Variations of Pb Content in the Bottom Waters of the Jiaozhou Bay from the South of the Bay Mouth to the Central Bay Area

Dongfang Yang¹,², *, Danfeng Yang³, Hong Zhu¹, Weifeng Ling¹, and Haixia Li¹
¹Accountancy School, Xijing University, Xi’an 710123, China
²North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China
³The Fu Foundation School of Engineering and Applied Science, Columbia University, 10025, USA.
*dfyang_dfyang@126.com

Abstract: According to research data of the Jiaozhou Bay waters in 1992, current variation and horizontal distribution of Pb content in the bottom waters of the Jiaozhou Bay from the south of the bay mouth to the center of the bay were studied. The results show that in May, August, and October, Pb content in the Jiaozhou Bay water ranges from 4.20 to 24.39μg/L, which is in line with the national Class II, Class III, and Class IV seawater quality standards. This result indicates that in May, August and October, in the studied waters, the water quality was slightly, moderately and heavily polluted by Pb content, further revealing that under the effect of vertical water bodies, the bottom waters from the south of the bay mouth to the southeast of the bay, to the center and the southwest of the bay have been severely polluted by human discharge of Pb content. In addition, in the bottom waters of the Jiaozhou Bay from the south of the bay mouth to the center of the bay, Pb content showed high settlement: in May, the southeastern waters; in August, in the central waters; in October, in the southern waters. Therefore, the lead content of Jiaozhou Bay in different months and different places showed high deposition.

1. Introduction
Through the transportation of rivers, surface runoffs, and ship docks, the lead (Pb) content has been transporting to the ocean for many years, resulting in changes in the content of Pb in marine water bodies [1-6]. Pb content passes through the water body from the surface to the bottom. It has undergone the effect of vertical water bodies, showing the changes of Pb content in the bottom waters of Jiaozhou Bay from the south of the bay mouth to the center of the bay. Therefore, according to the research data of Jiaozhou Bay in 1992, bottom waters of Jiaozhou Bay from the south of the mouth to the central bay were studied to determine the size, distribution and subsidence area of Pb content, suggesting the current status and distribution characteristics of Pb and providing a scientific basis for the study of the existence and migration process.

2. Waters, Materials, and Methods of Investigation
2.1 Natural Environment of Jiaozhou Bay. Jiaozhou Bay is a semi-closed bay between 120°04' - 120°23'E, 35°58' - 36°18'N with the boundary between Tuan Island and Xuejia Island, facing toward with The Yellow Sea. The bay presented an area of about 446km² and an average water depth of about
7m. flowing into the sea in Jiaozhou Bay, Dagu River, Haibo River, Licun River, and Loushan River around the bay are seasonal rivers and their hydrological characteristics have obvious seasonal changes [7, 8].

2.2 Materials and Methods. Data of Pb in Jiaozhou Bay waters adopted in this research in May, August, and October 1992 were contributed by the North Sea Monitoring Center of the State Oceanic Administration. In May, two water sampling stations were decided in Jiaozhou Bay waters: stations 55 and 60; in August, four water sampling stations were set: stations 53, 54, 55, and 60; And in October, three water sampling stations: stations 52, 55 and 60 (Figure 1). Samples were got three times in May, August, and October 1992, according to water depth (surface layer and gulf bottom were got when >10m and only surface layer was got when <10m). The Pb method, which was included in the National Marine Monitoring Code (1991) [9], was carried out in accordance with the national standard method.

