Surface Distribution and Sources of Pb content in the ocean current of Jiaozhou Bay

Dongfang Yang1,2,*, Dong Lin1, Longlei Zhang1, Qi Wang1, and Haixia Li1
1Accountancy School, XiJing University, Xi’an710123, China; 2North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China; *dfyang@shou.edu.cn

Abstract: According to the data on the investigation of Jiaozhou Bay in May, August and October, 1992, the Pb content and the horizontal distribution in the surface of Jiaozhou Bay were studied. The results show that in May, in the waters of Jiaozhou Bay, there were three Pb high content sources - open ocean current, ships and wharf, and Licun River. The open ocean current entered Jiaozhou Bay from the bay outside into the bay inside through the bay mouth with a high content of Pb. The Pb content in the mouth of the bay was 20.79 μg/L. In the bay, the ocean current moved forward the shore of the northeast and reached southeast waters of the bay, transporting 5.54 μg/L Pb content. Then, the ocean current continued to move along the nearshore to the northeast and reached the eastern nearshore waters of Jiaozhou Bay. Here, Pb content was transported via ships and wharf and was 16.34 μg/L. After that, the ocean current continued to move along the nearshore to the northeast and reached the waters in the northeast of the bay, with the Pb content 7.09 μg/L. The ocean current continued to move along the nearshore to the northeast and got the coastal waters near the mouth of the Licun River. Here, Pb content was transported via the Licun River and the Pb content was 37.90 μg/L. Afterwards, the ocean current continued to move along the shore to the northeast and reached the waters in the northeast of the bay, carrying 18.27 μg/L Pb content. Then, the ocean current turned westward along the near-shore direction and got the northern waters of the bay, where the Pb content transported via ocean current was 13.72 μg/L. The ocean current continued to run along the shore to the west and got to the westernmost waters in the northwest of the bay. The Pb content transported via the ocean current was 12.84 μg/L. After that, the ocean current turned southward along the near-shore and reached the waters in the southwest of the bay transporting 8.62 μg/L Pb content. At this moment, a low Pb content area of 7.37 μg/L appeared in the central waters of Jiaozhou Bay.

1. Introduction
With the China’s development, the heavy metal lead (Pb) has been widely used. However, through the production process of products containing Pb, people continuously emit Pb content forward to the land, ocean and atmosphere [1-6]. Therefore, the migration process and migration trajectory of Pb content have become the focus of research, which provides a scientific theoretical basis for the study on the sources, pollution degree and migration process of Pb in the water body of Jiaozhou Bay.

2. The waters and methods of investigation
2.1 Investigation waters. Jiaozhou Bay located at 120°04’ - 120°23’E and 35°58’ - 36°18’N, which looked like a typical semi-closed bay between Tuan Island and Xuejia Island, facing forward the Yellow Sea. Jiaozhou Bay has a large area of about 446 km² and showed about 7 m by the average water depth. Dagu River, Yanghe River
and Haibo River, Licun River and Loushan River, and so on flowed into the sea in Jiaozhou Bay, the estuaries of the rivers surrounded the Qingdao City. Moreover, These rivers presented the large runoff and sediment content with obvious seasonal change [7, 8].

2.2 Materials and methods. The North Sea Monitoring Center of the State Oceanic Administration showed the Pb survey data used in this study, the investigation of the data contributed to the Jiaozhou Bay water body in May, August and October 1992. We would pick up the water samples at 13 stations in the Jiaozhou Bay waters in May, August and October 1992. The stations included the stations from station 52 to station 61, and from station 2014 to station 2016 (Figure 1). We got the water samples by the water depth. If the water depth is more than 10 m, we would pick up the water samples from surface layer and bottom layer. If the water depth is less than 10 m, we would pick up them from only the surface layer. The method used during the investigation of Pb in Jiaozhou Bay water body abided by the national standard method included in the National Marine Monitoring Specification (1991) [9].

