Marine Pollution Bulletin xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Distribution and ecological risk assessment of heavy metals in surface sediments of a typical restored mangrove–aquaculture wetland in Shenzhen, China

Jianxiang Feng [a,b], Xiaoshan Zhu [a,*], Hao Wu [c], Cunxin Ning [d], Guanghui Lin [a,e,**]

[a] Division of Ocean Science and Technology, Graduate School at Shenzhen, Tsinghua University, Shenzhen, 518055, PR China
[b] School of Life Sciences, Sun Yat-Sen University, Guangzhou, 510275, PR China
[c] Food Inspection and Quarantine Center, Shenzhen Entry-Exit Inspection and Quarantine Bureau, Shenzhen 518016, PR China
[d] School of Civil and Environmental Engineering, Harbin Institute of Technology Shenzhen Graduate School, Shenzhen, 518055, PR China
[e] Center for Earth System Science, Tsinghua University, Beijing, 100084, PR China

ARTICLE INFO

Article history:
Received 31 August 2016
Received in revised form 28 December 2016
Accepted 2 January 2017
Available online xxxx

Keywords:
Ecological risk
Heavy metals
Mangrove restoration
Pearl River estuary
Sediment

ABSTRACT

The restoration of wetlands has attracted the attention in different countries. Restored coastal wetlands, especially urban wetlands, are sensitive to external pressures. Thus, it is necessary to evaluate the efficiency of the restoration of coastal wetlands, which benefits their management and functional maintenance. In this study, a restored mangrove-aquaculture system in Waterlands Resort at Shenzhen was selected for analysis. The distribution and ecological risk assessment of heavy metals in surface sediments were investigated. The results showed that restoration could effectively decrease the heavy metal concentrations in the sediment, while the restored mangrove posed a moderate ecological risk. Most of the heavy metal concentrations were higher during the dry season compared with the wet season. In addition, during the whole investigation, the sediment quality remained failed to achieve the marine sediment criteria required for aquaculture in China.

1. Introduction

Mangrove forests are diverse ecosystems that are located in intertidal zones in the tropics and subtropics and are influenced by both marine and terrestrial environments (Alongi 2014; Lewis et al. 2011). Due to the adverse effects of anthropogenic activities such as urbanization and aquaculture, the mangrove forest area has declined by 30%–50% worldwide over the last few decades (Alongi 2002; Chen et al. 2009). However, as one of the most productive ecosystem types, mangrove forests play important roles in maintaining high levels of biodiversity and providing an energy base for adjacent food webs (Nagelkerken et al. 2008). With the recent recognition of the ecological and economic value of mangrove forests, considerable efforts have been made to preserve and restore them in China since the early 1990s (Chen et al. 2009). For example, integrated mangrove-aquaculture systems, a typical restoration method, have been developed to achieve the combined aims of mangrove conservation and productive aquaculture (Peng et al. 2013).

In mangrove forests, the special hydro-environment facilitates the deposition of fine sediments that are rich in nutrients, metal elements, and minerals (Prasad and Ramanathan 2008), resulting in a large number of nutrients and heavy metals in sediments, especially surface sediments (Tam and Wong 1994). However, mangrove forests require a large amount of nutrients that are essential for plant growth (Middelburg et al. 1996). Thus, nutrients in municipal or aquaculture wastewater could effectively be decreased via mangrove uptake (Peng et al. 2013; Wu et al. 2008). In contrast, the deposition of heavy metals along with fine particles has resulted in mangrove sediments acting as heavy metal sinks (Zhou et al., 2010). Although mangroves themselves exhibit a high tolerance to anthropogenic pollutants (Lewis et al. 2011), heavy metals in the sediments of mangrove forests could still be enriched by other marine organisms and become even more hazardous following their transfer along the marine food chain (Bastami et al. 2014; Lewis et al. 2011). Therefore, investigation of the effects of mangrove forests on the clearance of heavy metals in sediments would be useful to fully assess the environmental functions of mangrove forests.

