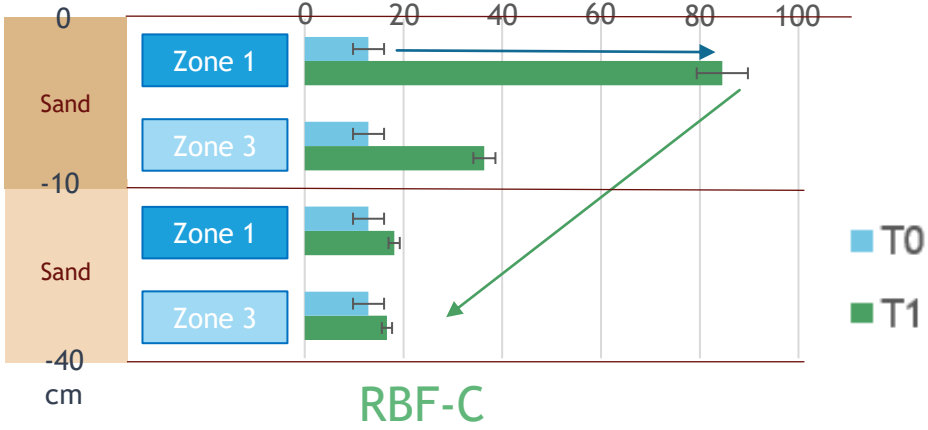


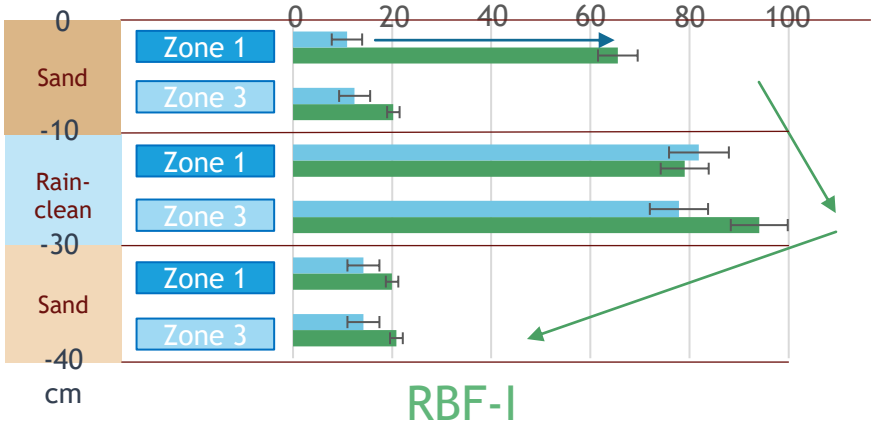
- **Vertical profile of Zinc content in RBF-C and RBF-I between T0/T1 and zone 1/3 (n=1)**

Total Zn (mg/kg dry)



RBF-C

Total Zn (mg/kg dry)



RBF-I

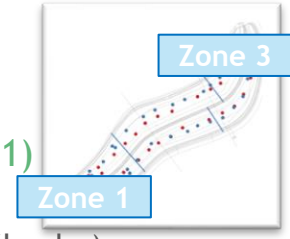
T0 < T1

Horizontal: Contents zone 1 > zone 3

Vertical: Surface content > Deep content

Few increase in Adsorbing substrate

RESULTS 2) Space-time evolution of Metals



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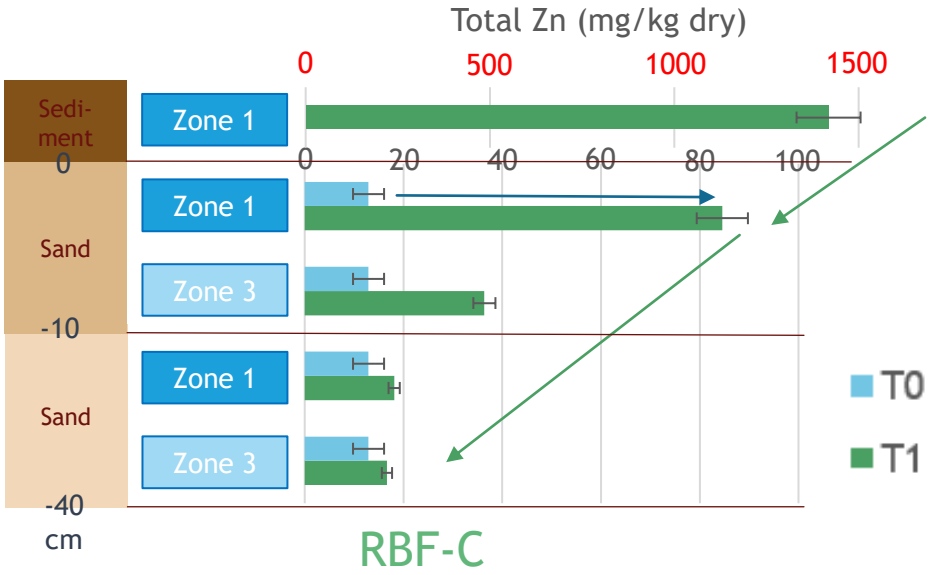
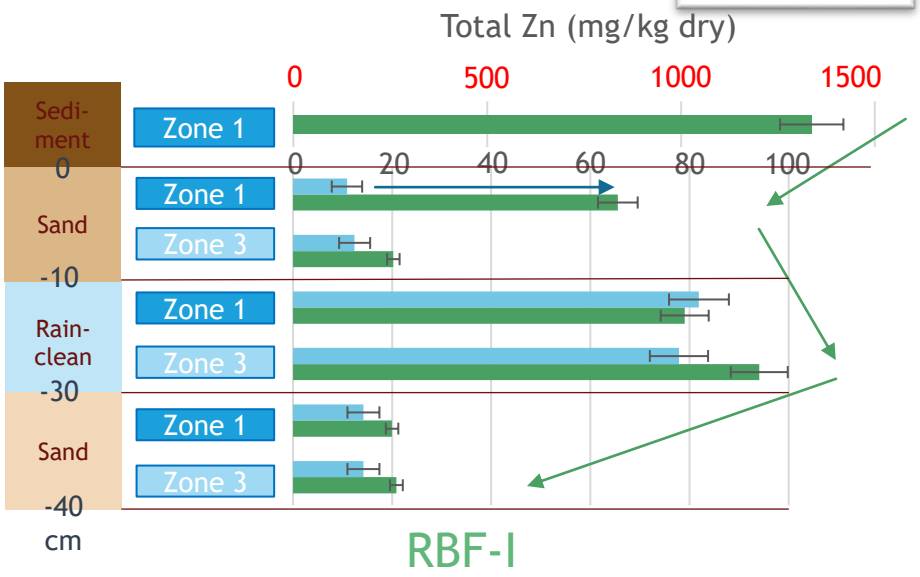




