The Distribution of Heavy Metals in the Sediment of Low Tidal Flat, Eastern Chongming Island, China

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Abstract. The distribution of heavy metals in the tidal flat is of great significance on the estuary environment. This study aims to find the heavy metal distribution mechanism at low tidal flat in Yangtze Estuary, China. 4 sediment cores were collected at low tidal flat of eastern Chongming Island at four seasons spring, summer, autumn and winter. The concentrations of element Al, Cu, Cr, Fe, Mn, Pb, Rb, Zn, Zr in the sediment were analyzed. The vertical distribution of different element with depth were analyzed and the main factors that control the distribution of heavy metals in the sediments of low tidal flat were discussed. The results showed that the source of sediment and tidal hydrodynamics are the two main factors that controls the distribution of heavy metals in the sediment of low tidal flat. Zr in the sediments can be used as geochemical marker to reflect the erosion and deposition changes in tidal flat.

1. Introduction

Tidal flats, as wetland habitats, are an important ecosystem and of great ecological significance for humans. Estuarine flats provide vital feeding grounds for migrant and native birds as well as nursery zones for fish [1]. However due to increasing urban and industrial development in surrounding areas, more and more contaminants such as heavy metals are discharged into these ecologically sensitive areas. The tidal flats tend to become a sink or source for the heavy metals [1-3]. Heavy metals are adsorbed onto suspended particles, deposit on the bottom as sediments and accumulate in the sediments of tidal flats [3]. Sediments are regarded as an effective archive that can record heavy metal contamination [4].

Sediment pollution by heavy metals has become a critical problem in marine environment due to their toxicity, persistence, bioaccumulation and non-degradability in the environment [4-7]. Heavy metals in the sediments could significantly affect the health of marine ecosystems, and they can act as a source of heavy metals, imparting them into water and degrade water quality when the conditions of sedimentary environment change [4]. Therefore the study of heavy metal distribution in the sediments of estuary tidal flats is of great importance for the sustainable development of this region.

The Yangtze River is considered the largest and most important river in Asia [8]. It ranks ninth globally in terms of drainage area, and fourth in sediment flux (500 Mt/year before its decline in the 1970s) [8]. Among 470 million tons of silt carried by the Yangtze River annually, about half is deposited on Shanghai tidal flats [9]. Eastern Chongming tidal flat is a well-developed tidal flat and the largest intertidal zone of the Yangtze River estuary [9]. The study area is located on the eastern coast of Chongming island (Figure 1). The sediment in this tidal flat has obvious zonation and divided into high, middle and low tidal flat from land to sea. Our study is focus on the low tidal flat and study the heavy metal distribution mechanism in the sediment of this zone.

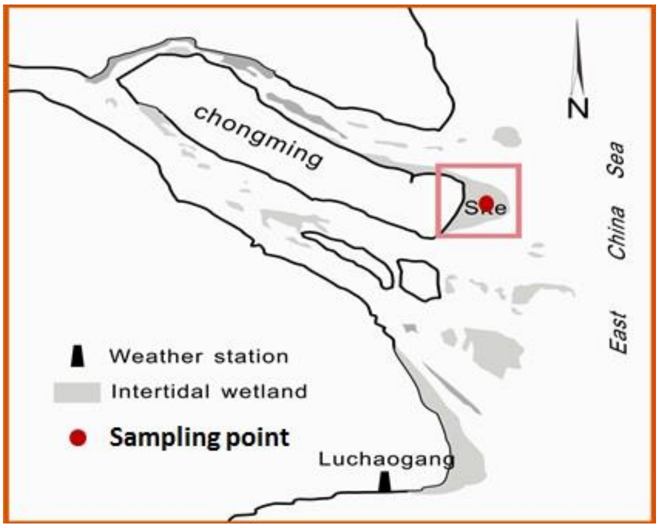

Figure 1. The study area and sampling site [9]

2. Materials and Methods

2.1. Sampling and Pretreatment

Four sediment cores were collected with PVC pipe (ca. 40cm in length, 100mm in diameter) at low tidal flat during ebbing period (Figure 1). The sampling was performed during a year at four different seasons in January, April, July and September. The sampling and pretreatment follow the same procedure at that described in [9].

