

PAPER • OPEN ACCESS

The Low Cadmium Content Discharged in Jiaozhou Bay

To cite this article: Dongfang Yang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **310** 042055

View the [article online](#) for updates and enhancements.

The Low Cadmium Content Discharged in Jiaozhou Bay

Dongfang Yang^{1,2,3,a}, Danfeng Yang⁴, Wenliang Tao^{1,2}, Bailing Fan^{1,2}, and Chunhua Su^{1,2}

¹Research Center for Karst Wetland Ecology, Guizhou Minzu University, Guizhou Guiyang, Guizhou Guiyang, China

²College of Chemistry and Environmental Science, Guizhou Minzu University, Shanghai, 550025, China

³North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China

⁴The Fu Foundation School of Engineering and Applied Science, Columbia University, 10025, USA.

adfyang_dfyang@126.com

Abstract: In May, August and October of 1991, the variation range of Cd content in Jiaozhou Bay was 0.06-0.58 µg/L, which meets the water quality standard of this kind of seawater. It indicated that in terms of Cd content, the water of Jiaozhou Bay was not polluted by Cd in May, August and October. There were four sources of Cd content in Jiaozhou Bay: river streams, ships and wharfs, atmospheric sedimentation and overland runoff. The Cd content from river streams was 0.38-0.55 µg/L, 0.48-0.58 µg/L from ships and wharfs, 0.40 µg/L from atmospheric sedimentation, and 0.52 µg/L from overland runoff. This showed that these four sources were not polluted by Cd content. The Cd content of human emissions mainly included land, ocean and atmosphere with an order of ocean > land > atmosphere. Besides, the Cd content of three emissions were less than 1.00 µg/L, which indicated that land, atmosphere and ocean were not impacted by Cd content. The transport passages of Cd content were different, whereas, the Cd content of marine waters was almost consistent, and Cd contents by three different transport were less than 0.20 µg/L. Finally, the modelling chart was further built to display the transport passages of Cd content, and disclose the transport of Cd content from human emissions to land, atmosphere and lastly ocean in a quantitative way.

1. Introduction

A large amount of waste water, exhaust gas and solid waste containing cadmium were discharged with the rapid development of industry. So people discharged Cd to land, atmosphere and finally ocean waters [1-7]. Thus, the study on its pollution and pollution source in coastal waters is beneficial for protecting marine environment and maintaining the sustainable development of ecology. According to the investigation in 1991, this paper analyzed Cd content, its horizontal distribution and source in Jiaozhou Bay, and studied the water quality, transport passage and value of Cd content, to provide scientifically theoretical basis for the study on source, pollution and transport process of Cd content in Jiaozhou Bay.



2. Investigation Waters, Materials and Method

2.1 Natural environment of Jiaozhou Bay

Jiaozhou Bay, located in southern Shandong Peninsula, is a typical semi-closed bay. The geographical location is 120°04'-120°23'E, 35°58'-36°18'N. Bounded by the line connecting Tuandao Cape and Xuejiadao Island, it connects with Yellow Sea, covering an area of about 446km², with the average depth of about 7m. There are dozens of rivers reaching the ocean in Jiaozhou Bay, among of which, the rivers with a larger volume of runoff and sand content include Dagu River, Yang River, Haibo River in Qingdao, Licun River, Loushan River and so on. These rivers are seasonal streams, and hydrological characteristics vary seasonally [12, 13].

2.2 Materials and method

The materials about Cd in Jiaozhou Bay waters in May, August and October of 1991 is provided by North China Sea Environment Monitoring Center, State Oceanic Administration. 13 sites were set in Jiaozhou Bay for sampling, including 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 2104, 2105 and 2106, shown in Figure 1. Samples were performed in May, August and October of 1991 respectively. According to the depth of water, sampling and survey are conducted (surface and bottom layers are sampled when the depth of water is more than 10m, but just surface layer when less than 10m). The survey on Cd of Jiaozhou Bay waters was in accordance with national standard method, which was included in The Specification for Marine Monitoring (1991) [14].