T0 < T1

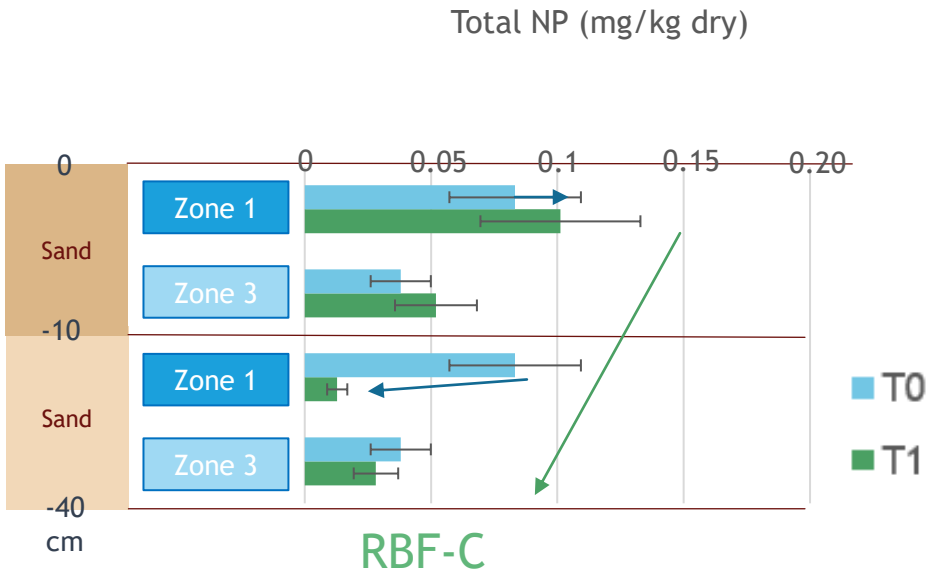
Horizontal: Contents zone 1 > zone 3

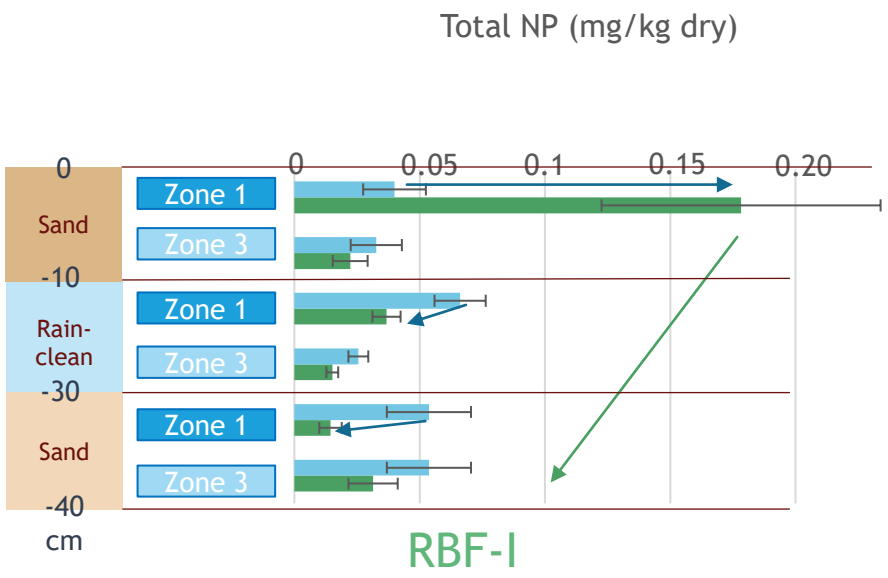
Vertical: Surface content > Deep content
Few increase in Adsorbing substrate

Sediment : majority of metals
→ 17 to 20 time more than surface sand

RESULTS 3) Space-time evolution of Organic MPs

- **Vertical profile of Nonylphenol** content in RBF-C and RBF-I between T0/T1 and zone 1/3 (n=1)





