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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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Contents

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

Table 2
Summary of Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) Concentrations for Stormflow from Urban Residential and Commercial Land Uses (extract from Table 4.1 in BCC, 2004).

Land use	Parameter	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Urban residential (n = 209)	Mean concentration	240	0.45	2.12
	Standard Deviation	288	0.47	1.21
	Min. recorded value	7	0.04	0.47
	Max. recorded value	1710	3.9	8.2
Commercial (n = 120)	Mean concentration	205	0.7	3.44
	Standard Deviation	219	1.37	3.56
	Min. recorded value	6	0.05	0.4
	Max. recorded value	1830	14	21

+ Nitrate) and DON. This conclusion is now starting to be applied as a selection criteria for determining SQIDs performance in some planning guidelines. For example, Gold Coast City Council's (GCCC) new draft Development Application Requirements and Performance Protocol for Proprietary SQIDs (DesignFlow and E2Designlab, 2015) provides values for typical nitrogen species fractions that they will accept for SQID performance studies inflow concentrations. These include NOx between 25% and 40%, Organic N between 45% and 70%, and TKN between 55% and 75%.

Taylor et al. (2005) highlighted the uncertainty surrounding the different fractions of nitrogen species found in urban stormwater runoff in Australia. This paper evaluates nitrogen composition in stormwater runoff samples from recent SEQ monitoring sites to help clarify the range of typical nitrogen species expected in urban runoff in SEQ. The objectives of this paper are to collate recent research into urban runoff concentrations and nitrogen forms, compare this against existing guidelines (WBD, 2010), and the previous dataset of nitrogen species concentrations (Francey, 2010; Taylor et al., 2005), to better inform pollutant export modelling inputs and guide potential treatment measure selection in Australia.

3. Study overview — recent monitoring programs

This study analysed the results from stormwater monitoring programs that have been undertaken on 12 sites (seven were 100% residential and five were 100% commercial land uses) in Southeast Queensland undertaken since 2004. These monitoring programs were performed by the authors, and by other academic researchers. Summary information is presented in Table 3.

Flow-weighted samples were collected at each of the study locations (Table 4) using auto-samplers to produce Event Mean Concentrations (EMC) for each site. Each of the research sites is classified entirely of the nominated land use. The Commercial catchments do not contain parks, or other uses that could be considered to influence pollutant concentrations. Therefore, the pollutant characterisation can be fully attributed to that particular land use.

4. Materials and methods

Automatic water sampling equipment was installed at 12 field monitoring sites across SEQ. The auto-samplers were triggered by signals from rain gauges and specified flow intervals during rainfall events. Samples were continuously collected throughout the event until flow ceased and they were then composited. PhD students or independent contractors were engaged to collect the water samples within the recommended time frame after the events. Samples from qualifying events were delivered to a National Association of Testing Authorities (NATA)-accredited testing laboratory for analysis to determine the EMC for TSS, TN, Nitrite (NO_2), Nitrate (NO_3), TKN, NH_3, Orthophosphate (PO_4) and TP.

Each of the study monitoring sites had a similar, predetermined sampling protocol to identify qualifying events that were developed based on the protocol methodology prescribed by the United States Environmental Protection Agency's (USEPA) Stormwater Best Management Practice (BMP) Monitoring Manual, Auckland Regional Council's Proprietary Device Evaluation Protocol (PDEP) for Stormwater Quality Treatment Devices, and Stormwater Australia's Draft Stormwater Quality Improvement Device Evaluation Protocol (SQIDEP) (Geosyntec Consultants and Wright Water Engineers, Inc, 2009; Auckland Regional Council, 2012; Stormwater Australia, 2015). Examples of the protocols can be found in Lucke and Nichols (2015), Nichols et al. (2015), Drapper and Hornbuckle (2015), Drapper and Hornbuckle (2016) and Nichols et al. (2016).

5. Results

Water quality data from the research projects has been collated and EMCs for the different land uses presented in Table 4.

