The effect of Cd Content from Different Sources on the Surface and Bottom of the Water Column

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Abstract: according to the survey data from Jiaozhou Bay water area in 1992, the vertical distribution and monthly change of Cd content in surface and bottom waters from the center to the southern bay mouth of Jiaozhou Bay are studied, and the influence of source, change process and principle of Cd content in the surface and bottom are determined. The water body in the southeastern part of Jiaozhou Bay is considered to be a circular column of water. The main sea current carrying Cd content passed through the surface of the column, while the Haibo River carrying Cd content passed by the surface. The results show that the Cd content in the main sea current transport varied from low to high in October, May and August; and the content of Haibo River transport varied from low to high in August, October and May. Moreover, the Cd content in the surface layer of southeast bay changed from low to high in May, October and August, and the content in the bottom layer varied from low to high in August, May and October. This reflects the monthly change process of Cd content in the southeast bay waters with two significant characteristics. 1) In August, the Cd content transported through the main sea current and the content in surface water in the southeast of the bay at the same time reached the highest value. 2) In August, the Cd content transported through the Haibo River and the content in bottom water body in the southeast of the bay varied to the minimum value simultaneously. Therefore, the authors put forward the principle of monthly variation of Cd content on the surface and bottom of the southeastern bay. And the model block diagrams are established to show the change process and principle of matter content deposition and migration. The principle shows that from May to October, the Cd content transported through the main sea current determined that on the water column’s surface in the southeast bay, while the Cd content transported through the Haibo River did not affect the Cd content on the water column’s surface. From May to October, Cd content in the bottom of the water column was determined by that in the Haibo River transport, while Cd content in the main sea transport had no effect on that at the bottom of the water column.

1. Introduction
Humans transport large amounts of cadmium (Cd) into the land, sea and atmosphere. On land, through the erosion of rainwater and convergence of surface runoff, Cd content is transferred to rivers and finally reaches the surface of ocean water, which is continuously transported to all waters by ocean current. In the process of river transport and ocean current transport, Cd content forms different water layer distribution in seawater [1-13]. Therefore, with the aid of the survey data of Cd from Jiaozhou Bay in 1992, the authors studies the vertical distribution of Cd and the influence of the source in the surface and bottom water in the south of bay mouth, to determine the horizontal distribution and vertical distribution of Cd content and sources influence principle on the surface the bottom. Moreover,
the horizontal and vertical settlement process of Cd content in the Jiaozhou Bay waters and provides a scientific basis for the research for the vertical settlement consistency and horizontal migration decreasing property of Cd.

2. Water Areas, Materials, and Methods

2.1 Natural Environment of Jiaozhou Bay.
The geographical position of Jiaozhou Bay, a bay in the south of Shandong Peninsula, is 120°04'-120°23' east and 35°58'-36°18' north. It is bounded by a line from Tuan Island to Xuejia Island and connected with the Yellow Sea. The area is about 446km², and the average water depth is about 7m. This is a typical semi-enclosed bay. Jiaozhou Bay has more than ten rivers entering the sea, some of which such as Dagu River and Yang River, and Haibo River, Licun River and Loushan River in Qingdao urban area, etc. have a large amount of sediment runoff. These rivers are seasonal rivers, and their hydrological characteristics show obvious seasonal changes [14, 15].

2.2 Materials and Methods.
This paper uses the survey data of Cd in Jiaozhou Bay in May, August and October 1992, provided by North China Sea Environmental Monitoring Center. Three water sampling stations were set up in the waters of Jiaozhou Bay in May, August and October: sites 52, 59 and 60; (Figure 1). Three samples were taken for investigation in May, August and October 1992, respectively, according to the depth (when the depth was more than 10m, take the sample for the surface and bottom; otherwise, only take the sample from the surface layer). The investigation of Cd in Jiaozhou Bay water body is carried out according to the standard method stipulated in the National Specification for Marine Monitoring (1991) [16].

3 Results

3.1 Current Track in the Bay.
Jiaozhou Bay is a shallow bay with a dustpan shape that slopes directly at its mouth and then to the east. The water depth is shallow in the northwest and deep in the southeast. The matter content transported by the main sea current enters Jiaozhou Bay through the bay mouth. The main sea current follows along nearshore inshore waters through the southeastern waters body to the most northeastern...
part of the bay where Loushan River flows into the sea. Then it turns west and crosses the inshore waters to the north of the bay. It then moves to the westernmost part of the northwest bay to reach the estuary of the Dagu River, and then moves south to follow the coastal waters of the west bay to the bay mouth (Figure 2). Therefore, the main sea current carries matter content into The Jiaozhou Bay and surrounds the inshore waters of the bay.

The Cd content transported by the main sea current was 0.59μg/L in May, 1.11μg/L in August and 0.39μg/L in October. The change of Cd content in the current from low to high was October, May and August.

![Figure 2 The flow path of the main sea current with a high content of Cd in Jiaozhou Bay in August (μg/L)](image)

In May, August, and October, the waters through which the main sea current flowed were located in the southeastern part of the bay site 60.

