Calculation of Loss Amount from Southeast of the Bay to West of Bay Mouth

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Abstract: Using survey data of Pb in water body from southeast of Jiaozhou Bay to west of bay mouth in August 1992 and according to the horizontal change model and the vertical change model of matter content put forward by authors, we calculate the horizontal loss amount, vertical diluted amount and vertical sediment amount of Pb in surface and bottom layer and determine the model diagram of Pb content horizontal and vertical changes. The results showed that in water body from southeast of Jiaozhou Bay to west of bay mouth in August, the absolutely horizontal loss amount of Pb content in surface layer and bottom layer was 4.32 - 5.29μg/L, and the relatively horizontal loss amount of Pb content was 28.01 - 38.23%. The absolutely vertical sediment amount of Pb was 6.61 - 7.58μg/L in both surface and bottom layer, and the relatively vertical sediment amount was 40.14 - 48.63%. In the surface water in August, the main sea current carrying Pb content moved through a ring of nearshore water when the Pb content in the surface and bottom layer deposited to the seabed in large quantities. During the horizontal migration of Pb content in the surface and bottom waters, the loss amount of Pb content in the surface layer and bottom layer reached almost 30.00% and that in the surface layer even reached almost 40.00%. It revealed that the high content Pb on the surface could rapidly and continuously settle to the seabed almost 30.00% of the Pb content in the water remained at the bottom of Jiaozhou Bay. In August, in the process of vertical migration, the Pb content transported by main sea current was relatively high. From the waters in the southeast of the bay to the waters in the west of bay mouth, the vertical sediment amount of Pb content in the surface and bottom increased from 40.14% to 48.63%, and the deposition of high Pb content accumulated in the seabed of Jiaozhou Bay.

1. Introduction
The Pb content in the surface waters of Jiaozhou Bay increased due to the high Pb content carried by the main sea current from the outside to the inside of bay through the bay mouth. In the horizontal migration process, Pb content moves from the surface of one water to the surface of another. In the process of vertical migration, it passes through the water from the surface layer, settling to the seabed [1]. Authors propose the horizontal change model and the vertical change model of matter content, using the survey data about Pb content of the Jiaozhou Bay water in August 1992, showing the horizontal migration process and vertical subsidence process of Pb content in the Jiaozhou Bay waters and illustrating process and level of the Pb content pollution derived from the main sea current, to provide a scientific basis for the study of the Pb content’s vertical settlement and horizontal migration in surface and bottom waters.
2. The Waters, Materials and Methods of the Survey

2.1 Natural Environment of Jiaozhou Bay. Jiaozhou Bay is located between 120°04' - 120°23'E, 35°58' - 36°18'N. The boundary between the bay and the Yellow Sea is the line between Tuan Island and Xuejia Island. With the area about 446 km² and the average water depth about 7m, it is a typical semi-enclosed bay. There are more than a dozen rivers which have large runoff and sediment concentration in Jiaozhou Bay entering the sea, among which Dagu River and Yang River, and Haibo River, Licun River and Loushan River [2, 3].

2.2 Materials and Methods. The investigation data of Pb in Jiaozhou Bay in August 1992 were provided by The North China Sea Environmental Monitoring Center. Two stations were set up in the waters of Jiaozhou Bay to take water samples: Stations 60 and 53 (Figure 1). In August 1992, samples were taken subject to the depth of water (>10m, take the surface and bottom layer; <10m, only the surface layer was taken) for survey. The PHC survey of Jiaozhou Bay water body was conducted in keeping with the national standard method, which was included in the Specification for Marine Monitoring (1991) [4].

3. Results

3.1 Waters from Southeast of the Bay to West of bay mouth. The main sea current carried high Pb content through the bay mouth into Jiaozhou Bay and circled around the inshore waters. Station 60 lies in the southeastern waters of Jiaozhou Bay. Station 53 is located in the western waters of bay mouth. In surface waters in August, the main sea current passed through the southern waters of the bay mouth and entered into the bay. The Pb content is 11.30μg/L at station 60. Then the main sea current made a circle around the inshore waters of the bay and reached station 53, with a Pb content of 6.98μg/L. In almost the same way, in the bottom waters, the current moved through the southern waters of the bay mouth and entered into the bay. The main sea current first reached station 60 with the Pb content maximum value of 18.88μg/L, and then the main sea current circled around the offshore waters and arrived at station 53 with the Pb content of 13.59μg/L.