T0 > T1 except for **surface** sand

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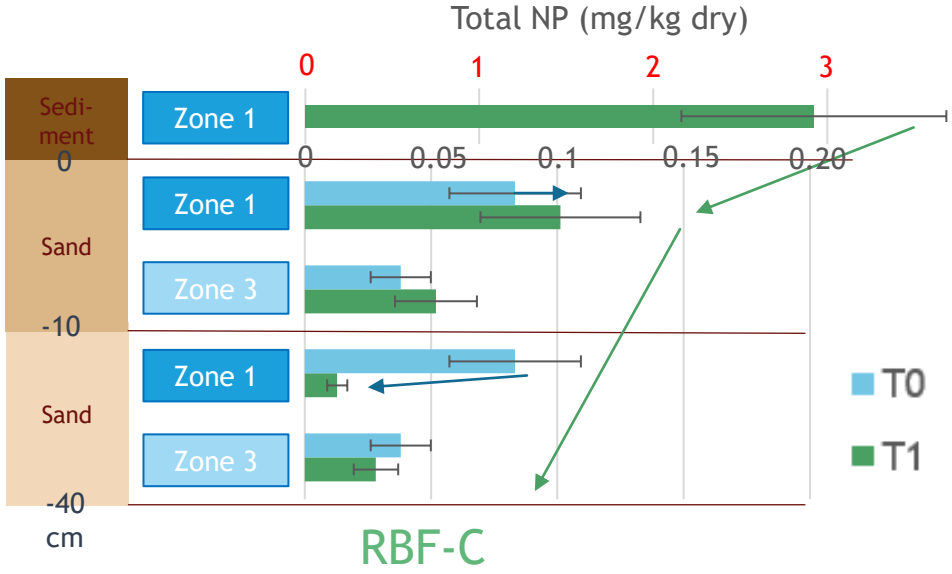
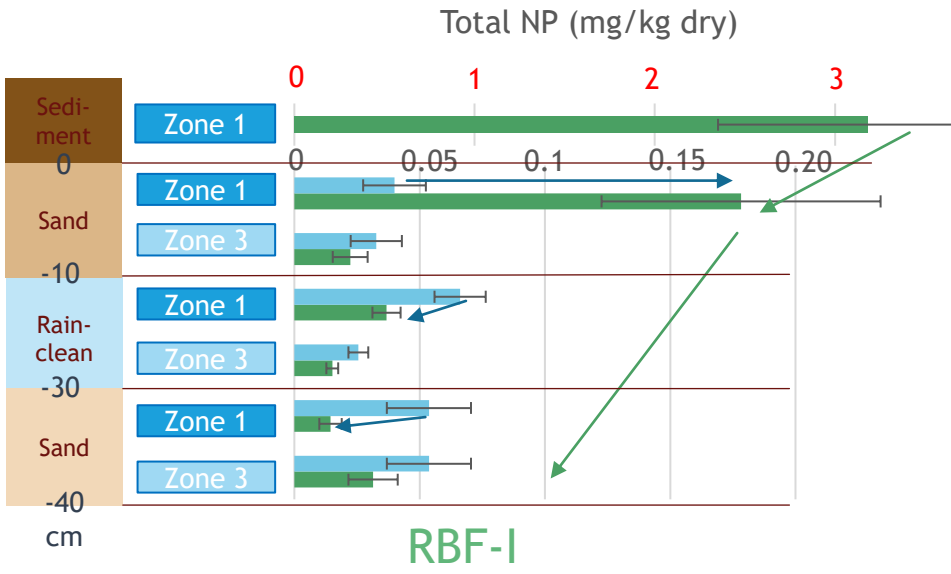


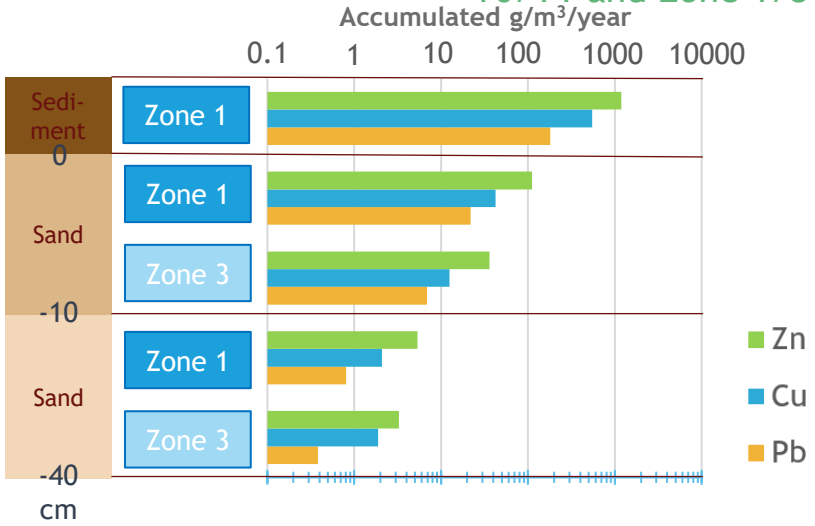


T0 > T1 except for **surface** sand
Horizontal: Contents zone 1 > zone 3
Vertical: Surface content > Deep content

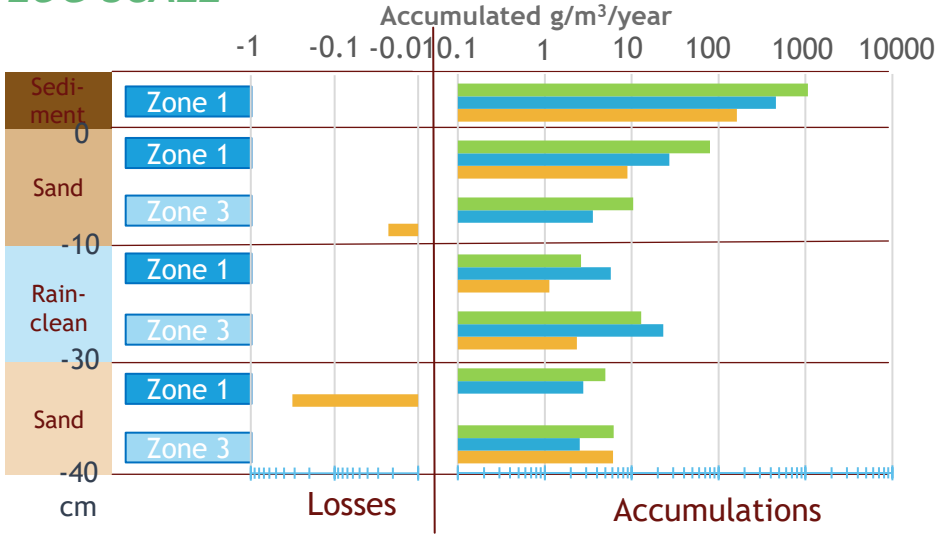
Sediment : majority of Organic MPs
→ 18 to 28 time more than surface sand

