Transfer Mechanism and Change Process of Matter Content in Jiaozhou Bay

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Abstract. Based on the survey data of Jiaozhou Bay in 1992, the changes of Pb content in the surface and bottom waters affected by the ocean current in the process of transportation in Jiaozhou Bay were studied, and the sedimentation process and mechanism of Pb content in the surface and bottom waters were determined. The time change process of sedimentation shows that: from May to October, 1) the Pb content transported by the ocean current from the main sea decided the Pb content change in the bottom water; 2) in August, under the carrying of a large number of plankton and suspended particulate matter, the Pb content transported by the ocean current and that in the surface and bottom water reached the maximum value in a year. According to the spatial change process of subsidence, the results show that in August and October, the inlet of the "Cangkou Channel", the outlet of the "Former Reef Channel" and the deep channel of the strait on the side of Xuejia Island all revealed narrower channel, accelerated current, and deep erosion, forming a deep channel. In such waters, a large amount of Pb content was deposited. On the basis of the sedimentation process in the center of the bay, the outer sea current carried a high content of Pb to surround the nearshore waters in the bay. In May, the main sea current did not affect the surface water in the center of Jiaozhou Bay, nor did it affect the bottom water in the center of Jiaozhou Bay. From May to October, the ocean current didn't affect the surface water in the center of Jiaozhou Bay, either, but it has brought a huge impact on the bottom water in the center of Jiaozhou Bay. In the transfer process of Pb content in the water body in the center of the bay, the authors put forward the transfer mechanism of the matter content in Jiaozhou Bay, and establish the block diagram of the modelwhich demonstrates the mechanism and the change process of the matter content transfer.

1 Introduction

There is already a large amount of Pb in Marine waters [1-6]. with the aid of the survey data about lead (Pb) in Jiaozhou Bay of in 1992, the authors researched the influence of current in the process of transportation on the change of Pb content in the surface and bottom waters of Jiaozhou Bay.

2 Waters and Methods of the Survey

2.1 Natural Environment of Jiaozhou Bay

Located between 120°04'-120°23'E, 35°58'-36°18'N, Jiaozhou Bay is a typical semi-closed bay with an area of about 446km^2 and an average water depth of about 7m.

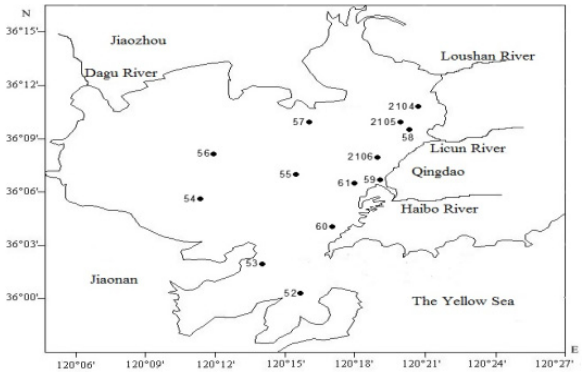

Figure 1 Investigation sites in Jiaozhou Bay

2.2 Materials and Methods

The Pb survey data of the Jiaozhou Bay water body in May, August and October of 1992 used in this research were supplied by North China Sea Environmental Monitoring Center. Water samples were collected from two stations 53, 54, 55 and 60 (Figure 1), under the authority of the national standard method in the Specification for Marine Monitoring (1991) [7].

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3 Results

3.1 Track of Current in Bay

Jiaozhou Bay, a shallow one, on the whole is a dustpan straight tilt, but slopes to the east in the bay area. Its water is shallow in the northwest but deep in the southeast. The main sea current with a high content of Pb enters Jiaozhou Bay through the bay mouth. In the bay, it follows along the coastal waters in the northeast to the bay head waters in the northeast of the bay and reaches the estuary of Loushan River. It then turns westward through the nearshore waters in the north of the bay. To the westernmost waters in the northwest of the bay, it arrives at the entrance of Dagu River; then it turns to the south, along the coastal waters in the west of the bay, reaching the waters at the bay mouth (Figure 2).In a word, the main sea current brings a high content of Pb into Jiaozhou Bay where the current surrounds the nearshore waters.

