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Spatial settling process of Pb in Jiaozhou Bay

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Abstract. We analyzed the vertical distributions, seasonal variations and transfer processes of Pb in Jiaozhou Bay based on investigation data in surface and bottom waters in 1986. Results showed that Pb contents in surface waters were in order of spring < autumn < summer. By means of vertical water's effect, Pb was settling from surface waters to bottom waters continuously, and was accumulating in bottom waters continuously, resulting in Pb contents in bottom waters were in order of spring < summer < autumn. The variation ranges of Pb contents in April, July and October in waters in the bay mouth were basically consistent. In case of Pb contents in surface waters were low, accumulation effect was making a role in bottom waters. In case of Pb contents in surface waters were high, dilution effect was making a role in bottom waters. The seasonal variations of Pb contents in surface waters were following to the seasonal variation of the inflow rivers, while the seasonal variations of Pb contents in bottom waters were determining by vertical water's accumulation effect. For spatial scale, Pb contents in surface and bottom waters were tending to be consist, no matter the input of Pb was different in time, source and source strength. In generally, the seasonal variations, variation ranges and horizontal distributions of Pb contents in surface and bottom waters were confirming the vertical settling process that Pb was settling to sea bottom rapidly by means of gravity force and marine current.

Introduction

Pb is one of the widely used heavy metal elements in instrumentation, electrolysis and smelting etc. A large amount of Pb-containing wastes were generated and discharged to the environment along with the rapid development of industry. Pb is also one of the critical heavy metal due to high toxicity and long persistent. The sea waters have been polluted by Pb finally since ocean is the sink of various pollutants [1-6]. Therefore, understanding of the transfer process of Pb in marine bay is essential to environmental protection.

Jiaozhou Bay is a semi-closed bay located in Shandong Province, China. This bay had been polluted by various pollutants including Pb after China's reform and opening-up [1-6]. Based on investigation data in surface and bottom waters in 1986 in this bay, the aim of this paper is to analyze the vertical distributions, seasonal variations and transfer processes of Pb in surface and bottom waters in the bay, and to provide scientific basis for pollution control.

Materials and method

Jiaozhou Bay is located in the south of Shandong Province, eastern China (35°55′-36°18′ N, 120°04′-120°23′ E), which is connected to the Yellow Sea in the south. This bay is a typical of semi-closed bay, and the total area, average water depth and bay mouth width are 446 km^2, 7 m and 3 km, respectively. 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 [7-8].

The investigation on Cd in Jiaozhou Bay was carried on in April, July and Pctober 1986 in three investigation sites namely 2031, 2032 and 2033, respectively (Fig. 1). Pb in waters was sampled and monitored follow by National Specification for Marine Monitoring [9].

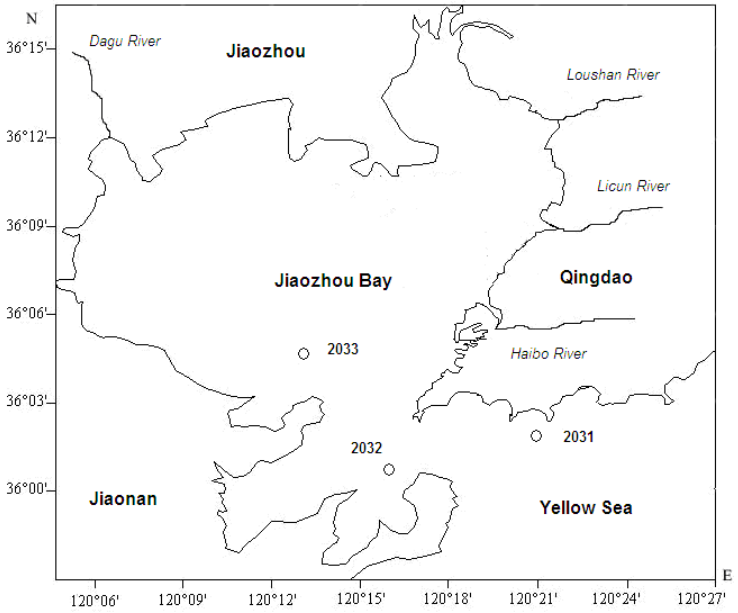

Fig. 1 Geographic location and sampling sites in Jiaozhou Bay

Results

Seasonal variations of Pb. Pb contents in surface waters in April, July and October 1986 in Jiaozhou Bay were 12.63-25.60 μg L^{-1}, 27.56-34.91 μg L^{-1} and 20.37-27.40 μg L^{-1}, respectively, while in bottom waters were 11.30-18.17 μg L^{-1}, 22.20-34.33 μg L^{-1} and 22.48-35.42 μg L^{-1}, respectively. In according to Chinese Sea Water Quality Standard, the pollution level of Pb in Jiaozhou Bay was Grade IV, indicating that this bay had been heavy polluted by Pb in 1986. April and July and October were spring, summer and autumn in study area. In generally, Pb contents in surface waters were in order of spring < autumn < summer, while in bottom waters were in order of spring < summer < autumn.

