LIFE ADSORB PROJECT
2018 - 2025

OPTIMIZING STORMWATER MANAGEMENT IN PARIS WHILE PRESERVING BIODIVERSITY

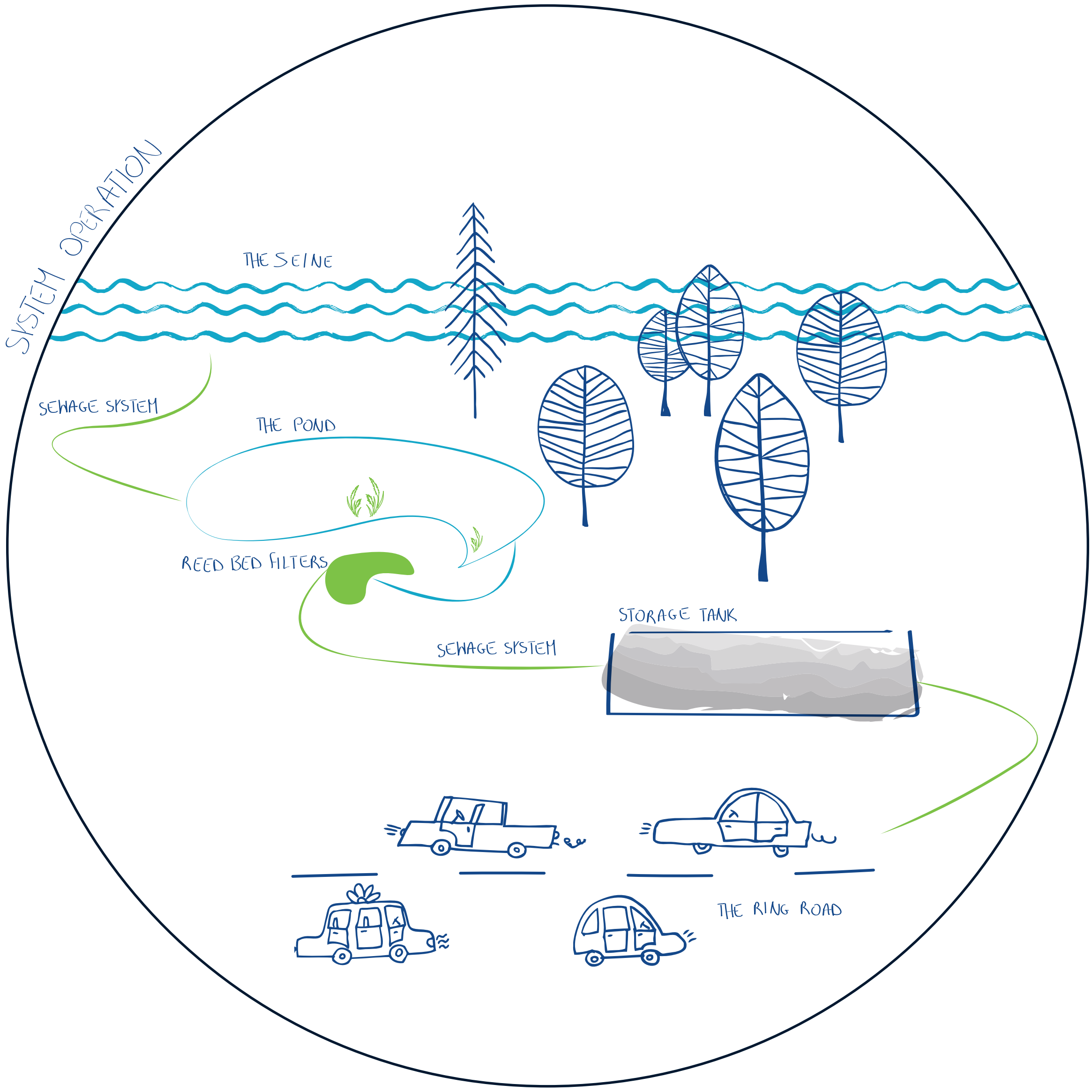
CONTEXT

Rainwater falling on a section of the western ring road (boulevard périphérique ouest) in Paris flows along the roadway before being collected and conveyed to the Bugeaud storm overflow, located in the 16th arrondissement. This runoff is heavily loaded with suspended solids, to which macropollutants (such as carbon-based organic matter) as well as micropollutants are attached, notably metals and chemical residues originating from vehicles, road surfaces, and air pollution. Some of these pollutants are also present in dissolved form, unbound to particles.

