Changes of Cd sources in Jiaozhou Bay 1984-1988

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Abstract. By investigating the dataset Cadmium (Cd) in Jiaozhou Bay from 1984 to 1988, the paper showed horizontal distributions of Cd, the major sources, and the changes of the major sources. Results unveiled that the major Cd sources during this time period were marine current, river discharge and atmosphere deposition, whose source strengths were 0.12-6.48 μg L⁻¹, 0.12-1.07 μg L⁻¹ and 0.04 μg L⁻¹, respectively. During this time period, the source input from marine was sometimes weak and sometimes strong. The source input from river discharge was changing from little input to relative weak, and then to relative strong. The source input from atmosphere deposition was changing from little input to occurring finally. The human activities resulted in the increasing of the source input of Cd to the bay, and influenced the water quality continuously.

1. Introduction
Cd has been often appearing in the environment including the industry and agriculture, as well as every day life. However, Cd has the high toxicity and brings the health risk for the people. Cd brought the pollution for many marine bays because of the economic development. Ocean received a large amount of pollutants from the various sources, for example atmosphere deposition, marine traffic, river discharge. Probably the major sources' changes should be essential to have the environmental protection in marine bay. Jiaozhou Bay located in Shandong Province, China, in which various pollutants including Cd has polluted since 1980s. Cd in this bay during 1984-1988 would show the horizontal distributions, and expressed the major sources, and unveiled the changes of the sources for this time period. Therefore, the results in this paper would provide scientific basis for pollution protection in many bays.

2. Materials and data source
2.1. Study area. Jiaozhou Bay (120°04′-120°23′ E, 35°55′-36°18′ N) showed the place on being in the south of Shandong Province, eastern China (Fig. 1). There would be many inflow rivers including Haibo River, Licun River, and Loushan River.
2.2. Data source. The dataset from North China Sea Environmental Monitoring Center showed the investigations in July, August and October 1984, April, July and October 1985, April, July and October 1986, May and November 1987, and April, July and October 1988, respectively. Surface water samples were got according to the National Specification for Marine Monitoring [1].

3. Results and discussion

3.1. Horizontal distribution and sources of Cd in 1984. In July 1984, there was a high value region of Cd contents in the outer side of the bay, and Cd contents were decreasing from the high value (0.17 µg L⁻¹) to the bay mouth (0.16 µg L⁻¹), and the inner side of the bay (0.06 µg L⁻¹). In August 1984, there was a high value region of Cd contents in the northeast of the bay, and Cd contents were decreasing from the high value (0.11 µg L⁻¹) to the center of the bay (0.10 µg L⁻¹). In October 1984, there was a high value region of Cd contents in the outside of the bay, and Cd contents were decreasing from the high value (0.11 µg L⁻¹) to the inner side of the bay (0.10 µg L⁻¹). It could be defined that the major Cd sources in July, August, and October 1984 were marine current, river discharge and marine current, whose source strengths were 0.17 µg L⁻¹, 0.10-0.11 µg L⁻¹, and 0.20 µg L⁻¹, respectively.

3.2. Horizontal distribution and sources of Cd in 1985. In April 1985, there was a high value region of Cd contents in the estuary of Licun River in the northeast of the bay, and Cd contents were decreasing from the high value (0.44 µg L⁻¹) to the center of the bay (0.19 µg L⁻¹). In July 1985, there was a high value region of Cd contents in the northeast of the bay in where there were the estuaries of the major rivers, and Cd contents were decreasing from the high value (0.21 µg L⁻¹) to the bay mouth (0.16 µg L⁻¹). In October 1985, there was a high value region of Cd contents in the estuary of Licun River in the northeast of the bay, and Cd contents were decreasing from the high value (0.39 µg L⁻¹) to the bay mouth (0.03 µg L⁻¹). It could be defined that the major Cd sources in April, July, and October 1985

Fig. 1 Geographic location of Jiaozhou Bay
were river discharge of Licun River, river charge of Licun River and Haibo River, and river discharge of Licun River, whose source strengths were 0.44 μg L⁻¹, 0.21 μg L⁻¹, and 0.39 μg L⁻¹, respectively.

3.3. Horizontal distribution and sources of Cd in 1986. In April 1986, there was a high value region of Cd contents in the estuary of Licun River in the northeast of the bay, and Cd contents were decreasing from the high value (0.94 μg L⁻¹) to the bay mouth (0.01 μg L⁻¹). In July 1986, there was a high value region of Cd contents in the outer side of the bay mouth, and Cd contents were decreasing from the high value (6.48 μg L⁻¹) to inner side of the bay (0.10 μg L⁻¹). In October 1986, there was a high value region of Cd contents in the estuary of Licun River in the northeast of the bay, and Cd contents were decreasing from the high value (0.75 μg L⁻¹) to the center of the bay (0.19 μg L⁻¹). It could be defined that the major Cd sources in April, July, and October 1986 were river charge of Licun River, and marine current, and river charge of Licun River, whose source strengths were 0.94 μg L⁻¹, 6.48 μg L⁻¹ and 0.75 μg L⁻¹, respectively.

