Horizontal distribution trends of Cd in Jiaozhou Bay

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Abstract. Using investigation on Cadmium (Cd) in surface and bottom waters in this bay during 1984-1986, this paper analyzed the horizontal distributions, identified the different distribution trends, and provided block diagram model to demonstrate the migration processes of Cd. Results showed that the horizontal distriution trends of Cd in bay waters were determined by the source inputs, the transport paths and the horizontal and vertical water's effects. This indicated that the distribution trends of Cd contents in surface and botom waters would be consistent even if the source strengths were different. There were three different horizontal distribution trends, namely "Yang's horizontal distribution trends". The horizontal migration processes were showing three different status as 1) the settlement of Cd had not been arrived at sea bottom, 2) the settlement of Cd had been arrived at sea bottom, and 3) the accumulation of Cd had been occurred at sea bottom. The path ways and remaining traces of Cd could be defined in according to "Yang's horizontal distribution trends".

1.Introduction

Heavy metal contamination has been one of the critical environmental issues since industrial revolution [1-5]. After China's Reform and Opening-up, many marine bays have been polluted by heavy metals due to the lag of waste treat to the rapid development of industry and economic [6-10]. Cd is one of the widely used heavy metal elements and therefore understanding the distributions of Cd in marine waters is essential to environmetal protection and remadiation [11-20]. Jiaozhou Bay is a semi-closed bay located in Shandong Province, China. By using investigation on Cd in surface and bottom waters in this bay during 1984-1986, this paper analyzed the horizontal distributions, identified the different distribution trends, and provided block diagram model to demonstrate the migration processes of Cd. The aim of this paper is to provide basis for research on the migration of Cd in marine bay.

2. Materials and dataset

Jiaozhou Bay is located in the south of Shandong Province, eastern China (35°55′-36°18′ N, 120°04′-120°23′ E). The total area and average water depth are 446 km^2 and 7 m, respectively (Fig. 1). The bay mouth is very narrow (3 km), and is connected to the Yellow Sea in the south. There are a dozen of rivers including Dagu River, Haibo Rriver, Licun Rriver, and Loushan Rriver etc., all of which are seasonal rivers [21-22].

Dataset on Cd in Jiaozhou Bay was provided by North China Sea Environmental Monitoring Center [3-20]. The investigations were carried on in July and October 1984, April, July and October 1985, and April and July 1986, respectively. Cd in waters was monitored follow by National Specification for Marine Monitoring [23].
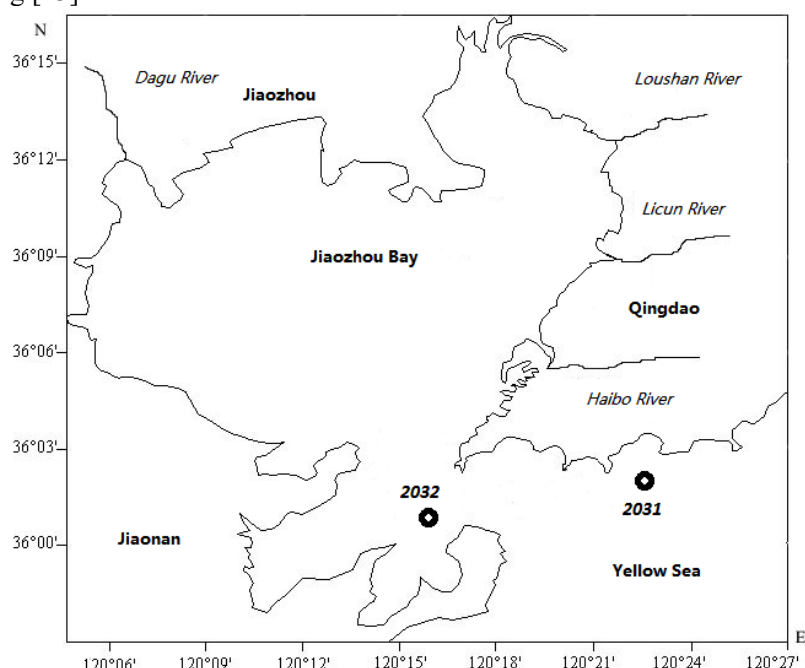