In addition, the network may receive, to a lesser extent, water from a combined sewer catchment area, and it also transports, throughout the year, infiltration water from groundwater.

Before the project was implemented, this stormwater was discharged directly into the Seine without any treatment. To comply with current regulations, **a pretreatment system was introduced in the form of two reed-planted filters.**

This choice draws on the experience of three similar projects, helping to optimize filter design, material selection, and the overall efficiency of the system.



PROJECT OBJECTIVES

Implement and demonstrate an innovative solution to...

- **Effectively reduce the pollutant load of stormwater** discharged into the natural environment
-Treat organic and mineral micropollutants originating from urban runoff
-Target contaminants such as trace metals, suspended solids, hydrocarbons, phthalates, alkylphenols, and perfluorinated compounds
- Conventional pollution control systems perform poorly in addressing dissolved-phase contamination: **LIFE-ADSORB project will fill this gap.**

Build, Share, and Act

Integrated into a protected wooded area, a true reservoir of biodiversity, the project also aims to:
- Reconcile the management of contaminated stormwater with the preservation of natural heritage and biodiversity

A nature centered project

LIFE-ADSORB will contribute to:
- Enriching the knowledge base on stormwater treatment
- Designing a solution adaptable to existing infrastructures
- Meeting the needs of diverse territories: rural, dense urban, and industrial areas

Operational tool

The project aims to create:
A new tool available for **the design of innovative structures** enabling the sustainable improvement of water quality

THE DEMONSTRATOR

The demonstrator consists **of two reed-planted filters** with vertical flow, covering an area of 1100 m^2. Water infiltrates vertically through substrate layers, retaining and degrading pollutants.

Filter n°1, used as a reference, is composed only of sand and gravel. **The second filter incorporates a layer of Rainclean©, an adsorbent material targeting pollutants** such as heavy metals and hydrocarbons. A system of drains and ventilation ensures the collection and aeration of the treated water.

Both compartments operate alternately every 29 days, allowing a resting period favorable for biological regeneration and limiting clogging. The supply is done by batch feeding to promote oxygenation.

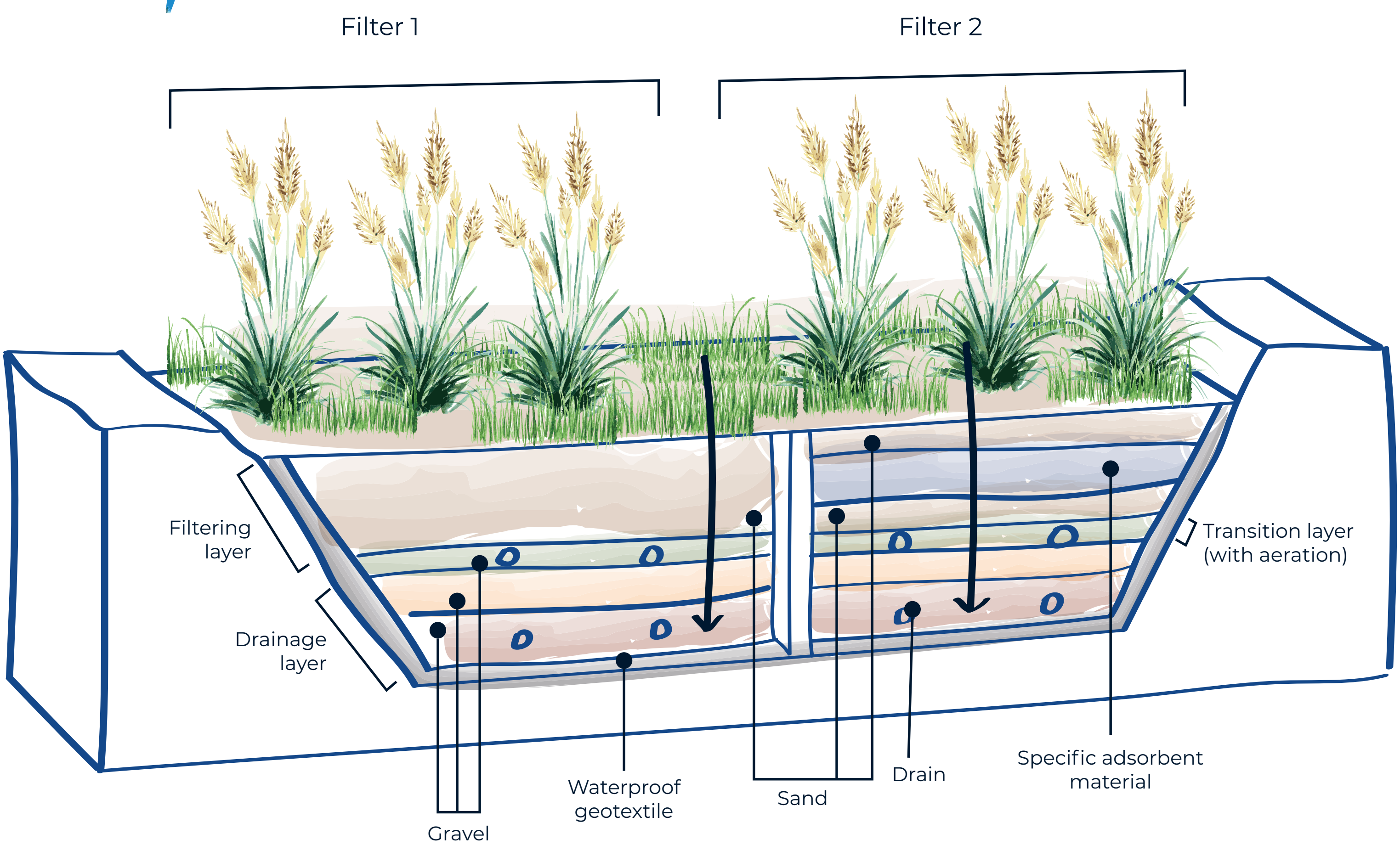
T**he treated water is then discharged into the Saint James River**, and then flows towards the ponds of the same name.

