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Distribution and source analysis of heavy metals in soils and sediments of Yueqing Bay basin, East China Sea

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ABSTRACT

Concentrations of heavy metals in coastal soils, stream sediments and intertidal sediments of Yueqing Bay basin were analyzed to study their distribution and trace the possible sources. According to various single- and multi-index methods, heavy metal enrichment, especially for Cu, Zn, Cr and Ni in stream sediments, should draw environmental concern. Controlling factors such as inorganic scavengers, organic matter, sample grain size and hydrodynamic conditions were identified to influence the transportation and distribution of metals within coastal soils and sediments. Principal component analysis indicated that most metals in soils and stream sediments originate primarily from natural and anthropogenic sources, respectively. Most metals in intertidal sediments, originating both from natural processes and human activities, tend to be concentrated in fine particles. The exchange of water and sediment between the bay and open waters is strong enough to keep the metals in the tidal flats from rising to very high levels.

Coastal areas at the continent-ocean interface are vulnerable to environmental changes and have been largely disturbed by human activities (Masson et al., 2006; Rahmanpour et al., 2014). During the past few decades, significant amounts of heavy metals, singly or in combination, have been released into the coastal environment with potential long-term risks for human health and the ecosystem (Dou et al., 2013; Fishbein, 1981; Nobi et al., 2010). Their occurrence in coastal zones results from both natural and anthropogenic inputs. The background levels of heavy metals in these areas depend on lithogenic sources (Brady et al., 2014). However, heavy metals found in coastal environments are often of manmade origins, such as those from mining and smelting, fossil fuel combustion, industrial activities, sewage discharges and agricultural chemicals (Loska and Wiechula, 2003; Rahmanpour et al., 2014; Zhuang and Gao, 2014).

Stream and intertidal sediments are important components of aquatic systems, which serve as the main sink and source for heavy metals (Zhang et al., 2014). When effluents containing heavy metals enter the surface water, metals do not remain in soluble forms for a long time and have a tendency to deposit in sediments (Alonso Castillo et al., 2013; Kabata-Pendias, 2011; Zhao et al., 2014). Thus, sediments are considered a more reliable indicator of water pollution by heavy metals and act as a useful tool to assess the pollution status of coastal environments (Looi et al., 2015; Satapathy and Panda, 2015; Xu et al., 2014). However, some sediment-bound heavy metals may be released back to the overlying water column through re-suspension processes in estuarine and near-coastal environments when environmental conditions change (Kalnejais et al., 2010). Among the processes that contribute heavy metals to sediments, adjacent soil leaching is one of the basic natural transport pathways (Kabata-Pendias, 2011). However, studies about the accumulation of heavy metals in coastal environments have focused mainly on the single aspect of stream sediments or coastal sediments (Apeti and Hartwell, 2015; Chai et al., 2014; Pinedo et al., 2014; Satapathy and Panda, 2015), and few have touched upon nearshore soils. Lack of integrated information about the accumulation of heavy metals in different environmental media limit our understanding of transport and sources of heavy metals in coastal regions.

Yueqing Bay is one of the most important mariculture bases located on the coast of the East China Sea. Although previous studies have indicated that there was an elevation of heavy metals in the Yueqing Bay basin (Ding et al., 2010; Zhao et al., 2005), the data of heavy metals in this region are limited and lack spatial resolution. Hence, a systematic investigation covering intertidal sediments, stream sediments and coastal soils was carried out in the Yueqing Bay basin. The main objectives of the study were (1) to investigate the characteristics of heavy metal accumulation and distribution in the surface soils and sediments, (2) to identify controlling factors for heavy metal distributions, and (3) to distinguish the possible sources of heavy metals.

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The semi-enclosed Yueqing Bay lies on the east coast of Zhejiang Province with its mouth facing the East China Sea. Yueqing Bay, covering an area of approximately 463.6 km^2, has a total catchment area of 1470 km^2. More than 30 rivers, including the Dajin river, Qingjiang river, Huwu river and Chumen river, discharge into the bay a mean annual runoff of 10.3×10^4 m^3. The climate in this study area is a warm and humid subtropical monsoon climate with an average of temperature of 17.0 °C and average annual precipitation of 1700 mm. According to its morphological characteristics, the bay can be divided into three parts: inner bay, central bay and outer bay (shown in Fig. 1). The geomorphologic processes of Yueqing Bay are profoundly influenced by runoff and tidal currents. The tides in the Yueqing Bay are irregularly semidiurnal, with average and maximum tidal ranges of 4.2 and 8.34 m, respectively. Thus, the tidal flats in the study area are very exposed to waves. The exchange rate with open waters from the East China Sea progressively decreases from the outer bay to the inner bay. The intertidal zone, composed mainly of mud flats, represents >47% of the total bay area. The highest part of the mud flats had been reclaimed for agriculture in the past fifty years, while the lowest parts are mostly unvegetated. The invasion of *S. alterniflora* has occupied much of the area between the reclaimed lands and bare flats. In general, as suitable bases for mudflat aquaculture and important reserved land resources, the tidal flats of Yueqing Bay have been intensively used and reclaimed during recent years.

