Different stages and status of vertical transporting process of Cu in Jiaozhou Bay

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Abstract. Understanding the stages and status of vertical transporting process of pollutant in marine bay is essential to pollution control. This paper analyzed the stages and status of Cu’s vertical transporting process in waters in Jiaozhou Bay. Results showed that the vertical transporting process in waters in Jiaozhou Bay included four stages of 1) Cu was imported to the bay by major sources, 2) Cu was transported to surface waters, 3) Cu was transported from surface waters to sediment in sea bottom, and 4) Cu was fixed and buried in sediment. Furthermore, Cu’s vertical transporting process could be divided into seven status in detail, and he characteristics of the vertical transport process of Cu were also analyzed.

1. Introduction
Cu is one of the heavy metal elements widely existing in the natural environment, and is one of the necessary trace elements for biology. However, the excessive exposure and intake of Cu is harmful to organism [1-6]. Along with the rapid development of industry, a large amount of Cu-containing wastes were discharged to marine bays via sources of marine current, river flow, island top, atmosphere deposition, overland runoff and wharf, etc., and Cu pollution has been one of the critical environmental issues in many marine bays [7-16]. By means of water’s effect, a big part of Cu in marine waters was transported to sea bottom. Therefore, and understanding the vertical transporting process of Cu in marine bays is essential to pollution control. Jiaozhou Bay is a semi-closed bay located in Shandong Province, eastern China. This paper analyzed the stages and status of Cu’s vertical transporting process, and provided basis information to scientific research and pollution control practice.

2. Study area and data collection
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, average water depth and bay mouth width are 446 km\textsuperscript{2}, 7 m and 3 km, respectively. This bay is a typical of semi-closed bay which is connected to the Yellow Sea in the south. There are a dozen of rivers, and the majors are Dagu River, Haibo Rriver, Licun Rriver, and Loushan Rriver etc., all of which are seasonal rivers [17-18]. The investigation on Cu in Jiaozhou Bay was carried on in July and October 1982, May, September and October 1983, July and October 1984, and April, July and October 1985 [3-16] (Fig. 1). Cu in waters was sampled and monitored follow by
National Specification for Marine Monitoring [19].

![Geographic location of Jiaozhou Bay](image)

**Fig. 1** Geographic location of Jiaozhou Bay

3. **Results and discussion**

**Variations of Cu contents in surface and bottom waters.** In 1982, Cu contents in surface waters in July and October were 0.50-1.53 μg L\(^{-1}\) and 2.22-3.56 μg L\(^{-1}\), respectively, while in bottom waters were 0.23-1.46 μg L\(^{-1}\) and 1.56-3.22 μg L\(^{-1}\), respectively. In 1983, Cu contents in surface waters in May, September and October were 2.47-20.60 μg L\(^{-1}\), 1.28-4.86 μg L\(^{-1}\) and 0.77-2.28 μg L\(^{-1}\), respectively, while in bottom waters were 0.86-3.95 μg L\(^{-1}\), 1.31-1.90 μg L\(^{-1}\) and 0.24-2.00 μg L\(^{-1}\), respectively. In 1984, Cu contents in surface waters in July and October were 0.28-1.83 μg L\(^{-1}\) and 0.90-2.00 μg L\(^{-1}\), respectively, while in bottom waters were 0.13-2.97 μg L\(^{-1}\) and 0.40-0.61 μg L\(^{-1}\), respectively. In 1985, Cu contents in surface waters in April, July and October were 0.11-0.39 μg L\(^{-1}\), 0.10-0.12 μg L\(^{-1}\) and 0.18-0.39 μg L\(^{-1}\), respectively, while in bottom waters were 0.10-0.12 μg L\(^{-1}\), 0.19-0.42 μg L\(^{-1}\) and 0.19-0.30 μg L\(^{-1}\), respectively. It could be found that in case of Cu contents in bottom waters were high, Cu contents in surface waters would be relative high. However, in case of Cu contents in surface waters were low, Cu contents in surface waters would be uncertain.

Cu in Jiaozhou Bay were mainly sourced from marine current, river flow, island top, atmosphere deposition, overland runoff and wharf, etc., and the source strengths of these major sources were showing spatial and temporal variations. Hence, by means of water’s effect, the vertical transporting process of Cu in marine bay were showing spatial and temporal variations, and identification of the stages and status of the vertical transporting process was essential to environmental protection.

**Stages and status of vertical transport process of Cu.** In according to the vertical distributions of Cu in waters in Jiaozhou Bay, it could be concluded that the distributions were determined by the vertical transporting process. In general, the vertical transporting process of Cu in marine bays could be divided in to four stages. Stage 1: Cu was imported to the bay by major sources. Stage 2: Cu was transported to surface waters. Stage 3: Cu was transported from surface waters to sediment in sea bottom. Stage 4: Cu was fixed and buried in sediment. These four stages were showed in a block diagram model in Fig. 2. In according to the block diagram model, the transporting path and the remaining trace of Cu contents could be defined. The four different stages and the block diagram model were revealing the vertical transporting process of Cu, which could be further divided into
seven different status.

