Transferring Process of Matter Content in the Center of the Bay

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Abstract: Based on investigation data on Pb in Jiaozhou Bay waters in May, August and October 1992, the author introduces horizontal and vertical variation models of matter content to calculate the horizontal loss amount, vertical dilution amount and vertical sediment amount of the Pb content in both surface and bottom waters and establishes modeling chart of its horizontal and vertical variation. The results show that the absolutely and relatively horizontal loss amount of the Pb content in the bottom waters were 6.23μg/L and 59.73% respectively in May. Absolutely horizontal increase amount of the Pb content in the bottom waters varied from 4.14 to 5.51μg/L, and relatively horizontal increase amount varied from 22.59% to 35.59% in August and October. In May, August and October, the Pb content in both surface and bottom waters had an absolutely vertical dilution amount of 2.18μg/L and a relatively vertical dilution amount of 22.54% in the waters of the southeast of the bay. Besides, the absolutely vertical sediment amount of the Pb content in both surface and bottom waters ranged from 4.89μg/L to 7.58μg/L and the relatively vertical sediment amount ranged from 40.14 to 46.88% in the same waters. As for in the central waters of the bay, the absolutely and relatively vertical dilution amount were 3.17μg/L and 43.01% respectively, the absolutely and relatively vertical sediment amount were 1.18-18.86μg/L and 10.14-77.32% respectively during the same period. The variation model of matter content reveals that the Pb content transported by the main sea currents settled as sediment in the waters of the southeast of the bay, and it continued to accumulate in the bottom waters from May to August. The Pb content in that area was transported to the bottom waters of the center of the bay through the bottom of ocean floor so that a large amount of the Pb content was accumulated there from August to October. The author introduces the transferring process of the matter content in the center of Jiaozhou Bay: matter content brought by the main sea currents settles as sediment in the offshore waters and keeps accumulating in its bottom layer under the tidal effect and current action then moves through the bottom layer of the ocean floor to the bottom waters of the center of the bay. As a result, the matter content accumulates a lot there, and keeps rising to reach its surface waters.

1. Introduction

Main sea currents, with a high content of Pb, flow into Jiaozhou Bay through its bay mouth, go around its offshore waters and then leave the waters of the inner bay. When currents flow into the bay, the Pb content experiences horizontal and vertical transferring, a process that the Pb content transfers from the surface waters to the bottom waters and then rises back to the surface waters with the help of currents. Therefore, based on investigation data on Pb in Jiaozhou Bay waters in May, August and October 1992, the author’s horizontal and vertical variation models of matter content demonstrate the
horizontal transferring and vertical sedimentation process of the Pb content in Jiaozhou Bay waters and illustrate the variation of the Pb content in surface and bottom waters during this process.

2. Investigated Waters & Materials and Methods

2.1 Natural Environment of Jiaozhou Bay.
Jiaozhou Bay (120°04′-120°23′E, 35°55′-36°18′N) is located in the south of Shandong Province, eastern China. It is a semi-closed bay, bounded by Tuan Island and Xuejia Island, connects the Yellow Sea with the total area and average water depth of 446km², 7m and 3km, respectively. There are more than ten inflow rivers, among which Dagu River and Yang River, Haibo River, Licun River and Loushan River in Qingdao city have greater runoff and sediment concentration. They are all seasonal rivers with obvious seasonal changes in hydrological characteristics of rivers [7, 8].

![Figure 1 Investigation sites in Jiaozhou Bay](image)

2.2 Materials and Methods.
The investigation data on Pb in Jiaozhou Bay waters in May, August and October 1992 adopted by this research are provided by the North Sea Monitoring Center of the State Oceanic Administration. In May, August and October, two sites were set to take water samples in Jiaozhou Bay waters: site 55 and site 60 (Figure 1). Three samples were taken according to depth for sample investigation in May, August, and October 1992, (surface and bottom waters were taken when >10m, and only surface waters were taken when <10m). The investigation of Pb in Jiaozhou Bay waters was carried out in line with the national standard method which has been added in the National “Ocean Monitoring Code” (1991) [9].

3. Results

3.1 Current Flows Through Waters in the Southeast of the Bay.
Main sea currents, with a high content of Pb, flow into Jiaozhou Bay through its bay mouth, go around its offshore waters and then leave the inner bay for the waters of the west of bay mouth (Figure 2).
In May, August and October, site 60 was set in southeast waters of Jiaozhou Bay. In terms of the surface waters, main sea currents from the outer bay passed through the bay mouth and entered the bay, reaching the southeast waters of the bay. That is how main sea currents affect the surface waters of the southeast of the bay.