Previous studies have focused on the ability of mangroves to remove heavy metals and the distribution of heavy metals in the sediments of natural mangrove forests (He et al. 2013; Tam and Wong 1994; Zhang et al. 2010; Zhang et al. 2014), and the results indicated that mangroves (*Avicennia marina*) are highly efficient bioaccumulators of heavy metals (Usman et al. 2013; MacFarlane et al. 2003). However, little information

* Correspondence to: X. Zhu, Graduate School at Shenzhen, Tsinghua University, Shenzhen 518055, PR China.
** Correspondence to: G. Lin, Center for Earth System Science, Tsinghua University, Beijing 100084, PR China.
E-mail addresses: zhu.xiaoshan@sz.tsinghua.edu.cn (X. Zhu), lingh@tsinghua.edu.cn (G. Lin).

http://dx.doi.org/10.1016/j.marpolbul.2017.01.004
0025-326X/© 2016 Elsevier Ltd. All rights reserved.

is available regarding the effect of mangrove restoration on the heavy metal distribution and accumulation in sediment. Zhang et al. (2010) emphasized that mangrove wetlands exhibit greater potential for removing heavy metals than systems that do not include mangroves. In contrast, Zhou et al. (2010) suggested that mangrove reforestation facilitated the accumulation of heavy metals in the upper sediment layers but decreased their bioavailability and mobility. These conflicting results might be due to differences in local environments and/or sampling seasons. Long-term reclamation of mangrove forests would demonstrate superior heavy metal clearance performance than short-term reclamation (Bai et al. 2011), and increased surface runoff would likely either bring more contaminants to mangrove forests or bring more clean water to dilute contaminants in the mangrove area during the wet season compared with the dry season. Additional investigations are required to test this hypothesis.

As the only mangrove ecosystem located in the center of a modern metropolis, Shenzhen Futian mangrove forest (P. R. China) suffers more serious ecological risks compared with most of the other mangrove forests in China (Li et al. 2016). To restore mangrove forests and improve the environmental conditions for aquaculture, several integrated mangrove-aquaculture systems have been sequentially constructed in the Waterland Resort since 2002, which is adjacent to Shenzhen City, China. This area was selected for sample collection in the present analysis. We analyzed heavy mental concentrations in sediments of mangrove forests with different restoration terms during both dry and wet seasons. The distribution and ecological risks of heavy metals were subsequently assessed. Our objectives were to assess the effects of mangrove systems on the heavy metal concentrations in the sediment of the restored mangrove zone and the environmental risks of the mangrove-restored area. Moreover, the effects of restoration time and sampling season on heavy mental concentrations were also investigated.

2. Materials and methods

2.1. Study sites

This study was conducted at the Waterlands Resort in Shenzhen, Guangdong Province, China (23°43′14″N, 113°45′53″E, Fig. 1), adjacent to the eastern side of Pearl River estuary. Four sites that had undergone restoration efforts for varying durations were selected. The mangrove experimental base (denoted JD) was constructed in 2002 and has an area of 6.8 hm^2. The JD site comprises 25.5% mangrove trees, mainly *Kandelia obovata* and *Aegiceras corniculatum*. The mangrove exhibition garden (denoted BL) has an area of 5.5 hm^2 and was constructed in 2004. Various mangrove species account for 47.4% of the total area of BL, and the dominant species are *K. obovata* and *Bruguiera gymnorrhiza*. The mulberry fishpond (denoted SJ) was constructed in 2008 and has an area of 2.8 hm^2. In the SJ site, the mangrove species *K. obovata* and *A. corniculatum* occupy 12.5% of the total area. A control site (denoted HD) along the polluted Dongbao River was selected for comparison with the restored mangrove aquaculture systems. The HD site includes *K. obovata* and *Acanthus ilicifolius*. Sites SJ, BL and JD are enclosed ponds, and the water in the ponds was not exchanged with outside river water during the study unless supplementation was necessary. The mangrove system at the HD site was inundated periodically by natural tides.