Two types of instrumentation are installed on site: one is used to monitor and regulate water flow, the other to check water quality.

Since filter supply cannot be done by simple gravity, **a pumping station was built to improve storage capacity (3500 m^3) and the water supply to the filters.**

To facilitate site operation, the system has been automated, enabling remote control. All data are transmitted to the supervision center of the Paris sanitation network, called GASPAAR.

For more information, visit our website by scanning the QR code.



FROM THE RING ROAD TO THE SEINE: THE DEPOLLUTION OF STORMWATER

1. Rainwater from the ring road flows through the spillway to the storage station
2. The stored water is then pumped to the reed bed filters
3. The water arrives at the filters and passes through it to be purified
4. The purified water flows into the river, which then feeds into the Saint-James pond
5. The overflow from the pond is directed
6. The treated water flows into the River Seine

UNDERSTANDING FILTER PERFORMANCE THROUGH TRACER TESTS AND NUMERICAL MODELS

Tracing: Tracking the Path of Water in Filters

Tracing involve injecting a harmless chemical tracer (amino-G acid) into the water entering the filters. By then measuring the tracer concentration at the outlet over several hours or even days, researchers **can reconstruct the path of the water inside the filter.**

This method makes it possible to identify:

-Dead zones, where water circulates little or not at all.

-Preferential pathways, where water flows too quickly without being effectively filtered.

The results show notable differences between the two filters tested:

-Filter 1 (filled only with sand):Irregular flow. The tracer exits quickly, indicating that the filter volume is poorly utilized and filtration is inefficient.

-Filter 2 (with a layer of Rainclean® adsorbent material): The tracer is partially retained, demonstrating good pollutant adsorption capacity.

Numerical Models: Exploring What Remains Invisible

To deepen the analysis, scientists developed a 2D numerical model using COMSOL Multiphysics® and MATLAB. This model makes it possible **to simulate : the flow of water through the different layers of the filter,** the movement, attachment, and release of pollutants.

Using data from the tracer tests, the model was calibrated and then used to test various scenarios, such as: rainy or dry conditions,homogeneous or irregular water flow,the presence or absence of adsorbent materials.

Key Findings of the Project

The simulations and tests made it possible to draw several important conclusions:

A uniform distribution of water across the entire filter surface significantly improves its efficiency. Filter 2, enhanced with adsorbent material, retains pollutants more effectively, but it can also release them if the water suddenly becomes very clean.

