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Urban stormwater characterisation and nitrogen composition from lot-scale catchments — New management implications

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HIGHLIGHTS

- Urban runoff pollutants from SEQ land-uses were researched, reviewed and compared.
- Results for urban residential (n = 220), & commercial catchments (n = 100) <7.5 hectares.
- Latest research finds pollutant concentrations significantly lower than guidelines.
- Evaluation of nitrogen forms observed that Organic N made up 62%–76% of TN.
- NO_x treatment measures not only solution to achieve TN reduction.

GRAPHICAL ABSTRACT

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ABSTRACT

Stormwater runoff from urban areas has been shown to contain a variety of pollutants which are often linked to the specific land use of the catchment. This research program investigated the pollutant concentrations in stormwater runoff from several sites in South-east Queensland (SEQ), in Australia. The study sites are predominantly single development lots, under 7.5 hectares (Ha) in area, with a single land-use classification that have been developed with stormwater treatment measures to manage pollutant loads as required by local regulations. The testing program also analysed the nitrogen composition in the catchment runoff samples (prior to treatment) during storm events and compared them to current Australian guidelines. The results to date (n = 320) have shown pollutant concentrations to be significantly lower than those historically published as typical for Australian land uses ($p < 0.05$). Ongoing application of out-dated influent values as part of development assessment processes could potentially provide inaccurate results, incorrectly sized and under-performing treatment measures. This current research also suggests that nitrogen in runoff from lot-scale, urban residential catchments has average nitrogen oxides (NOx) ~16% and ammonia ~9% as percentage of total nitrogen (TN). Total Kjeldahl nitrogen (TKN) forms on average ~84% of the total nitrogen concentration during events. Where it was previously recommended that to achieve water quality targets of 45% total nitrogen load reduction, treatment measures targeting NOx were required (e.g. Vegetated systems), this latest research indicates that solutions removing organic nitrogen also may be necessary, increasing the options available to designers.

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1. Introduction

In the late 1990s, the Cooperative Research Centre for Catchment Hydrology in Australia undertook a comprehensive investigation to characterize the pollutants found in urban stormwater. The seminal literature review by Duncan (1999) collated the water quality findings from over 500, mostly international, studies on urban stormwater. The statistical analysis undertaken by Duncan (1999) revealed some important relationships between the concentrations of up to 21 different pollutants and land use type. It also highlighted knowledge gaps in existing Australian studies.

Brisbane City Council (BCC) undertook an extension project in 1994 to characterize stormwater pollutants emanating from various land uses across the city (BCC, 2004) to fill some of these gaps. The monitoring program collected base-flow and storm-flow water samples from multiple sites which were downstream of relatively large catchments with a variety of land uses in each catchment. The characteristics of the urban residential and commercial catchments from the BCC (2004) study are summarized in Table 1.

The findings from Duncan (1999) and BCC (2004) were combined to develop recommended stormwater pollutant concentration values for use in stormwater pollution modelling guidelines for new development applications in Brisbane (BCC, 2004; WBD, 2010). These model input values are summarized in Table 2. The modelling application most used in Australia at present is the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) (http://ewater.org.au/products/music/).

Table 1
Summary of urban monitoring site characteristics (after BCC, 2004).

Study catchment	Land use classification	Catchment area (hectares)	Effective impervious area (EIA)
Sandy Creek, Indooroopilly	79% Residential 10% Institutional 6% Commercial 4% Recreation & Parks 1% Bushland	220	37.3%
Cressey St, Wavell Heights	94% Residential 3% Institutional 3% Recreation & Parks	107	38.0%
Keating St, Indooroopilly	55% Residential 45% Commercial	10	61.3%
Wynnum	63% Residential 24% Commercial 7% Industrial 6% Recreation & Parks	35	70.8%

The results in Table 2 were collected more than a decade ago. There have been many changes in stormwater management in the last 10 years including new stormwater treatment practices in response to new planning regulations, changes to community practices regarding fertilizer application and clean-up of animal faeces, and the development of new vehicular fuels (State of Queensland, 2017). However, follow up research into the characterisation of stormwater pollutants and evaluation of treatment measures in Australia has not been collated or reviewed since despite multiple studies being completed (Francey, 2010; Manganka, 2013; Goonetilleke and Egodawatta, 2017; Liu, 2011; Parker, 2010; Drapper and Hornbuckle, 2015; Lucke and Nichols, 2015). This paper reviews and summarizes stormwater pollution concentration findings from recent studies in SEQ with a focus on the regulated pollutants of total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN). It discusses the implications for the existing guidelines, in particular, investigating the role of nitrogen and its composition in stormwater pollution.

2. Background

2.1. Evaluation of treatment measures — stormwater quality improvement devices

In Australia, most States have implemented planning legislation or policies that specify pollutant load reduction criteria for stormwater runoff resulting from new development (e.g. State of Queensland, 2017; State of Victoria, 2006). In Southeast Queensland, the load reduction criteria are 80% TSS, 60% TP and 45% TN (State of Queensland, 2017). To achieve these criteria, also referred to as water quality objectives (WQOs), new land developments must implement stormwater quality improvement devices, commonly referred to as SQIDs. These can be proprietary (manufactured) devices, or water sensitive/low impact designed measures, e.g. biofiltration, constructed wetlands or other green infrastructure.

According to various planning guidelines (e.g. BCC, 2003; WBD, 2010), to demonstrate that the proposed new development is designed to achieve the required WQOs, development proposals must model the performance of the SQIDs using a pollutant export modelling software (e.g. MUSIC). Pollutant export models, such as MUSIC, are also being applied in the United Kingdom (UK), Singapore and China (eWater, 2017a, 2017b). Local guidelines, however, provide limited advice as to how to demonstrate the performance inputs of proprietary SQIDs for modelling and how to select appropriate SQIDs for specific applications.

In order to meet the required WQOs, Taylor et al. (2005) concluded that stormwater treatment measures need to target NO_x (i.e. Nitrite