Spatial-temporal variations of Cd in Jiaozhou Bay

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Abstract. We analyzed the horizontal, vertical and seasonal variations of Cd in waters in the bay mouth of Jiaozhou Bay, eastern China in 1984. Results showed that, for seasonal variation Cd contents in waters were higher in autumn than in summer, which were determined by the equatorial Kuroshio flowing. For horizontal variation, Cd contents in surface waters in summer were decreasing from the outside of the bay mouth to the bay mouth, and then to the inside of the bay mouth, yet there was no trend in autumn. However, Cd contents in both surface and bottom waters in summer and autumn were both decreasing from the outside of the bay mouth to the bay mouth, and then to the inside of the bay mouth. For vertical variation, the differences of Cd contents in surface and between which in bottom waters were little no matter Cd contents were high or low, due to the rapidly and continuously sedimentation of Cd. For regional variation, a little amount of Cd was inputted by marine current, leading to the higher Cd contents in surface waters than in bottom waters. Both the temporal and spatial variations of Cd contents in waters were revealing the horizontal water's effect and vertical water's effect, as well as the horizontal transfer process and horizontal sedimentation process.

Introduction

Cd has been widely used in industries of salt electrolysis, instrument and apparatus, metal smelting etc., and a large amount of Cd-containing waste waters was generated and discharged to the environment with the rapid development of industries. Hence, the marine environment had been polluted by Cd due to the ocean is the sink of pollutants [1-4]. Jiaozhou Bay is a semi-closed bay located in Shandong Province, eastern China. Due to the rapid development of industrialization and urbanization, this bay had been polluted by various pollutants including Cd [5-7]. Based on investigation data on Cd in waters in Jiaozhou Bay in 1984, this paper tried to analyze the spatial and temporal variations of Cd, and to provide basis for research on the vertical migration sedimentation process and the horizontal distribution process of Cd.

Materials and method

Jiaozhou Bay is located in the south of Shandong Province, eastern China (35°55′-36°18′ N, 120°04′-120°23′ E), and is connected to the Yellow Sea in the south. The total area, average water depth and bay mouth width are 446 km^2, 7 m and 3 km, respectively. This bay is a typical of semi-closed bay. There are a dozen of inflow rivers, and the majors are Dagu River, Haibo Rriver, Licun Rriver, and Loushan Rriver etc., all of which are seasonal rivers [8-9].

The investigation on Cd in surface and bottom waters in Jiaozhou Bay was carried on in July and October 1984 in three investigation sites namely 2031, 2032 and 2033, respectively (Fig. 1). Cd

in waters were sampled and monitored follow by National Specification for Marine Monitoring [10].

