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Human health risk assessment of heavy metals in urban stormwater

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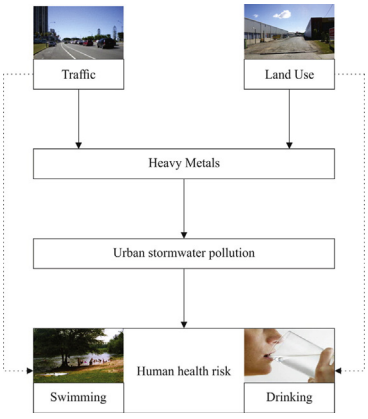
HIGHLIGHTS

- Heavy metal concentration in stormwater is a function of traffic and land use.
- Quantitative approach developed to assess risk from heavy metals in stormwater.
- Hazard index rather than concentration is important to assess risk to human health.
- Guideline thresholds for heavy metals should consider hazard index.
- Cr contributes most to the risks of the HM mixture in stormwater.

GRAPHICAL ABSTRACT



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ABSTRACT

Toxic chemical pollutants such as heavy metals (HMs) are commonly present in urban stormwater. These pollutants can pose a significant risk to human health and hence a significant barrier for urban stormwater reuse. The primary aim of this study was to develop an approach for quantitatively assessing the risk to human health due to the presence of HMs in stormwater. This approach will lead to informed decision making in relation to risk management of urban stormwater reuse, enabling efficient implementation of appropriate treatment strategies. In this study, risks to human health from heavy metals were assessed as hazard index (HI) and quantified as a function of traffic and land use related parameters. Traffic and land use are the primary factors influencing heavy metal loads in the urban environment. The risks posed by heavy metals associated with total solids and fine solids (<150 μm) were considered to represent the maximum and minimum risk levels, respectively. The study outcomes confirmed that Cr, Mn and Pb pose the highest risks, although these elements are generally present in low concentrations. The study also found that even though the presence of a single heavy metal does not pose a significant risk, the presence of multiple heavy metals could be detrimental to human health. These findings suggest that stormwater guidelines should consider the combined risk from multiple heavy metals rather than the threshold concentration of an individual species. Furthermore, it was found that risk to human health from heavy metals in stormwater is significantly influenced by traffic volume and the risk associated with stormwater from industrial areas is generally higher than that from commercial and residential areas.

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1. Introduction

Anthropogenic activities common to urban areas generate a diverse range of pollutant loads of physical, chemical and biological origin. These pollutants are initially build-up on urban surfaces during the dry periods and are washed-off by stormwater runoff, posing a threat to receiving water environments (Goonetilleke et al., 2005). Among the various anthropogenic activities, motor traffic and urban land use activities are the two main sources that generate large amounts of chemical pollutants (Brown and Peake, 2006). For example, chemical pollutants such as heavy metals are primarily generated by motor traffic related sources such as brake wear, tyre wear and vehicle exhaust together with commercial and industrial activities (Gunawardana et al., 2012; Parra et al., 2006; Wei and Yang, 2010).

Heavy metals (HMs) are among the most critical pollutants impacting human and ecosystem health due to their toxicity (Wong et al., 2007). Exposure to HMs can lead to various diseases such as cancer, hypertension and renal dysfunction (Hu, 2002). According to past research studies, high concentration of HMs in urban stormwater is a common issue worldwide and have the potential to exceed the threshold values recommended in guidelines for recreational and potable uses (Birch et al., 2004; Wang et al., 2013; Zgheib et al., 2012).

Due to the ever increasing demand for potable water in urban areas, stormwater reuse is an attractive alternative. Currently, stormwater is a highly under-utilised resource. Furthermore, urban water environments are important community areas. As urbanisation intensifies, water environments play a significant role as aesthetic and recreational assets. In this context, managing the risks posed by HMs is essential for stormwater pollution management and stormwater reuse. As risk assessment is the essential foundation of risk management (AS/NZS, 2009), it is important to develop a reliable approach to quantitatively assess risk to human health posed by HMs in stormwater.

The primary aim of the study discussed in this paper was to develop an innovative approach for undertaking a quantitative assessment of the risk posed by HMs in stormwater, incorporating traffic and land use characteristics as the influential drivers. Traffic and land use characteristics play the key roles in influencing the risk posed by HMs in stormwater. Land use primarily defines the types of anthropogenic activities within a specific urban area, while traffic characteristics can vary within the same land use and between different land use areas creating diversity in HM loads and composition.

