LIFE ADSORB PROJECT

Results obtained

The LIFE ADSORB project explores a number of aspects in order to gain a comprehensive view of stormwater treatment using a reed filter. The results obtained are presented in this section.

Socio-economic impact assessment

The Bois de Boulogne storm spillway in the Bois de Boulogne has undergone major renovation. Previously, it discharged rainwater from a section of the ring road directly into the Seine, but the City of Paris has recently fitted it with a system for storing and treating this water using a reed filter before discharging it into the Bois de Boulogne drainage network and eventually into the Seine.

As part of the Life Adsorb project, a sociological component was included in order to analyse the appropriation of this structure by the local authority's technical services, local residents and visitors to the wood. The study of its socio-spatial integration is based on a framework for analysing social acceptability, distinguishing between the notion of an issue and that of an acceptability problem. To obtain a complete picture, the different phases of the project were examined.

The social acceptability of a facility to treat run-off water, which is perceived as polluted, must be analysed from two angles:

- **its operation** - i.e. the way it is used by those who operate and maintain it
- **its socio-spatial integration** - i.e. how it is perceived by local residents.

This study revealed that the structure does not give rise to any objections, mainly because the planted filter remains virtually invisible thanks to the landscaping. However, to maintain this discretion over the long term, the maintenance of the system needs to be optimised.

From an organisational point of view, the planted filter can be considered as a border object, situated at the intersection of several professional universes. It is subject to various interpretations and is the subject of numerous adjustments between the departments of the City of Paris, as well as between these departments and the researchers involved in the project.

The study highlights certain tensions, particularly in the definition of responsibilities between the various departments of the City, such as Green Spaces and Water/Sanitation. Differences may also emerge between the expectations of the researchers and the reality on the ground for the operational players.

The persistent uncertainty as to the allocation of maintenance tasks and responsibilities after the end of the European project highlights a lack of capitalisation on the lessons learned from past projects. This deficit does not only concern the City of Paris, but also all the work available in scientific and professional literature.

It therefore seems essential to ensure that the knowledge gained from these initiatives is maintained, both within the local authorities that develop these alternative techniques and through better dissemination of the sociological and organisational knowledge acquired throughout the deployment of these innovative stormwater treatment systems.

 For more information, please refer to the full report available in the section Socio-economic impact assessment | LifeAdsorb (https://life-adsorb.eu/en/socio-economic-impact-assessment)

Environmental impact assessment on ecosystems

Initial state: assessment prior to the construction phase

Some of the information obtained from the assessment of the initial state must be taken into account in the next stages in order to interpret the impact of the construction and operation of the prototype on the ecosystem.

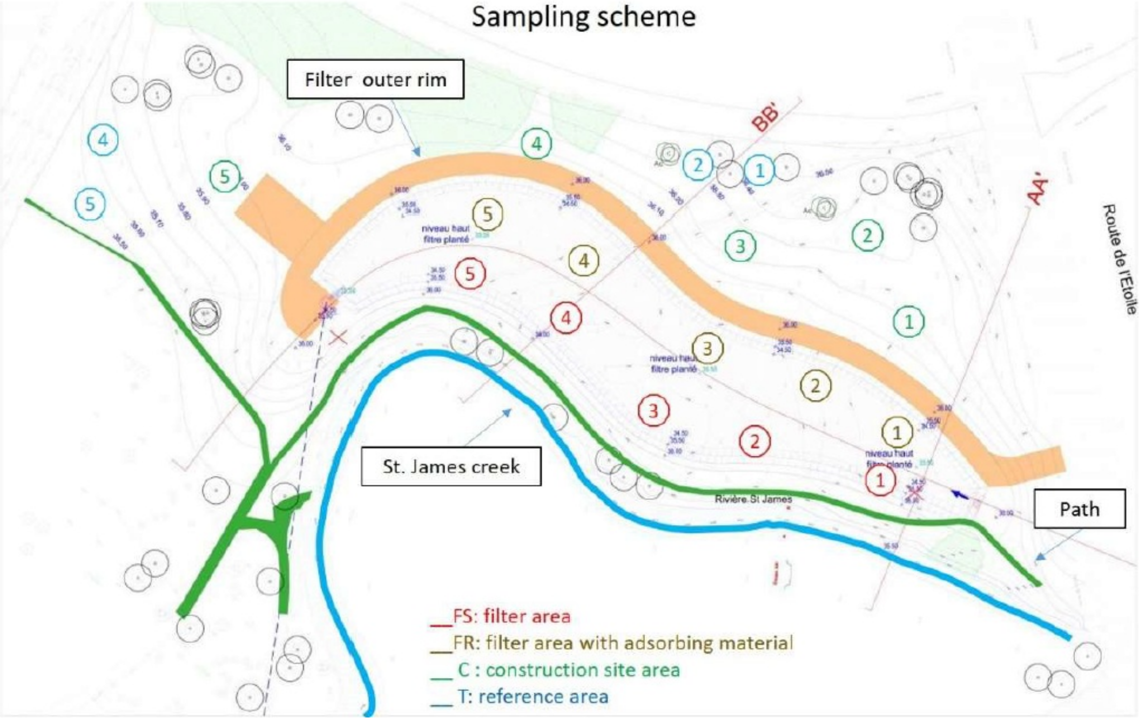
The siting area initially showed spatial variability, due to the differences observed, particularly in terms of vegetation cover. In addition, the proximity of major roads encouraged the accumulation of metallic and organic contaminants, resulting in a heterogeneous concentration of pollutants and site characteristics.