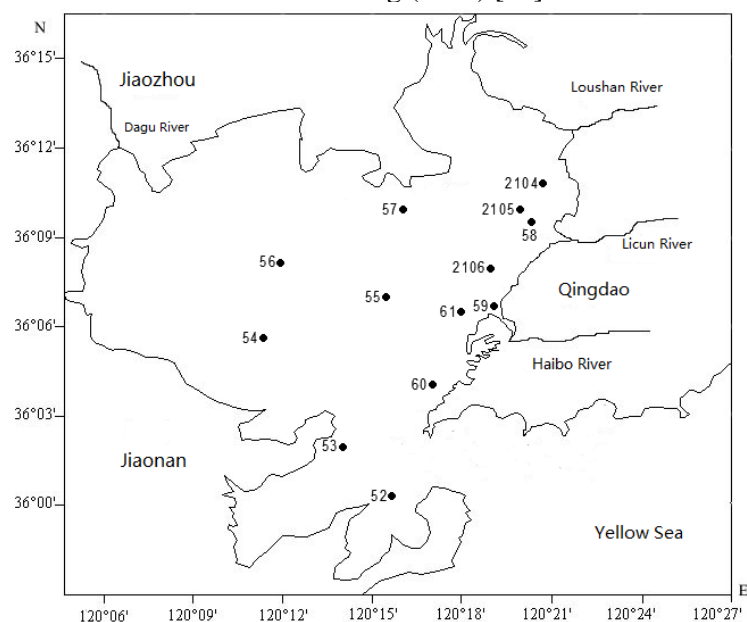


Fig. 1 Investigation sites in Jiaozhou Bay

3. Results

3.1 Content

In May, the variation range of Cd content in Jiaozhou Bay was 0.06-0.58μg/L, shown in Table 1. The high-value area was nearshore waters in estuary of Haibo River and eastern wharf waters, with a variation range of 0.49-0.58μg/L, which meets Case I Sea Water Quality Standard (1.00μg/L). Besides, in other waters of Jiaozhou Bay, such as northeastern bay, northern bay, bay center, northwestern bay and waters of bay mouth, the Cd contents were relatively lower, less than 0.25μg/L, and far lower than Case I Sea Water Quality Standard (1.00μg/L).

In August, the variation range of Cd content in Jiaozhou Bay was 0.12-0.40μg/L, shown in Table 1. The high-value area was waters of bay center of Jiaozhou Bay, and nearshore waters in estuary of

Licun River, with a variation range of 0.38-0.40 $\mu\text{g/L}$, which meets Case I Sea Water Quality Standard (1.00 $\mu\text{g/L}$). Besides, in other waters of Jiaozhou Bay, such as northern bay, western bay and waters of bay mouth, the Cd contents were relatively lower, less than 0.36 $\mu\text{g/L}$, and far lower than Case I Sea Water Quality Standard.

In October, the variation range of Cd content in Jiaozhou Bay was 0.17-0.55 $\mu\text{g/L}$, shown in Table 1. The high-value area was waters of estuary in Dagou River, northern nearshore waters and eastern wharf waters, with a variation range of 0.48-0.55 $\mu\text{g/L}$, which meets Case I Sea Water Quality Standard (1.00 $\mu\text{g/L}$). Besides, in other waters of Jiaozhou Bay, such as northeastern bay, southwestern bay and waters of bay mouth, the Cd contents were relatively lower, less than 0.43 $\mu\text{g/L}$, and far lower than Case I Sea Water Quality Standard.

Hence, in May, August and October, the variation range of Cd content in Jiaozhou Bay was 0.06-0.58 $\mu\text{g/L}$, which meets Case I Sea Water Quality Standard. It indicates that in May, August and October, the entire waters of Jiaozhou Bay was not polluted by Cd, shown in Table 1.

