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Baseline

Spatial distribution and sources of heavy metals and petroleum hydrocarbon in the sand flats of Shuangtaizi Estuary, Bohai Sea of China

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ABSTRACT

The concentrations of heavy metals and petroleum hydrocarbons (PHCs) in surface sediments were investigated in the sand flats of Shuangtaizi Estuary, Bohai Sea of China in May, 2013. Ecological risk assessment indicated that most heavy metals cause low ecological risk to the estuarine environment, with the exception of Cd and Hg (considerable and moderate risk, respectively). Principal component analysis in combination with correlation analysis among heavy metals, PHCs and geological factors (e.g., granularity) was used to identify possible sources of pollutants in Shuangtaizi Estuary. Results showed that the main pollution sources of the area come from anthropogenic factors, such as sewage discharge and oil exploitation.

Large amounts of contamination, including heavy metals and petroleum hydrocarbons (PHCs), are introduced into estuarine and coastal environments with the rapid growth of urbanization and industrialization, leaving a series of toxicological effects on benthic fauna and associated species around the world (Wang and Rainbow, 2008). Heavy metals are characterized by bioaccumulation, persistence and high toxicity to biota (DeForest et al., 2007) and mainly originate from anthropogenic discharge, geological matrix erosion and urbanization. Industrial accidents, such as natural seeps and oil spills (Molisani et al., 1999; Ou et al., 2004), and combustion of fossil fuels (Ou et al., 2004) are the main reasons PHCs are introduced to aquatic environments.

Sediments, the primary reservoir for PHCs and heavy metals, are sensitive to variations in anthropogenic and natural sources. They are generally considered as sensitive indicators in research on contamination of coastal environments (Calmano et al., 1996; Salamons, 1995). Salomons and Förstner (1984) found that sediments are generally affected by anthropogenic activities and local geology. Therefore, surface sediments, which can mirror the current sediment contaminant status (Yan et al., 2009), are deemed an appropriate medium with which to study the pollutants of coastal environments (Sprovieri et al., 2007).

Shuangtaizi River, one of the most polluted rivers in China, flows a distance of approximately 130 km from the southwestern part of Liaoning Province to Bohai Sea and carries more than 12,258 t pollutants annually (Liu et al., 2010). The basin area of Shuangtaizi River reaches 13,292 km^2 and receives various contaminants, such as heavy metals, and petroleum from a large number of domestic sewage inputs, urban activities and agricultural discharges. It also receives contaminants from industrial activities, especially from exploitation of the Liao River oil field, which is the third largest oil field in China, where the oil-producing regions Xinglongtai and Huanxilin are located in the southeast on the mouth of Shuangtaizi River. Shuangtaizi Estuary (121°30′–122°00′E, 40°50′–41°20′N), located north of Liaodong Bay (the largest bays of Bohai Sea), is immediately adjacent to the industrial cities of Jinzhou and Panjin (Fig. 1).

Shuangtaizi Estuary is one of the few remaining intertidal sand flats and an important clam fishery area (Zhang et al., 2013). Around the estuary, three main rivers, Shuangtaizi River, Daliao River and Daling River, continuously flow into the sea and form the present landform, which covers a mudflat area of 67,000 ha,