In May, August and October, the main sea currents flowed around the offshore waters of the inner bay without reaching the surface waters of the center of Jiaozhou Bay.

In May, August and October, with matter content, the main sea currents reached the surface waters of the southeast of the bay. Then, a large amount of matter content moved from the surface to the bottom waters, forming huge sediment in the southeast waters of the bay. The newly generated Pb sediment on the ocean floor was gradually transported to the bottom waters of the center of the bay along the bottom of offshore ocean floor under the effect of gravity, tides and currents (Figure 3). As the Pb content in the bottom waters of the center of the bay continued to accumulate, it started to rise to the surface waters of the center of the bay.

Therefore, the vertical sediment amount and horizontal variation amount in the two bottom waters are calculated by applying the author’s variation models of matter content.

3.2 Definition of Horizontal Variation of Matter Content.
Matter content in Jiaozhou Bay has constantly decreased with currents movement. [10-13] Therefore, through water exchange, the horizontal loss amount, vertical dilution amount and vertical sediment amount of the matter content can be calculated according to the definitions and formulas proposed by the author. The horizontal loss amount of the matter content is divided into absolutely horizontal loss...
amount and relatively horizontal loss amount. The vertical dilution amount and vertical sediment amount of matter content are divided into absolutely vertical dilution amount and sediment amount and relatively vertical dilution amount and sediment amount.

3.3 Definition and Formula of Horizontal Variation of Matter Content.
In the surface waters from the southeast to the center of Jiaozhou Bay, it is assumed that the content of the matter (M) in the southeast water of the bay is A, and the content of the matter in the central waters of the bay is B.

When the absolutely horizontal loss amount of the matter content is \( D > 0 \), matter moves from the southeast waters to the central of the bay, and the relatively horizontal loss amount is E. When \( D < 0 \), it means that matter moves from the central to the southeast waters of the bay, and the absolutely horizontal loss amount of the matter content is \(-D > 0\).

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

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

When the absolutely horizontal loss amount of the matter content is \( d > 0 \), matter moves from the southeast waters to the central of the bay, and the relatively horizontal loss amount of the matter content is “e”. When \( d < 0 \), it means that matter moves from the central to the southeast waters of the bay and the absolutely horizontal loss amount of the matter content is \(-d > 0\).

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

3.4 Definition and Formula of Vertical Variation of Matter Content.
In the waters from the southeast to the center of the bay, it is assumed that the matter content in the surface waters in the southeast of the bay is A, the matter content in the bottom waters is a, and the location of the water is n. From the surface waters to the bottom waters, the absolutely vertical dilution amount of the matter content is \( V_{na} > 0 \), and the relatively vertical dilution amount is \( V_{nr} \). When \( V_{na} < 0 \), it means the absolutely vertical sediment amount of the matter content is \(-V_{na} > 0\) and the relatively vertical sediment amount is \( V_{nr} \).

\[
V_{na} = A - a, \quad V_{nr} = \frac{|A - a|}{\max(A, a)} \quad (3)
\]

3.5 Horizontal Loss Amount in Surface and Bottom Waters.
It is assumed that the movement of matter from site 60 in the southeast waters to site 55 in the central waters is simply recognized as the movement from A to B. The Pb content is the main matter to be researched. The horizontal variation of the Pb content reveals its horizontal loss amount in surface and bottom waters.

It is necessary to calculate horizontal loss amount of Pb in the bottom waters according to the trail of currents.

In May, August and October, the Pb content is quite different in the bottom waters of the southeast and the central waters of Jiaozhou Bay [10]. The horizontal loss amount of the Pb content in the bottom waters is calculated (Table 1) according to the formula (2).

| From A to B | d   | e   | e    |
|-------------|-----|-----|------|
| May         | 6.23| 0.5973| 59.73%|
| August      | -5.51| 0.2259| 22.59%|
| October     | -4.14| 0.3559| 35.59%|

3.6 Vertical Dilution Amount and Vertical Sediment Amount.
The Pb content is the main matter to be researched. Its vertical variation reveals its vertical dilution amount and vertical sediment amount in both surface and bottom waters.

