Theories on migration processes of Cd in Jiaozhou Bay

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Abstract. Understanding the migration progress is essential to pollution control, while developing theories for the migration progress is the scientific basis. This paper further developed five key theories on migration processes of Cd including homogeneous theory, environmental dynamic theory, horizontal loss theory, migration trend theory and vertical migration theory, respectively. The performance and practical values of these theories were demonstrated in the application of these on analyzing the migration process of Cd in Jiaozhou Bay. Results these theory helpful to better understand the migration progress of pollutants in marine bay.

1. Introduction
Cd is one of the widely used heavy metal elements in industries. However, Cd is high toxic and the excessive Cd contents in the environment could cause harmful to the ecosystem and human [1-10]. A large amount of Cd-containing wastes were discharged to the environment along with the rapid development of industry. Many marine bays have been polluted by various pollutants, and understanding the migration process is essential to pollution control, and developing theories for the migration process is essential to scientific research.

Jiaozhou Bay is a semi-closed bay located in Shandong Province, eastern China, and had been polluted by various pollutants including Cd [3-17]. This paper further developed five key theories on migration processes of Cd including homogeneous theory, environmental dynamic theory, horizontal loss theory, migration trend theory and vertical migration theory, respectively. The research results were helpful for better understanding the migration of Cd in marine bay, providing basis for scientific research and pollution control.

2. Study area and data collection
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, average water depth and bay mouth width are 446 km², 7 m and 3 km, respectively (Fig. 1). This bay is connected to the Yellow Sea in the south. There are a dozen of rivers, and the majors are Dagu River, Haibo River, Licun River, and Loushan River etc., all of which are seasonal rivers [18-19].

The investigation on Cd content in Jiaozhou Bay was conducted in May, August, and November 1979, June, July and September 1980, April, August and November 1981, April, June, July and October 1982, and, May, September and November 1983, respectively [3-17]. Cd in waters was sampled and monitored follow by National Specification for Marine Monitoring (Fig. 1)[20]. In study
area, April, May and June are spring, July, August and September are summer, while October, November and December are autumn.

Fig. 1 Geographic location and sampling sites in Jiaozhou Bay

3. Results and discussion

3.1 Homogeneous theory
By means of the analysis of the horizontal distributions of Cd contents in different seasons in Jiaozhou Bay, it was found that the distributions of had features of both homogeneity and heterogeneity that could be transformed. The distributions of Cd contents in marine bay could be transformed between homogeneity and heterogeneity. In case of little or small Cd input to the bay, the distribution of Cr was homogeneity. While in case of large input, the distribution was heterogeneity. In generally, the heterogeneity was determined by Cd input, while the homogeneity was determined by tide and marine current.

3.2 Environmental dynamic theory
We developed the definition and structural model of environmental dynamic value of substance in marine bay and the variables including basic background value, environmental background value, input value and environmental dynamic value in analyzing the change process and change trend of Cd in Jiaozhou Bay. Based on the environmental structure and numerical values, the change process and trend of Cd in Jiaozhou Bay could be identified, providing basis for environmental conservation and scientific research. The identification of change process and the change trend of Cd provided scientific basis for division of grade standards of Cd in marine bay.

3.3 Horizontal loss theory
We developed the horizontal loss theory in quantifying the horizontal absolute and relative loss rates of Cd contents in Jiaozhou Bay. The horizontal loss rate model was useful to reveal the unit-distance loss rate of substance contents in marine bay during the transferring process. The laws of horizontal loss rate of substance could be revealed by this model. For a certain substance and in a same water body, if the relative unit-distance loss rate was stable and constant, the relative horizontal loss rate for
a certain substance and in a same water body would be same and closed. The horizontal absolute loss rates of Cd contents in May, August and November 1979 were 6.4 YDF, 11.4 YDF and 3.5 YDF, respectively.

3.4 Migration trend theory

We developed the migration trend theory to better understand the different stages of the migration process of Cd in Jiaozhou Bay. The migration process in waters included seven stages of: 1) the sedimentation of Cd content was beginning, 2) the sedimentation of Cd content was increasing, 3) the sedimentation of Cd content was increasing greatly, 4) the sedimentation of Cd content was beginning to decrease, 5) the sedimentation of Cd content was decreasing stably, 6) the sedimentation of Cd content was beginning to stop, and 7) the sedimentation of Cd content was beginning to fully stop. In order to facilitate the classification of Cd contents in surface and bottom waters and their relationships could be defined and predicted.

3.5 Vertical migration theory

We developed the vertical migration theory to better understand the vertical migration process of Cd in Jiaozhou Bay. The absolute and relative sedimentation amounts, as well as absolute and relative accumulation amounts were quantified by means of the vertical migration theory. During 1979—1983, the absolute sedimentation amount and relative sedimentation amount of Cd were 0.23—3.23 μg L⁻¹ and 79.2%—100.0%, respectively, while for absolute accumulation amount and relative accumulation amount were 0.08—1.97 μg L⁻¹ and 75.4%—100.0%, respectively. The absolute sedimentation and accumulation were strongly impacted by Cd contents in waters, while the relative sedimentation and accumulation were not impacted by Cd contents in waters but were notable and stable along with year. Once there was little Cd in surface waters, the sedimentation and accumulation of Cd in bottom waters were stopping, and Cd contents were tending to be little.

4. Conclusion

In according to the investigation data on Cd in Jiaozhou Bay and previous studies, we further developed key theories on migration processes of Cd. These theories included homogeneous theory, environmental dynamic theory, horizontal loss theory, migration trend theory and vertical migration theory, respectively. The performance and practical values of these theories were demonstrated in the application of these on analyzing the migration process of Cd in Jiaozhou Bay. These theory helpful to better understand the migration progress of pollutants in marine bay.

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