The Settlement of Pb Content Determined by Sources and Volume

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Abstract: According to the investigation materials in the waters of Jiaozhou Bay in 1991, this paper studies the vertical distribution and seasonal changes of Pb content in the surface and bottom waters of Jiaozhou Bay from the center of bay to the north of bay mouth, and determines the seasonal distribution, range of variations and the trend of horizontal distribution. The results show that in May and August, the Pb content in waters ranges within 4.27-31.66μg/L from the north of bay mouth to the center of the bay, from the surface layer to the bottom, conforming to the 2nd, 3rd and 4th quality standards of sea waters and corresponding to slight, moderate and severe contamination respectively. In May and August, the waters from the north bay mouth to the center of the bay reveal the rule that the Pb content in the surface and bottom layers from May to August showed the changing of low to high. Therefore, the Pb content in the surface and bottom waters from low to high is spring and summer in sequence. In the waters of north of bay mouth and bay center, the Pb content is high in the bottom waters when it in the surface is high; the Pb content is low in the bottom waters when it in the surface is low. In May and August, the horizontal and vertical distribution of Pb content shows the same trend in the waters of north of bay mouth and bay center. Therefore, from May to August, the different supply volume from the same source determines the different seasonal changes of Pb content in the waters of north of bay mouth. In the same period, different supply volume from various sources determine the different seasonal changes of Pb content in the waters of bay center. Thus, in different waters and periods, different sources of water bring different Pb content. And seasonal changes are different as well. Based on the mentioned above, the author gets the conclusion that different sources of Pb content and various volume determine the various seasonal changes in waters. In addition, the results in the waters from north of bay mouth to the center of bay indicate that in the temporal and spacial scale, Pb content quickly and continuously settles to the seabed, resulting in the consistency in the waters between the north of bay mouth and the bay center. The horizontal distribution trends of Pb content are same in the surface and bottom waters in various sources of water and any time. This consistency is because of the gravity effect of Pb content. Human activities discharge Pb to the waters and land, settled to the seabed through water body effect, resulting in all the contamination of Pb content in the ocean.

1. Introduction
As the rapid development in industries, Pb gets widespread application. Through the delivery of land, ocean and atmosphere, a large volume of Pb content is carried to the surface of water bodies relying on the ship terminals, direct surface runoff, and rivers, and then, migrated to the seabed through the vertical water body[1-6]. Hence, this paper studies the vertical distribution and seasonal changes of Pb
content in the surface and bottom waters from the north of bay mouth to the center of bay, based on the investigation materials about Pb content in Jiaozhou Bay in 1991, and determines the seasonal distribution, range of changing and horizontal distribution of Pb content in waters, and displays the seasonal changing process and vertical settlement process of Pb content, then and provides scientific basis for the consistency of vertical settlement and horizontal migration.

2. Investigated waters, materials and methods

2.1 Natural environment in Jiaozhou Bay
Jiaozhou Bay is located in the southern part of Shandong Peninsula between between 120°04′-120°23′E, 35°58′-36°18′N. Bounded by the connection of Tuandao and Xuejiadao, and connected to the Yellow Sea, with an area of approximate 446km² and average depth of 7m, it is a typical semi-enclosed bay. There are more than ten rivers entering into the Jiaozhou Bay, such as the Dagu River and Yang River, Haipo River, Licun River and Loushan River [7, 8].

2.2 Materials and methods
The investigation material of Pb content in the waters of Jiaozhou Bay in May and August in the year 1991 used in this study was provided by the Beihai Monitoring Center of the State Oceanic Administration. In May, 2 stations were set to take water samples: No.55 and No.60; and the same in August (Fig. 1). samples were taken three times in May and August in 1991, based on the depth of waters: from surface and bottom layers when the depth >10m; from the surface layer only when the depth <10m. The investigation method of Pb in Jiaozhou Bay is based on the national standard method which is recorded in the national The Specification for Marine Monitoring (1991)[9].

Fig.1 Investigation sites in Jiaozhou Bay

3. Results

3.1 Water bodies in surface and bottom layers
In May, the Pb content in the surface layer of waters from the north bay mouth to the center of bay is 4.27-16.00μg/L, and the corresponding Pb content in the bottom layer is 5.57-6.69μg/L. It indicates that the Pb contents in the whole waters from the surface layer to the bottom and from the north of bay mouth to the center of bay are all larger than 1.00μg/L, but smaller than 50.00μg/L, which conforming to the 2nd, 3rd, and 4th water quality standard, meaning slight, moderate, and severe pollution respectively.

In August, the Pb content in the surface layer is 17.85-31.66μg/L, and the corresponding Pb content in bottom is 17.02-27.22μg/L, which indicates that the Pb contents in the surface and bottom of the whole waters from the north of bay mouth to the center of bay are all larger than 10.00μg/L, but smaller than 50.00μg/L, conforming to the 4th water quality standard, severe pollution level.