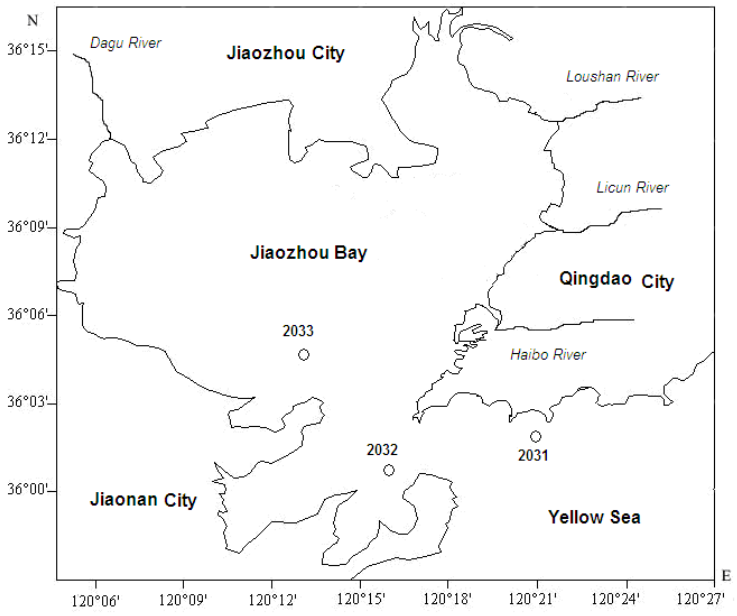

Fig.1 Investigation sites in Jiaozhou Bay

Results and discussion

Seasonal variations of Cd. Cd contents in surface waters in July and October in Jiaozhou Bay in 1984 were 0.06-0.17 μg L^{-1} and 0.08-0.20 μg L^{-1}, respectively, while in bottom waters were 0.05-0.06 μg L^{-1} and 0.08-0.18 μg L^{-1}, respectively. July and October were summer and autumn in study area. Cd contents in surface waters were in order of summer > autumn, while in bottom waters were also in order of summer > autumn. Hence, the seasonal variations of Cd contents in bottom waters were consistent with in surface waters.

Horizontal variations of Cd. The three sampling Sites of 2031, 2032 and 2033 were located in the outside of the bay mouth, the bay mouth and the inside of the bay mouth, respectively. In July, Cd contents in both surface waters were decreasing from the outside of the bay mouth, the bay mouth, and to the inside of the bay mouth, yet there was no trend in bottom waters. In October, Cd contents in both surface and bottom waters were also decreasing from the outside of the bay mouth, the bay mouth, and to the inside of the bay mouth. Hence, the horizontal distributions of Cd contents in both surface and bottom waters in summer were different, while in autumn were consistent.

Vertical variations of Cd. Cd contents in surface waters in July were relative low (0.06-0.17 μg L^{-1}), and Cd contents in bottom waters were also relative low (0.05-0.06 μg L^{-1}). Similarly, Cd contents in surface waters in October were relative high (0.08-0.20 μg L^{-1}), and Cd contents in bottom waters were also relative high (0.08-0.18 μg L^{-1}). In order to reveal the vertical variations of Cd, the contents in surface waters in the three sampling sites in July and October 1984. For the whole year, the subtraction of Cd contents in surface from which in bottom waters ranged from -1.15-0.12 μg L^{-1}, indicated that Cd contents in surface and bottom waters were very closed. In July, the differences ranged from 0.00 to 0.12 μg L^{-1}, and the differences were positive in Site 2031 and 2032, and were zero in Site 2033 (Table 1). In October, the differences ranged from 0.02 to 0.04 μg L^{-1}, and the differences were positive in Site 2031 and 2032 (Table 1). In generally, Cd contents in bottom waters were increasing/decreasing along with the increasing/decreasing of which in surface waters, yet the Cd contents in surface and bottom waters were closed.

Table 1 Results of subtracting Cd contents in surface waters from which in bottoms in the three sampling sites in July and October 1983

Month	2031	2032	2033
July	Positive	Positive	Positive
October	Negative	Positive	Positive

Discussion

Sedimentation process of Cd. Cd contents were changing while transferring through the water body by means of vertical water's effect [10]. In summer, the activities of zooplankton and phytoplankton were increasing, and the adsorption capacities of suspended particulate matters were enhancing due to the large production of colloid [8]. Hence, a large amount of Cd in waters was absorbing and settling to the sea bottom under the force of gravity and current was the horizontal settling process of Cd [1-6].

Seasonal variations process of Cd. The major Cd source in Jiaozhou Bay was equatorial Kuroshio flowing, which was stronger in autumn than in summer. Hence, the inputs of Cd to the bay were higher in autumn than in summer, leading to high Cd contents in autumn than in summer. By means of vertical water's effect [11-12], Cd contents in bottom waters were mainly determined by which in surface waters, leading to the consistence of the seasonal variations of Cd contents in surface and bottom waters. In generally, the seasonal variations of Cd were determined by source strengths of equatorial Kuroshio flowing, and the sedimentation of Cd.

Spatial sedimentation process of Cd. Cd contents in July both surface waters were decreasing from the outside of the bay mouth, the bay mouth, and to the inside of the bay mouth, yet there was no trend in bottom waters. The major reason was that the source strength of Cd was weak and Cd contents in surface waters were low in July. Hence, the sedimentation of Cd to bottom waters was also weak, and the horizontal distributions of Cd contents in bottom waters were almost not impacted by which in surface waters. In October, Cd contents in both surface and bottom waters were also decreasing from the outside of the bay mouth, the bay mouth, and to the inside of the bay mouth. The major reason was that the source strength of Cd was strong and Cd contents in surface waters were high in October, and the sedimentation of Cd to bottom waters was also strong. Hence, the sedimentation of Cd to bottom waters was also strong, and the horizontal distributions of Cd contents in bottom waters were strongly impacted by which in surface waters, and tending to be consistent with in surface waters.