In May, August and October, the Pb content changed a lot from the bottom to the surface in the southeast to the central waters of Jiaozhou Bay [11-13]. The vertical dilution amount and vertical
sediment amount of the Pb content in the bottom waters are calculated (Table 2) according to the formula (3).

Table 2 Vertical dilution amount and vertical sediment amount of Pb in the bottom water

| Month   | Waters                | Vna   | Vnr   | Vnr  |
|---------|-----------------------|-------|-------|------|
| May     | southeast waters of the bay | -4.89 | 0.4688 | 46.88% |
|         | central waters of the bay | 3.17  | 0.4301 | 43.01% |
| August  | southeast waters of the bay | -7.58 | 0.4014 | 40.14% |
|         | central waters of the bay | -18.86 | 0.7732 | 77.32% |
| October | southeast waters of the bay | 2.18  | 0.2254 | 22.54% |
|         | central waters of the bay | -1.18  | 0.1014 | 10.14% |

4. Discussion

4.1 Variation of the Matter Content.
In May, main sea currents carrying with a high content of Pb flowed around the offshore waters of the bay without reaching the surface as well as the bottom waters of the center of Jiaozhou Bay. (Figure 4)

From May to August, main sea currents carrying with a high content of Pb continued to travel around the offshore waters of the inner bay, which didn’t affect the surface waters of the center of Jiaozhou Bay, but brought dramatic impact to the bottom waters there. (Figure 5).
From August to October, with a high content of Pb beginning to reduce significantly, main sea currents flowed around the offshore waters of the inner bay, which didn't affect the surface waters of the center of Jiaozhou Bay, but brought dramatic impact to the bottom waters there. Then the surface waters of the center of the bay were affected by its bottom waters (Figure 6).

During the transferring process, the matter content is changed. The Pb content in the southeast waters of the bay is transported by main sea currents. According to the principles of the vertical water effect of the matter, the horizontal water effect of the matter and the principle of the water effect [11-13], the horizontal variation of the matter content reveals the horizontal loss effect of waters; variation in the surface and the bottom waters reveals the vertical diluting effect and vertical sediment effect of waters. Therefore, the horizontal and vertical transferring processes of the Pb content in the waters from the southeast to the center of the bay are quantitatively studied by applying the horizontal and vertical variation models of matter content proposed by the author.
4.2 Horizontal and Vertical Variation of the Pb Content.
In May, August and October, the horizontal loss amount of the Pb content in the bottom waters is calculated (Table 1) according to formula (2). The vertical dilution amount and vertical sediment amount of the Pb content in the surface and the bottom waters are calculated (Table 2) according to formula (3).

From the spatial perspective, research studies from the southeast waters to the central of Jiaozhou Bay.

In May, the Pb content was transported from the southeast waters to the central of the bay through the bottom waters of the ocean floor, with the horizontal loss amount in the bottom waters reaching a relatively high level of 59.73% (Figure 7). Considering the two waters, the vertical sediment amount of the Pb content in the southeast waters of the bay is relatively high, registering 46.88%, but the vertical dilution amount content in the central waters of the bay is relatively high, reaching 43.01%. (Figure 7).

Figure 7 modeling chart of the horizontal and vertical variation of the Pb content in May

In August, the Pb content was transported from the southeast waters to the central of the bay through the bottom waters of the ocean floor, with the horizontal increase amount in the bottom waters reaching a relatively high level of 22.59% (Figure 8). Considering the two waters of the bay, the vertical sediment amount of the Pb content in the southeast waters of the bay is relatively high, registering 40.14%, and is extremely high in the central waters, reaching 77.32%. (Figure 8).

Figure 8 modeling chart of the horizontal and vertical variation of the Pb content in August

In October, the Pb content was transported from the southeast waters to the central of the bay through the bottom waters of the ocean floor, with the horizontal increase amount in the bottom waters reaching a relatively high level of 35.59% (Figure 9). Considering the two waters of the bay, the vertical dilution amount of the Pb content in the southeast waters of the bay is relatively high, registering 22.54%, while the vertical sediment amount of the Pb content in the central waters of the bay is relatively low, reaching 10.14%. (Figure 9).

