Source Strength Ratio and Source input Ratio of Cd in Marine Bay

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Abstract. Using investigation on Cadmium (Cd) in surfac waters in Jiaozhou Bay during 1984-1988, this paper researched seasonal variations of Cd contents and the variations of the source inputs, identified the source strength ratio and source input ratio, and displayed the changing processes of Cd. Result showed that the major sources of Cd in Jiaozhou Bay were marine current, river runoff and atmosphere deposition, and the source strengths were 0.12-6.48 \(\mu\)g L\(^{-1}\), 0.12-1.07 \(\mu\)g L\(^{-1}\), 0.04 \(\mu\)g L\(^{-1}\), respectively. The seasonal variations of Cd contents were mainly determined by the seasonal variations of the source inputs. Marine current was the strongest Cd source and source input in Jiaozhou Bay during 1984-1988, yet the source strength and source input of atmosphere deposition could be considered as very slight. The highest value of Cd contents and Cd inputs in this bay was mainly determined by marine current.

1. Introduction
Cd is one of the heavy metal elements has been widely used in various industries such as semiconductor, metallurgy, pesticides and electroplating. A large amount of Cd-containing wastes have been discharging to the environmental in the past several decades. Nowadays, many marine bays have been polluted by Cd [1-5]. Understanding the contents, sources and seasonal variations 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 surface waters in this bay during 1984-1988, this paper researched seasonal variations of Cd contents and the variations of the source inputs, identified the source strength ratio and source input ratio, and displayed the changing processes 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\(^\circ\)55'-36\(^\circ\)18' N, 120\(^\circ\)04'-120\(^\circ\)23' E). The total area and average water depth are 446 km\(^2\) 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 Dag River, Haibo Rriver, Licun Rriver, and Loushan Rriver 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 May and November 1984, April, July and October 1985, April and July 1986, May, July and November 1987, and April, July and October 1988, respectively. Cd in waters was sampled and monitored follow by National Specification for Marine Monitoring [15].

![Fig. 1 Geographic location of Jiaozhou Bay](image)

3. Results and discussion

3.1 Contents and seasonal variations of Cd.
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. In 1984, Cd contents in May and November were 0.06-0.17 μg L⁻¹ and 0.08-0.20 μg L⁻¹, and the seasonal variation was summer < autumn. In 1985, Cd contents in April, July and October were 0.19-0.44 μg L⁻¹, 0.16-0.21 μg L⁻¹ and 0.03-0.39 μg L⁻¹, and the seasonal variation was summer < autumn < spring. In 1986, Cd contents in in April and July were 0.01-0.38 μg L⁻¹ and 0.13-6.48 μg L⁻¹, and the seasonal variation was spring < summer. In 1987, Cd contents in May, July and November were 0.09-0.68 μg L⁻¹, 0.08 μg L⁻¹ and 0.07-0.12 μg L⁻¹, and the seasonal variation was summer < autumn < spring. In 1988, Cd contents in April and July were 0.09-0.12 μg L⁻¹ and 0.10-0.45 μg L⁻¹, and the seasonal variation was spring < summer. In general, during 1984-1988, the major sources of Cd in Jiaozhou Bay were marine current, river runoff and atmosphere deposition, and the source strengths were 0.12-6.48 μg L⁻¹, 0.12-1.07 μg L⁻¹, 0.04 μg L⁻¹, respectively (Table 1). The seasonal variations of Cd contents were mainly determined by the seasonal variations of the source inputs.

| Year and season | Marine current | River runoff | Atmosphere deposition |
|----------------|----------------|--------------|-----------------------|
| 1984 May      | 0.17            |              |                       |
| 1984 August   | 0.20            |              |                       |
| 1984 November |                |              |                       |
| 1985 April    | 0.44            |              |                       |
| 1985 July     | 0.21            |              |                       |
| 1985 October  | 0.39            |              |                       |
3.2 Source strength ratio of Cd.

The source inputs of Cd to Jiaozhou Bay include three processes: 1) Cd is discharged to the coastal waters via river runoff, 2) Cd is inputted to the bay waters directly via atmosphere deposition, and 3) Cd is transported to the bay by means of marine current with Cd content being relatively high. In order to quantify the difference of the source strengths, we provide a model to calculate the highest source strength ratio. The mathematical expression is:

$$SSR = \frac{HST}{\sum_{i=1}^{n} HST_i}$$

(1)

where, SSR refers to the highest source strength ratio of a certain source, HST refers to the highest source strength of a certain source, n is the number of the sources, HST_i is the highest value of the source strengths of the sources.

In accordance with Table 1 and Eq. (1), the highest source strength ratios of marine current, river runoff and atmosphere deposition were calculated as 85.37%, 14.09% and 0.52%, respectively. Obviously, marine current was the strongest Cd source in Jiaozhou Bay during 1984-1988, yet the source strength of atmosphere deposition could be considered as very slight. In general, the highest value of Cd contents in this bay was mainly determined by the highest value of the source strengths of marine current.

3.3 Source input ratio of Cd.

In order to quantify the difference of the source inputs, we provide a model to calculate the highest source input ratio. The mathematical expression is:

$$SIR = \frac{\sum_{j=1}^{m} ST_j}{\sum_{j=1}^{m}\sum_{i=1}^{n} ST_{ij}}$$

(2)

where, SIR refers to the highest source input ratio of a certain source, ST_j refers to the source strength of j source, m is the number of the values of the source strengths of the j source, n is the number of the different sources.

In accordance with Table 1 and Eq. (2), the highest source input ratios of marine current, river runoff and atmosphere deposition were calculated as 60.03%, 39.62% and 0.34%, respectively. In general, marine current was the strongest Cd source input in Jiaozhou Bay during 1984-1988, yet the source input of atmosphere deposition could be considered as very slight. As a whole, the highest value of Cd inputs in this bay was mainly determined by the source input of marine current.

4. Conclusions

During 1984-1988, the major sources of Cd in Jiaozhou Bay were marine current, river runoff and atmosphere deposition, and the source strengths were 0.12-6.48 μg L^{-1}, 0.12-1.07 μg L^{-1}, 0.04 μg L^{-1},
respectively. The seasonal variations of Cd contents were mainly determined by the seasonal variations of the source inputs.

Marine current was the strongest Cd source and source input in Jiaozhou Bay during 1984-1988, yet the source strength and source input of atmosphere deposition could be considered as very slight. In general, the highest value of Cd contents and Cd inputs in this bay was mainly determined by marine current.

Acknowledgement
This research was sponsored by Doctoral Degree Construction Library of Guizhou Nationalities University, Research Projects of Guizhou Nationalities University ([2014]02), Research Projects of Guizhou Province Ministry of Education (KY [2014] 266), Research Projects of Guizhou Province Ministry of Science and Technology (LH [2014] 7376).

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