Fig. 1 Geographic location and sampling sites of Jiaozhou Bay

3. Results and discussion

3.1 Horizontal distributions of Cd.

The two sampling sites were located in the open waters (Site 2031) and the bay mouth (Site 2032), respectively. By taking from the open waters to the bay mouth as the direction, the horizontal distributions of Cd in different monitoring times were defined. In July 1984, Cd contents in surface waters were decreasing from the open waters (0.17 μg L^{-1}) to the bay mouth (0.16 μg L^{-1}), while in bottom waters were stable as 0.05 μg L^{-1}. In October 1984, Cd contents in both surface and bottom waters were decreasing from the open waters (0.33 μg L^{-1} and 0.32 μg L^{-1}) to the bay mouth (0.21 μg L^{-1} and 0.19 μg L^{-1}) . In April 1985, Cd contents in surface waters were stable as 0.16 μg L^{-1}, while in bottom waters were increasing from the open waters (0.12 μg L^{-1}) to the bay mouth (0.17 μg L^{-1}). In October 1985, Cd contents in both surface and bottom waters were decreasing from the open waters (0.13 μg L^{-1} and 0.17 μg L^{-1}) to the bay mouth (0.03 μg L^{-1} and 0.04 μg L^{-1}). In April 1986, Cd contents in both surface and bottom waters were decreasing from the open waters (0.38 μg L^{-1} and 0.22 μg L^{-1}) to the bay mouth (0.01 μg L^{-1} and 0.00 μg L^{-1}), and in July 1986 Cd contents in both surface and bottom waters were also decreasing from the open

waters (6.48 μg L^{-1} and 1.29 μg L^{-1}) to the bay mouth (0.73 μg L^{-1} and 0.34 μg L^{-1}). The major Cd sources in Jiaozhou Bay were river discharge and marine current [3-12]. The horizontal distributions of Cd in bay waters were determined by the source inputs and the horizontal and vertical water's effects [24-26].

3.2Horizontal distribution trends of Cd.
The horizontal distribution trends of Cd in bay waters were determined by the source inputs, the transport paths and the horizontal and vertical water's effects [24-26]. In July 1984, the dominant Cd source was marine current whose source strength was relative low, and Cd contents in surface waters were decreasing from the open waters to the bay mouth along with the flow direction of marine current, while Cd contents in bottom waters were tending to be stable since the settlement of Cd from surface waters to bottom waters was still limited. In October 1984, the dominant Cd source was river discharge whose source strength was relative low, and Cd contents in surface waters were decreasing from the bay mouth to the open waters, as well as in bottom waters since the settlement of Cd was rapid. In April and October 1985, the dominant Cd source was river discharge whose source strength was relatively high, and Cd contents in surface waters were decreasing from the bay mouth to the open waters along with the flow direction of river discharge, as well as in bottom waters since the settlement of Cd was rapid. In July 1985, the dominant Cd source was river discharge whose source strength was relatively low, and Cd contents in surface waters were decreasing from the bay mouth to the open waters along with the flow direction of river discharge, as well as in bottom waters since the settlement of Cd was rapid. In April 1986, the dominant Cd source was marine current whose source strength was relatively low, and Cd contents in surface waters were decreasing from the open waters to the bay mouth along with the flow direction of marine current, as well as in bottom waters since the settlement of Cd from surface waters to bottom waters was rapid. In July 1986, the dominant Cd source was marine current whose source strength was relatively high, and Cd contents in surface waters were decreasing from the open waters to the bay mouth along with the flow direction of marine current, as well as in bottom waters since the settlement of Cd from surface waters to bottom waters was rapid. This results above indicated that the distribution trends of Cd contents in surface and bottom waters would be consistent even if the source strengths were different by means of horizontal and vertical water's effects [24-26].

3.3Block diagram model of horizontal distribution trends of Cd.
The horizontal distribution trends of Cd in surface and bottom waters in Jiaozhou Bay indicated that in case of Cd contents in surface waters were relative high the settlement was rapid and there was accumulation process in bottom waters, while in case of Cd contents in surface waters were relative low the settlement was limited and Cd could be washed away by marine current. In general, there were three different horizontal distribution trends, namely "Yang's horizontal distribution trends" (Table 1).

