Almost half of the Pb content leaving in the bottom of the sea

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Abstract. Using survey data of Pb in water body from southwest 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 August, the absolutely horizontal loss amount of Pb content in surface layer and bottom layer was 8.92μg/L, and the relatively horizontal loss amount of Pb content was 56.10%. The absolutely horizontal increase amount of Pb was 5.74μg/L in bottom layer, and the relatively horizontal increase amount was 42.23%. In the southwestern waters of the bay, the absolutely vertical diluted amount of Pb was 8.05μg/L in both surface and bottom layer, and the relatively vertical diluted amount was 50.62%. Meanwhile, in the western waters of bay mouth, Pb content in the surface and bottom layer had an absolutely vertical sediment amount of 6.61μg/L and a relatively vertical sediment amount of 48.63%. From the southwestern waters of the bay to the western waters of the bay mouth, a large amount of Pb content in the surface layer is deposited on the seabed. Therefore, during the horizontal migration of Pb content on the surface, the loss was nearly 60.00% when the current left the bay. However, Pb content in the bottom layer increased by 42.23% during its horizontal migration. Thus, the high Pb content in the surface layer is retained at the bottom of Jiaozhou Bay. When the current left the inside of the bay, Pb content in the surface layer was relatively high with the vertical diluted amount of Pb content in the surface layer and bottom layer reaching almost 50%. When the main sea current reached the western part of the bay mouth, the Pb content in the surface layer could settle on the seabed rapidly and continuously with a high sediment amount of 48.63%.

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. When the current left the bay, Pb content passed through the water from the surface and settledon the seabed byits own horizontal and vertical migration, [1-6].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 when the current leftJiaozhou Bay waters and illustrating that Pb content derived from main currents migrated from the surface of one water body to that of another and then settled to the bottom of the sea, to provide 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 JiaozhouBay

Jiaozhou Bay is located in the south of Shandong Peninsula, its geographical position is 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 446km2 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 in Qingdao urban area are seasonal rivers whose hydrological characteristics have obvious seasonal changes [7, 8].

2.2 Materials and Methods

The investigation data of Pb in Jiaozhou Bay in August 1992 were provided by The North China Sea

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Environmental Monitoring Center. Two stations were set up in the waters of Jiaozhou Bay to take water samples: Stations 54 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 Pb 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) [9].

Figure 1 Investigation stations in Jiaozhou Bay

3 Results

3.1 Waters from Southwest 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. Then it left the bay and reached the western waters of the bay mouth.

Station 54 lies in the southwestern 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 into Jiaozhou Bay. After that, the main sea current made a circle around the inshore waters of the bay. First, it reached station 54 where the Pb content was 15.90μg/L. Then the currentarrived at 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. Afterwards, the main sea current circled around the offshore waters. The main sea current first reached station 54 with the Pb content maximum value of 7.85μg/L, and then it 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 [10-13]. 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 southwest of Jiaozhou Bay to west of the bay mouth, it is assumed that the content of matter (M) in the southwest of the bay is A and that in the west of the bay mouth is B.

From the southwestern 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 southwest of the bay is $-D > 0$.

$$D = A - B,\ E = |A - B| / \max(A, B) \quad (1)$$

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

From the southwestern 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 southwest of the bay is $-d < 0$.

$$d = a - b,\ e = |a - b| / \max(a, b) \quad (2)$$

3.4 Formula of Vertical Substance Content Change

In the waters from southwest 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 $Vna > 0$. The relatively vertical diluted amount of substance content was Vnr. When $Vna < 0$, the absolutely vertical diluted amount of material content is $-Vna > 0$ and the relatively vertical diluted amount of substance content is Vnr.

$$Vna = A - a,\ Vnr = |A - a| / \max(A, a) \quad (3)$$

3.5 Horizontal Loss Amount of Surface Layer and Bottom Layer

We assume that movement from station 54 in the southwestern 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, in the surface waters of Jiaozhou Bay from the southwest of the bay to the west of the bay mouth, the Pb content changed greatly when the current left the bay

[10]. The horizontal loss amount of Pb content in the surface waters was calculated by formula (1) (Table 1).

