Vertical migration and sedimentation of Pb in Jiaozhou Bay

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Keywords: Pb; Vertical distribution; Seasonal variation; Sedimentation; Jiaozhou Bay

Abstract. Based on investigation data on Pb in surface and bottom waters in Jiaozhou Bay, eastern China in 1985, we analyzed the spatial and seasonal variations Pb in waters, and defined the seasonal distribution, horizontal distribution, variation range, vertical variation, vertical transfer process and high sedimentation rate region. Results showed that, the seasonal variations of Pb contents in surface and bottom waters were consist that Pb contents were in order of autumn<spring<summer. In spatial scale, Pb contents in surface and bottom waters were consist. In variation scale, the variation ranges of Pb contents in surface and bottom waters were closed. In vertical scale, Pb contents in surface and bottom waters were consist. In regional scale, Pb contents in bottom waters in the bay mouth were relative high, and high sedimentation rate was occurring in this region. We found that Pb contents in Jiaozhou Bay were determined by precipitation. This research confirmed the vertical transfer process that Pb could be settling to the bottom by force of gravity and current.

Introduction

Pb has been widely used in salt electrolysis, metal smelting etc., and a large mount of Pb-containing waste water was discharged due to the rapid increasing of these industries. Hence, Pb has been considered as one of the critical strong pollutants due to the high toxicity and persistence in the environment. The Pb pollution in the land could cause the Pb pollution in the ocean finally [1-6]. Based on investigation data on Pb in surface and bottom waters in Jiaozhou Bay, eastern China in 1985, we analyzed the spatial and seasonal variations Pb in waters, and defined the seasonal distribution, horizontal distribution, variation range, vertical variation, vertical transfer process and high sedimentation rate region. The aim of this research was to provide basis for the research and practice of environmental protection.

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, whose total area, average water depth and bay mouth width are 446 km^2, 7 m and 3 km, respectively. There are a dozen of inflow rivers, and the majors are Dagu River, Haibo Rriver, Licun Rriver, and Loushan Rriver etc., all of which are seasonal rivers [8-9]. The investigation on Pb in Jiaozhou Bay was carried on in April, July and October 1985 in three investigation sites namely 2031, 2032 and 2033, respectively (Fig. 1). Pb in surface and bottom waters was sampled and monitored follow by National Specification for Marine Monitoring [10].

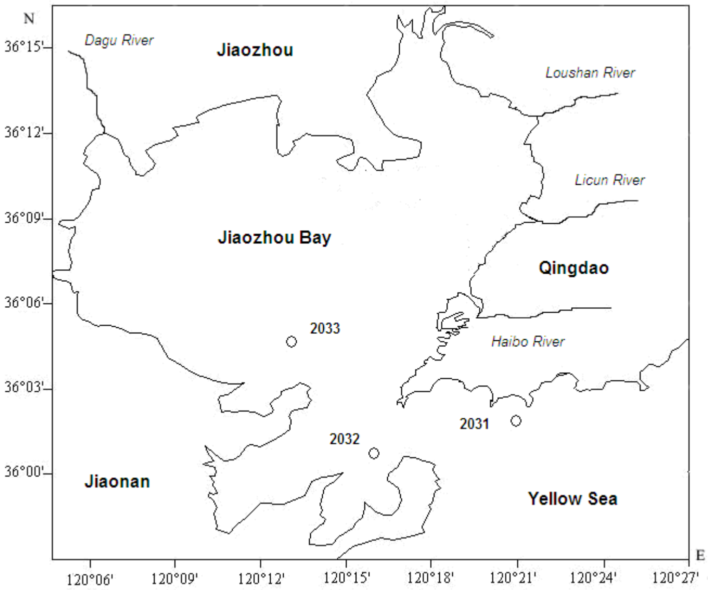

Fig. 1 Geographic location and sampling sites in Jiaozhou Bay

Results

Seasonal variations of Pb. Pb contents in surface waters in April, July and October in Jiaozhou Bay in 1985 were 12.61-25.82 μg L^{-1}, 23.60-42.81 μg L^{-1} and 11.14-22.73 μg L^{-1}, respectively, while in bottom waters were 12.89-15.48 μg L^{-1}, 16.03-36.35 μg L^{-1} and 8.57-15.10 μg L^{-1}, respectively. April, July and October were spring, summer and autumn in study area. Pb contents in both surface and bottom waters were in order of autumn<spring<summer. Hence, the seasonal variations of Cu contents in surface and bottom waters were consistent.

