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Characterising stormwater gross pollutants captured in catch basin inserts

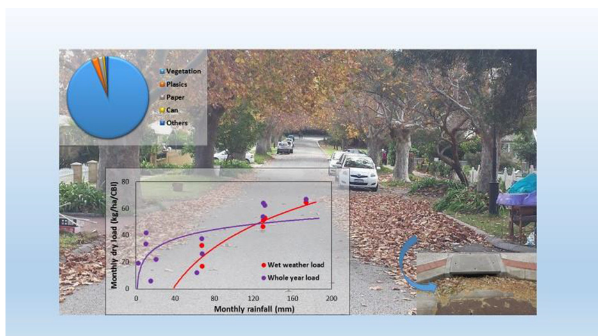
Md Zahanggir Alam [a,*], A.H.M. Faisal Anwar [a], Dipok Chandra Sarker [a], Anna Heitz [a], Craig Rothleitner [b]

[a] Department of Civil Engineering, Curtin University, GPO Box U1987, Perth, WA 6845, Australia
[b] Urban Stormwater Technologies, Level 3, 267 St Georges Terrace, Perth, WA 6000, Australia

HIGHLIGHTS

- Catch basin insert is a promising technology to capture stormwater gross pollutant (GP) at source.
- A new type of catch basin insert was evaluated which has the capacity of capturing pollutants down to 150 μm.
- Effects of catchment characteristics on GP, moisture content, particle size distribution and GP composition were studied.
- Loading rate coefficient of pollutants was determined which mainly contributed from vegetation.

GRAPHICAL ABSTRACT



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ABSTRACT

The accumulation of wash-off solid waste, termed gross pollutants (GPs), in drainage systems has become a major constraint for best management practices (BMPs) of stormwater. GPs should be captured at source before the material clogs the drainage network, seals the infiltration capacity of side entry pits or affects the aquatic life in receiving waters. BMPs intended to reduce stormwater pollutants include oil and grit separators, grassed swales, vegetated filter strips, retention ponds, and catch basin inserts (CBIs) are used to remove GP at the source and have no extra land use requirement because they are typically mounted within a catch basin (e.g. side entry pits; grate or gully pits). In this study, a new type of CBI, recently developed by Urban Stormwater Technologies (UST) was studied for its performance at a site in Gosnells, Western Australia. This new type of CBI can capture pollutants down to particle sizes of 150 μm while retaining its shape and pollutant capturing capacity for at least 1 year. Data on GP and associated water samples were collected during monthly servicing of CBIs for one year. The main component of GPs was found to be vegetation (93%): its accumulation showed a strong relationship ($r^2 = 0.9$) with rainfall especially during the wet season. The average accumulation of total GP load for each CBI was 384 kg/ha/yr (dry mass) with the GP moisture content ranging from 24 to 52.5%. Analysis of grain sizes of GPs captured in each CBI showed similar distributions in the different CBIs. The loading rate coefficient (K) calculated from runoff and GP load showed higher K-values for CBI located near trees. The UST developed CBI in this study showed higher potential to capture GPs down to 150 μm in diameter than similar CBI devices described in previous studies.

* Corresponding author.
E-mail address: m.alam11@student.curtin.edu.au (M.Z. Alam).

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1. Introduction

In urban areas, natural vegetation has been replaced by paved surfaces, resulting in soil compaction, which renders the surfaces impervious and prevents the natural infiltration of rainwater, increasing surface runoff. This rapid urbanization with the construction of new urban assembly may drastically change the hydrologic, hydraulic and environmental characteristics of rural catchments (Sidek et al., 2016). Urbanization not only causes flooding as a physical impact but also increases pollution problems in urban rivers and other receiving waters (Wong et al., 2002). Stormwater pollutants may cause physical, chemical and/or biological damage to the environment.

Stormwater pollutants may be broadly classified into two categories: (i) gross pollutants (GP) such as vegetation (plant-based debris), litter (paper, plastic, cans and others) and sediments of different sizes and (ii) dissolved pollutants including nutrients, heavy metals, and hydrocarbons. The dissolved pollutants result mainly from automobile emissions, fluid leaks from vehicles, residential use fertilizers and pesticides, refuse, and animal faces (Harmayani and Anwar, 2016). The pollutants such as trash, litter and vegetation with diameters larger than 5 mm are usually considered as GPs (ASCE, 2007). In this study, pollutants down to 150 μm diameter captured in catch basin inserts (CBI) were considered as GPs. These finer particles are classified as suspended solid (SS) in stormwater runoff and remain suspended in flowing waters which can carry harmful pollutants (Zhao and Li, 2013; Zhao et al., 2010).

The concentration of nutrients such as total phosphorous (TP) or total nitrogen (TN) may increase in urban waterways because of decomposition of vegetation. These pollutants are particularly problematic because they contribute to eutrophication in receiving water bodies (Meng Nan et al., 2011; Sansalone and Buchberger, 1997; Taylor et al., 2005; Seitzinger et al., 2002) hypoxia, and loss of biodiversity. While some data exists for TN and TP contribution to waterbodies from vegetation or leaf litter captured in continuous deflective systems (CDSs) and side entry pit traps (SEPTs) (Allison et al., 1998b) there is no data available for CBIs.