Table 1 Horizontal loss amount of Pb content in the surface layer

From A to B	D	E	E
August	8.92	0.5610	56.10%

At the same time, in the bottom water of Jiaozhou Bay from station 54 to Station 53, the Pb content also changed greatly when the current left the bay [10]. With formula (2), the horizontal loss amount of Pb in the bottom water was calculated (Table 2).

Table 2 Horizontal loss amount of Pb content in the bottom layer

From A to B	d	e	e
August	-5.74	0.4223	42.23%

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 southwest of Jiaozhou Bay to the west of the bay mouth, Pb content in both surface and bottom waters changed greatly [11-13]. 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 southwestern bay	8.05	0.5062	50.62%
	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

In the waters of Jiaozhou Bay, Pb content 37.53μg/L was derived from the main sea current in August. The main sea current carried high Pb content into Jiaozhou Bay, surrounding the nearshore waters around the bay (Figure 2). The current passed through the water body in the southwest of the bay (station 54) and reached the water body in the west of the bay mouth (station 53). The horizontal and vertical migration of Pb content in the waters from southwest 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.

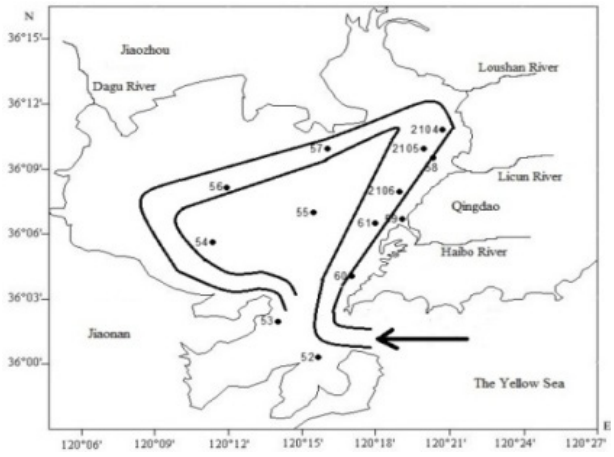

Figure 2 The flow path of the main sea current with a high content of Pb in Jiaozhou Bay (μg/L)

4.2 Horizontal and Vertical Variations of Pb Content

Pb content 37.53μg/L in the waters from southwestern Jiaozhou Bay to the west of the bay mouth 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 southwest 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 rose enormously. It indicates that from the southwest of the bay to the west of the bay mouth especially from the inside of bay to the bay mouth, when the current left the bay, the Pb content of surface water had a lot of settlement.

During the current movement, Pb content in surface water decreased significantly , and the absolutely horizontal loss amount was 8.92μg/L), while that in bottom water increased enormously, and the absolutely horizontal increase amount was 5.74μg/L. It reveals that some of the high Pb content transported to Jiaozhou Bay by the main sea current was left on the bottom when the current left the bay.

In August, from the waters in the southwest of the bay to the waters in the west of the bay mouth, the horizontal loss amount of Pb content in the surface layer reached a high level of 56.10% when the current left the bay. Similarly, the horizontal increment of Pb bottom layer content reached a high value of 42.23%. (Figure 3). In southwestern waters of the bay, the vertical diluted amount of Pb content in the surface layer and bottom layer was relatively high, reaching 50.62%. While in western waters of the bay mouth, the vertical sediment amount of Pb content 48.63% in the surface layer and bottom layer was relatively high (Figure 3).

In conclusion, in August, the absolutely horizontal loss amount of Pb in the surface layer was 8.92μg/L and the relatively horizontal loss amount was 56.10%.The absolutely horizontal increase amount of Pb content in the bottom layer was 5.74μg/L, and the relatively horizontal increase amount was 42.23%.In the southwestern waters of the bay, the Pb content in the bottom layer showed an

absolutely vertical diluted amount of 8.05μg/L and a relatively vertical diluted amount of 50.62%.Meantime, in the western waters of the bay mouth, the Pb content in the bottom layer had an absolute vertical accumulation of 6.61μg/L and a relative vertical accumulation of 48.63%.

