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Distribution of heavy metals and environmental assessment of surface sediment of typical estuaries in eastern China

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ABSTRACT

Estuary sediment is a major pollutant enrichment medium and is an important biological habitat. This sediment has attracted the attention of the marine environmental scientists because it is a more stable and effective medium than water for monitoring regional environmental quality conditions and trends. Based on a large amount of measurement data, we analyzed the concentrations, distribution, and sources of seven heavy metals (As, Cd, Cr, Cu, Hg, Pb, and Zn) in the surface sediment of typical estuaries that empty into the sea in eastern China: the Liaohe River Estuary, Yellow River Estuary, Yangtze River Estuary, Minjiang River Estuary, and Pearl River Estuary. The heavy metal concentrations in the sediments vary considerably from one estuary to the next. The Liaohe River Estuary sediment contains elevated levels of Cd, Hg, and Zn. The Yellow River Estuary sediment contains elevated levels of As. The sediments in the Yangtze River and Minjiang River estuaries contain elevated levels of Cd and Cu and of Pb and Zn, respectively. The sediment in the Pearl River Estuary contains elevated levels of all seven heavy metals. We used the Nemerow index method to assess the environment quality. The heavy metal pollution in the Liaohe River and Pearl River estuaries is more severe than that in the other estuaries. Additional work indicates that the heavy metal pollution in the Liaohe River and Pearl River estuaries is caused mainly by human activity.

Sediment serves as the source and sink of contaminants in aqueous environments. It is an indicator of heavy metal pollution in an aqueous environment (Forstner, 1978; Livett, 1988; Liu et al., 2015). Therefore, heavy metals in sediment yield valuable geologic and environmental information and can serve as good indicators of regional pollution conditions. They serve as important evidence in ecological environmental quality assessments (Ma and Wang, 2003; Zhang et al., 2006). Since the 1950s, because of environmental disasters such as *itai-itai* disease (Cd) and minamata disease (Hg) in Japan, the study of heavy metal pollution has been important (Chen and Zhou, 1992). Heavy metals are non-degradable and toxic and undergo biomagnification; therefore, they can be a pollution threat to ecosystems. Studies of heavy metal pollution have gradually become a hot topic in aqueous environmental risk assessment (Luo et al., 2014). Because of their biomagnification in food chains, heavy metals convert to more-toxic metal-organic compounds, which have corresponding effects on human health (Mandal and Suzuki, 2002). For human health and stable ecosystem development, it is necessary to conduct ecological risk assessments of heavy metal pollution, analyze the degree of pollution, and develop corresponding control measures (Zhang et al., 2011; Wang et al., 2012).

Pollutants generated by human activity affect the marine environment through various paths. All this information is recorded in the marine sediment. Therefore, analyzing the geochemical characteristics of element concentrations in near-shore sediment and their distributions can reveal changes in the aqueous environment and the history of local human activity (Lan et al., 2011). Researchers studied heavy metal pollution in the shell sediment in Los Angeles Bay, the Dead Sea, the Rhine River, and Germanic Bay in the 1970s. The study by Calmanl et al. (1995) showed that sediment enrichment in Hg, Cd, and Zn in the upstream Elbe River of the North Sea had reached 10 to 100 times the natural background concentrations. The study by (Mudroch and Azcue, 1995) in Lake Erie and Lake Ontario in North America indicated that the Pb content in the lake sediment across large areas was as high as $100–150 \times 10^{-6}$. The study by Taylor and Birch (1996) indicated that the Pb content in the settling particulate matter in the seawater of Port Jackson in the Australia Harbor was as high as $365–750 \times 10^{-6}$, the Zn content was as high as $700–1100 \times 10^{-6}$, and the Cu content was as high as $170–280 \times 10^{-6}$. International researchers have also