The unfavourable conditions made it difficult to characterise the oligochaete communities. However, the species identified appear to be representative of the site as a whole.

A floristic and faunistic study carried out in 2015 revealed that the site presented a low biodiversity challenge, as the species inventoried were common in the region.

State zero: evaluation after filter construction

Characterisation of the quality of the environment at ground zero will enable us to assess the impact of the construction site on the ecosystem and will serve as a reference for assessing the impact of the filter on its environment.



A significant difference in chemical and biological analyses was observed between the filter zone and zones T and C. It is therefore essential to set up intra-zone monitoring over time in order to accurately assess and monitor the impact of the filter.

The distribution of polycyclic aromatic hydrocarbons (PAHs) follows the trend observed during the initial assessment. However, some points in the construction site area show higher concentrations. However, these values must be put into perspective in relation to the concentrations measured in the control zone.

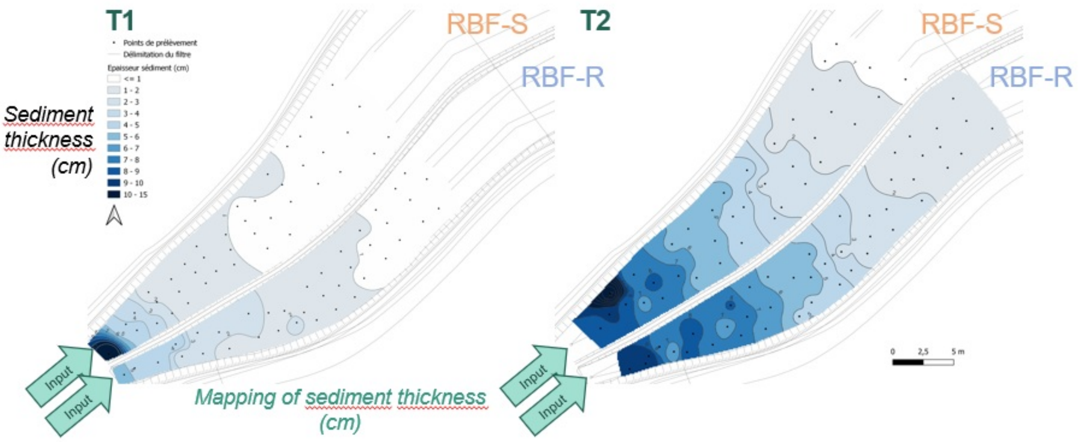
No significant difference was found for most of the enzymatic activities analysed between T0 and Tin.

The study of the soil fauna revealed a variation in terms of richness and abundance of oligochaete species between the filter zone and zones C and T. In addition, zone T had richer and more abundant communities of earthworms and enchytreids than zone C. Overall, these parameters appear to be higher than those observed during the Tin campaign.

