The Consistency of the Cd Content in Lands and Oceans

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Abstract: Based on the data from May, August, and October 1992, the Cd content in the Jiaozhou Bay waters varied from 0.11 to 1.53μg/L, up to the water quality standards of Class I and II seawater. This indicates that the water quality of the entire bay was slightly or not polluted by Cd during this period. In May, the variation of the Cd content in the bay ranged from 0.23 to 1.53μg/L, more specifically, the Cd content reached a relatively high level of 1.00-1.53μg/L in the offshore waters near the estuary of Dagu River, Loushan River, Licun River and Haibo River and offshore waters of the north of the bay, leading to a mild contamination, while other waters in the bay were not polluted by the Cd content at all. In August, the variation of Cd content in the bay ranged from 0.11 to 1.11μg/L, more specifically, the Cd content hit the record high of 1.11μg/L in the offshore waters near the estuary of Dagu River and in the waters of the south of the bay mouth, making the waters polluted slightly, while other waters in the bay were not polluted by the Cd content at all. In October, the variation of the Cd content in the bay ranged from 0.12 to 1.11μg/L, more specifically, the Cd content reached a relatively high level of 1.04-1.11μg/L in the offshore waters near the estuary of Loushan River and Licun River, leading to mild contamination, while other waters in the bay were not polluted by the Cd content at all. There are three sources of the Cd content in the Jiaozhou Bay waters: rivers, main sea currents and surface runoff. In other words, these are three ways to transport the Cd content. In these ways, 0.96-1.53μg/L, 1.11μg/L and 1.10μg/L of Cd content are transported respectively. In this regard, the order from the largest to smallest of Cd content delivery is as follows: rivers, main sea currents and surface runoff. The Cd content transported by surface runoff is very close to that transported by main sea currents, indicating that the Cd content emitted by humans to land is consistent with that released to the oceans. Besides, the Cd content transported by the three sources is higher than or close to 1.00μg/L, suggesting that both lands and oceans are mildly polluted by the Cd content.

1. Introduction
With the rapid development of industry, a large amount of waste water, waste gas and solid waste containing cadmium (Cd) have been released in the processing and production of products, which leaves lands, atmosphere and oceans to be polluted by the Cd content. In nature, the Cd content is transported to ocean water. [1-7] According to the investigation data in 1992, the paper identifies the water quality of the bay, travel path and transported amounts of Cd by studying the level, horizontal distribution and sources of the Cd content, which provides a scientific theoretical basis for research on source, pollution degree and transferring process of the Cd content in Jiaozhou Bay.
2. Investigated Waters & Materials and Methods

2.1 Natural Environment of Jiaozhou Bay. Jiaozhou Bay (120°04′-120°23′E, 35°55′-36°18′N) is located in the south of Shandong Province, eastern China. It is a semi-closed bay, bounded by Tuan Island and Xuejia Island, connecting the Yellow Sea with the total area and average water depth of 446km² and 7m, respectively. There are more than ten inflow rivers, among which Dagu River and Yang River, Haibo River, Licun River and Loushan River in Qingdao city have greater runoff and sediment concentration. They are all seasonal rivers with obvious seasonal changes in hydrological characteristics of rivers [12, 13].

2.2 Materials and Methods. The investigation data on Cd in the Jiaozhou Bay waters in May, August and October 1992 adopted by this research are provided by the North Sea Monitoring Center of the State Oceanic Administration. 13 sites were set to take water samples in the Jiaozhou Bay waters, they are site 52, site 53, site 54, site 55, site 56, site 57, site 58, site 59, site 60, site 61, site 2104, site 2105 and site 2106 (Figure 1). Three samples were taken according to depth for sample investigation in May, August, and October 1992, (surface and bottom waters were taken when > 10m, and only surface waters were taken when < 10m). The investigation of Cd in the Jiaozhou Bay waters is carried out in line with the national standard method which has been added in the National “Ocean Monitoring Code” (1991) [14].

3. Results

3.1 Level of Content. In May, August and October, the Cd content in the Jiaozhou Bay waters varied from 0.11μg/L to 1.53μg/L, up to the national water quality standards of Class I (1.00μg/L) and II seawater (5.00μg/L).

