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Anthropogenic land uses elevate metal levels in stream water in an urbanizing watershed

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HIGHLIGHTS

• Urban and agricultural land uses contribute to instream metal loadings.
• Urban land use acts as a "flashy" source for instream metal loadings.
• Rainfall acts as a source and a key driver for instream metal loadings.

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ABSTRACT

Land use/cover change is a dominant factor affecting surface water quality in rapidly developing areas of Asia. In this study we examined relationships between land use and instream metal loadings in a rapidly developing mixed land use watershed in southeastern China. Five developing subwatersheds and one forested reference site (head water) were instrumented with timing- and rainfall-triggered autosampler and instream loadings of anthropogenic metals (Cu, Zn, Pb, Cr, Cd, and Mn) were monitored from March 2012 to December 2013. Farm land and urban land were positively, and forest and green land were negatively associated with metal loadings (except Cr) in stream water. All developing sites had higher loadings than the reference head water site. Assessed by Chinese surface water quality standard (GB3830-2002), instream loadings of Cu and Zn occasionally exceeded the Class I thresholds at monitoring points within farmland dominated subwatersheds while Mn loadings were greater than the limit for drinking water sources at all monitoring points. Farm land use highly and positively contributed to statistical models of instream loadings of Cu, Zn, Cd, and Mn while urban land use was the dominant contributor to models of Pb and Cd loadings. Rainfall played a crucial role in metal loadings in stream water as a direct source (there were significant levels of Cu and Zn in rain water) and as a driver of watershed processes (loadings were higher in wet years and seasons). Urbanization effects on metal loadings in this watershed are likely to change rapidly with development in future years. Further monitoring to characterize these changes is clearly warranted and should help to develop plans to avoid conflicts between economic development and water quality degradation in this watershed and in watersheds throughout rapidly developing areas of Asia.

1. Introduction

Land use change has become a force of global importance in recent decades, creating conflicts between immediate human needs and sustaining natural ecosystem service capacity (Foley et al., 2005). Increasing human population and development pressures motivate land use change for cropland and urban areas (Martinuzzi et al., 2014). Both these changes alter freshwater biodiversity and water quality (Martinuzzi et al., 2014), in-stream processes, watershed hydrological regimes (O'Driscoll et al., 2010), and river landscapes (Chin, 2006).

Runoff from urbanized catchments has been identified as a major source of contaminants, especially metals, impairing receiving waters (Yu et al., 2012; Xu et al., 2013; Memon et al., 2013; Kuusisto-Hjort and Hjort, 2013). In China, 13 out of 21 investigated cities had elevated metal levels in urban soils (Luo et al., 2012). Elevated metal levels were found in surface sediments and soils of urban parks in Shanghai (Li et al.,