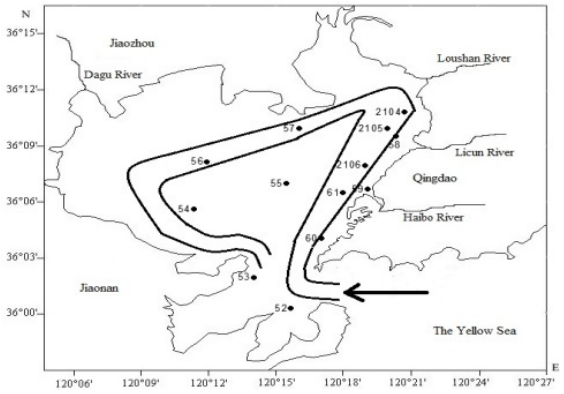

Figure 2 The flow path of the main sea current with a high content of Pb in Jiaozhou Bay (μg/L)

In May, the Pb content was 20.79μg/L from the main sea current; In August, 37.53μg/L from the main sea current. In October, 13.25μg/L from the main sea current. However, in the surface water in the center of Jiaozhou Bay, from May to October, the Pb content has no source.

In May, in the water body main sea current passed through lies station 60; in August, stations 60, 54 and 53; in October, stations 52 and 60.

In May, August and October, the water body through which the current did not pass lies station 55 at the center of bay.

3.2 Temporal Variation of the Water Body through Which the Main Sea Current Passed

In May, August and October, the main sea current passed through the southeastern water of Jiaozhou Bay where station 60 lies.

In the surface water in the southeast of Jiaozhou Bay, Pb content gradually increased from the relatively low value of 5.54μg/L in May. In August, it reached a maximum value of 11.30μg/L, and then began to decrease gradually. In October, it reached a higher value of 9.67μg/L. Therefore, the monthly changes of Pb content in the surface water from low to high were as follows: May, October, and August (Table 1).

Similarly, in the bottom water body of this water area, Pb content gradually increased from the high value of 10.43μg/L in May. In August, it reached a maximum of 18.88μg/L, and then began to decrease gradually. In October, it reached a higher value of 7.49μg/L. As a result, the monthly changes of Pb content in the bottom water from low to high were as follows: October, May and August (Table 1).

Table 1 Monthly changes of Pb content from low to high in different locations in the southeastern waters of the bay

Location	Monthly changes of Pb content from low to high		
Pb content transported by main sea current	October	May	Augu
Pb content in the surface layer	May	October	August
Pb content in the bottom layer	October	May	August

From May to October, in the southeastern water of Jiaozhou Bay, the monthly changes of Pb content in the surface layer from low to high were as follows: May, August, October; that of the Pb content at the bottom layer: October, May and August; that of the Pb content delivered by the main sea current: October, May and August. Therefore, the monthly variation of Pb content in the bottom layer is mainly determined by that of Pb content transported by the main sea current.

3.3 Spatial Variation of the Water Body through Which the Main Sea Current Passed

In August, the main sea current passed through stations 60, 54 and 53; in October, stations 52 and 60.

Station 60 lies in the southeastern waters of Jiaozhou Bay; station 54 in the southwestern waters; station 53 in the western waters of the bay mouth. In August, in the surface waters, the main sea current entered the bay through the water in the south of the bay mouth. The Pb content was 11.30μg/L when the current got to station 60 first. Then, the main sea current surrounded the nearshore waters of the bay and reached station 54 where the Pb content was 15.90μg/L. Finally, at station 53, Pb content was 6.98μg/L. In the bottom water area, the main sea current got into the bay through the bay mouth. It went to station 60 first, and the Pb content is 18.88μg/L, the highest value. Then, itmoved around the nearshore waters in a circle of the bay reaching station 54 where the Pb content is 7.85μg/L. Finally, it arrived at station 53 with 13.59μg/L Pb content.

In August, in the southeastern waters of Jiaozhou Bay, the Pb content in the bottom layer 18.88μg/L was much higher than that in the surface layer 11.30μg/L. Hence, there was a high precipitation of Pb content. Similarly, in the western waters of the bay mouth, Pb content in the bottom layer is 13.59μg/L, which is higher than that in the surface layer 6.98μg/L, leading to a high precipitation of Pb content.

In October, in the waters south of the bay mouth lies station 52; in the southeastern waters of Jiaozhou Bay lies station 60. In the surface waters, the outer sea current entered the bay through station 52 where Pb content was 13.25μg/L and reached station 60 where Pb content was

9.67μg/L.In the bottom water area, the outer sea current passed through the station 52, 15.38μg/L, and entered the bay at 60, 7.49μg/L.