3. Results and Discussions

3.1 Pb Content Surface Distribution. In May, the Pb content at station 58 was the highest value of 37.90 μg/L in the coastal waters near the mouth of Licun River. The high Pb content area was formed centered on the coastal waters near the mouth of Licun River in Jiaozhou Bay, and the Pb content decreased from the highest value in the center along the gradient (Figure 2). At the station 61 in the eastern coastal waters of Jiaozhou Bay, the Pb content was 16.34 μg/L at the highest value, forming the high Pb content area centered on the eastern coastal waters and decreasing in all directions along the gradient from the high content 16.34 μg/L in the center (Figure 2). At the station 52 in the waters at the mouth of Jiaozhou Bay, the Pb content is the highest value of 20.79 μg/L. The high Pb content area was formed centered on the waters at the mouth of Jiaozhou Bay where the Pb content decreased in all directions along the gradient from the high content in the center (Figure 2). The low-value area appeared at the station 55 in the central waters of Jiaozhou Bay. The Pb content here was relatively low 7.37 μg/L (Figure 2).
In August, the highest Pb content was at station 52 in the mouth of Jiaozhou Bay. The high Pb content area was formed centered on the mouth of the bay where the Pb content decreased along the gradient from the highest value of 37.53 μg/L in the center (Figure 3). At station 54, station 56, station 57, station 58, station 59, station 60, station 61, station 2014, station 2015 and station 2016, with a circle of nearshore waters in the bay as the center, the high content area of Pb was formed. The content range of Pb in the water body is 11.30 - 27.44 μg/L (Figure 3). The low value area appeared at station 55 in the water area in the center of Jiaozhou Bay where the content of Pb was 5.53 μg/L and was relatively low (Figure 3).
3.2 Sources. In May, a high Pb content area was formed in the coastal waters near the mouth of Licun River in Jiaozhou Bay where the Pb content was relatively high 37.90 μg/L, indicating that the Pb content was from Licun River. In the eastern coastal waters of Jiaozhou Bay, a high Pb content area with 16.34 μg/L Pb content was formed, which manifested that the Pb content here was from ships and wharf. In addition, a high Pb content zone was formed in the mouth of Jiaozhou Bay, which demonstrated that the Pb content came from the open ocean current. And the Pb content was 20.79 μg/L.

In August, a high Pb content zone was formed in the mouth of Jiaozhou Bay. So, we can know that the Pb content came from the ocean current. The Pb content was 37.53 μg/L, which was relatively high.

In May, there were three main sources of Pb content in the waters of Jiaozhou Bay - ships and wharf, rivers and open ocean current. Pb content from the ships and wharf was 16.34 μg/L, from the rivers was 37.90 Pb/L, and from the open ocean current was 20.79 μg/L.

In August, there was only one main Pb content source in the waters of Jiaozhou Bay - open ocean current transport. The Pb content transported via ocean current was 37.53 μg/L.

3.3 Migration Process and Direction in May. At station 58 in the coastal waters near the mouth of Licun River in Jiaozhou Bay, Pb content reached the highest value of 37.90 μg/L, and the high Pb content zone was formed centered on the coastal waters. Along the nearshore to the northeast direction to station 2014, Pb content in the northeastern bay waters was 18.27 μg/L. Then, turn along the shore to the west to station 57. Pb content in the northern waters of the bay was 13.72 μg/L. Continue to move along the shore westward to station 56, Pb content was 12.84 μg/L in the northwest waters of the bay. After that, turn southward along the nearshore to station 54 where Pb content was 8.62 μg/L in the waters southwest of the bay (Figure 2). Therefore, it is believed that the high-content Pb transported via Licun river migrated along the coastal waters of Jiaozhou Bay with the ocean current. First, it migrated along the coastal direction to the northeast. Then, it turned and moved along the coastal direction to the west. Afterwards, it turned and migrated along the coastal direction to the south. Finally, it reached the waters on the west side of the mouth of the bay. In addition, with the high content of Pb transported via ocean current in the bay, the Pb content was continuously decreasing.

At station 61 in the eastern coastal waters of Jiaozhou Bay, the Pb content was 16.34 μg/L, the highest value. Centered on the eastern coastal waters, the high Pb content zone was formed. Along the nearshore to the northeast to station 2016, the Pb content in the waters in the northeast of the bay was 7.09 μg/L (Figure 2). Therefore, it is believed that the high-content Pb transported via the ships and wharf moves along the coastal waters of Jiaozhou Bay along with the ocean current. The direction of the ocean current is northeast, in which the ocean current migrates to the waters in the northeast of Jiaozhou Bay. In addition, with the high content of Pb transported via ocean current in the bay, the Pb content was continuously decreasing.

At station 52 at the mouth of Jiaozhou Bay, the Pb content was the highest value of 20.79 μg/L, forming the high Pb content zone centered on the waters at the bay mouth. Along the nearshore to the northeast to station 60 where the Pb content in the southeastern waters of the bay was 5.54 μg/L (Figure 2). Therefore, it is believed that the high-content Pb transported via open ocean current migrates along the estuary of Jiaozhou Bay along with the ocean current. The direction of the ocean current which moves to the southeastern waters of Jiaozhou Bay is northeast. What’s more, the Pb content is continuously decreasing with the high content of Pb transported via ocean current in the bay.