Table 3
Summary of 12 monitoring sites reviewed in this study.

Site	Study	Land use	Catchment area (hectares)	Effective impervious area (EIA)	Number of events sampled (n)
Urban residential land use					
Bainbridge St, Ormiston	Goonetilleke and Egodawatta, 2017	100% Residential	0.203	81%	92
Coomera Waters, Sub-catchment 1	Parker, 2010; Manganka, 2013	100% Residential	0.653	52%	32
Alextown	Liu, 2011	100% Residential	1.7	70%	21
Gumbeel	Liu, 2011	100% Residential	1.2	70%	17
Birdlife Park	Liu, 2011	100% Residential	7.5	46%	17
Bribie Lakes, Bongaree	Lucke, 2017a, 2017b	100% Residential	7.46	30%	26
Golden Beach	Lucke, 2017a, 2017b	100% Residential	5.25	40%	15
Commercial land use					
Car Depot, Brisbane Airport	Lucke and Sanicola, 2016	100% Commercial	0.24	99%	33
Southport Fuel Station	Obst and Hughes, 2017	100% Commercial	0.337	99%	18
University of the Sunshine Coast Carpark	Lucke, 2017a, 2017b	100% Commercial	0.0155	99%	5
Salvation Army, Nambour	Nichols et al., 2015	100% Commercial	0.28	99%	26
292 Brisbane St, West Ipswich	Goonetilleke and Egodawatta, 2017	100% Commercial	0.168	99%	17

Table 4
Summary of EMC pollutant concentrations for study sites.

Land use	Parameter	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Urban residential (n = 220)	Mean concentration	54.4	0.34	1.57
	SD	73.9	0.73	1.74
	Minimum value	1[a]	0.01[a]	0.03[a]
	Maximum value	599	6.94	14.5
Commercial (n = 100)	Mean concentration	36.5.	0.211	1.362
	SD	41.95	0.285	1.08
	Minimum value	2[a]	0.01[a]	0.168
	Maximum value	207	1.28	6.0

[a] Values below the Limit of Detection (LOD) are given as LOD to be conservative.

Normality testing (Anderson-Darling) of the datasets confirmed that the TSS and TP datasets were log-normally distributed for the Urban Residential land use, and all Commercial land use pollutant datasets were log-normally distributed. This is in keeping with previous observations that log-normal distributions are commonly used to represent intrinsically positive, often highly-skewed, environmental monitoring data as this satisfies the assumptions for a parametric comparison (e.g. Student's *t*-test) with other log-normally distributed datasets (Blackwood, 1992). Where datasets do not fit a normal or log-normal distribution, such as the TN results in this study, a Student's *t*-test is less reliable for comparison of datasets (McDonald, 2008). It is possible that the residential TN dataset does not conform to a log-normal distribution because several data points were identified at the LOD, and selected others were more than two standard deviations from the mean.

Where normality assumptions were met, a comparison of the *Urban Residential* and *Commercial* EMC results from this study with the EMC dataset provided in the current MUSIC Modelling guidelines (WBD, 2010) was performed using an unpaired Student's *t-test*. The results of the comparison demonstrated that the EMCs were statistically, significantly different ($p < 0.05$) between the two data sets for TSS and TP on the residential catchment, and TSS, TP and TN on the commercial catchment. Summary statistics of the log-transformed datasets are presented in Table 5 and compared with recent TN and TP data from a residential catchment in Tampa, Florida (Yang and Toor, 2016).

Laboratory analyses for the various Nitrogen forms including NO_x, NH_3 and TKN were undertaken on the study storm event samples when sufficient volume was collected. Results for all Nitrogen forms were available for 266 of the 320 monitored events. Organic N (DON + PON) was calculated by subtracting the NH_3 concentration from the TKN concentration. The study nitrogen species results were compared to GCCC's draft "*Development Application Requirements and Performance Protocol for Proprietary Devices on the Gold Coast*" (DesignFlow and E2Designlab, 2015) recommendations, and Melbourne storm event EMC data reported by Taylor et al. (2005) and Francey (2010). This has been summarized in Table 6.