RESULTS 4) Accumulation of Organic and Metallic MPs

- **Mass Balance : Metals accumulation (g/m³/year)** in RBF-C and RBF-I between T0/T1 and Zone 1/3 - ***LOG SCALE***



RBF-C



RBF-I

Mass/volume (g/m³) = Content (mg/kg) * volumic mass (kg/m³) ; **Accumulated mass (g/m3/y)** = Mass T1 – Mass T0
Total accumulated mass/surface (g/m²) = Σ accumulated masses/total surface of filter

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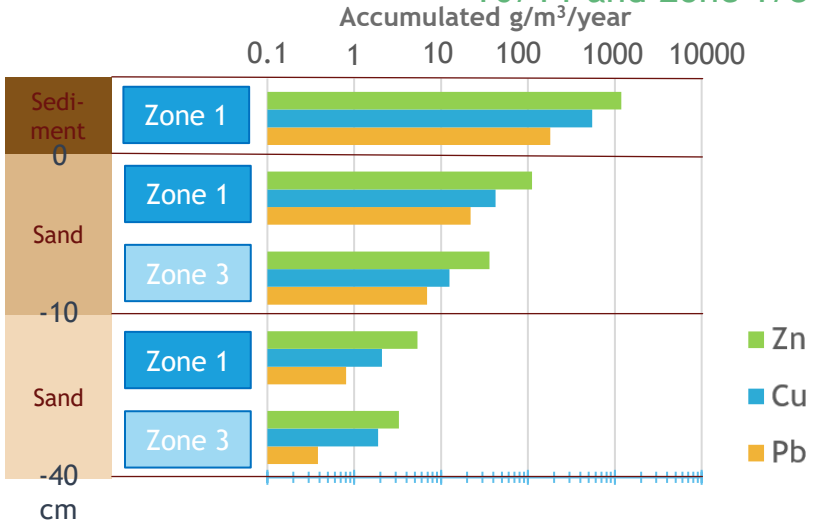
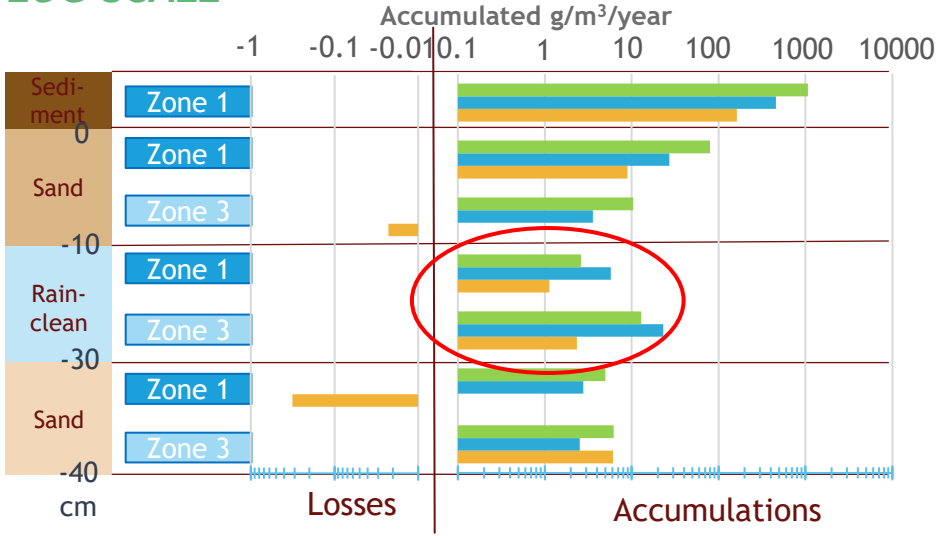


