Inputs and spatial distribution patterns of Cr in Jiaozhou Bay

Dongfang Yang[1,2, a], Zhenqing Miao[3, b,c] ,Xinmin Huang[1] , LinzhenWei[1],Ming Feng[1]

[1]School of International Economics, Shaanxi Institute of International Trade & commerce, Xi'an 712046, China;

[2]North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China;

[3]College of Fisheries, Zhejiang Ocean University, Zhoushan, 316022, China.

[a]dfyang_dfyang@126.com, [b] corresponding author, [c]mzq@zjou.edu.cn

Abstract. Cr pollution in marine bays has been one of the critical environmental issues, and understanding the input and spatial distribution patterns is essential to pollution control. In according to the source strengths of the major pollution sources, the input patterns of pollutants to marine bay include slight, moderate and heavy, and the spatial distribution are corresponding to three block models respectively. This paper analyzed input patterns and distributions of Cr in Jiaozhou Bay, eastern China based on investigation on Cr in surface waters during 1979-1983. Results showed that the input strengths of Cr in Jiaozhou Bay could be classified as moderate input and slight input, and the input strengths were 32.32-112.30 μg L^{-1} and 4.17-19.76 μg L^{-1}, respectively. The input patterns of Cr included two patterns of moderate input and slight input, and the horizontal distributions could be defined by means of Block Model 2 and Block Model 3, respectively. In case of moderate input pattern via overland runoff, Cr contents were decreasing from the estuaries to the bay mouth, and the distribution pattern was parallel. In case of moderate input pattern via marine current, Cr contents were decreasing from the bay mouth to the bay, and the distribution pattern was parallel to circular. The Block Models were able to reveal the transferring process of various pollutants, and were helpful to understand the distributions of pollutants in marine bay.

1. Introduction

Many marine bays have been polluted along with the rapid development of industrialization and urbanization, and understanding the input and spatial distribution patterns of pollutants in marine bays are essential to pollution control [1-2]. In general, the input patterns of pollutants to marine bay include slight, moderate and heavy, and the spatial distribution are corresponding to three block models respectively. Cr is a widely used heavy metal in various industries, and Cr pollution in marine bays has been one of the critical environmental issues [3-4]. iaozhou Bay is a semi-closed bay located in Shandong Province, eastern China, and has been polluted by various pollutants including Cr due to the rapid increasing of industry along with China’s Reform and Opening-up [5-8].

In order to better understand the input and spatial distribution patterns of Cr, this paper analyzed distributions and spatial-temporal variations of Cr in Jiaozhou Bay, eastern China based on investigation data during 1979-1983. Results showed that the input strengths of Cr in Jiaozhou Bay could be classified as moderate input and slight input, and the input strengths were 32.32-112.30 μg L^{-1} and 4.17-19.76 μg L^{-1}, respectively. The input patterns of Cr included moderate two patterns of moderate input and slight input, and the horizontal distributions could be defined by means of Block

Model 2 and Block Model 3, respectively.

2. Materials and method

Jiaozhou Bay (35°55′-36°18′ N, 120°04′-120°23′ E) is located in the south of Shandong Peninsula, eastern China. The area, bay mouth width and average water depth and average water depth are 390 km^2, 2.5 km and 7.0 m, respectively (Fig. 1). This bay is surrounding by cities of Qingdao, Jiaozhou and Jiaonan in the east, north and south, respectively. The bay mouth is located in the south of the bay, and is connected with the Yellow Sea. There are more than ten inflow rivers such as Loushan River, Licun River and Haibo River, all of which are seasonal rivers [9-10].

The investigation on Cr in surface waters in Jiaozhou Bay was conducted by North China Sea Environmental Monitoring Center. The investigation times were in May and August 1979, April and August 1981, June1982, and May, September and October 1983, respectively [1-8], and the sampling sites were showed in Fig. 1. The investigation and measurement of Cr were following by National Specification for Marine Monitoring [11].