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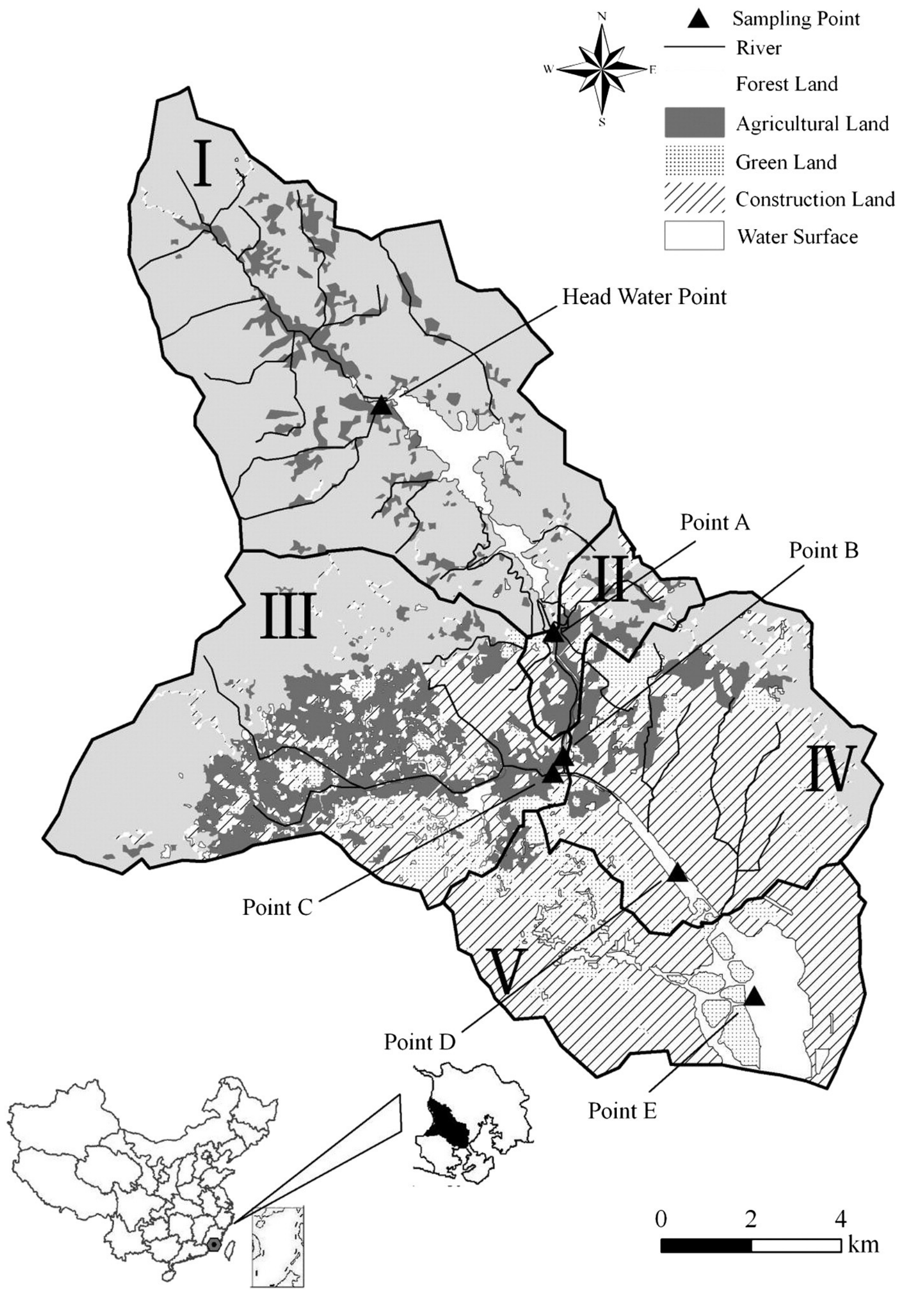

Fig. 1. Map of the Bantou watershed in Jimei County, Xiamen, China. Five subwatersheds are identified based on DEM data and named as forested headwater subwatershed (I), mixed subwatershed (II), agricultural dominated watershed (III), old residential subwatershed (IV), and estuarine subwatershed (V). Closed triangles indicate stream water sampling points equipped with automatic surface water samples (Point A, B, C, D, E and Head Water).

2012b). Kuusisto-Hjort and Hjort (2013) suggested that the intensity of urbanization could be an indicator for metal contamination in watersheds.

Metal loadings in urban watersheds can be derived from vehicle traffic, especially Zn, Cu, Pb and Cd (Sansalone et al., 2005; Zhao et al., 2010; Apeagyei et al., 2011). Sansalone et al. (2005) found that loadings of these metals were higher in urban stormwater than in untreated municipal wastewater in a city with a population of 800,000. Apeagyei et al. (2011) found that Zn and Ti significantly increased with traffic volume. In Shanghai, vehicular Pb and Hg contributed 10–30% of total Pb and Hg content in sediment cores over a century while coal combustion was the dominant source (>50%) (Li et al., 2012a, 2013). Lead enrichment in sediment increased with the level of urbanization (Li et al., 2012a; Le Pape et al., 2013). Sewage leaks are another source of metal loadings in urban watersheds (Le Pape et al., 2012, 2013).

While numerous studies have addressed urban sources of metal loading to stream water (Göbel et al., 2007), few have compared urban, agricultural and natural sources in mixed use watersheds. Shen et al. (2011) found that nutrient loads in urban reaches of the Cao-E River, China fluctuated with flow rate while agricultural reaches and mixed reaches had more consistent loads. Shields et al. (2008) found that in comparison with forested, agricultural, and even low-density suburban catchments, urbanized catchments exported more nitrogen at higher but less frequent flows. Nutrient loads in stream water clearly arise from fertilization in agricultural watersheds and from sewage in urban areas (Kaushal et al., 2011), but metal loadings in mixed use