Table 1 The surface water quality in Jiaozhou Bay in May, August and October

	May	August	October
Cd content in seawater/ $\mu\text{g}\cdot\text{L}^{-1}$	0.06-0.58	0.12-0.40	0.17-0.55
Sea Water Quality Standard	Case 1 Sea Water	Case 1 Sea Water	Case 1 Sea Water

3.2 Surface horizontal distribution

In May, in nearshore waters in estuary of Haibo River and eastern wharf waters, the Cd content reached high 0.49-0.58 $\mu\text{g/L}$, forming an area with high Cd content centered by nearshore waters in estuary of Haibo River and eastern wharf waters, a series of semi-concentric circles with different gradients in nearshore waters in estuary of Haibo River, and a series of semi-ellipses with different gradients in nearshore waters in estuary of Haibo River and eastern wharf waters. The Cd content declined progressively from the high content of 0.49-0.58 $\mu\text{g/L}$ in the center to the periphery along the gradients, to 0.06 $\mu\text{g/L}$ in bay center waters and to 0.06 $\mu\text{g/L}$ in nearshore waters of southern bay mouth, shown in Figure 2.

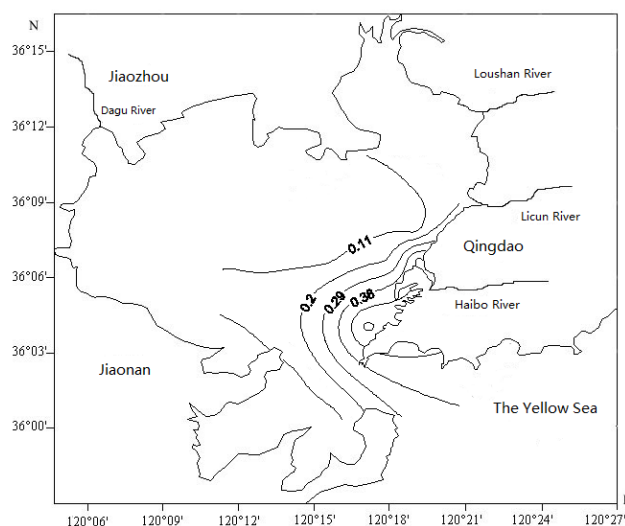


Fig. 2 Cd content distribution at the surface in Jiaozhou Bay in May ($\mu\text{g/L}$)

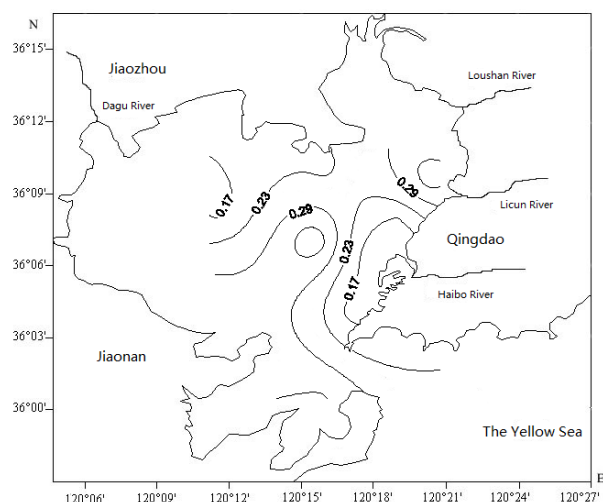


Fig. 3 Cd content distribution at the surface in Jiaozhou Bay in August ($\mu\text{g/L}$)

In August, in bay center of Jiaozhou Bay, and nearshore waters in estuary of Licun River, the Cd content reached high $0.38\text{--}0.40\mu\text{g/L}$, forming an area with high Cd content centered by waters of bay center and a series of concentric circles with different gradients. The Cd content declined progressively from the high content of $0.40\mu\text{g/L}$ in the center to the bay mouth along the gradients, to $0.36\mu\text{g/L}$ in waters of southern bay mouth, to $0.22\mu\text{g/L}$ in waters of southern bay, to $0.29\mu\text{g/L}$ in waters of western bay and to $0.12\mu\text{g/L}$ in waters of eastern bay, shown in Figure 3. Cd content was high in nearshore waters in estuary of Licun River, forming a series of concentric circles with different gradients. The Cd content declined progressively from the high content of $0.38\mu\text{g/L}$ in the center to the periphery along the gradients, to $0.22\mu\text{g/L}$ in waters of northern bay and to $0.12\mu\text{g/L}$ in waters of eastern bay, shown in Figure 3.