Vertical sedimentation process of Cd. As we known that Cd contents in bottom waters were increasing/decreasing along with the increasing/decreasing of which in surface waters, yet the Cd contents in surface and bottom waters were closed. The reason was that the rapidly and continuously sedimentation of Cd leading to the variations of Cd contents in surface and bottom waters were consistent. In comparison, the variations of Cd contents were bigger than in bottom waters, which were revealing the vertical water's effect and horizontal water's effect [11-12], based on which the accumulation effect and diffuse effect of vertical water body were revealed. In cased on low and Cd contents in surface waters in July and October, and by means of vertical water's effect and horizontal water's effect, the loss ranges of Cd were 0.06-0.05 μg L^{-1} to 0.20-0.18 μg L^{-1}, that was 0.01-0.02 μg L^{-1}. Hence for vertical scale, Cd contents in surface and bottom waters were closed no matter Cd contents in waters were high or low.

Regional sedimentation process of Cd. The subtractions of Cd contents in surface waters from which in bottom waters were changing along with time, indicating the variations of Cd contents in surface and bottom waters. Once Cd was inputted to the bay, which was originally arrived at the surface waters, and then was settling to the bottom waters rapidly and continuously by means of horizontal water's effect. The major source of Cd in July was marine current whose source strength was very low, leading to the higher contents in surface than in bottom waters in the bay mouth, and no differences in the inside of the bay mouth. Since the inputs of Cd in July were still little, the influences of surface waters to bottom waters were also weak, and the horizontal distributions of Cd

contents in surface and bottom waters were not same. In October, the source strength of Cd was high, and Cd contents in the outside of the bay mouth and the bay mouth were lower than in surface waters due to the accumulation of Cd in bottom waters. As time goes by, the inputs of Cd to the bay were increasing from July to October, and Cd contents in waters in the inside of the bay mouth were impacted by the marine current strongly. Hence, the horizontal distributions of Cd contents in bottom waters were consistent with in surface waters. As a whole, once the inputs of Cd were arriving at one place, Cd contents in surface waters were higher than in bottom waters; on the contrast, Cd contents in surface and bottom waters were consist.

Conclusion

Cd contents in surface waters were in order of summer > autumn, while in bottom waters were also in order of summer > autumn, which were determined by the equatorial Kuroshio flowing, as well as the vertical water's effect. For horizontal variation, Cd contents in surface waters in summer were decreasing from the outside of the bay mouth to the bay mouth, and then to the inside of the bay mouth, yet there was no trend in autumn. However, Cd contents in both surface and bottom waters in summer and autumn were both decreasing from the outside of the bay mouth to the bay mouth, and then to the inside of the bay mouth. For vertical scale, Cd contents in surface and bottom waters were closed no matter Cd contents in waters were high or low, due to the rapidly and continuously sedimentation of Cd. For regional variation, since the inputs of Cd in July were still little, the influences of surface waters to bottom waters were also weak, and the horizontal distributions of Cd contents in surface and bottom waters were not same.As time goes by, the inputs of Cd to the bay were increasing from July to October, and Cd contents in waters in the inside of the bay mouth were impacted by the marine current strongly, and the horizontal distributions of Cd contents in bottom waters were consistent with in surface waters. As a whole, once the inputs of Cd were arriving at one place, Cd contents in surface waters were higher than in bottom waters; on the contrast, Cd contents in surface and bottom waters were consist. For regional variation, a little amount of Cd was inputted by marine current, leading to the higher Cd contents in surface waters than in bottom waters. Both the temporal and spatial variations of Cd contents in waters were revealing the horizontal water's effect and vertical water's effect, as well as the horizontal transfer process and horizontal sedimentation process.

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