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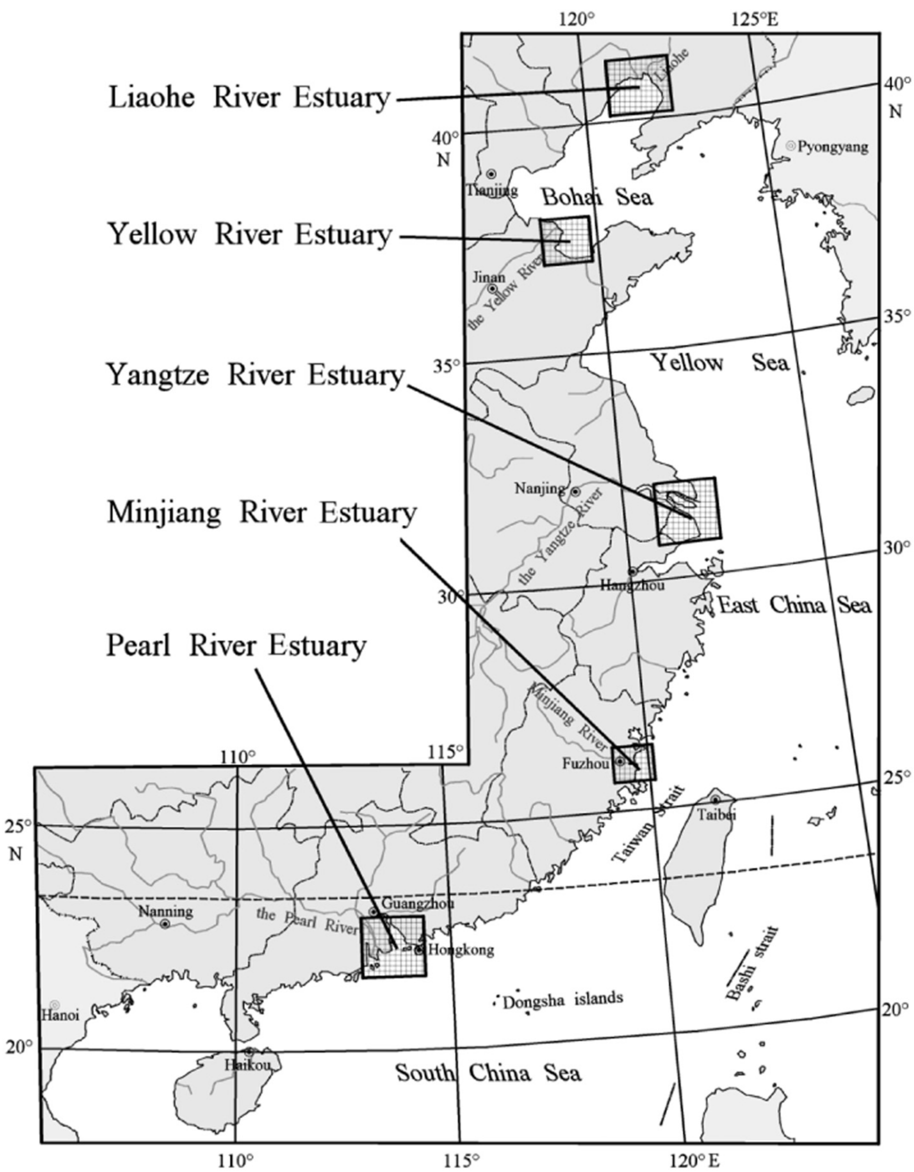

Fig. 1. Location of the study area.

studied heavy metal concentrations in sediment and found significant patterns. For example, Singh et al. (2003) revealed the degree of enrichment in heavy metals in the Ganges, which is one of the major sediment transportation systems of the world. Srinivasa Reddy et al. (2004) studied the distribution and enrichment in heavy metals in coastal sediment. Their results showed that the enrichment in the Sosiya region in Arun was relatively high. The study by Huang et al. (1994) in Piratininga Lake showed that the sediment enrichment by Pb, Cu, and Zn was consistent and correlated with anthropogenic discharge.

China's eastern coastline is 18,000 km long. The geology of the coastline is complex, and the coastline spans various climate zones. Economic development along the coastline is not uniform. The heavy metals in the surface sediment in river estuaries derive from multiple sources (Zhang et al., 2012). In a series of studies, Chinese researchers measured the distribution of total metals in the estuaries emptying into the sea in eastern China (Zhang et al., 2012; Ye et al., 2011; Jia et al., 2008; Tong et al., 2010; Zhai et al., 2010; Cai et al., 2011; Yu et al., 2008; Liu et al., 2015; Hu et al., 2015). Xia et al. (2011) used factor analysis and concluded that the heavy metals Cu, Zn, and Cr in the nearshore surface sediment in Lianyungang were derived mainly from natural sources and were present mainly in the fine-grained clay minerals. In addition to these background levels, anthropogenic Pb, Cd, and As were also present. Liu et al. (2003) concluded that the concentrations of Zn, Cr, Cu, and Cd in cylindrical surface sediment samples collected from the Pearl River Estuary gradually decreased from northwest to southeast. The concentrations were affected mainly by pollution discharge sources and water dynamics in the estuary. Liu et al. (1995) studied the heavy metal concentrations in particles of various grain sizes and bonding states in surface sediment samples in the western sea region of Xiamen. The results showed that the behaviors of Cu and Zn in this region were closely related, which might be connected to biological activities because these elements were derived mainly from urban pollution. Gong et al. (2007) concluded that the concentrations of eight heavy metals in the surface sediment of Quanzhou Bay gradually decreased in the river estuary from the interior to the outlet of the bay, indicating that the bay was severely affected by anthropogenic pollution and that the heavy metals were derived mainly from the river input.

Based on a large amount of measurement data, we analyzed the distribution, environmental quality, and controlling factors of heavy metals in the sediment in typical estuaries emptying into the sea in eastern China. The results can provide scientific support for management of these marine environments.

We used uncontaminated special tools to collect surface sediment