RBF-C



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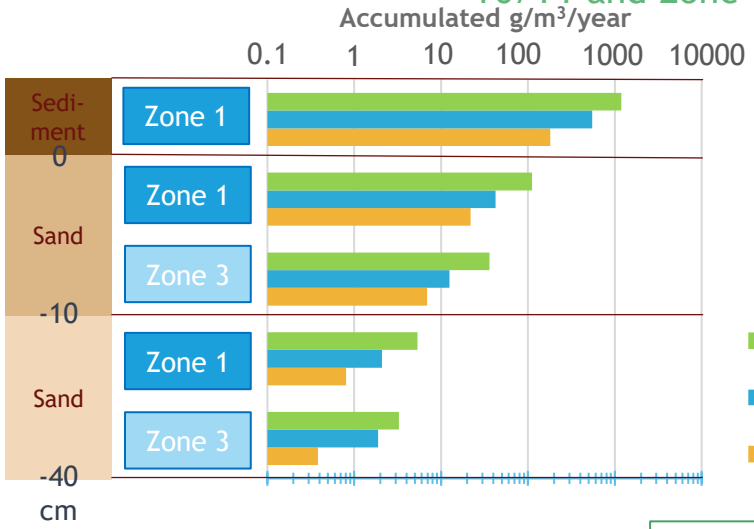
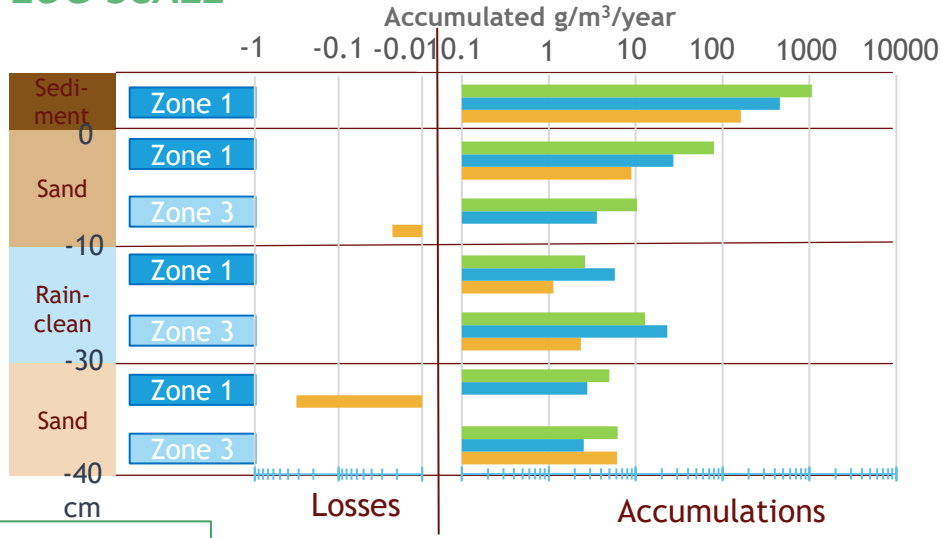




RBF-C ➡ Cu: 2,02 g/m²/y
Pb: 0,67 g/m²/y
Zn : 4,94 g/m²/y

Sediment :
1% volume
35-45% contribution

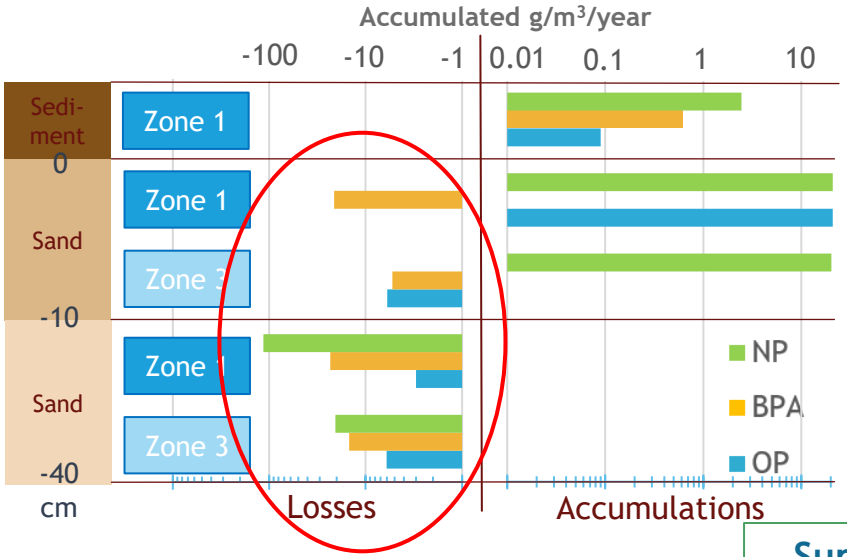
RBF-C > RBF-I

RBF-I ➡ Cu: 1,74 g/m²/y
Pb: 0,57 g/m²/y
Zn : 3,21 g/m²/y

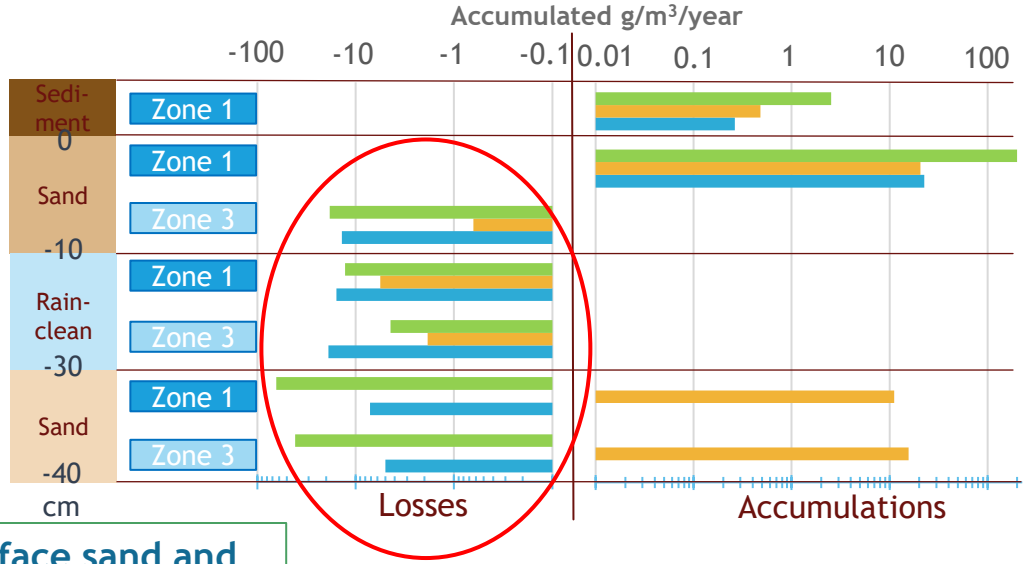
Mass/volume (g/m³) = Content (mg/kg) * volumic mass (kg/m³) ; **Accumulated mass (g/m3/y)** = Mass T1 – Mass T0
Total accumulated mass/surface (g/m²) = Σ accumulated masses/total surface of filter