In October, in waters of estuary in Dagou River, northern nearshore waters and eastern wharf waters, the Cd content reached high $0.52\text{--}0.55\mu\text{g/L}$, forming an area with high Cd content centered by waters of estuary in Dagou River and a series of parallel lines with different gradients. The Cd content declined progressively from the high content of $0.55\mu\text{g/L}$ in the center to $0.17\mu\text{g/L}$ in bay center along the gradients, shown in Figure 4. Cd content was high in northern nearshore waters, forming a series of parallel lines with different gradients. The Cd content declined progressively from the high content of $0.55\mu\text{g/L}$ in the center to $0.17\mu\text{g/L}$ in bay center, shown in Figure 4. Cd content was high in eastern wharf waters, forming a series of parallel lines with different gradients. The Cd content declined progressively from the high content of $0.48\mu\text{g/L}$ in the center to $0.17\mu\text{g/L}$ in bay center, shown in Figure 4.

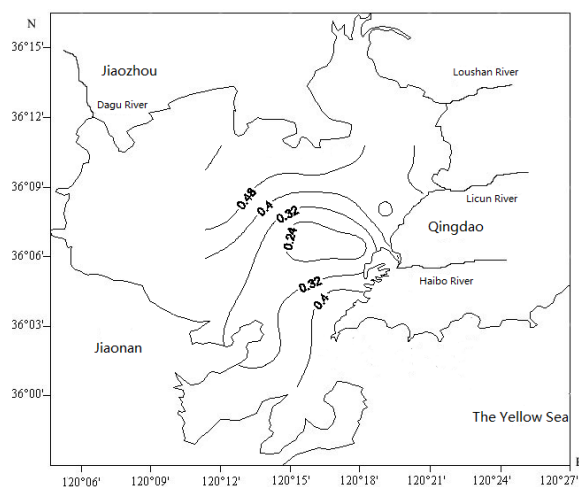


Fig. 4 Cd content distribution at the surface in Jiaozhou Bay in October ($\mu\text{g/L}$)

4. Discussion

4.1 Water quality

In May, August and October, the variation range of Cd content in Jiaozhou Bay waters was $0.06\text{--}0.58\mu\text{g/L}$, which meets Case I Sea Water Quality Standard, which indicates that the entire waters of Jiaozhou Bay was not polluted by Cd in May, August and October.

In May, the variation range was $0.06\text{--}0.58\mu\text{g/L}$, which shows that there was no pollution of Cd. In nearshore waters in estuary of Haibo River and eastern wharf waters, the Cd content reached high $0.49\text{--}0.58\mu\text{g/L}$, which indicates that the water was not polluted by Cd. Besides, in other waters of Jiaozhou Bay, such as northeastern bay, western bay, bay center, northwestern bay and waters of bay mouth, the Cd content was relatively lower, less than $0.25\mu\text{g/L}$, which shows that in addition to nearshore waters in estuary of Haibo River and eastern wharf waters, other waters was high-quality, and the water was clean, not polluted by Cd content.

In August, the variation range was $0.06\text{--}0.58\mu\text{g/L}$, which shows that there was no pollution of Cd. In bay center and nearshore waters in estuary of Licun River, the Cd content reached high $0.38\text{--}0.40\mu\text{g/L}$, which indicates that the water was not polluted by Cd. In addition to bay center and nearshore waters in estuary of Licun River, in other waters of Jiaozhou Bay, such as northern bay, western bay and waters of bay mouth, Cd content was relatively lower, less than $0.36\mu\text{g/L}$, which indicates that the water reached high-quality standard of seawater, the water was clean, not polluted by Cd.