![Diagram of Cu's vertical transporting process](image)

**Fig. 2** Block diagram model for the four stages of Cu’s vertical transporting process

Status 1: the sources discharged a lot of Cu to the bay, and therefore Cu contents in surface waters were higher than in bottom waters. Status 2: the input of Cu was increasing, and therefore Cu contents in surface waters were still higher than in bottom waters. Status 3: the input of Cu was continuing, a big part of Cu was transported to the sea bottom by sedimentation, and therefore Cu contents in surface and bottom waters were closed. Status 4: the input of Cu was decreasing, yet a big part of Cu was transporting to bottom water, and therefore Cd contents in surface waters were lower than in bottom waters. Status 5: the input of Cu had been stopped, yet a big part of Cu had been transported to bottom water, Cu contents in surface waters were very low and were lower than in bottom waters. Status 6: the input of the input of Cu had been stopped, and the sedimentation of Cu had also been stopped, yet a big part of Cu had been exported in the sediment, and therefore Cu contents in surface and bottom waters were little and closed. Status 7: a big part of Cu had been fix and buried in the sediment, and therefore Cu contents would be disappeared. These stages and status were revealing the vertical transporting process of Cu clearly, and were consistent with the vertical transporting process of other pollutants such as hexachlorocyclohexane, Hg and Cr [23-24].

**Characteristics of the vertical transport process of Cu.** In according to the vertical distributions of Cu in waters in Jiaozhou Bay, it could be concluded that the vertical variations of Cu contents in marine bay were determined by the source strengths of the major Cu sources and the transporting distances of Cu in waters, as well as vertical water’s effect. There were sedimentation process of Cu in water body, and there were accumulation process of Cu in bottom waters. The continuous sedimentation and accumulation processes of Cu could result in the increasing and relative high Cu contents in bottom waters. Once the input of Cu was stopped, Cu contents in surface waters would be decreasing, and in bottom waters would be decreasing sequentially. Along with the continuously fixing and bury of Cu to the sedimentation, Cu contents in the surface of the sedimentation in sea bottom would be finally disappeared. Therefore, Cu contents in surface and bottom waters would be returning to the original status of no source input. That were the characteristics of the vertical transporting process of Cu in marine bays.

4. **Conclusions**

The vertical transporting process in waters in Jiaozhou Bay included four stages of 1) Cu was imported to the bay by major sources, 2) Cu was transported to surface waters, 3) Cu was transported from surface waters to sediment in sea bottom, and 4) Cu was fixed and buried in sediment. The
vertical transporting process could be divided into seven status. The characteristics of the vertical transport process of Cu were also analyzed. These findings were helpful to better understanding to transport processes of Cu, as well as to other pollutants.

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References

[1] Yang DF and Miao ZQ: Marine Bay Ecology (I): Beijing, Ocean Precess, (2010), p. 1-320. (in Chinese)
[2] Yang DF and Gao ZH: Marine Bay Ecology (II): Beijing, Ocean Precess, (2010), p. 1-330. (in Chinese)
[3] Yang DF, Miao ZQ, Song WP, et al.: Advanced Materials Research, Vol.1092-1093 (2015), p. 1013-1016.
[4] Yang DF, Miao ZQ, Cui WL, et al.: Advances in intelligent systems research, (2015), p. 17-20.
[5] Yang DF, Wang FY, Zhu SX, et al.: Advances in Engineering Research, Vol. 31(2015): p. 1284-1287.
[6] Yang DF, Zhu SX, Wu YJ, et al.: Advances in Engineering Research, Vol. 31(2015): p. 1288-1291.
[7] Yang DF, Wang FY, Zhu SX, et al.: Materials Engineering and Information Technology Aplication, Vol. 2015, p. 554-557.
[8] Yang DF, Zhu SX, Zhao XL, et al.: Advances in Engineering Research, Vol. 40 (2015), p. 770-775.
[9] Yang DF, Zhu SX, Wang FY, et al.: Advances in Computer Science Research, Vol. (2015), p. 1765-1769.
[10] Yang DF, Zhu SX, Wang FY, et al.: Advances in Engineering Research, Vol. 60(2016), p. 408-411.
[11] Yang DF, Zhu SX, Wang M, et al.: Advances in Engineering Research, Vol. 67(2016), p. 1311-1314.
[12] Yang DF, Yang DF, Wang M, et al.: Advances in Engineering Research, Vol. (2016), Part G, p. 1917-1920.
[13] Yang DF, Yang DF, He HZ, et al.: Advances in Engineering Research, Vol. 84 (2016), p. 852-856.
[14] Yang DF, He HZ, Wang FY, et al.: Advances in Materials Science, Energy Technology and Environmental Engineering, Vol. (2017), p. 291-294.
[15] Yang DF, Zhu SX, Yang DF, et al.: Computer Life, Vol. 4 (2016), p. 579-584.
[16] Yang DF, Yang DF, Tao XZ, et al.: World Scientific Research Journal, Vol. 22 (2016), p. 69-73.
[17] Yang DF, Chen Y, Gao ZH, et al.: Chinese Journal of Oceanology and Limnology, Vol. 23(2005), p. 72-90. (in Chinese)
[18] Yang DF, Wang FY, Gao ZH, et al.: Marine Science, Vol. 28 (2004), p. 71-74. (in Chinese)
[19] China's State Oceanic Administration: The specification for marine monitoring (Ocean Press, Beijing 1991), p.1-300. (in Chinese)
[20] Yang DF, Wang FY, He HZ, et al.: Proceedings of the 2015 international symposium on computers and informatics, Vol. (2015), p. 2655-2660.
[21] Yang DF, Wang FY, Zhao XL, et al.: Sustainable Energy and Environment Protection, Vol. (2015), p. 191-195.
[22] Yang DF, Wang FY, Yang XQ, et al.: Advances in Computer Science Research, Vol. (2015), p. 2352: 198-204.
[23] Yang DF, Miao ZQ, Xu HZ, et al.: Ocean Development and Management, Vol. 30 (2013), p.
46-50.
[24] Yang DF, Wang FY, Zhu SX, et al.: Applied Mechanics and Materials. Vol.651-653 (2014), p. 1415-1418.