2.2. Major and Trace Element Analysis

4g sediment sample was weighed and put onto a low pressure polyethylene base. The sample pretreatment and analysis methods is the same as that described in [9].

2.3. Standardization of Elements

Grain size is an important parameter to affect the distribution of heavy metals. Natural transport processes of heavy metals mainly depend on the presence and transport of find-grained sediment, which is an efficient sink for heavy metals, with the capacity to concentrate and retain heavy metals [7]. Therefore before analyzing the temporal and spatial distribution of heavy metals in sediments, the concentrations of elements are normally standardized with Aluminum, one of the major chemical components of fine-grained sediments, to eliminate the effect of grain size on heavy metals content [9]. The standardization method is as follows:

$$\mathbf{C_{i\ normalised}} = \frac{\mathbf{C_i}}{\mathbf{C_{Al}}}$$

Where $\mathbf{C_{i\ normalised}}$, $\mathbf{C_i}$, $\mathbf{C_{Al}}$ indicate the content of element **i** after normalization, content of element **i** before normalization and content of Al before normalization.

3. Results and Discussions

The vertical distributions of heavy metals in the four seasons were analyzed and the results were shown in Figure 2-5. The distribution mechanisms of heavy metals in different seasons were discussed in the following section.

3.1. The Vertical Distribution of Heavy Metals in the Sediment in Spring

In spring, Cr and Zr showed very consistent vertical distribution characteristics, which indicates that Cr mainly migrates with relatively course particles? In a depth deeper than 12cm, Fe and Mn showed similar distribution characteristics as that of Cr and Zr, which showed a relatively large peak at a depth of 16cm and a relatively small peak at a depth of 22cm. However, Cu, Pb, Rb and Zn exhibit an opposite vertical distribution from that of Zr and Cr. Since Zr mainly produced and enriched in heavy minerals, it is estimated that the vertical distribution of Fe and Mn in the sediments of low tidal flat in spring is primarily caused by the source of sediments. Fe and Mn are mainly enriched in the heavy minerals of course particles. While the distribution of Cr, Cu, Pb, Rb, and Zn are more affected by the grain size, and mainly attached to the fine sedimental particles and migrate with fine grain size particles. Due to the strong hydrodynamic effect in the low tidal flat, the sediment is under constant stirring. The enrichment of heavy metals in the redox boundary layer during early diagenesis is a relatively slow process. So if the sediment deposits at a relatively slow speed, heavy metals have sufficient time for post-deposition migration and form a peak at the redox boundary layer. In the contrary, if the sediment deposit at a fast speed, it is difficult to form a peak. Therefore the strong hydrodynamic conditions at low tidal flat are not conducive to the formation of redox boundary layer. So the vertical distribution of heavy metals in the sediment of low tidal flat is mainly affected by the source of sediment, and the post-migration after deposition process is weak.