Therefore, the absolutely and relatively horizontal loss amount of the Pb content in the bottom waters were 6.23μg/L and 59.73% respectively in May. Absolutely horizontal increase of the Pb
content in the bottom waters varied from 4.14 to 5.51μg/L, and the relatively horizontal increase varied from 22.59% to 35.59% in August and October. In May, August and October, the Pb content in both surface and bottom waters had an absolutely vertical dilution amount of 2.18μg/L and a relatively vertical dilution amount of 22.54% in the waters of the southeast of the bay. Besides, the absolutely vertical sediment amount of the Pb content in both surface and bottom waters ranged from 4.89μg/L to 7.58μg/L and the relatively vertical sediment amount ranged from 40.14 to 46.88% in the same waters. As for in the central waters of the bay, during the same period, the absolutely and relatively vertical dilution amount were 3.17μg/L and 43.01% respectively, the absolutely and relatively vertical sediment amount were 1.18-18.86μg/L and 10.14-77.32% respectively.

4.3 Horizontal Loss Amount.

Pb content was transported from the southeast waters to the central of the bay through the bottom waters of the ocean floor. In May, the horizontal loss amount of the Pb content in the bottom waters reached an extremely high level of 59.73%. In August, its horizontal increase amount reached a relatively high level of 22.59% and a relatively high level of 35.59% in October (Table 1). Therefore, in May, its horizontal loss amount in the bottom waters showed an extremely high level 59.73%. In August and October, the horizontal level of the Pb content increased by a relatively high 22.59-35.59%, which indicates the transferring of the Pb content from the bottom waters in the southeast to the center of the bay.

In May, the bottom waters in the southeast of the bay transported 59.73% Pb content to the center of the bay whose Pb content was relatively low. From May to August, the horizontal loss amount of 59.73% Pb content in the bottom waters shifted to the horizontal increase amount of 22.59% Pb content, making the Pb content in the bottom waters of the center of the bay reaching a relatively high level. From August to October, the horizontal increase amount of the Pb content in the bottom waters of the center of the bay grew to 35.59%, representing a higher level.

4.4 Vertical Loss Amount.

In May, vertical sediment amount of the surface and bottom Pb content reached a relatively high level of 46.88% in the southeast waters of Jiaozhou Bay while in the central waters of the bay, the vertical dilution amount of the surface and bottom Pb content was 43.01%. This indicates that the Pb content in the southeast waters of the bay had a large amount of sediment and formed huge accumulation in the bottom waters in May. However, the Pb content did not accumulate in the bottom waters of the center of the bay.

In August, vertical sediment amount of the surface and bottom Pb content was at a high level of 40.14% in the southeast waters of the bay, and 77.32% in the central waters of the bay. This indicates a continuous Pb sedimentation in the southeast waters of the bay and Pb accumulation in the bottom waters in August. At the same time, a large amount of the Pb content also accumulated in the bottom waters of the center of the bay.

In October, vertical dilution amount of the surface and bottom Pb content reached a relatively high level of 22.54% in the southeast waters of Jiaozhou Bay while in the central waters of the bay, the vertical sediment amount of the surface and bottom Pb content was 10.14%. This indicates that the Pb content had a large amount of sediment in the southeast waters but there is no accumulation in the bottom waters. However, the bottom Pb content kept accumulating in the central waters.

4.5 Transferring Process of Matter Content.

In May, August and October, main sea currents, carrying with a high content of Pb, flowed into Jiaozhou Bay through its bay mouth, went around its offshore waters and then left the bay. (Figure 2)

Transported by main sea currents, the Pb content in Jiaozhou Bay was 20.79μg/L in May, 37.53μg/L in August and 13.25μg/L in October. From May to October, there was no source of the Pb content in the surface waters of the center of the bay.

In May, the Pb content transported by main sea currents produced huge sediment in the southeast
waters of the bay and the vertical sediment amount reached 46.88%. At the same time, 59.73% of the Pb content in the bottom waters of the southeast of the bay was transferred to the bottom waters of the center of the bay, where the Pb content was relatively low and didn’t accumulate.

In August, the Pb content transported by main sea currents produced huge sediment in the southeast waters of the bay and the vertical sediment amount reached 40.14%. The bottom waters of southeast of the bay saw its ongoing Pb content sedimentation and huge accumulation on the ocean floor. Pb content in the bottom waters of the southeast of the bay was transported to the bottom waters of the center of the bay. From May to August, the horizontal loss amount of 59.73% Pb content in the bottom waters shifted to the horizontal increase amount of 22.59% Pb content, making the Pb content in the center of the bay reaching a relatively high level. Besides, a large amount of the Pb content accumulation was found in the bottom waters of the center of the bay, which led to a relatively high level of vertical sediment amount, arriving at 77.32%.