6. Discussion

6.1. Nitrogen forms in the environment

Nitrogen can exist in the environment in a variety of forms including organic, inorganic, dissolved and particulate forms. Early research noted that the proportions of organic nitrogen, its bioavailability and ecosystem effects was not well described in stormwater research, highlighting an area for further research (Seitzinger et al., 2002). Taylor et al. (2005) explained that it is important to understand the nitrogen species compositions in order for stormwater treatment to be effective. Chesapeake Bay has been a focus of nutrient monitoring over many years. In the last decade, the program has expanded to include the various forms of both nitrogen and phosphorus previously identified as knowledge gaps (http://data.chesapeakebay.net/WaterQuality). Modelling of the collected data using a regional ocean modelling system (ROMS) and estuarine carbon biogeochemistry (ECB) model for a continuous 5-year period, found that one third of excess nitrogen was denitrified and buried in the sediment. The balance of the nitrogen was exported from the Bay in organic form (Dissolved Organic Nitrogen [DON] + Particulate Organic Nitrogen [PON]) after being converted from dissolved inorganic nitrogen (DIN) (Feng et al., 2015). This is a different process to that previously hypothesised by Galloway et al. (2003) where DIN was thought to be the primary nitrogen form of concern. Relevant to the current research area, recent publications on Moreton Bay, in SEQ, conclude that it is not nitrogen- but phosphorus-limited and that reductions in DIN loads from wastewater have had little effect on algal biomass (Wulff et al., 2011). They now advocate for strategies to address phosphorus removal for Moreton Bay. This has linked implications to the release and management of stormwater in SEQ.

The proportions of different types of nitrogen found in urban stormwater runoff from 32 storm events was investigated by Taylor et al. (2005) for eight catchments >4 Ha in Melbourne, Victoria (VIC). Runoff from three of these catchments was sampled once, while one catchment had nine runoff events analysed. Nitrogen forms in the Melbourne storm runoff were the lowest for Ammonia (NH_3) (13%) followed by PON (24%) and DON (28%) with nitrogen oxides (NO_x) the highest proportion (36%). Francey (2010) also monitored baseflow and stormflow concentrations of TSS, TP and TN for 7 catchments in Melbourne, where all but one catchment was >7.5 Ha. The Francey (2010) found three catchments had relatively high DIN, specifically NH_3, and suggested that this was likely due to septic influences or other contamination sources. Yang and Toor (2016, 2017) investigated an 11 Ha, low-density urban residential catchment in Tampa, Florida and found that the nitrate proportion of urban street runoff varied seasonally but had an annual average of 24% of TN, with 43–71% of the nitrate contributed by atmospheric deposition. The mean and standard deviation of the Melbourne data and Duncan literature review is summarized in Table 7 below and compared with the recent research. It indicates that the levels of NO_x may be lower than previously understood.

Table 5
Comparison of Log-transformed MUSIC Modelling Guideline EMCs (WBD, 2010), Study EMCs for different land use types in SEQ, and Residential Stormwater runoff in Tampa, Florida.

		TSS $\log_{10}$ values (mg/l)		TP $\log_{10}$ values (mg/l)			TN $\log_{10}$ values (mg/l)		
Land use	Parameter	WBD	Study[a]	WBD	Study[a]	Tampa	WBD	Study[a]	Tampa
Urban residential	Number of events (n)	209	220	209	220	121	209	220	121
	Mean	2.18	1.47	−0.47	−0.87	−0.37	0.26	0.04	−0.013
	Std. Dev.	0.39	0.51	0.32	0.63	0.34	0.23	0.38	0.24
Commercial	Number of events (n)	120	100	120	100	–	120	100	–
	Mean	2.16	1.343	−0.39	−1.01	–	0.37	0.019	–
	Std. Dev.	0.38	0.429	0.34	0.58	–	0.34	0.106	–

[a] Note that the mean of the log-transformed dataset is not mathematically equivalent to the log-transformation of the raw dataset mean.

