Distribution and pollution assessment of heavy metals in surface sediments in Xiaoqing river estuary and its adjacent sea of Laizhou bay

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Abstract. In this paper, the monitoring results of four heavy metals Cu, Pb, Zn and Hg at 10 sampling stations in Xiaoqing river estuary and its adjacent sea of Laizhou Bay in November 2008 were analyzed and evaluated. The results showed that the concentrations of heavy metals in the steam channel and estuary are higher than those in the adjacent sea, and the metal concentrations were below the standard for I class of marine sediment quality, excepting the station 2 in the steam channel and station 5 in the estuary. The assessment of the single-factor pollution index showed that the overall pollution level of the study area was relatively low, but there was serious pollution phenomenon in individual station. The potential ecological risk of heavy metals in the surface sediments was generally at a low level, and Hg had the highest potential risk.

1. Introduction
Xiaoqing River and its adjacent sea is located in Shandong Province, with transportation, flood control, irrigation and other functions, and it is an important industrial and agricultural production base [1]. With the expansion of urban construction scale, the ecological functions of Xiaoqing River and its adjacent sea have been severely damaged. Sediment pollution is one of the most serious environmental problems [2][3], among which, heavy metals are a kind of pollutants which seriously affect the quality of sediments due to their harmful effects on persistence, biological toxicity and enrichment effect of the food chain [4]. Sediments, as an important aggregation site of heavy metals in water, can adsorb and release heavy metals. Therefore, the distribution and ecological risk assessment of heavy metal pollution have become prevalent both at home and on abroad [5]. The purpose of this study was to analyze the pollution characteristics of heavy metals Cu, Zn, Pb and Hg in the surface sediments in the Xiaoqing River estuary and its adjacent sea of Laizhou Bay. The assessment of the heavy metal pollution and potential ecological risk were carried out to provide a basic data for ecological management.

2. Materials and methods

2.1 Sampling
In November 2008, a total of 10 sampling stations were set up in Xiaoqing River estuary and its adjacent sea of Laizhou Bay. Two stations (station 1 and 2) were located in the steam channel, four stations
(station 3-6) were located in the estuary, and four stations (station 7-10) were located in Laizhou Bay area. Sampling stations were showed in Figure 1.

![Figure 1](image)

**Figure 1.** Location of sampling sites in Xiaoqing River estuary and its adjacent area of Laizhou Bay

2.2 **Sampling Treatment**

The heavy metals Cu, Zn and Pb were measured by the American Thermoelectric M6 Flame Atomic Absorption Spectrophotometry. The concentration of Hg was measured by AFS-920 cold atomic absorption spectrometry. The offshore sediment standard samples (GBW07314) were used as internal samples for quality control, the recovery of heavy metal was between 90% and 110%, and the standard deviation of parallel samples were less than 10%.

2.3 **Statistical analysis**

Using the single-factor pollution index (SI) and the comprehensive pollution index (CI) to indicate the pollution level of heavy metals in sediments. Hakanson potential ecological risk assessment was used to assess the risk of heavy metals, which can reflect the different environmental sensitivity to heavy metals. Significant differences among the stations were analyzed using one-way analysis of variance (ANOVA) using Statistical Product and Service Solutions Software 20.0 (SPSS 20.0).

3. **Result and discussion**

3.1 **Distribution of Heavy Metals in surface Sediments**

Heavy metal concentrations in surface sediments were demonstrated in Figure 2. The concentrations of heavy metals in surface sediments were relatively low. In addition to the Cu, the average concentrations of other heavy metals were lower than the first criterion of the marine sediment quality standards, and the highest value was also lower than the standard for II class of marine sediment quality. The average concentrations of four heavy metals were Zn > Cu > Pb > Hg in the steam channel and the estuary area, Zn > Pb > Cu > Hg in the adjacent sea. By comparing the average concentrations of the heavy metals in the three areas, we found that the heavy metal concentrations in the steam channel and estuary were higher than those in the adjacent sea. A one-way ANOVA indicated that there was no significant differences between the concentrations of heavy metals in the three areas (P> 0.05).
3.2 Analysis of Heavy Metal Pollution in Surface Sediments

Figure 3 showed the single-factor pollution index (SI) and the comprehensive pollution index (CI) of heavy metals in surface sediments of Xiaoqing River estuary and its adjacent sea of Laizhou Bay. There was no uniform standard selected for the background value of Xiaoqing River estuary. Considering the current status of regional research, the background reference values of Cu, Pb, Zn and Hg were 24.68, 17.50, 73.01 and 0.15 mg · kg⁻¹, respectively [2]. In the study area, average SI order was Cu (1.55), Pb (0.99), Zn (0.86) and Hg (0.42). So Cu was the main environmental pollution factor of Xiaoqing River Estuary and its adjacent area. The SI value of Cu in the station 2 and station 5 were above 5, with the high pollution level. The SI value of Cu, Pb, Zn and Hg in station 4-7 in the estuary area was close to 1, which indicated the “moderate” level of pollution. The CI value indicated that only two stations was above 5, and the remaining stations were below 5, with the low pollution level.

3.3 Potential ecological risk assessment of heavy metals in surface sediments

Figure 4 showed the single potential ecological risk index (SRI) and comprehensive potential ecological risk index (CRI) of heavy metals in surface sediments. The SRI of four heavy metals in the three areas ranged from 0-46.72. Due to the SRI value of Hg at station 5 in the estuary area was greater than 40,
and the other heavy metals at all stations were less than 40, the potential ecological risk of heavy metals was at low level. In the study area, the average SRI was Hg > Cu > Pb > Zn, the SRI value of Hg was the highest. Therefore, Hg was the most significant potential ecological risk factor of Xiaoqing River estuary and its adjacent sea of Laizhou Bay. The CRI of heavy metals in each station was less than 150, which meant the potential ecological risk of heavy metals was at the low level.

4. Conclusion
The concentrations of Cu, Pb, Zn and Hg in surface sediments were low, and most of them were lower than the first class of marine sediment quality. The concentrations of Zn, Cu and Hg in the steam channel and estuary were high, and Pb in the adjacent sea presented high value. The single-factor pollution index indicated that the area was seriously polluted by Cu, which was the main environmental pollution factor of Xiaoqing River estuary and its adjacent sea of Laizhou Bay. The potential ecological risk assessment was low in the study area, and the highest potential ecological risk was Hg.

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