In October, the Pb content transported by main sea currents continued to produce huge sediment in the southeast waters of the bay and the vertical sediment amount reached 22.54% but there was no accumulation on the sea floor. In August and October, the Pb content was transported from the southeast waters to the central of the bay through the bottom waters of the ocean floor, with the horizontal increase amount in the bottom waters reaching a relatively high level of 35.59%. From August to October, the horizontal increase amount grew from 22.59% to 35.59%, representing a higher level of the Pb content in the bottom waters of the center of the bay. Also, the Pb content in the bottom waters kept accumulating.

In a word, the transferring process of the matter content in the center of the Jiaozhou Bay is that matter content, brought by the main sea currents, settles as sediment in the offshore waters and keeps accumulating in its bottom layer under the tidal effect and current action, then and moves through the bottom layer of the ocean floor to the bottom waters of the center of the bay. As a result, the matter content accumulates a lot there, and keeps rising to reach its surface waters. (Figure 10)

For instance, from August to October, the Pb content transported by main sea currents produced huge sediment in the southeast waters of the bay and kept massive accumulating on the ocean floor. From August to October, the Pb content in that area was transported to the bottom waters of the center of the bay through the bottom of ocean floor, forming a huge accumulation of the Pb content in the bottom waters of the center of the bay.

5. Conclusion
In applying the horizontal and vertical variation model of matter content introduced by the author, the
horizontal loss amount, vertical dilution amount and vertical sediment amount of the Pb content in both surface and bottom waters are calculated and modeling chart of its horizontal and vertical variation is established. The results show that the absolutely and relatively horizontal loss amount of the Pb content in the bottom waters were 6.23μg/L and 59.73% respectively in May. Absolutely horizontal increase amount of the Pb content in the bottom waters varied from 4.14 to 5.51μg/L, and relatively horizontal increase amount varied from 22.59% to 35.59% in August and October.

In May, August and October, the Pb content in both surface and bottom waters had an absolutely vertical dilution amount of 2.18μg/L and a relatively vertical dilution amount of 22.54% in the waters of the southeast of the bay. Besides, the absolutely vertical sediment amount of the Pb content in both surface and bottom waters ranged from 4.89μg/L to 7.58μg/L and the relatively vertical sediment amount ranged from 40.14 to 46.88% in the same waters.

As for in the central waters of the bay, the absolutely and relatively vertical dilution amount were 3.17μg/L and 43.01% respectively, the absolutely and relatively vertical sediment amount were 1.18-18.86μg/L and 10.14-77.32% respectively during the same period.

Pb content was transported from the bottom waters in the southeast of the bay to the center of the bay, reaching 59.73% in May when the bottom waters of the center of the bay had a relatively low Pb content. From May to August, the horizontal loss amount of 59.73% Pb content in the bottom waters shifted to the horizontal increase amount of 22.59% Pb content, making the Pb content in the bottom waters of the center of the bay reaching a relatively high level. From August to October, the horizontal increase amount grew from 22.59% to 35.59%, representing a higher level of the Pb content in the bottom waters of the center of the bay.

In May, a large amount of Pb sediment was found in the southeast waters of the bay and continuous accumulation in the ocean floor but there was no accumulated Pb content in the bottom waters of the center of the bay. In August, Pb sedimentation and accumulation were maintained in the southeast waters of the bay and the ocean floor respectively. At the same time, the Pb content accumulated heavily in the bottom waters of the center of the bay. In October, the Pb content kept settling as sediment without accumulation on the ocean floor in the southeast waters of the bay. However, Pb accumulation continued in the waters of the center of the bay.

From May to August, the Pb content transported by main sea currents produced huge sediment in the southeast waters of the bay and kept massive accumulating on the ocean floor. From August to October, the Pb content in that area was transported to the bottom waters of the center of the bay through the bottom of ocean floor, forming huge accumulation of the Pb content in the bottom waters of the center of the bay.

The author introduces the transferring process of the matter content in the center of Jiaozhou Bay: matter content brought by the main sea currents settles as sediment in the offshore waters and keeps accumulating in its bottom layer under the tidal effect and current action then moves through the bottom layer of ocean floor to the bottom waters of the center of the bay. As a result, the matter content accumulates a lot there, and keeps rising to reach its surface waters.

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