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Influencing factors on the horizontal and vertical migration of Cr in marine bay

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Abstract. This paper analyzed the horizontal and vertical migration processes of Cadmium (Cd) and the influencing factors in Jiaozhou Bay in 1989. Results showed that the absolute horizontal losses of Cr were 0.20-0.89 μg L-1, and the relative horizontal losses of Cr were 14.49-46.84%, respectively. The absolute vertical dilution of Cd was 0.52-0.56 μg L-1, and the relative vertical dilution of Cr was 27.36-34.14%. The absolute vertical accumulation of Cd was 0.17 μg L-1, and the relative vertical accumulation of Cr was 14.40%. Once migrating from the bay center to the bay mouth, Contents in both surface and bottom were decreasing in a certain degree. In case of the loss rate of Cr in surface water was relative high, the loss rate of Cr in bottom water would also be relative high, and vice versa. The changing of Cr contents in surface and bottom waters were determined by the changing of the source inputs and the distance of migration paths.

1. Introduction

Cr is one of the widely used heavy metal elements in many industries [1−2]. The industries in many countries and regions are increasing rapidly in the past several decades [3−5], resulting in a great deal of Cr-containing wastes are generating and discharging to the environmental [6−9]. Many marine bays have been polluted by Cr since the waste treatment in many countries and regions is always lagging [10−13]. Hence, understanding the horizontal and vertical migration processes of Cr in marine bay is essential to environmental protection and remediation [12−21].

Jiaozhou Bay is a semi-closed bay located in Shandong Province, China [21−25]. This bay had been polluted by various pollutants including Cr since 1980s due to the rapid development of industry [1−2].By using investigation on Cr in surface and bottom waters in 1989 in Jiaozhou Bay, this paper researched the horizontal and vertical distributions, and analyzed the influencing factors. The aim of this paper is to provide basis for research on the vertical sedimentation and horizontal migration of Cr in marine bay.

2. Materials and method

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 and average water depth are 446 km^2 and 7 m, respectively. 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 River, Licun River, and Loushan River etc., all of which are seasonal rivers [22−23].

The investigation on Cr in Jiaozhou Bay was carried on by North China Sea Environmental Monitoring Center. In April and July1989, Cr contents in surface and bottom waters were measured in Site 85 and Sit 90 in the bay center and the bay mouth, respectively (Fig 1). Cr in waters was sampled and monitored follow by National Specification for Marine Monitoring [24].

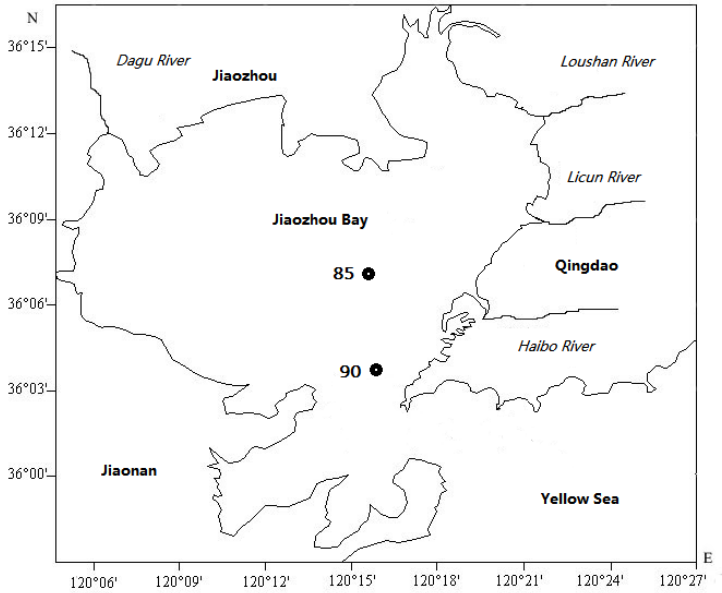

Fig 1 Geographic location and monitoring sites in Jiaozhou Bay

Modeling for horizontal migration processes of Cr. Supposed that Cr contents in surface and bottom waters in the bay center are *A* and *a*, in the bay mouth are *B* and *b*, respectively.