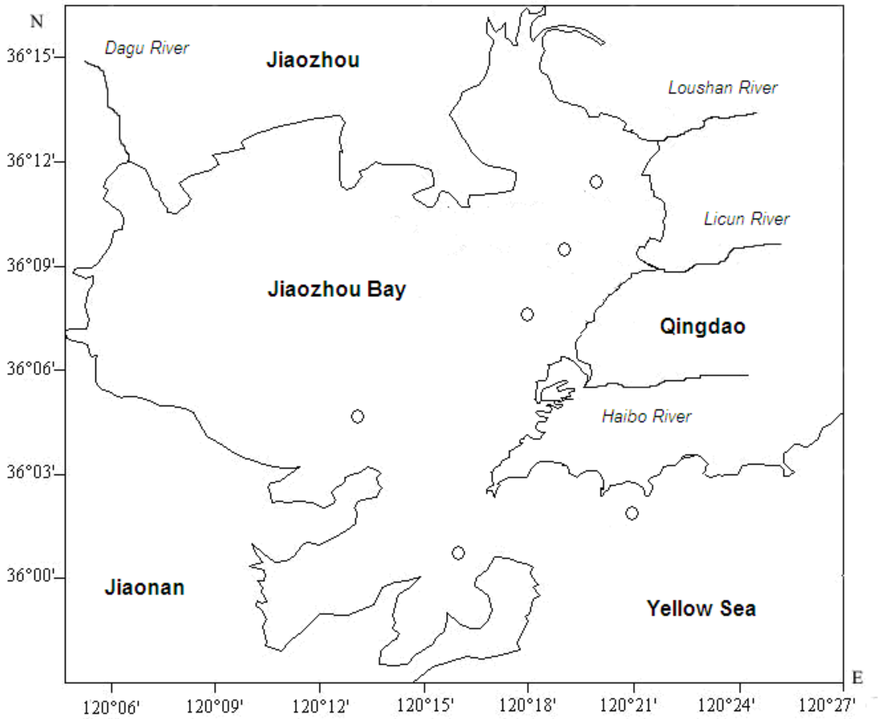

Fig.1 Geographic location and sampling sites of Jiaozhou Bay

3. Input patterns of Cr

Both of the spatial and temporal variations of Cr contents in Jiaozhou Bay were mainly determined by spatial-temporal variations of Cr inputs, and the input patterns of Cr could be defined by spatial-temporal distributions of Cr contents. In 1979, high Cr contents were appearing the estuaries of Haibo River, Loushan River and Licun River, and the source strength was 112.30 μg L^{-1}. In 1981, high Cr contents were appearing the estuaries of Haibo River and Loushan River, and the source strength was 32.32 μg L^{-1}. In 1982, high Cr contents were appearing the estuaries of Loushan River, and the source strength was 9.76 μg L^{-1}. In 1983, high Cr contents were appearing the estuaries of Loushan River and Licun River, and the source strength was 4.17 μg L^{-1}. In generally, the input strengths of Cr in Jiaozhou Bay could be classified as moderate input and slight input, and the input strengths were 32.32-112.30 μg L^{-1} and 4.17-19.76 μg L^{-1}, respectively.

4. Spatial distribution patterns of Cr

Obviously, the spatial-temporal variations of Cr contents in Jiaozhou Bay was significant, yet the major input source of Cr was always by river. For different input patterns, different distributions of Cr contents would be appearing (Table 1). In case of moderate Cr input pattern, the distribution pattern of Cr contents was semicircular, whereas in case of slight Cr input pattern, the distribution pattern of Cr contents was parallel. For example, the Cr inputs in 1979 and 1981 was moderate, and the distribution pattern of Cr contents was semicircular (Fig. 2a and Fig. 2b). Another example, the Cr inputs in 1982 and 1983 was slight, and the distribution pattern of Cr contents was parallel (Fig. 2c and Fig. 2d). In generally, climate (particularly rainfall-runoff) was one of the major influence factors of the distributions of Cr in the bay, yet the input patterns was the most important one.

