Settlement processes and features of Cd in Jiaozhou Bay

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Abstract. Using investigation on Cadmium (Cd) in bottom waters in this bay during 1984-1988, this paper analyzed the pollution level, horizontal distribution and settlement process ofCd. Results showed that Cd contents in all of the sampling days except July 1986 were lower than 1.0 μg L⁻¹ and were conform wo Grade I, while Cd contents in July 1986 were higher than 1.0 μg L⁻¹ and were conform wo Grade II. The pollution levels of the Cd in bottom waters in Jiaozhou Bay during 1984-1988 were still very slight. The settlement processes were determined by source input, vertical water’s effect and horizontal water’s effect, and the high sediment processes were resulting in accumulation effects in bottom waters. Cd sourced from river runoff was able to arrive the bottom waters in the inner side of the bay mouth, the bay mouth and the outer side of the bay mouth. Cd sources from marine current could impact bottom waters in the inner and outer side of the bay mouth. In case of the source strength of marine current was relative high, there was high settlement process in the outer side of the bay mouth. In case of the source strength of river runoff was relative high, there was high settlement process in the inner side of the bay mouth.

1.Introduction
The industry and economic in China have been developing rapidly over that past four decades, yet the pollution treatment is always lagging, resulting in serious environmental pollution issues. Cd is one of the heavy metal elements having been widely used in various industries. However, Cd is high toxic, and the excess existence of Cd in the environmental could result in health risk. Nowadays, many marine bays have been polluted by Cd since ocean is the sink of pollutants [1-5]. Understanding the migration processes of Cd in marine bay is essential to environmental protection and remediation [6-12]. Jiaozhou Bay is a semi-closed bay located in Shandong Province, China. By using investigation on Cd in bottom waters in this bay during 1984-1988, this paper analyzed the pollution level, horizontal distribution and settlement process of Cd. The aim of this paper is to provide basis for research on the migration of Cd in marine bay.

2.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). The total area and average water depth are 446 km² and 7 m, respectively (Fig. 1). The bay mouth is very narrow (3 km), and is connected to the Yellow Sea in the south. There are a dozen of rivers including Dagu River, Haibo River, Licun River, and Loushan River etc., all of
which are seasonal rivers [13-14].

Dataset on Cd in Jiaozhou Bay was provided by North China Sea Environmental Monitoring Center [1-10]. The investigations were carried on in July and October 1984, April, July and October 1985, May and July 1986, May 1987, and April and July 1988, respectively. Cd in waters was monitored follow by National Specification for Marine Monitoring [15].

3. Results and discussion

Contents and pollution levels of Cd. During 1984-1988, Cd contents in bottom waters in Jiaozhou Bay were listed in Table 1. The China Sea Water Quality Standard (GB 3097-1997) establishes guide lines for Cd (Table 2). Cd contents in all of the sampling days except July 1986 were lower than 1.0 μg L\(^{-1}\) and were conform wo Grade I, while Cd contents in July 1986 were higher than 1.0 μg L\(^{-1}\) and were conform wo Grade II. In general, the pollution levels of the Cd in bottom waters in Jiaozhou Bay during 1984-1988 were still very slight. In study area, April, May and June belong to spring, July, August and September belong to summer, and October, November and December belong to autumn, respectively. During 1984-1988, Cd contents in spring, summer and autumn were 0.00-0.34 μg L\(^{-1}\), 0.05-1.29 μg L\(^{-1}\) and 0.04-0.18 μg L\(^{-1}\), respectively. For seasonal variation, Cd contents were in order of summer > spring > autumn, and were forming an inverted v-shape in according to time within year. During 1984-1988, the highest and lowest values of Cd contents in each monitor months ranged from 0.06-1.29 μg L\(^{-1}\) and 0.00-0.19 μg L\(^{-1}\). Obviously, by means of vertical water’s effect [14], the difference of the low values of Cd contents were tending to be very small.

| Year | April | May   | July  | October |
|------|-------|-------|-------|---------|
| 1984 | 0.19-0.32 | 0.05-0.06 | 0.11-0.17 | 0.08-0.18 |
| 1985 | 0.00-0.22 | 0.14-0.34 | 0.17-1.29 | 0.04-0.17 |
| 1986 | 0.00-0.22 | 0.14-0.34 | 0.17-1.29 | 0.04-0.17 |
| 1987 | 0.08-0.10 | 0.14-0.34 | 0.09-0.61 |
| 1988 | 0.08-0.10 | 0.14-0.34 | 0.09-0.61 |

Table 2 China Sea Water Quality Standard (GB 3097-1997) guide lines for Cd
Grade I II III and V

| Content/μg L⁻¹ | 1.00 | 5.00 | 10.00 |

bGuide lines for Cd of Grade III and V are same.