 For more information, please refer to the full report available in the section [Assessment of the impact on ecosystems | LifeAdsorb](https://life-adsorb.eu/en/assessment-impact-ecosystems) (https://life-adsorb.eu/en/assessment-impact-ecosystems)

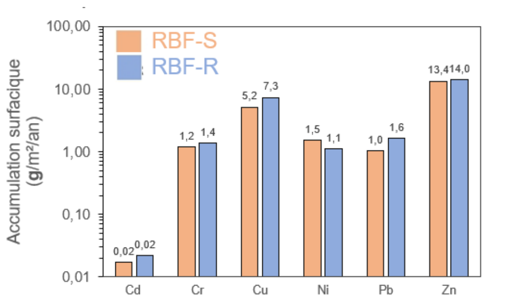
Spatial evaluation of sediment accumulation

Sedimentation and filtration are the predominant processes upstream and at the surface. Their impact decreases with distance, from 12 cm to less than 2 cm beyond 30 metres. Sediment is mainly present upstream, covering between 32% and 42% of the total surface area of the filter at T2. The average annual accumulation rate is estimated at 4.1 m³/year (± 0.37) and tends to increase over time.

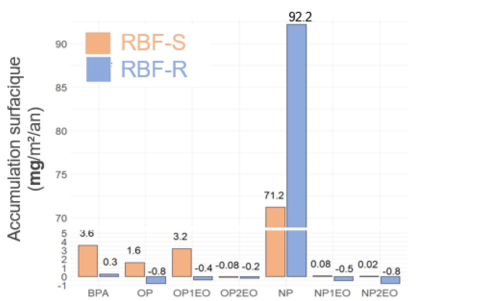


Annual accumulation in filters

At the filter scale after one year of feeding, trace metal elements accumulate while organic micropollutants (OMPs) do not, with the exception of 4-NP. No significant differences were observed between the two types of filter, the main variation being related to sediments.