3. Results

3.1 Pb Content in the Bottom. During the three months of study, in the bottom waters of the Jiaozhou Bay from the center of the bay to the northern part of the bay mouth, Pb content varied from 4.20 to 24.39μg/L, which was in line with the national Class III seawater quality standard (10.00μg/L ) and Class IV seawater (50.00μg/L). In May, Pb content ranged from 4.20 to 10.43μg/L, which was in accordance with Class II, III, and IV standards. In August, Pb content is in the range of 7.85 to 24.39μg/L, which fits the national water quality standards Class III and Class IV. And in October, Pb content ranged from 7.49 to 15.38μg/L, in line with Class III and Class IV national water quality standards. In conclusion, during the three months described above, Pb content in the water body of Jiaozhou Bay ranged from 4.20 to 24.39μg/L, in accordance with the national Class II, Class III, and Class IV seawater quality standards. This result indicates that in terms of Pb content, in the studies water areas, water quality was slightly, moderately, and heavily polluted, respectively in May, August, and October (Table 1).
Table 1 The bottom water quality in Jiaozhou bay in May and August and October

|                        | May            | August         | October        |
|------------------------|----------------|----------------|----------------|
| Pb content in seawater/μg·L⁻¹ | 4.20-10.43    | 7.85-24.39     | 7.49-15.38     |
| National seawater standards | Class II, III, and IV | Class III and Class IV | Class III and Class IV |

3.2 Horizontal Distribution of Pb in the Gulf Bottom. In May, in Jiaozhou Bay, the bottom waters from the southeast to the center of the bay. The waters in the southeast at station 60, Pb content reached a high level of 10.43μg/L and a high content area of Pb was formed centering the southeast with a series of parallel lines of different gradients. Pb content decreased from 10.43μg/L in the high content area toward the north along the gradient to 4.20μg/L in the center of the bay.

Similarly, in August, the bottom waters from the center of the bay to the southwest. In the center of the bay, station 55, Pb content was relatively high at 24.39μg/L. The central waters of the bay formed a high Pb content area, following a series of semi-circular lines with different gradients. And Pb content lowered from 24.39μg/L in the high content area with the gradient to 7.85μg/L in the southwest (Figure 2).

![Figure 2 Pb content distribution at the bottom in Jiaozhou Bay in August(μg/L)](image)

Finally, in October, at station 52, where the bottom waters from the south of the bay mouth to the southeast of the bay were sampled, Pb content reached 15.38μg/L. Parallel lines with different gradients were formed with a high Pb content area centering on the southern waters of bay mouth. Pb decreased from 15.38μg/L toward the north along the gradient to 7.49μg/L in the waters in the southeast (Figure 3).
4. Discussion

4.1 Water Quality. In the waters of Jiaozhou Bay, Pb content comes from four main transportation: offshore currents, ship terminals, surface runoffs, and rivers. Pb first came to the surface of the water and passing through the water body to the bottom, where it has undergone the effect of vertical water. Therefore, the changing process of Pb in the bottom waters is shown.

In May, August and October, Pb content transported from the offshore current was 13.25 - 37.53μg/L in the bay mouth waters of Jiaozhou Bay. And the bottom water area from the southern part of the bay mouth to the center of the bay varies from 4.20 to 24.39μg/L, which meets the national seawater quality standards of Class II, Class III, and Class IV. This indicating slight, moderate, and heavy Pb respectively in May, August, and October in the studied area.

In May, in the bottom waters, Pb in Jiaozhou Bay ranged from 4.20 to 10.43μg/L, suggesting that the waters were slightly, moderately, and heavily polluted. In the bottom waters of Jiaozhou Bay, from the southeast to the central waters, Pb abated from higher than 10.00μg/L, higher than 5.00μg/L, and further lower than 5.00μg/L, indicating that water quality from the southeast to the center has reduced from Class IV to Class III, and further to Class II, and The pollution has been declined from heavy to moderate, and then to light.

In August, Pb level is at 7.85 to 24.39μg/L in the bottom waters and the waters were moderately and heavily polluted. From the center of the bay to the southwest, Pb content decreased from more than 10.00μg/L to less than 10.00μg/L, showing that water quality has been lowered from meeting the standards of Class IV to Class III. Consequently, water quality has been reduced from severe pollution to moderate.

