The Calculation and Model Block Diagram of the Surface Cd Content of Haibo River from Land Sources

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Abstract: Applying the survey data of the Cd content in the water of Jiaozhou Bay in October 1992, from the southern waters of the bay mouth to the southeastern waters, the author calculates out the horizontal loss amount, the vertical disputed amount and the vertical sediment amount of the Cd content in the surface and bottom of the water body and determines the model block diagram of the horizontal and vertical changes of Cd content, based on the content changing models of the horizontal matter and the vertical matter proposed by the author himself. The calculation results show that in October, the absolutely horizontal increase amount of Cd content in the surface and bottom layer is 0.12-0.89 $\mu$g/L, and the relatively horizontal increase amount of Cd content in the surface and bottom layer is 23.52-74.78%. In the southern waters of the bay mouth, the Cd content in the surface and bottom layer has an absolutely vertical disputed amount of 0.09 $\mu$g/L, and its relatively vertical disputed amount is 23.07%. In the southeastern waters of the bay, the Cd content in the surface and bottom layer has an absolutely vertical sediment amount of 0.68 $\mu$g/L, and its relatively vertical sediment amount is 57.14%. There is the Haibo River near the southeastern waters of Jiaozhou Bay. In October, the Cd content of the Haibo River is 0.51 $\mu$g/L, which is higher than the Cd content of 0.39 $\mu$g/L carried by ocean currents. It provides a lot of supplements to the ocean currents passing the southeastern waters of the bay. During the horizontal migration of the Cd content in the surface and bottom layer, Haibo River supplements the Cd content in the ocean current with the loss and increase of the surface and bottom layer. Through the horizontal changing model of matter content, the horizontal increase of the surface Cd content is calculated. The absolute increase of the Cd content is 0.12 $\mu$g/L, and the relative increase is 23.52%. Similarly, the horizontal increase of Cd content in the bottom layer is calculated. The absolute increase of Cd content is 0.89 $\mu$g/L, and the relative increase is 74.78%. During the vertical migration process, the vertical change of the Cd content in the southern waters of the bay mouth and the southeastern waters of the bay reveals the following law: when the surface Cd content is low, the waters present a vertical dilution of the Cd content at the surface and bottom layer, and there is no Cd content accumulation on the seafloor. When the Cd content in the surface layers is high, the waters present a vertical accumulation of Cd content in the surface and bottom layers, and there is an accumulation of Cd content on the seafloor. According to the formula for calculating the Cd content of river sources proposed by author himself, the Cd content of the surface of Haibo River source from land is calculated to be 1.01 $\mu$g/L.

1. Introduction
There is already a large amount of cadmium (Cd) in the ocean water bodies. The currents of open sea carry the Cd content into Jiaozhou Bay. The open sea currents pass through the mouth of the bay into...
the bay, causing the Cd content of the surface of the sea in Jiaozhou Bay to increase. After the ocean current enters the bay, the Cd content undergoes horizontal migration and vertical settlement, passing through the water body from the surface layer, and sinking to the seabed [1-6]. Therefore, applying the content changing model of horizontal matter and vertical matter proposed by the author, and the survey data of Cd content of Jiaozhou Bay in October 1992, it indicates that the Cd content originating from the open sea currents migrates from the surface of one water body to another and then sinks to the seabed of the bottom layer, which provides scientific basis for the research of the vertical settlement and horizontal migration of Cd content in the surface and bottom waters.

2. Survey waters and methods

2.1 The natural environment of Jiaozhou Bay. Jiaozhou Bay showed up between 120°04'-120°23'E and 35°58'-36°18'N, with the line connecting Tuan Island and Xuejia Island, and faced to the Yellow Sea. It's a typical semi-enclosed bay with its area of about 446km² and its average water depth of about 7 m, it is. There are more than a dozen rivers flowing into Jiaozhou Bay, around which the Dagu River, Yang River and the Haibo River, Licun River and Loushan River in Qingdao City with larger runoff and sand content [7, 8].

2.2 Matters and methods. The survey data of Cd content in Jiaozhou Bay in October 1992 in this paper is originated from the North Sea Monitoring Center of the State Oceanic Administration. In October, two stations were set up in the waters of Jiaozhou Bay to take water samples: stations 52 and 60 (Figure 1). Sampling was got once in October 1992, and water samples were taken according to the water depth (surface and bottom layers were taken when the depth >10m, and only the surface layer was taken when the depth <10m) for investigation and sampling. The survey of Cd content in Jiaozhou Bay water body was completed by the national standard method, recorded in the national “Marine Monitoring Code” (1991) [9].

