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Characterizing heavy metal build-up on urban road surfaces: Implication for stormwater reuse

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HIGHLIGHTS

- Heavy metal (HM) build-up varies with traffic and road surface conditions.
- Traffic congestion and surface roughness exert a higher impact on HM build-up.
- A "fit-for-purpose" strategy could suit urban road stormwater reuse.

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ABSTRACT

Stormwater reuse is increasingly popular in the worldwide. In terms of urban road stormwater, it commonly contains toxic pollutants such as heavy metals, which could undermine the reuse safety. The research study investigated heavy metal build-up characteristics on urban roads in a typical megacity of South China. The research outcomes show the high variability in heavy metal build-up loads among different urban road sites. The degree of traffic congestion and road surface roughness was found to exert a more significant influence on heavy metal build-up rather than traffic volume. Due to relatively higher heavy metal loads, stormwater from roads with more congested traffic conditions or rougher surfaces might be suitable for low-water-quality required activities while the stormwater from by-pass road sections could be appropriate for relatively high-water-quality required purposes since the stormwater could be relatively less polluted. Based on the research outcomes, a decision-making process for heavy metals based urban road stormwater reuse was proposed. The new finding highlights the importance to undertaking a "fit-for-purpose" road stormwater reuse strategy. Additionally, the research results can also contribute to enhancing stormwater reuse safety.

1. Introduction

Stormwater is receiving significant attention as a viable alternate water resource for reuse which is currently under-utilized (Al-Salaymeh et al, 2011; Shannak et al., 2014). This is particularly important to water-scarce regions and areas where rainfall characteristics such as rainfall pattern and rainfall frequency are predicted to be influenced by climate change (Tang et al., 2013). Additionally, reusing stormwater is important in the context of creating water sensitive human settlements, where urban areas act as water supply catchments with access to water from a diversity of sources, including stormwater (Floyd et al., 2014). In this context, understanding stormwater pollutant processes to ensure safe reuse is particularly important due to the fact that there are a range of toxic pollutants such as heavy metals present in stormwater runoff (Brown and Peake, 2006; Mahbub et al., 2010).

Past researchers have identified urban roads as a primary pollutant source to stormwater runoff (Wei and Yang, 2010; Adachi and Tainosho, 2004; Johansson et al., 2009). Since road stormwater commonly contains toxic pollutants (such as traffic-related heavy metals), its reuse is potentially relevant to purposes which do not require high water quality such as street clean, public toilet flushing, landscape, roadside plant irrigation and river recharge. Additionally, these toxic pollutants could potentially pose ecological risks, which vary with pollutant types, pollutant loads, pollutant toxicity and pollutant mobility. Therefore, for some reuse purposes such as plant irrigation and river recharge, it should take the potential ecological risk into account while it could not be necessarily concerned for other purposes such as street clean and public toilet flushing.

Furthermore, since urban road runoff could be highly variable with road site characteristics such as traffic and road surface conditions, how to appropriately reuse them according to their quality characteristics

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and potential ecological risk becomes an essential question. This requires an in-depth understanding of pollutant availability on road surfaces, namely build-up. Pollutant build-up represents pollutant availability for wash-off by runoff. Additionally, sufficient runoff volumes, which are generated by relatively large rainfall events are necessary for stormwater reuse. In this case, most of pollutants built-up on the road surfaces can be washed-off. Therefore, it was considered that pollutant build-up is able to indicate the pollutant amount present in the stormwater runoff. In other words, pollutants that are built-up are eventually washed-off by runoff and hence have a direct influence on pollutant species and concentrations in the stormwater. This in turn has an important influence on stormwater reuse strategies. For example, which road site/s' stormwater runoff are suitable for reuse? What reuse purposes are the stormwater suitable for? In this context, only build-up characteristics were investigated in the research study rather than both build-up and wash-off characteristics.

Heavy metals have been of concern in the stormwater reuse due to their potential toxicity (Yi et al., 2011). This paper presents the outcomes of an extensive research study on heavy metal build-up on a range of urban roads in a typical megacity of South China. The primary objectives were: (1) to characterize heavy metal build-up loads; (2) to analyze the key factors which influence heavy metal build-up; (3) to assess potential ecological risk posed by these heavy metal loads; and (4) to develop a decision-making process for heavy metals based road stormwater reuse. The new finding is expected to contribute to applying adequate stormwater reuse strategy and hence enhancing the safety of urban road stormwater reuse.