2.2. Sample collection and analysis

Sediment samples were collected in March and August 2014 from all sampling sites. At each sampling site, four replicates of surface 10-cm sediment were collected and then immediately sealed in plastic bags and transported to the laboratory in an ice-box for further analysis. All samples were freeze-dried and ground using a porcelain mortar and pestle. Large particles and shoots or roots were removed by screening

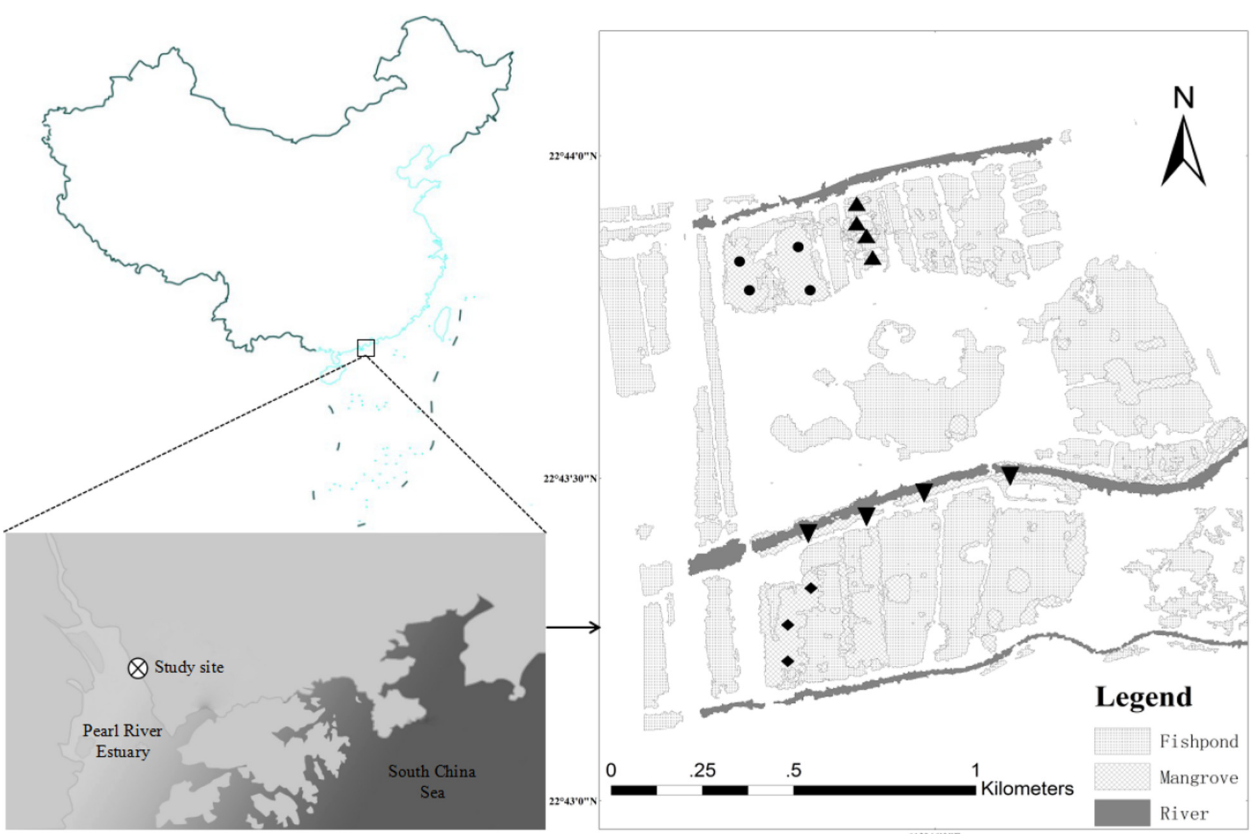

Fig. 1. Map of the sampling sites at Waterlands Resort in Shenzhen (● SJ: 6-year-old Mulberry fish pond; ▲ BL: 10-year-old mangrove exhibition park: ♦ JD: 12-year-old mangrove research base; ▼ HD: non-restored mangrove along river bank.)

Please cite this article as: Feng, J., et al., Distribution and ecological risk assessment of heavy metals in surface sediments of a typical restored mangrove–aquaculture wetl..., Marine Pollution Bulletin (2016), http://dx.doi.org/10.1016/j.marpolbul.2017.01.004