RESULTS 4) Accumulation of Organic and Metallic MPs

- **Mass Balance : Emerging Organic MPs accumulation (mg/m3/year)** in RBF-C and RBF-I between T0/T1 and Zone 1/3 - ***LOG SCALE***



RBF-C

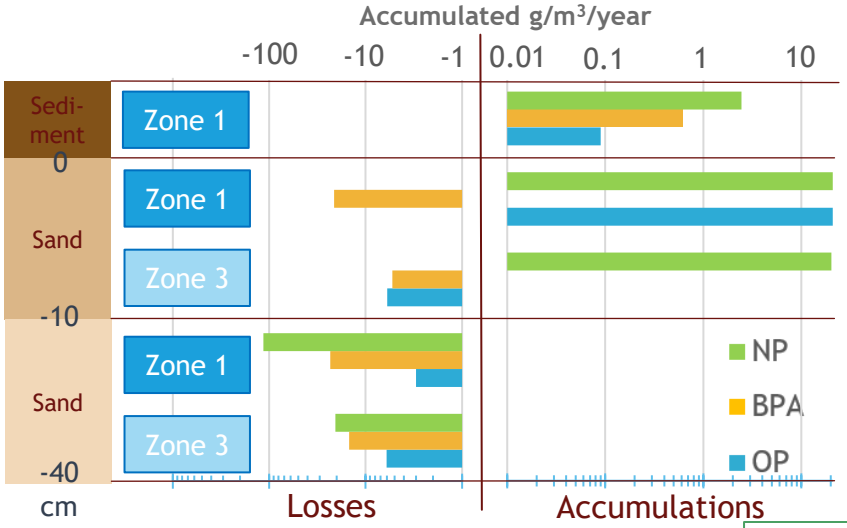


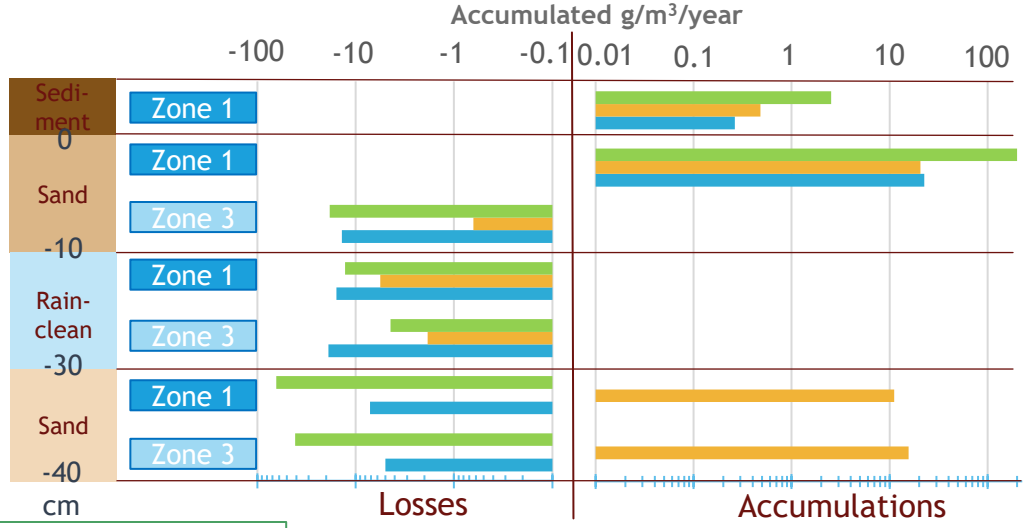
RBF-I

Surface sand and Sediment = accumulation

RESULTS 4) Accumulation of Organic and Metallic MPs

- **Mass Balance : Emerging Organic MPs accumulation (mg/m3/year)** in RBF-C and RBF-I between T0/T1 and Zone 1/3 - ***LOG SCALE***





RBF-C ➡ BPA: -2,51 mg/m²/y
NP: -2,49 mg/m²/y
OP : -1,34 mg/m²/y

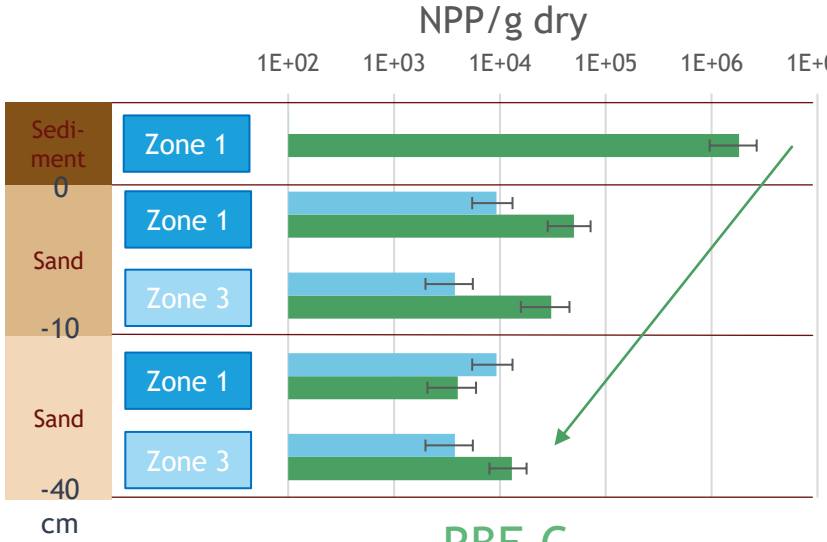
Surface sand and Sediment = accumulation