2. Materials and methods

2.1. Study sites

The research study was conducted in South China, which is a sub-tropical zone with abundant annual rainfall (ranging from 1400 to 2000 mm) but usually suffers from water scarcity. Shenzhen, which is a typical megacity in South China (the extent of about 2000 km^2 and a population of over 11 million), was selected as the study sites. In order to investigate heavy metal build-up, ten urban road surfaces in Shenzhen encompassing different land uses, traffic characteristics and road surface conditions were selected as study sites. The ten roads are primarily paved with asphalt since asphalt paved road surfaces are the typical road type in China. There are no other pollutant sources such as industrial plants close to the selected road surfaces. This ensures

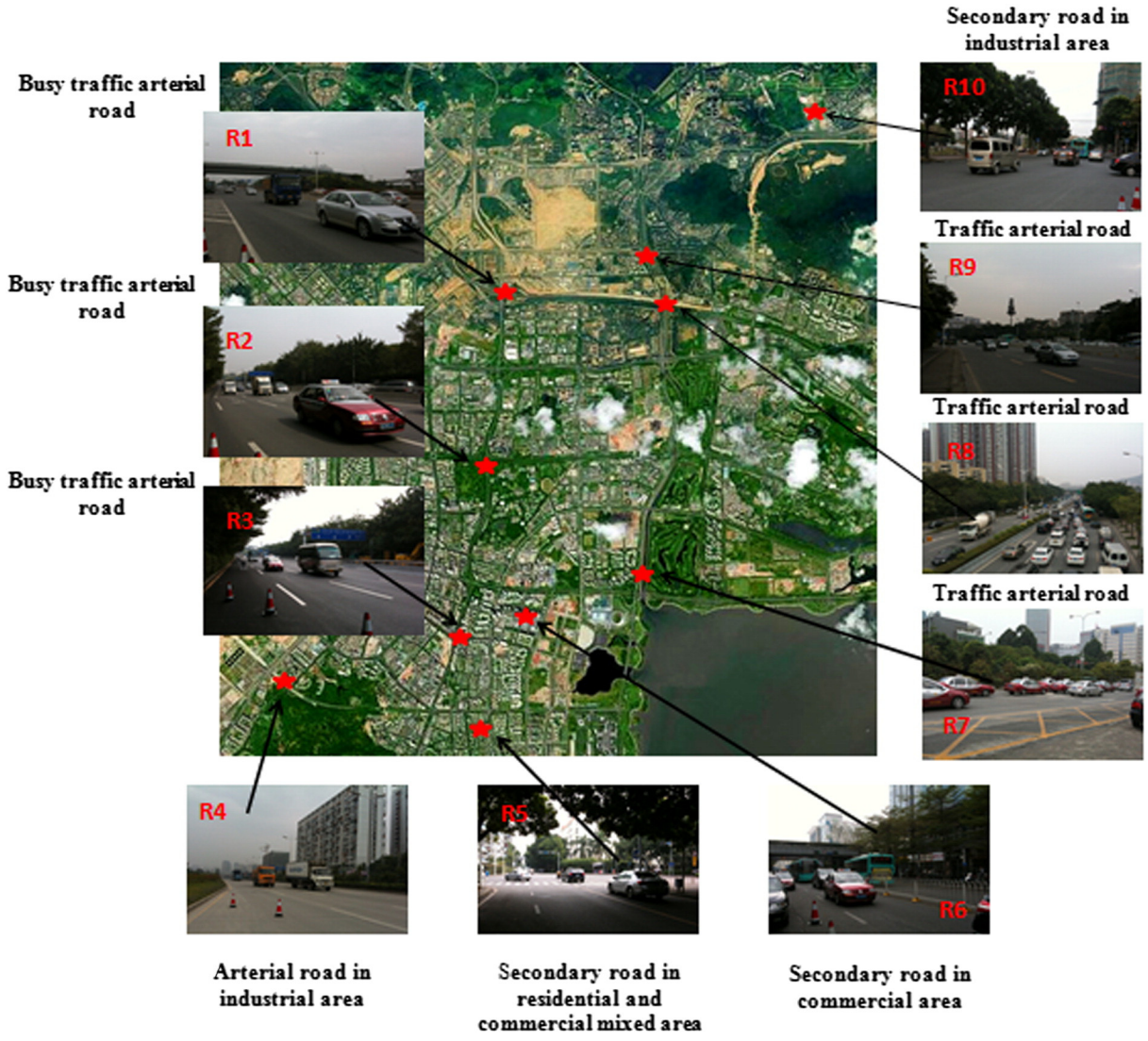

Fig. 1. Selected study road sites and their characteristics.