Horizontal distributions of Pb. Thesampling Sites of 2031, 2032 and 2033 were located in the outside of the bay mouth, the bay mouth and the inside of the bay mouth, respectively. In April, Pb contents in surface waters were increasing from the bay mouth (22.04 μg L^{-1}) to the open waters(22.25μg L^{-1}), and in bottom waters were also increasing from the bay mouth (12.89 μg L^{-1}) to the open waters (15.48 μg L^{-1}). In July, Pb contents in surface waters were decreasing from the bay mouth (33.47 μg L^{-1}) to the open waters (32.73 μg L^{-1}), and in bottom waters were also decreasing from the bay mouth (36.35 μg L^{-1}) to the open waters(16.03 μg L^{-1}). In October, Pb contents in surface waters were increasing from the bay mouth (11.14 μg L^{-1}) to the open waters (18.92 μg L^{-1}), and in bottom waters were also increasing from the bay mouth (12.67 μg L^{-1}) to the open waters (15.10 μg L^{-1}). The horizontal distributions of Pb contents in surface and bottom waters were consist in different seasons.

Variation ranges of Pb. Pb contents in surface waters (12.61-25.82 μg L^{-1}) were relative high in April, and Pb contents in bottom waters (12.89-15.48 μg L^{-1}) were also relative high. Pb contents in surface waters (23.60-42.81 μg L^{-1}) were very high in July, and Pb contents in bottom waters (16.03-36.35 μg L^{-1}) were also very high. Pb contents in surface waters (11.14-22.73 μg L^{-1}) were relative low in October, and Pb contents in bottom waters (8.57-15.10 μg L^{-1}) were also relative low. It could be concluded that Pb contents were increasing/decreasing with the increasing/decreasing of which in bottom waters.

Vertical variations of Pb. Pb contents in surface waters in each sampling site were subtracted by which in bottom waters, and the differences was -2.88 to 17.10 μg L^{-1}. In April, the differences ranged from 3.56 to 9.15 μg L^{-1}, and the differences were positive in all of the three sites (Table 1). In July, the differences ranged from -2.88 to 17.10 μg L^{-1}, and the differences were positive in Site 2031 and 2033, and were negative in Site 2032 (Table 1). In October, the differences ranged from 0.50 to 1.39 μg L^{-1}, and the differences were positive in Site 2031 and 2032 (Table 1).

Table 1 Results of subtracting Pb contents in surface waters from which in bottoms in the three sampling sites in April, July and October 1985

Month	2031	2032	2033
April	Positive	Positive	Positive
July	Positive	Negative	Positive
October	Positive	PNegative	Positive

Discussion

Sedimentation process of Pb. Pb contents were changing while transferring through the water body by means of vertical water's effect [10]. Pb iron is strong hydrophic, and could be absorbed by phytoplankton and suspended particulate matters. In summer, the activities of zooplankton and phytoplankton were increasing [8], and the adsorption capacities of suspended particulate matters were enhancing due to the large production of colloid. Hence, a large amount of Pb in waters was absorbing and settling to the sea bottom continuously under the force of gravity and current [1-6]. This was the horizontal settling process of Pb.

Seasonal variations process of Pb. Pb contents in surface waters were relative low in April (25.82 μg L^{-1}), and were highest in July (42.81 μg L^{-1}), and were decreasing to the lowest in October (22.73 μg L^{-1}), showing an order of autumn<spring<summer.

