

## COLLECTION AND TREATMENT OF RUN-OFF WATER FOR REUSE

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### Abstract

The world is currently facing a severe water crisis, exacerbated by climate change, which intensifies droughts and torrential rainfall, reduces infiltration, and increases urban run-off laden with pollutants. The main goal of this work (part of LIFE DrainRain project) was to evaluate the system implemented to treat stormwater collected under two contrasting scenarios: Ferrol (Galicia), characterised by frequent but low-intensity rainfall, and Calasparra (Murcia), where precipitation is scarce yet torrential. The interventions were carried out in the Port of Ferrol and on a road in Calasparra, where run-off could affect the estuary, shellfish harvesting areas, and agricultural environments vulnerable to contamination, respectively. The systems implemented includes porous photocatalytic pavement, a hydrodynamic separator, an activated carbon filter and a storage tank. Significant reductions in solids (80-100%), *E. coli* (100%), metals (75-100%) and organic compounds (over 80%) were achieved, enabling the treated water to be reused.

**Key words:** Sustainable Urban Drainage Systems, water reuse, urban runoff.

### 1 Introduction

Nowadays, we live in a severe water crisis worldwide. The climate change increases significantly droughts periods, climate change is significantly increasing drought periods, both in terms of duration and the temperatures reached [1], which leads to a reduction in the availability of freshwater in soils and rivers. Likewise, episodes of torrential rainfall are becoming more frequent. When these events occur over very dry soil, infiltration is extremely low, which increases surface runoff. Moreover, the growth of urbanization also contributes to the reduction of water infiltration. It is estimated that a 1% increase in urbanized area can lead to a 41% reduction in infiltration and a 100% increase in surface runoff [2], resulting in higher peak flows, increased flooding, and the expansion of diffuse pollution sources.

When rainfall events occur, especially after periods of drought, surface runoff carries solids and pollutants accumulated on urban and rural pavements. In cities, particles from tire wear, metals emitted by vehicles, oils and greases, as well as other organic compounds, gradually accumulate on road surfaces and surrounding areas. In rural areas, in addition to pollutants generated by road traffic, fertilizers and compounds used in agricultural activities can also be found. During rainfall events, these contaminants are washed away, substantially increasing the pollutant load of runoff water that eventually reaches rivers and seas.

In this context, Sustainable Urban Drainage Systems (SUDS) have emerged with the aim of increasing infiltration and improving water quality. In recent years, different systems have been developed, including green roofs, vegetated swales, permeable pavements, rain gardens, constructed wetlands, among others [3].

The LIFE DrainRain project has designed a modular SUDS system based on a porous photocatalytic pavement followed by different treatment stages (a hydrodynamic separator, an activated carbon filter and a storage tank) for stormwater treatment and storage to achieve reuse quality under different climatic conditions.

## 2 Materials and methods

### 1.1 Pilot description

The LIFE DrainRain system (Figure 1) was designed in a modular way, consisting of a porous photocatalytic pavement that enables water infiltration and capture, while also providing an initial treatment step for organic compounds degradation (such as polycyclic Aromatic Hydrocarbons (PAH), polychlorinated biphenyl (PCB), Pesticides) and microbial pollutants removal. Subsequently, a hydrodynamic separator and a prefilter was used to reduce the presence of large solids and removal grease and oil and remove fine solids, respectively; an activated carbon filter was included to remove heavy metals and remaining organic pollutants (PAH, PCB, pesticides), finally a storage tank was used for storing the treated water.

