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Ecological risk assessments and context-dependence analysis of heavy metal contamination in the sediments of mangrove swamp in Leizhou Peninsula, China

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ABSTRACT

Sediments in eight types of mangroves were sampled in the Leizhou Peninsula. Heavy metals were analyzed to investigate the effects on metal distribution of mangrove communities, to evaluate contamination levels, identify sources and relationships between the two. Results showed that mangrove communities have effects on most heavy metal distributions in sediments, especially in the sediment with shrub communities of *Aegiceras corniculatum* where the contents of many metals are highest. As, Cr and Ni were identified as metal pollutants of primary concern, while Cd was of no concern. Zn, Pb, As mainly originated from anthropogenic source while the other metals are geogenic. Heavy metal distributions were affected by the independent and joint effects of landscape and sediment context; landscape context explains more variations in heavy metals than does sediment physicochemical variables. Total sulfur, total phosphorus and total potassium in sediment, and the existence of paddy field and forest land within 2000 m around the sampling sites are significant variables also.

1. Introduction

Mangrove forests are diverse vegetation communities that commonly thrive in the intertidal zones of tropical and subtropical coastal rivers, estuaries and bays (Yim and Tam, 1999). Mangrove ecosystems provide food sources, diverse ideal habitats for residents and migratory organisms, and maintain stabilization for adjacent coastal landforms (MacFarlane et al., 2007). It is well known that mangroves have the capacity to act as a sink or buffer to remove or immobilize metals before they reach nearby aquatic ecosystems (Macfarlane and Burchett, 2001). However, the rapid development of agriculture, industrial and traffic practices bring large numbers of heavy metal pollutants to estuarine wetlands, which exert damaging effects on mangrove biodiversity and human health with its persistence, non-biodegradation, toxicity and bioavailability (Agoramoorthy et al., 2008; Tam and Wong, 2000). Therefore, metal contamination in mangrove swamp has received more concern.

Heavy metals derived from either weathering of rock and soil or the main anthropogenic activities, such as mining and smelting activities, disposal of untreated and partially treated effluents contain toxic metals, as well as metal chelates from different industries and indiscriminate use of heavy metal-containing fertilizer and pesticides in agricultural fields (Macklin et al., 2006; Nouri et al., 2008; Reza and Singh, 2010; Varol and Şen, 2012). In addition, there are many explainable variables for metal immobilization, deposition or accumulation, including organic matter, carbonates, phosphates, pH and sulfur compound in sediment (Bai et al., 2011; Cui et al., 2009; Kumpiene et al., 2008; Macfarlane and Burchett, 2001), and the land use at landscape scales (Xin et al., 2014). It is well-known that these explainable variables are often highly intercorrelated (Castrignanò and Buttafuoco, 2004; Facchinelli et al., 2001; Lin and Chang, 2000; Mico et al., 2006; Slavković et al., 2004). Thus, for effective control of heavy metals in mangrove swamp, it is necessary to identify the essentially important variables and gain an understanding of the interaction between these variables accounting for the variation of heavy metals, except to get the whole comprehension of heavy metal extent.

Multivariate statistical methods become very helpful to assess the interrelationships among the measured data. Principle component analysis (PCA) has been an effective tool for source identification of heavy metals (Bai et al., 2011; Han et al., 2006; Mico et al., 2006). Constrained ordination combined with variation partitioning among sets of explanatory variables was applied to examine the relative importance of these explanatory variables and their independent and joint effects on heavy metals (Borcard et al., 1992; Matthews et al., 2009; Wang et al., 2013).

Leizhou Peninsula harbors about 33% of Chinese mangroves (Gao et al., 2009). Although great efforts have been undertaken to monitor metal pollution level in mangrove swamp in Leizhou Peninsula (Zhang et al., 2006; Zhu et al., 2014), very few studies have considered the extent of heavy metal contamination in sediments with different mangrove vegetation. Several studies showed that mangroves have high capacity to accumulate heavy metals (Liu et al., 2014; MacFarlane et al., 2003; Qiu et al., 2011), while available heavy metals in the sediment could be reintroduced to water or be uptaken by plants (DeWolf and

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Rashid, 2008; Liu et al., 2014; MacFarlane et al., 2003). To understand the fate of heavy metals in a mangrove swamp, it is important to explore the difference of heavy metals in the sediments with different vegetation cover. Thus, the primary objectives of this study are: (1) to investigate heavy metal contamination in the sediments with different mangrove vegetation in Leizhou Peninsula; (2) to evaluate the potential ecological risks of heavy metals; (3) to identify the pollution sources and context dependence of these heavy metals using multivariate analysis.

