Science of the Total Environment 536 (2015) 784–792

Contents lists available at ScienceDirect

Science of the Total Environment

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

The pollution removal and stormwater reduction performance of street-side bioretention basins after ten years in operation

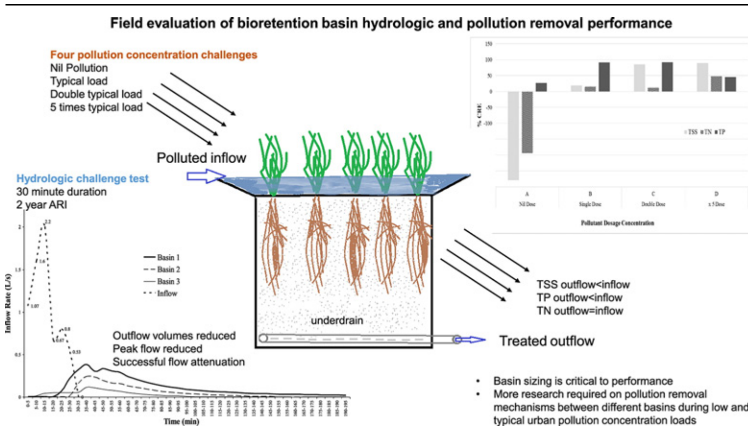
Terry Lucke *, Peter W.B. Nichols

Stormwater Research Group, University of the Sunshine Coast, Sippy Downs, Queensland 4558, Australia

HIGHLIGHTS

- Hydrologic and pollution removal performance of 10 year old bioretention basins evaluated.
- The basins successfully reduced peak flow, and runoff volumes.
- Pollution removal performance successful for TSS and TP across some pollution concentrations.
- Bioretention basins found to contribute both TSS and TN to downstream aquatic environments.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 1 July 2015
Received in revised form 29 July 2015
Accepted 29 July 2015
Available online 5 August 2015

Editor: D. Barcelo

Keywords:
Bioretention
Hydrologic performance
Pollution removal performance
Clogging
Stormwater
Heavy metals
Hydrocarbons
Water sensitive urban design

ABSTRACT

This study evaluated the pollution removal and hydrologic performance of five, 10-year old street-side bioretention systems. The bioretention basins were subjected to a series of simulated rainfall events using synthetic stormwater. Four different pollution concentrations were tested on three of the bioretention basins. The four concentrations tested were: A) no pollution; B) typical Australian urban pollutant loads; C) double the typical pollution loads, and; D) five times the typical pollution loads. Tests were also undertaken to determine the levels of contaminant and heavy metals build-up that occurred in the filter media over the 10 year operational life of the bioretention systems. Although highly variable, the overall hydrological performance of the basins was found to be positive, with all basins attenuating flows, reducing both peak flow rates and total outflow volumes. Total suspended solids removal performance was variable for all tests and no correlation was found between performance and dosage. Total nitrogen (TN) removal was positive for Tests B, C and D. However, the TN removal results for Test A were found to be negative. Total phosphorus (TP) was the only pollutant to be effectively removed from all basins for all four synthetic stormwater tests. The study bioretention basins were found to export pollutants during tests where no pollutants were added to the simulated inflow water (Test A). Heavy metal and hydrocarbon testing undertaken on the bioretention systems found that the pollution levels of the filter media were still within acceptable limits after 10 years in operation. This field study has shown bioretention basin pollution removal performance to be highly variable and dependant on a range of factors

* Corresponding author.
E-mail address: tlucke@usc.edu.au (T. Lucke).

http://dx.doi.org/10.1016/j.scitotenv.2015.07.142

including inflow pollution concentrations, filter media, construction methods and environmental factors. Further research is required in order to fully understand the potential stormwater management benefits of these systems.

1. Introduction

The increase in impervious surface accompanying urban development over recent decades has increased both the volume of stormwater runoff, and the amount of pollution flowing downstream to receiving waters (Dietz, 2007; Lucke and Beecham, 2011). Consequently, the management of stormwater in urban areas has become a priority issue for those responsible for planning and construction of new developments, and maintenance of existing stormwater infrastructure (Nichols et al., 2015).

Bioretention (biofiltration) systems have been widely implemented in urban areas over the past decade to manage stormwater by reducing peak flows and downstream pollution loads (Davis, 2008; Hunt et al., 2008; Le Coustumer et al., 2012). Part of the reason for the recent popularity of bioretention systems is the flexibility in their design which assists with their relatively simple integration (retrofitting) into existing urban areas (Bratieres et al., 2008). They are also considered to contribute a range of benefits beyond the conventional stormwater quality and quality functions, including aesthetic and social benefits (Deletic et al., 2014; Mullaney et al., 2015). A smaller sized bioretention system is often incorporated into existing roadways in place of a traditional grassed nature strip or verge.

