Heavy metals and phosphorus in tidal flat sediments of the Yangtze estuary

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Abstract: Concentrations of heavy metals (Cu, Pb, Zn, Cr and Cd), and phosphorous (P) were determined in surface tidal flat sediments of the Yangtze estuary and Shanghai coast. Results demonstrate that there were significant differences among the accumulation of the heavy metals in sediments, following the order: Zn > Cu > Cr > Pb > Cd. The spatial distribution and chemical forms of heavy metals in tidal flat sediments were closely related to the distribution of pollution resources (outlet of sewage) and the local sedimentary and hydrodynamic conditions. The dominated form of non-residual heavy metals is bound to Fe/Mn oxides, and the next form is bound to carbonates. Moreover, contents of total P in sediments range from 18.0 μmol.g⁻¹ to 31.4 μmol.g⁻¹ along the coastline, speciation of P in sediments was different, most of P in tidal flat sediments is associated with calcium phases (as Ca-P) similar to marine sediments.

Key words: heavy metals; phosphorus; tidal flat sediments; Yangtze estuary

1 Introduction

Estuary and coastal area are recognized as being highly vulnerable to gradually increasing pollutant inputs from river and adjacent areas. With the rapid development of cities along the Yangtze River, especially after the Pudong development of Shanghai, a large amount of industrial and domestic wastewater has been input into the Yangtze River and to the Yangtze estuary, which exerts a great impact on the coastal environment quality. In recent years, there has been great concern about the effect of increasing pollutant input into the estuary and coastal region, such as heavy metals (Gambrell, 1994; Gerritse, 1998; Millward and Glegg, 1997; Amini Ranjbar, 1997; Xu, 1997; Williams, 1994; Zhang, 1992; Zwolsman, 1996), nutrient (Klump and Martens, 1981; Zwolsman, 1994; Jensen, 1995; Sanders, 1997). In aquatic environment, particles and sediments represent the main carrier of pollutants. Every year, a large amount of suspended sediment adhering pollutants is input and deposited on these areas of the Yangtze estuary and Shanghai coast, where, as a result, pollutants are considerably enriched. It thus becomes most imperative to research the behavior of pollutants in the coast sediment and their environmental impacts. In the present paper, we mainly focus on the content and distribution of heavy metals (Cu, Pb, Zn, Cd, Cr), and P in the tidal flat sediments from the Yangtze estuary and Shanghai coast.

2 Study area

As the largest river of China, the Yangtze River has a yearly discharge of 9.24 × 10¹¹ m³, and carries an annual sediment load of 4.86 × 10⁶ t into the sea. These sediments feed the delta's continued seaward expansion. Shanghai, the biggest metropolitan city of China, lies on the southeastern frontier of the Yangtze Delta, on the East China's central coast. Tidal flats have

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been formed along the eastern and southern coasts of Shanghai (Figure 1), which have a slope of 1 to 3 (°), and a width of between 1,000 and 3,000 m (Xu, 1998). Along the coastline (about 130 km) of Shanghai, from Liuhe on the north, to Nanhui cape on the southeast, and to Jinshan (JS) on the west, the area of tidal flats is about 250 km² (40% of the total tidal flat area). The largest tidal flat of the Yangtze estuary with a width of >10 km is on the east of Chongming (CM) Island, and Jiuduansa (JDS) is a new shoal located in the Yangtze River mouth (Figure 1). However, tidal flats vary along Shanghai coastline, which reflects different sedimentary environments. In the past years, many studies have been conducted on the geomorphic characteristics of the Yangtze delta (Yan and Xu, 1987). There exists erosion-deposition change in tidal flats of different sections of the Yangtze estuary, especially along Shanghai coast (Figure 1), successively, represented by stable bank (from Liuhe to Chuansha), accumulating bank (Chuansha to Nanhui Cape near Luchao (LC) station), and erosion-deposition alternate bank (from Nanhui Cape to the JS site) (Xu, 1997).

As the consequence of the high population and the rapid development of industry of Shanghai, the potential environmental impact of pollution upon the Yangtze estuary and coast is considerable. Along the south bank of the Yangtze estuary, the two sewage outlet at Baoshan (Shidongkou) and BL sites, which discharge into the intertidal zone, were built in the late 1960s to the early 1970s, respectively, and discharge about 0.7 and 0.3 million t of sewage each day (Dai, 1990). In addition, in the early 1990s, there were about 4 million t of sewage/day which were directly entered the Huangpu River, and discharged through the Wusongkou (WSK) to the Yangtze estuary (Figure 1).

3 Materials and methods

3.1 Sediment sampling

In July, 1998, surface sediment samples were taken from 14 sampling sites distributed along the southern Yangtze tidal flat, including the east tidal flat of the CM and JDS sites (Figure 1). At each site, two or three sediment samples were respectively collected from the high tidal flat, mid-tidal flat and low tidal flat. All sediment samples were stored in plastic bags in a freezer, and then dried in a natural condition (25°C) and ground through sieve (100 mesh) before laboratory analysis.

3.2 Heavy metal analysis

Heavy metals in sediments were digested by HNO₃-HClO₄-HF. The five different forms of heavy metals in sediments, such as exchangeable, bound to carbonate, bound to Fe/Mn oxides, bound to organic matter, and residual form, were extracted by Tessier methods (Tessier, 1979). Throughout analytical work, deionized distilled water was used. All the reagents were of high purity. The heavy metals in digested and extracted solutions were determined on a PE5100 model flame atomic absorption spectrophotometer (AAS). For quality assurance blanks were carried out throughout all stages of sample collection and analysis. Standard deviations of measurements for heavy metals were less than 10%.

3.3 Phosphorus analysis

Total P in sediments was digested by H₂SO₄-HClO₄. P as orthophosphate was determined by