As a conclusion, the Pb content ranges in 4.27-31.66μg/L in the waters from the north of bay mouth to the center of bay, from the surface to the bottom, in May and August, conforming to the 2nd, 3rd, and 4th water quality standard, slight, moderate, and severe pollution levels correspondingly.
3.2 Seasonal distribution in the surface
In May, the Pb content ranges 4.27-16.00μg/L in the surface water bodies from the north of bay mouth to the center of bay. In August, 17.85-31.66μg/L. This indicates that the Pb content in the surface has large changes, within 4.27-31.66μg/L. The surface content of Pb is from low to high in May and August. Therefore, the surface content of Pb from low to high in seasons is from spring to summer.

3.3 Seasonal distribution in the bottom
In May, the Pb content ranges 5.57-6.69μg/L in the bottom water bodies from the north of bay mouth to the center of bay. In August, 17.02-27.22μg/L. This indicates that the Pb content in the bottom also has large changes, within 5.57-27.22μg/L. The bottom content of Pb is from low to high in May and August. Therefore, the bottom content of Pb from low to high in seasons is from spring to summer.

3.4 Variation ranges in surface and bottom layers
In the waters of Jiaozhou Bay from the north bay mouth to the center of bay, the surface content of Pb in May is at a lower level, 4.27-16.00μg/L, and corresponding bottom content is at a lower level as well, 5.57-6.69μg/L. In August, the surface content of Pb is at a high level, 17.85-31.66μg/L, and the bottom content is also high in the level of 17.02-27.22μg/L. Meanwhile, the range of surface content variation 11.73-13.81μg/L is larger than the bottom content 1.12-10.10μg/L, with almost the same variation. Hence, when the surface content of Pb is high, the bottom content is high; when the surface content of Pb is low, the bottom content is also low. In May and August, Pb content loses much in all surface and bottom waters.

3.5 Horizontal distribution in surface and bottom layers
In May, from station 60 in the northern waters of bay mouth to station 55 in the waters of the bay center, the Pb content decreased along the gradient from 16.00 μg/L to 4.27 μg/L in the surface layer. The Pb content decreased along the gradient from 6.69 μg/L to 5.57 μg/L at the bottom layer. This indicates that the horizontal distribution trend of the surface and the bottom layer is consistent.

In August, from station 60 in the northern waters of bay mouth to station 55 in the waters of the bay center, the Pb content decreased along the gradient from 31.66μg/L to 17.85μg/L in the surface layer. The Pb content decreased along the gradient from 27.22μg/L to 17.02μg/L at the bottom layer. This indicates that the horizontal distribution trend of the surface and the bottom layer is consistent.

In May and August, the horizontal distribution of surface content of Pb in the waters of Jiaozhou Bay from the north of the bay mouth to the center of the bay is consistent with the horizontal distribution of the bottom layer.

4. Discussion
4.1 Settlement process
Undergone the effect of vertical water bodies [10-12], the Pb content has changed greatly after passing through the water body. Pb ions are highly hydrophilic, and easily combined with phytoplankton and floating particles in seawater. In summer, marine organisms multiply and the number increases rapidly [8]. Due to the breeding activities of plankton, the surface of suspended particles forms a colloid. At this time, the adsorption force is the strongest, and a large amount of Pb ions are adsorbed and brought to the surface water body. Meanwhile, because of the effects of gravity and water stream, Pb continuously settles to the seabed [1-6]. Therefore, the content of Pb continuously settles from the surface water to the seabed, presenting the sedimentation and migration process.

4.2 Seasonal changing process in the north of bay mouth
In May and in the surface waters in the north of Jiaozhou Bay, the Pb content changes from a higher value of 16.00 μg/L, then begins to rise and gradually increased. By August, the Pb content reaches a higher value of 31.66 μg/L. Thus, the surface content of Pb changes from low to high in seasons:
In spring and summer, in the surface waters in the north of bay mouth, the Pb content is carried from the ship wharf, and the Pb content is relatively high, so the Pb content in spring is relatively high. In the summer, carried from the ship wharf, the Pb content is higher, so the Pb content in summer is higher. This indicates that Pb ions are adsorbed higher in the surface waters in the northern waters of Jiaozhou Bay. On the surface of the suspended particles, Pb continuously settles to the bottom of the sea under the effects of gravity and water stream, according to the effect theory of vertical water body, horizontal water body and water bodies [10-12], Pb content rapidly and continuously settles to the seabed, and obtains cumulative effect and dilution effect, showing that the Pb content in the bottom changes from low to high is from spring to summer. Therefore, in the bottom water body in the north bay mouth, the Pb content changes from a high value of 6.69μg/L, then begins to rise and gradually increased in May. By August, the Pb content reaches a higher value of 27.22μg/L. Thus, the bottom content of Pb changes from low to high seasons: spring, summer.

