Vertical distribution and settling process of Pb in Jiaozhou bay

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Abstract. Based on the investigation data on Pb in Jiaozhou Bay in May, September and October in 1983, were analyzed the horizontal and seasonal distribution of Pb. The results in this paper showed that Pb contents in surface and bottom waters were closed in the bay mouth in different seasons. For seasonal distributions, Pb contents in surface waters were in order of Summer > Autumn > Spring, while for bottom waters were in order of Autumn > Summer > Spring. In the bay mouth waters, in the temporal scale, the seasonal change order of the Pb content from the high value to the low in the surface waters was summer, autumn and spring, it in the bottom was autumn, summer and spring. The horizontal distributions of Pb in surface and bottom waters were consistent in waters inside the bay in May, while in waters outside the bay in September and October were inverse. The vertical distribution and seasonal change of Pb in the Jiaozhou Bay waters unveiled the settling process of Pb in waters.

Introduction

A large amount of Pb-containing waste water and waste gas had been generated from anthropic industry and agriculture. Pb was finally transferred to the ocean by stream flow discharge and atmosphere deposition [1, 2]. Hence, understanding the transfer processes of Pb in marine waters is essential to pollution protection. Based on investigation data on Pb in waters in Jiaozhou Bay, eastern China, this paper analyzed the horizontal and seasonal distribution of Pb, and to reveal the settling process of Pb. The aim of this study was to provide the background information of Pb in this bay, and the provide basis for pollution control and environmental remediation.

Study area and data collection

Jiaozhou Bay (35°55′-36°18′ N, 120°04′-120°23′ E) is located in Shandong Province, eastern China. Cities of Qingdao, Jiaozhou and Jiaonan are located in the east, north and west of the bay, while the bay mouth is connected to the Yellow Sea in the south (Fig. 1). The size of the bay and average water depth are 446 km^2 and 7 m, respectively. However, the width of the bay mouth is only 2.5 km. Obviously, this bay is typically a semi-closed bay. There are more than ten inflow rivers, such as Dagu River, Haibo River, Licun River and Loushan River, most of which are seasonal rivers whose hydrological characteristics are mainly impacted by rainfall [3-4]. The data was provided by North China Sea Environmental Monitoring Center. The survey was conducted in May, September and October 1983. Surface and bottom water samples in five sampling sites (H34, H35, H36, H37 and H82) were collected and measured followed by National Specification for Marine Monitoring [5].