Surface accumulation (**g/m²/year**) of TMs on the scale of RBFs

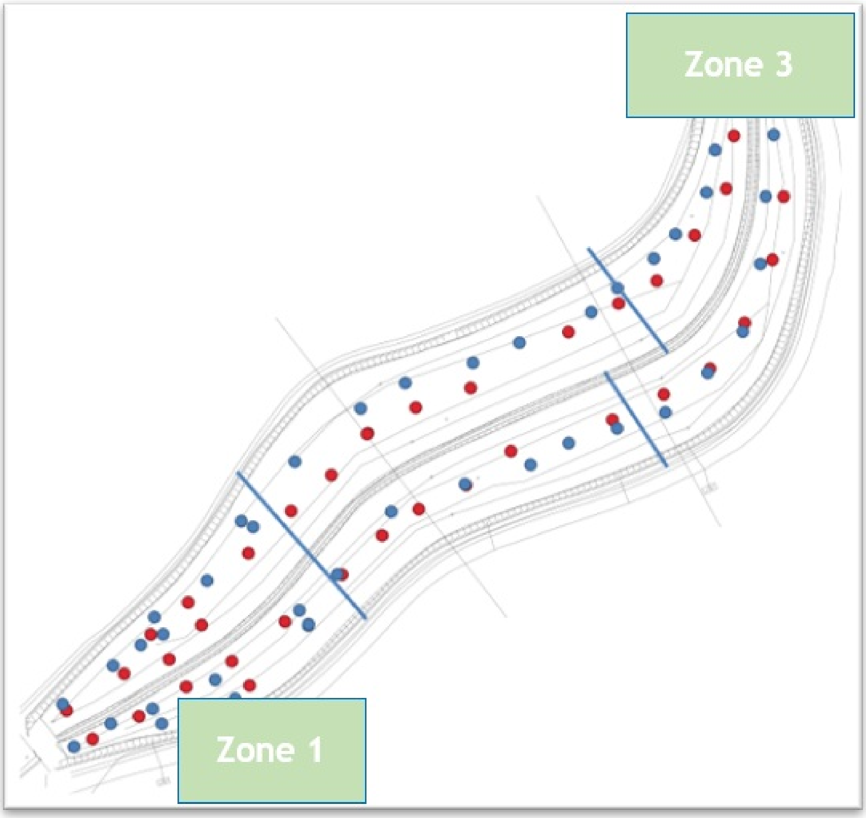


Surface accumulation (**mg/m²/year**) of OMPs on the scale of RBFs

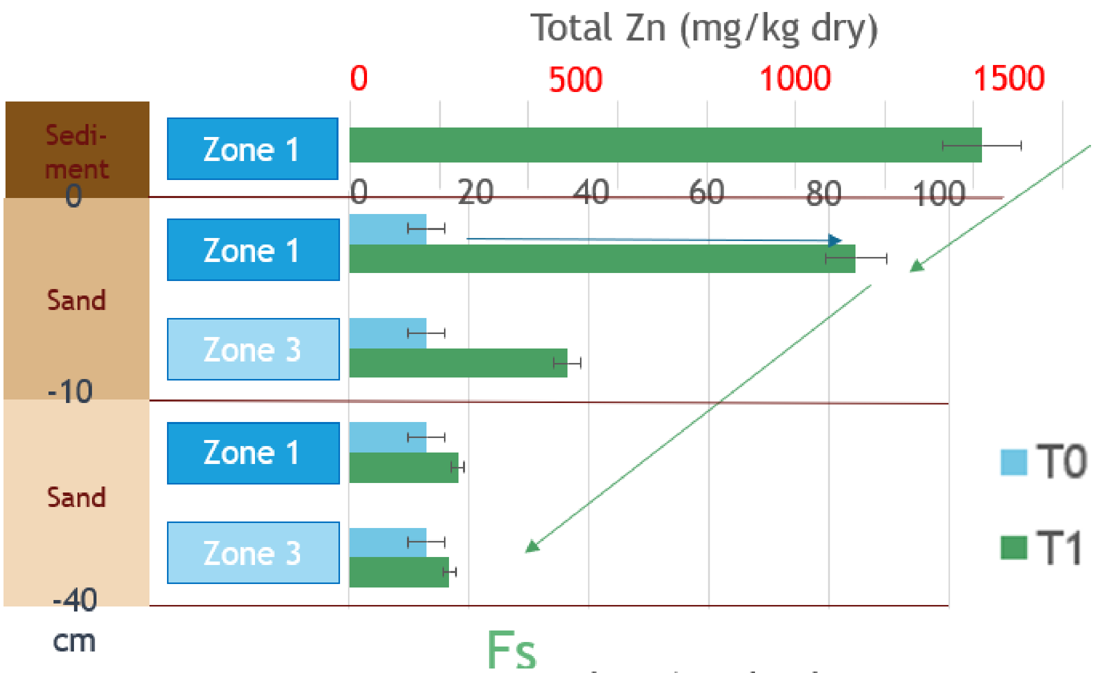
Vertical profile evaluation of zinc

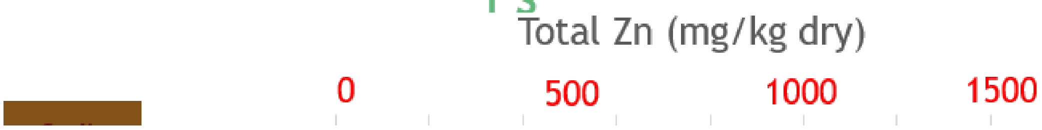
Zinc concentrations increased from one year to the next.

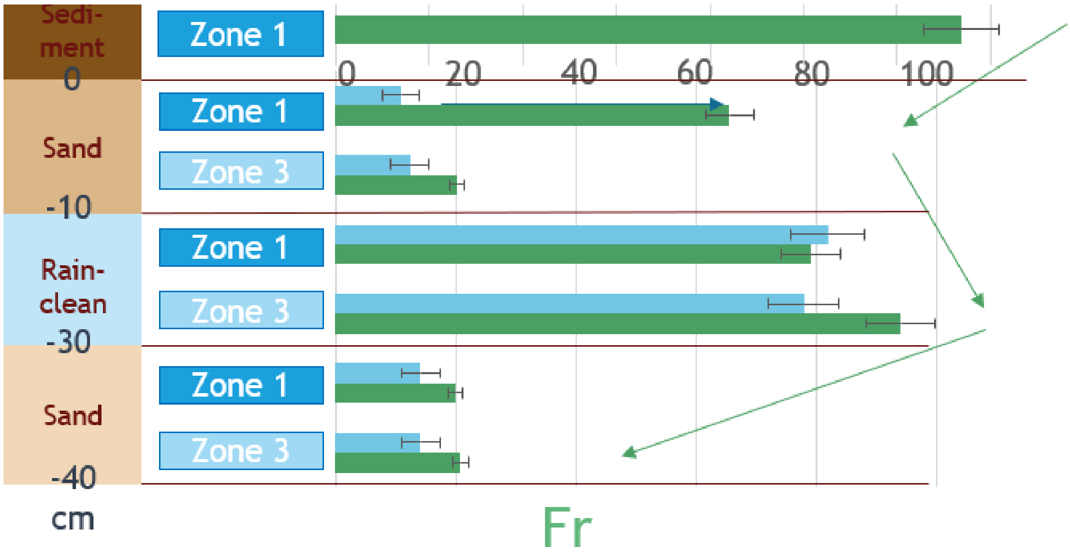
In terms of spatial distribution, the results show that after one year, most of the zinc is retained in zone 1, close to the water supply point, in both filters.