In surface waters, and from the bay center to the bay mouth, the calculation formula for migration process is:

$$D=A-B, \qquad E=(100\times \mid A-B \mid /\max(A, B))\% \tag{1}$$

where, *D* is the horizontal absolute loss amount in surface waters, *E* is the horizontal relative loss amount.

In bottom waters, and from the bay center to the bay mouth, the calculation formula for migration process is:

$$d=a-b, \qquad e=(100\times \mid a-b \mid /\max(a, b))\% \tag{2}$$

where, *d* is the horizontal absolute loss amount in bottom waters from the bay center to the bay mouth, *e* is the horizontal relative loss amount.

Modeling for vertical migration processes of Cr. Supposed that Cr contents in surface and bottom waters in Site *n* in the bay center are *A* and *a,* respectively. From surface waters to bottom waters, the calculation formula for this migration process is:

$$V_{na}=A-a, \qquad V_{nr}=(100\times \mid A-a \mid /\max(A, a))\% \tag{3}$$

where, V_{na} is the horizontal absolute dilution amount from surface waters to bottom waters, V_{nr} is the horizontal relative dilution amount. While from bottom waters to surface waters, V_{na} refers to the horizontal absolute accumulation amount, and V_{nr} refers to the horizontal relative accumulation amount.

3. Results

Horizontal changes of Cr. The horizontal migration process of Cr in surface waters were calculated in according to Cr contents in Site 85 and Site 90. The horizontal losses of Cr in surface and bottom waters were calculated by Eq. (1) and Eq. (2), respectively. It could be seen from in Table 1 that the horizontal absolute loss amounts of Cr were 0.20−0.89 μg L^{-1}, and the horizontal relative loss amounts were 14.49−46.84%.

Table 1 Horizontal changes of Hg in surface and bottom waters in Jiaozhou Bay 1989

Month	Surface waters		Bottom waters	
	D/μg L^{-1}	*E*/%	*d*/μg L^{-1}	*e*/%
April	0.89	46.84	0.20	14.49

Vertical loss of Cr. The vertical migration processes of Cr were calculated by Eq. (3) and listed in Table 2. It could be seen from in Table 2 that the vertical absolute dilution amounts of Cr were 0.52−0.56 μg L^{-1}, and the horizontal relative dilution amounts were 27.36−34.14%. The vertical absolute accumulation amounts of Cr were 0.17 μg L^{-1}, and the vertical relative accumulation amounts were 14.40%.

Table 2 Vertical changes of Hg in waters in Jiaozhou Bay 1989

Time	Location	V_{na}/μg L^{-1}	V_{nr}/%
April	Bay center	0.52	27.36
	Bay mouth	-0.17	14.40
July	Bay mouth	0.56	34.14

4. Discussion

Horizontal and vertical changes of Cr. The changes of Cr contents in marine waters were influenced by vertical water's effect and horizontal waters's effect, as well as the source inputs [25−28]. In the internal waters of Jiaozhou Bay, Cr was mainly sourced from river runoff, and Cr contents were decreasing from the high value region to peripheral zones by means of marine current and tide. In April 1989, along with the migration path from the bay center to the bay mouth, the horizontal losses of Cr in surface and waters were 46.84% and 14.49%, respectively (Fig 2). Meanwhile, the vertical dilution of Cr in the bay center was relative low as 27.36%, while the vertical accumulation of Cr in the bay mouth was very low as 14.40% (Fig 2). In July 1989, the vertical dilution of Cr in the bay mouth was relative low as 34.14%. In general, Cr contents in both surface and bottom waters were decreasing in a certain degree during the horizontal and vertical migration processes.