3. Results

3.1 The waters from the south of the bay mouth to the southeast of the bay. The open sea currents enter Jiaozhou Bay with a high Cd content, and the open sea currents pass from the mouth of the bay to the inside. Ocean currents first reach the south of the bay mouth, then enters Jiaozhou Bay and reaches the waters of the southeast of the bay.
In October, the station is 52 in the southern waters of the mouth of Jiaozhou Bay. In the southeastern waters of Jiaozhou Bay, the station is 60. In the surface waters, the open sea currents pass through the southern waters of the mouth of Jiaozhou Bay into the inner waters of the bay. In the surface waters, the ocean currents first reach the southern waters of the mouth of Jiaozhou Bay with a Cd content of 0.39 μg/L, and reach the southeastern waters of Jiaozhou Bay with a Cd content of 0.51 μg/L. In the bottom waters, the open sea currents from outside the bay to the southern waters of the mouth of Jiaozhou Bay, the Cd content is 0.30 μg/L, and then enters the waters in the bay, reaching the southeastern waters of Jiaozhou Bay with the Cd content of 1.19 μg/L.

3.2 The definition of the content changing of horizontal matter. In Jiaozhou Bay, ocean currents carry matter content, and with the movement of ocean currents, the matter content continues to decrease [10]. According to the definitions and formulas of horizontal loss amount, vertical disputed amount and vertical sediment amount of matter content proposed by the author, the calculations for matter can be conducted. The horizontal loss amount of matter content is divided into the absolutely horizontal loss amount and the relatively horizontal loss amount. The vertical disputed amount and vertical sediment amount of matter content are divided into absolutely vertical disputed and sediment amounts, and relatively vertical disputed and sediment amounts.

3.3 The formula of horizontal matter content changing. In the surface waters of Jiaozhou Bay from the south of the bay mouth to the southeast of the bay, it is assumed that the matter (M) content in the southern waters of the bay mouth is A, and the matter content in the southeast waters of the bay is B.

From the southern waters of the bay mouth to the southeastern waters of the bay, the absolutely horizontal loss amount of matter is D>0, and the relatively horizontal loss amount of matter is E. When D<0, it means that the absolutely horizontal loss amount of matter is -D>0 in the waters from the southeast to the southern of the bay. Or when D<0, it means that the absolutely horizontal increase amount in the waters from the southeast of the bay to the west is -D>0.

\[ D=A-B, \quad E=\frac{|A-B|}{\max(A,B)} \]  \tag{1}

In the bottom waters of Jiaozhou Bay from the south of the bay mouth to the southeast of the bay, it is assumed that the matter content in the southern waters of the bay mouth is a, and the matter content in the southeast waters of the bay is b.

From the southern waters of the bay mouth to the southeastern waters of the bay, the absolutely horizontal loss amount is d>0, and the relatively horizontal loss amount is e. When d<0, it means that the absolutely horizontal loss amount is -d>0 from the southeastern waters of the bay to the southern waters. Or when d<0, it means that the absolutely horizontal increase amount is -d>0 from the southeastern waters of the bay to the waters of the west.

\[ d=a-b, \quad e=\frac{|a-b|}{\max(a,b)} \]  \tag{2}

3.4 The formula of vertical Matter content changing. In the waters of Jiaozhou Bay from the south of the bay mouth to the southeast of the bay, it is assumed that the matter content of the surface waters in the south of the bay mouth is A and the matter content of the bottom waters is a. Assuming the location of the water area is n, from the surface water area to the bottom, the absolutely vertical disputed amount is Vna>0, and the relatively vertical disputed amount is Vnr. When Vna<0, it means the absolutely vertical sediment amount is -Vna>0. When Vna<0, the relatively vertical sediment amount is Vnr.

\[ Vna=A-a, \quad Vnr=\frac{|A-a|}{\max(A,a)} \]  \tag{3}

3.5 Horizontal loss amount in the surface and bottom layers. Assume that from the station 52 in the southern waters of the bay mouth to the station 60 in the southeastern waters of the bay simply refer to from A to B. The matter content is mainly made up of Cd content. Through the horizontal change of Cd content, it reveals the horizontal loss of Cd content in the surface and bottom layers.
In October, in the surface waters of Jiaozhou Bay from the south of the bay mouth to the southeast of the bay, when the ocean currents enter the bay, the surface content of Cd in the water body changes greatly [10]. Through formula (1), the horizontal increase of Cd content in surface layer is calculated (Table 1).