As for the vertical distribution, in the reference filter (Fs), a rapid decrease in concentrations was observed after the first 10 centimetres of depth. In the innovative filter (Fr), although the initial zinc concentration was higher in the surface sand, after one year it was close to that of the reference filter. This suggests that this metal is mainly retained in the surface layer of sand.







Finally, it is clear that the highest concentrations are found in the surface sediment, which is consistent with the well-established fact that metals are strongly adsorbed onto suspended matter, which is trapped by the first layer of sand.

Accumulation of pollutants after 2 years of monitoring

Julia Roux's results

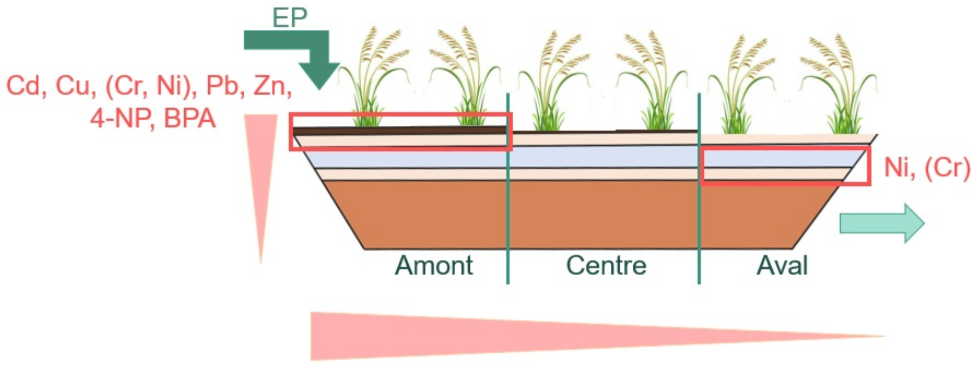
Thesis: Fate of micropollutants in a reed filter treating road runoff - Importance of microbial communities

Retention processes were assessed by studying the accumulation of micropollutants (MP). The heterogeneous water loads led to a spatial heterogeneity of contamination, with most of the micropollutants accumulating on the surface and upstream, in the surface sediments and sand. This reflects rapid trapping of the micropollutants, followed by low mobility, with the exception of chromium (Cr) and nickel (Ni), which tended to accumulate downstream and at depth, due to greater remobilisation by the water during dry periods.

The results showed that sedimentation and particle filtration were the dominant retention processes. Adsorption of organic micropollutants (OMPs) in sediments was also demonstrated, and was linked to hydrophobic interactions associated with high concentrations of organic carbon (Corg) in sediments.

Trace metals (TMEs) showed greater accumulation than organic *micropollutants, with 4-NP predominating.*

Finally, over a two-year period, filter-scale accumulation was similar, indicating a limited impact of Rainclean©, although local differences were observed. The water quality data will allow us to conclude whether a retention effect is present and whether the purification efficiency is improved in the RPFs, although a longer period is needed to fully assess its impact.



Julia Roux Thesis : "Fate of Micropollutants in a reed bed filter Road Runoff – The Role of Microbial Communities"

Filtering Polluted Water with Reeds: A Natural Solution Tested in Paris

What if plants could help clean up our cities? This is the idea explored by Julia Roux in her doctoral thesis, defended on January 31, 2024, at the LEESU laboratory (Université Paris-Est Créteil). Her research focuses on an innovative solution to treat urban runoff: **constructed wetlands planted with reeds**, known as *reed bed filters* (FPR).

The Challenge: Urban Micropollutants

Every time it rains, streets wash a cocktail of **micropollutants** into stormwater systems: trace metals (cadmium, lead, zinc...), hydrocarbons, bisphenol A, and phthalates. These contaminants end up in aquatic environments, threatening biodiversity and water quality.

