# Assisting the Natural-Based Treatment of Harvested Rainwater by UVC Photocatalytic Processes

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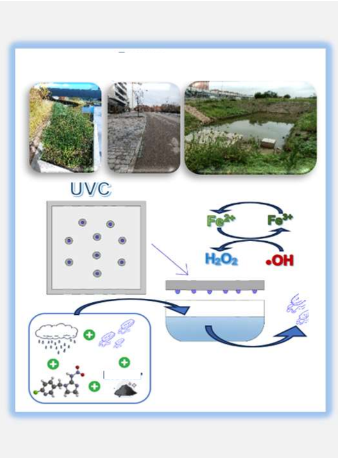


Sustainable urban drainage systems (SuDS) are innovative rainwater management facilities minimizing runoff and flooding negative effects, increasing the possibilities of water reuse applications, and ultimately contributing to a more sustainable urban development in the frame of the Climate Change. The monitorization of water quality from different SuDS located in the city of Madrid is herein reported, especially considering the efficiency of an integrated nature-based treatment system, such as a biofilter, further assisted with a UV lamp for disinfection security. The biofilter + UVC lamp treatment addressed potable water quality requirements. An alternative 275 nm UV-radiation heterogeneous photo-Fenton treatment at lab scale is herein assessed as well, combining disinfection with the treatment of bio-recalcitrant contaminants of emerging concern at the lab scale. Full disinfection was addressed before 10 seconds of treatment; whereas imidacloprid, a pesticide found present in the stormwater monitorization assessment, was fully degraded after 30 min of heterogeneous photo-Fenton treatment.

## Introduction

Water is a basic resource for life, in general, and for the sustainability of the population growth and the economic development, in particular. Urbanization growth is increasing the demand for this vital resource, including the associated agricultural and industrial activity growth that is required to feed and provide other goods to the population; therefore, the development of new water management practices ensuring its sustainable use and management is a priority of increasing level [1]. Moreover, conventional urbanization development implies the installation of extensive impervious areas preventing rainwater in-filtration and altering the water cycle in the cities, which may cause more or less serious flooding events.

The installation of more sustainable urban drainage systems (SuDS) combined with harvesting facilities, and nature-based stormwater treatment technologies, may increase water reuse applications, besides minimising the negative impacts of flooding events. These new management practices will decisively contribute to develop more sustainable and resilient cities [2]. The characteristics of stormwater are affected by the materials present in the surfaces with which it interacts, such as building roofs, pavements, parking lots, and green areas, as well as the overall air quality of the surrounding environment [3-5].

In this contribution, a comparison was made among the quality of stormwater harvested after different types of SuDS, a biofilter installed in one of them to treat stormwater for reuse, and a complementary heterogeneous UVC-photo-Fenton treatment to ensure disinfection and target bio-recalcitrant contaminants of emerging concern.

**Table 1.** Water quality parameters assessed to characterize harvested stormwater from SuDS.

| Parameter | Unit |
|---|---|
| Turbidity | NTU |
| Total dissolved solids | $mg \cdot L^{-1}$ |
| Volatile solids | |
| Suspended solids | |
| Ammonium | |
| Alkalinity | |
| Calcium | |
| Chloride | |
| Phosphate | |
| Sulfate | |
| Magnesium | |
| Nitrite | |
| Nitrate | |
| Total nitrogen | |
| Sodium | |
| $BOD_5$ | |
| COD | |
| Total coliforms | $CFU \cdot 100\ mL^{-1}$ |
| *Escherichia coli* | $CFU \cdot 100\ mL^{-1}$ |

## Materials and Methods

Different SuDS types located in the city of Madrid, including permeable pavement under contrasted environments, a rain garden, and a biofilter for the treatment of harvested stormwater by drainage ditches, were monitored regarding the receiving and delivered quality of water, and treatment requirements for potential applications. Water quality