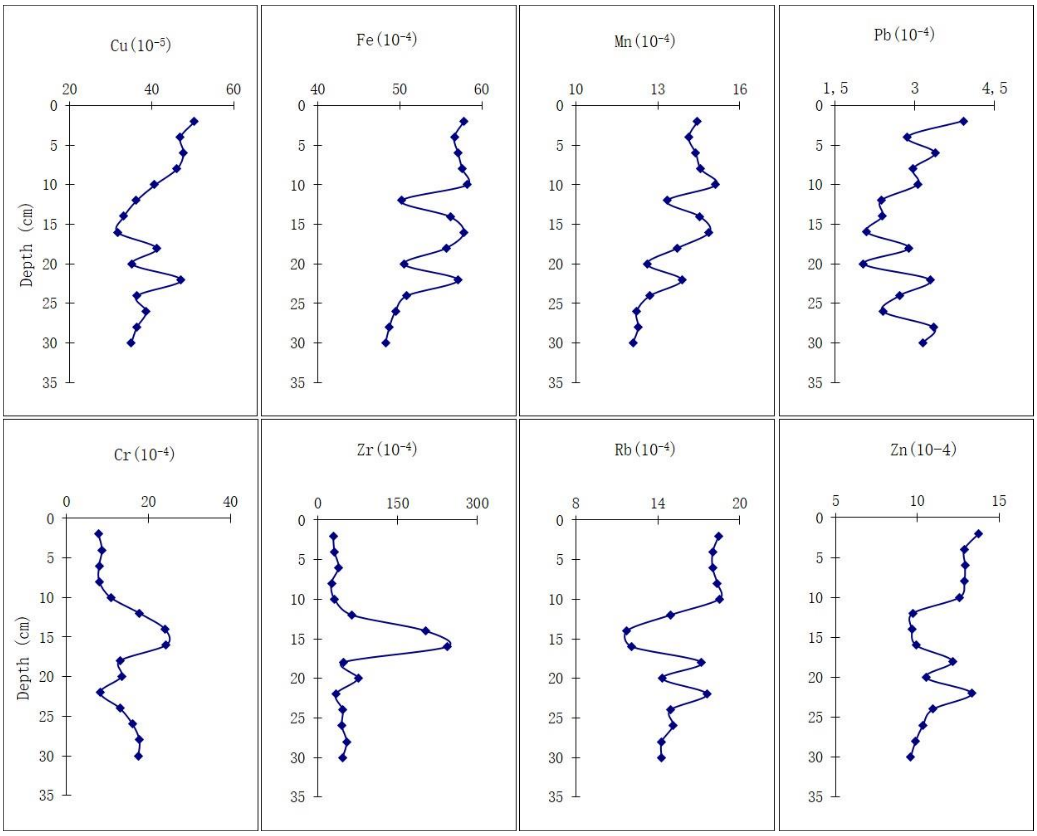

Figure 2. The vertical distributions of metals in the middle tidal flat in spring

3.2. The Vertical Distribution of Heavy Metals in the Sediment in Summer

In summer, Fe, Mn and Cr, Zr showed similar vertical distribution in the sediment of low tidal flat at a depth deeper than 18cm. Zr is very stable in the sediment, and the post-migration is extremely weak. Therefore the similar distribution of Fe, Mn and Cr, Zr indicates that the distribution of Fe, Mn is mainly affected by the source of sediment. Fe and Mn are not in the form of oxides and are mainly present in the heavy minerals rich in Zr. The peak value moved from 16cm to about 26cm. This is mainly because the tidal flat is dominated by siltation process from spring to summer. The sedimentation depth is about 10cm. At a depth lower than 18cm, Cu, Pb, Zn, Fe and Mn exhibit an opposite distribution characteristic to Cr, which is especially obvious between the distribution of Cu and Cr. Zr indicates a relatively course sediment source and Cr migrates mainly with relatively course particles in the sediment. So the vertical distribution of heavy metals in the sediment of low tidal flat in the summer is mainly affected by the source of sediment and tidal flat siltation process.