The major source of Pb in this bay in spring was stream flow, whose source strength was relative weak, the major source in summer was overland runoff, whose source strength was strongest, and in autumn was stream flow, whose source strength was weakest. Hence, Pb contents in summer was highest, and then spring and autumn. Due to the sedimentation of Pb to the ocean bottom, Pb contents in bottom waters were determined by which in surface waters by means of vertical water's effect [10], resulting in the consist of seasonal variations in bottom waters with in surface waters.

Spatial sedimentation of Pb. In spatial scale, the sources of Pb in April, July and October were stream flow, overland runoff and stream flow, respectively. The horizontal distributions of Pb contents in surface and bottom waters were consist, due to. Pb could be absorbed by phytoplankton and suspended particulate matters, and the sedimentation of Pb to bottom waters was rapid enough, resulting in the consist horizontal distributions of Pb contents in bottom waters. That was the spatial sedimentation process of Pb.

Variation sedimentation of Pb. In variation scale, the variation ranges of Pb contents in surface and bottom waters were closed, and Pb contents in bottom waters were increasing/decreasing with the increasing/decreasing of which in surface waters. These revealed that the rapid and continuous sedimentation of Pb to bottom waters, leading to the close variation ranges in surface and bottom waters.

Vertical sedimentation of Pb. In vertical scale, in case of low Pb contents, there was little loss but accumulation by means of vertical water's effect. In case of high Pb contents in waters, the loss was as small as 1.14 μg L^{-1}-18.57 μg L^{-1} to 42.81 μg L^{-1}-36.35 μg L^{-1}, that was -7.43 to 6.46 μg L^{-1}. Hence, Pb contents in surface and bottom waters were keeping closed in any case. Once Pb contents was low, little Pb could be transported by current but was settling to the bottom. Once Pb contents was high, Pb could be settling to bottom waters rapidly. That's why Pb contents in surface and bottom waters were consist.

Regional sedimentation of Pb. The subtractions of Pb contents in surface waters from which in bottom waters were changing along with time, indicating the variations of Pb contents in surface and bottom waters. Once Pb was inputted to the bay, which was originally arrived at the surface waters, and than was settling to the bottom waters rapidly and continuously by means of horizontal water's effect. The source strength of Pb in April was relative low, and Pb contents in surface waters in the whole region were higher than in bottom waters. The reason was that, the raining season was beginning and a little amount of Pb was inputted to the bay. The source strength of Pb in July was highest, and Pb contents in surface waters in the bay and the bay mouth were higher than in bottom waters, yet in the open waters were lower. The reason was that a large amount of Pb was discharged to the bay by stream flow, and Pb was spreading to the whole region, and Pb contents in all the regions except the bay mouth were higher in surface waters than in bottom waters, due to the high sedimentation rate in the bay mouth. In October, the source strength of Pb was lowest, and Pb contents in surface waters inside and outside the bay mouth were higher than in bottom waters, yet in the bay mouth were lower. Since the raining season was over in October, the inputs of Pb was fewest, yet the accumulation of Pb to the bottom waters in the bay mouth was continuous from April to October, leading to high Pb contents in bottom waters. In generally, high sedimentation rate of Pb was occurring in the bay mouth.

4 Conclusion

The seasonal variations of Pb contents in surface and bottom waters were consist that Pb contents were in order of autumn<spring<summer. In spatial scale, Pb could be absorbed by phytoplankton and suspended particulate matters, and the sedimentation of Pb to bottom waters was rapid enough, resulting in the consist horizontal distributions of Pb contents in bottom waters. In variation scale, the variation ranges of Pb contents in surface and bottom waters were closed, and the rapid and continuous sedimentation of Pb to bottom waters, leading to the close variation ranges in surface and bottom waters. In vertical scale,Once Pb contents was low, little Pb could be transported by current but was settling to the bottom. Once Pb contents was high, Pb could be settling to bottom waters rapidly, resulting in Pb contents in surface and bottom waters were consist. In regional scale, high sedimentation rate of Pb was occurring in the bay mouth. Pb contents were determined by precipitation.

Acknowledgement

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) ，Major Project of Science and Technology of Guizhou Provincial（[2004]6007-01)，Guizhou R&D Program for Social Development ([2014] 3036) and 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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