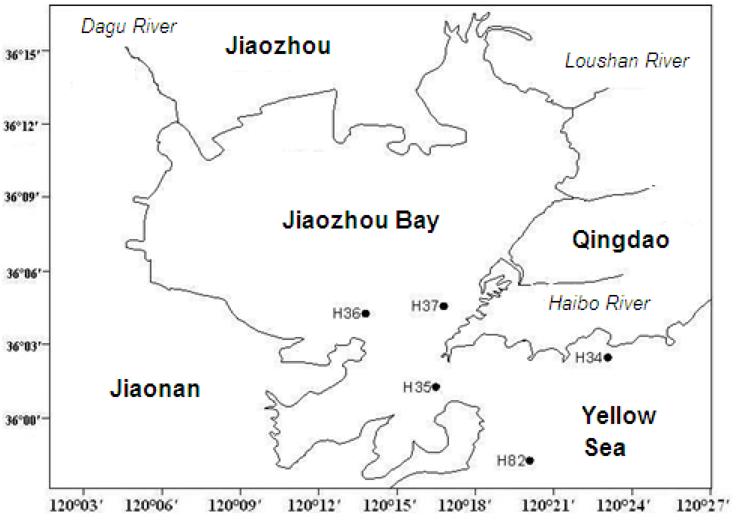

Fig. 1 Geographic location and sampling sites of Jiaozhou Bay

Results

Horizontal distribution of Pb in bottom waters

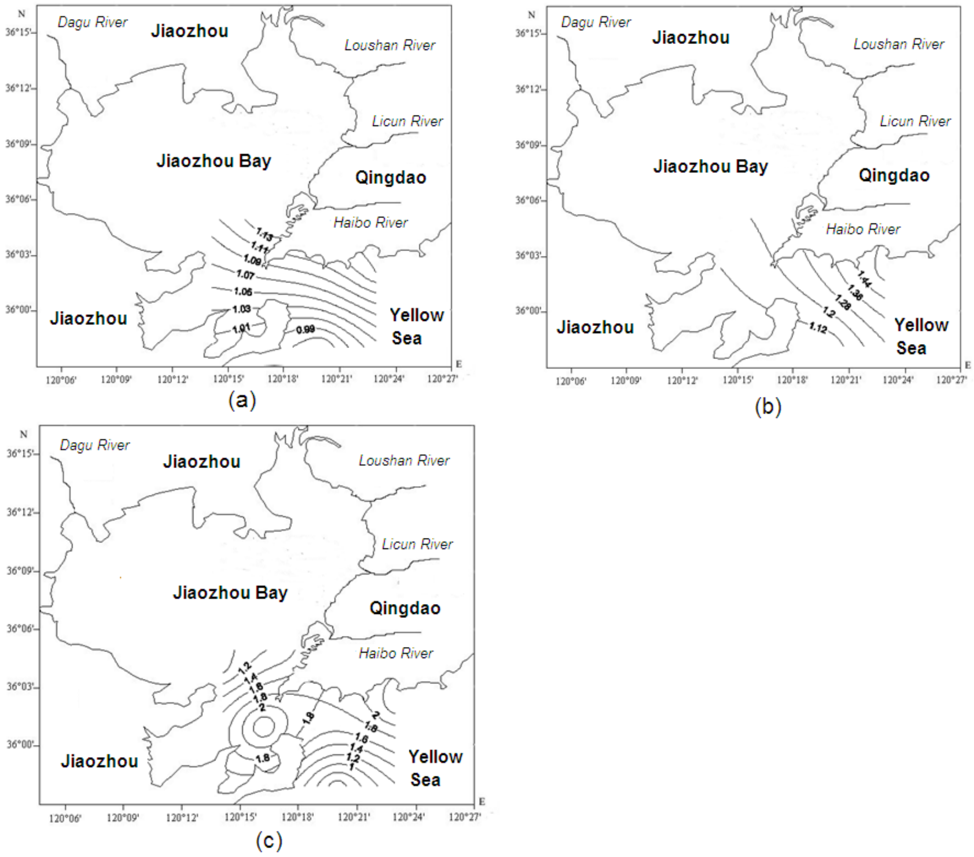

Fig. 2 Distributions of Pb contents in bottom waters in a) May, b) September and c) October 1983

The horizontal distribution of Pb in bottom waters in May, September and October 1983 were showed in Fig. 2, respectively. In May, the highest value (1.15 μg L^{-1}) was occurred in Site H37 in the coastal area in the east, and the contour lines were forming a series of parallel lines (Fig. 2a). The horizontal distribution of Pb in bottom waters displayed a decreasing trend from the bay (in the east) to the open bay (in the south). In September, the highest value (1.56 μg L^{-1}) was occurred in Site H34 in the coastal area in the east, and the contour lines were also forming a series of parallel lines (Fig. 2b). Pb contents were decreasing from the high value center in the coastal waters in the east to the bay mouth in the south. In September, there were two high value centers in Site H35 and

Site H34. A series of semi-concentric circles were forming around Site H35, which were decreasing from the high value center to the north of the bay (Fig. 2c). A series of parallel lines were forming from Site H34, and were decreasing from the high value center the the south of the bay.

Vertical distribution of Pb in waters

For the horizontal distribution of Pb in surface waters in May, a decreasing trend from the coastal waters to the bay mouth was occurred, which was consistent to the horizontal distribution of Pb in bottom waters. In September, Pb in surface waters were increasing from the coastal waters to the bay mouth, and were inverse to the horizontal distribution of Pb in bottom waters. In October, Pb in surface waters were also increasing from the coastal waters to the bay mouth, and were inverse to the horizontal distribution of Pb in bottom waters.

Pb contents in surface waters and bottom waters in May, September and October ranged from 0.75-1.47 μg L^{-1} and 0.95-1.15 μg L^{-1}, 0.67-2.33 μg L^{-1} and 1.06-1.56 μg L^{-1}, 1.00-2.22 μg L^{-1} and 0.67-2.33 μg L^{-1}, respectively. In generally, the higher Pb contents in surface waters, the higher Pb contents in bottom waters. For the whole year, Pb contents in in surface waters and bottom waters ranged from 0.46-2.40 μg L^{-1} and 0.67-2.33 μg L^{-1}, whose variations were basically the same.

In order to reveal the vertical variations, Pb contents in surface waters in the fiver sampling sites were subtracted from which in bottom waters. For the whole year, the differences ranged from -1.07-1.19 μg L^{-1}, indicated that Pb contents in surface and bottom waters were very closed. In May, the differences ranged from -0.30-0.32 μg L^{-1}. There was a high value region in the east of the bay. The differences in Site H37 and H82 were positive, while in the remaining three sites were negative. In September, the differences ranged from -0.89-1.19 μg L^{-1}. There was a high value region in the bay mouth. The differences in Site H35 and H36, Site H34 and H37, and Site H82 were positive, negative, and zero, respectively. In October, the differences ranged from -1.07-0.62 μg L^{-1}. The differences in Site H34 and H35 were negative, while in the remaining three sites were positive.

