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Heavy metal contamination and ecological risk assessments in the sediments and zoobenthos of selected mangrove ecosystems, South China

Jinling Liu [a,c,1], Hao Wu [b,1], Jianxiang Feng [d], Zhengjie Li [d], Guanghui Lin [b,e,*]

[a] China University of Geosciences, Faculty of Earth Sciences, Wuhan 430074, China
[b] Division of Ocean Science and Technology, Graduate School at Shenzhen, Tsinghua University, University Town, Shenzhen 518055, China
[c] Key Laboratory of Tropical Marine Bio-resources and Ecology, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China
[d] Key Lab of MOE for Coast and Wetland Ecosystems, College of the Environment, Xiamen University, Xiamen 361005, China
[e] Ministry of Education Key Laboratory for Earth System Modeling, Center for Earth System Science, Tsinghua University, Beijing 100084, China

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ABSTRACT

Mangrove ecosystems provide ideal habitats for many marine organisms, but few studies have been conducted on the possible impact of heavy metals on these fragile inter-tidal estuarine wetlands. This study aimed to investigate heavy metal contamination in the sediments and zoobenthos in different mangrove ecosystems of southern China and to evaluate potential ecology risks of heavy metals in the sediment of mangrove ecosystems. Significant differences among different geographical regions were observed for the contents of Cu, Zn, As, Cd, and Pb in the sediment, while no significant differences were found among different vegetations. Except for Pb, the heavy metal contents in two species of crabs (*Perisesarma bidens* and *Parasesarma plicata*) in the *Aegiceras corniculatum* forest were lower than those in *Bruguiera gymnorrhiza* forest or *Pagatpat* forest. The sediment in the most mangrove ecosystems of China posed considerable or moderate ecological risk. Correlation analysis and principal component analysis (PCA) revealed that Cr, Cu, Zn and Pb were mainly derived from anthropogenic activities such as industrial effluents and domestic sewage.

1. Introduction

Mangrove ecosystems are critical inter-tidal estuarine wetlands, which provide ideal habitats for many marine organisms and migratory birds (Cuong et al., 2005; Nagelkerken et al., 2008). The most special characteristic of mangrove ecosystems is the high primary productivity rate, attributed to high decomposition rate and efficient recycling of nutrients such as phosphorus, carbon, and nitrogen (Bosire et al., 2005). It is well known that as one of the most important coastal ecosystems in the tropics, mangroves stabilize mobile sediments and act as a buffer against coastal erosion (El-Said and Youssef, 2013; Tam and Wong, 1996). However, this fragile ecosystem has been degraded seriously because of environmental changes such as global climate change and environmental pollution (Gilman et al., 2006). Among various pollutants, heavy metals with persistence, non-biodegradation, toxicity and bioavailability pose a major threat to mangrove biodiversity and human health.

Many previous studies focus on the heavy metal pollution in mangrove sediments (Cuong et al., 2005; El-Said and Youssef, 2013), mangrove plants (MacFarlane et al., 2003; Qiu et al., 2011), and other organisms (De wolf and Rashid, 2008). These studies have demonstrated that mangroves have high capacity to accumulate heavy metals, which were discharged to the nearshore marine. Rich sulfide, high organic matter content and redox conditions are widely believed to be the main factors responsible for the retention of water-borne heavy metals in mangrove ecosystems (De Wolf and Rashid, 2008; Qiu et al., 2011). However, available heavy metals in the sediment could be also reintroduced to water or be uptake by plants and benthic organisms (De wolf and Rashid, 2008; MacFarlane et al., 2003). Therefore, the sediment in mangrove wetlands has been considered as a sink of contaminants and a record for the anthropogenic pollutant input (El-Said and Youssef, 2013). To understand the behavior and fate of heavy metals in mangrove wetlands, it is important to explore the heavy metal contamination in all compartments of an ecosystem. However, although great efforts have been undertaken to monitor pollution levels in the sediment of mangrove wetlands, very few studies have considered the effect of sediment on the marine fauna and flora (Cuong et al., 2005; El-Said and Youssef, 2013; Marchand et al., 2011). Thus, the present study aimed to investigate heavy metal contamination in the sediments and zoobenthos in different mangrove vegetations of South China and

* Corresponding author at: Division of Ocean Science and Technology, Graduate School at Shenzhen, Tsinghua University, University Town, Shenzhen 518055, China. Tel./fax: +86 0756 26036292.
E-mail addresses: lin.guanghui@sz.tsinghua.edu.cn, lingh@tsinghua.edu.cn (G. Lin).
[1] These authors contributed equally to this work.

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to evaluate the potential ecology risks of heavy metals in the sediment of mangrove ecosystems in China.

2. Materials and methods

2.1. Study area and sampling

Five mangrove nature reserves (MNRs) of China at different latitude areas were selected for this study (Fig. 1). Three MNRs including Changle (CL) (N 26°01′, E 119°38′), Quanzhou (QZ) (N 24°56′, E 118°40′), and Yunxiao (YX) (N 23°55′, E 117°24′) are located in Fujian province, where the mangrove vegetation was dominated by *Kandelia obovata*. CL and QZ are industrial cities in Fujian Province, with significant annual productions from their textile, steel and food industries. The Zhanjiang (ZJ) MNR (N 21°33′, E 109°45′) with mangrove vegetation of *Aegiceras corniculatum*, *Bruguiera gymnorrhiza*, and *Sonneratia apetala* is located in Guangdong province. In ZJ, there are few industries around the mangrove area, so marine culture and agriculture provide the main financial resources for local residents and government. With large areas of mangrove vegetation dominated by *Rhizophora stylosa*, *Bruguiera sexangula* and *S. apetala*, Dongzhaigang (DZG) MNR (N 19°54′ ~ 19°20′, E 110°31′ ~ 110°38′) is located in Meilan District, Haikou, Hainan province, where the agriculture and tourist industries are the pillar industry of local government.

