

# Atmospheric deposition having been one of the major source of Pb in Jiaozhou Bay

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**Abstract.** Many marine bays have been polluted by Pb due to the rapid development of industry, and identifying the major source of Pb is essential to pollution control. This paper analyzed the distribution and pollution source of Pb in Jiaozhou Bay in 1988. Results showed that Pb contents in surface waters in Jiaozhou Bay in April, July and October 1988 were 5.52-24.61  $\mu\text{g L}^{-1}$ , 7.66-38.62  $\mu\text{g L}^{-1}$  and 6.89-19.30  $\mu\text{g L}^{-1}$ , respectively. The major Pb sources in this bay were atmospheric deposition, and marine current, whose source strengths were 19.30-24.61  $\mu\text{g L}^{-1}$  and 38.62  $\mu\text{g L}^{-1}$ , respectively. Atmospheric deposition had been one of the major Pb sources in Jiaozhou Bay, and the source strengths were stable and strong. The pollution level of Pb in this bay in 1988 was moderate to heavy, and the source control measurements were necessary.

## 1. Introduction

Many marine bays have been polluted along with the rapid development of industry, and Pb pollution in marine bays has been one of the most critical environmental issues [1-2]. Pb could be inputted to marine bay from many sources including point source and non-point source, and identifying the major source of Pb is essential to pollution control [3-4]. Jiaozhou Bay is a semi-closed bay located in Shandong Province, China, and has been polluted by various pollutants along with the rapid development of economic after 1980 [5-6]. Based on investigation data in surface waters in April, July and October 1988 in Jiaozhou Bay, the aim of this paper is to identify the pollution source of Pb, and to provide basic information for scientific research and pollution control.

## 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), with the total area and average water depth of 446 km<sup>2</sup> and 7 m, respectively. The bay mouth is very narrow (3 km), and is connected to the Yellow Sea. There are a dozen of rivers including Dagu River, Haibo River, Licun River, and Loushan River etc., all of which are seasonal rivers [7-8]. The investigation on Pb in surface waters in Jiaozhou Bay was carried on in April, July and October 1988. In April and July, there were 13 monitoring sites (i.e., 31, 32, 33, 34, 35, 36, 84, 85, 86, 87, 88, 89 and 90), while in October there were 6 monitoring sites (i.e., 84, 85, 86, 87, 88, and 89) (Fig. 1). Pb in waters was sampled and monitored follow by National Specification for Marine Monitoring [9].



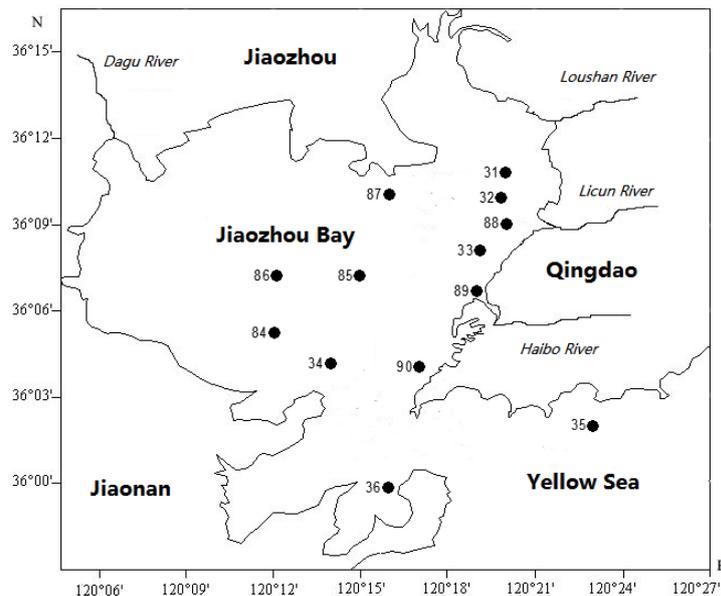


Fig. 1 Geographic location and sampling sites of Jiaozhou Bay

### 3. Results

Pb contents in surface waters in Jiaozhou Bay in April, July and October 1988 were  $5.52\text{--}24.61\ \mu\text{g L}^{-1}$ ,  $7.66\text{--}38.62\ \mu\text{g L}^{-1}$  and  $6.89\text{--}19.30\ \mu\text{g L}^{-1}$ , respectively. In April 1988, high value ( $24.61\ \mu\text{g L}^{-1}$ ) of Pb contents in surface waters was occurring in Site 34 in the coastal waters in the southwest of the bay, and Pb contents were decreasing from the high value center to the bay mouth ( $21.49\ \mu\text{g L}^{-1}$ ) and to the open waters ( $14.58\ \mu\text{g L}^{-1}$ ) (Fig. 2). In July 1988, high value ( $38.62\ \mu\text{g L}^{-1}$ ) of Pb contents in surface waters was occurring in Site 35 in the open waters, and Pb contents were decreasing from the open waters to the bay mouth ( $9.96\ \mu\text{g L}^{-1}$ ) (Fig. 3). In October 1988, high value ( $19.30\ \mu\text{g L}^{-1}$ ) of Pb contents in surface waters was occurring in Site 85 in the center of the bay, and Pb contents were decreasing from the center of the bay to the north ( $7.61\ \mu\text{g L}^{-1}$ ), south ( $6.89\ \mu\text{g L}^{-1}$ ), west ( $9.96\ \mu\text{g L}^{-1}$ ) and southwest ( $15.44\ \mu\text{g L}^{-1}$ ) of the bay (Fig. 4).