3.2 Definition of Horizontal Substance Content Change. In Jiaozhou Bay, the material content transferred by the current decreased continuously with the movement of the current [5-8]. According to
the definition and formula proposed by the authors, horizontal loss amount, vertical diluted amount and vertical sediment amount of material content are calculated. Horizontal loss amount is divided into absolutely horizontal loss amount and relatively horizontal loss amount. Vertical diluted amount is divided into absolutely vertical diluted and sediment amount and relatively vertical diluted and sediment amount.

3.3 Formula for the Change of Horizontal Substance Content. In the surface waters from southeast of Jiaozhou Bay to west of the bay mouth, it is assumed that the content of matter (M) in the southeast of the bay is A and that in the west of the bay mouth is B.

From the southeastern waters of the bay to the western waters of the bay mouth, the absolutely horizontal loss amount is \( D > 0 \). The relatively horizontal loss amount is \( E \). When \( D < 0 \), absolutely horizontal loss amount of material content in the waters from west of the bay mouth to southeast of the bay is \(-D > 0\).

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

In a similar way, in the bottom waters from southeast of Jiaozhou Bay to west of the bay mouth, it is assumed that the material content in the southeast of the bay is a and that in the west of bay mouth is b.

From the southeastern waters of the bay to the western waters of the bay mouth, the absolutely horizontal loss amount is \( d > 0 \), the relatively horizontal loss amount is \( e \). When \( d < 0 \), the absolutely horizontal loss amount in the waters from west of the bay mouth to southeast of the bay is \(-d < 0\).

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

3.4 Formula of Vertical Substance Content Change. In the waters of from southeast of Jiaozhou Bay to west of the bay mouth, it is assumed that the matter content of surface water is A, that of bottom water is a, and the station of the water area is n. From the surface waters to the bottom waters, the absolutely vertical diluted amount of material content was \( V_{na} > 0 \). The relatively vertical diluted amount of substance content was \( V_{nr} \). When \( V_{na} < 0 \), the absolutely vertical diluted amount of material content is \(-V_{na} > 0\) and the relatively vertical diluted amount of substance content is \( V_{nr} \).

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

3.5 Horizontal Loss Amount of Surface Layer and Bottom Layer. We assume that movement from station 60 in the southeastern waters of the bay to station 53 in the western waters of the bay mouth simply refers to that from A to B and Pb content is the main part of matter content. Then the horizontal loss amount of Pb content in the surface layer and the bottom layer were revealed by the horizontal change of Pb content.

In August, after the surface waters passing through the coastal waters from station 60 to Station 53, the Pb content in the water changed greatly [5]. The horizontal loss amount of Pb content in the surface waters was calculated by formula (1) (Table 1).

| From A to B | D  | E   | E   |
|-------------|----|-----|-----|
| August      | 4.32 | 0.3823 | 38.23% |

At the same time, in the bottom water of Jiaozhou Bay from station 60 to Station 53, the Pb content also changed greatly after the water passing through the nearshore waters [5]. With formula (2), the horizontal loss amount of Pb in the bottom water was calculated (Table 2).

| From A to B | d  | e   | e   |
|-------------|----|-----|-----|
| August      | 5.29 | 0.2801 | 28.01% |
3.6 Vertical Diluted and Sediment Amounts. Most of the matter content was the Pb content. The vertical diluted and sediment amounts of Pb in surface layer and bottom layer were disclosed by the vertical variation of Pb content.

In August, in the waters from the southeast of Jiaozhou Bay to the west of the bay mouth, Pb content in both surface and bottom waters changed greatly [6-8]. The vertical diluted and sediment amounts of Pb content in the bottom layer were calculated by formula (3) (Table 3).