The Tested Solution: Vegetated Filters

On a pilot site in the **Bois de Boulogne, Paris**, two reed bed systems were compared:

- A **conventional filter**, made with sand.
- An **innovative filter**, enhanced with adsorbent materials and planted with **Phragmites australis** (common reeds).

These filters remove pollutants through natural processes such as **sedimentation, filtration, adsorption, and most importantly microbial biodegradation**.

Promising Results

After two years of monitoring:

- Micropollutants were efficiently trapped at the surface and upstream of the filters.
- **Microorganisms** developed within the substrates and contributed to pollutant breakdown, particularly in sediment layers.
- The presence of plants proved crucial: they enhance microbial activity and speed up the biodegradation of compounds like BPA and 4-nonylphenol.

A Path Toward Greener Cities

This research, conducted as part of the **European Life ADSORB project**, confirms the potential of reed bed filters to **manage stormwater in an ecological and decentralized way**. Julia Roux recommends regular monitoring of pollutant buildup in substrates and suggests that the plants can be **reused as green waste** at the end of their cycle.

Applied research that bridges ecology, urban planning, and microbiology — and shows that even reeds can be powerful allies in the ecological transition.

Hydraulic performance

As part of the LIFE ADSORB project, co-funded by the European Union, a prototype system for treating
stormwater runoff from the Paris ring road was installed in the Bois de Boulogne. This report (B2.2) provides an analysis of the system's hydraulic performance over a period of two and a half years (May 2021 to December 2023).

The system is composed of three main components: a storm overflow

The system is composed of three main components: a storm overflow structure (P115), a pumping station, and a reed bed filter divided into two compartments. One compartment (F1) contains a conventional sand substrate, while the other (F2) includes an innovative adsorbent material called Rainclean®. The compartments are fed alternately to allow each to rest between operational phases.

A comprehensive instrumentation system was implemented to continuously monitor flow rates, water levels, rainfall, and water quality. All data were collected and centralized using the GAASPAR monitoring platform of the City of Paris.

The analysis shows that the system generally operated as intended, although several adjustments had tobe made during the study:

- • Adjusting pump activation thresholds based on dry or wet weather conditions.
- • Reducing the drainage delay time and increasing pumping rates to prevent malfunctions.
- • Detecting water transfers between compartments due to leaks in the central berm.

Volume measurements revealed that the system was used more often in dry weather mode (62% of the pumped volumes), and that compartment F2 was slightly more frequently used. However, notable discrepancies were found between inflow, pumped, and outflow volumes—attributed to measurement uncertainty and internal leaks.

Lastly, the report highlights the impact of climatic variations—especially the dry year 2022—on system behavior. Seasonal analysis indicates greater hydraulic activity during the summer months, in line with higher recorded rainfall during that time.

 For more information, please refer to the full report available in the section Modelling and optimising operations | LifeAdsorb (https://life-adsorb.eu/en/modelling-and-optimising-operations)

Modelling

The modelling present work carried out within the LIFE ADSORB project to simulate and analyze the hydraulic behavior and micropollutant transport in two constructed wetlands designed for stormwater management. The main objective was to develop a robust numerical model capable of capturing the complexity of water flow and contaminant dynamics under varying weather and operational conditions.

The modelling platform was built using COMSOL Multiphysics, supplemented by custom MATLAB scripts to address specific features such as surface water flow and underdrain hydraulics. The two filters studied differ in their filtering media: Filter 1 is composed solely of sand, while Filter 2 includes a reactive layer (Rainclean®) between two sand layers, designed to enhance micropollutant adsorption.

To calibrate and validate the model, tracer tests were conducted under real field conditions, in both dry and wet weather operation modes. These experiments revealed significant heterogeneity in flow patterns, including preferential pathways and stagnant zones, particularly in the absence of a well-distributed inlet or a sufficiently dimensioned drainage network.

Simulation results showed that micropollutants are better retained in Filter 2 due to the presence of Rainclean®, but also highlighted a risk of desorption when the system receives cleaner water during dry periods. Simulations alternating between dry and wet weather confirmed a cyclical adsorption/desorption pattern, with implications for the long-term efficiency of the filters.