Table 6
Comparison of Mean ± 1 SD Nitrogen Fractions from various sources against the Study results, and GCCC draft protocol.

Nitrogen species	Taylor et al., 2005	Francey (2010)	SEQ urban residential	SEQ commercial	GCCC draft protocol[b]	
					Typical fraction	Minimum fraction
NO_x	36% ± 11%	35% ± 9%	16.2% ± 17.3%	20.9% ± 15.6%	25%–40%	20%
NH_3	13% ± 10%	12% ± 10%	8.6% ± 11.7%	14.1% ± 15.1%	10–20%	5%
DON	28% ± 11%	20% ± 3%	75.8% ± 26.4%	62.6% ± 25.8%	45–70%	–
PON	24% ± 15%	33% ± 10%				
TKN	65%[a]	65% ± 9%[c]	84.0% ± 22.1%	76.7% ± 18.1%	55–75%	

[a] By calculation from Taylor et al., 2005.

[b] Source: (Development Application Requirements and Performance Protocol for Proprietary Devices on the Gold Coast, Designflow & E2Designlab, 2015).

[c] By calculation from Francey (2010).

6.2. Comparison between guidelines and recent stormwater pollutant concentrations

This review of collated urban runoff quality data from 12 monitoring sites by various researchers found that TSS, TP and TN concentrations in stormwater runoff from residential and commercial landuses in relatively small SEQ catchments (Table 5) were significantly lower ($p < 0.05$) than previously reported and subsequently implemented in local guidelines (BCC, 2004). Review of the 320 storm events on urban residential and commercial catchments observed mean EMCs for TSS ~61% lower, TP ~18% lower, and TN ~10% lower than those recommended by local guidelines. Background data for the guidelines was collected more than a decade ago and whilst several studies have characterized catchment runoff concentrations, until now, they have not been collated into a dataset of sufficient size to enable statistical comparison, due to temporal and fiscal constraints. Various factors may be causing lower pollutant concentrations in urban runoff from the monitoring sites including different catchment scales, advances in catchment management practices (e.g. lower lawn fertilization rates, rainwater harvesting), changes in vehicle fuels, different road surfaces or larger-scale climatic variability in rainfall, intensity and washoff characteristics. Many Councils in Australia have encouraged the use of native plant species and lower fertilization of grass (lawn) verges thereby likely producing lower nutrient concentrations in runoff. Further, many have also implemented community education programs encouraging dog owners to collect and dispose of droppings instead of leaving them on footpaths to contaminate runoff with NH_3 and bacteria. Rainwater harvesting has been implemented in some areas, which could be collecting a portion of dissolved nitrogen in rainfall and reducing it in runoff. The scope of this study did not include investigating the potential influencing factors with any certainty. However, future research is recommended to quantify this.

6.3. Comparison of SEQ nitrogen forms — draft GCCC protocol and Melbourne data

This review found that NH_3 was the least prevalent form of nitrogen observed in the SEQ storm event concentrations (Table 7). This is consistent with findings from Taylor et al. (2005). Ammonia is typically formed as a result of breakdown of organic matter, excretions from animals, and processes with organic waste products, e.g. sewage (Smith, 2013). Therefore, observations of high concentrations and high relative proportions of NH_3 compared to TN in stormwater runoff could be interpreted as indicators of cross-connection of sanitary sewers to stormwater drainage, even though this is practice is prohibited in Australia. The relatively low proportions of NH_3 observed in the SEQ data suggests cross-connection from sewer to stormwater is highly unlikely at these sites.