Sampling campaign was carried out at these five MNRs between 2009 and 2011. At each MNR, 3 or 5 field plots with dimensions of 10 m × 10 m were established. In each field plot, the surface sediment (0–1 cm) and benthic organism samples (gastropod and crabs) were collected. Each sediment sample was mixed with 5 sub-samples collected from each sampling plot, while each gastropod sample consisted of 8–10 animals and each crab sample consisted of 3–5 animals collected from the same sampling plot. The most common crabs including *Parasesarma plicata*, *Uca arcuata* and *Perisesarma bidens* were collected in all the studied areas. *Chiromantes dehaani* was only collected in Changle MNR. *Dense astrologer*, *Metaplax longipes* and *Helice latimera* were only captured in Hainan Dongzhaigang MNR. Snail samples of *Littoraria melanostoma*, *Cerithidea ornate* and *Certhidea microtera* were collected in the Quanzhou and Zhanjiang MNRs.

To avoid cross contamination, each sample was collected in a sealed polyethylene bag and stored frozen in a cooler before bring back to the laboratory for the analyses.

2.2. Sample treatment and analysis

In the laboratory, the samples were freeze-dried, ground, sieved and homogenized. Prior to chemical analysis, the sediment and organism samples were microwave-digested in Teflon vessels containing nitric acid and hydrofluoric acid. The detailed procedures of sediment and organism samples were described in a previous study (Yi et al., 2011).

All the samples were analyzed for the contents of Cu, Zn, Cr, Cd, Pb and As using inductively coupled plasma mass spectrometry (ICP-MS) (DRC-II, Perkin Elmer, USA). Concentrations of Hg in the sediment and organism samples were measured by cold atomic fluorescence spectrometry (CAFS) (F732-V, Shanghai, China). Analytical quality control included analysis of reagent blank, sample blank, reference material, and duplicate samples. The certified reference material GSD1-3 (IGGEC, Institute of Geophysical and Geochemical Exploration, China) and TORT-2 (NRC, Institute of National Measurement Standards, Canada) were used to check the test quality of the sediment and organism samples, respectively.

3. Results and discussion

3.1. Contents of heavy metals in mangrove sediments

The concentrations of common heavy metals (Cr, Cu, Zn, As, Cd, Pb, and Hg) in the sediments of the five MNRs are listed in Table 1. The ranges of average concentrations of Cr, Cu, Zn, As, Pb, Cd, and Hg were 28.5–86.6 mg/kg, 10.3–30.9 mg/kg, 24.8–87.0 mg/kg, 2.44–20.1 mg/kg, 25.6–86.4 mg/kg, 0.07–0.39 mg/kg, and 0.061–0.24 mg/kg, respectively. All heavy metal contents in the sediment from the sampled mangrove areas did not exceed the Marine Sediment Quality

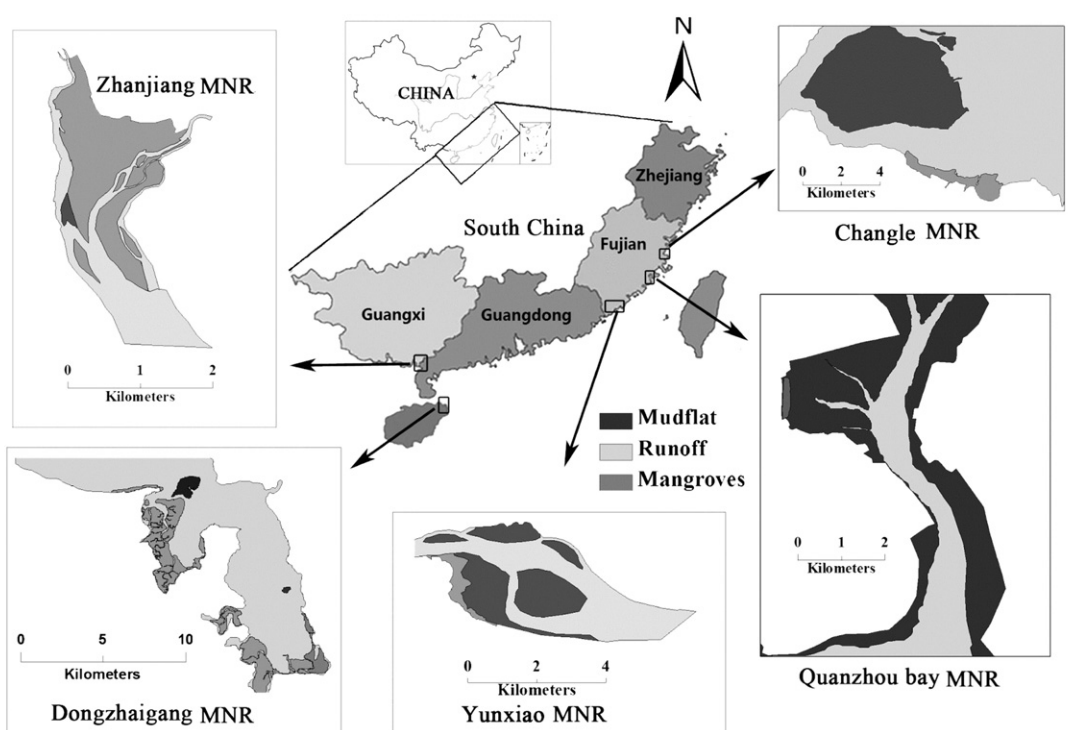

Fig. 1. Map of the southern China and study sites (MNR: Mangrove Nature Reserves).