Marine Pollution Bulletin xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Baseline

Spatial variation, environmental risk and biological hazard assessment of heavy metals in surface sediments of the Yangtze River estuary

Haotian Wang, Jiawei Wang, Ruimin Liu *, Wenwen Yu, Zhenyao Shen

State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, No. 19, Xinjiekouwai Street, Beijing 100875, China

A R T I C L E I N F O

Article history:
Available online xxxx

Keywords:
Yangtze River estuary
Heavy metal contamination
Spatial distribution
Environmental risk assessment
Biological hazard assessment

A B S T R A C T

30 samples of eight heavy metals were collected in February 2011 within Yangtze River estuary (YRE). The mean concentrations met the primary standard criteria based on Marine Sediments Quality of China. The spatial distribution showed that a gradient concentration decreased gradually from inner-estuary to river mouth. Anthropogenic inputs might be the main contributor, and fine grained sediments might also aggravate the heavy metal contamination. The assessment results indicated that the YRE was in low risk of contamination caused by every single heavy metal. However, it was in considerable degree of contamination considering combination of all the heavy metals. The toxicities of heavy metals might be elevated when heavy metals were in combination. Arsenic should be of primary concern due to its higher assessment values and the potential of adverse biological effects. And the concentration of As in the YRE had a trend to increase because of anthropogenic activities nearby.

Metallic elements from anthropogenic inputs due to the rapid economic development especially in the vicinity of coastal areas have caused severe environmental crises in marine ecosystem (Gao and Chen, 2012; Xu et al., 2014). Heavy metal contamination in aquatic environment has recently drawn particular public attentions due to their toxicity, persistence and biological accumulation (Hu et al., 2013c; Li et al., 2013a). In addition, heavy metals are likely to be conserved and accumulated by aquatic organisms (Sharma and Agrawal, 2005). Once enriched by aquatic organisms, heavy metals might be converted to more toxic organic complexes, which might cause potential risk to human health through food web (Jiang et al., 2012; Hu et al., 2013b). When accumulating to a toxic concentration level, heavy metals might lead to biological hazard risk (Yi et al., 2011). So heavy metal contamination might not only pose a risk to aquatic organisms, but cause long-term implication on human health, even damage on ecosystem (Ip et al., 2007; Wang and Rainbow, 2008; Dou et al., 2013).

Sediments show a great capacity to accumulate heavy metals even from low concentrations in aquatic environment (Nemr et al., 2007; Christophoridis et al., 2009). It has been reported that most heavy metals loaded in aquatic ecosystem are associated with sediments, especially the bottom sediments (Singh et al., 2005; Kucuksezgin et al., 2008; Zahra et al., 2014). Heavy metals fixed by sediments which act as both final sink for various chemical pollutants and potential secondary source might be released back into water columns with changed environmental conditions (Hill et al., 2013; Hu et al., 2013a).

In order to take measures to protect aquatic ecosystem, it is necessary to assess the heavy metal contamination in sediments, and it is important to differentiate the influence caused by natural source or anthropogenic source (Yu et al., 2008). Besides assessing the heavy metal contamination, evaluating the biological adverse risk is equally important. Enrichment factor (EF), index of geoaccumulation (I_{geo}), degree of contamination (DC), sediment quality guidelines (SQGs), mean ERM quotient (M-ERM-Q) and hazard quotients (HQ) were indices which widely applied to assess the degree of contamination and adverse ecological effects respectively (Feng et al., 2011; Sundaray, et al., 2011; Gao and Chen, 2012; Lin et al., 2013; Hasan et al., 2013; Li et al., 2013b; Wang et al., 2014).

For small scale regions, mean concentration values are enough to be used to assess the heavy metal contamination. But the spatial distribution of heavy metals is of primary concern in assessing pollution for large scale regions. Many studies have proved that heavy metal contaminants are not uniformly distributed and varied spatially and temporally (Zhao et al., 2012a; Gu et al., 2012; Qiao et al., 2013). Generally, geostatistics and geographic information system (GIS) are widely used to exhibit an overall distribution of heavy metals in study areas (Ho et al., 2013).

The Yangtze River estuary (YRE) is one of the largest estuaries in China. With the fastest economic development, the YRE has suffered heavy metal contamination (Feng et al., 2004). As a very

---

* Corresponding author. Tel./fax: +86 10 5880 0829.
E-mail address: liurm@bnu.edu.cn (R. Liu).

http://dx.doi.org/10.1016/j.marpolbul.2015.01.026
0025-326X/© 2015 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Wang, H., et al. Spatial variation, environmental risk and biological hazard assessment of heavy metals in surface sediments of the Yangtze River estuary. Mar. Pollut. Bull. (2015), http://dx.doi.org/10.1016/j.marpolbul.2015.01.026

important industrial center, shipyards, petrochemical plants, steel mills and many other plants are built in ambient towns (Du et al., 2013). There were more than $5 * 10^6$ tons/d of industrial effluent and domestic sewage discharged into the YRE (Zhang et al., 2009). In addition, the construction of the Three Gorges Dam in the upstream of the YRE has influenced some properties of coastal waters and sediments of the East China Sea such as nutrient status, salinity and sediments regime, which might affect the toxicity and distribution of heavy metals (Christophoridis et al., 2009; Gao and Li, 2012; Feng et al., 2014b). There have been many previous studies dedicated to investigating heavy metals in the YRE (Zhang et al., 2007; Li et al., 2009; Zhao et al, 2012a; Feng et al., 2014a; Wang et al., 2014). However, it is also meaningful to carry out continuous deep investigation on heavy metal contamination and corresponding assessment.