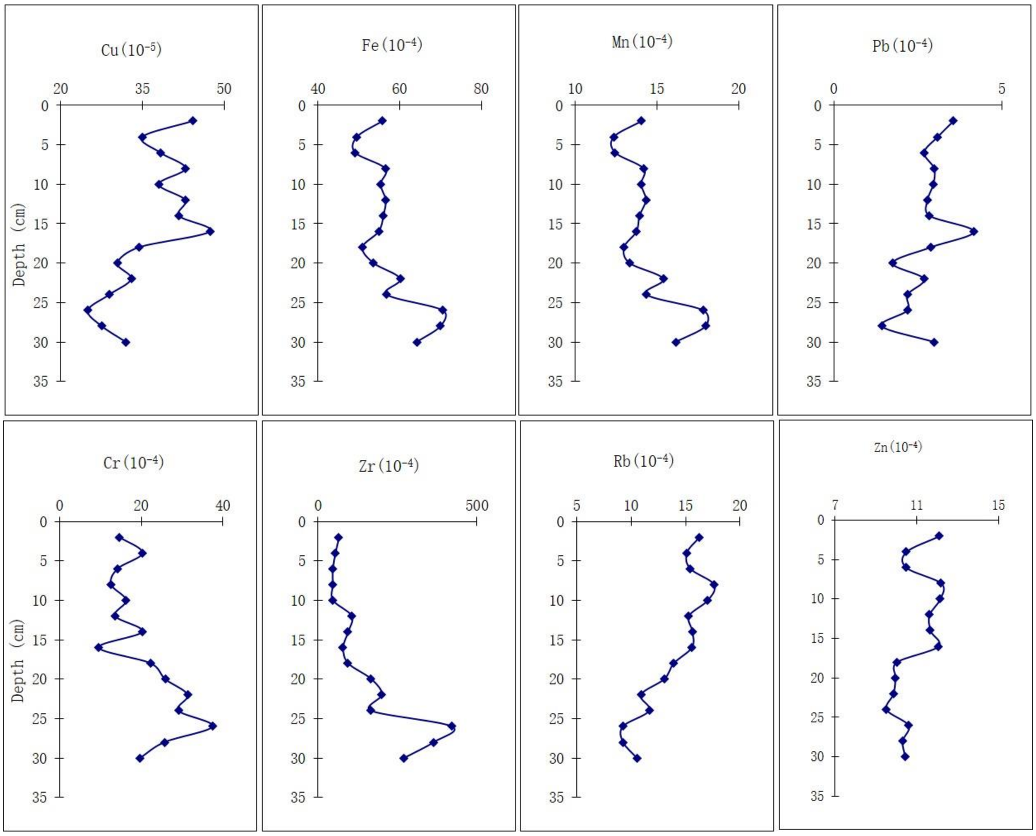

Figure 3. The vertical distributions of metals in the low tidal flat in summer

3.3. The Vertical Distribution of Heavy Metals in the Sediment in Autumn

In autumn, Fe, Mn and Zr, Cr showed similar vertical distribution characteristics at a depth deeper than 14cm and both have a peak value at a depth of 16cm. This indicates that the tidal flat experiences mainly a scouring effect from summer to autumn and about 10cm of sediments are washed away from surface. From 14cm to surface layer, Zr and Cr showed little change, while Cu, Pb, Zn, Fe and Mn showed an increasing trend from 16cm to the surface. This may be the combined effect of sediment source and organic matter.

3.4. The Vertical Distribution of Heavy Metals in the Sediment in Winter

From autumn to winter, the tidal flat is still dominated by scouring effect. The depth of scouring is about 10cm. The peak value moved from a depth of 16cm in autumn to about 6cm. From 14cm to the surface layer, the heavy metals generally showed a decreasing trend and enriched in the surface. This may be related to the sediment source and the hydrodynamic effect.

In summary, the distribution of heavy metals in the sediments of low tidal flat is mainly affected by the sediment source and the tidal hydrodynamic forces. The low tidal flat is under constant strong hydrodynamic effect and experiences intense erosion and siltation process throughout seasons. The average erosion and deposition depth is about 10cm. In winter and spring the siltation process dominates and in summer and autumn, the souring process dominates (Figure 6).

4. Conclusions

The distribution of heavy metals in the sediments of low tidal flat is mainly affected by the sediment source and the tidal hydrodynamic forces. The low tidal flat is under constant strong hydrodynamic effect and experiences intense erosion and siltation process throughout seasons. The average erosion and deposition depth is about 10cm. In winter and spring the siltation process dominates and in summer and autumn, the souring process dominates. The enrichment depth of Zr can be used as an indicator to indicate the erosion and deposition of tidal flat.