Therefore, from May to August and from spring to summer, in the surface waters of the north bay mouth, the Pb content in the surface and bottom layers changes from low to high.

### 4.3 Seasonal changing process in the center of bay

In the surface water of the center of Jiaozhou Bay, the Pb content changes from a low value of 4.27μg/L, then begins to rise and gradually increases in May. By August, the Pb content reaches a higher value of 17.85μg/L. Thus, the surface content of Pb changes from low to high in seasons, from spring to summer.

In the spring, the source of Pb is from Haipo River, and its Pb content is 16.04μg/L. When it affects the center of the bay, the Pb content changes to a relatively low level, so the Pb content is relatively low in the spring. In the summer, the source of Pb content is from surface runoff, and its Pb content is 30.47μg/L. The content of Pb is relatively high, so the Pb content in summer is relatively high. This indicates that in the surface water of the central bay, since Pb ions are adsorbed on the surface of a large number of suspended particles, Pb continuously settles to the seabed under the effects of gravity and water stream. According to the effect theory of vertical water body, horizontal water body and water bodies [12-14], Pb content rapidly and continuously settles to the seabed, and the surface content of Pb obtains cumulative effect and dilution effect, which shows from spring to summer, the bottom content of Pb changes from low to high. Therefore, in the bottom water body of center bay, the Pb content changes from a low value of 5.57μg/L, then began to rise and gradually increased in May. By August, the Pb content reaches a high value of 17.02μg/L. Thus, the bottom content of Pb changes from low to high seasons from spring to summer.

Therefore, from May to August, in the surface waters of the center bay, the seasonal and low-to-high Pb content changes from spring to summer.

### 4.4 Seasonal changing mechanism

In spring and in the surface waters in the north of bay mouth, the Pb content is carried from the ship wharf, and the Pb content is relatively high, so the Pb content in spring is relatively high. In the summer, carried from the ship wharf, the Pb content is higher, so the Pb content in summer is higher. Therefore, from May to August, in the surface waters in the north of bay mouth, Pb content changes from low to high in spring to summer.

In the surface waters of the center of Jiaozhou Bay, in the spring, the Pb content is from the Haibo River, and the Pb content is relatively low, so the Pb content in spring is relatively low. In the summer, the Pb content comes from surface runoff and the Pb content is relatively high, so the Pb content in spring is relatively high. Therefore, from May to August, in the surface waters of the bay center, Pb content changes from low to high in spring to summer.

In the waters of the north of bay mouth, from May to August, the different supply from the same source determines the different seasonal variations of Pb content in the water. In the waters in the center of Jiaozhou Bay, from May to August, different supply from different sources determines the
different seasonal variations of Pb content in water. Therefore, in different waters of the bay and in different periods, the source of Pb content is different, and the Pb content in the water is different as well. Thus, the seasonal variation of Pb content in water bodies is different in different waters and different periods of the bay. Different sources and different amounts of Pb content determine different seasonal variations in Pb content in water.

4.5 Time settlement
On the time scale, in the waters of Jiaozhou Bay from the north of bay mouth to the center of the bay, the Pb contents in the surface and the bottom layers are basically the same in May and August. When the surface content of Pb is relatively low, the corresponding bottom content is relatively low; the surface layer content of Pb is relatively high, and the corresponding bottom content is relatively high. This shows that the Pb content is rapidly and continuously settled to the seabed, resulting in a consistent change in the Pb content in the surface and bottom layers. The surface content of Pb varies larger than the bottom layer, which demonstrates the author's theory of vertical, horizontal water bodies effect [10-12].

According to the principle of vertical, horizontal water bodies effect proposed by the author [10-12], the surface and bottom changes of Pb content reveal the cumulative effect and dilution effect of vertical water body. In May, the high content of surface Pb reaches the seabed and obtains the dilution effect. The low content of surface Pb reaches the seabed and gets the accumulated effect. In August, the high and low content of surface Pb reaches the seabed and obtains dilution effects.

Therefore, the surface content of Pb varies from 4.27 to 31.66 μg/L, which is greater than the range of 5.57 to 27.22 μg/L in the bottom, of which the maximum value in the surface content is larger than that of bottom and the minimum value in the surface content is smaller than that of bottom.

4.6 Space settlement
On a spatial scale, the Pb content in the surface waters in the north bay mouth is 16.00 μg/L from the ship's wharf in May. In August, the Pb content is carried by the ship terminals in the surface waters of the bay center, 31.66 μg / L. In the surface water body of the center of Jiaozhou Bay, the Pb content is 16.04 μg/L from the Haibo River in May. In August, the Pb content is 30.47 μg/L from the surface runoff. In May and August, the Pb content in the north bay mouth is higher than that in the center of bay and the sedimentation in the north is higher than that in the central waters as well.