Seasonal distribution of Pb in waters

Pb contents in surface waters in May, September and October ranged from 0.75-1.47 μg L^{-1}, 0.67-2.33 μg L^{-1} and 1.00-2.22 μg L^{-1}, respectively. These values indicated that the variations of Pb contents in surface waters were small, and Pb contents in surface waters were in order of Summer > Autumn > Spring. For bottom waters, Pb contents in in May, September and October ranged from 0.95-1.15 μg L^{-1}, 1.06-1.56 μg L^{-1} and 0.67-2.33 μg L^{-1}, respectively. The variations of Pb contents in bottom waters were also small, while Pb contents in surface waters were in order of Autumn > Summer > Spring.

Discussion

Vertical migration of Pb

In May, Pb was mainly sourced from the inflow rivers in the east of the bay. Hence, Pb contents in surface waters in the east were higher than in bottom waters, while for the other regions Pb contents in surface waters in the east were lower than in bottom waters. This showed that from the bay to the open bay in May, Pb was settling to the bottom waters by vertical migration. In September, Pb was mainly sourced from the ocean current from the bay mouth. Hence, Pb contents in surface waters in the bay mouth were higher than in bottom waters, while for the other regions Pb contents in surface waters in the east were lower than in bottom waters. This showed that from the bay mouth to the bay in September, Pb was settling to the bottom waters by vertical migration. In October, Pb was mainly sourced from the harbors and wharfs in the coastal areas inside the bay mouth. Hence, Pb contents in surface waters in the coastal areas inside the bay mouth were higher than in bottom waters, while for the other regions Pb contents in surface waters in the east were lower than in bottom waters. This showed that from the coastal areas inside the bay mouth to the areas far away in October, Pb was settling to the bottom waters by vertical migration. It should be pointed out that Pb contents in Surface waters were lower than 1.00 μg L^{-1} and higher than in bottom waters in both May and October in Site H82 located in the south of the bay mouth. The reason was that Pb in this site were transferred by ocean current, and the settling process in this site was cut down. Hence, Pb contents in bottom waters in this site were also very low. However, Pb contents in surface and bottom waters in this site were same in September, indicated the mix of the waters was very well. Obviously, the vertical distributions of Pb in May, September and October were fully displaying the vertical migration process of Pb in waters.

Settling process of Pb

In the study area, Pb contents in surface and bottom waters were closed in May, September and October, revealed that the settling process of Pb was very fast. Therefore, both ranges and differences of Pb contents in surface and bottom waters were closed. In time scale, Pb contents in surface waters were in order of Summer > Autumn > Spring, while for bottom waters were Autumn > Summer > Spring. This showed that Pb contents were beginning to increase in Spring, and the reaching the climax in Summer, and finally decreasing in Autumn. The temporal variations of Pb contents in surface waters were impacting the Pb contents in bottom waters by means of settling. Hence, Pb contents in bottom waters Spring and Summer were also low and high. However, by means of the continuous settling, Pb was accumulated in the bottom waters with time, and was reaching the climax in Autumn.

In spacial scale, the horizontal distributions of Pb in surface and bottom waters were consistent in May, while were inverse in September and October. These features indicated that a large amount of Pb was discharged to the bay in May from the stream flow in the east of the bay. Once Pb was originally transferred the the surface waters, it could be absorbed, complex and co-precipitated by particulate and organic matters [1-2], so the Pb contents were decreasing with the distance from the pollution sources. Hence, the horizontal distributions of Pb in surface and bottom waters were consistent in areas near the pollution sources in the bay. While for waters in the open bay, the source strength of Pb was weak, and along with the settling of Pb, the horizontal distributions of Pb in surface and bottom waters were inverse. These showed the settling process of Pb in waters.

Conclusion

In the study area, Pb contents in surface and bottom waters were closed in May, September and October, revealed that the settling process of Pb was very fast, and both ranges and differences of Pb contents in surface and bottom waters were closed. Pb contents in surface waters were in order of Summer > Autumn > Spring, while for bottom waters were Autumn > Summer > Spring, indicated that Pb contents were beginning to increase in Spring, and the reaching the climax in Summer, and finally decreasing in Autumn. The temporal variations of Pb contents in surface waters were impacting the Pb contents in bottom waters by means of settling.

In spacial scale, the horizontal distributions of Pb in surface and bottom waters were consistent in May, while were inverse in September and October. The horizontal distributions of Pb in surface and bottom waters were consistent in areas near the pollution sources in the bay. While for waters in the open bay, the source strength of Pb was weak, and along with the settling of Pb, the horizontal distributions of Pb in surface and bottom waters were inverse. These showed the settling process of Pb in waters.

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