At station 55 in the central waters of Jiaozhou Bay, the Pb content in the water body was 7.37 μg/L. The Pb content is relatively low (Figure 2), indicating that the central waters of Jiaozhou Bay have always been in the low Pb content area.

3.4 Migration Process and Direction in August. The Pb content was 37.53 μg/L at the highest at station 52 in the waters at the mouth of Jiaozhou Bay, forming the high Pb content area centered on the bay mouth area. The ocean current passed from the outside of the bay to the inside of the bay through the mouth along station 54, station 56, station 57, station 58, station 59, station 60, station 61, station 2014 station 2015 and station 2016 in the coastal waters, bringing a high Pb content zone of 11.30 - 27.44 μg/L to the coastal waters. Therefore, we might say that the high content Pb carried via open ocean current migrates along the coastal waters of Jiaozhou Bay with the ocean current, leaving high content of Pb.

At station 55 in the central waters of Jiaozhou Bay, the Pb content in the water body was relatively low 5.53 μg/L (Figure 3), showing that the central waters of Jiaozhou Bay were always in the low Pb content area.

4. Conclusion
In May, a high Pb content zone of 37.90 μg/L was formed in the coastal waters near the mouth of Licun River in
Jiaozhou Bay. And in the eastern coastal waters of Jiaozhou Bay, a high Pb content area of 16.34 μg/L was formed. The high Pb content zone of 20.79 μg/L was formed in the mouth of Jiaozhou Bay. However, in the central waters of Jiaozhou Bay, there was a low Pb content area of 7.37 μg/L where the Pb content was relatively low.

In August, a high Pb content zone of 37.53 μg/L was formed in the Jiaozhou Bay mouth. And a high Pb content zone of 11.30 - 27.44 μg/L was formed in a circle of coastal waters in the bay. But in the central waters of Jiaozhou Bay, a low Pb content area appeared. The Pb content here was 5.53 μg/L, which was relatively low.

In May, there were three main sources of Pb content in the waters of Jiaozhou Bay. They were transportation via ships and wharf, rivers and open ocean current. Pb content from ships and wharf transportation, river transportation and open ocean current transportation was 16.34 μg/L, 37.90 μg/L, and 20.79 μg/L respectively. Nevertheless, in August, there was just one main source - open ocean current transport. The Pb content transported via open ocean current was 37.53 μg/L.

References
[1] Dongfang Yang, Sixi Zhu, Xiaoli Zhao, Yunjie Wu, Fengyou Wang. Environmental conditions of Jiaozhou Bay, 1981[J]. Advances in Engineering Research. 2015, 40: 770-775.
[2] Dongfang Yang, Junhui Guo, Yinjiang Zhang, Ziru Ding, Zhiguo Bu. Pb distribution and sources in Jiaozhou Bay, East China[J]. Journal of Water Resource and Protection. 2011, 3(1): 41-49.
[3] Dongfang Yang, Zhengming Miao, Yu Chen, Qiang Shi, Huanzhi Xu. Human discharge and phytoplankton takeup for the atmospheric carbon balance[J]. Atmospheric and Climate Sciences, 2011, 1(4): 189-196.
[4] Dongfang Yang, Zhengming Miao, Qiang Shi, Yu Chen, Guoguang Chen. Silicon limitation on primary production and its destiny in Jiaozhou Bay, China VIII: The variation of atmospheric carbon determined by both phytoplankton and human[J]. Chin. J. Oceanol. Limnol. 2010, 28(2): 416-425.
[5] Dongfang Yang, Chang Su, Zhenhui Gao, Peiyang Sun and Lixin Cao. Pb distribution and translocation in Jiaozhou Bay[J]. Chin. J. Oceanol. Limnol. 2008, 26(3): 296-299.
[6] Dongfang Yang, Jianping Wu, Shengtao Chen and Qing Lu. The teleconnection between marine silicon supply and desertification in China[J]. Chin. J. Oceanol. Limnol. 2007, 25(1): 116-122.
[7] Yang Dongfang, Zhang Jing, Lu Jibin, Gao Zhenhui, Chen Yu. Examination of Silicate Limitation of Primary Production in the Jiaozhou Bay, North China I. Silicate Being a Limiting Factor of Phytoplankton Primary Production[J]. Chin. J. Oceanol. Limnol. 2002, 20(3): 208-225.
[8] Dongfang Yang, Zhenhui Gao, Pei-gang Wang, Pei-yan Sun, Shuang Liu. Silicon limitation on primary production and its destiny in Jiaozhou Bay, China V. Silicon deficit process[J]. Chin. J. Oceanol. Limnol. 2005, 23(2): 169-175.
[9] State Oceanic Administration. Specifications on Ocean Monitoring [Z]. Beijing: China Ocean Press, 1991.