Table 1 The horizontal increase of Cd content in the surface layer

| From A to B | D   | E   | E   |
|-------------|-----|-----|-----|
| October     | -0.12 | 0.2352 | 23.52% |

In October, in the bottom waters of Jiaozhou Bay from the south of the bay mouth to the southeast of the bay, when the ocean currents enter the bay, the bottom content of Cd in the water body greatly changes [10]. Through formula (2), the horizontal increase of Cd bottom layer is calculated (Table 2).

Table 2 The horizontal increase of Cd content in the bottom layer

| From A to B | d   | e   | e   |
|-------------|-----|-----|-----|
| October     | -0.89 | 0.7478 | 74.78% |

3.6 Vertical disputed amount and vertical sediment amount. The matter content is mainly Cd content, and the vertical change of Cd content reveals the vertical disputed amount and vertical sediment amount in the bottom layer.

In October, in the waters of Jiaozhou Bay from the south of the bay to the southeast, from the surface to the bottom, the Cd content in the surface and bottom layers of the water body changes greatly [10]. Through formula (3), the vertical disputed amount and vertical sediment amount of Cd content in the bottom layer are calculated (Table 3).

Table 3 The vertical disputed and sediment amount of Cd content in the bottom layer

| Time  | Water bodies                  | Vna | Vnr  | Vnr  |
|-------|-------------------------------|-----|------|------|
| October | Waters in the south of bay mouth | 0.09 | 0.2307 | 23.07% |
|        | Waters in the southeast of the bay | -0.68 | 0.5714 | 57.14% |

4. Discussion

Figure 2 The flow track of high-level Cd content carried by the open sea current in Jiaozhou Bay (μg/L)

4.1 Matter content changing of ocean current tracks in the bay. In the waters of Jiaozhou Bay, the Cd
content is 0.39μg/L from the transportation of open sea currents in October. The open sea currents enter the Jiaozhou Bay with low levels of Cd content, and the currents surround the nearshore waters in the bay and then leave the bay (Figure 2). The open sea currents first pass through the water body in the south of the bay mouth at station 52 and reach the water body in the southeast of the bay at station 60. Through the horizontal matter content changing model and the vertical matter content changing model proposed by the author, the horizontal and vertical migration process of Cd content in the waters from the south of the bay mouth to the southeast of the bay is quantitatively studied.

4.2 Horizontal changes of Cd content. In the waters of Jiaozhou Bay from the south of the bay mouth to the southeast of the bay, the Cd content is 0.39μg/L from the transportation of open sea currents in October. In the waters of Jiaozhou Bay, under the action of tides and currents, the Cd content is continuously decreasing along the gradient.

When the sea currents reach the southern waters of the bay mouth, then enter the bay, and reach the waters of the southeast of the bay, that is, when the currents enter the inner of the bay, the Cd content of the surface water body rises sharply, and at the same time, the Cd content of the bottom water body also rises sharply, which indicates that in the waters from south of the bay mouth to the southeast of the bay, there must be a source of Cd content that provides high Cd content to the surface waters of the southeast of the bay, caused by the Haibo River near the waters of the southeast of Jiaozhou Bay entering the bay. When the Haibo River enters the bay, the Cd content it carries will affect the Cd content in the waters of the southeast Jiaozhou Bay. In October, the Cd content transported by the Haibo River is 0.51μg/L, which is higher than the Cd content 0.39μg/L carried by ocean currents. Therefore, in terms of Cd content, the Haibo River has a slight impact on the surface water body, and the relatively horizontal increase has reached 23.52%. The Haibo River has a significant impact on the bottom water body of the ocean, with a relatively horizontal increase of 74.78% (Figure 3). Therefore, the waters in the southeast of Jiaozhou Bay have been affected by the Haibo River and have a large amount of Cd subsidence.

