Journal of Environmental Management 204 (2017) 454–466

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Learning from the operation, pathology and maintenance of a bioretention system to optimize urban drainage practices

Marina Batalini de Macedo [a, *], Altair Rosa [a], César Ambrogi Ferreira do Lago [a], Eduardo Mario Mendiondo [a], Vladimir Caramori Borges de Souza [b]

[a] Escola de Engenharia de Sao Carlos/USP, Av. Trabalhador Saocarlense, 400, CP 359, Postal Code 13566-590, São Carlos, SP, Brazil
[b] Universidade Federal do Alagoas – UFAL, Campus A. C. Simões - Rod. BR 104 km 14, CTEC, Cidade Universitaria, Postal Code 57072-970, Maceió, AL, Brazil

ARTICLE INFO

Article history:
Received 25 October 2016
Received in revised form
3 August 2017
Accepted 14 August 2017

Keywords:
Runoff
Stormwater
LID practices
Maintenance needs
SUDS
Percolation rate

ABSTRACT

LID practices for runoff control are increasingly being used as an integrated solution in urban drainage, helping to achieve hydrological balance close to the pre-urbanized period and decrease the diffuse pollution transported to urban rivers. Regarding bioretention, there is already broad knowledge about the detention of peak flows and their treatment capacity for many pollutants. However, there are still few field studies in microdrainage scale, which analyze the actual operation of these devices and raise common problems found, especially in subtropical climate. Therefore, this study aims to show what was learnt from the field operation of a bioretention cell on a micro-drainage scale, located in an urban catchment of a Brazilian city, suggesting maintenance actions as adaptations to the pathologies found. Five rainy events were monitored during the dry season, in order to carry out a preliminary analysis for critical conditions in terms of maintenance and diffuse pollution accumulation. From the first water balance results, low storage and low infiltration capacity of the soil were found as main pathologies. They led to a great amount of runoff passing directly through the cell surface and at a high velocity, resulting in soil erosion and low water retention efficiency. To overcome these problems, some structural adaptations were made over the cell, highlighting the semi-direct injection. The maintenance and adaptations proposed were suitable to avoid the erosion process, increasing the storage and improving the water retention efficiency in bioretention. They should be considered from the very initial stages, to using sites with low permeability.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Changes in land use and occupation due to the urbanization process normally results in an increase in impervious area, e.g. road network and buildings, also leading to an increase in runoff generation and the total diffuse pollution load transferred to urban rivers. Therefore, from rainy events, situations such as river contamination and floods in urban centers are increasingly more frequent. Classic urban drainage systems are not capable to qualitatively treat runoff and they are not even able to reestablish the water balance close to the pre-urbanized conditions. Thus, the development of alternative, more sustainable and cost efficient urban drainage systems scale has been growing.

These alternative urban drainage systems present a variety of denominations. Among them are the following: Low Impact Development (LID), Best Management Practice (BMP), Water Sensitive Urban Design (WSUD) and Sustainable Urban Drainage Systems (SUDS), which vary according to the authors (Rosa, 2016). Within this new developed concept, some approaches are integrated from participative planning, environmental education and source reduction to techniques and devices in lot and micro-drainage scales (Fletcher et al., 2013; Marsalek and Schreier, 2009). Concerning techniques and devices, other examples are green roof, infiltrating trenches, wetponds and bioretention basins. The latter is the object of study in this paper. Many studies have focused on water retention efficiency or pollutants retention capacity from these devices at the laboratory (Bratieres et al., 2008; Liu et al., 2014; Wang et al., 2015, 2016) and field scale (Davis, 2007, 2008; Hatt et al., 2009; Lefevre et al., 2014; Winston et al., 2016). In addition, in Brazil and other subtropical regions, studies carried out in the field are still recent and focus on a short period.

* Corresponding author.
E-mail address: marina_batalini@hotmail.com (M.B. de Macedo).

http://dx.doi.org/10.1016/j.jenvman.2017.08.023
0301-4797/© 2017 Elsevier Ltd. All rights reserved.

Therefore, there is a lack of knowledge concerning the effects and problems which take place during conception, construction and operation in the long term.

Since the 1990s, the need of maintenance for a good operation and performance of the LID practices over time has already been pointed out. Lindsey et al. (1992) conducted a study on many LID practices types (infiltration basins, infiltration trenches, dry wells, porous pavement and vegetated swales) and observed that the operation conditions decreased significantly in only four years. Moreover, almost half of them were not working according to the initial project and two thirds needed maintenance. In their study, they also realized that the technique that required more maintenance needs was infiltration basins, associated not only to vegetation, but also to sediment, waste and stabilization problems that resulted in erosion. In the same decade, EPA had already developed a user manual on the use of various SUDS, including bioretention, highlighting the necessary maintenance and importance of constant inspection (EPA, 1999).