Certain areas of the filter (notably at the inlet) are underutilized, while others are overloaded, which can negatively affect overall performance.

The combination of tracing and numerical models provides a powerful tool for optimizing filter design and operation. It allows for a better understanding of internal dynamics and helps propose solutions to improve the management of polluted urban stormwater.

RAINCLEAN AGAINST POLLUTANTS: TEST RESULTS

To evaluate the effectiveness of Rainclean® in removing pollutants typically found in urban stormwater, **laboratory tests** were conducted to draw conclusions.

For this purpose, effluents were prepared to replicate the composition of contaminated urban rainfall with pollutants. They contained metals (zinc, copper, lead, nickel, etc.), suspended solids (SS), as well as hydrocarbons and other organic molecules, at concentrations representative of levels observed in the field.

Batch tests showed that **the media effectively adsorbs micropollutants,** with rapid adsorption followed by saturation, and provided the parameters necessary to design column tests.

Column tests aim to simulate field conditions while controlling parameters. Different hydraulic regimes were tested to best represent on-site conditions. Analyses were conducted at both the inlet and outlet of the columns.

Rainclean® captures metals very effectively (often >90% removal under laboratory conditions).
It performs well even at high flow rates, which is important during heavy rainfall.
Its performance decreases once the material becomes saturated, indicating that it needs to be replaced after a certain period of use.

FURTHER EXPLORATION: TESTS ON OTHER MATERIALS

Just like the tests on Rainclean®, both batch and column tests were conducted.
The study followed an experimental protocol combining **batch and column tests** to evaluate the adsorption capacities of five materials (Rainclean®, Urbanclean®, zeolite, biochar, activated carbon) for trace metals (Cd, Cu, Ni, Pb, Zn) and organic micropollutants (BPA, NP, OP).

The batch test determines the adsorption isotherm parameters, compares the materials, and includes a leaching test (material alone in clean water) to check for the potential release of pollutants. The column test is used to simulate what happens in the filter.

TRACE METALS AND ORGANIC COMPOUNDS: WHICH MATERIALS PERFORM BEST?

-**Rainclean® and Urbanclean®** show **good adsorption performance for metals and organic micropollutants,** with Urbanclean® being more effective due to its higher activated carbon content.
-**Activated carbon** has a **very high adsorption** capacity for both pollutant types, but cost and availability may limit its large-scale use.
-**Biochar** has **intermediate performance**, particularly effective for certain metals but more limited for organic pollutants.
-**Zeolite** shows notable adsorption for certain metals (especially Zn) but low performance for organic pollutants.

Column tests proved essential for obtaining realistic parameters usable in filter design (ORAGE software), unlike batch tests alone, which tend to overestimate material performance and lifespan.

The simplified protocol (10 cm of material, reduced duration, limited number of samples) allows a reliable comparative evaluation while remaining accessible to industrial users.

GO FURTHER: ORAGE SOFTWARE INCLUDES MICROPOLLUTANTS

The ORAGE software, developed by INRAE, helps design reed-bed filters for treating stormwater and combined sewer overflows. As part of the LIFE ADSORB project, it has been enhanced with a specific module to simulate the behavior of micropollutants (both metallic and organic) in these filters.

Module objective

Assess the capacity of filters to retain or remove micropollutants.

Test different configurations (surface area filters, height, and type of adsorbing material).

Estimate the service life and performance of the adsorbing material.

Results provided

Inlet/outlet concentrations over one year.

Loads of micropollutants supplied and retained.

Saturation rate of the adsorbing material.

Graphical visualizations
(box plots, summary tables).

Target

Trace metals and organic compounds, extendable to other pollutants if data are available.

Simulated processes :
adsorption/desorption, biodegradation (organics), and particle capture (~80%).

"A SIMPLE TOOL TO ANTICIPATE TREATMENT PERFORMANCE, OPTIMIZE DESIGN, AND REDUCE MAINTENANCE COSTS, WHILE IMPROVING THE MANAGEMENT OF URBAN DISCHARGES DURING RAINFALL EVENTS."