Table 3 Vertical diluted and sediment amounts of Pb content in the surface and bottom layer

| time          | water                      | Vna | Vnr     | Vnr |
|---------------|----------------------------|-----|---------|------|
| August        | waters of Southeastern bay | -7.58 | 0.4014 | 40.14% |
|               | waters of western bay mouth| -6.61 | 0.4863 | 48.63% |

4. Discuss

4.1 Changes in the Substance Content of the Current Track in the Bay. Jiaozhou Bay is a shallow bay with a dustpan shape that tilts directly in the bay mouth and then to the east. But the water depth in the northwest is shallower than that in the southeast. Offshore currents carried high Pb content from outside to Jiaozhou Bay through the bay mouth. The main sea current followed the inshore waters in the northeast of the bay to the bayhead waters in the northeast of the bay, reaching the estuary of Loushan River. Then it turned to the west, passing through the nearshore waters at the north of the bay to the westernmost waters at the northwest of the bay and arriving at the estuary of the Dagu River. After that, turning southward and passing the inshore waters at the west of the bay, the main sea current reached the bay mouth waters (Figure 2). Therefore, the main sea current carried high Pb content into Jiaozhou Bay, surrounding the nearshore waters around the bay.

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

The content of the substance changed during its migration. In the waters of Jiaozhou Bay, Pb content 37.53μg/L was derived from the main sea current in August. After entering the bay, the main sea current passed through the southeastern water body of Jiaozhou Bay (station 60) and the western water body of the bay mouth (station 53). According to the authors’ vertical water effect principle of substance, horizontal water effect principle of substance and water effect principle [6-8], horizontal change of substance content reveals the horizontal water loss effect. Moreover, changes of substance content in
the surface layer and the bottom layer discloses the sediment effect and dilution effect of vertical water. As a result, the horizontal and vertical migration of Pb content in the waters from southeast of the bay to west of the bay mouth were quantitatively studied by using the horizontal matter content change model and vertical matter content change model proposed by the authors.

4.2 Horizontal and Vertical Variations of Pb Content. Pb content 37.53μg/L in the surface waters of southeastern Jiaozhou Bay in August was derived from main sea current transport. In the waters of Jiaozhou Bay, Pb content decreased along the gradient under the action of tides and currents. However, when the current surrounded the inshore waters from the southeast of the bay to the west of the bay mouth, Pb content in surface water decreased significantly. At the same time, Pb content in the bottom water decreased significantly. It indicates that the main sea current carried a high Pb content of 37.53μg/L from the outside of bay to the inside of bay through bay mouth. Pb content reached the western waters of the bay mouth with the current circling around the coastal waters. During the current movement, with the substantial drop in Pb content in surface and bottom water, the absolutely horizontal loss amount of Pb in surface was 4.32μg/L and the absolutely horizontal loss amount of Pb content in the bottom layer was 5.29μg/L. It revealed that a part of the high Pb content transported to Jiaozhou Bay by the main sea current was left on the bottom of Jiaozhou Bay when the current left the bay.

In August, from the waters in the southeast of the bay to the waters in the west of the bay mouth, the horizontal loss amount of Pb content on the surface was relatively high, reaching 38.23%. Similarly, the horizontal loss amount of Pb content in the bottom layer was relatively high, reaching 28.01% (Figure 3). In southeastern waters of the bay, the vertical sediment amount of Pb content in the surface layer and bottom layer 40.14% was relatively high, while in western waters of the bay mouth, the vertical sediment amount of Pb content in the surface layer and bottom layer was relatively high, reaching 48.63% (Figure 3).

4.3 Horizontal Loss Amount. In August, from southeast of the bay passing through a circle of nearshore waters to the waters in the west of the bay mouth, the horizontal loss amount of Pb content in the surface layer was relatively high, reaching 38.23% (Table 5). Thus, a large amount of Pb content in the surface layer settled to the seabed here. As a result, during the horizontal migration of Pb surface content, nearly 40.00% of Pb content loss amount in the surface was left to the bottom of Jiaozhou Bay.

Meanwhile, the horizontal loss amount of Pb content in the bottom layer reached a relatively high
level of 28.01% from the waters in the southeast of the bay to those in the west of the bay mouth (Table 5). It indicates that there was a large amount of Pb content in the bottom layer settling to the sea floor here. In the process of horizontal migration of Pb content in the bottom layer, nearly 30.00% of Pb content loss amount in the surface was left to the bottom of Jiaozhou Bay.

