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Intrinsic and extrinsic factors which influence metal adsorption to road dust

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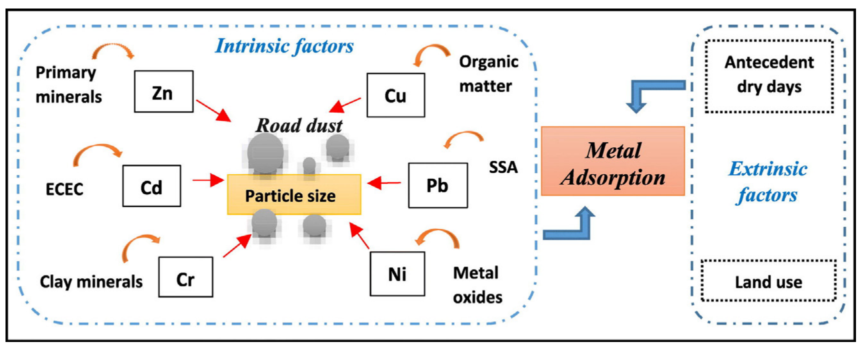
HIGHLIGHTS

- Key influential factors in relation to metal adsorption were investigated.
- Not all the factors exert same level of influence in metal adsorption.
- Initial antecedent dry days have a significant influence on metal adsorption.
- Influence of intrinsic properties of solids vary from one metal species to another.

GRAPHICAL ABSTRACT



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ABSTRACT

The adsorption behaviour of metals deposited on road surfaces is a complex process and influenced by a range of factors common to the urban environment. However, all factors do not have the same level of importance. It is therefore important to identify the most crucial factors for accurate stormwater quality predictions and to implement effective stormwater pollution mitigation measures. Accordingly, this study investigated the extrinsic and intrinsic factors in terms of their degree of influence on the adsorption of individual metal cations to particulates. The variability associated with the adsorption of Zn, Cu, Pb, Cd, Cr and Ni to road dust was found to be influenced by changes to the antecedent dry days and land use characteristics. The initial dry days after a storm event exerts a significant influence on adsorption compared to the later dry days in all land uses. In terms of the intrinsic physico-chemical properties of road dust, the parameters that influence the adsorption process differ in terms of the type of metal cation and particle size fractions of solids. Based on the influential parameters identified, the bioavailability characteristics of Zn, Cd, Pb and Ni in <150 μm size fraction of road dust and potential stormwater quality impacts can be highlighted.

1. Introduction

Pollutants originating from diverse sources common to urban areas are deposited on impervious surfaces such as roads over the dry period and are primarily associated with road deposited solids, which is generally termed as road dust (Lee et al., 2005; Mahbub et al., 2011). Metals attached to road dust have been identified as one of the key pollutants that can cause adverse impacts on the receiving water environment (Fairbrother et al., 2007; Huber et al., 2016). Consequently, the development of effective strategies to mitigate metal pollution has gained wide attention in recent years. In this context, an in-depth understanding of the adsorption behaviour of metals is essential for effective decision making for stormwater quality management.

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A range of factors influences the adsorption behaviour of different metal cations and their bioavailability characteristics. These influential factors can be identified as intrinsic factors, such as physical and chemical properties of associated solids such as particle size, mineralogy, organic matter content and specific surface area and extrinsic factors, such as land use characteristics and climatic parameters (Egodawatta et al., 2013; Gunawardana et al., 2015; Liu et al., 2016; Wicke et al., 2012). These factors can either, individually or selectively influence metal adsorption to solids and they do not necessarily have the same level of influence. Due to the complex nature of associated solids and dynamic changes to influential factors, the fate of metals and their impacts on stormwater quality would be different for different metal cations. However, as pointed out by Wijesiri et al. (2016), the variability and the uncertainty associated with pollutant processes, which are primarily influenced by the complex chemical behaviour of particle bound pollutants are not adequately accounted in the stormwater quality analyses.

There is significant knowledge existing in relation to the factors that influence metal build-up due to the range of studies undertaken to investigate factors that influence metal accumulation (build-up) on road surfaces. For example, Egodawatta and Goonetilleke (2006), Egodawatta et al. (2013) and Wicke et al. (2012) investigated and modelled the metal build-up load as a function of antecedent dry days (ADDs). The role of land use characteristics, traffic volume and meteorological conditions on metal build-up were investigated by Gunawardena et al. (2014), Mahbub et al. (2010) and Murphy et al. (2015). Furthermore, a comprehensive study was carried out by Liu et al. (2016), taking into consideration a wide range of influential factors on heavy metal build-up.