1) Yang's horizontal distribution trend 1. Cd contents were relative low in surface waters, yet the settlement of Cd was limited and not arrived at sea bottom, Cd contents in surface waters were tending to be decreasing along with the flow direction of the dominant source, while in bottom waters were tending to be stable (Fig. 2).

2) Yang's horizontal distribution trend 2. Cd contents were relative high in surface waters, and the settlement of Cd was rapid and not accumulated in sea bottom, Cd contents in surface waters were tending to be decreasing along with the flow direction of the dominant source, as well as in bottom waters due to the rapid settlement of Cd (Fig. 3).

3) Yang's horizontal distribution trend 3. Cd contents were relative high in surface waters, and the settlement of Cd was rapid and accumulated in sea bottom, Cd contents in surface waters were tending to be stable since the source input was abundant, while in bottom waters the distribution trend was increasing since the accumulation of Cd in bottom waters (Fig. 4).

In according to the block diagram models, the horizontal migration processes were showing three different status as 1) the settlement of Cd had not been arrived at sea bottom, 2) the settlement of Cd had been arrived at sea bottom, and 3) the accumulation of Cd had been occurred at sea bottom. As a result, the path ways and remaining traces of Cd could be defined.

Table 1 Yang's horizontal distribution trends of Cd in surface and bottom waters in Jiaozhou Bay

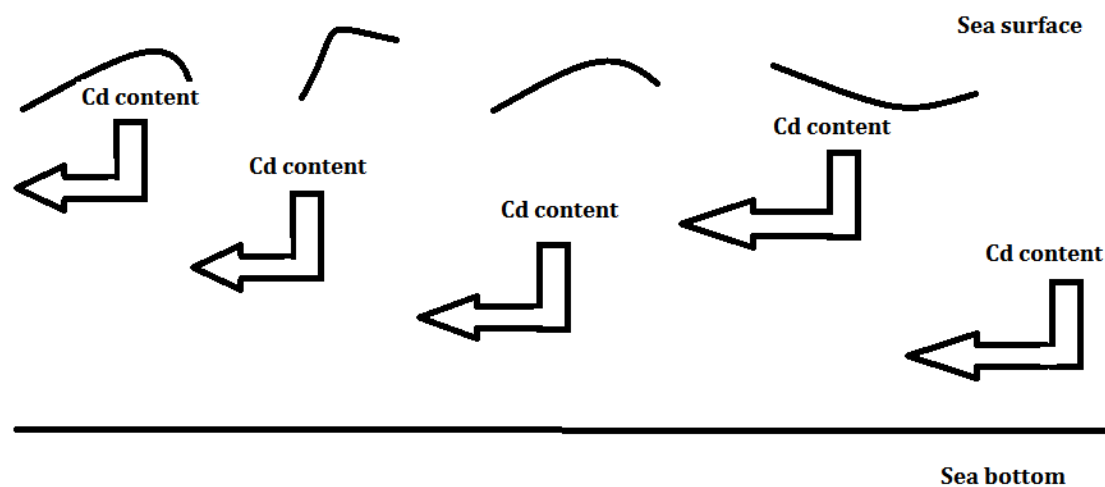|	Settlement	Surface waters	Bottom waters	Distribution trend
Trend 1	Not arrived at sea bottom	Cd contents were relatively low	Cd contents were relatively stable	Inconsistent
Trend 2	Not accumulated in sea bottom	Cd contents were relatively high	Cd contents were relatively high	Consistent
Trend 3	Accumulated in sea bottom	Cd contents were relatively stable	Cd contents were higher	Inconsistent

