Some insights about green roof research in Spain

Réflexions sur de la recherche sur les toits verts en Espagne

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RÉSUMÉ

Cet article présente les résultats préliminaires d'une recherche menée dans des conditions contrôlées dans un modèle physique sur la capacité d'écoulement et de contrôle de la pollution d'un toit vert à l'échelle pilote. Ce travail, développé dans le cadre d'un projet de recherche coordonné par l'Universidade da Coruña, l'Universitat Politécnica de Valencia et l'Universidad de Cantabria, présente les prochains défis de la recherche sur les toits verts en Espagne.

ABSTRACT

This paper presents the preliminary results of an investigation carried out under controlled conditions in a physical model on the flow and pollution control capacity of a pilot-scale green roof. The work, developed in the scope of a research project coordinated by the Universidade da Coruña, Universitat Politécnica de Valencia and the Universidad de Cantabria, presents the next challenges on green roof research in Spain.

KEYWORDS

(Green roofs, Nature Based Solutions, Rainfall simulators)

1 INTRODUCTION

In urban areas, roofs make up about 40-50% of impervious surfaces (Stovin, et al., 2017). Therefore, to reduce the magnitude of storm runoff into sewerage systems, it is key to control this source. From this perspective new approaches such as Sustainable Urban Drainage Systems (SuDS) are becoming a common solution to address the increase in flow discharges and runoff volumes caused by urban growth (Ashley et al. 2020). However, in some countries such as Spain, some barriers are delaying the transition to their full implementation (Andrés-Doménech et al., 2021). Within the technical challenges, the fragmentation trend of research teams to integrate the knowledge generated in Spain on SuDS must be overcome, fostering the association and coordination of research teams to develop and promote the exchange of knowledge and the validation of methodologies.

In this framework, research on Green Roofs (GR) is nowadays widespread over the past decade in Spain due to their advantages in relation to other roof typologies in terms of pollution (Getter et al., 2009), the reduction of urban heat islands (Denardo et al., 2005), runoff (Mentens et al., 2006, Gregoire, 2011) and satisfactory hydrological performance (Carson et al., 2013; Ercolani et al., 2018). Among them, other achievements such as landscaping, support the presence of animal species, ecosystem development, visual benefit, enhanced building performance (Raymond et al. 2017, Guzmán-Sánchez et al., 2018). However, there is a shortage of standard methods and tools to assess the efficiency of the GR and the retention of rainfall volume and reduction of runoff peaks still need to be improved (Liu et al., 2021).

In this study, the impact on the hydrology behavior and removal efficiency of GR is assessed by comparing three different rainfall intensities of 30, 50 and 80 mm/h, using a small-scale rainfall simulator available at the Center for Technological Innovation in Construction and Civil Engineering (CITEEC) of the Universidade da Coruña. The overall objective is to analyze the impact of GR on the hydrology and the mobilization of pollutants under laboratory-controlled conditions, comparing different rainfall intensities. This work has been developed under the framework SUDS-long coordinated research project among the three Spanish research teams with probably the largest research experience in SuDS: Universidade da Coruña (UDC), Universitat Politècnica de València (UPV) and Universidad de Cantabria (UC).

2 EXPERIMENTAL SETUP

A rainfall simulator located in the hydraulic laboratory of CITEEC at Universidade da Coruña (UDC), as described in Naves et al. (2020) have been used to assess the hydrological performance of the GR module (Fig. 1a). To simulate the day-night cycles operation LED lamps were installed. Additionaly, an electronic precision scale which allows to continuously determine the weight of the green roof module was installed to determine water loss by evapotranspiration during the tests. The rainwater used for the simulation comes from tap water and once it is filtered through the vegetated system is first collected into the storage module and then drained in a circular tank at the lateral of the experimental bench. The filtered flow discharge is estimated from the level variation into the tank using SN-SR04T ultrasonic probes previously calibrated.

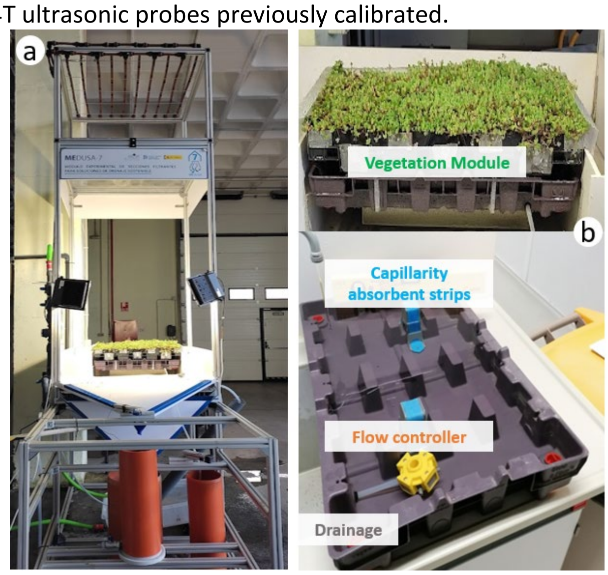

Figure 1 (a) Rainfall simulator and (b) Hydropack © green roof module

The modular system Hydropack ©, provided by Renolit company, is seed with *Sedum* type vegetation, a layer of 60 mm thick mineral substrate on a storage layer, and, additionally, it is complemented by an underlying plastic reservoir equipped with an effluent flow controller and two absorbent strips for capillary irrigation (Fig. 1b). Each vegetated module in an unsaturated state has the capacity to retain approximately 15 L of rain, which is released at different rates depending on the configuration.