3.2 River Track in the Bay.
Near the waters in the southeast of Jiaozhou Bay, there is a river flowing into Jiaozhou Bay, called Haibo River. When Haibo River entered the bay, the matter content in it flowed in the direction of the ocean current (Figure 3).

![Figure 3 Flow trace of the main sea current and rivers carrying matter content in southeastern waters (μg/L)](image)
In the waters of Jiaozhou Bay, Cd content of the Haibo River’s transportation was 1.07μg/L in May, 0.11μg/L in August and 0.66μg/L in October. The change of Cd content in Haibo River from low to high was: August, October and May.

In May, August and October, Haibo River passed by site 60 in water bodies in the southeast of the bay.

3.3 Temporal change of water body.

In May, August and October, the water body through which the main sea current passed was site 60 in the southeast of Jiaozhou Bay.

The Cd content in the surface water of the southeast of Jiaozhou Bay increased from a low value 0.23μg/L in May to the peak 0.75μg/L in August, and then decreased gradually to a high value of 0.51μg/L in October. Therefore, Cd content in the surface layer changed from low to high in May, October and August (Table 1).

Cd content in the bottom water of the southeast of Jiaozhou Bay began to decrease from the high value of 0.72μg/L in May gradually. In August, the Cd content was as low as 0.14μg/L, and then began to rise gradually. In October, Cd content peaked at 1.19μg/L. The results showed that the Cd content in the bottom of the water body changed from low to high in August, May and October (Table 1).

Table 1 Monthly changes of Cd content from low to high in the southeastern waters of the bay

| Location of Cd content | Monthly changes of Cd content from low to high |
|------------------------|-----------------------------------------------|
| Main sea current       | October | May | August |
| rivers                 |         |     |       |
| surface                |         |     |       |
| bottom                 |         |     |       |
| August                 | May     | October |
| August                 | October | August |
| August                 | May     | October |

From May to October, there are two distinct characteristics in Jiaozhou Bay. 1) In August, the Cd content transported by the main sea current reached the highest level in line with that in the surface water of the southeastern waters of the bay. 2) In August, the Cd content at the bottom of the water body of the southeastern waters of the bay reached the minimum value in line with that in the Haibo River.

4. Discussion

4.1 Sedimentation Process.

Affected by the vertical water body [17-19], Cd content will settle to the seabed after passing through the water body. Cd ions are highly hydrophilic and readily combine with plankton and particles in seawater. In the summer, Marine life proliferates and increases rapidly[11]. At the same time, summer is also the peak of flood and the period when the river has the most suspended particulate matter. In this way, a large number of suspended particles form colloids on the surface under the propagation of many plankton. At this time, the adsorption capacity is the strongest, and a large number of Cd ions are absorbed and brought into the surface water. Due to gravity and water flow, Cd content continuously sinks to the seabed [1-15]. Therefore, the continuous subsidence process from surface water to seabed is the process of Cd deposition and migration.

4.2 Monthly Change Process of Cd Content in Southeastern Waters of the Bay.

The Cd content in the surface water of the southeast Jiaozhou Bay increased from a low value 0.23μg/L in May to the peak of 0.75μg/L in August, and then decreased gradually to a high value of 0.51μg/L in October. Therefore, Cd surface content changed from low to high in May, October and August (Table 1).

The main sea current passed through the southeast waters of the bay which is relatively close to the estuary of the Haibo River. Therefore, the surface and bottom waters of the southeastern bay waters were affected by Cd content transported by the Haibo River and the main sea current.

Considering the influence of the main sea current on surface waters of the southeast Jiaozhou Bay,
the Cd content transported by the main sea current was relatively low 0.59μg/L, so the Cd content in surface waters was relatively low, with 0.23μg/L. In August, the Cd content transported by the main sea current was 1.11μg/L, reaching the highest level. Therefore, Cd content in surface water reaches the highest level, 0.75μg/L. In October, the Cd content via main sea current dropped significantly to 0.39μg/L. As a result, from August to October, Cd content in surface water also dropped a little from the peak to a high value 0.51μg/L in October. Therefore, the Cd content in the southeastern surface waters of the bay is determined by the main current transport. The temporal order of Cd content changing from low to high in the southeastern surface waters of the bay was May, October and August respectively.

The Cd ions in the surface waters of the southeast Jiaozhou Bay were adsorbed on the surface of suspended particles. According to the theory of vertical water body, horizontal water body and water body effect [17-19], Cd content rapidly and continuously sank to the sea floor, obtaining the cumulative effect and dilution effect.

Therefore, the Cd content in the lower part of the southeastern waters of Jiaozhou Bay began to decrease from the high value 0.72μg/L in May gradually. In August, the Cd content was as low as 0.14μg/L, and then began to rise gradually. In October, Cd content peaked at 1.19μg/L. The results showed that the Cd content in the bottom of the water body changed from low to high in August, May and October (Table 1).