Table 3 Pollution levels of Cd in bottom waters in Jiaozhou Bay 1984-1988

| Year   | April | May | July | October |
|--------|-------|-----|------|---------|
| 1984   | I     | I   |      | I       |
| 1985   | I     | I   | I    |         |
| 1986   | I     | II  |      |         |
| 1987   | I     | I   |      |         |
| 1988   | I     | I   |      |         |

Horizontal distribution of Cd. By means of water exchange, Cd contents in bottom waters in Jiaozhou Bay were changing continuously [14]. In July 1984, Cd contents were decreasing from the southwest of the bay (0.06 μg L⁻¹) to the open waters (0.05 μg L⁻¹), while in October were decreasing from the open waters (0.18 μg L⁻¹) to the bay mouth (0.08 μg L⁻¹). In April 1985 were decreasing from the open waters (0.32 μg L⁻¹) to the bay mouth (0.19 μg L⁻¹), while in July were decreasing from the bay mouth (0.17 μg L⁻¹) to the open waters (0.12 μg L⁻¹), and in October were decreasing from the open waters (0.17 μg L⁻¹) to the bay mouth (0.04 μg L⁻¹). In April 1986, Cd contents were decreasing from the outer side of the bay mouth (0.22 μg L⁻¹) to the inner side of the bay mouth (0.00 μg L⁻¹), while in July were decreasing from the open waters (1.29 μg L⁻¹) to the inner side of the bay mouth (0.17 μg L⁻¹). In May 1987 Cd contents were decreasing from the bay mouth (0.34 μg L⁻¹) to the north of the bay (0.14 μg L⁻¹). In April 1988, Cd contents were decreasing from the bay center (0.10 μg L⁻¹) to the open waters (0.08 μg L⁻¹), while in July were decreasing from the inner side of the bay mouth (0.61 μg L⁻¹) to the bay mouth (0.09 μg L⁻¹). In general, the horizontal distributions of Cd in bottom waters were determined by water exchange and vertical and horizontal water’s effects [14-18].

Settlement process of Cd. In according to the horizontal distributions, the settlement processes could be defined, as well as the high sediment processes. In July and October 1984, there were high settlement processes in the inner side and outer side of the bay mouth, respectively. In April, July and October 1985, high settlement processes were in the outer side of the bay mouth, the center of the bay mouth and the outer side of the bay mouth, respectively. In April and July 1986, high settlement processes were both in the outer side of the bay mouth. In May 1987, high settlement process was in the bay mouth. In April and July 1988, high settlement processes were both in the inner side of the bay mouth. The major Cd sources in Jiaozhou Bay were river runoff, marine current and atmosphere deposition. These high settlement processes were determined by source input, vertical water’s effect and horizontal water’s effect [14-18], and the high sediment processes were resulting in accumulation effects in bottom waters. Cd sourced from river runoff was able to arrive the bottom waters in the inner side of the bay mouth, the bay mouth and the outer side of the bay mouth. Cd sources from marine current could impact bottom waters in the inner and outer side of the bay mouth. However, the source strength of Cd from atmosphere was very slight and the influence was little. In case of the source strength of marine current was relative high, there was high settlement process in the outer side of the bay mouth. In case of the source strength of river runoff was relative high, there was high settlement process in the inner side of the bay mouth (Table 4). That was the mechanism of the settlement processes of Cd in Jiaozhou Bay.

Table 4 Sources and high settlement regions in Jiaozhou Bay

| Source | 1984   | 1985   | 1986   | 1987   | 1988   |
|--------|--------|--------|--------|--------|--------|
| Marine current | 0.17-0.20 | 0.21-0.44 | 0.94 and 6.48 | 0.68 | 1.07 and 0.12 |
| River runoff and marine current |                    |            |                          |       |          |
4. Conclusions

Cd contents in all of the sampling days except July 1986 were lower than 1.0 μg L\(^{-1}\) and were conform wo Grade I, while Cd contents in July 1986 were higher than 1.0 μg L\(^{-1}\) and were conform wo Grade II. The pollution levels of the Cd in bottom waters in Jiaozhou Bay during 1984-1988 were still very slight. The horizontal distributions of Cd in bottom waters were determined by water exchange and vertical and horizontal water’s effects. These high settlement processes were determined by source input, vertical water’s effect and horizontal water’s effect, and the high sediment processes were resulting in accumulation effects in bottom waters. Cd sourced from river runoff was able to arrive the bottom waters in the inner side of the bay mouth, the bay mouth and the outer side of the bay mouth. Cd sources from marine current could impact bottom waters in the inner and outer side of the bay mouth.

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