RBF-C < RBF-I

RBF-I ➡ BPA: 1,11 mg/m²/y
NP: 2,95 mg/m²/y
OP : -2,4 mg/m²/y

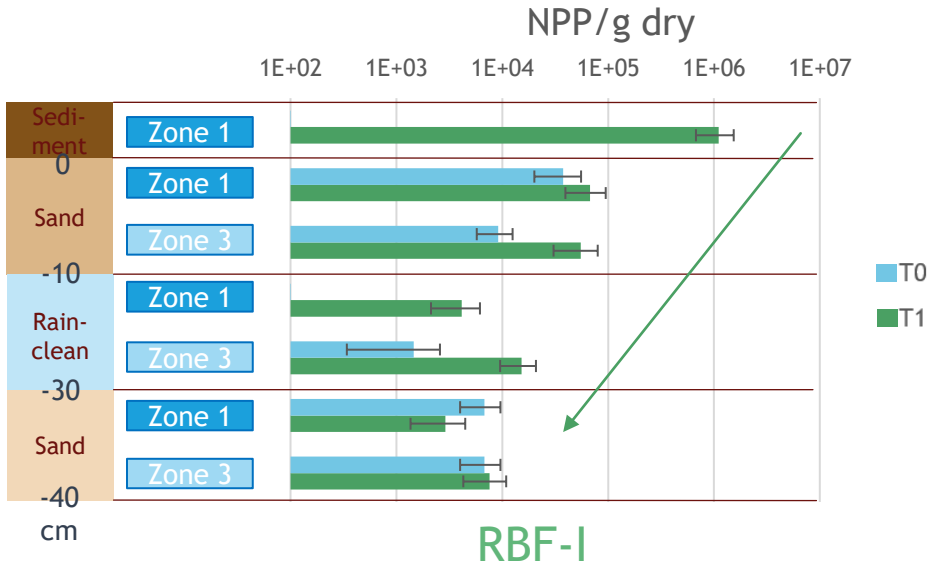
RESULTS 5) Microbial communities

- **Abundance:** Evolution of **bacterial biomass** (NPP/g dry) between T0/T1 and Zone 1/3 (n=3) - ***LOG SCALE***



RBF-C

T0 < T1 → Colonization
Horizontal: zone 1 > zone 3
Vertical: Surface content > Deep content

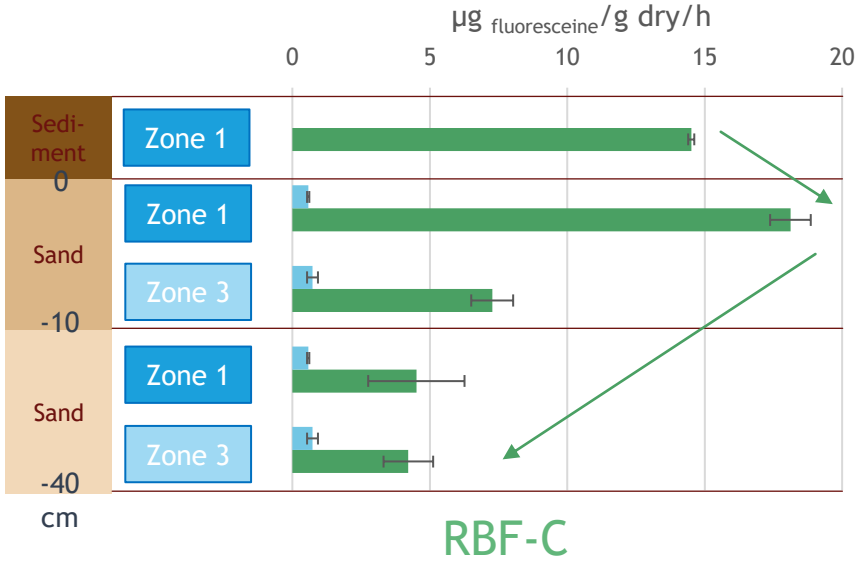


RBF-I

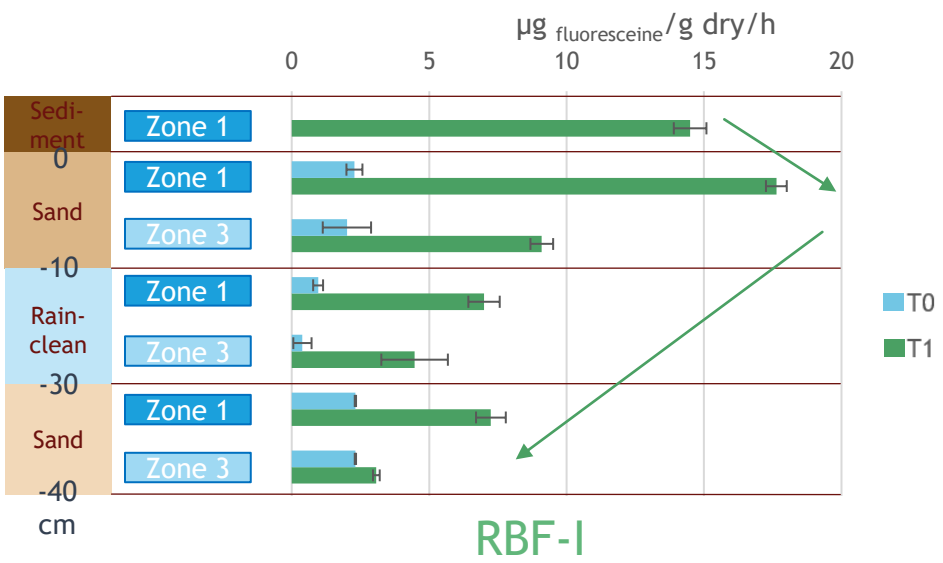
Sediment : most organic substrate
→ Higher abundance