Considering the impact of river transport on the bottom water body in the southeast of Jiaozhou Bay, in the surface water body of the estuary of Haibo River in Jiaozhou Bay, the Cd content transported by the river was the highest 1.07μg/L in May. At this time, the Cd content in the bottom water of the southeastern waters of Jiaozhou Bay was relatively high, which was 0.72μg/L. In August, Cd content in river transport was the lowest 0.11μg/L. At this time, the Cd content in the southeastern waters of Jiaozhou Bay was the lowest, 0.14μg/L. In October, the Cd content transported by the rivers was 0.66μg/L, which was relatively high. At this time, Cd content in the bottom water of the southeastern waters of Jiaozhou Bay was the highest 1.19μg/L by accumulation at the bottom of the sea. Therefore, under the influence of Cd content transported by Haibo River, Cd content in the southeastern bottom water of the bay changed from low to high in August, May and October.

4.3 Principle of Monthly Change of Cd Content on the Surface of Southeastern Waters of the Bay.

The water body in the southeastern part of Jiaozhou Bay is considered to be a circular column of water. The main sea current carrying Cd content passed through the surface of the column, while Haibo River carrying Cd content passed by the column’s surface.

The highest Cd content in the main sea current in August was 1.11μg/L. At this time, the Cd content on the surface of the water column also reached its maximum value, which was 0.75μg/L. Cd content transported by rivers was as low as 0.11μg/L. Therefore, the Cd content transported by the main sea current determined that in the surface layer of water column (Figure 4).
In May, the Cd content transported by the ocean current was relatively low 0.59μg/L. At this time, the Cd content on the surface of the water column also reached a low level of 0.23μg/L. The highest Cd content in the river was 1.07μg/L. In this way, Cd content transported by rivers did not affect Cd content on column surface (Figure 4).

Therefore, from May to October, the Cd content transported by the main sea current determined that on the surface of the water column of southeast bay, while the Cd content transported by the rivers had no effect.

4.4 Principle of Seasonal Variation of Cd Content at the bottom of Southeastern Waters of the Bay.
Cd content transported by the main sea current and rivers first reached the surface of the water column. Due to gravity and water flow, Cd content sank to the bottom of the water column.

According to the definition and model of Dongfang Yang’s content changing degree, it can be calculated that when the matter content on the surface transported from the source rose, that at the bottom first rose. With the decrease of matter content on surface in source transport, the content at bottom decreased rapidly.

In August, the lowest Cd content in river transportation was 0.11μg/L, and the lowest Cd content in water column bottom was 0.14μg/L. The Cd content transported by the main sea current was the highest at 1.11μg/L. Therefore, the Cd content transported by the river determined the Cd content at the bottom of the water body (Figure 4).

In May, the highest Cd content in river transportation was 1.07μg/L. At this time, the Cd content at the bottom of the water column also reached a high value of 0.72μg/L. The Cd content of the main sea current transport was relatively low 0.59μg/L. In this way, the Cd content transported by the main sea current did not affect the Cd content on the water column surface (Figure 4).

Therefore, from May to October, the Cd content at the bottom of water column in the southeast bay was determined by that of river transport, while the Cd content transported by the main current did not affect that at the bottom of water column in the southeast bay.

5. Conclusion
The main sea current passed through the southeast waters of the bay and the estuary of the Haibo
River is relatively close to the southeast waters of the bay. Therefore, the surface and bottom waters of the southeastern bay were affected by Cd content transported by the Haibo River and the main sea current.

In May, August and October, the main sea current passed through the waters in the southeast of the bay, and Haibo River passed by the waters in the southeast of the bay.

Changes in Cd content transported by the main sea current from low to high were: October, May and August; Cd content from low to high in Haibo River changed from low to high in August, October and May; Cd content on the surface in southeast bay changed from low to high in May, October and August; Cd content at the bottom in southeast bay changed from low to high as follows: August, May and October. From May to October, there are two distinct characteristics in Jiaozhou Bay. 1) In August, the Cd content transported by the main sea current reached the highest level in line with that on the surface of southeast bay. 2) In August, the Cd content at the bottom of the water body reached the minimum value in line with that transported by the Haibo River.

According to changes in Cd content transported by the main sea current and by Haibo River, and changes in Cd content in the surface and bottom layer in the southeast bay, the monthly variation process of Cd content in the southeastern waters of the bay was presented. In addition, the monthly variation principle of Cd content in the surface and bottom of the southeast bay is also proposed. The model block diagram is established to show the change process and principle of matter content deposition and migration. The principle shows that from May to October, Cd content transported by the main sea current determined that on water column surface in the southeast bay, while the Cd content transported by Haibo River had little effect here. Furthermore, according to the definition and model of Dongfang Yang’s content changing degree, the principle shows that from May to October, Cd content in the bottom of the water column in the southeast bay was determined by the content of Haibo River transport, while it was rarely affected by Cd content transport by the main sea current.

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