In May, the Cd content in the Jiaozhou Bay waters varied from 0.23μg/L to 1.53μg/L (Table 1). The first high-content area was in the offshore waters near the estuary of Dagu River where the site 56 was located, with the Cd content peaking at 1.53μg/L there. The second one was in the offshore waters near the estuary of Licun River where site 58 was located, with the Cd content peaking at 1.20μg/L there. The third one was in the offshore waters near the estuary of Haibo River where site 59 was located, with the Cd content peaking at 1.07μg/L there. The fourth one was in the offshore waters near the estuary of Loushan River where the site 2105 and site 2104 were located, with the Cd content peaking at 1.6μg/L there. The fifth one was in the offshore waters of the north of the bay where site 57 was located, with the Cd content peaking at 1.10μg/L there. The Cd content in waters mentioned above was up to the
national water quality standards of Class II seawater (5.00μg/L). Meanwhile, the Cd content was lower than 1.00μg/L in other waters in Jiaozhou Bay, such as in waters of the southeast, center and west of the bay and waters of bay mouth, up to the national water quality standards of Class I seawater (1.00μg/L).

In August, the Cd content in the Jiaozhou Bay waters varied from 0.11μg/L to 1.11μg/L (Table 1). The first high-content area was in the south waters of the bay mouth where the site 52 was located, with the Cd content peaking at 1.11μg/L there, up to the national water quality standards of Class II seawater (5.00μg/L). The second one was in the offshore waters near the estuary of Dagu River where the site 56 was located, with the Cd content peaking at 0.96μg/L there, up to the national water quality standards of Class I seawater (1.00μg/L). Meanwhile, the Cd content was lower than 1.00μg/L in other waters in Jiaozhou Bay, such as in waters of the north, center and northeast of the bay, also up to the national water quality standards of Class I seawater (1.00μg/L).

In October, the Cd content in the Jiaozhou Bay waters varied from 0.12μg/L to 1.11μg/L (Table 1). The first high-content area was in the offshore waters near the estuary of Licun River where the site 58 was located, with the Cd content peaking at 1.11μg/L there. The second one was in the offshore waters near the estuary of Loushan River where the site 2104 was located, with the Cd content peaking at 1.04μg/L there. The Cd content in waters mentioned above is up to the national water quality standards of Class II seawater (5.00μg/L). Meanwhile, in other waters in Jiaozhou Bay, such as in waters of the north, center and southwest of the bay, the Cd content was lower than 1.00μg/L, up to the national water quality standards of Class I seawater (1.00μg/L).

To sum up, the Cd content in the Jiaozhou Bay waters varied from 0.11 to 1.53μg/L in May, August, and October, up to the water quality standards of Class I and II seawater. This indicates that the water quality of the entire bay was slightly or not polluted by Cd at all. (Table 1)

| Table 1 | The surface water quality in Jiaozhou Bay in May, August and October |
|---------|-----------------------------|
| Cd content in ocean waters/μg·L⁻¹ | May | August | October |
| National water quality standards of seawater | Class I and II | Class I and II | Class I and II |

3.2 Horizontal Distribution in the Surface Waters. In May, the Cd content ranged from 1.00μg/L to 1.53μg/L, a relatively high level in the offshore waters near the estuaries of Dagu River, Loushan River, Licun River and Haibo River and the north waters of the bay, around which a high-content area was formed and was together presented in a series of parallel lines and semi-ovals with different gradients. The Cd content decreased along the gradient from 1.00-1.53μg/L in the high-content area to 0.23μg/L in the southeast waters of the bay and to 0.26μg/L in the offshore waters of the west of the bay (Figure 2).

In August, the Cd content ranged from 0.96μg/L to 1.11μg/L, a relatively high level in the offshore waters near the estuary of Dagu River and the south waters of the bay mouth, around which two high-content areas were formed separately and were presented in a series of parallel lines and semi-ovals with different gradients respectively. From this series of parallel lines, the Cd content decreased along the gradient from 1.11μg/L in the high-content area to 0.12μg/L in the central waters of the bay (Figure 3). From these semi-ovals, the Cd content decreased from 0.96μg/L to 0.12μg/L in the same way. (Figure 3)
Figure 2 Cd content distribution at the surface in Jiaozhou Bay in May (μg/L)

Figure 3 Cd content distribution at the surface in Jiaozhou Bay in August (μg/L)

Figure 4 Cd content distribution at the surface in Jiaozhou Bay in October (μg/L)
In October, the Cd content ranged from 1.04μg/L to 1.11μg/L, a relatively high level in the offshore waters near the estuary of Loushan River and Licun River, around which a high-content area was formed and was together presented in a series of parallel lines. The Cd content decreased along the gradient from 1.04μg/L-1.11μg/L in the high-content area to 0.51μg/L in the southeast waters of the bay and 0.59μg/L in the southwest waters of the bay. (Figure 4)

4. Discussion

4.1 Water Quality

In May, August and October, the Cd content in the Jiaozhou Bay waters varied from 0.11 to 1.53μg/L, up to the water quality standards of Class I and II seawater. This indicates that the water quality of the entire bay was slightly or not polluted by Cd during this period.