Bioretention systems are generally soil–plant based systems that typically consist of a filter medium (usually sandy), underlain by a gravel drainage layer (Dietz, 2007; Deletic et al., 2014). Bioretention systems may be lined with some type of geofabric to allow infiltration, or include an impermeable liner to assist in stormwater capture and reuse (FAWB, 2009). Bioretention systems treat stormwater via a range of physical, chemical and biological processes. These include mechanical filtration, sedimentation, adsorption, and plant and microbial uptake (Deletic et al., 2014).

Previous studies have found that the pollution removal performance of bioretention basins can be closely related to the site rainfall characteristics and the basin inflow and outflow limits (Davis, 2008; Hunt et al., 2008; Mangangka et al., 2015). Despite a significant number of previous research studies into the performance of bioretention systems, the major treatment mechanisms through which pollutants are removed or treated are not yet well understood (Deletic et al., 2014). There has also been limited research that demonstrates the long-term capability of bioretention systems to trap and/or treat contaminants, particularly heavy metals (Hatt et al., 2011).

Issues related to heavy metal accumulation or breakthrough have been attributed to clogging of bioretention systems over time (Le Coustumer et al., 2012; Hatt et al., 2009a), and to the depth and sizing of the filter media (Hatt et al., 2011). Heavy metal breakthrough may occur even faster in sub-tropical locations (such as Brisbane) that experience higher rainfall intensities. It has also been suggested that if the filter media needs replacement during regular maintenance of these systems, it may need to be classified as contaminated waste due to the accumulation of pollutants in the filter media over time and hence require special disposal procedures (Hatt et al., 2011).

Many of the previous studies investigating the performance of bioretention systems have been laboratory scale studies (Hatt et al., 2009a; Hatt et al., 2011; Bratieres et al., 2008; Le Coustumer et al., 2012; Deletic et al., 2014). The studies that have incorporated field-based testing have reported varied results, particularly in relation to the treatment of soluble forms of nutrients (N and P) and areas subject to high contaminant loading such as fuel stations or waste recycling sites (Dietz, 2007). The capacity of bioretention systems to treat the peak flow rates of stormwater generated by high-intensity rainfall events is also limited by the relatively small bioretention area to catchment area ratio of approximately 2–4% (Dietz, 2007; Hunt et al., 2008; Hatt et al., 2009a). In addition to the challenge of basin sizing, bioretention system hydrologic and nutrient pollution removal performance have been shown to be dependent on the antecedent dry period before storm events (Mangangka et al., 2015; Hunt et al., 2008).

This paper presents the pollution removal and hydrologic performance results of field-based experiments undertaken on a series of 10-year old street-side bioretention systems. The bioretention basins, located in Caloundra, on the Sunshine Coast, Australia, were subjected to a series of simulated rainfall events using synthetic stormwater. Four different synthetic stormwater pollutant concentrations were used in the study. Tests were also undertaken to determine the levels of contaminant and heavy metals build-up that occurred in the filter media over the 10 year operational life of the bioretention systems.

2. Methodology

2.1. Site description

The bioretention systems evaluated in this study were installed in 2005 to treat stormwater road runoff from a mixed commercial and industrial catchment of approximately 0.6 ha in area. There are five discrete bioretention basins located directly adjacent to the roadway which runs centrally through the catchment (Fig. 1). The bioretention basins were designed to have an operational hydraulic conductivity of 180 mm/h and achieve the recommended regulatory pollution reduction objectives of 80% of Total Suspended Solids (TSS), 60% of Total Phosphorus (TP), and 45% of Total Nitrogen (TN) (ANZECC, 2000).

Figs. 2 and 3 show the design and construction plans of the bioretention basins evaluated in the study. The design comprised an impermeable plastic liner, a 200 mm gravel drainage layer base surrounding a 100 mm diameter, perforated drainage pipe. A 100 mm thick sand transition layer was laid above the gravel base and a 900 mm sandy-loam filter media was included above the sand (Fig. 3). An indigenous plant species *Lomandra longifolia* (Matt Rush) was planted in the surface of the filter media at a typical spacing of one plant per square metre. Outflow pipes from the bioretention systems were diverted through

Fig. 1. One of the bioretention basins evaluated in the study.