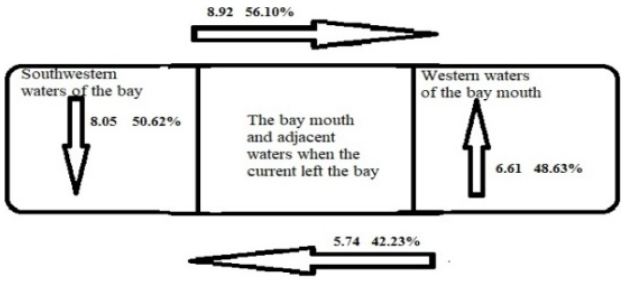

Figure 3 Model block diagram of horizontal and vertical changes of Pb content in August

4.3 Horizontal Loss Amount

In August, the horizontal loss amount of Pb content in the surface layer 56.10% reached a relatively high level (Table 1), nearly 60.00%, from the southwest of the bay to the west of the bay mouth. It indicates that when the current left the bay, a large amount of Pb content in the surface layer rapidly and continuously deposited to the bottom of Jiaozhou Bay.

Meanwhile, from the waters in the southwest of the bay to the waters in the west of the bay mouth, the horizontal increase amount of Pb content in the bottom layer 42.23% reached a relatively high level too (Table 2). The horizontal increase amount of nearly half indicates that during the horizontal migration of Pb content in the bottom layer, Pb content in the surface layer rapidly and continuously sank to the seabed, accumulating and leading to the increase of Pb content in the bottom layer.

Judging from these, in the surface water in August, the Pb content in the surface layer 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 and left the bay. As a result, the Pb content at the bottom of the sea floor increased greatly, reaching a relatively high level 42.23%. During the horizontal migration of Pb content in the surface and bottom layers, when the current left the bay, the loss amount of Pb content in the surface layer reached 56.10%, while the increase amount of Pb content in the bottom layer reached 42.23%. It revealed that the high Pb content in the surface layer could rapidly and continuously settle to the seabed when the current left Jiaozhou Bay, which caused a large amount of Pb content to be lost in the surface layer and increased in the bottom layer. The difference between the loss amount of Pb content in the surface layer and the increase amount of Pb content in the bottom layer was about 15.00%, indicating that during the horizontal migration of Pb content in the surface layer and the bottom layer, Pb content both in the surface layer and the bottom layer almost settled to the seabed and the loss amount of Pb content from the surface layer to bottom layer was only about 15.00% during the process.

4.4 Vertical Loss Amount

In Jiaozhou Bay, in August, the high Pb content transported by the main sea current first reached the waters in the southwest of the baywhere the vertical diluted amount of Pb content in the surface layer and bottom layer reached a high value of 50.62%. Then the main sea current left the inner waters and reached the waters west of the bay mouth where the vertical sediment amount of Pb content in the surface and bottom reached a high value of 48.63%. It revealed that Pb content in the surface layer was relatively high when the current left the bay, and the vertical diluted amount of Pb content in the surface layer and bottom layer reached almost half. When the main sea current reached the waters west of the bay mouth, the Pb content in the surface layer could settle rapidly and continuously to the seabed where a high accumulation of 48.63% of Pb content was obtained.

To put it in a nutshell, in August, in the vertical migration process, the vertical diluted amount of Pb content in surface and bottom layers 50.62%was changed to the vertical sediment amount of Pb content in surface and bottom layers 48.63% before and after the main sea current left the bay which shows that the Pb content transported by the ocean current had a large amount of deposition during the process of the main sea current left the bay, leaving almost half of the Pb content on the seabed.

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 August, the absolutely horizontal loss amount of Pb content in surface layer was 8.92μg/L and the relatively horizontal loss amount was 56.10%. The absolutely horizontal increase amount of Pb content in the bottom layer was 5.74μg/L, and the relatively horizontal increase amount was 42.23 %. In the waters southwest of the bay, the absolutely vertical diluted amount of Pb content both in surface layer and bottom layer was 8.05μg/L, and the relatively vertical diluted amount was 50.62%. While in the western waters of the bay mouth, the absolutely vertical sediment amount of Pb in the surface and bottom was 6.61μg/L, and the relative vertical sediment amount was 48.63%.

