Pb distribution and translocation in Jiaozhou Bay*

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Abstract The trends of distribution, translocation and seasonal change of heavy metal Pb were studied based on the surface and bottom water sampling in Jiaozhou Bay in 1979, and compared with those in 1990's. The results showed that the source of Pb in the bay was from wastewater and sewage in the east of Jiaozhou Bay from ocean vessels. Pb concentration was higher in spring and lower in summer and autumn, and remained stable through sedimentation in the bottom layer. The overall water quality was good in 1970's. Compared with the environmental monitoring data of 1995–1999, Pb pollution had become serious. Therefore, more efforts should be made to protect the bay from Pb pollution.

Keyword: heavy metal Pb; distribution; pollution source; translocation; Jiaozhou Bay

1 INTRODUCTION

With the development in agriculture and industry and the exploitation of marine resources, heavy metals were increasingly drained into the ocean and retained in sediment, especially in the inshore region that was the main place of contamination (Qiao et al., 2004). Under some physical and chemical conditions, heavy metal in sediment could be released into seawater and became the second pollution source harming aquatic organisms (Huang et al., 2003; Lin and Liang, 1995; Lou, 1996). As a main contamination, it not only affects the growth and propagation of aquatic organisms, but also threatens the human beings ultimately through the food chain (Dai and Sun, 2001).

Therefore, the study in this area is important. In this paper, historical data of Pb concentration in the bay were used and compared with recent ones. As a familiar poison species, Pb distributes widely on the Earth. With the development of modern industry and transportation, Pb has been used in many fields. Pb is azury soft metal, with good ductibility, and resisting to corrosion, high density and low melting point. In virtue of these traits, Pb is used frequently in industry and becomes a risky element in the

environment if not treated properly (Abraham and Parker, 2002; Stéphane et al., 2004). Progresses in the study on Pb pollution have been made in recent years (Meng and Sun, 1996; Cui et al., 1997). Based on the data in the end of 1970's, this paper reports the pollution trend to the 1990's, and gives forecast and prevention.

Jiaozhou Bay is located in the middle of the Yellow Sea and the south bank of Shandong Peninsula, between 120°04' and 120°23'E, and 35°58' and 36°18' N, 27.8 km wide east to west, and 33.3 km long south to north. The bay has a coastline of 163 km and the total area is 423 km², including tidelands 125 km². The average water depth is 6–7 m and the biggest depth is 64 m. The 3 km wide mouth opens southeastward. Therefore, it is a partially closed bay. The main contributing rivers are Haibo, Licun, Baisha, Dagou, Yanghe, and Loushan rivers, all being seasonal ones in hydrological features (Yang et al., 2004; 2005). The tide is normal half-day flow that favors the diffusion,

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transfer, and dilution of contamination (Yin et al., 2001; Xu et al., 2005).

2 MATERIAL AND METHOD

The data used here were recorded in May, August, and November in 1979 by the North China Sea Environmental Monitoring Center, SOA, in eight stations: H34, H35, H36, H37, H38, H39, H40, and H41 (Fig.1). The water samples were deposited in plastic bottles, and frozen at 0°C for measurement in lab with flameless atomic absorption spectrometric method (National Marine Monitoring Criterion (1991).

Fig.1 Investigation sites in Jiaozhou Bay

3 RESULTS

In horizontal dimension, the eastern Jiaozhou Bay was more seriously polluted by Pb than those in other parts (Figs.2-4). In temporal scale, in spring, the concentration of Pb was generally higher with a high center around Station H38 from which the concentration decreased gradually from 0.99 to 0.37 $\mu\text{g/L}$, except for H34 at east bay where frequent ocean-shipping operations were performed. In summer, the concentration of Pb descended gradually east-west from 1.52 to 0.25 $\mu\text{g/L}$. Also, the highest concentration of Pb occurred at H34 whose seawater quality was worse than Category I of the National Standard of China for Seawater Quality GB3097-1997 (in which 4 categories 1 to 4 are classified from the best to the worst). In autumn, the concentration was decreased from 0.75 to 0.29 $\mu\text{g/L}$ east-west, similar to that in summer.

In vertical distribution, in spring, summer and autumn, taking H34 as an example, the

concentration at surface was 0.75 to 1.52 $\mu\text{g/L}$, which was higher than all bottom ones ranging 0.55 to 0.72 $\mu\text{g/L}$; while at H35, the concentration of Pb at surface was 0.32 to 0.54 $\mu\text{g/L}$, lower than that of the bottom from 0.55 to 0.70 $\mu\text{g/L}$; and at H36, the concentration at surface was 0.39 to 0.66 $\mu\text{g/L}$. However, it was higher in the surface than in the bottom in spring, but reversed in summer and autumn (Fig.5).