A critical review on urban catchments showed that a significant amount of street waste enters stormwater drainage systems due to rain and wind (Madhani et al., 2009) and that this waste also has important effects on the dissolved and total nutrient content being discharged to the environment by stormwater. Selbig (2016) studied the reduction of nutrient concentrations in road runoff by implementing municipal leaf collection and street cleaning programs. It was shown that the total and dissolved phosphorus could be reduced by 84 and 83% and total and dissolved nitrogen by 74 and 71%, respectively, by implementing these programs. However, the current Australian street sweeping practices are not effective for removing the growing street wastes (Walker and Wong, 1999). Similar findings were also found elsewhere in the USA (Lippner et al., 2000). This led to the development of stormwater quality improvement devices at the point of waste generation such as a drain basket/SEPT in order to protect the urban waterways from street borne pollution (Allison et al., 1998a). The other type of device used for the removal of GP is the GP Trap (GPT) but this is difficult to clean periodically and is not effective for removal of pollutants <5 mm. The GPT is not effective in treating stormwater at the source because it is placed at outlets of piped drainage system and mainly captures litter and debris (Ghani et al., 2011; Allison et al., 1998a; Madhani et al., 2009; Madhani and Brown, 2011; Madhani and Brown, 2015; Saberi et al., 2008).

A few studies have focused on capturing pollutants using drain baskets (also termed as catch basin insert-CBI) in side entry pits before they enter the drainage system (CIWMB, 2005; GeoSyntec and UCLA, 2005; Kostarelos and Khan, 2007; MacLure, 2009; Kostarelos et al., 2011). Kostarelos and Khan (2007) and Kostarelos et al. (2011) evaluated pollutant removal efficiency of six CBIs under laboratory and field conditions. They studied the removal of five water quality parameters (TSS, TN, TP, TPH and BOD_5) at three different flow rates (50, 150 and 300 L/min) with three contaminant concentrations (low, medium, high). The study also focused on the installation characteristics, durability and maintenance of CBIs, as well as whether the inserts can be conveniently, safely, and economically installed and maintained. A similar study was performed by GeoSyntec and UCLA (2005) to remove oil and grease in four CBIs. Chrispijn (2004) did a field survey for three different ASPT namely Enviropod Filter, Ecosol RSF 100 and SEPTs (designed by Hobart City Council). A small number of traps from each type were installed in comparable locations in and around Sullivans Cove, Hobart, Tasmania, Australia to monitor the retention of pollutant materials (e.g., GP) including heavy metals for 6 months 22 days. Lau et al. (2001) performed field and laboratory tests on CBI in the City of Santa Monica, USA, collecting the GP from CBI twice during their testing period to determine the pollutant size distribution. Although different types of trapping devices are now available, there is a dearth of information on pollutant characteristics captured in CBIs. The characteristics of pollutants captured in CBIs has not been fully tested in practical field conditions under the influence of seasonal variations for a Mediterranean climate such as occurs in Perth, Western Australia where high rainfall intensity in short duration prevails.

A new form of CBIs has recently been introduced by Urban Stormwater Technologies Pty Ltd (UST; previously known as Templug) to remove stormwater pollutants at source in the drainage systems and installed by a few city councils in Western Australia (Rothleitner, 2011). In this study, gross pollutants (GPs) and water quality data were collected from the new UST CBIs during their monthly servicing over one year. The data are presented to understand the types, quantities, physical and chemical properties of urban stormwater pollutants captured at source in the CBIs and the contribution of nutrients from these pollutants to the aquatic environment.

2. Study area, materials and methods

2.1. Study site

The study site was Federation Parade (City of Gosnells, Western Australia) (Fig. 1), which is located in the vicinity of a market and library and surrounded by trees, primarily *Eucalyptus salubris*. The catchment contributing the road runoff has an area of 2.83 ha. Only the runoff from this catchment, as shown by the boundary lines in Fig. 1 enters the pits. The site is classified as a commercial land use type. The city of Gosnells is within the Perth metropolitan area (32.0481°S 115.9844°E) located 20 km southeast of Perth CBD and is 10 m above average mean sea level. The city maintains an extensive drainage network designed to prevent flooding of roads and properties. As part of this maintenance, sweeping of roads and cleaning of gullies is undertaken on a regular basis to reduce build-up of leaf litter and other detritus in drains. Although a considerable level of effort is undertaken, leaves and debris washed from private property can still block the drainage network. Due to the high-water table and the nature of the soil types across the city, on-site stormwater disposal for new real estate developments is becoming increasingly complex.

2.2. The UST catch basin insert (CBI)

The CBIs used in this study were designed and developed by UST (formerly Templug) which can capture pollutants down to 150 μm. None of the previously discussed CBIs can capture pollutants down to these small particle sizes. The UST CBI has a bypass flow section for high flows of heavy rain to avoid flooding; a diffuser (a small perforated section) into the basket to dissipate the energy of incoming water flow; a special type of geotextile which is reusable (>12 times) that does not deform with time and heavy load (Fig. 2). CBIs reported in the literature comprise either only framed structures or only geotextile bags or both, without the above features (Kostarelos et al., 2011; MacLure, 2009;