In October, in the southern waters of the bay mouth, the Pb content in the bottom layer was 15.38μg/L which was higher than that in the surface layer13.25μg/L, proving a high Pb content sediment.

3.4 Water Body through without the Main Sea Current Did Not Pass

In May, August and October, the water body through which the main sea current did not pass was at station 55 at the center of the bay.

In the surface water at station 55, Pb content started to decrease from the low value of 7.37μg/L in May. It reached the minimum value of 5.53μg/L in August, and then began to increase. In October, it reached a higher value of 10.45μg/L. So, the monthly changes of Pb content in the surface layer from low to high were as follows: August, May and October (Table 2).

Nevertheless, in the bottom water body in the central waters of Jiaozhou Bay, Pb content started to increase from the low value of 4.20μg/L in May. In August, Pb content reached a high value of 24.39μg/L, and then began to decrease. In October, Pb content reached a high value of 11.63μg/L. Therefore, the monthly changes of Pb substrate content from low to high were as follows: May, October, and August (Table 2).

Table 2 changes of Pb content from low to high in different locations in the central waters of the bay

location	Monthly changes of Pb content from low to high		
Pb content transported by main sea current	October	May	August
Pb content in the surface layer	August	May	October
Pb content in the bottom layer	May	October	August

Then, presented from May to October, in the water in the center of Jiaozhou Bay, Pb content of surface layer changed from low to high in the following months: August, May and October; monthly changes of Pb content in the bottom layer from low to high were as follows: May, August, October; those in main sea current transport were as follows: October, May and August. It is shown that in the central waters of Jiaozhou Bay, the monthly changes of Pb content in the bottom layer were different from those in the surface layer and those in the ocean current.

According to the effect theory of vertical water body, horizontal water body and water body [12-14], Pb content rapidly and continuously sinks to the seabed. The accumulation and dilution effects were obtained by Pb content in the surface layer reaching the seabed. However, the monthly changes of Pb contents in the surface and bottom layers of the water in the center of Jiaozhou Bay revealed different results. The monthly changes of Pb content in the bottom layer were not impacted by those in the surface layer or thosein the main current transport. For this reason, it is necessary to further explore and study which the monthly changes of Pb content in the bottom layer were influenced by.

4 Discussion

4.1 Temporal Variation Process of Sedimentation

In May, August and October, the main sea current passed through the waters in the southeastern part of Jiaozhou Bay, at station 60.

In May, Pb content 20.79μg/L in the waters of Jiaozhou Bay was induced by the outer sea current. At this time, at station 60, in the surface water, Pb content was 5.54μg/L. The Pb content was 10.43μg/L in the bottom water. It is demonstrated that under the effect of vertical water body [10-12], Pb content sank to the sea floor in large quantities after passing through the water body.

In August, Pb content37.53μg/L in the waters of the bay came from the transportation of the main sea current. This was the highest level of current transport in a year when Pb content in surface water reached the highest value of 11.30μg/L at station 60; in the bottom water, Pb content reached a maximum of 18.88μg/L, which shows that under the vertical water effect [10-12], in summer, Marine organisms multiplied in large numbers and increased rapidly [8]. In addition, due to the propagation of plankton, the suspended particles formed colloids on the surface. As a result, they had the strongest power to absorb a large number of Pb ions, bring them into the bottom water and settle them to the sea floor.

In October, Pb content13.25 μg/L in the waters was also led by the main sea current () which was much lower. Similarly, at station 60, Pb content in surface water decreased to 9.67μg/L. In the bottom water, Pb content also dropped to 7.49μg/L. It reveals that due to the effect of vertical water [10-12], only part of Pb content sank to the seabed without the carrier of a great quantity of plankton and suspended particles.

From May to October, the time change process of sedimentation shows: 1) the Pb content change in the main sea current transport determined that in the bottom water. 2) In August, under the carrier of a large number of plankton and suspended particles, the Pb content transported by the ocean current and that in the surface and bottom waters both reached the maximum value in a year.