Figure 3 The model block diagram of the horizontal and vertical changes of Cd content in October

4.3 Vertical changes of Cd content. The open sea currents first reach the water body in the south of the bay mouth, and then flow to the water body in the southeast of the bay. In October, when the sea currents enter the bay, it travels from the southern waters of the bay mouth to the southeastern waters of the bay. In the southern waters of the bay mouth, the vertical disputed amount of the Cd content in the surface and bottom layers is as low as 23.07% (Figure 3), which indicates that in the southern waters of the bay mouth, only the offshore currents carry the low Cd content of 0.39 μg/L, and nothing else provides the Cd content. In this way, the southern waters of the bay mouth present a low-value vertical disputed amount of Cd content. In the southeast waters of the bay, the vertical sediment
amount of Cd content in the surface and bottom content reaches a high level of 57.14% (Figure 3), which indicates that in the southeast waters of the bay, not only the offshore currents carry a low Cd content of 0.39μg/L, but also the Cd content in waters provided by Haibo River is 0.66μg/L, so the waters in the southeast of the bay present a high vertical sediment amount of Cd content.

4.4 Horizontal increase amount. In October, in the waters from the south of the bay mouth to the southeast of the bay, the horizontal increase amount of Cd content in the surface layer reaches a relatively high 23.52% (Table 1). From the southern waters of the bay mouth to the southeastern waters of the bay, the Cd content in the surface layer has increased partly. This indicates that the surface Cd content in the process of currents flowing from the southern waters of the bay mouth to the southeastern waters of the bay, has been supplemented to a certain extent. There is the Haibo River near the waters in the southeast of Jiaozhou Bay. The Cd content of the Haibo River is 0.51μg/L, which is higher than the 0.39μg/L Cd carried by the ocean current, which provides a large amount of supplement. According to the effect of the vertical water body [10], the Cd content continues to sink to the seabed after passing through the water body. The Cd content of 0.39μg/L carried by the ocean current reaches the waters near the southeast of Jiaozhou Bay, and there has been a large amount of subsidence. At this time, the surface Cd content supplemented by the Haibo River to the ocean currents has two parts, one of which needs to be supplemented is the loss of Cd content by the ocean currents from the southern waters of the bay mouth to the southeastern waters of the bay, and the other part needs to supplement the increase in surface Cd content that is higher than the Cd content carried by the ocean currents. Therefore, during the horizontal migration of Cd surface content, the source of Haibo River supplements the loss and increase of surface Cd content to the ocean currents. Through the horizontal changing model of matter content, the horizontal increase of Cd content in the surface layer can be calculated out. The absolutely horizontal increase of Cd content is 0.12μg/L, and the relatively horizontal increase is 23.52%.

In October, from the southern waters of the bay mouth to the southeastern waters of the bay, the horizontal increase amount of Cd content in the bottom layer increases to a high degree of 74.78% (Table 1). The Cd content carried by the ocean current is 0.39μg/L, and at the same time, the Cd content conveyed by the Haibo River is 0.51μg/L, which provides a large amount of supplement for the ocean current passing through the southeast waters of the bay. According to the effect of the vertical water body [10], it continuously sinks to the seabed after the Cd content passes through the water body. In this way, the high Cd content in the surface layer of southeastern waters can quickly and continuously sinks to the seabed, leaving it at the bottom of the water body in the southeast of Jiaozhou Bay. At the bottom of southeastern waters of Jiaozhou Bay, the Cd content of the bottom layer comes from the settlement of two parts, one part is the Cd content carried by the ocean currents, and the other part is the Cd content transported by the Haibo River. Therefore, during the horizontal migration of Cd bottom content, the ocean currents and the Haibo River replenishes a large amount of Cd content to the bottom of southeastern waters of the bay. The horizontal increase amount of Cd content in the bottom layer is calculated through the horizontal changing model of matter content. The absolutely horizontal increase of Cd content is 0.89μg/L, and the relatively horizontal increase is 74.78%.