The study emphasizes the importance of uniform inflow distribution and properly sized drainage to optimize the use of the filter surface and reduce dead zones. Recommendations include avoiding abrupt changes in inflow pollutant concentrations and improving design features to maintain micropollutant retention performance over time.

▯ The numerical model is available for download on the project website Modelling and optimising operations | LifeAdsorb (https://life-adsorb.eu/en/modelling-and-optimising-operations)

Cost-effectiveness analysis

The stormwater treatment system using a FPR (Filter Percolation Reactor) enhanced with an adsorbent material layer for the retention of dissolved micropollutants is a low-tech and promising solution, as it offers both robustness and high performance compared to other conventional approaches.

The economic viability of this system has been investigated and compared with other technical solutions for the quantitative and qualitative management of stormwater that fulfill similar functions.

More specifically, the approach developed in this study enabled a comparison —for similar treatment efficiency (for both major pollutants and micropollutants)—of the investment (CAPEX) and operating (OPEX) costs between the FPR system with a specific adsorbent substrate and more conventional stormwater management and treatment systems such as storage basins with enhanced sedimentation.

Under the implementation conditions detailed in the document, the FPR system proves to be the most advantageous in terms of both investment and operational costs for standard major pollutant removal objectives. Its economic benefit is even greater for micropollutants, since it only requires the addition of a supplementary layer within the filtration substrate. However, the operating costs (mainly due to replacement of the adsorbent) may exceed those of some other intensive micropollutant treatment processes, depending on the quality of water treated and available studies.

The study also focused on a techno-economic comparative analysis of various adsorbent materials examined within the project. Depending on the targeted pollutants, this analysis helps identify—on a case-by-case basis—the most technically (performance and minimal volume) and economically (CAPEX/OPEX) effective material, whether used in an FPR system or not.

Both investment and operating economic performance is optimized by using materials offering a broad spectrum of micropollutant removal, particularly those composed of multiple adsorbent substances, with performance increasing proportionally to their activated carbon content.

 To lean more, consult the full report available the section Socio-economic impact assessment | LifeAdsorb (https://life-adsorb.eu/en/socio-economic-impact-assessment)

Rainclean® Testing

The project focuses on evaluating the adsorption performance of **Rainclean®**, a filtering media used in reed-bed filters, to retain micropollutants from road runoff, especially heavy metals and certain organic compounds (BPA, alkylphenols).

Two main testing methods were used:

- **Batch tests** to determine adsorption kinetics and isotherms.
- **Column tests** to simulate field-like flow conditions and saturation.

Three filter substrates were tested: **Rainclean®**, sand, and site-collected sediment. Rainclean® showed promising adsorption capacity, particularly for metals (Zn, Cu) and organic pollutants, though its heterogeneous nature led to variability in results.

Modelling tools (Hydrus-1D, STANMOD) were employed to calibrate adsorption and transport parameters, which are critical for predicting the long-term performance of the LifeAdsorb reed-bed filter prototype.

□ To lean more, consult the full report available the section [Sizing tool | LifeAdsorb (https://life-adsorb.eu/en/sizing-tool)]

Innovative filters for stormwater: efficiency, retention, and biodegradation

Monitoring and Analysis Summary

From February 2024 onward, the filters were supplied with runoff water and infiltration water collected within the storm overflow basin. Flow rates were monitored under both dry and wet weather conditions (in the collector, upstream, and downstream of the filters).

From September 2022 to March 2025, representative composite samples were collected during dry and rainy periods. These were analyzed for the following parameters:

- **Global physico-chemical parameters:** TSS, pH, conductivity, TOC, COD, nutrients, and indicator bacteria
- **Trace metals:** Cd, Cr, Cu, Ni, Pb, and Zn
- **Organic micropollutants:** hydrocarbons, PAHs, BPA, alkylphenols, and phthalates (with distinction between dissolved and particulate phases)
- **Sedimentation and ecotoxicological tests:** suspended solids settling tests and *Daphnia sp.* assays

Why monitor these parameters?

- **Global physico-chemical parameters** assess overall water quality. They provide information on particle load, mineralization, organic matter, nutrients responsible for eutrophication, and microbiological contamination from natural, domestic, agricultural, or industrial sources.
- **Trace metals** are persistent and often toxic inorganic pollutants. They mainly originate from industrial activities, urban runoff, fertilizers, or material corrosion, and can accumulate in living organisms.
- **Organic micropollutants** come from petroleum products, plastics, detergents, or combustion. Even at very low concentrations, they can be endocrine disruptors or carcinogenic. Their disscolved fraction is bioavailable, whereas the particulate fraction is bound to suspended solids.