The software and its user guide are available for download on the website https://life-adsorb.eu/deliverables (Deliverables B3)

EVALUATION OF THE QUALITY OF EFFLUENTS TREATED BY THE FILTER

Reed-bed filters provide significant treatment capacity for a wide range of pollutants present in stormwater. **Trace metals, such as copper** (Cu), zinc (Zn), lead (Pb), and nickel (Ni), **are particularly well retained, with average reductions ranging from 60 to 90%.** These results reflect the combined effectiveness of physical filtration, sedimentation, and adsorption processes. **The analysis did not demonstrate that the filter incorporating Rainclean® performs better than the conventional design filter (filled with sand).**

For **organic compounds** such as bisphenol A (BPA), nonylphenol (NP), and octylphenol (OP), **removal rates generally exceed 70% and can occasionally reach more than 90%**, depending on hydraulic conditions and pollutant load. However, some variability is observed: certain organic pollutants do not achieve the same removal efficiencies as the compounds mentioned above. **The system is therefore more effective for metals than for organic compounds.**

For suspended solids (SS), reductions are around 80%, confirming the filter's capacity to effectively trap solid particles.

Due to the heterogeneity of concentrations observed **for organic micropollutants, environmental quality standards associated with achieving good water body status are not met.** By itself, this type of system does not allow compliance with the level of treatment required under European regulations.

Regarding **microbiological quality**, measurements indicate that concentrations of Escherichia coli and intestinal enterococci meet, in approximately **80% of cases, the thresholds set by the European Bathing Water Directive.**

Overall, these results confirm that this type of system provides a robust and versatile solution for reducing stormwater pollution, while offering some flexibility to adapt to local contexts and specific environmental objectives.

More information is available on the website: https://life-adsorb.eu/deliverables/ (Deliverables C1)

TREATMENT PERFORMANCE OF THE FILTER BASED ON SEDIMENTS

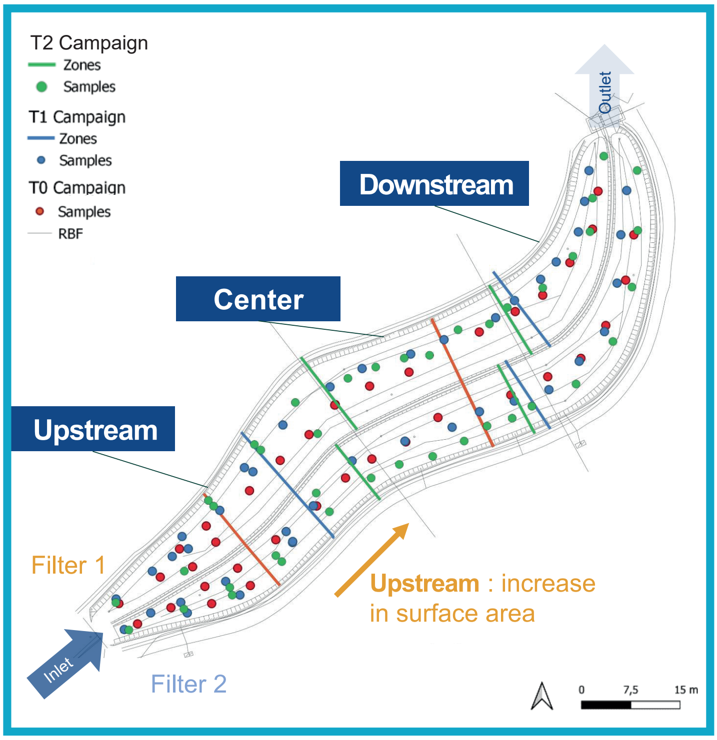
The analysis of sediments collected in the filters highlighted significant pollutant **accumulation, particularly concentrated in the surface layers of the substrate and in the inlet zone of the systems.**

Trace metals, notably zinc (Zn), copper (Cu), and lead (Pb), show markedly lower concentrations downstream, confirming their effective retention upstream in the filter beds. Total hydrocarbons and certain organic micropollutants follow the same trend, with maximum concentrations in the first few centimeters.

Vertical distribution shows that the majority of particles and contaminants are trapped at the surface, with concentrations gradually decreasing with depth. This stratification reflects the effectiveness of mechanical filtration and adsorption in the upper layer.

Performance varies depending on the type of filter: those incorporating Rainclean® adsorbing material exhibit higher concentrations of metals and hydrocarbons in surface sediments, indicating enhanced capture compared to a conventional filter (sand-only).