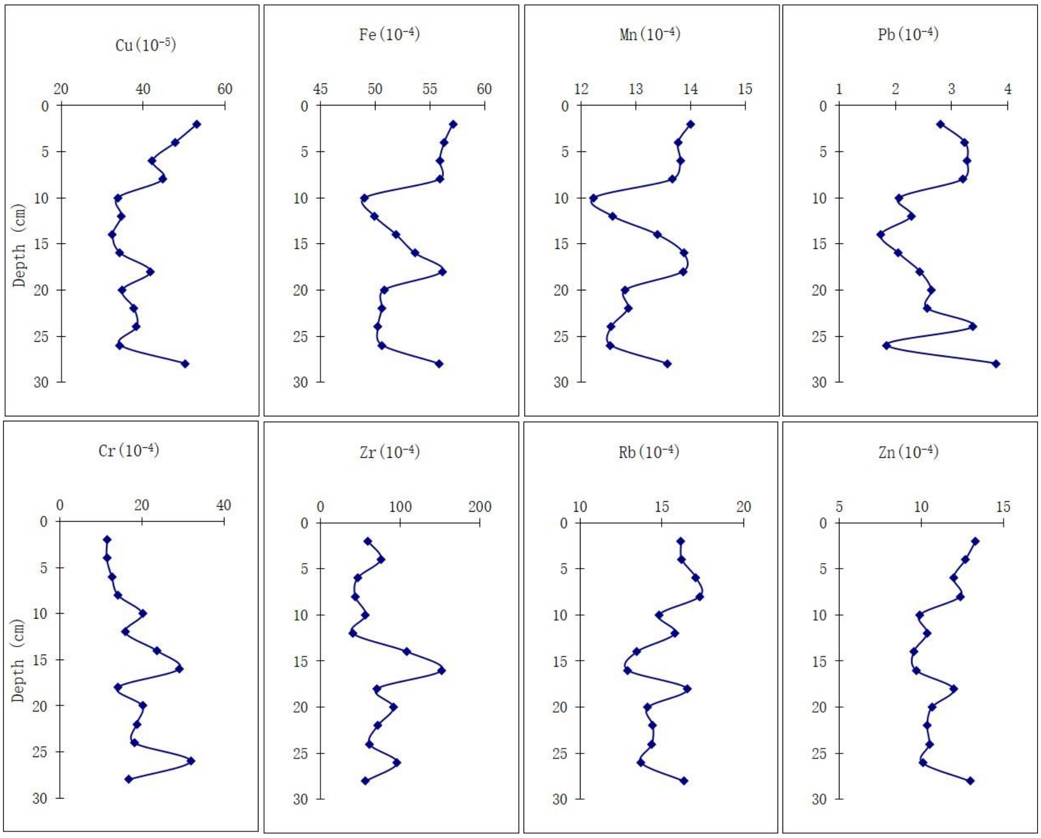

Figure 4. The vertical distributions of heavy metals in the low tidal flat in autumn