However, recent studies still highlight the problems caused by a lack of maintenance and inspection, showing that this activity is still being neglected in many cases. Blecken et al. (2015) conducted an extensive review of LID practices with long field application times, observing the main problems occurred and the maintenance needed. They realized that after construction, many of the LID devices were forgotten or it was assumed (by the managers) that they would work indefinitely, leading in a decrease in the work efficiency and operational failures. Brown and Hunt (2012) showed a lack of maintenance effects in bioretention system performance, leading to an overflow even for small rainy events, and a reduction in pollutant removal rates. These failures, which result in a decrease in the efficiency of the system, lead to a loss of public trust in these alternative techniques, therefore leading to a lack of interest in installing it.

For tropical and subtropical climate regions, it is important to remember to carry out maintenance activities to prevent mosquito proliferation, as they can transmit diseases which are epidemic in these areas. Barrett (2003) also included this activity as one of the most important ones.

Maintenance needs and proposals for the necessary routine maintenance for different technique types were listed from the problems found by this study. Blecken et al. (2015) noticed that the common maintenance need for all practices is related to the access of people to site and the required equipment. Specifically for bioretention, they observed vegetation upkeep (inspecting and cleaning the inlet and overflow structure) and preserving the surface infiltration rates of the surface media as main maintenance needs. Lim and Lu (2016) presented erosion control (mainly in the system inlet) and maintain vegetation growth as maintenance routines, recommending higher frequencies during the first year of operation, to prevent weeds establishment. Davis et al. (2009) stated that the exact type of maintenance varies depending on the contribution area. They still list as activities the waste and mulch layer removal to maintain the infiltration rates fixed, removing and replacing the top layers of the filtering media and revitalizing the performance in a qualitative aspect.

To a LID system operate according to that proposed in the sizing project, frequent maintenance must be performed, from routine to main maintenance, according to Erickson et al. (2013). There are still few studies focused on tropical and subtropical regions, where, besides the climate conditions, the socioeconomic factors are different from the temperate regions. In addition, there is a wide range of lab-scale studies. However, when the systems are used in the field, it can be observed that there are some unidentified needs and problems in the laboratory that can change how it works and its efficiency.

This study aims to present the implementation and operation of a bioretention basin in a subtropical climate, showing all the adversities and pathologies found during the process and the proposed maintenance as a solution, adaptation and mitigation of risks. We present the first experimental results of the device application. The purpose was to make a preliminary analysis for the critical conditions in terms of maintenance and pollution, not targeting a statistical analysis. Firstly, a description of the implantation area is presented, evaluating the quality and quantity efficiency of the LID practice. Afterwards, we identify the pathologies that occurred during the rainfall events and the routine problems found to propose maintenance that is able to minimize the risks and return to the sizing performance. Finally, we evaluated if the proposed maintenance solutions were able to compensate and mitigate the pathologies.

2. Methodology

2.1. Area and LID bioretention practice descriptions

The LID practice was implemented in Campus 2 at the University of Sao Paulo (USP) in Sao Carlos, located in the city of Sao Carlos, São Paulo state. The city is included in the sub-watershed of the Mineirinho river, which consists of the urban basin of Sao Carlos (Fig. 1).

This experimental area is representative of other Brazilian cities with urbanization ranging from medium to fast rates. As to climate classification, it is under Koeppen climate classification Cwa (humid subtropical climate with dry winters and hot summers). São Carlos has an average daily temperature of 21.5 °C, an average daily relative humidity of the air of 74.3%, and an average annual rainfall of 1361.6 mm, with higher rain concentration in January and lower concentration in July and August (EMBRAPA, 2017).

The LID practice receives a runoff contribution of a 2.3ha catchment surface and is considered a micro-drainage scale. The represented area is still poorly paved, and most of its surface is composed by short vegetation. The main runoff contribution is from roads, footpaths and the impervious area related to the laboratory building, correspondent to approximately 22% of the catchment (Fig. 1).

The bioretention basin was constructed in 2015 and soon after started operations. It had an area of 60.63 m^2 and a depth of 3.2 m. It consists of a vegetated layer followed by two filtrating layers, separated by a geotextile, as shown in Fig. 2: gravel with a diameter of 5 cm and porosity of 40%, and coarse sand with 1 mm diameter and porosity of 30%. Finally, the basin is covered by the region's natural soil, with sandy loam characteristics. The surface layer is vegetated in order to preserve the landscape integration and soil stabilization.

This study shows the first experimental results for this bioretention basin applied in the field. The main purpose is not carry out a statistical analysis with parameterization and synthesis of the results, but rather a preliminary analysis for critical conditions in terms of maintenance and from the point of view of diffuse pollution accumulation, especially suspended solids. Therefore, five rainfall events were chosen in July and August, representing the dry season (months with lower total precipitation depth) and, consequently, the period of greatest accumulation of solids and pollution. Furthermore, in these months, the relative humidity and temperature are lower than the rest of the year, leading to lower chemical reaction rates, degradation and pollutant removal.

The bioretention basin configuration analyzed in this study was chosen to consider a more specific focus in terms of retaining solid particles and reducing the effects of clogging. The upper gravel

Download English Version:

https://daneshyari.com/en/article/5116283

Download Persian Version:

https://daneshyari.com/article/5116283

Daneshyari.com