In terms of management, these results highlight **the importance of regular maintenance by cleaning the surface layer** to prevent hydraulic clogging and avoid resuspension of trapped pollutants.



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BIODIVERSITY AT THE HEART OF THE PROJECT

As part of the LIFE ADSORB project, an in-depth biodiversity study was conducted at the Bois de Boulogne (Paris) before the installation of an experimental filter designed to treat stormwater runoff.

This initial phase, referred to as the **“baseline”,** aimed to assess the soil and environmental characteristics prior to construction, providing a reference to evaluate later the effects of the filter’s presence.

The site was divided into three distinct zones: the filter zone, where the treatment system will be installed; the construction zone, reserved for machinery during works; and the control zone, which will remain untouched and serve as a reference for assessing the project’s environmental impact.

Analyses focused on various aspects of the site, **including soil physical and chemical characteristics,** aboveground and belowground biodiversity, among others. The study found that the site’s soil is mostly sandy, although some areas—particularly near roads—show greater compaction or signs of contamination. Pollution by trace metals such as lead and zinc, as well as hydrocarbons, was noted near roadways. **Soil biological activity, measured through enzyme activity, was higher in the wooded area corresponding to the control zone.** Overall biodiversity across the site was low and dominated by common species, and no protected species or habitats of particular ecological interest were identified.

This diagnostic phase provides a valuable reference baseline to assess, in subsequent project phases, the environmental impacts of the filter once installed and operational.

Following the baseline monitoring, a “time zero” assessment was conducted to evaluate the construction’s impact on the environment, serving as a reference point to measure the filter’s effectiveness over the coming years. Samples were collected in 2020 from soils, water, and fauna (earthworms and small crustaceans called gammarids). Results confirmed that **the construction did not generate major pollution**, but the filter itself still needed time to develop into a functional ecosystem.

After several years of operation, analyses indicate that the filter evolves over time and begins to exhibit characteristics of a natural soil. It effectively traps pollutants without releasing harmful substances into the nearby river. Contamination levels remain low, and no major toxic effects were observed on fauna.

In conclusion, **the filter appears to be an effective and environmentally friendly** solution for reducing urban water pollution before discharge into natural water bodies.

More information is available at: https://life-adsorb.eu/deliverables/ (Deliverables C2)

LIFE CYCLE ANALYSIS OF THE FILTERS

What it is and why it is useful?

A life cycle analysis (LCA) is a method **used to assess the environmental footprint of a product**, service, or process. It involves tracing all stages of its "life," from the extraction of raw materials needed for its production, through transportation and use, to its end of life (recycling, reuse, or disposal).

The objective is to obtain a comprehensive view of environmental impacts, including energy and water consumption, greenhouse gas emissions, air and soil pollution, and the use of natural resources.

From Analysis to Action: What LCA Reveals

Life Cycle Analysis (LCA) shows that **the most significant environmental impacts occur mainly during the manufacturing phase,** due to the production of materials and components, as well as during the use **phase, related to energy consumption.**

To reduce this footprint, several action levers emerge: optimizing material selection, **reducing energy consumption, and improving end-of-life management of products, particularly through recycling and recovery.**

Beyond its diagnostic role, LCA proves to be a valuable decision-support tool, allowing the comparison of different solutions and guiding choices toward the most sustainable options.

In summary, LCA identifies the most impactful stages and provides concrete guidance for designing, using, and managing products in a more environmentally responsible way.

Strengths and Weaknesses of Life Cycle Analysis

The life cycle analysis conducted has several limitations that should be kept in mind when interpreting the results.

First, the lack of experience regarding the end-of-life of this type of filter requires working with sometimes uncertain assumptions, such as systematically sending substrates to hazardous waste disposal centers, which may overestimate impacts. Similarly, the actual service life of the system remains poorly documented and could be under- or overestimated.

Furthermore, monitoring of water quality and volumes was limited, particularly during rainfall events. The low number of samples and differences in acquisition periods introduce uncertainties regarding the actual emissions released into the environment. **In addition, the calculation of annual pollutant loads is based on averages and modeled flows, which further increases these uncertainties.**

REED-BED FILTERS: AN ECOLOGICAL SOLUTION, A HUMAN CHALLENGE

Socio-spatial study

One aspect of the project involved studying how a reed-bed filter, installed in the Bois de Boulogne to treat polluted stormwater (notably from the ring road), is perceived and integrated by park visitors and the professionals responsible for its management.