In May and August, the horizontal distribution in the surface of Pb content in the waters of Jiaozhou Bay is consistent with the horizontal distribution of the bottom layer. This indicates that in the surface water of the north bay mouth, the Pb content decreases as the gradient from the north bay mouth to the central waters of the bay. Because Pb ions are adsorbed on the surface of a large number of suspended particles, the Pb content is relatively high. Under the effect of gravity and water stream, the Pb content is quickly settled to the seabed. Therefore, the Pb content is consistent in the horizontal distribution of the surface and the bottom layer.

Then, in any water area, at any time, from different sources, the Pb content is consistent in the horizontal distribution of the surface and bottom layer. The gravity characteristic of Pb content determines the consistency of the horizontal distribution of the substance content in the surface and the bottom layer.

5. Conclusion
In May and August, the Pb content in waters ranges within 4.27-31.66μg/L from the north of bay mouth to the center of the bay, from the surface layer to the bottom, conforming to the 2nd, 3rd and 4th quality standards of sea waters and corresponding to slight, moderate and severe contamination respectively.

From May to August, the Pb content in the surface and bottom waters of north of bay mouth and center of bay is from low to high. Therefore, from spring to summer, the content of Pb is from low to high in the water. In the north bay mouth and center of bay, when the surface Pb content is high, the
corresponding bottom content is high; when the surface Pb content is low, the corresponding bottom content is low as well. In May and August, the horizontal distribution of Pb content in the surface and bottom layers are consistent. All of these characteristics show that due to the breeding activities of plankton, the surface of suspended particles forms a colloid. At this time, the adsorption force is the strongest, and a large amount of Pb ions are adsorbed and brought to the surface water body. Meanwhile, because of the effects of gravity and water stream, Pb continuously settles to the seabed. Therefore, the content of Pb continuously settles from the surface water to the seabed, presenting the sedimentation and migration process.

In the surface waters of the north bay mouth, the Pb content is relatively high in the spring, and it is carried from the ship terminals. Therefore, the Pb content in spring is relatively high. In the summer, the Pb content becomes higher, so the Pb content in summer is higher. Therefore, from May to August, in the surface waters of the north bay mouth, the seasonal changes of Pb content from low-to-high happens from spring to summer.

In the surface waters of the center of bay, the Pb content is from the Haibo River in spring, and is relatively low, so the Pb content in spring is relatively low. In the summer, the Pb content comes from surface runoff and the Pb content is relatively high, so the Pb content in summer is relatively high. Therefore, from May to August, in the surface waters of the center of bay, the seasonal changes of Pb content from low-to-high happens from spring to summer.

In the waters in the north of bay mouth, from May to August, the different supply from the same source determines the different seasonal variations of Pb content in the water. In the waters of the center of bay, from May to August, different supply from different sources determines the different seasonal variations of Pb content in water. Therefore, in different waters of the bay and in different periods, the source of Pb content is different, and the Pb content in the waters is different. Thus, the seasonal variation of Pb content in water bodies is different in various waters and different periods. Thus, different sources and amounts of Pb content determine different seasonal variations in Pb content in waters.

On the time scale, in the waters of Jiaozhou Bay from the north of bay mouth to the center of the bay, the Pb contents in the surface and the bottom layers are basically the same in May and August. When the surface content of Pb is relatively low, the corresponding bottom content is relatively low; the surface layer content of Pb is relatively high, and the corresponding bottom content is relatively high. This shows that the Pb content is rapidly and continuously settled to the seabed, resulting in a consistent change in the Pb content in the surface and bottom layers.

On a spatial scale, Jiaozhou Bay is from the center of the bay to the waters of the bay mouth. In May and August, the horizontal distribution of surface Pb in the water body from the Bay Center to the northern part of the Bay of Jiaozhou Bay is consistent with the horizontal distribution of the bottom layer. Thus, in any water area, at any time, from different sources, the Pb content is consistent in the horizontal distribution of the surface and bottom layer. The gravity characteristics of the Pb content determine the consistency of the horizontal distribution of the substance content in the surface and the bottom layer.

On the spatial scale, in May and August, the horizontal distribution in the surface of Pb content in the waters of Jiaozhou Bay is consistent with the horizontal distribution of the bottom layer. Then, in any water area, at any time, from different sources, the Pb content is consistent in the horizontal distribution of the surface and bottom layer. The gravity characteristic of Pb content determines the consistency of the horizontal distribution of the substance content in the surface and the bottom layer.

In May and August, the waters from the north of bay mouth to central bay, from surface to the bottom, are polluted slightly, moderately and severely. Hence, human activities discharge Pb content to the land and waters, and to the seabed through the settlement effect of water body, resulting in Pb pollution in all the oceanic waters.

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