In October, the variation range was $0.17\text{--}0.55\mu\text{g/L}$, which shows that there was no pollution of Cd. In estuary of Dagou River, northern nearshore waters and eastern wharf waters, the Cd content reached high $0.48\text{--}0.55\mu\text{g/L}$, which indicates that there was no pollution. In addition to estuary of Dagou River, northern nearshore waters and eastern wharf waters, in other waters of Jiaozhou Bay, such as northeastern bay, southwestern bay and waters of bay mouth, the Cd content was relatively lower, less than $0.43\mu\text{g/L}$, showing that in addition to these areas, the water quality reached the high-quality standard of seawater, the water is clean, not polluted by Cd.

4.2 Source

In May, Cd content was high as $0.49\mu\text{g/L}$ in nearshore waters in estuary of Haibo River mainly from river flow, which was relatively high. Cd content was high as $0.58\mu\text{g/L}$ in eastern wharf waters of Jiaozhou Bay, mainly from ships and wharfs, which was relatively high.

In August, Cd content in bay center was high as $0.40\mu\text{g/L}$ mainly from atmospheric sedimentation, which was relatively high. Cd content was high as $0.38\mu\text{g/L}$ in nearshore waters in estuary of Licun

River mainly from river flow, which was relatively high.

In October, Cd content was high as 0.55 $\mu\text{g/L}$ in estuary in Dagu River mainly from river flow, which was relatively high. Cd content was high as 0.52 $\mu\text{g/L}$ in northern nearshore waters mainly from overland runoff, which was relatively high. Cd content was high as 0.48 $\mu\text{g/L}$ in eastern wharf waters mainly from ships and wharfs, which was relatively high.

Hence, the Cd contents transported from river flow, ships and wharfs, atmospheric sedimentation and overland runoff satisfy Case I Sea Water Quality Standard (1.00 $\mu\text{g/L}$), which indicates that these four sources are not polluted by Cd content, shown in Table 2.

Table 2 The Cd contents from the different sources in Jiaozhou Bay

Different sources	River flow	Ships and wharfs	Atmospheric sedimentation	Overland runoff
Cd content/ $\mu\text{g}\cdot\text{L}^{-1}$	0.38-0.55	0.48-0.58	0.40	0.52

4.3 Sources and transport quantities

There were four sources of Cd content in Jiaozhou Bay, including river flow, ships and wharfs, atmospheric sedimentation and overland runoff. The Cd content from river flow was 0.38-0.55 $\mu\text{g/L}$, from ships and wharfs was 0.48-0.58 $\mu\text{g/L}$, from atmospheric sedimentation was 0.40 $\mu\text{g/L}$, and from overland runoff was 0.52 $\mu\text{g/L}$. Hence, Cd content discharged by human emissions to land, ocean and atmosphere.

The Cd content from ships and wharfs was 0.48-0.58 $\mu\text{g/L}$, higher than 0.38-0.55 $\mu\text{g/L}$ from river flow, 0.52 $\mu\text{g/L}$ from overland runoff and 0.40 $\mu\text{g/L}$ from atmospheric sedimentation. It shows that the Cd content of human emissions to ocean was the highest, greatly impacting the Cd pollution in ocean.

The Cd content of 0.38-0.55 $\mu\text{g/L}$ from river flow and Cd content of 0.52 $\mu\text{g/L}$ from overland runoff was higher than 0.40 $\mu\text{g/L}$ from atmospheric sedimentation. It indicates that the Cd content of human emissions to land was relatively high, second only to ocean.

The Cd content of 0.40 $\mu\text{g/L}$ from atmospheric sedimentation was the lowest, so the Cd content of human emissions to atmosphere was the lowest. As a result, Cd content in human emissions to ocean > land > atmosphere. In addition, the Cd contents by human emissions in three ways were less than 1.00, which indicates that land, atmosphere and ocean were not polluted by Cd.