analyses included in Table 1 were monitored in these sustainable urban drainage systems (SuDS) at several rainy events of 2023.
Whether the assessed biofiltering treatment includes a UVC lamp post-treatment to ensure disinfection, a lab prototype of a 275 nm UVC-LED lamp (≈ 8 mW of optical output power) was further assessed for the combination of disinfection and the conversion of bio-recalcitrant contaminants of emerging concern by a heterogeneous photo-Fenton treatment at the lab scale. Imidacloprid (IMD; 5 $mg \cdot L^{-1}$) was used as the model pollutant to degrade because it has previously been found present in stormwater. Harvested stormwater from the previous monitorization study was used as the water matrix to prepare the IMD solution. The stoichiometric amount of $H_2O_2$ and 0.5 $g \cdot L^{-1}$ of a biochar-supported iron oxide catalyst were used to perform the 275 nm photo-Fenton treatment. Biochar was obtained from triturated pinewood saw flakes waste. 0.22 µm filtered samples were withdrawn along treatment to assess disinfection and IMD conversion efficiency.
Disinfection was assessed in terms of bacterial growth in petri dishes loaded with a film of selective agar broths. Besides *Escherichia coli*, *Enterobacter aerogenes* was just found present in the initial water matrix. The degradation of IMD was monitored by high-performance liquid chromatography (HPLC, Agilent), and mineralization was monitored by the content of total organic carbon (TOC Analyzer, Shimadzu). The content of hydrogen peroxide and leached iron were measured by UV-visible spectrophotometric methods (Thermo Scientific Model Evolution 201, USA) [6]. All trials were performed in triplicate.
Finally, the Life Cycle Assessment (LCA) of the biofilter treatment system was compared to the conventional management practice through sewers and wastewater treatment plants to conventional was carried out by SimaPro software considering the materials that were used in the construction phase (concrete, PVC, polypropylene, glass fiber, cast iron, etc) and the use of electricity along the operation of the system.

## Results and Discussion

Harvested stormwater from the different assessed SuDS addressed an average removal of the 86% of turbidity, 80% of suspended solids, 33% of volatile solids, and 44% of phosphate, 38% of chemical oxygen demand (COD), and the 42% of biological oxygen demand ($BOD_5$). In addition, the treatment of the biofilter assisted with a posterior UVC lamp, addressed a much higher improvement of the recovered water quality, ensuring disinfection and complying with the water reuse requirements set by the legislation in force regarding for the parameters included in Table 1.
Considering the alternative UVC disinfection treatment at lab scale, photolysis was efficient totally removing *E. coli* and *E. aerogenes* after 20 and 60 seconds of treatment, respectively; as well as IMD was almost fully degraded after 120 min of irradiation. Moreover, the designed heterogeneous UVC photo-Fenton process addressed the total disinfection of *E. coli* after 7 seconds of treatment, whereas *E. aerogenes* was fully removed after 10 seconds. IMD was fully degraded after 30 min of heterogeneous photo-Fenton treatment.
LCA addressed the generation of a significant much lower carbon footprint for the treated stormwater by the application of the assessed alternative biofiltering + UVC treatment technology (≈ 0.12 kg $CO_2$-eq$\cdot m^{-3}$ of treated stormwater) than for the conventional centralized treatment strategy of sewers distribution to wastewater treatment plants.

## Conclusions

Turbidity and suspended solids were extensively reduced in stormwater after flowing through SuDS, permeable pavement especially. An integrated treatment system with a SuDS, consisting of a biofilter + UVC radiation, addressed a significant improvement of water quality, even providing potable water standards. The assessed 275 nm UVC photolytic treatment at lab scale ensured disinfection and was able to directly degrade imidacloprid; but the tested heterogeneous UVC photo-Fenton treatment addressed better results, including the total degradation of imidacloprid, in a much shorter time of treatment (less than 10 seconds for disinfection, and 30 minutes for imidacloprid).

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***References***
**[1]** M. Kasprzyk *et al*., *Sci.Total Environ.*, 835 (2022),155487.
**[2]** P. Ferrans *et al*., *Sci. Total Environ.,* 806 (2022),150447.
**[3]** *A. Campisano et al., Water Res.* 115 (2017), 195.
**[4]** S. Perales-Momparler *et al*., *Clean Soil Air Water*, 42 (2014), 178.
**[5]** L. Mutzner, *et al*. *Environ. Sci. Water Res. Technol*. 9 (2023), 3094.
**[6]** *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association (APHA), American Water Works Association (AMMA), Water Environment Federation (WEF) (Eds.), Washington DC, APHA, 2005.