In May, the variation of the Cd content in the bay ranged from 0.23 to1.53μg/L, which indicates that the water quality of the entire bay was slightly or not polluted by Cd during this period. More specifically, the Cd content reached a relatively high level of 1.00-1.53μg/L in the offshore waters near the estuary of Dagu River, Loushan River, Licun River and Haibo River and offshore waters of the north of the bay, leading to a mild contamination while the Cd content was in a relatively low level, lower than 1.00μg/L, in other waters like waters of the southeast, center and southwest of the bay, and waters of the bay mouth, suggesting that waters there were in high and clean quality without any pollution caused by the Cd content.

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4.2 Sources of the Cd content.

In May, a high Cd content area formed in the offshore waters near the estuary of Dagu River, Loushan River, Licun River and Haibo River, which indicates that the Cd content was brought by rivers, reaching a relatively high transported content of 1.00-1.53μg/L. Meanwhile, another high Cd content area formed in the offshore waters of the north of the bay, which indicates that the Cd content was brought by surface runoff, reaching a relatively high transported content of 1.10μg/L.

In August, a high Cd content area formed in the waters of the south of the bay mouth, which indicates that the Cd content was brought by main sea currents, reaching a relatively high transported content of 1.11μg/L. Meanwhile, another high Cd content area formed in the offshore waters near the estuary of Dagu River, which indicates that the Cd content was brought by rivers, reaching a relatively high transported content of 1.10μg/L.

In October, a high Cd content area formed in the offshore waters near the estuary of Licun River, which indicates that the Cd content was brought by rivers, reaching a relatively high transported content of 1.11μg/L. Meanwhile, another high Cd content area formed in the offshore waters near the estuary of Loushan River, which indicates that the Cd content was brought by rivers, reaching a relatively high transported content of 1.04μg/L.

Therefore, the Cd content transported to Jiaozhou Bay by rivers, main sea currents and surface runoff
exceeds the maximum limit (1.00μg/L) set by the national water quality standard of Class I seawater but conforms to the national water quality standard of class II seawater (5.00μg/L), indicating that rivers, main sea currents and surface runoff are slightly polluted by Cd content (Table 2).

| Different sources | Transported by rivers | Transported by main sea currents | Transported by surface runoff |
|-------------------|-----------------------|---------------------------------|-------------------------------|
| Cd content /μg·L⁻¹ | 0.96-1.53             | 1.11                            | 1.10                          |

4.3 Ways to be Transported and the Transformed Content. There are three sources of the Cd content in the Jiaozhou Bay waters: rivers, main sea currents and surface runoff. In other words, these are three ways to transport the Cd content. In these ways, 0.96-1.53μg/L, 1.11μg/L and 1.10μg/L of Cd content are transported respectively. The Cd content transported in different ways ranges from 0.96μg/L to 1.53μg/L (Figure 5). The order from the largest to smallest of Cd content delivery is as follows: rivers with Cd content 0.96-1.53μg/L, main sea currents with Cd content 1.11μg/L and surface runoff with Cd content 1.10μg/L. The Cd content transported by surface runoff is very close to that transported by main sea currents, indicating that the Cd content emitted by humans to lands is consistent with that released to oceans. Due to the erosion and collection of rainwater on the land surface, the Cd content in rivers is relatively high so that the Cd content transported by rivers is higher than that transported by surface runoff and by main sea currents.

![Figure 5 the passages and values of the Cd content in transport process (μg/L)](image)

The Cd content transported by rivers, main sea currents and surface runoff is higher than or close to 1.00μg/L, which means that both lands and oceans are slightly polluted by the Cd content. Lands transport the Cd content to seas through rivers and surface runoff, and oceans transport the Cd content from one water body to another through the offshore currents, which is a process that humans release the Cd content to lands and to oceans. It follows that the Cd content always ends up reaching the ocean water body and keeping flowing and depositing.

5. Conclusion
In May, August and October, the Cd content in the Jiaozhou Bay waters varied from 0.11 to 1.53μg/L, up to the water quality standards of Class I and II seawater. This indicates that the water quality of the entire bay was slightly or not polluted by Cd during this period.

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In October, the variation of the Cd content in the bay ranged from 0.12μg/L to 1.11μg/L, which indicates that the water quality of the entire bay was slightly or not polluted by Cd during this period. More specifically, the Cd content reached a relatively high level of 1.04-1.11μg/L in the offshore waters near the estuary of Loushan River and Licun River, leading to mild contamination while other waters in the bay were in high and clean quality without any pollution caused by the Cd content.

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