Fig.2 Pb distribution in the surface water of Jiaozhou Bay in May ($\mu\text{g/L}$)

Fig.3 Pb distribution in surface water in Jiaozhou Bay in August ($\mu\text{g/L}$)

Pb concentration changed greatly at different stations in the same month (Fig.6). In the May, the concentration at the surface varied 0.37 to 0.99 $\mu\text{g/L}$, the highest at H38 and the lowest at H39, in average of 0.64 $\mu\text{g/L}$, which was above the Category 1 seawater, the lightest polluted. In August, the

concentration of Pb at the surface was 0.25 to 1.52 $\mu\text{g/L}$, highest at H34 and lowest at H41. Except for H34, the concentration was below the benchmark of the Category 1. In August, it was 0.47 $\mu\text{g/L}$ on average and the highest one was six times more than the lowest one. In October, the concentration at the surface was 0.29 to 0.75 $\mu\text{g/L}$. The highest also at H34 being 0.75 $\mu\text{g/L}$ and the lowest at H39 for 0.29 $\mu\text{g/L}$, average of 0.39 $\mu\text{g/L}$. Besides, the content was evenly distributed in other stations.

Fig.4 Pb distribution in the surface water of Jiaozhou Bay in October ($\mu\text{g/L}$)

Fig.5 Pb content in the surface water and bottom

Fig.6 Pb content change in the surface water in Jiaozhou Bay

4 DISCUSSION

4.1 The pollution source

At H34 located in the east of the bay, the concentration of Pb stayed high in a year between 0.75 and 1.52 $\mu\text{g/L}$ at surface and between 0.55 and 0.72 $\mu\text{g/L}$ at bottom. This is because the area of H34 was close to industrial and household discharge area, and also to major ports or wharves where ships docked and released ballast water and living sewage, which were the main sources of Pb concentration in Jiaozhou Bay. In the whole bay, the Pb concentration was below the Category 1 except H34, which also proved the Pb origination. Therefore, the water quality of Jiaozhou Bay was good and almost no Pb pollution in overall.

4.2 Seasonal change and transfer of Pb

Analysis on seasonal change of Pb shows that much contaminant settled on the land in winter because of low temperature. But in rainy seasons, spring and summer, Pb was brought into rivers and entered Jiaozhou Bay causing rise in content of Pb at the surface. As the sedimentation proceeded, Pb was transferred in the bay. As the result, Pb concentration at surface decreased gradually from spring, summer to autumn.

Analysis on vertical distribution of Pb showed that ocean current entered Jiaozhou Bay along H34, passed through H36, and exited at H35. The pattern of the concentration showed that the gradual concentration gradual decrease was resulted from the current movement.

The Pb concentration was always higher at surface than at bottom in H34, the origination area of Pb, and so did H36, but only in spring. At H35, the case was opposite, lower at surface and higher at bottom all year. This indicates the downward Pb transfer from H34, H35 to H36. Pb could be naturally absorbed, complexed, and deposited with particles or organic matter and then transferred from water to sediment, which resulted in the decrease in Pb content in water. In addition, most heavy metals could be absorbed on the surface by organic colloid such as humus to form unstable organic matter. Subsequently, they combined with silicate or oxide of iron and manganese to form stable complexes (Zheng et al., 1982; Wang et al., 2004), by which Pb in the seawater was gradually depleted from the source. On the other hand, Pb concentration at bottom was between 0.45 to 0.72 $\mu\text{g/L}$ all year, even at H34 whose Pb content at surface water as the Pb

source area of the Jiaozhou Bay, the content at the bottom was low, suggesting that the current played an important role in transporting Pb into other places. Therefore, the authors believed that under the influence of the gravity and current, Pb was transferred downstream the current, not just in horizontal or vertical directions. From the end of raining season and start of next spring, Pb stayed in land until next rain season in May coming when Pb was again flushed into the bay.

4.3 Trend of Pb pollution

Compared with the data from 1995 to 1999 (Table.1), the content of Pb at most stations has been worsening. It ran up to 3–3.5 $\mu\text{g/L}$ at some stations which exceeded the national Category 1 level. The Pb pollution increased, but still moderate in 1990's, and deteriorated in 2 000 as the result of economic booming.

Table 1 The trend of Pb concentration in Jiaozhou Bay ($\mu\text{g/L}$)

Year	1979	1995	1996	1997	1999
Range	0.25–1.52	1.0–2.50	0.60–3.50	0.40–1.50	0.30–3.20

5 CONCLUSION

In 1979, the water quality of Jiaozhou Bay was good in spring, summer, and autumn, and complied with Category 1 of the Natural Seawater Standard of China. Based on the analysis on the horizontal and vertical distribution of the content of Pb, we determined that the source of Pb pollution in Jiaozhou Bay was in the east of the bay near docks, wharves, major wastewater outlets from local industry and household, and blast waters from vessels.

With the coming of rainy season in May, Pb contamination on land was scoured by rain and outrushed to Jiaozhou Bay, resulting in the increase of Pb content in surface seawater, and it later deposited with particles or organic matters down to the bottom in autumn, causing Pb concentration rise. During the deposition, marine current played important roles in carrying partial Pb away from entering the sediment and away to the open ocean.

From 1979 to 2000, the pollution of Pb in Jiaozhou Bay has been worsening, warning us to control the pollution and protect the environment, and set up sewage treatment plant and make Jiaozhou Bay clearer in the future.

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