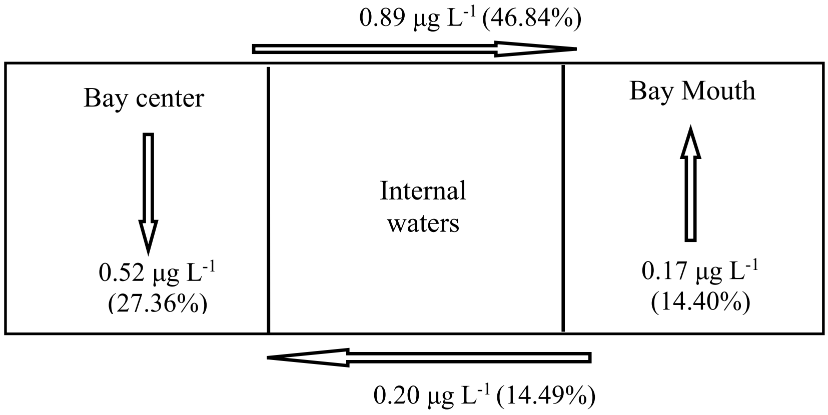

Fig 2 Block diagram model for horizontal-vertical changes of Cr in Jiaozhou Bay in April 1989

Horizontal loss of Cr. In April 1989, from the bay center to the bay mouth, the horizontal loss of Cr in surface waters was relative high as 46.84%. Meanwhile, from the bay center to the bay mouth, the horizontal loss of Cr in surface waters was also relative low as 14.49%. In general, no matter from the bay center to the bay mouth, or from the bay mouth to the bay centers, Cr contents were decreasing in a certain degree. In case of the loss rate of Cr in surface water was relative high, the loss rate of Cd in bottom water would be relative low.

Vertical loss of Cr. Cr contents were also changing a lot during the vertical migration process. In April 1989, Cd contents in surface and bottom waters were relative low as 1.01−1.90 µg L^{-1} and 1.18−1.38 µg L^{-1}, respectively. In general, Cr contents in both surface and bottom waters in April 1989 were relative low, the vertical dilution in the bay center and vertical accumulation were also relative low as 27.36% and 14.40%, respectively. This indicated that Cr in surface waters could be transported to sea bottom rapidly and continuously, and the vertical losses of Cr in April in Jiaozhou Bay were ~1/7. In July 1989 in the bay mouth, Cr contents in surface and bottom waters were relative low as 1.64 µg L^{-1} and 1.08 µg L^{-1}, respectively. The vertical dilution of Cr in the bay mouth was 34.14%, which indicated that the vertical loss of Cr in July was also relative low, and ~1/3 of Cr was losing during the vertical migration path from surface waters to bottom waters.

Influencing factors on migration of Cr. Cr in April 1989 was mainly sourced from atmosphere deposition. Hence, Cr contents in the bay centers were relative high, and were higher than in bottom waters. By means of the transportation via marine current, Cr contents in surface waters were decreasing along with the migration path, yet a big part of Cr was transported to and accumulated in sea bottom, resulting in Cr contents in bottom waters in the bay mouth were higher than in surface waters. Cr was mainly source from river runoff, and therefore Cr contents in surface waters in the bay mouth were higher than in bottom waters. As a whole, the changing of Cr contents in surface and bottom waters was determined by the changing of the source inputs and the distance of migration paths.

5. Conclusions

The horizontal absolute loss amounts of Cr were 0.20−0.89 µg L^{-1}, and the horizontal relative loss amounts were 14.49−46.84%. The horizontal relative dilution amounts were 27.36−34.14%, and the vertical relative accumulation amounts were 14.40%.

No matter from the bay center to the bay mouth, or from the bay mouth to the bay centers, Cr contents were decreasing in a certain degree. In case of the loss rate of Cr in surface water was relative high, the loss rate of Cd in bottom water would be relative low.

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The vertical losses of Cr in April and July were relative low, and ~1/7 and ~1/3 of Cr was losing during the vertical migration path from surface waters to bottom waters, respectively. The changing of Cr contents in surface and bottom waters was determined by the changing of the source inputs and the distance of migration paths.