In October, Pb of the studied area ranged from 7.49 to 15.38μg/L, showing moderate to severe pollution. In the bottom waters, content of Pb decreased from more than 10.00μg/L to less than 10.00μg/L from the south of the bay mouth to the southeast indicating water quality has reduced from Class IV to Class III. Water quality, in turn, reduced from severe pollution to moderate. In the bottom waters, the content of Pb has always been higher than 10.00μg/L, meeting only Class IV standards and suffering severe pollution.
4.2 Sedimentation Areas. In Jiaozhou Bay, since seawater in the bay constantly exchanges with the offshore waters through the bay mouth, the concentration of the substance continuously decreases.

In May, in the bottom waters of the Jiaozhou Bay from southeast to center, Pb content ranged from 4.20 to 10.43μg/L, decreasing along the gradient. As a result, Pb content has a relatively high sedimentation rate at the southeast and a rather low rate in the center.

In August, bottom waters of the Jiaozhou Bay from the center to the southwest of the bay has a Pb range of 7.85 to 24.39μg/L, also decreasing along the gradient. It is shown that sedimentation rate in the central waters is relatively high and quite low in the southwestern areas.

In October, in the bottom waters from the south of the bay mouth to the center of the bay, Pb content ranged from 7.49 to 15.38μg/L, declining with a similar pattern as May and August. This result demonstrates that in the waters south of the bay mouth, Pb settlement rate is high, whereas in the waters southeast of the bay, the settlement rate is low.

4.3 Horizontal Migration Process. In May, the offshore current transported to the surface waters of the bay mouth, carrying Pb content of 20.79μg/L. The current flowed northeast along the nearshore and reached the southeast waters of the bay, where Pb content transported is 5.54μg/L. In this way, under the effect of vertical water [7-9], in the bottom waters of the southeast, Pb content sedimentation is high at 10.43μg/L. On the contrary, there were no transportation sources in the surface waters of the central waters. Thus, under the effect of vertical water bodies, Pb appeared in the bottom waters of the center with low sedimentation of 4.20μg/L.

In August, the offshore current was transported to the waters of the bay mouth, with a Pb content of 37.53μg/L. The current then continued from the nearshore to the northeast and arrived in the southeast waters. Pb content transported is 11.30μg/L. As a result, under the effect of vertical water bodies [7-9], in the bottom waters of the center of the bay appeared a high Pb content settlement of 24.39μg/L. And in the surface waters of the southwestern, no sources of transportation existed, so under the same effect [7-9], low sedimentation of Pb content was 7.85μg/L occurred in the bottom waters of the southwestern.

In October, Pb transported from offshore to the waters of the bay mouth was 13.25μg/L. The current continued northeast and reached the southeast of the bay, where Pb content with the current was 9.67μg/L. Under the effect of vertical water bodies, a high Pb settling of 15.38μg/L is shown in the bottom waters of the southern bay mouth. Whereas the low sedimentation of Pb content of 7.49μg/L appeared in the bottom waters of the southeastern bay.

5. Conclusion
In the three months of research, the range of the bottom waters in the Jiaozhou Bay from the south of bay mouth to the center areas ranged from 4.20 to 24.39μg/L, which is in line with the national water quality standards of Class II, Class III, and Class IV. This result indicates that in the studied areas, the water quality was slightly, moderately and heavily polluted by Pb content, revealing that under the effect of vertical water bodies, bottom waters from the south of the bay mouth to the southeast, the center, and the southwest of the bay have been seriously polluted by human discharge.

In May, in the bottom waters, Pb content was relatively high, and the water quality was slightly, moderately, and heavily polluted by Pb content, especially heavy pollution in the bottom waters of the southeast. In August, Pb content was high, and the water quality was moderately and severely polluted by Pb content, with the central areas facing the most pollution. And in October, Pb content was also high, and water quality was moderately and severely polluted, especially severe pollution in the south of the bay mouth.

In bottom waters from the south of the bay mouth to the bottom of the center of the bay, high settlement appeared in the southeast of the bay in May. In August, high settlement was in the central waters whereas, in October, it was in the southern waters of the bay mouth. Therefore, in the waters of Jiaozhou Bay, Pb content showed high settlement in different places in different months.
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