2. Materials and methods

2.1. Study sites and sampling

The Leizhou Peninsula is located on the northern boundary of the tropics in South China with longitude 109°30′–110°55′E and latitude 20°12′–21°35′N. The mangrove area recorded by local governments was 7 305.8 ha in 2001, comprising 33% of total mangrove area in China and 80% in Guangdong Province (Gao et al., 2009). The field survey and sample collection at low tide were conducted in October and November 2012. Fourteen representative sampling sites were selected for this study (Fig. 1), including eight communities: dominated by tree community of *Avicennia marina*, *Phizophora stylosa*, *Kandelia candel*, *Sonneratia apetala* and *Aegiceras corniculatum* and shrub community of *A. marina*, *K. candel* and *A. corniculatum*. A community is here defined as having a certain, often monospecific, floristic composition, and covering an area above 300 m^2 for a tree community and 75 m^2 for a shrub community. Additionally, the tree community of *A. corniculatum*, *A. marina* and *K. candel* are all native vegetation, while most of their shrubs community have been planted. On every site, a sample transect was established parallel to the shoreline and three sub-sample plots (10 × 10 m size for tree community or 5 × 5 m size for shrub community) were established.

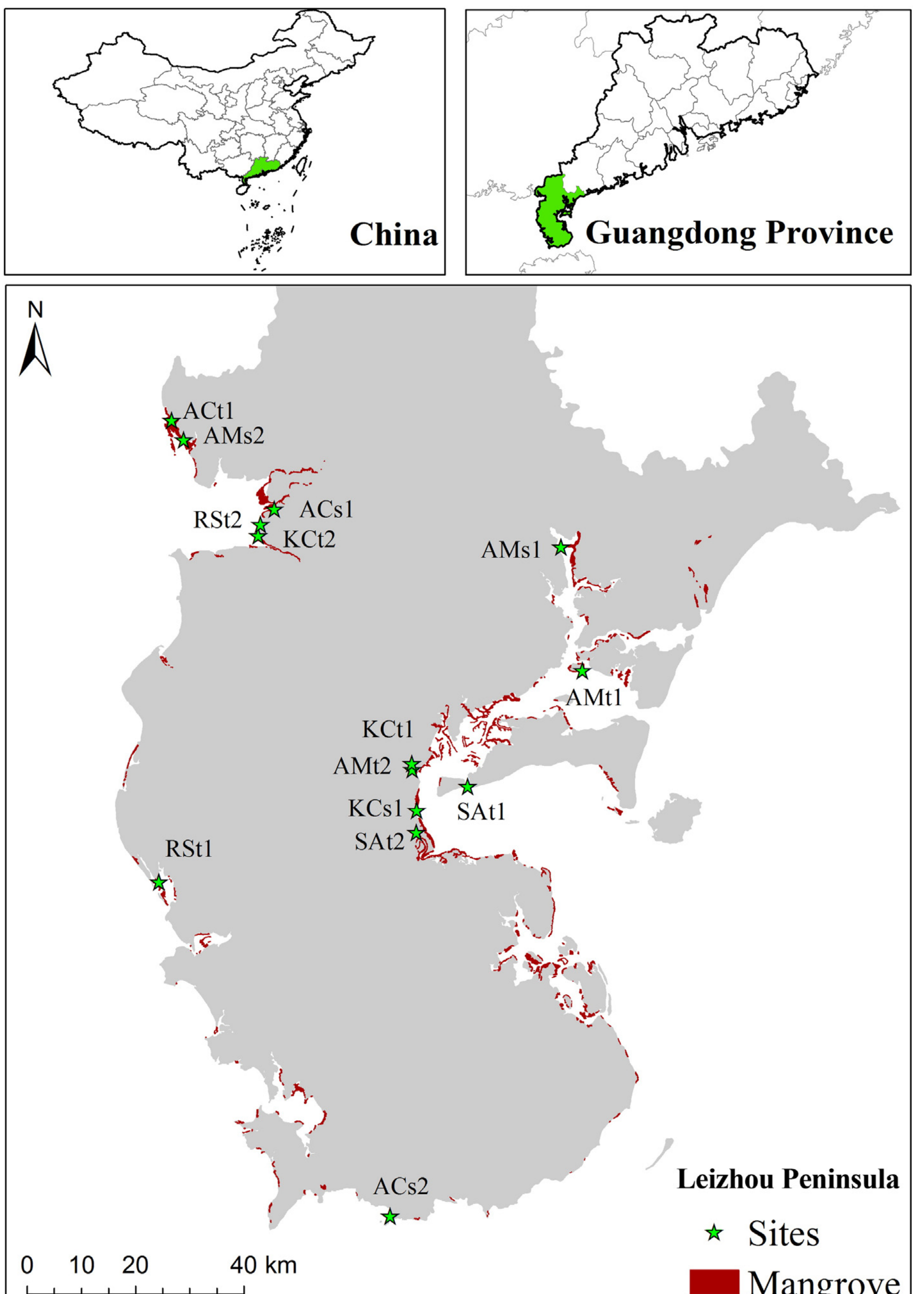

Fig. 1. Location of sampling sites in mangrove swamp in Leizhou Peninsula, China.