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References
[1] Yang DF, Gao ZH, Sun JY, et al.: Coastal Enginerring, Vol. 27 (2008), p. 48- 53. (in Chinese)
[2] Yang DF, Zhu SX, Wang FY, He HZ, Wu YJ.: Applied Mechanics and Materials, Vol. 644-650 (2014), p. 5325-5328.
[3] Yang DF, Wang FY, He HZ, Yang C, Zhu SX.:Applied Mechanics and Materials Vol. 675-677(2014), p. 329-331.
[4] Yang DF, Zhu SX, Wang FY, et al.: 2014 IEEE workshop on advanced research and technology industry applications. Part D, Vol. (2014), p. 1018-1020.
[5] Yang DF, Zhu SX, Sun ZH, Zhao XL, Wang FY.: Advances in Engineering research, 2015, p. 1375-1378.
[6] Yang DF, Zhu SX, Yang XQ, Luo JL, Wang FY.: Advances in Engineering research, 2015, p. 1383-1387.
[7] Yang DF, Wang FY, Sun ZH, Zhao XL, Zhu SX.: Materials Engineering and Information Technology Apllication, 2015, p. 562-564.
[8] Yang DF, Wang FY, Zhu SX, Wang M, Yang XQ.: Advances in Engineering Research, Vol. 71 (2016), p. 1341-1344.
[9] Yang DF, Zhu SX, Wang FY, Wang ZK, Yang XQ.: Advances in Engineering Research, Vol. 71 (2016), p. 1358-1361.
[10] Yang DF, Wang FY, Yang XQ, Zhao XL, Zhu SX.: International Core Journal of Engineering, Vol. 2 (2016), p. 14-17.
[11] Yang DF, Wang FY, Zhu SX, Wang ZK, Zhao ZL.: International Journal of Science, Vol. 4(2017), p. 9-12.
[12] Yang DF, Li HX, Zhang LL, Li JM, Nan N.:Earth and Environment Science, Vol. 61 (2017), p. 1-4.
[13] Yang DF, Wang FY, Zhu SX, Su CH, Wang ZK.: Earth and Environment Science, Vol. 61(2017), p. 1-5.
[14] Yang DF, Li HX, Zhao XL, Li JM, Nan N.:Advances in Engineering Research, Vol. 123(2017), p.1367-1370.
[15] Yang DF, Wei LZ, Feng M, Lu M, Li C.:Advances in Engineering Research, Vol. 141 (2017), p. 296-299.
[16] Yang DF, Li HX, Ding J Zhang LL, Li JM.:Advances in Engineering Research, Vol. 141 (2017), p. 1237-1240.
[17] Yang DF, Wang FY, Zhu SX, He HZ, Wu FY.:Meterological and Environmental Research, Vol. 8 (2017),p. 73-75.
[18] Yang DF, Zhu SX, Wang FY, Yang XQ, Zhao XL.:Meterological and Environmental Research, Vol. 8 (2017), p.125-127.
[19] Yang DF, Miao ZQ, Li HX, Ding J, Zhang LL.:Advances in Engineering Research, Vo.148 (2017), p. 206-209.
[20] Yang DF, Miao ZQ Wei LZ, Feng M, Chen M.: Advances in Engineering Research, Vol. 148 (2017), p.298-301.
[21] Yang DF, Zhu SX, Wang ZK, Yang XQ, Wang FY.:Meterological and Environmental Research,

Vol. 86 (2017), p.70-71,77.
[22] Yang DF, Chen Y, Gao ZH, et al.: Chinese Journal of Oceanology and Limnology, Vol. 23(2005), p. 72-90.
[23] Yang DF, Wang FY, Gao ZH, et al.: Marine Science, Vol. 28 (2004), p. 71-74.
[24] China's State Oceanic Administration: The specification for marine monitoring (Ocean Press, Beijiang 1991), p.205-280.
[25] Yang DF, Wang FY, He HZ, et al.: Proceedings of the 2015 international symposium on computers and informatics,2015, p. 2655-2660.
[26] Yang DF, Wang FY, Zhao XL, et al.: Sustainable Energy and Enviroment Protection, 2015, p. 191-195.
[27] Yang DF, Wang FY, Yang XQ, et al.: Advances in Computer Science Research, Vol. 2352 (2015), p. 198-204.
[28] Yang DF, Miao ZQ, Xu HZ, et al.: Marine Environmental Science, Vol. 32 (2013), p. 373-380.