Theories of transporting processes of Cu in Jiaozhou Bay

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Abstract. Many marine bays have been polluted along with the rapid development of industry and population size, and understanding the transporting progresses of pollutants is essential to pollution control. In order to better understanding the transporting progresses of pollutants in marine, this paper carried on a comprehensive research of the theories of transporting processes of Cu in Jiaozhou Bay. Results showed that the transporting processes of Cu in this bay could be summarized into seven key theories including homogeneous theory, environmental dynamic theory, horizontal loss theory, source to waters transporting theory, sedimentation transporting theory, migration trend theory and vertical transporting theory, respectively. These theories helpful to better understand the migration progress of pollutants in marine bay.

1. Introduction

In the pass several decades, the economic and population were increasing rapidly, and a large amount of wastes were generated and discharged to the environment [1-3]. Many marine bays have been polluted by various pollutants since ocean is the sink of pollutants [4-5]. Cu pollution in marine bays has been one of the critical environmental issues due to the excessive Cu contents were harmful to the organism and ecosystem, and to human beings finally by food chain [1-2]. Hence, understanding the transporting laws in marine bays is essential to environmental protection.

Jiaozhou Bay is a semi-closed bay located in Shandong Province, eastern China. This bay is surrounded by cities of Jiaonan, Qingdao and Jiaozhou, and had been polluted along with the rapid development of industry and economic [1-8]. This paper provided a comprehensive research on the theories of transporting processes in Jiaozhou Bay [3-16]. The aim of this paper was to provided basis information to scientific research and pollution control practice in marine bay.

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 km², 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].
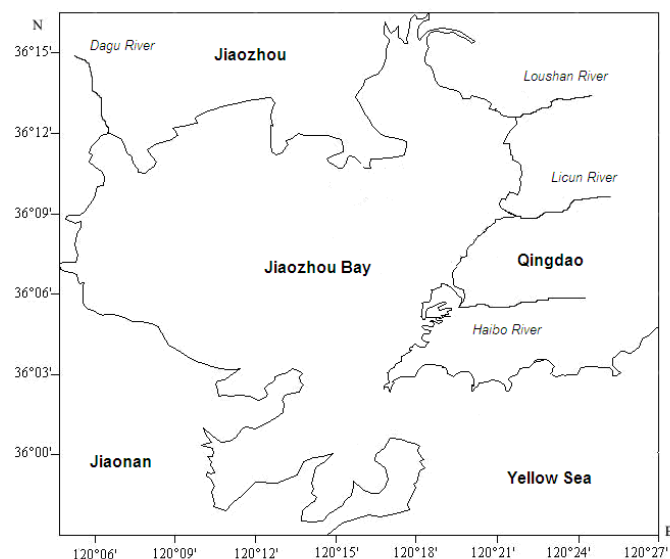
Fig. 1 Geographic location of Jiaozhou Bay

3. Results and discussion

Homogeneous theory. In according to the spatial and temporal distributions of Cu in Jiaozhou Bay, we proposed the homogeneous theory of substance in medium (i.e., gaseous, liquid and solid). In case of little source input of substance to the medium, the distribution of substance's contents was homogeneity, while in case of large input, the distribution was heterogeneity. The heterogeneity of substance's contents was determined by source input, while the homogeneity was determined by the moving of the earth. In general, there were three status of substance in the medium. Firstly, all of the substance's contents were homogeneous in the medium originally. Secondly, if there was source input of substance, the distribution of substance's contents would be transformed from homogeneity to heterogeneity. Thirdly, the feature of heterogeneity could be transformed to homogeneity by means of the moving of earth. Substance's contents in medium were moving in endless cycles among these three status.

Environmental dynamic theory. The definition and structural model of environmental dynamic value of substance in marine bay were provided, and the variables including basic background value, environmental background value, input value and environmental dynamic value were used in analyzing the change process and change trend of Cu in Jiaozhou Bay. Dring 1982-1986, the major Cu sources in this bay were marine current, river flow, island top, overland runoff and marine traffic, whose source strength were 0.39-20.60 µg L^{-1}, 0.37-10.57 µg L^{-1}, 0.77-4.86 µg L^{-1}, 2.28-3.56 µg L^{-1}, and 9.48 µg L^{-1}, respectively, and Cu contents resulted by these sources were 0.37-20.60 µg L^{-1}. By means of the environmental structure and numerical values, the change process and trend of Cu in Jiaozhou Bay were identified, providing scientific basis for division of grade standards of Cd in marine bay.

