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Seasonal and spatial distributions and possible sources of polychlorinated biphenyls in surface sediments of Yangtze Estuary, China

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HIGHLIGHTS

- ▶ PCBs in the estuarine surface sediments showed significant seasonal variations.
- ▶ The effects of the surface sediment properties on PCB distributions were studied.
- ▶ Light PCBs with 2–3 chlorines showed a predominant proportion.
- ▶ Atmospheric deposition and surface runoff were suggested as the major PCB sources.

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ABSTRACT

The surface sediment samples taken from 30 sites of the Yangtze Estuary in both the flood and dry seasons were analyzed to reveal the spatial and seasonal distributions of polychlorinated biphenyls (PCBs). Samples collected in the flood season showed higher PCB concentrations, larger PCB fluctuations and higher portions of large grain sediments in the inner estuary area compared with those collected in the dry season, indicating significant seasonal variations of PCBs. The effects of the physicochemical characteristics (TOC and grain size) of surface sediments on the distributions of PCBs were also investigated. Masked by various other factors, the TOC contents and sediment grain sizes did not exhibit a strong influence on the distributions of PCBs. Analysis of the PCB homolog and congener distribution patterns revealed a predominant proportion of light PCBs with 2–3 chlorines. According to the PCB homolog profiles and principal component analysis (PCA) of source contributions, non-point sources including atmospheric deposition and surface runoff associated with stormwater were suggested to be the major sources of PCBs in the surface sediments of the Yangtze Estuary.

1. Introduction

Polychlorinated biphenyls (PCBs) represent a group of persistent organic pollutants (POPs) of strong environmental concern. The global production of PCBs has been estimated to be over 1.3 million tons (Breivik et al., 2002). The production of PCBs in China began in 1965 and was banned in 1983, resulting in a total production of over 10,000 tons. Despite the prohibition of PCB production in most countries, the products manufactured before the prohibition are still used, mostly as dielectric fluid in electrical equipment servicing industries (Dodoo et al., 2012). Potential PCB emission sources include leaks and spills of PCBs, illegal disposal of PCB-containing products, municipal solid waste incineration, and historical contamination of bottom sediments (Xia et al., 2012). PCBs are widespread in the environment because of their high thermodynamic stability and environmental mobility. PCBs have been detected globally from the most urbanized areas in the world to the pristine Arctic areas (Hartmann et al., 2004; Borga et al., 2005; Xing et al., 2005; Negri et al., 2006; Li et al., 2009). The ability of PCBs to volatilize to the atmosphere as well as their high resistance to thermal degradation makes atmospheric transport the primary mode of PCB global distribution.

PCBs enter the surface soils and waters mainly by dry and wet deposition, surface runoff, and industrial wastes (Hiller et al., 2011). PCBs tend to stick to particles and sediments in water, therefore, sediments at the bottom of a large body of water act as a reservoir of PCBs. As a transition zone between river environments and ocean environments, estuaries are subject to both the riverine influences, such as flows of fresh water and sediments, and marine influences, such as tides, waves, and seawater influx (McLusky and Elliott, 2004). Therefore, the water flow and

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sediment movements in the estuarine area undergo a strong disturbance and the transport and fate processes of estuarine POPs in the surface microlayer of the water body, on the surface of suspended particles, or at the sediment–water interface become more complex than in other water bodies.

The Yangtze Estuary is the lower, tide-affected part of the Yangtze River, one of the largest rivers by discharge volume in the world. Over half of the sediments carried by the Yangtze River are deposited in the Yangtze Estuary (Li et al., 2012). Several studies have investigated the distributions of PCBs in the water body, suspended particles and sediments of the Yangtze Estuary, most of which focused on the nearshore area (Liu et al., 2003, 2004; Yang et al., 2003; Cheng et al., 2006; An et al., 2009; Hui et al., 2009). In recent years, the river flow and sediment discharge of the Yangtze River have been greatly reduced, largely due to the Three Gorges Dam project farther upstream. Consequently, the intrusion of salt water has occurred more frequently in the Yangtze Estuary. However, the pollution status of PCBs around the estuary associated with the reduction of river flow and sediment discharge remains unexplored.

In this study, we investigated the seasonal and spatial distributions of PCBs in both the nearshore and offshore surface sediments of the Yangtze Estuary and evaluated the upstream and local effects of the estuary on PCB pollution. The homolog and congener distribution patterns of PCBs were also analyzed to reveal the possible sources of PCBs in the Yangtze Estuary.

