A review on the sources and spatial-temporal distributions of Pb in Jiaozhou Bay

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Abstract. This paper provided a review on the source, spatial-distribution, temporal variations of Pb in Jiaozhou Bay based on investigation of Pb in surface and waters in different seasons during 1979-1983. The source strengths of Pb sources in Jiaozhou Bay were showing increasing trends, and the pollution level of Pb in this bay was slight or moderate in the early stage of reform and opening-up. Pb contents in the marine bay were mainly determined by the strength and frequency of Pb inputs from human activities, and Pb could be moving from high content areas to low content areas in the ocean interior. Surface waters in the ocean was polluted by human activities, and bottom waters was polluted by means of vertical water’s effect. The process of spatial distribution of Pb in waters was including three steps, i.e., 1) Pb was transferring to surface waters in the bay, 2) Pb was transferring to surface waters, and 3) Pb was transferring to and accumulating in bottom waters.

1. Introduction
Ocean is the sink of various pollutants, and many marine bays are suffering from various pollutants including Pb for a long time. Marine bay could be polluted by Pb by various processes such as stream flow and atmosphere deposition, and the ocean could be the sink of Pb and the other pollutants. With the rapid increasing of population and the development of economic, Pb pollution in marine bays has been one of the critical environmental issues. Understanding the pollution sources, spatial-temporal variations, and transferring process of Pb is essential to environmental protection [1-6].

Jiaozhou Bay is a semi-closed bay located in south of Shandong Peninsula, eastern China. The aim of this paper was to analyze the spatial-temporal variations of Pb in surface and bottom waters in Jiaozhou Bay based on investigation data in waters in different seasons during 1979-1983, to provided a comprehensive analysis on the source, spatial-temporal distribution and their variations, and to provide scientific basis for environmental protection and the sustainable development of study area.

2. Study area and data collection
Jiaozhou Bay (120°04′-120°23′ E, 35°55′-36°18′ N) is located in the south of Shandong Province, eastern China (Fig. 1). It is a semi-closed bay with the total area, average water depth and bay mouth...
width of 446 km², 7 m and 3 km, respectively. There are more than ten inflow rivers (i.e., Haibo River, Licun River, Dagu River, and Loushan River), most of which have seasonal features [7-8].

The data was provided by North China Sea Environmental Monitoring Center. The survey was conducted in May, September and October 1979; June, July and September 1980; April, August and November 1981; April, June, July and October 1982; and May, September and October 1983 [1-6]. Surface and bottom water samples were collected and measured followed by National Specification for Marine Monitoring [9]. In study area, April, May and June belong to spring; July, August and September belong to summer; October, November and December belong to autumn.

![Fig. 1 Geographic location and sampling sites in Jiaozhou Bay](image)

3. Results and discussion

Pollution levels of Pb. In according to National Sea Water Quality Standard (GB 3097-1997) for Pb, the pollution levels of Pb in surface waters in Jiaozhou Bay were all Grade I and II. In generally, the pollution level of Pb during 1979-1983 was slight. However, there was increasing trend of annual Pb contents, indicating that the pollution levels of Pb in Jiaozhou Bay would be deteriorating.

Changing of Pb sources. During 1979-1983, the major Pb sources were stream flow, overland runoff, atmosphere deposition, marine current, and maritime transportation, whose source strengths were 0-75-3.35 μg L⁻¹, 2.65-3.30 μg L⁻¹, 0.69-2.55 μg L⁻¹, 1.47-1.82 μg L⁻¹, 0.76-3.34 μg L⁻¹ and 2.39-3.25 μg L⁻¹, respectively. Anthropogenic activities had discharged a significant amount of Pb to the environment, and caused the Pb pollution in streams, as well as in the ocean. Hence, both streams and the open waters had been two of the major Pb sources in this bay. Meanwhile, the Pb-containing waste gas generated by industries and vehicle exhaust had polluted the atmosphere, and atmosphere deposition had also been one of the major Pb sources. The rapid development of maritime transportation was also another major Pb sources due to the fuel combustion and leakage. The source strengths were showing increasing trends, and the pollution level of Pb in this bay was slight or moderate in the early stage of reform and opening-up.

Land transferring process of Pb. At spatial scale, there were wide Pb sources in marine waters, and the sources were influencing the Pb contents in different positions. At temporal scale, the source strengths were changing significantly. In some cases, Pb was discharged suddenly, and the source strength was very strong. The temporal variations and spatial distributions of the Pb sources were the
major influencing factor of the spatial-temporal variations of Pb contents in marine bay. The land transferring process of Pb was defined that, t Pb contents in the marine bay were mainly determined by the strength and frequency of Pb inputs from anthropogenic activities, and meanwhile, Pb was moving from high content areas to low content areas in the ocean interior.

**Variations of Pb in bottom waters.** Pb contents in bottom waters were showing significant temporal variations during 1979-1983. During April to November, Pb contents in bottom waters were ranging from 0.01-7.00 μg L^-1, which were meeting Grade to Grade in according to Chinese Sea Water Quality Standard, indicating that belonging to moderated polluted level. The pollution level of Pb in July was non-polluted, in August was moderate, while in the other months was slight. Meanwhile, during April to June, and during September to November, Pb’s pollution level could be return to non-polluted from slight polluted. In August in the early years, Pb’s pollution level could be return to non-polluted from moderate polluted, yet in the later years, Pb’s pollution level could only be return to slight polluted from moderate polluted. In generally, Pb contents were reaching the peak in summer. It was found that surface waters in the ocean was polluted by human activities, and bottom waters was polluted by means of vertical water’s effect.

**The process of spatial distribution of Pb.** Pb contents were showing significant spatial-temporal variations during 1979-1983 by means of the strength and frequency of Pb inputs from anthropogenic activities, and the vertical water’s effect. The process of spatial distribution of Pb in waters was including three steps, i.e., 1) Pb was transferring to surface waters in the bay, 2) Pb was transferring to surface waters, and 3) Pb was transferring to and accumulating in bottom waters. These steps were clearly revealing the transferring process of Pb in waters.

**4. Conclusion**

The source strengths of Pb sources in Jiaozhou Bay were showing increasing trends, and the pollution level of Pb in this bay was slight or moderate in the early stage of reform and opening-up. Pb contents were mainly determined by the strength and frequency of Pb inputs from human activities, and Pb was moving from high content areas to low content areas in the ocean interior. Surface waters in the ocean was polluted by human activities, and bottom waters was polluted by means of vertical water’s effect. The process of spatial distribution of Pb was: 1) Pb was transferring to surface waters in the bay, 2) Pb was transferring to surface waters, and 3) Pb was transferring to and accumulating in bottom waters. These findings would be helpful to better understanding the migration and transferring process of Pb and the mechanism 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 Foundations (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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