From the visitors' perspective, the filter is largely invisible: it was deliberately integrated into the landscape to avoid altering the environment. As a result, few people notice it or understand its purpose, which prevents conflicts but also limits public awareness.

For professionals (municipal staff, researchers, technicians), the system represents an interesting innovation but also raises organizational questions. It is not always clear who is responsible for its maintenance or how to integrate it into routine practices. This highlights a lack of coordination among the various departments of the City of Paris involved in the project.

Overall, **the filter is well accepted because it is discreet, but its integration into daily use and long-term management still requires adjustments.**

The study emphasizes the importance of involving future users from the design stage and improving communication around this type of infrastructure.

Economy study

As part of the LIFE ADSORB project, this report evaluates the economic cost of an ecological solution for treating polluted urban stormwater: reed-bed filters (RBFs) enhanced with an adsorbing material designed to capture micropollutants (heavy metals, hydrocarbons, etc.).

The study compares this solution to more conventional systems, such as sedimentation basins with flocculation, commonly used in urban areas. The results show that reed-bed filters are more economical to build and maintain, while being equally or even more effective at treating certain pollutants.

The report also analyzes several specific materials to determine which are the most technically and economically efficient. Among them, UrbanClean® and Rainclean® stand out for their ability to capture a wide range of micropollutants.

In summary, **the RBF solution is simple, robust, and more cost-effective, especially when targeting hard-to-remove pollutants.** It is particularly advantageous when suitable land is available and can additionally provide environmental benefits such as greening, biodiversity enhancement, and mitigation of urban heat islands.

More information
Website URL: https://life-adsorb.eu/deliverables/
(Deliverable C3)

WHAT CHARACTERISTICS TO CONSIDER WHEN IMPLEMENTING THIS TYPE OF SYSTEM

Site selection

- Highly impervious urban watershed
- Chronic pollution (traffic, industry, urban activities)
- Stormwater network directed toward a single/semi-centralized point
- Technical accessibility and land ownership control
-Identified maintenance constraints

Stormwater management

- Even distribution at the inlet
- Safety overflow in case of heavy rain
- Supplementary irrigation system during drought

Vegetation

- Plants: Phragmites australis, Typha latifolia, Juncus / Scirpus / Carex
- Hardy species
- Maintenance: annual mowing, control of expansion

Technical design

- Vertical filters (preferably gravity-fed)
- Upstream buffer basin for sedimentation/regulation
- Screening / wire basket at the inlet
- Hydrocarbon sensors if treating road runoff
- Two parallel lines with alternating monthly operation/rest
- Waterproofing with geosynthetic liner
- Layers: drainage (20–40 mm), filtration (sand/pumice/zeolite), optional adsorbent layer

Quality and biodiversity

- System effective for conventional parameters and some trace metals (ETMs).
- Efficiency more variable for organic pollutants.
- System less suitable for use near a bathing area, given performance on microbiological indicators.
- No impact on biodiversity observed at the studied site.

Management and acceptability

- Consultation with elected officials, technical services, and local residents
- Landscape integration and absence of nuisances
- Communication on objectives and results

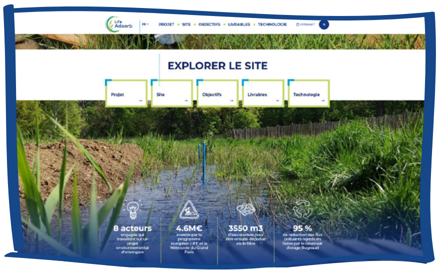
Monitoring and instrumentation

- Inlet/outlet samplers, flow-controlled
- Accessible sampling points
- Regular analyses (physico-chemical, micropollutants)

Adsorbent materials

- Trace metals (ETMs) only: Zeolite or Rainclean® depending on economic objectives
- ETMs + micropollutants: UrbanClean® (optimized option), activated carbon (maximum performance), biochar (sustainable alternative)

COMMUNICATION AND AWARENESS COMMUNICATION TOOLS



Website

A website presents the site, the project objectives, and the actions carried out. Visitors can also download publications and communication materials related to the project.