The Cd content can be transported through river flow and overland runoff, from land to ocean, the Cd content can be transported through sedimentation, from atmosphere to ocean, and the Cd content also can be transported to ocean directly from ships and wharfs. In a word, the Cd content is finally transported to seawaters.

The Cd content of 0.38-0.55 $\mu\text{g/L}$ from river flow, 0.52 $\mu\text{g/L}$ from overland runoff and 0.48-0.58 $\mu\text{g/L}$ from ships and wharfs, were close to 0.40 $\mu\text{g/L}$ from atmospheric sedimentation. The variation range of three Cd contents was 0.38-0.58 $\mu\text{g/L}$. This determined that with different transport passages, the Cd contents finally reaching seawaters were consistent, and the variation was less than 0.20 $\mu\text{g/L}$, shown in Figure 5.

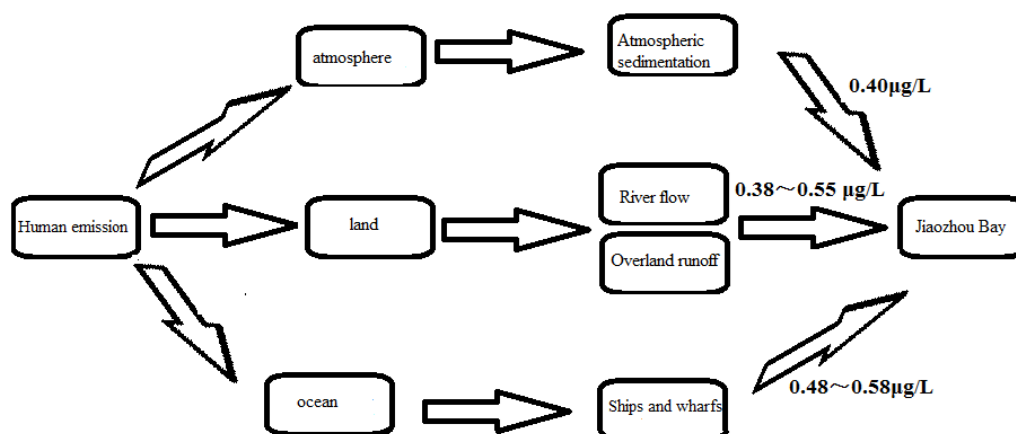


Fig. 5 The passages and values of Cd content in transport process ($\mu\text{g/L}$)

5. Conclusion

In May, August and October, the variation range of Cd contents in Jiaozhou Bay was 0.06-0.58 $\mu\text{g/L}$, meeting Case I Sea Water Quality Standard. It indicates that the entire waters of Jiaozhou Bay was not polluted by Cd in May, August and October.

In May, the variation range was 0.06-0.58 $\mu\text{g/L}$, meaning that there was no pollution of Cd in Jiaozhou Bay. In nearshore waters in estuary of Haibo River and eastern wharf waters, the Cd content reached high 0.49-0.58 $\mu\text{g/L}$. The water was high-quality and clean, not polluted by Cd content.

In August, the variation range was 0.12-0.40 $\mu\text{g/L}$, showing that there was no pollution of Cd in Jiaozhou Bay. In waters of bay center of Jiaozhou Bay, and nearshore waters in estuary of Licun River, the Cd content reached high 0.38-0.40 $\mu\text{g/L}$. The water was high-quality and clean, not polluted by Cd content.

In October, the variation range was 0.17-0.55 $\mu\text{g/L}$, which shows that there was no pollution of Cd. In waters of estuary in Dagou River, northern nearshore waters and eastern wharf waters, the Cd content reached high 0.48-0.55 $\mu\text{g/L}$. The water was high-quality and clean, not polluted by Cd content.