Table 1 Input and spatial distribution patterns of Cr in Jiaozhou Bay

Time	Input source	Input strength/ μg L^{-1}	Input pattern	Distribution pattern
1979-1981	River	32.32-112.30	Moderate	Semicircular
1982-1983	River	4.17-9.76	Slight	Parallel

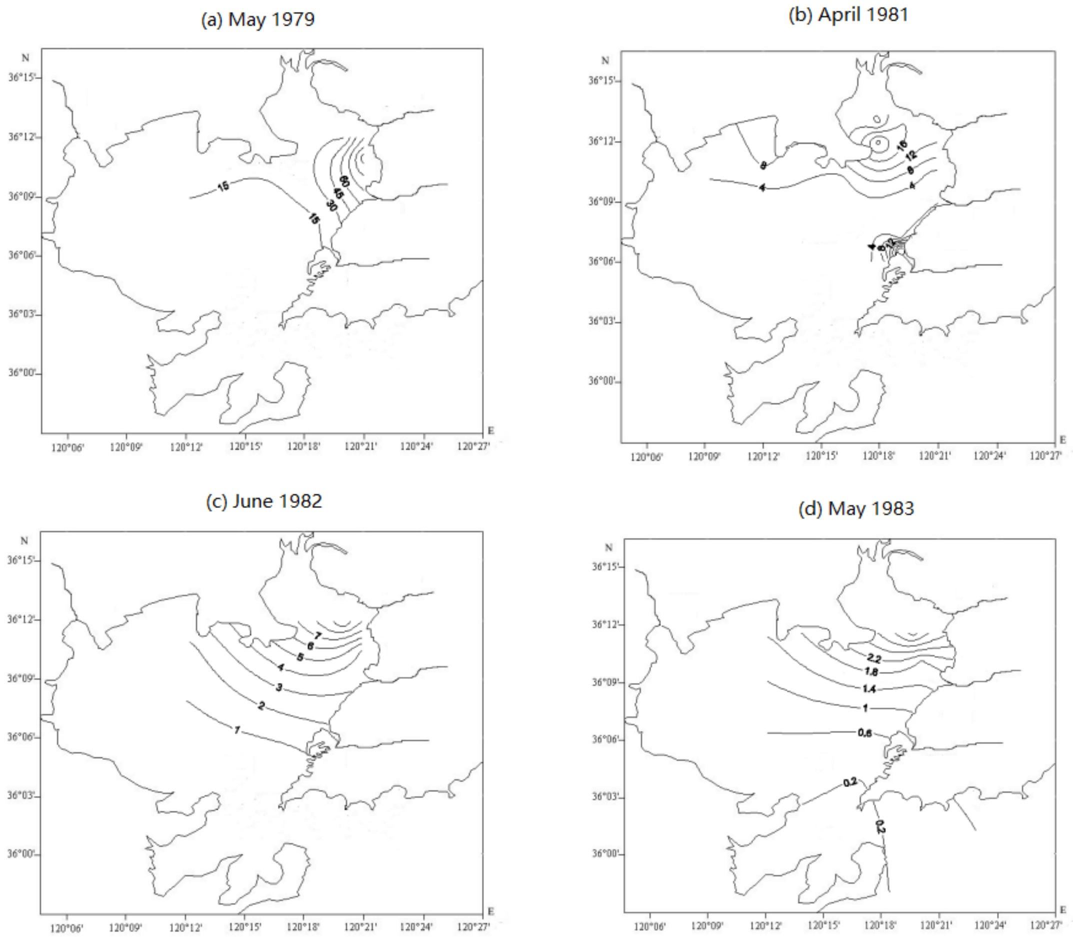

Fig.2 Horizontal distributions of Cr in different months in Jiaozhou Bay/μg L^{-1}

5. Block model of Cr

By means of different input patterns, as well as the other factors (etc., precipitation, hydrology, temperature), contents of the pollutants in Jiaozhou Bay were showing spatial-temporal variations. In generally, the input patterns of the pollutants included heavy input, moderate input and slight input, whose sources were river flow, overland runoff and marine current, respectively, and the spatial distributions of pollutants (etc., Hg, HCH, PHC, Cr) could be defined as three block models [10-14]. In case of heavy input pattern via river inflow , the contents of pollutants were decreasing from the estuaries to the bay mouth, and the distribution pattern was semicircular (Fig. 3a), that was Block Model 1. In case of moderate input pattern via overland runoff, the contents of pollutants were decreasing from the estuaries to the bay mouth, and the distribution pattern was parallel (Fig. 3b), that was Block Model 2. In case of moderate input pattern via marine current, the contents of pollutants were decreasing from the bay mouth to the bay, and the was a low value center in the top of the bay, and the distribution pattern was parallel to circular (Fig. 3c), that was Block Model 3. For Cr in Jiaozhou Bay, the input patterns included moderate input and slight input, and the distribution patterns were consist with Block Model 2 (Fig. 2a, Fig.2b and Fig.3b) and Block Model 3 (Fig. 2c, Fig.2d and Fig.3c), respectively. In generally, the three input patterns and the corresponding Block Models could reveal the transferring process of various pollutants in this bay, which were helpful to understand the spatial-temporal distributions of pollutants.