Sediments and Substrate

Monitoring showed that sediments act as the main reservoir for particles and pollutants, followed by the upper sand layer. The aerial parts of reeds (*Phragmites australis*) accumulated very little metal (0.01–0.3% of the total stock) but a more notable share of emerging organic micropollutants (up to 4.8%).

Over roughly 3 years (Dec 2020–Oct 2023), the filters retained about **10.4 tons of particulate matter (≈4 t/year)**, corresponding to the following annual pollutant loads:

CD	CR	CU	NI	PB	ZN	BPA	OP	NP
27 g	3.94 kg	7.36 kg	4.40 kg	2.97 kg	17.03 kg	3.5 g	1.7 g	51.3 g

Both substrates showed similar retention efficiency, indicating no added particulate retention value of Rainclean© compared with sand.

Biodegradation Experiments

Biodegradation tests showed that organic micropollutants were mainly removed through biotic processes (68-92,5%) , with rapid degradation within the first 10 days.

- **BPA** degraded fastest (DT_{50}: 2.3–4 days)
- **4-NP** and **4-OP** had longer half-lives (2.5–15.6 days and 4.8–13.6 days respectively)

Rainclean© performed **better than sand**, except for BPA under planted conditions.
Sediments showed degradation rates comparable to Rainclean©, except for BPA (DT_{50}: 21.7 days).

The presence of *Phragmites australis* enhanced degradation, particularly in sand filters.

All substrates hosted microbial communities capable of degrading OMPs, thus reducing the risk of accumulation. However, sediments and unplanted Rainclean© retained more OMPs due to their adsorptive properties, which could lead to long-term accumulation risks.

Water Phase

Monitoring of the liquid phase revealed **high treatment efficiency (median values)** for many pollutants:

Very high (≥90%): TSS (99%), Pb (99%), Cr (98%), Zn (98%), Cu (97%), Ni (90%), PAHs (92%)

Moderate (40–75%): NH_4^+ (73%), NP (69%), BPA (64%), hydrocarbons (61%), TKN (60%), DEHP (56%), Cd (39%)

Low (<30%):
Total P (24%), TOC (25%), NO_3^- (7%)

Negative: PO_4^{3-} (-73%) and phthalates, likely due to leaching from prototype materials (geomembranes, bitumen, drains).

No significant difference was observed between sand and Rainclean© filters.Upstream tests confirmed a strong **natural settling potential** of stormwater.

Annual Mass Balance

The filters prevented the following pollutant quantities from being discharged into the receiving environment:

- **TSS:** 6–23 t
- **Metals:** Zn = 26–61 kg; Cu = 8–23 kg; Pb = 2–8 kg; Cr = 1.5–4 kg; Ni = 0.8–4 kg
- **PAHs:** 11 kg
- **Hydrocarbons:** 590 g
- **NP:** 127–422 g
- **Cd:** 30–50 g; **DEHP:** 16 g; **BPA:** 2–34 g; **OP:** 2–14 g

Influent waters did not show significant toxicity; therefore, no clear conclusion could be drawn regarding a possible reduction in overall toxicity (at least according to *Daphnia* assays and the measured parameters). However, despite the absence of acute toxicity differences between influent and effluent, further studies are needed to assess long-term chronic effects of low-concentration chemical mixtures on this key aquatic species.

Points for Improvement

The project experienced delays from the start, mainly due to implementation issues at the site. This initial difficulty affected the entire project timeline.

Due to extensive maintenance work and the need to analyze sampler malfunctions, a large part of the monitoring was delayed. Consequently, most sampling occured only in late 2024 and early 2025. The monitoring campaign was therefore less effective than initially planned: in total, only 19 events (dry and wet weather) were monitored for both filters, due to various technical and operational issues (overflow between filters, berm rupture, clogging, effluent flow through aeration chimneys).

No monitoring of the porous plates on filter n°2 could be performed. The installation of this device faced numerous technical difficulties, making its regular operation very complex. Moreover, the required hydrological conditions—specifically, sufficient rainfall to supply filter n°2 were not always met, which strongly limited monitoring possibilities.