4.2 Spatial Variation Process of Sedimentation

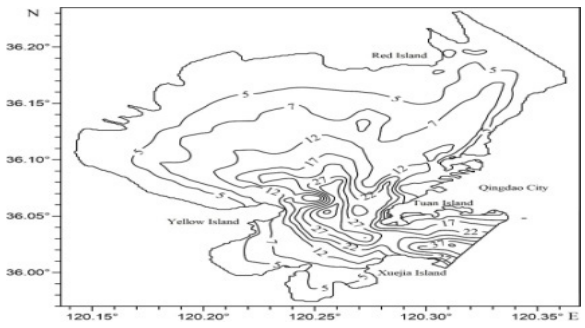

Figure 3 Water depth and topography of Jiaozhou Bay (m)

The main sea current passed through the water body at stations 60, 54 and 53 in August; and in October, it passed through the water body at stations 52 and 60.

In August, at station 60, there was a high precipitation of Pb content. The Pb content 18.88μg/L in the bottom layer was much higher than that 11.30μg/L in the surface layer. The waters in the southeastern part of Jiaozhou Bay, namely the waters in the eastern part of the bay mouth, are the water intake of "Cangkou Channel" (Figure 3) which have 10-meter and 15-meter isobath lines, forming an open gully, extending to the bayhead along the west-north direction, and are close to the coastal waters in the northeastern part of Jiaozhou Bay. It indicates that there is a large amount of Pb content deposition at the inlet of "Cangkou Channel".

At the same time, there was also a high precipitation of Pb content at station 53. The Pb content in the bottom layer was 13.59μg/L, which was much higher than that6.98μg/L in the surface layer. The west side of Jiaozhou Bay is the "Former Reef Channel". The 10-meter isobath extends from the estuary of Dagu River to southeast to the southwestern coastal waters of Jiaozhou Bay. The western part of the bay mouth is the outlet of "Former Reef Channel" (Figure 3). A depression extending from the south to the north of the southeastern part of Huang Island is also here. It is about 12 kilometers long and 1 kilometer wide, with a maximum depth of 51 meters. It is shown that around the top of the Yellow Island, the channel narrows and the current speeds up, scouring the deep "Former Reef Channel". Therefore, there is a large amount of Pb content deposition at the outlet of the "Former Reef Channel".

Similarly, in October, in the southern waters of the bay mouth of Jiaozhou Bay, there was a high precipitation of Pb content. The Pb content in the bottom layer was 15.38μg/L, which was higher than that13.25μg/L in the surface layer. In the direction from Tuan Island to the northern tip of Xuejia Island, the slope of the bayhead is large. The deep channel of the strait is inclined to the side near Xuejia Island, and the south bank of the slope is steep at this side, with an average slope of 30‰. The sea floor on the north shore is relatively gentle, with an average slope of 16‰ (Figure 3). The steep position of the southern waters of the bay mouth on the side of Xuejia Island is also inclined to the deep channel on the side of Xuejia Island where a large amount of Pb content deposition occurs.

In August and October, the water intake of the "Cangkou Channel", the outlet of the "Former Reef Channel" and the channel on the side of Xuejia Island all revealed narrow channel, accelerated flow of the current, and deep erosion, presenting a deep channel. In such waters, a large amount of Pb content was deposited.

4.3 Sedimentation Process in the Bay Center

In May, August and October, the water body through which the current did not pass is at station 55 at the center of the bay.

In the central waters of Jiaozhou Bay, the monthly changes of Pb content in the bottom layer are different from those in the surface layer and those in the main sea current. The monthly changes of Pb content in the surface and bottom layer of the water body in the center of Jiaozhou Bay revealed different results. The monthly changes of Pb content in the bottom layer were not affected by those of Pb content in the surface layer or those of Pb content transported by the main sea current.

Therefore, the authors should consider not only the main sea current entering Jiaozhou Bay with a high content of Pb, but also it surrounding the offshore waters with a high Pb content.

The main sea current passed through the bay mouth to the inside of the bay along a circle of nearshore waters (stations 52, 53, 54, 56, 57, 58, 59, 60, 61, 2104, 210 and 2106) of Jiaozhou Bay, carrying a high content of Pb there (Figure 2).

In May, the main sea current passing through the bay mouth brought a Pb high content zone with 5.54 - 37.90μg/L to a circle of nearshore waters in the bay. However, in the surface water body in the center of Jiaozhou Bay, Pb content was low 7.37μg/L, indicating that the main sea current did not influence the water body here. At the same time, Pb content in the bottom water body in the center of Jiaozhou Bay was even lower 4.20μg/L, which manifests that the outer sea current did not affect the water body here too.