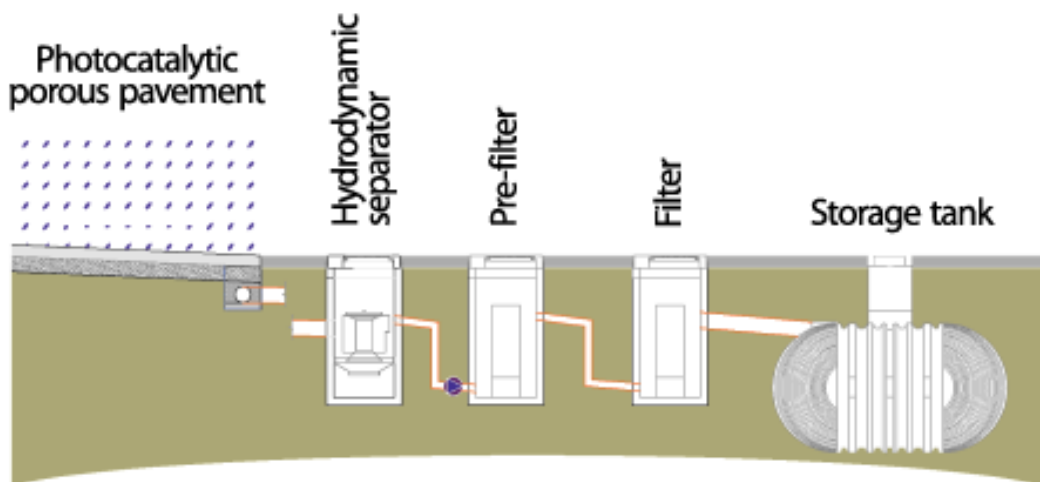


Figure 1. LIFE DrainRain system scheme.

The efficiency of the LIFE DrainRain system were evaluated by two pilots with different sizes. Firstly, the porous photocatalytic pavement was assessed with 900 m<sup>2</sup> and 150 m<sup>2</sup>, respectively. Subsequently, the active carbon filter and storage tank were sizing based on the flow treated and water pollution.

The performance of both pilots in rainy periods was evaluated taking runoff samplings weekly before (water runoff, point 1) and after the treatment (outlet of filter unit, point 4), as well as the treated water storage in the tank (point 5). Moreover, every two weeks sampling was taken between different treatment modules: after pervious concrete pavement (point 2) and after hydrodynamic separator (point 3).

Table 1 included the parameters and frequency of the analysis in each sampling point evaluated.

Table 1. Water analysis sampling plan.

Parameter Group	Parameter	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4	Sampling point 5
<b>Physicochemical</b>	pH	Weekly	–	–	Weekly	–
	Conductivity	Weekly	–	–	Weekly	–
	Dissolved Oxygen (DO)	Weekly	–	–	Weekly	–
	Turbidity	Weekly	–	–	Weekly	–
<b>Organic Load</b>	Chemical oxygen demand (COD)	Weekly	–	–	Weekly	–
	Biological oxygen demand (BOD)	Weekly	–	–	Weekly	–
<b>Solids</b>	Total suspended solids (TSS)	Weekly	Biweekly	Biweekly	Weekly	–
<b>Nutrients</b>	Total Nitrogen (TN)	Weekly	–	–	Weekly	–
	Total Phosphorus (TP)	Weekly	–	–	Weekly	–
<b>Microbiological</b>	<i>E. coli</i>	–	–	–	–	Biweekly
	<i>Legionella spp.</i>	–	–	–	–	Monthly
	Nematode eggs	–	–	–	–	Monthly
<b>Micropollutants</b>	Heavy metals	–	–	Biweekly	–	–
	PAHs	–	–	–	–	–
	PCBs	–	Biweekly	–	–	–
	Pesticides	–	–	–	–	–
<b>Others</b>	Grease and oils	–	–	–	Weekly	–

**Legend:** Weekly = 1 sample/week; Biweekly = 1 sample/2 weeks; Monthly = 1 sample/month.

## 1.2 Locations

The LIFE DrainRain system was evaluated in two climatically locations, Ferrol (Galicia) and Calasparra (Murcia). The first pilot was in the commercial dock in the inland seaport of Ferrol (Figure 2). The Ria of Ferrol, are in a coastal area an Atlantic climate, characterised for water

abundance due to abundant and consistent rainfall throughout the year. Moreover, this area suffers over years the pollution of the water due to the discharge of urban and industrial wastewater, affecting significantly shellfish harvesting, the economic driver of the area, as well as the environment.