The results from this study (Table 7) indicate that the average proportion of NO_x in runoff from lot-scale SEQ catchments is 16–20% lower than the findings from Melbourne (Francey, 2010; Taylor et al., 2005). It is also below the range of values given in the GCCC draft protocol (DesignFlow and E2Designlab, 2015). The study results show that the proportion of Organic N is 9–22% greater than the findings from Melbourne (Francey, 2010; Taylor et al., 2005). This concludes that the selection of the Melbourne data on nitrogen forms for use in guidelines in SEQ is inappropriate.

6.4. Implications for stormwater management

As previously stated, current guidelines (State of Queensland, 2017) for stormwater treatment in Southeast Queensland set water quality improvement targets at 80% load removal for TSS, 60% for TP and 45% for TN. The effectiveness of treatment measures is typically modelled assuming there is a background concentration beyond which further removal is unlikely (eWater, 2017a).

If the stormwater pollutant concentrations (i.e. loads) leaving the catchment are lower than previously reported, as the results of this review appears to suggest, stormwater treatment measures may struggle to achieve the State of Queensland (2017) load reduction targets. In other words, if the influent concentration and background concentration converge, the load available for removal is limited. This could have a significant influence on the type and area of stormwater treatment measures required to achieve the targets in future developments. It implies that all lot-scale developments in SEQ are presently being modelled with incorrect input pollutant concentrations that are over-estimating the efficiency of treatment measures, and therefore incorrectly sizing them. This has a significant financial implication for development projects, could be creating a detrimental environmental outcome and result in assets that may become a financial burden to local authorities.

Based on this research and review, it is suggested that the current guidelines input concentrations for pollutant export modelling be revised, and subsequently the target pollutant load reductions (WQOs) be reconsidered, especially at the smaller lot scale. A second influent

Table 7
Mean ± 1 Standard Deviation (SD) for the Storm Flow Nitrogen Composition from reviewed Literature and recent research.

	Nitrogen species	SEQ urban residential	Taylor et al. (2005) Melbourne	Francey (2010) Melbourne	Duncan (1999) International	Yang and Toor (2016, 2017)
DIN	NO_x (Nitrite + Nitrate)	16% ± 17%	36% ± 11%	35% ± 9%	24% ± 13%	24% ± 36%
	NH_3	9% ± 12%	13% ± 10%	12% ± 10%	5% ± 4%	–
Organic N	DON	76% ± 26%	28% ± 11%	20% ± 3%	71%[a]	73% ± 11%
	PON	84% ± 22%	24% ± 15%	33% ± 10%		

[a] Assumed value as proportions of Organic Nitrogen not reported in international literature.

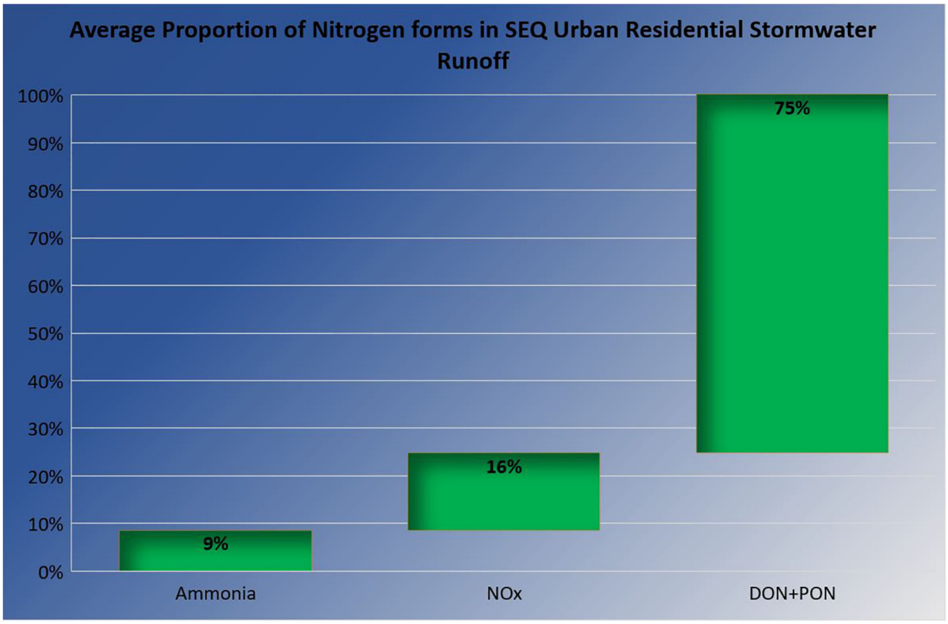

Fig. 1. Relative Average Proportion of Nitrogen forms in SEQ urban residential runoff.