3.4. Horizontal distribution and sources of Cd in 1987. In May 1987, there was a high value region of Cd contents in the estuary of Licun River in the northeast of the bay, and Cd contents were decreasing from the high value (0.68 μg L⁻¹) to the bay mouth (0.09 μg L⁻¹). In November 1987, there was a high value region of Cd contents in estuary of Haibo River, and Cd contents were decreasing from the high value (0.12 μg L⁻¹) to center of the bay (0.08 μg L⁻¹). It could be defined that the major Cd sources in May and November 1987 were river charge of Licun River, and river charge of Haibo River, whose source strengths were 0.68 μg L⁻¹ and 0.12 μg L⁻¹, respectively.

3.5. Horizontal distribution and sources of Cd in 1988. In April 1988, there was a high value region of Cd contents in outer side of the bay mouth, and Cd contents were decreasing from the high value (0.12 μg L⁻¹) to the bay mouth (0.09 μg L⁻¹). In July 1988, there was a high value region of Cd contents in the estuary of Haibo River, and Cd contents were decreasing from the high value (1.07 μg L⁻¹) to the center of the bay (0.45 μg L⁻¹), and to the coastal waters in the southwest of the bay (0.10 μg L⁻¹). In October 1988, there was a high value region of Cd contents in the center of the bay, and Cd contents were decreasing from the high value (0.04 μg L⁻¹) to waters far away (0.03 μg L⁻¹). It could be defined that the major Cd sources in April, July, and October 1988 were marine current, river discharge of Haibo River, and atmosphere deposition, whose source strengths were 0.12 μg L⁻¹, 1.07 μg L⁻¹, and 0.04 μg L⁻¹, respectively.

3.6. Summary on the changes of Cd sources 1984-1988. In general, the major Cd sources during this time period were marine current, river discharge and atmosphere deposition, whose source strengths were 0.12-6.48 μg L⁻¹, 0.12-1.07 μg L⁻¹ and 0.04 μg L⁻¹, respectively (Table 1). During 1984-1988, the source input from marine current was on and off. It should be noticed that the source strength of marine current was as high as 6.48 μg L⁻¹, and the pollution level was Grade III and IV that indicated moderate polluted (Table 2). In 1984, there was no source input from river discharge. However, during 1985-1988, the source input from river discharge was occurring, and the source strength was increasing to 1.07 μg L⁻¹ in 1988, indicated that the pollution level was Grade II and slight polluted. For atmosphere deposition, there was no source input until 1988. The source strength of atmosphere deposition was weak (0.04 μg L⁻¹), yet the influence was considerable since the wide range of impacting region by atmosphere deposition. During this time period, the source input from marine was sometimes weak and sometimes strong. The source input from river discharge was changing from little input to relative weak, and then to relative strong. The source input from atmosphere deposition was changing from little input to occurring finally. The human activities resulted in the increasing of the source input of Cd to the bay, and influenced the water quality continuously.
Table 1 Annual changes of Cd sources in Jiaozhou Bay 1984-1988

| Year | Marine current/μg L\(^{-1}\) | River discharge/μg L\(^{-1}\) | Atmosphere deposition/μg L\(^{-1}\) |
|------|-------------------------------|---------------------------------|----------------------------------|
| 1984 | 0.17-0.20                     |                                 |                                  |
| 1985 |                               | 0.21-0.44                       |                                  |
| 1986 |                               | 6.48                            | 0.75-0.94                        |
| 1987 |                               |                                 | 0.12-0.68                        |
| 1988 | 0.12                          | 1.07                            | 0.04                             |

Table 2 China Sea Water Quality Standard (GB 3097-1997) guidelines for Cd

| Grade  | I     | II    | III and V\(^b\) |
|--------|-------|-------|-----------------|
| Content/μg L\(^{-1}\) | 1.00  | 5.00  | 10.00           |

\(^b\)Guide lines for Cd of Grade III and V are same.

4. Conclusion
The major Cd sources in July, August, and October 1984 were marine current, river discharge and marine current, whose source strengths were 0.17 μg L\(^{-1}\), 0.10-0.11 μg L\(^{-1}\), and 0.20 μg L\(^{-1}\), respectively. The major Cd sources in April, July, and October 1985 were river discharge of Licun River, river charge of Licun River and Haibo River, and river discharge of Licun River, whose source strengths were 0.44 μg L\(^{-1}\), 0.21 μg L\(^{-1}\), and 0.39 μg L\(^{-1}\), respectively. The major Cd sources in April, July, and October 1986 were river charge of Licun River, and marine current, and river charge of Licun River, whose source strengths were 0.94 μg L\(^{-1}\), 6.48 μg L\(^{-1}\) and 0.75 μg L\(^{-1}\), respectively. The major Cd sources in April, July, and October 1988 were marine current, river discharge of Haibo River, and atmosphere deposition, whose source strengths were 0.12 μg L\(^{-1}\), 1.07 μg L\(^{-1}\), and 0.04 μg L\(^{-1}\), respectively.

In general, the major Cd sources during this time period were marine current, river discharge and atmosphere deposition, whose source strengths were 0.12-6.48 μg L\(^{-1}\), 0.12-1.07 μg L\(^{-1}\) and 0.04 μg L\(^{-1}\), respectively. During this time period, the source input from marine was sometimes weak and sometimes strong. The source input from river discharge was changing from little input to relative weak, and then to relative strong. The source input from atmosphere deposition was changing from little input to occurring finally. The human activities resulted in the increasing of the source input of Cd to the bay, and influenced the water quality continuously.

References
[1] China's State Oceanic Administration: The specification for marine monitoring (Ocean Press, Beijing 1991), p.1-300.