Figure 2. Porous photocatalytic pavement in Ferrol pilot.

The second pilot was implemented in km 44 shoulder of the MU-714 road (Figure 3), in a Mediterranean climate area. The water scarcity in this area is critical, with prolonged drought and heavy rainfall episodes. The pilot was emplaced in agricultural area with high hydric requirements of the rivers of the proximity.



Figure 3. Porous photocatalytic pavement in Calasparra pilot (a) and treatment system (b) .

### 1.3 Validation period

Ferrol pilot was assessed from September of 2019 to September of 2022, sampling every week in rainy periods, except for several months due to COVID 19 impact. The total rainfall over the validation in Ferrol was: 1,458.6 L/m<sup>2</sup> in 2019 (September – December), 2,712.4 L/m<sup>2</sup> in 2020, 1,443.5 L/m<sup>2</sup> in 2021 and 436.2 L/m<sup>2</sup> in 2022 (January to September).

Calasparra pilot was assessed from December of 2020 to September 2022, sampling every week in rainy periods. The total rainfall in these periods was: 0.5 L/m<sup>2</sup> in 2020 (December), 340.3 L/m<sup>2</sup> in 2021 and 313.3 L/m<sup>2</sup> in 2022 (January to September).

As could be observed, the rainfall in Calasparra was significantly lower in comparison with Ferrol.

### 1.4 Analytical methods

Analysis were carried out following the Standard Methods for the Examination of Water and Wastewater. Measurements of pH, conductivity and DO by a Multi-parameter pHenomenal ® MU 6100L; turbidity by TB300 IR turbidirect Turbidimeter; DBO by Velp Scientifica BOD system; COD, TN and TP using Thermoreactor Lovibond RD 125 and Lovibond MD 600 photometer; *E. coli* using an Incubator JP Selecta bacteriological and culture stove, Nematodes eggs by Mic. B Labophot Y2; Metals by inductively coupled plasma mass spectrometry (ICP-MS) ElementXR of Thermo Finnigan; Pesticides by Gas Chromatography and Doubled Mass Detection (GC-MS-MS) and High-Performance Liquid Chromatography coupled to Mass Spectrometry (HPLC-MS); PCB by liquid-liquid extraction, liquid-solid chromatography and Gas Chromatography coupled with Mass Detector (GC-MS), using a Thermo Finnigan MAT95 XP High Resolution Gas Chromatograph coupled with a Mass detector; PAH by a CG-MS with ion trap detection (Thermo Finnigan Polaris Q in MS-MS mode).

## 3 Results

On one hand, the pollutant load of urban runoff in Ferrol exhibited significant temporal variability throughout the monitoring period, particularly for TSS, metals, and PAH. This variability was directly reflected in the performance fluctuations observed across the treatment train.

The porous photocatalytic pavement achieved efficiencies ranging from 20 – 70 % for PAH, 74 – 100% for PCB and 21 - 100% for pesticides, indicating a high but variable capacity for organic micropollutant attenuation. The hydrodynamic separator consistently reduced TSS concentrations, with efficiencies between 54% and 84%, confirming its role as a primary physical treatment barrier. The filter unit provided additional polishing, achieving removal efficiencies of 72–95% for metals, 74–100% for PAHs, 10–82% for PCBs, and 85–100% for pesticides. In addition, the storage tank contributed to microbiological stabilization, with absence of nematode eggs and *Legionella spp.* across all samples, and *E. coli* undetected in more than 90% of the monitoring events.

The combination of the different treatment stages enabled an effective overall treatment of stormwater runoff, achieving final removal efficiencies of 80–100% for TSS, 75–100% for metals, 100% for *E. coli*, 80–100% for PAHs, and ≥95% for both PCBs and pesticides. These results demonstrate a significant improvement in runoff water quality after treatment, as well as

during the storage phase, highlighting the complementary and synergistic role of the different units within the system in enhancing overall performance.