In August, the main sea current continued to pass through the bay mouth, bringing a Pb high content zone with 6.98 - 37.53μg/L to a circle of coastal waters in the bay. Nevertheless, in the surface water body in the center of Jiaozhou Bay, Pb content decreased further, reaching a low value of 5.53μg/L, which indicates that from May to August, the main sea current did not impact the surface water body in the center of Jiaozhou Bay. On the contrary, in the bottom water body in the central waters, Pb content rose rapidly and reached the highest value of 24.39μg/L. It shows that from May to August, the main sea current has had a huge impact on the bottom water body in the central waters of Jiaozhou Bay.

In October, the Pb content transported by the main sea current began to decrease greatly, which brought a Pb high-content zone with 3.87 - 14.85μg/L to a circle of coastal waters in the bay through the bay mouth. But in the surface water body in the center of Jiaozhou Bay, Pb content began to rise, reaching a high value of 10.45μg/L. It reveals that from August to October, the main sea current has not affected the surface water body in the center of Jiaozhou Bay. In the bottom water body in the central waters of Jiaozhou Bay, Pb content started to drop significantly, and the Pb content reached a high value of 11.63μg/L. Quite the contrary. It manifests that from August to October, the main sea current has brought a great influence on the bottom water body in the central waters of Jiaozhou Bay.

4.4 Transfer Mechanism in the Bay Center

In May, the main sea current with a high content of Pb surrounded the nearshore waters of the bay, which did not affect the surface water in the center of Jiaozhou Bay, nor the bottom water in the center of the bay (Figure 4).

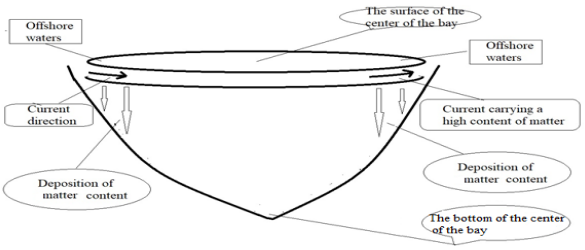

Figure 4 The main sea current with a high content of substance in Jiaozhou Bay

From May to August, the main sea current continued to take a high content of Pb to surround the nearshore waters in the bay. It did not affect the surface water in the center of Jiaozhou Bay, but it brought a huge impact on the bottom water in the center of Jiaozhou Bay.

From May to August, according to the effect theory of vertical water body, horizontal water body and water body, the effect of vertical water body caused the Pb content to change greatly after passing through the water body. Pb ions had strong hydrophilicity and were easy to combine with phytoplankton, zooplankton and suspended particulate in sea water. In summer, Marine organisms multiplied and increased rapidly. In addition, owing to the propagation of plankton, the suspended particles formed colloids on their surface. At this time, the absorption force was the strongest, which absorbed a large number of Pb ions and brought into the surface water. Thanks to the action of gravity and water flow, Pb content continuously sank to the seabed [1-6]. Jiaozhou Bay is on the whole a shallow dustpan - shaped straight tilt, while slopes east at the bay mouth. It is shallow in the northwest and deep in the southeast. The average depth of the bay is 7.0 meters. The maximum depth near the bay mouth is 64 meters and inside the bay 51 meters. Therefore, the Pb content, which was constantly settling to the seafloor, gradually migrated to the bottom of the center of the bay along the nearshore seafloor under the action of gravity and tidal currents. Thus, from May to August, in the coastal waters surrounding the bay, the Pb content settling to the sea floor migrated to the bottom of the center of the bay where a Pb high-content zone24.39μg/L was formed (Figure 5).

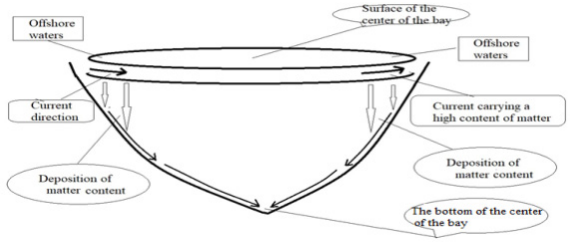

Figure 5 Sediment of the high content substance carried by the main sea current in Jiaozhou Bay

From August to October, the high content of Pb in a circle of coastal waters around the bay carried by the main sea current began to decrease significantly, which did not affect the surface water in the center of Jiaozhou Bay. However, the bottom water in the center of Jiaozhou Bay has been brought a great impact on. In the bottom of the center of the bay, Pb content has also greatly reduced, reaching 11.63μg/L.