Communication leaflet

It was designed to raise awareness among both sector stakeholders and the general public. It highlights the key points to know about the pilot site and is also available in English.

Educational Panel

This panel aims to educate the public about the issues of stormwater pollution and to showcase the project implemented to address them.

COMMUNICATION AND AWARENESS

“ CURIOUS VISITORS EAGER TO LEARN MORE ”

Visits are organized on-site to present the prototype to local and international stakeholders. They provide an opportunity to share the project context, explain the filter's operation, showcase its specific features, and allow the public to see its appearance firsthand.

More information
Website URL : https://life-adsorb.eu

COMMUNICATION AND AWARENESS DISSEMINATION ACTIVITIES (CONFERENCES, SCIENTIFIC ARTICLES, PRESS ARTICLES, ETC.)

State of the Art of Triad-Based Ecological Risk Assessment: Current Limitations and Needed Implementations in the Case of Soil Diffuse Contamination

Giacomo Grassi[1*] Isabelle Lamy[1] Nicolas Pucheux[2] Benoit Jean Dominique Ferrari[3,4]
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Un filtre planté dans le bois de Boulogne : quelle intégration socio-spatiale d'un objet-frontière ?

A reed bed filter in Paris (bois de Boulogne): analysis of the social and spatial integration of a boundary object

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Étude présentée au 101e congrès de l'Association scientifique et technique pour l'eau et l'environnement (Astee) organisé à Dunkerque en 2022.

Life Adsorb (75) anticipe l'absorption des pluies fortes

PAROLE DE COLLECTIVITÉ

Afin de vous permettre de mieux appréhender la mise en place des projets de gestion de l'eau sur votre territoire, aquagir part à la rencontre d'**élus et de porteurs de projets qui sont passés à l'action**

Auparavant, au niveau du Bois de Boulogne, lors des orages et des fortes pluies, le réseau parisien n'était pas en capacité de récolter et d'acheminer toute l' **eau (https://aquagir.fr/tout-savoir-sur-leau/glossaire/eau)** vers les stations d'épuration. L'eau arrivait directement dans la Seine, ce qui était d'autant plus problématique qu'elle pouvait être polluée par la proximité du périphérique.

Désormais, grâce au projet Life Adsorb, l'eau est récoltée dans un grand réservoir et est filtrée avant de retourner dans le **milieu naturel (https://aquagir.fr/tout-savoir-sur-leau/glossaire/milieu-naturel)**. Le projet, de par sa complexité, nécessite des compétences importantes et des fonds financiers.

L'Union Européenne, l'Agence de l'Eau Seine Normandie et la Métropole du Grand Paris ont grandement participé à son financement.

Filtre en fonctionnement dans le Bois de Boulogne après une alimentation • Crédits photo : Ville de Paris

Throughout the project, its achievements were widely promoted through numerous presentations at national and international conferences, helping to increase its visibility and impact both in France and abroad.

In parallel, the project led to publications in the general press, raising public awareness, as well as scientific articles, demonstrating its recognition and relevance within the research community.

More information
Website URL: https://life-adsorb.eu/deliverables/ deliverables D1

CONCLUSION AND PERSPECTIVES

The project was successfully completed despite certain challenges, particularly the lack of analytical results on water quality at the start of the project. Nevertheless, it generated numerous valuable findings, **demonstrating the richness and relevance of this approach.** Beyond these initial insights, this innovative project opens promising prospects and deserves to be continued and further developed to **fully exploit its potential.**

The momentum initiated by this project does not stop at the experimental phase. **Continued monitoring of water quality** is necessary to consolidate results and **ensure the long-term sustainability of the system.**

At the same time, expanding the information available in the ORAGE software, along with training activities, will strengthen stakeholders' understanding and use of the tool. The project would also benefit from enhanced communication efforts to better showcase its results to partners and the general public.

Finally, developing on-site visits will provide an additional opportunity to share the acquired experience, disseminate best practices, and increase the visibility of this innovative initiative.

PARTNERS

FINANCIAL

This work was made possible thanks to the financial support provided by our partner, whom we sincerely wish to thank.

PROJECT PARTNERS

This multi-partner project brought together stakeholders from diverse backgrounds, fostering a rich and complementary collaboration that enabled the design, implementation, and monitoring of a truly innovative project.