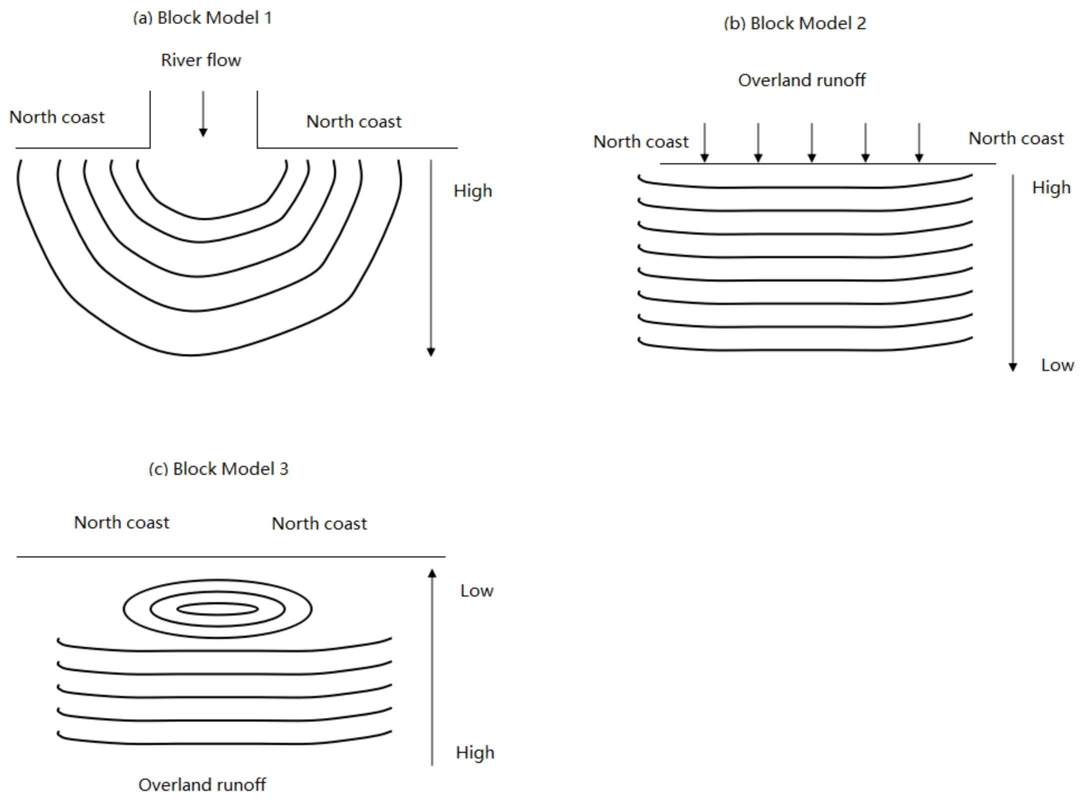

Fig.3 Block Models for input and distribution patterns of pollutants in Jiaozhou Bay

6. Conclusions

The input patterns and the horizontal distributions of Cr in Jiaozhou Bay were analyzed. The input strengths of Cr in Jiaozhou Bay could be classified as moderate input and slight input, and the input strengths were 32.32-112.30 μg L^{-1} and 4.17-19.76 μg L^{-1}, respectively. The input patterns of Cr included moderate two patterns of moderate input and slight input, and the horizontal distributions could be defined by means of Block Model 2 and Block Model 3, respectively. The Block Models were able to reveal the transferring process of various pollutants, and were helpful to understand the distributions of pollutants in marine bay.

Acknowledgment
This research was sponsored by Doctoral Degree Construction Library of Guizhou Nationalities University, Education Ministry's New Century Excellent Talents Supporting Plan (NCET-12-0659), the China National Natural Science Foundation (31560107) and (31500394), 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).

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