Based on 30 samples collected from the YRE in February 2011, the contamination of eight heavy metals was assessed with GIS, geostatistics and some indices. The main objectives of this study were: (1) examine the spatial variation of heavy metals in surface sediments; (2) assess the environmental risk; and (3) evaluate the potential biological hazard.

The Yangtze River estuary (YRE), the boundary between the Yellow Sea and the East China Sea, is always divided into the South Branch and the North Branch (Fig. 1). The South Branch gradually becomes the main stream of the estuary and receives over 95% of the total estuarine runoff, whereas the runoff in the North Branch is continuously decreasing (Chen, 2009). In this study, the YRE was divided into two regions: the inner-estuary and the river mouth.

In February 2011, 30 sampling sites were set in the YRE (121E–122.75E, 31.75N–32N (Fig. 1). The surface sediments were sampled to a depth of 2–5 cm. At each site, three surfaces sediments were collected and mixed into a composite sample. All the samples were frozen dried and sieved through a 1 mm clean plastic net and then ground in an agate mortar. The grained samples were shaken through nylon membrane sieve (0.071 mm) to obtain a fine homogeneous powder. Samples were microwave-digested in acid-cleaned Teflon vessels containing 5 mL of nitric acid and 2 mL hydrofluoric acid for 30 min at 200 °C. After cooling for at least 1 h, the vessels were added to 0.9 g of boric acid and then microwave-digested for another 30 min. After cooling for at least 1 h again, the digested sample was transferred to a plastic test tube with an additional 0.5 mL HF and brought up to volume with milli-q water (Yi et al., 2011). The inductively coupled plasma-mass spectrometry method (ICP-MS, Thermo) was used to measure the concentrations of eight heavy metals: arsenic (As), cadmium (Cd) chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn).

Quality assurance and quality control were assessed using duplicates, method blanks, and standard reference materials. The accuracy of the determination method was systematically and routinely examined with standard reference materials (GSF). Three replicates were conducted to determine the total contents of the metals. The metal contents of the standard reference materials were found to be within 86–102% of the certified values.

ArcGIS 9.3 was used to analyze the spatial variations and environmental risk assessment indices. Ordinary kriging was used to

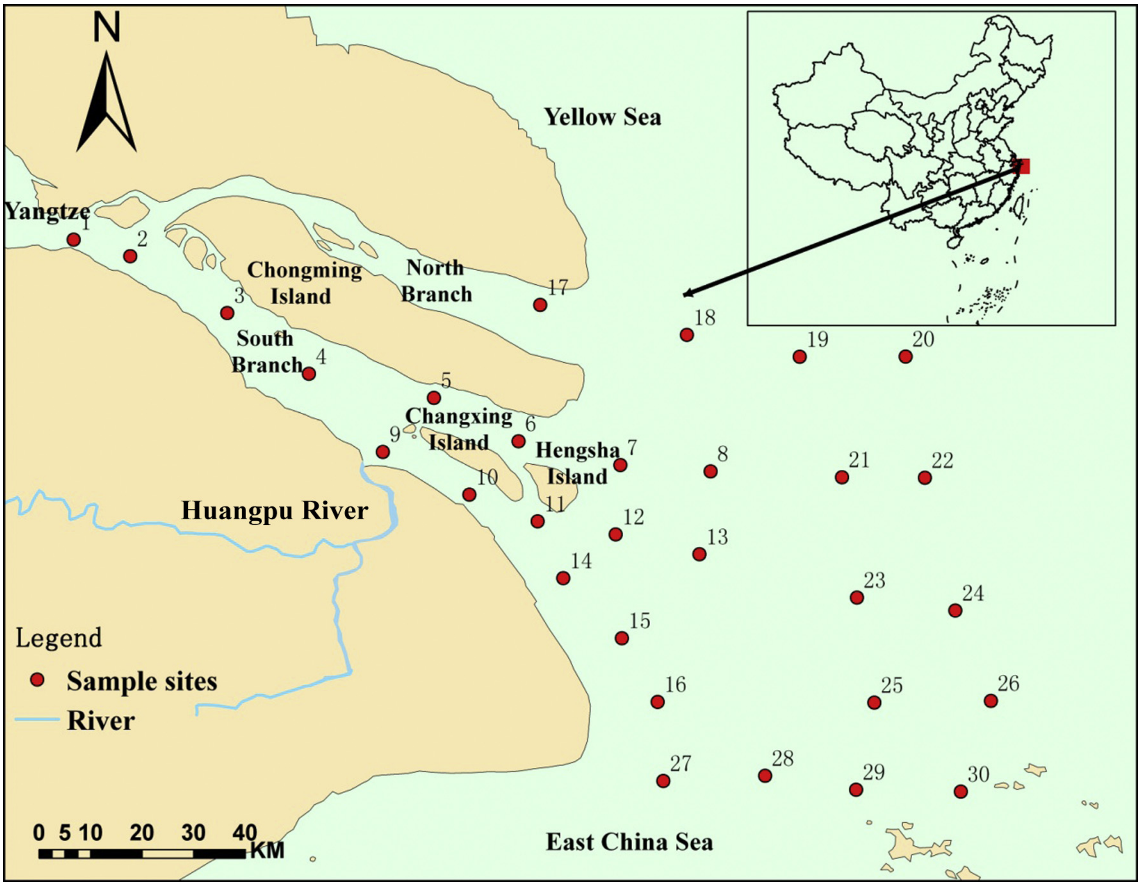

Fig. 1. Map of study area and location of sample sites.

Please cite this article in press as: Wang, H., et al. Spatial variation, environmental risk and biological hazard assessment of heavy metals in surface sediments of the Yangtze River estuary. Mar. Pollut. Bull. (2015), http://dx.doi.org/10.1016/j.marpolbul.2015.01.026