The treated runoff consistently met the quality requirements established by Spanish legislation (R.D. 1620/2007), including thresholds for TSS ( $\leq 20$  mg/L), turbidity ( $\leq 10$  NTU), *E. coli* ( $\leq 2.0 \times 10^2$  CFU/100 mL), nematode eggs ( $\leq 1$  egg/10 L), and *Legionella spp.* ( $\leq 100$  CFU/L). These results confirm the suitability of the effluent for reuse applications such as street cleaning (quality class 1.2).

On the other hand, runoff in Calasparra also showed pronounced temporal variability in pollutant concentrations, which influenced system performance. Notably, PCBs and pesticides were not detected in either the influent runoff or the treated effluent, suggesting a lower baseline contamination compared to Ferrol and simplifying the treatment requirements for these compounds.

The porous photocatalytic pavements in Calasparra achieved higher TSS removal efficiencies (82–100%) than those observed in Ferrol, indicating improved solid retention under local runoff conditions. The hydrodynamic unit exhibited TSS removal efficiencies ranging from 33% to 86%, following a similar trend to that observed in Ferrol, although with a slightly wider variability range. The filtration unit achieved removal efficiencies of 10–80% for metals and approximately 49% for PAHs, both somewhat lower than those reported in Ferrol. Finally, the storage tank again played a relevant role in microbial quality stabilization, with absence of nematode eggs throughout the study period, while *E. coli* and *Legionella spp.* were absent in more than 65% and 75% of samples, respectively.

As observed in the Ferrol pilot, the combination of the different treatment stages enabled effective treatment of stormwater runoff, achieving final removal efficiencies of 85–98% for TSS, 68% for metals,  $\geq 99\%$  for *E. coli*, and 12–72% for PAHs. These results demonstrate a significant improvement in runoff water quality both after treatment and during the storage phase.

The treated runoff consistently met the quality requirements established by European legislation (Regulation (UE) 2020/741), including thresholds for TSS ( $\leq 35$  mg/L), turbidity ( $\leq 5$  NTU), BOD ( $\leq 10$  mg/L), *E. coli* ( $\leq 1.0 \times 10^1$  CFU/100 mL), nematode eggs ( $\leq 1$  eggs/10 L for irrigation of pastures or forage) and *Legionella spp.* ( $\leq 1,000$  CFU/L where there is a risk of aerosolisation). These results confirm the suitability of the effluent for agricultural reuse (quality C and D).

#### 4 Conclusion

The SUDS evaluated in Ferrol and Calasparra demonstrated consistently high performance across multiple pollutants, confirming the effectiveness of combining porous photocatalytic pavement with hydrodynamic separation and active carbon filtration.

In both pilots, strong overall removal efficiencies were achieved for key contaminants, including TSS, metals, and microbial indicators, with particularly high performance for *E. coli* ( $\geq 99\%$  removal) and consistently high reductions of PCBs and pesticides where present. PAH removal showed greater variability, reflecting differences in influent composition and operational conditions between sites.

The Ferrol system showed slightly higher overall robustness for metals and organic micropollutants, whereas the Calasparra system exhibited improved TSS removal at the pavement

level but lower and more variable performance in downstream treatment units, particularly for PAHs and metals.

The storage tanks demonstrate the good performance for avoid microbiological grows, including *E. coli*, nematode eggs, and *Legionella spp.* in most samples.

Overall, both systems produced treated runoff that met regulatory requirements (R.D. 1620/2007 and Regulation (UE) 2020/741), supporting its suitability for reuse applications such as street cleaning and agricultural reuse. The results confirm the viability of the proposed multi-stage approach as an effective decentralized solution for urban runoff treatment under variable environmental and pollutant load conditions.

## 5 References

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