Judging from these, in the surface water in August, the Pb content in the surface and bottom of the bay deposited to the bottom of the bay in large quantities after the main sea current passed through the inshore waters with high Pb content. During the horizontal migration of Pb content in the surface and bottom layers, the loss amount of Pb content in the surface and bottom layers reached almost 30.00% in a circle of nearshore water in Jiaozhou Bay, and the loss amount of Pb content in the surface layer even reached almost 40.00%. It revealed that the high Pb content in the surface layer could rapidly and continuously settle to the seafloor, leaving almost 30.00% of Pb content in the water in the seabed of Jiaozhou Bay.

4.4 Vertical Loss Amount. Pb content 37.53μg/L in Jiaozhou Bay was from the main sea current in August. The main sea current first entered the surface waters in the southeastern part of the bay. Then, it moved from the southeastern waters of the bay across a circle of nearshore waters to the western waters of the bay mouth. In the southeastern waters of the bay, the vertical sediment amount of Pb content in the surface and bottom waters 40.14% was relatively high. In western waters of the bay mouth in the meanwhile, the vertical sediment amount of Pb content in the surface and bottom layers 48.63% was relatively high.

It disclosed that the high Pb content transported by the main sea currents reached the southeastern waters of the bay first. The high Pb content in the surface layer could settle to the seabed rapidly and continuously, leading to a relatively high sediment amount 40.14% in the seabed. Then, passing through the nearshore waters in the bay, the main sea current reached the western waters of the bay. There was higher sediment amount 48.63% on the seabed, indicating that the vertical sediment of Pb content in the surface and bottom reaches a high value of 40.14 - 48.63% in the coastal waters within a circle of Jiaozhou Bay, and the high Pb content sediment accumulated in the seabed of Jiaozhou Bay.

To put it in a nutshell, in August, in the vertical migration process, the Pb content transported by the main sea current was relatively high. The vertical sediment amount of Pb content in the surface and bottom of the bay increased from 40.14% to 48.63%.

5. Conclusion
The horizontal loss amount, vertical diluted amount and vertical sediment amount of Pb in the surface layer and bottom layer were calculated and the model block diagram of the horizontal and vertical variation of Pb content was determined based on the horizontal substance content change model and vertical substance content change model proposed by the authors.

In the waters from the southeast of the bay to the west of the bay mouth in August, the absolutely horizontal loss amount of Pb content in surface layer was 4.32 - 5.29μg/L and the relatively horizontal loss amount was 28.01 - 38.23%. The absolutely vertical sediment amount of Pb content in the bottom layer was 6.61~7.58μg/L, and the relatively vertical sediment amount was 40.14~48.63%.

From the southeast of the bay to the west of the bay mouth, the main sea current carried a high Pb content of 37.53μg/L reaching the western waters of the bay mouth with a circle around the coastal waters. In this process, Pb content in surface and bottom water decreased significantly. The absolutely horizontal loss amount of Pb content in the surface layer was 4.32μg/L and that in the bottom layer was 5.29μg/L. It revealed the high Pb content transported to Jiaozhou Bay by the main current was left on the bottom of Jiaozhou Bay when the current went away.

From the southeast of the bay to the west of the bay mouth, a large amount of Pb content in the surface layer settled to the seabed. Thus, during the horizontal migration of Pb surface content, nearly 40.00% of Pb content loss amount in the surface was left at the bottom of Jiaozhou Bay.

Similarly, there is a large amount of Pb content in the bottom layer settling to the seabed at the same water area. As a result, during the horizontal migration of Pb bottom content, nearly 30.00% of Pb
content loss amount in the surface was left at the bottom of Jiaozhou Bay. The high Pb content transported by the main sea current reached the southeastern waters of the bay first. The Pb content in the surface layer could settle to the seabed rapidly and continuously, forming a high sediment amount of 40.14%. The main sea current then passed through the inshore waters of the bay to the waters in the west of the bay mouth. At this time, a higher sediment amount of 48.63% was obtained at the bottom of the sea. In that way, the vertical sediment amount of Pb content in the surface and bottom of a circle of nearshore water in Jiaozhou Bay reached a high value of 40.14~48.63%. High Pb content deposition accumulated at the bottom of Jiaozhou Bay.

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