From August to October, Pb content that had settled to the sea floor and moved to the bottom of the center of the bay, and accumulated here to form the zone with high Pb content 11.63 - 24.39μg/L. At this time, Pb content in the surface water body in the center of Jiaozhou Bay began to rise from the lowest value 5.53μg/L in August. To October, Pb content reached a high value 10.45μg/L. It reveals that the surface water in the center of the bay was affected by the bottom water. Moreover, when the high Pb content of the bottom water body in the center of the bay rose to the surface water body, the Pb content dropped to the high value of 10.45μg/L (Figure 6), confirming the rule of matter content migration proposed by the authors.

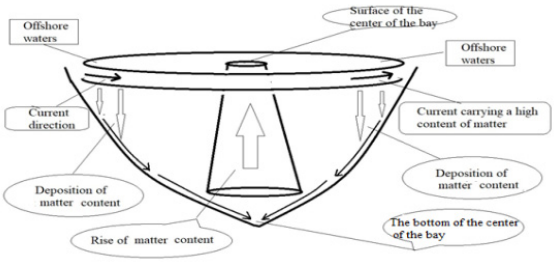

Figure 6 the subsidence and rise of high content of matter carried by the main sea current in Jiaozhou Bay

According the transfer process of Pb content in the water body at the center of the bay, the author proposed the transfer mechanism of the matter content in Jiaozhou Bay: 1) The main sea current carries a high content of substances around the nearshore waters of the bay. 2) In the nearshore waters around the bay, the high content of the substance that has settled to the sea floor moves to the bottom in the center of the bay, forming a high content area in the bottom in the center of the bay. 3) In the bottom water in the center of the bay, the high content of substances rises to the surface water, which increases the content of substances in the surface water. Therefore, block diagrams (Figure 4, 5, 6) are established to show the mechanism and change process of the transfer of matter content.

5 Conclusion

In May, August and October, the outer sea current passed through the waters of the southeastern part of Jiaozhou Bay. According to the time change process of sedimentation, the results show that from May to October: 1) the Pb content change from the main sea current transport determined that in the bottom water. 2) In August, under the carrier of a large number of plankton and suspended particles, the Pb content transported by the main sea current and that in the surface and bottom waters both reached the maximum value in a year.

In August, the main sea current passed through the waters of the southeastern part, the waters of the southwestern part and the waters of the western part of the bay. In October, the main sea current passed through the southern waters of the bay mouth and the southeastern waters of the bay. According to the spatial change process of settlement, the results show that in August and October, the water inlet of "Cangkou Waterway", the water outlet

of “Former Reef Channel" and the deep channel on the side of Xuejia Island revealed that channel got narrower, the velocity of ocean current accelerated, and the erosion got deep, presenting a deep channel. And in such waters, a great quantity of Pb content deposition occurred.

In May, August, and October, the water body through which the current did not pass is in the center of the bay. According to the sedimentation process in the center of the bay, the results indicate that in May, the main sea current with a high content of Pb surrounding the nearshore waters of the bay did not affect the surface water in the center of the bay, nor the bottom water in the center of the bay. From May to August, the main sea current continued to bring a high content of Pb to the nearshore waters around the bay, and it did not affect the surface water in the center of Jiaozhou Bay either. However, it had a huge impact on the bottom water in the center of Jiaozhou Bay. From May to August, in the nearshore waters surrounding the bay, Pb content settling to the sea floor migrated to the center of the bayhead, and a Pb high-content zone (24.39μg/L) was formed here. From August to October, the high content of Pb carried by the main sea current began to decrease significantly. Surrounding the nearshore waters in a circle, the main sea current did not affect the surface water in the center of Jiaozhou Bay. However, the bottom water in the center of Jiaozhou Bay has been brought a great impact on. Because in the center of the bay bottom, Pb content also greatly reduced, reaching 11.63μg/L.

Based on the transfer process of Pb content in the water body at the center of the bay, the authors put forward the transfer mechanism of the matter content in Jiaozhou Bay: 1) the offshore current carries a high content of the matter around the bay in a circle of nearshore waters. 2) in the nearshore waters around the bay, the high content of the settled substances migrate to the center of the bayhead, forming a high content area of the substances. 3) in the bottom water in the center of the bay, the high content of substances rises to the surface water, which increases the substances content in the surface water. A block diagram of the model is built to show the mechanism and change process of the matter content’s transfer.

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