(catchment) concentration dataset may be appropriate for pollutant export modelling of smaller catchments.

Previous research (Taylor et al., 2005) recommended that stormwater treatment measures focus on the removal of dissolved nitrogen species (DON and NO_x) from urban stormwater primarily with vegetated systems. This study on lot-scale developments in SEQ, has shown that the Organic N fraction (TKN) forms a greater proportion of TN than the NO_x fraction, as shown in Fig. 1. The findings of this research, therefore, counter the former advice that stormwater treatment measures should be designed to specifically target NO_x (e.g. Constructed wetlands and biofiltration). These measures alone may not necessarily achieve the 45% TN load removal target, or at the lower concentrations observed, may require a significantly larger footprint. The TN WQO can be achieved by targeting different nitrogen fractions with a range of alternate stormwater treatment measures. This provides stormwater designers greater flexibility in the selection of appropriate treatment measures to suit their site and provides potential cost-savings.

In larger catchments, >10 ha for example, there may be sufficient time for biological and physico-chemical processes to break down Organic N into NO_x, although this hypothesis was not investigated in this study. Further research is recommended to evaluate the potential for a spatial or temporal point at which the forms of nitrogen change as runoff is transported through the catchment. If this is happening at this regional scale, it will potentially guide the application of treatment measures, such as constructed wetlands and biofiltration, and their appropriate location in the catchment.

7. Conclusion

Much stormwater management policy in Australian is underpinned by results of a literature review undertaken in the late 1990s. While this literature review was a major step forward at the time, many of the studies reviewed were international, and not necessarily applicable to Australian conditions.

This study investigated the pollutant concentrations in runoff from residential and commercial land-use sites in South-east Queensland and compared them with the values recommended in current design guidelines. The study found that TSS, TP and TN concentrations in stormwater runoff from lot-scale developments with residential and commercial land-uses in SEQ were significantly lower ($p < 0.05$) than previously reported. The current research from 220 events on urban residential catchments and 100 events from commercial catchments observed mean concentrations for TSS ~61% lower, TP ~18% lower, and TN ~10% lower than previously reported. Ongoing application of out-dated influent values in pollutant export models (e.g. MUSIC) as part of development assessment processes could potentially provide inaccurate results, incorrectly sized and under-performing treatment measures, and adverse environmental and financial outcomes.

Evaluation of nitrogen forms in the SEQ study stormwater samples found that Organic N made up the largest percentage of TN. Where previously stormwater treatment systems, e.g. constructed wetlands and biofiltration, may have been recommended and sized to target NO_x, this latest data from SEQ catchments suggests that the proportion of NO_x in the TN load may not be sufficient to the achieve desired water quality objectives (i.e. 45% TN load reduction). Therefore, at the lot scale, it may be appropriate to meet pollution reduction targets by also capturing Organic N with a range of alternate treatment measures.

Further research is required to reinforce the findings of this study in other locations across Australia, and it is planned to continue this study and include future SEQ water quality research results. Research into the presence of a temporal point during a storm event, or spatial point in the catchment, at which nitrogen transforms from organic to dissolved inorganic forms is also recommended.

Declaration of interest

The research at 6 of the 12 sites summarized by this paper was independently undertaken by USC, project managed by Drapper Environmental Consultants, under a funding arrangement with SPEL Environmental. The catchment input concentrations reported in this paper are from samples prior to receiving any treatment.

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