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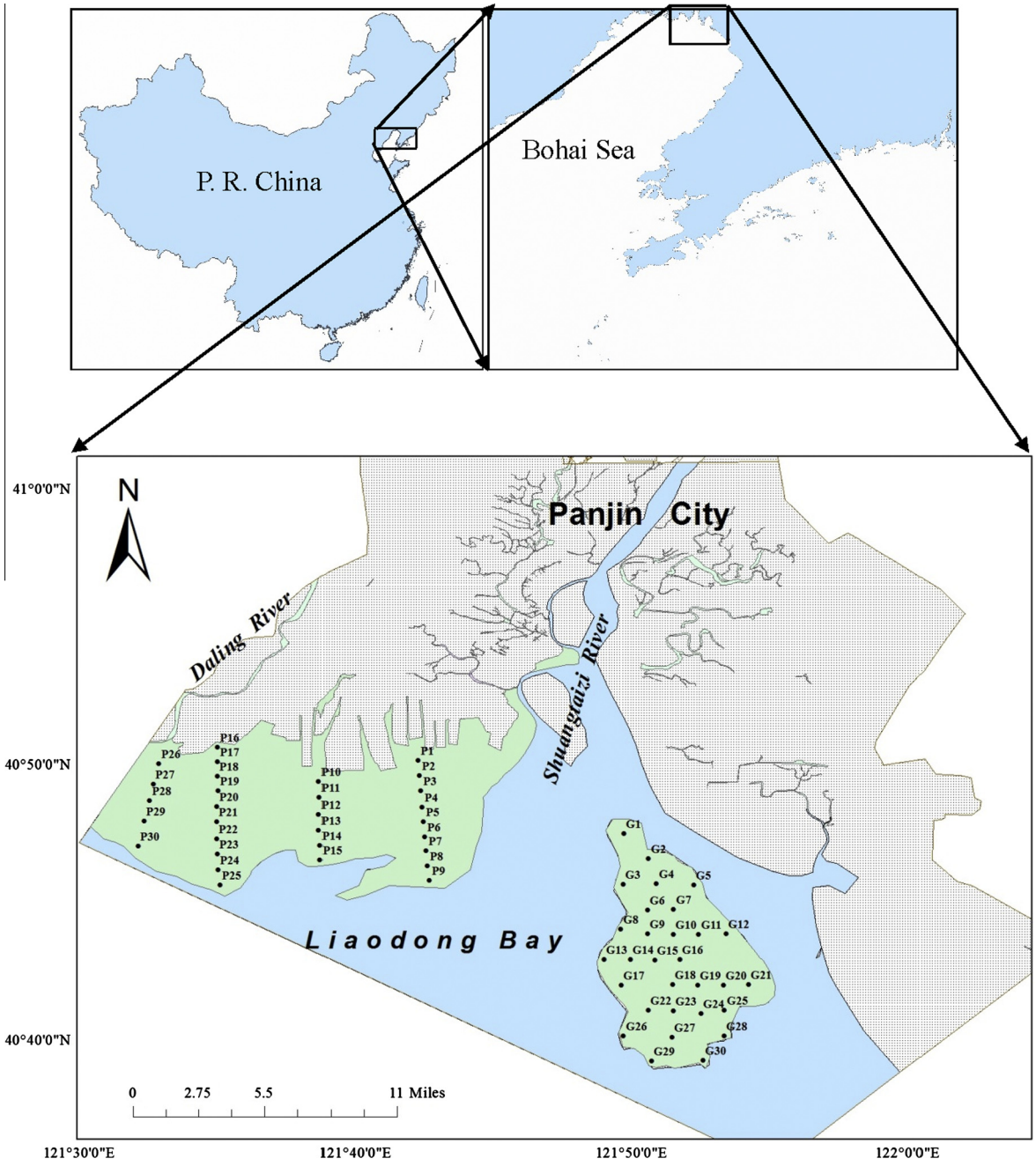

Fig. 1. Study areas showing location of sampling sites in sediment of Shuangtaizi Estuary.

accounting for 56% of the total mudflat area in Liaodong Bay (Fig. 1). The sand flats in Shuangtaizi Estuary are divided into two parts by Shuangtaizi River. One part is called Panshan Shore (PS), while the other part with a fusiform shape, is called Geligang Ridge (GLG) (Fig. 1). The sediments in these two parts consist principally of clayish silt and fine-grained sand, which is a suitable breeding habitat for many species of economic macrobenthos (Zhang et al., 2013).

Ecologically, understanding the environmental impacts of xenobiotics existing in the intertidal belts is a crucial subject. Several concrete investigations have been conducted on the aquatic environment of Shuangtaizi Estuary to identify the distribution of heavy metals in this area (Bao, 1988; Li et al., 1992; Feng et al., 2003) and PHCs (Meng et al., 2004; Luo et al., 2010). Analysis of the concentrations of heavy metals (Hg, Cd, Cu, As, Zn, and Pb) and PHCs in aquatic organisms (e.g., crustaceans, mollusks and fish), along with spatial and temporal trends, has also been conducted (Ma et al., 1999). Although a large number of studies focused on the distribution of pollutants in the water or wetland system and the effects of pollutants on aquatic creatures in Shuangtaizi Estuary, few studies concentrate on the sediment in the region's sand flat. Moreover, most of the previous studies were conducted decades ago, and limited reports on this region have been published in recent years. Furthermore, published studies failed to build a comprehensive analysis on pollutants in this area to indicate the complex interactions among heavy metals, PHCs, and other geochemical factors.

The present study aims to investigate spatial variations of heavy metals and PHCs and explore the relationships affecting the distribution of heavy metals and PHCs with geochemical factors, such