Currently, there is no reliable approach to quantitatively assess the risk posed by HMs in stormwater resulting from traffic and land use activities. This knowledge gap constrains the reliable assessment and management of human health risks posed by HMs in the context of beneficial reuse of stormwater. The outcomes of the study are expected to bridge this knowledge gap and thereby enhance the reuse of stormwater and to mitigate its adverse impacts on the urban environment.

2. Materials and methods

2.1. Study sites selection

The research study was based at Gold Coast, Queensland State, Australia. Differences in traffic volume and land use type were considered as the most important criteria in individual study site selection. Accordingly, a total of 20 sites spread over 5 suburbs were selected (Fig. 1). These suburbs were; Surfers Paradise, Benowa, Nerang, Clearview Estate-Nerang and Advancetown, representing commercial, mixed (i.e. commercial, industrial and residential), industrial, residential and natural land uses, respectively. Commercial suburb encompassed areas which included grocery stores, tourism related services, office space and vehicle related sales and services, while the industrial suburb included painting, welding, and steel and aluminium fabrication activities. Four study sites from each suburb were selected to accommodate different traffic characteristics. Fig. 1 shows the corresponding daily traffic volume (DTV) (average vehicle count per day) and the percentage of the different land use types demarcated as commercial, industrial and residential (C, I and R (%)) within an area enclosed by an area of 1 km radius at each study site. Traffic volume data was obtained from Gold Coast City Council. The different land use areas were demarcated using Google Earth software

Sites	DTV	C (%)	I (%)	R (%)
CE1	500	0	0	62%
CE2	750	0	0	32%
CE3	750	0	0	63%
CE4	3000	0	0	34%

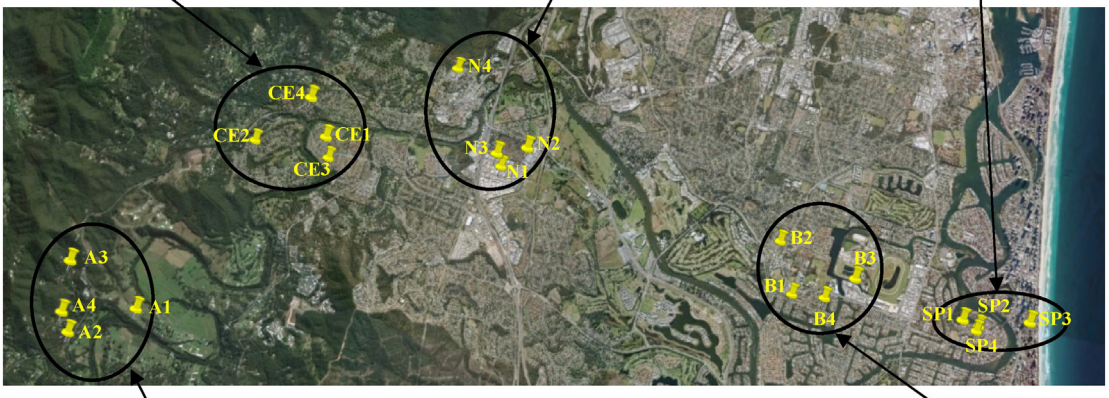
Clearview Estate-Nerang

Sites	DTV	C (%)	I (%)	R (%)
N1	3500	14%	20%	31%
N2	7000	6%	17%	22%
N3	750	14%	19%	31%
N4	3500	19%	2%	24%

Nerang

Sites	DTV	C (%)	I (%)	R (%)
SP1	750	11%	0	45%
SP2	750	18%	0	40%
SP3	3000	29%	0	21%
SP4	3000	16%	0	42%

Surfers Paradise



Sites	DTV	C (%)	I (%)	R (%)
A1	750	0	0	0
A2	1000	0	0	0
A3	150	0	0	0
A4	150	0	0	0

Advancetown

Sites	DTV	C (%)	I (%)	R (%)
B1	500	19%	0	52%
B2	750	18%	0	58%
B3	3000	50%	0	34%
B4	750	29%	0	51%

Benowa

Fig. 1. Map of selected sites. Note: DTV - daily traffic volume (average vehicle count per day); C, I and R - percentage of commercial, industrial and residential areas within 1 km (%).