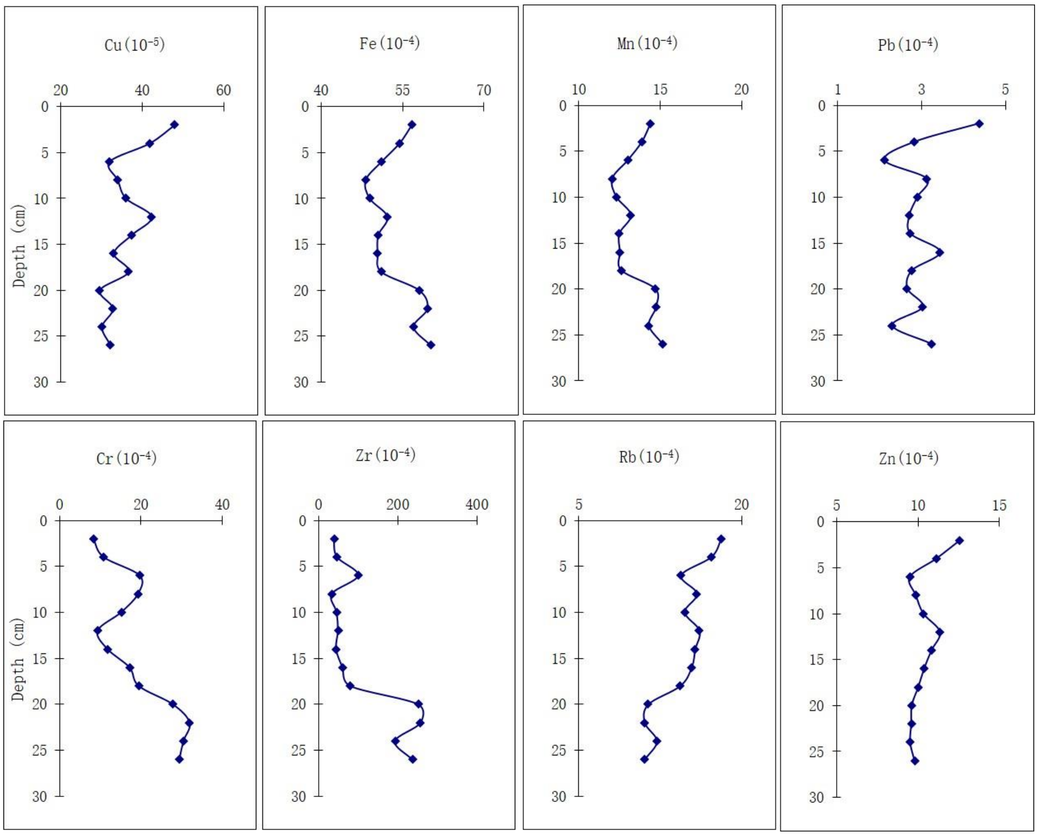

Figure 5. The vertical distributions of heavy metals in the low tidal flat in winter

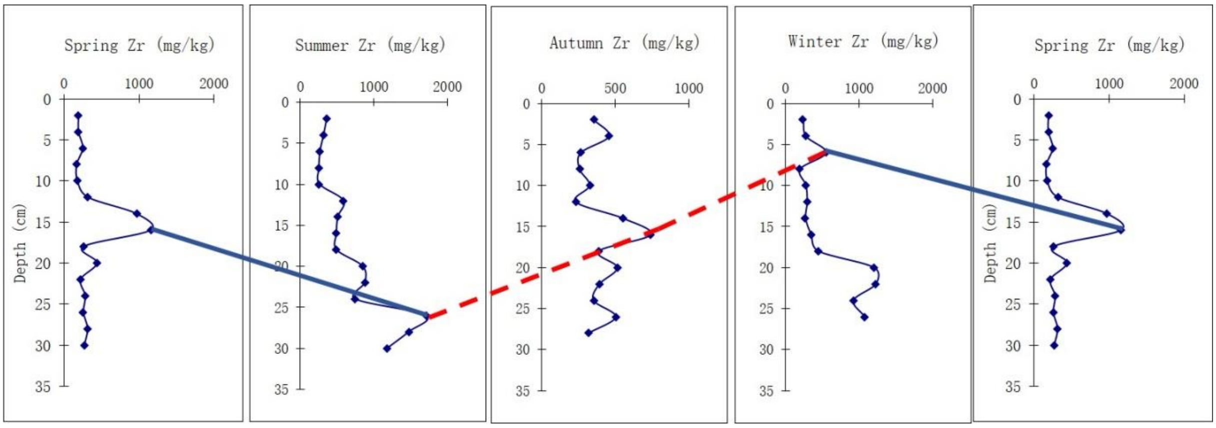

Figure 6. The erosion and siltation of low tidal flat in the four seasons

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