At the same time, in surface waters, the Pb content in the surface layer began to settle to the bottom in large quantities when the main sea current carries high Pb content and passes through a circle of inshore waters of the bay left, making the Pb content on bottom increase substantially to a relatively high level of 42.23%. During the horizontal migration of Pb content in the surface layer and bottom layer, the loss amount of Pb content in the surface layer reached 56.10% while the increase amount of Pb content in the bottom layer reached 42.23%. It discloses that the Pb content in the surface layer could rapidly and continuously settle to the seabed when the

current left the bay, causing a large loss amount of Pb content in the surface layer and a large increase in Pb content in the bottom layer.The difference between the loss amount of Pb content in the surface layer and the increase amount of Pb content in the bottom layer was about 15.00%, indicating that during the horizontal migration of Pb content in the surface layer and the bottom layer, Pb content in the surface layer and the bottom layer almost both settled to the seabed, and the loss of Pb content from the surface layer to the bottom layer was only about 15.00%.

In the meantime, in the process of vertical migration, before and after the main sea current left waters of the bay, vertical diluted amount of the Pb content of surface layer and the bottom layer50.62% was transformed into the vertical sediment amount of Pb content in the surface layer and the bottom layer 48.63%, which demonstrated that a large number of Pb content of current delivery settled, leaving almost half of the Pb content in the bottom of the sea.

References

1. Yang D F, Su C, Gao Z H, et al. Pb distribution and translocation in Jiaozhou Bay[J]. Chin. J. Oceanol. Limnol. 2008, 26(3): 296-299.
2. Yang Dongfang, Guo Junhui, Zhang Yinjiang, Ding Ziru, Bu Zhiguo. Pb distribution and sources in Jiaozhou Bay, East China [J]. Journal of Water Resource and Protection. 2011, 3(1): 41-49.
3. Dongfang Yang, Sixi Zhu, Fengyou Wang, Huazhong He and Xiuqing Yang. Distribution and source of plumbum in Jiaozhou Bay waters [J]. Applied Mechanics and Materials Vols.651-653. 2014, 1419-1422.
4. Dongfang Yang, Xiao Geng, Shengtao Chen, Zijun Xu and Wenlin Cui. Plumbum sink and transfer process in Jiaozhou Bay [J]. Applied Mechanics and Materials Vols.651-653. 2014, 1216-1219.
5. Dongfang Yang, Hongguang Ge, Fengmin Song, Chen Li and Bo Yang. The variation of the contents of Pb in surface waters in Jiaozhou Bay [J]. Applied Mechanics and Materials Vols.651-653. 2014, 1492-1495.
6. Dongfang Yang, Sixi Zhu, Fengyou Wang, Xiuqing Yang and Yunjie Wu. Study on the transport processes of Pb in Jiaozhou Bay [J]. Applied Mechanics and Materials Vols.651-653. 2014, 1292-1294.
7. Yang D F, Chen Y, Gao Z H, et al. SiLicon Limitation on primary production and its destiny in Jiaozhou Bay, China Ⅳ transect offshore the coast with estuaries [J]. Chin. J. OceanoL. LimnoL. 2005, 23(1): 72-90.
8. Dongfang Yang, Fan Wang, Zhenhui Gao, et al. Ecological Phenomena of Phytoplankton in Jiaozhou Bay [J]. Marine Science, 2004, 28 (6): 71-74.
9. State Oceanic Administration. The Specification for Marine Monitoring [Z]. Beijing: China Ocean Press, 1991.
10. Dongfang Yang, Zhenqing Miao, Huanzhi Xu, Yu Chen, Jingya Sun. Jiaozhou Bay water exchange time [J]. Marine Environmental Science, 2013, 32 (3): 373-380.
11. [11] Sixi Zhu and Yunjie Wu. Vertical water body effect of benzene hexachloride[J]. Proceedings of the 2015 international symposium on computers and informatics. 2015, 2655-2660.
12. Dongfang Yang, Fengyou Wang, Xiaoli Zhao, Yunjie Wu, Sixi Zhu. Horizontal waterbody effect of hexachlorocyclohexane [J]. Sustainable Energy and Enviroment Protection. 2015, 191-195.
13. Dongfang Yang, Fengyou Wang, Xiuqin Yang, Yunjie Wu and Sixi Zhu. Water's effect of benzene hexachloride [J]. Advances in Computer Science Research. 2015, 2352: 198-2