4.5 Vertical loss amount. In October, the high Cd content carried by the open sea currents first reaches the southern waters of the Jiaozhou Bay mouth. In the southern waters of the bay mouth, the vertical disputed amount of the Cd content in the bottom layer reaches a low value of 23.07%. Then, the open sea currents enter the waters of the southeast of the bay. In the southeastern part of the bay, the vertical sediment amount of Cd content in the surface and bottom layers reaches a high value of 57.14%. This reveals that when the ocean current enters the southern waters of the mouth of the bay, the low Cd content in the surface does not sink to the seabed in large amounts, nor does the Cd content accumulate on the seabed. In this way, the vertical disputed amount on the seafloor reaches a low value of 23.07%. When the ocean current enters the southeastern waters of the bay, the Haibo River
also enters the southeastern waters of the bay. At the same time, the ocean current and the Haibo River bring a lot of subsidence to the bottom of the southeast waters of the bay, so that the vertical sediment amount on the seafloor reaches a high level of 57.14%. Therefore, when the Cd content of the surface layer is low, the water presents a vertical disputed amount of the Cd content in the surface and bottom layers, and there is no sediment of Cd content on the seabed; when the Cd content of the surface layer is high, the water area presents a vertical sediment amount of Cd content in the surface and bottom layers, and there is sediment of Cd content on the seafloor.

4.6 The transportation of rivers on land. The Cd content of the source of the surface of Haibo River on the land is n, and the Cd content of the ocean current on the surface of the bay mouth is m. The Cd content in the surface layer of southeastern part of the bay sourced from ocean current and Haibo River is u, and the sediment amount of the bottom layer of the southeastern waters of the bay sourced from ocean current and Haibo River is x and y respectively (Figure 4). Therefore, the author proposes a formula for calculating Cd content from river sources.

\[
x + y = 0.89 \\
(m-x) + (n-y) = u = 0.51
\]

It can be calculated that, \( n = 1.01 \) (μg/L)

Therefore, the Cd content of the surface of Haibo River sourced from the land is 1.01 μg/L.

![Figure 4 The calculation model block diagram of Cd content in the surface layer of Haibo River sourced from land in October](image)

5. Conclusion
According to the horizontal matter content changing model and the vertical matter content changing model proposed by the author, the horizontal loss amount, vertical disputed amount and vertical sediment amount of Cd content in the surface and bottom layers have been calculated, and the model block diagram of the horizontal and vertical changes of Cd content has been determined. In October, the absolutely horizontal increase of Cd content in the surface and bottom layer is 0.12~0.89 μg/L, and the relatively horizontal increase of Cd content in the surface and bottom layer is 23.52~74.78%. In the southern waters of the bay mouth, the Cd content in the surface and bottom layer has an absolutely vertical disputed amount of 0.09 μg/L, and its relatively vertical disputed amount is 23.07%. In the southeastern waters of the bay, the Cd content in the surface and bottom layers has an absolutely vertical sediment amount of 0.68 μg/L, and its relatively vertical sediment amount is 57.14%.

There is a Haibo River near the southeast waters of Jiaozhou Bay. The Cd content conveyed by the Haibo River is 0.51 μg/L in October, which is higher than the Cd content of 0.39 μg/L carried by the ocean currents, which provides a lot of supplements to the southeast waters of the bay. During the horizontal migration of Cd surface content, the source of Haibo River supplements the loss and increase of Cd content in the surface layer of the ocean current. The horizontal increase amount of Cd
content in the surface can be calculated by the changing model of matter content. The absolutely horizontal increase of Cd content is 0.12 μg/L, and the relatively horizontal increase is 23.52%. Similarly, during the horizontal migration of the Cd content in the bottom layer, ocean currents and Haibo River replenish a large amount of Cd content to the bottom layer of the southeast waters of the bay. The horizontal increase of Cd content in the bottom layer is calculated through the horizontal changing model of matter content. The absolutely horizontal increase of Cd content is 0.89 μg/L, and the relatively horizontal increase is 74.78%.

In October, during the vertical migration process, when ocean currents enter the southern waters of the bay mouth, the low Cd content in the surface layer does not sink to the seabed in large amounts, nor does the Cd content settlement on the seabed. In this way, the vertical disputed amount on the seafloor reaches a low value of 23.07%. When the ocean currents enter the southeast waters of the bay, the Haibo River also enters the waters of the southeast of the bay. The ocean currents and the Haibo River bring a lot of sediment at the same time to the bottom of the southeast waters of the bay, so that the vertical sediment amount on the seafloor reaches a high value of 57.14%. Therefore, when the Cd content in the surface layer is low, the water area presents the vertical disputed amount of the Cd content, and there is the sediment of Cd content on the seafloor.

According to the calculation formula of the Cd content of river sources proposed by the author, the Cd content in the surface of the Haibo River sourced from the land is calculated to be 1.01 μg/L.

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