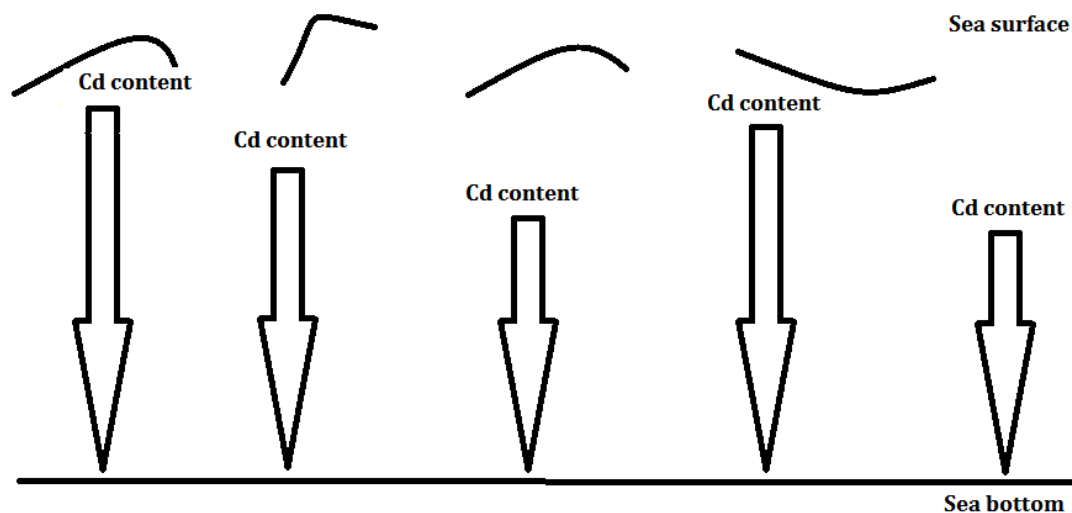Fig. 2 Block diagram model of Yang's horizontal distribution trend 1.

Fig. 3 Block diagram model of Yang's horizontal distribution trend 2.
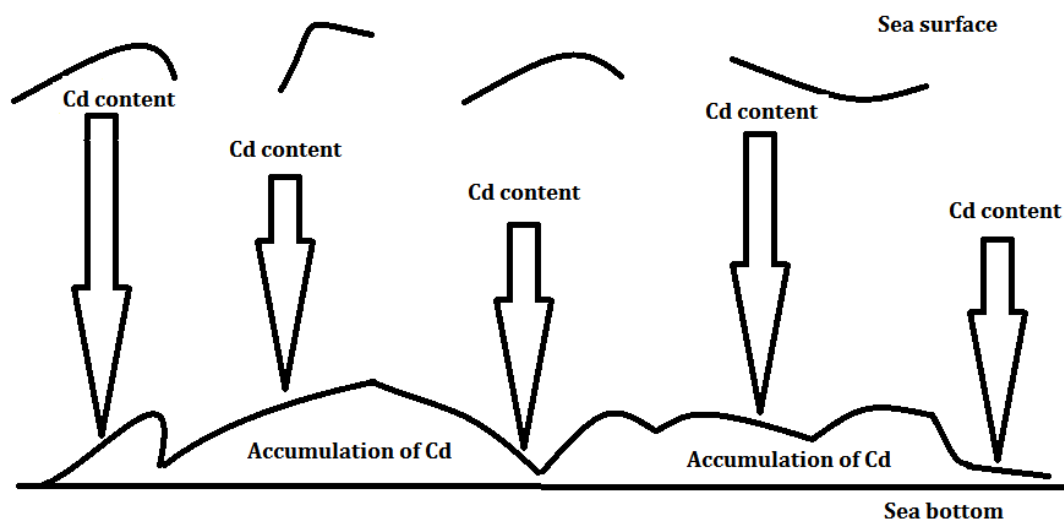

Fig. 4 Block diagram model of Yang's horizontal distribution trend 3.

4.Conclusions

The horizontal distribution trends of Cd in bay waters were determined by the source inputs, the transport paths and the horizontal and vertical water's effects. This indicated that the distribution trends of Cd contents in surface and bottom waters would be consistent even if the source strengths were different. There were three different horizontal distribution trends, namely "Yang's horizontal distribution trends". The horizontal migration processes were showing three different status as 1) the settlement of Cd had not been arrived at sea bottom, 2) the settlement of Cd had been arrived at sea bottom, and 3) the accumulation of Cd had been occurred at sea bottom. The path ways and remaining traces of Cd could be defined in according to "Yang's horizontal distribution trends".

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