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Influence of pollutant build-up on variability in wash-off from urban road surfaces

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HIGHLIGHTS

- Key characteristics of pollutant wash-off process variability are identified.
- Variability of pollutant build-up process influences pollutant wash-off process.
- Pollutant wash-off is a function of the build-up of particles <150 μm and >150 μm.
- Particles <150 μm generate significant variability in pollutant wash-off process.

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ABSTRACT

Variability in the pollutant wash-off process is a concept which needs to be understood in-depth in order to better assess the outcomes of stormwater quality models, and thereby strengthen stormwater pollution mitigation strategies. Current knowledge about the wash-off process does not extend to a clear understanding of the influence of the initially available pollutant build-up on the variability of the pollutant wash-off load and composition. Consequently, pollutant wash-off process variability is poorly characterised in stormwater quality models, which can result in inaccurate stormwater quality predictions. Mathematical simulation of particulate wash-off from three urban road surfaces confirmed that the wash-off load of particle size fractions <150 μm and >150 μm after a storm event vary with the build-up of the respective particle size fractions available at the beginning of the storm event. Furthermore, pollutant load and composition associated with the initially available build-up of <150 μm particles predominantly influence the variability in washed-off pollutant load and composition. The influence of the build-up of pollutants associated with >150 μm particles on wash-off process variability is significant only for relatively shorter duration storm events.

1. Introduction

Pollutants generated from a range of natural and anthropogenic activities in urban environments accumulate on impervious surfaces such as roads, over the dry weather period. During storms, these pollutants are mobilised and transported to receiving waters, leading to the deterioration of water quality. Pollutants adhering to the road surfaces are mobilised by the kinetic energy of raindrops and the turbulence created by flowing water (stormwater runoff). The phenomenon is known as pollutant wash-off (Duncan, 1995).

Egodawatta et al. (2007) reported that the amount of pollutants washed-off is a fraction of the pollutants available at the beginning of a storm event (pollutant build-up over antecedent dry weather period), and varies with rainfall and pollutant characteristics. As such, for a specific set of rainfall characteristics, the pollutant wash-off load varies primarily with the initially available load. Moreover, Wijesiri et al. (2015) found that during pollutant build-up, both, pollutant load and composition, which is the mixture of fractional amounts of pollutants with different characteristics, vary over the antecedent dry period. Therefore, a storm event with the same characteristics, but occurs after different antecedent dry weather conditions could generate significant variability in the pollutant wash-off load and composition.

Notably, the current knowledge about the pollutant wash-off process does not extend to a clear understanding about the variability (load and composition) associated with the process (Egodawatta and Goonetilleke, 2008; Hossain et al., 2011; Vaze and Chiew, 2003; Zhao and Li, 2013). Consequently, significant issues emerge in relation to the formulation of robust strategies for the mitigation of urban water pollution as poor characterisation of process variability in urban

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stormwater quality models will result in inaccurate stormwater quality predictions (Bartley et al., 2012; Dotto et al., 2011; Haddad et al., 2014; Shrestha et al., 2008).

The primary objective of the study discussed in this paper was to identify the important characteristics of variability in pollutant wash-off process that can be incorporated into stormwater quality models. As such, the influence of the initially available pollutant build-up on load and composition in pollutant wash-off was investigated. Wijesiri et al. (2015) reported that the variations in pollutant load and composition during build-up are primarily determined by the temporal variations in particle size fractions <150 μm and >150 μm over the antecedent dry period. The significance of these particle fractions was distinguished by their characteristic behaviour during build-up and the pollutant load associated with each fraction. Therefore, in the current study, it was hypothesised that the variations in pollutant wash-off load and composition can be explained in terms of the wash-off of initially available build-up of particle size fractions <150 μm and >150 μm.

Based on the relationships identified between particulate wash-off and initially available particulate build-up, this paper also presents the important characteristics associated with the variability of the pollutant wash-off process. The new knowledge presented will contribute to a better understanding and interpretation of model outcomes and lead to the development of robust stormwater pollution mitigation strategies. Additionally, the new knowledge can be incorporated into stormwater quality models, and thereby enhancing the accuracy of stormwater quality predictions.

2. Materials and methods

2.1. Study sites, test methods and experimental data

Experiments on particulate build-up and wash-off were conducted at three residential road sites (Gumbeel Court, Piccadilly Place and Lauder Court) located at Highland Park, Gold Coast, Australia. The aerial and street views of the study sites are shown in Fig. 1. The sites were selected encompassing different residential urban forms in the catchment and traffic volumes (Egodawatta, 2007). The details of the type of housing, number of households and population density at each site, and road surface characteristics such as longitudinal slope and texture depth are also included in Fig. 1.

The build-up and wash-off sampling were conducted using a portable wet vacuum system and a rainfall simulator, respectively. Prior to the field experiments, the vacuum system was tested for its sample

Fig. 1. Aerial and street views of study site locations in Highland Park Catchment.