However, there is a limited evidence in research literature in relation to the influence of intrinsic and extrinsic factors on metal adsorption, including antecedent dry days. The investigation of such factors collectively and subsequent identification of the most crucial factors for metal adsorption is important for accurate stormwater quality predictions and for the implementation of pollution mitigation measures targeting specific metal species. Accordingly, the objectives of this study were: (1) to identify the relevant factors which influence the variability associated with metal adsorption to road dust; and (2) to analyse the most crucial intrinsic factors related to the adsorption of individual metal cations to road dust.

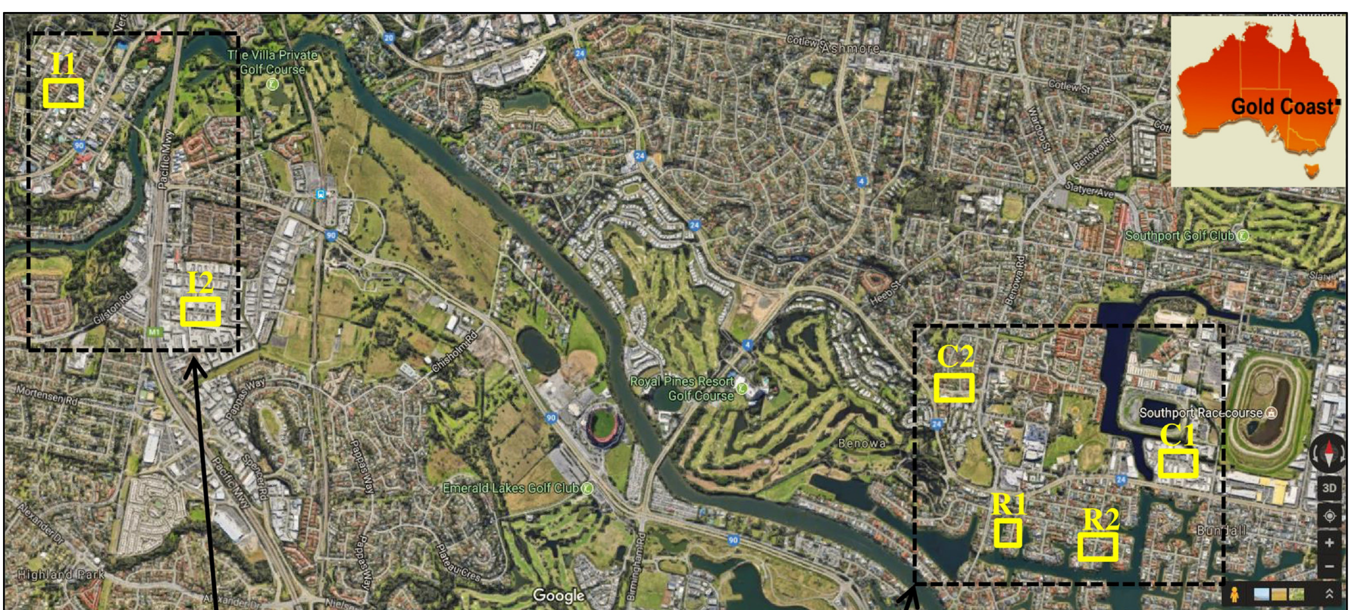
2. Material and methods

2.1. The study sites

The primary consideration in the study site selection was the collection of road dust samples with physico-chemical properties to represent the range of traffic and land use characteristics common to commercial, residential and industrial areas. Six study sites, representing two sites from each land use were selected from two urban suburbs, Benowa and Nerang, in Gold Coast, Australia (Fig. 1).

2.2. Sample collection and laboratory analyses

Road dust samples were collected using a dry and wet vacuum method as described by Jayarathne et al. (2017). A plot area of one-meter width by the distance from the kerb to the road centreline was demarcated at each study site, ensuring the representative collection of solids present on the road surface. In order to investigate the influence of antecedent dry days (ADDs) on metal adsorption, sampling was carried out for four different dry periods, namely, one, four, seven and eleven days.



Nerang

Site	Name	Landuse	DTV
I1	Stevens street	Industrial	3500
I2	Hilldon court	Industrial	3500

Benowa

Site	Name	Landuse	DTV
C1	Strathaird road	Commercial	3000
C2	Mediterranean drive	Commercial	750
R1	De Haviland avenue	Residential	500
R2	Village High road	Residential	750

Fig. 1. Study sites. Note: DTV-daily traffic volume (obtained from Gold Coast City Council).