RESULTS 5) Microbial communities

- **Function:** Evolution of **global enzymatic activity (GEA)** between T0/T1 and Zone 1/3 (n=3)



RBF-C



RBF-I

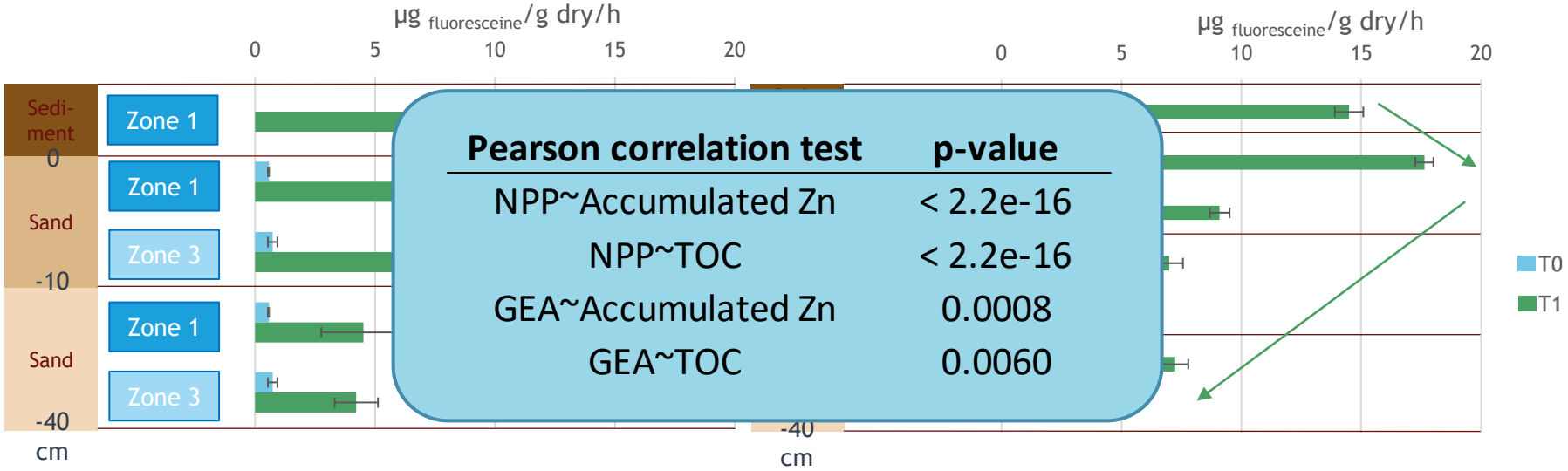
T0 << T1 → High increase of activity

Horizontal: zone 1 > zone 3

Vertical: Surface content > sediment > Rainclean and deep sand

RESULTS 5) Microbial communities

- **Function:** Evolution of **global enzymatic activity (GEA)** between T0/T1 and Zone 1/3 (n=3)



Pearson correlation test	p-value
NPP~Accumulated Zn	< 2.2e-16
NPP~TOC	< 2.2e-16
GEA~Accumulated Zn	0.0008
GEA~TOC	0.0060

➔ **Water supply** significantly and positively **promotes** microbial development

CONCLUSION AND PERPECTIVES

ICWS

Metallic and Organic MPs

Accumulation: ➔ **zone 1**
➔ **surface: sediment** + sand

Metals: accumulation but few losses = **Leaching ?**

Organic MPs: losses exept in surface/zone 1 = **Biodegradation ?**

Microbial communities : progressive colonization and spatial heterogeneity ➔ Which role ?

Filter Substrates

Sediment: low volume/High contamination and microbial activity

Rainclean: retention capacities not (yet) demonstrated

Mass balance

RBF-C > RBF-I for Metals ; opposite for Organic MPs ➔ Water data needed

CONCLUSION AND PERPECTIVES

ICWS

Metallic and Organic MPs

Accumulation: ➔ zone 1
➔ surface: sediment + sand

Metals: accumulation but few losses = **Leachi**

Organic MPs: losses exept in surface/zon

Microbial communities : pro
heterogeneity ➔ Which rôle ?

Laboratory experiments : **biodegradation kinetics + genetic diversity**

Filter Substrates

Sediment: low volume/High contamination a

Rainclean: retention capacities not (yet) demonstrated

Mass balance

RBF-C > RBF-I for Metals ; opposite for Organic MPs ➔ Water data needed

CONCLUSION AND PERPECTIVES

ICWS

Metallic and Organic MPs

Accumulation: ➔ zone 1
➔ surface: sediment + sand

Metals: accumulation but few

Organic MPs: losses

Microbial
heterogen

tial

➔ Input/output water analysis + contents in reeds : **global mass balance**

➔ **T2 campaign**

Filter Substrates

Sediment: low

Rainclean: retention c

Mass balance

RBF-C > RBF-I for Metals ; opposite for Organic MPs ➔ Water data needed


Thank you for your attention !
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Appendix

- **Rainclean composition : carbonates, coconut fibre, pumice stone, coal …**
- **Physico-chemical properties of substrates**

	pH T1	CaCO3 T1 (g/kg)	TOC T1 (g/kg)	CEC T1 (me/kg)
Sediment	7.5	22.3	151.0	138
Surface sand	9.0	0.6	4.6	15
Rainclean	9.1	15.1	20.7	192
Deep sand RBF-C	8.8	<1	1.9	10
Deep sand RBF-I	9.4	0.4	2.4	48

- **Flow of the filter** The output flow is regulated to a maximum of 20 L/s during rain periods