Vertical variations of Pb. In April, Pb contents in surface waters were relative high, and Pb contents in bottom waters were also relative high. In July, Pb contents in surface waters were highest, and Pb contents in bottom waters were also highest. In October, Pb contents in surface waters were relative high, and Pb contents in bottom waters were also relative high. Cd contents in surface and bottom waters were ranging from 12.63-34.91 μg L^{-1} and 11.30-35.42 μg L^{-1}, respectively, indicated that Pb contents in surface and bottom waters were tending to be consisting. The seasonal variations of Pb contents in surface waters were following to the seasonal variation of the inflow rivers, while the seasonal variations of Pb contents in bottom waters were determining by vertical water's accumulation effect [10-11].

Horizontal distributions of Pb. The three sampling Sites of 2031, 2032 and 2033 were located in the open sea, the bay mouth and the inside of the bay mouth, respectively. In April 1986, Pb contents in surface waters were decreasing from Site 2031 in the open waters (25.60 μg L^{-1}) to Site 2032 in the bay mouth (12.63 μg L^{-1}), while in bottom waters were also decreasing from Site 2031 in the open waters (18.17 μg L^{-1}) to Site 2032 in the bay mouth (16.02 μg L^{-1}). In July 1986, Pb contents in surface waters were decreasing from Site 2032 in the bay mouth (34.91 μg L^{-1}) to Site 2031 in the open waters (27.56 μg L^{-1}), while in bottom waters were also decreasing from Site 2032 in the bay mouth (22.86 μg L^{-1}) to Site 2031 in the open waters (22.20 μg L^{-1}). In October 1986, Pb contents in surface waters were decreasing from Site 2031 in the open waters (27.40 μg L^{-1}) to Site 2032 in the bay mouth (27.30 μg L^{-1}), while in bottom waters were also decreasing from Site 2031

in the open waters (35.42 μg L^{-1}) to Site 2032 in the bay mouth (33.06 μg L^{-1}). In generally, the horizontal distributions of Pb contents in surface and bottom waters were same in different seasons.

Discussion

Settling process of Pb. By means of vertical water's effect, Pb contents were changing a lot once Pb was crossing the water body [10]. Pb irons were strong hydrophilic, and were liable to combine to plankton and suspended particles in sea waters. The growth and reproduction of plankton were increasing rapidly [8], and a large amount of colloids were formed to enhance the adsorption capacity of the suspended particles. Hence, a large amount of Pb irons were absorbing and settling to sea bottom by means of gravity force and marine current. That was the vertical settling process of Pb.

Seasonal variation process of Cd. It was found that Pb contents in surface waters were in order of spring < autumn < summer. Pb was mainly sourced from stream flow and marine current. In spring, the source strength of stream flow was very weak. In summer, the source strength of stream flow was very strong. In autumn, the source strength of stream flow was relative weak. Hence, it could be concluded that Pb contents in surface waters were mainly determined by the pollution source and source strength. By means of vertical water's effect, Pb was settling from surface waters to bottom waters continuously, and was accumulating in bottom waters continuously, resulting in Pb contents in bottom waters were in order of spring < summer < autumn. Hence, it could be concluded that by means of vertical water's effect [10], Pb contents in bottom waters were mainly determined by which in surface waters and the accumulation of Pb in bottom waters.

Spatial settling of Pb. In April and October, Pb was mainly sourced from marine current, and the source strength of marine was relative high. Hence, the horizontal distributions of Pb contents in surface waters were in April and October were same that decreasing from the open waters to the bay mouth. By means of vertical water's effect [10, 11], Pb was settling from surface waters to bottom waters continuously, and was accumulating in bottom waters continuously, resulting in the horizontal distributions of Pb contents in bottom waters were decreasing from the open waters to the bay mouth. In July, Pb was mainly sourced from stream flow, and the source strength of stream flow was relative high. Hence, the horizontal distributions of Pb contents in surface waters in April and October were same that decreasing from the bay mouth to the open waters. By means of vertical water's effect [10, 11], Pb was settling from surface waters to bottom waters continuously, and was accumulating in bottom waters continuously, resulting in the horizontal distributions of Pb contents in bottom waters were decreasing from the bay mouth to the open waters. For spatial scale, Pb contents in surface and bottom waters were tending to be consist, no matter the input of Pb was different in time, source and source strength. In generally, the seasonal variations, variation ranges and horizontal distributions of Pb contents in surface and bottom waters were confirming the vertical settling process that Pb was settling to sea bottom rapidly by means of gravity force and marine current. That was the spatial settling process of Pb.

Conclusions

Jiaozhou Bay had been heavy polluted by Pb since 1986. Pb contents in surface waters were in order of spring < autumn < summer, while in bottom waters were in order of spring < summer < autumn.

Pb contents in surface waters were mainly determined by the pollution source and source strength, while Pb contents in bottom waters were mainly determined by which in surface waters and the accumulation of Pb in bottom waters.

Pb contents in surface and bottom waters were tending to be consist, no matter the input of Pb was different in time, source and source strength. The vertical settling process was that Pb was settling to sea bottom rapidly by means of gravity force and marine current.

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