There were four sources of Cd content in Jiaozhou Bay: river flow, ships and wharfs, atmospheric sedimentation and overland runoff. The Cd content from river flow was 0.38-0.55 $\mu\text{g/L}$, 0.48-0.58 $\mu\text{g/L}$ from ships and wharfs, 0.40 $\mu\text{g/L}$ from atmospheric sedimentation, and 0.52 $\mu\text{g/L}$ from overland runoff. In this way, these four sources all satisfied Case I Sea Water Quality Standard of 1.00 $\mu\text{g/L}$. In other words, river flow, ships and wharfs, atmospheric sedimentation and overland runoff were not polluted by Cd content.

The Cd contents were discharged by human in three ways: land, ocean and atmosphere. Its order shall be Cd content in human emissions to ocean > land > atmosphere. Besides, the three Cd contents were less than 1.00 $\mu\text{g/L}$, indicating that land, atmosphere and ocean were not polluted by Cd content.

The Cd content can be transported from land to ocean through river flow and overland runoff, the Cd content can be transported from atmosphere to ocean through sedimentation, and the Cd content also can be transported to ocean directly from ships and wharfs. In a word, the Cd content is finally transported to seawaters. The variation range of three Cd contents was 0.38-0.58 $\mu\text{g/L}$, which determined that with different transport passages, the Cd contents finally reaching seawaters were consistent, and the variation was less than 0.20 $\mu\text{g/L}$. Further, the modelling chart was further established to display the transport passages of Cd content, and disclose the transport of Cd content from human emissions to land and atmosphere, lastly ocean in a quantitative way.

Acknowledgement

This research was sponsored by Doctoral Degree Construction Library of Guizhou Nationalities

University and Research Projects of Guizhou Nationalities University ([2014]02), Research Projects of Guizhou Province Ministry of Education (KY [2014] 266), Research Projects of Guizhou Province Ministry of Science and Technology (LH [2014] 7376).

References

- [1] DongfangYang,ZhenqingMiao, Marine Bay Ecology (I) [M]. Beijing, China Ocean Press, (2010), 1-320.
- [2] DongfangYang, ZhenhuiGao, Marine Bay Ecology (II) [M]. Beijing, China Ocean Press, (2010), 1-330.
- [3] DongfangYang, YuChen, HongWang, ChunruYang, JunhuiGuo. Environmental Background Composition and Transfer Process of Cadmium in Jiaozhou Bay [J]. Coastal Engineering, 2010,29(4): 73-82.
- [4] DongfangYang, YuChen, YanxiangChang, ChunxiuLiu, YichanWeng. The Source and Distribution of Cadmium in Jiaozhou Bay [J]. Coastal Engineering, 2013, 32(3): 68- 78.
- [5] Dongfang Yang, Sixi Zhu, Fengyou Wang, Huazhong He and Yunjie Wu. The distribution and content of Cadmium in Jiaozhou Bay [J]. Applied Mechanics and Materials, 2014, 644-650, 5325-5328.
- [6] Dongfang Yang, Fengyou Wang, Youfu Wu, Huazhong He and Sixi Zhu. The structure of environmental background value of Cadmium in Jiaozhou Bay waters [J]. Applied Mechanics and Materials, 2014, 644-650, 5329-5312.
- [7] Dongfang Yang, Shengtao Chen, Baolei Li, Xiao Geng and Zijun Xu. Research on the vertical distribution of Cadmium in Jiaozhou Bay waters [J]. Proceedings of the 2015 international symposium on computers and informatics. 2015, 2667-2674.
- [8] Dongfang Yang, YuChen, Zhenhui Gao, et al. Silicon Limitation on primary production and its destiny in Jiaozhou Bay, China IV transect offshore the coast with estuaries [J]. Chinese Journal of Oceanology and Limnology. 2005, 23(1): 72-90.
- [9] DongfangYang, FanWang, ZhenhuiGao, et al. Ecological phenomena of phytoplankton in Jiaozhou Bay [J]. Marine Sciences, 2004, 28(6): 71-74.
- [10] State Oceanic Administration. The Specification for Marine Monitoring (HY003.4-91) [M]. Beijing: China Ocean Press, 1991: 205-282.