Horizontal loss theory. We developed the horizontal loss theory in quantifying the horizontal absolute and relative loss rates of Cu contents in Jiaozhou Bay. There were two different horizontal loss rate patterns for Cu content. In case of the source strength was relative high, the absolute horizontal loss rate (V_{asp}) of Cu content was relative high, yet the relative horizontal loss rate (V_{rsp}) was relative low. In case of the source strength was relative low, the absolute horizontal loss rate of Cu content was relative low, yet the relative horizontal loss rate was relative high. For instance, in June 1982, the major source was marine current and the source strength was relative high as 5.31µg L^{-1}, and the V_{asp} and V_{rsp} were 30.90 *AYDF* and 77.97 *RYDF*, respectively. In July 1982, the source strength was

also marine current yet the source strength was relative low as 2.33 μg L^{-1}, and the V_{asp} and V_{rsp} were 16.59 *AYDF* and 93.56 *RYDF*, respectively. In general, both absolute horizontal loss rate and relative horizontal loss rate of Cu could be calculated by horizontal loss rate model.

Source to waters transporting theory. We developed the source to waters theory for substance, and defined that the changing process of substance's contents were jointly determined by terrestrial transporting process and oceanic transporting process. Block diagram models were provided for identifying and showing the terrestrial and oceanic transporting processes of substance's contents, as well as the transporting paths and the remaining trances. The source to waters theory indicated that, in according to the contents and distributions of substance in waters, the major sources and the source inputs of the waters could be defined, and the changing processes of substance could be defined. Hence, by means of this source to waters theory, we could understand the changing processes of substance in bay waters, as well as the reasons of the changing processes.

Sedimentation transporting theory. Based on the analysis on the changes and distributions of Cu in bottom waters in Jiaozhou Bay, we proposed the sedimentation transporting theory, which could be further developed into theories of horizontal water's effect, vertical water's effect and water's effect. During 1982-1986, it was defined that there were sedimentation and accumulation processes 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 burying 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. In general, the spatial-temporal variations of Cu's sources and the horizontal water's effect, vertical water's effect and water's effect resulted in high sedimentation processes and regions in marine bay.

Transporting trend theory. In according to the analysis of the horizontal distribution trends of Cu in surface and bottom waters in Jiaozhou Bay, we proposed the transporting trend theory. In case of there was source input of Cu, the substance contents in surface waters were decreasing along with the directions of the input sources, as well as in bottom waters. The sedimentation process of substance contents were rapid, and there was accumulation process in bottom. The horizontal distribution trends in both surface and bottom waters were determined by directions of the source inputs determined, while the high sedimentation regions of substance contents were determined by the substance contents in the source inputs. Furthermore, four block diagram models for high sedimentation processes were provide in according to the transporting trend theory. By means of these block diagram models, the distribution trends of substance contents in surface and bottom waters could be determined, the high sedimentation locations could be defined, the transport path and the remaining trace of the substance contents could be defined, and the horizontal distribution trends of the substance contents could be predicted.

Vertical transporting theory. In according to the analysis of the horizontal and vertical distributions of Cu in surface and bottom waters in Jiaozhou Bay, we proposed the vertical transporting theory. Models of vertical content difference model, substance settlement amount model and substance accumulation amount model were established to quantify the vertical changes and processes of substance in marine bay waters. The relative accumulation amount indicated that the sedimentation of Cu contents was rapid and thorough, with feature of easy to be settled. The absolute accumulation amount indicated that the accumulation of Cu contents was stable and complete, with feature of easy to be accumulated and fixed. 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, the vertical transporting process could be divided into seven status.

4. Conclusions

A comprehensive research of the theories of transporting processes of Cu in Jiaozhou Bay were carried on. The transporting processes of Cu could be summarized into seven key theories of 1) homogeneous theory, 2) environmental dynamic theory, 3) horizontal loss theory, 4) source to waters transporting theory, 5) sedimentation transporting theory, 6) migration trend theory, and 7) vertical transporting theory, respectively. These theories were applied in the analysis of the transporting processes of Cu in Jiaozhou Bay, and were indicating that they were helpful to better understand the transporting progress of pollutants in marine bay.

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