The sampling sites in the Yueqing Bay basin were selected in order to achieve a systematic coverage of the study area, considering the land use pattern, topography, residential distribution, water depth and so on. A total of 80 surface soil and sediment samples (0–20 cm) were collected in July 2013, including 40 intertidal sediment samples (TS), 20 stream sediment samples (SS) and 20 soil samples from reclaimed tidal land (S). A handheld GPS was used to record the geographical locations of the sampling sites (Fig. 1).

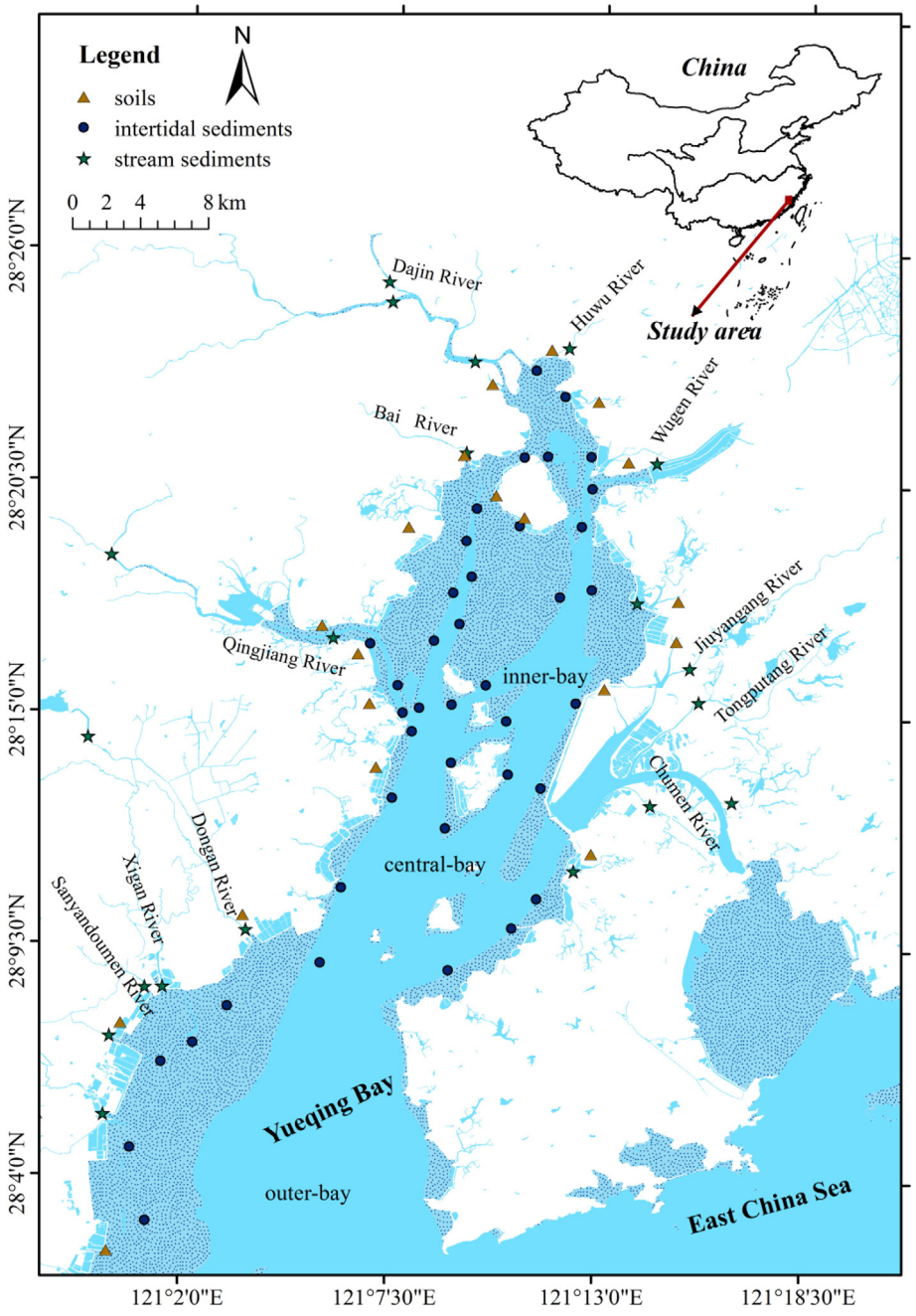

Fig. 1. Geographic location of the study area and the sampling sites.

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