During the tests, hydrology performance and water pollution parameters were recorded: pH, electric conductivity (EC), alkalinity, hardness, turbidity, total organic carbon (TOC), total nitrogen (TN), nitrate and total phosphorus (TP). Three tests have been carried out on saturated soil conditions with 30, 50 and 80 mm/h 30 minutes rainfall intensities under saturated soil conditions. In T1 test, outflow composite samples were collected 1 and 5 days after the rain, meanwhile in T2 and T3 tests, samples were collected on 1^{st} and 7^{th} day. Additionally, the accumulated volume in the underlying plastic reservoir is collected and analysed.

3 RESULTS AND DISCUSSIONS

Figure 2 shows the outflow hydrograph of the green roof module for test T3 (80 mm/h, 30 minutes) and the outflow discharge of an equivalent impermeable surface placed in the physical model for comparison purposes. These results confirmed and quantified the benefits of the GR in urban stormwater management and the importance of model scale and setup in analyzing this SuDS typology. Regarding the drained volume till the hydrograph recession limb, the hydrological efficiency of the vegetated module is reported to be between 43% - 27.5%. On the other hand, the system is capable to retain up to 16.8% of the rain into its reservoir. According to the water-mass balances, and under the controlled conditions in the laboratory, the ET calculated varies between 0.36-0.09 (mm/day).

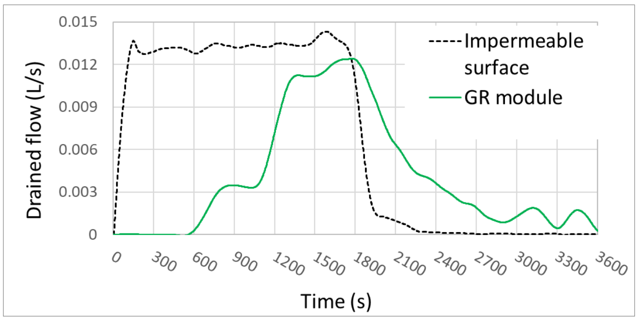

Figure 2. Comparison between the flow drained from the impermeable surface and the GR module

Recorded water quality parameters in the test are shown in Table 1. In general, the effluents from the vegetated cover present higher concentration values in all parameters compared to the blank rainfall. It has been observed that an increase in rainfall intensity produces an effluent with lower pH, EC, alkalinity, and hardness. However, increasing rainfall intensity tends to increase turbidity, while prolonging drainage time tends to decrease turbidity. Runoff organic matter leaching from the substrate soil (TOC) is absent in the blank rainfall and moves to a range of 13 to 22 mg/L in the effluent. The effect of rainfall intensity is similar to that observed for pH.

Table 1. Overview of average chemical composition after each rainfall event.

Parameter	Rainfall	Test 1 (30 mm/h)		Test 2 (50 mm/h)		Test 3 (80 mm/h)	
		5th day	5th day (reservoir)	1st day	7th day	1st day	7th day
pH (-)	6.63	8.04	8.04	7.76	7.94	7.44	7.80
EC (μS/cm)	164	364	364	326	372	283	340
Turbidity (FTU)	0.0	0.0	0.0	1.4	0.7	1.6	0.8
Alkalinity (mg/L $CaCO_3$)	15	114	114	80	111	65	99
Hardness (mg/L $CaCO_3$)	37	170	170	132	155	109	143
TOC (mg/L)	0.0	22	22	17	23	13	18
TN (mg/L)	2.6	1.2	1.2	2.2	1.3	2.4	1.7
Nitrate (mg N/L)	2.3	0.8	0.8	1.4	0.7	1.8	0.8
TP (mg/L)	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05

In the case of TP, both in the rain and in the effluent of the tests, its concentration was below the detection limit of the technique (< 0.05 mg/L). The higher the rainfall intensity, the higher the effluent nitrate concentration, while the longer the drainage time, the lower the nitrate concentration.

4 FUTURE RESEARCH AND CONCLUSIONS

The overall objective of this work was to analyze the impact of GR on the hydrology and the mobilization of pollutants under laboratory-controlled conditions, comparing different rainfall intensities. Although the hydrologic efficiency of green roofs has been proved, preliminary results obtained can reveal some problems of nutrients leaching at laboratory scale.

In order to solve scientific and technical knowledge gaps related to mid to long-term hydrological and environmental performance of different SuDS techniques, the co-ordinated project SUDS-long will analyse different real-scale green roofs and filtering techniques as permeable pavements, included in various living labs established in three Spanish geographic and climatic contexts (Galicia, Cantabria and Valencia regions). The teams involved in the project will develop complementary activities according to the skills and research potential of each university. UDC will monitor different SuDS techniques recently built at the university campus, meanwhile UPV and UC will focus their research on mature systems, in which clogging, and management practices can play an important role in the overall asset performance.

Complementary actions to long-term monitoring will be developed within the project such as the analysis of pollution source contribution, SuDS potential for microplastics retention or testing new materials and procedures for improving the performance of permeable pavements and green roofs. Coordinated project SUDSlong outcomes will contribute to generate and maintain Spanish redsuds.es network for planning, implementation and monitoring of SuDS techniques in Urban Drainage Systems.

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