2. Materials and methods

2.1. Study area

The Yangtze Estuary is divided into two branches by Chongming Island, namely the north branch and the south branch. The south branch receives the major inflow of the Yangtze River and is further separated into two parts by Changxing and Hengsha Islands: the northern part is called the north bay, and the southern part extends throughout Jiuduansha islands and is divided into the north passage and the south passage. The south branch of the Yangtze Estuary receives the Huangpu River inflow, which flows through the highly populated and industrialized city of Shanghai. Additionally, three wastewater outlets that dispose of industrial and domestic sewage from Shanghai city, are located along the south channel. Fig. 1 shows the study area of the Yangtze Estuary, which begins from Xuliujin and ends at the −20 m isobath within the range of 30.5–32°N and 121–122.6°E. The Yangtze Estuary lies in the eastern subtropical monsoon climate region with distinctive four seasons. The annual river flow discharge from the Yangtze River is $2.93 \times 10^4\ m^3\ s^{-1}$ and the annual suspended sediment load approaches 4.9×10^8 tons (Shi et al., 2006).

2.2. Sample collection

Field sampling was performed in August (flood season), 2010 and February (dry season), 2011. Surface sediment samples were collected with a grab sampler at 30 different sites of the inner Yangtze Estuary and the adjacent East China Sea, as shown in Fig. 1. Based on the island distribution characteristics, 20 sites (1–18, 27, 28) were chosen within the inner estuary and the other 10 samples (19–26, 29, 30) were taken along the −10 m and −20 m isobaths in the adjacent sea. Vertical sediment cores were collected at Site 31 of 30°46.128′N, 122°15.153′E in June, 2011. All the samples were stored in aluminum containers and kept in a refrigerator at −20 °C for further analysis.

2.3. Chemical analysis

The sediment samples were all freeze-dried and grounded to pass through a 100 mesh sieve. 20 g of each sieved sediment sample was homogeneously mixed with approximately 20 g diatomite and 8 g copper powder and transferred into the 66 mL extraction

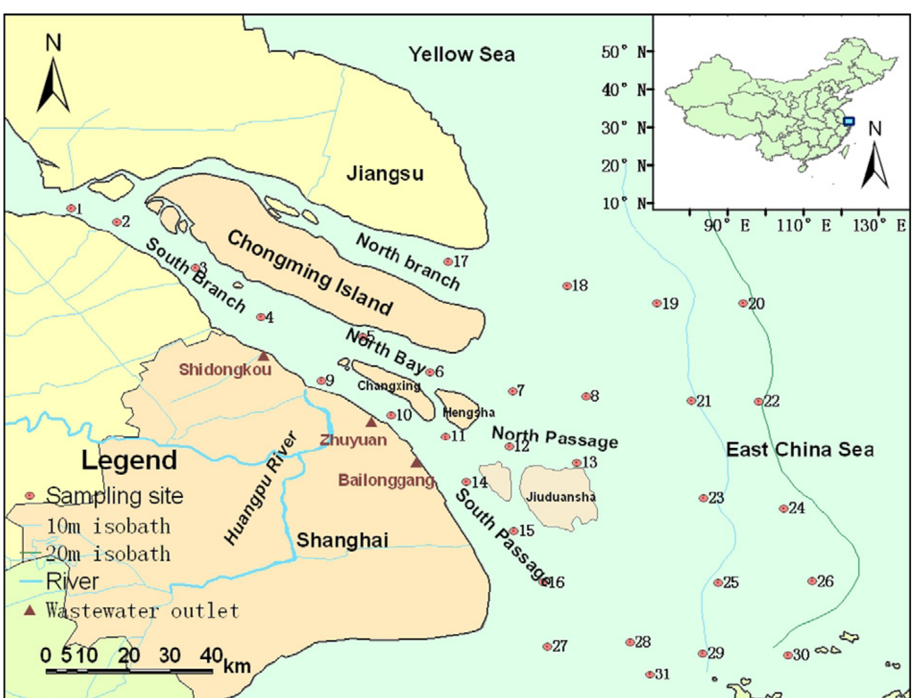

Fig. 1. Map of the study area of Yangtze Estuary and the sampling sites. The Yangtze Estuary is marked in blue in the inset overview of China. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)