### 4. Discussion

#### 4.1 Pollution level of Pb

In according Sea Water Quality Standard (GB3097-1997) (Table 1), the pollution levels of Pb in April, July and October 1988 were all ranging from Class III to Class IV, indicated that the pollution level of Pb in Jiaozhou Bay in 1988 was moderate to heavy. In April 1988, Pb contents in coastal waters in the estuary of Loushan River and the southwest were ranging from  $5.02\text{--}10.00\ \mu\text{g L}^{-1}$ , indicated that the pollution level of Pb in these waters were moderate (Class III), yet Pb contents in other waters were higher than  $10.00\ \mu\text{g L}^{-1}$ , indicated the pollution level of Pb in these waters were heavy (Class IV). In July 1988, Pb contents in coastal waters in the estuary of Loushan River the north of the bay were ranging from  $5.02\text{--}10.00\ \mu\text{g L}^{-1}$ , indicated that the pollution level of Pb in these waters were moderate (Class III), yet Pb contents in other waters were higher than  $10.00\ \mu\text{g L}^{-1}$ , indicated the pollution level of Pb in these waters were heavy (Class IV). Taken the flow direction of Licun River as a dividing line. In October 1988, Pb contents in waters in the north of the dividing line were ranging from  $5.02\text{--}10.00\ \mu\text{g L}^{-1}$ , indicated that the pollution level of Pb in these waters were moderate (Class III), yet Pb contents in the south of the dividing line were higher than  $10.00\ \mu\text{g L}^{-1}$ , indicated the pollution level of Pb in these waters were heavy (Class IV). In general, the pollution level of Pb in Jiaozhou Bay were showing temporal and spatial heterogeneity.

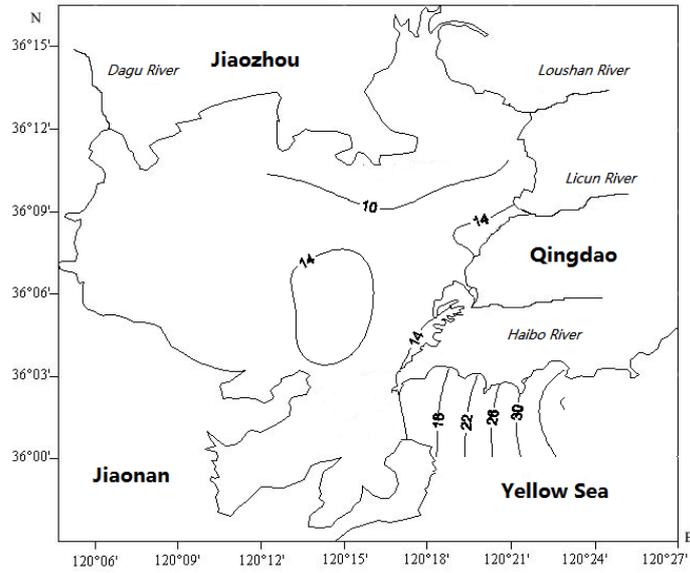


Fig. 2 Horizontal distribution of Pb contents in surface waters in Jiaozhou Bay in April 1988 / $\mu\text{g L}^{-1}$

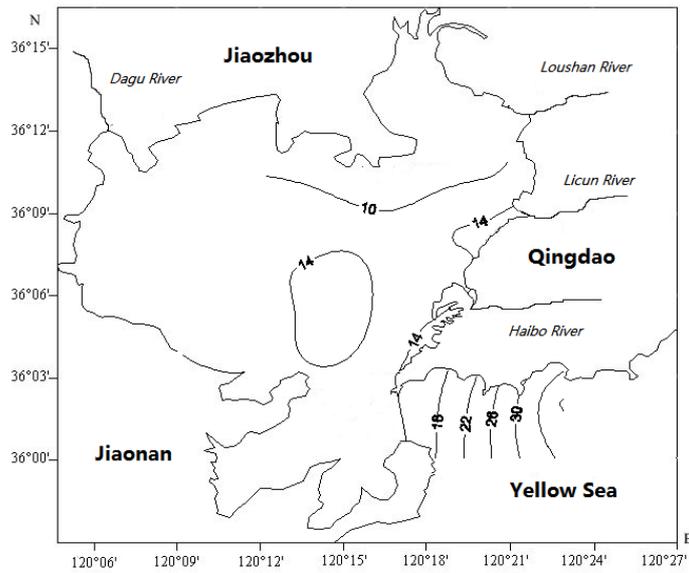


Fig. 3 Horizontal distribution of Pb contents in surface waters in Jiaozhou Bay in July 1988 / $\mu\text{g L}^{-1}$

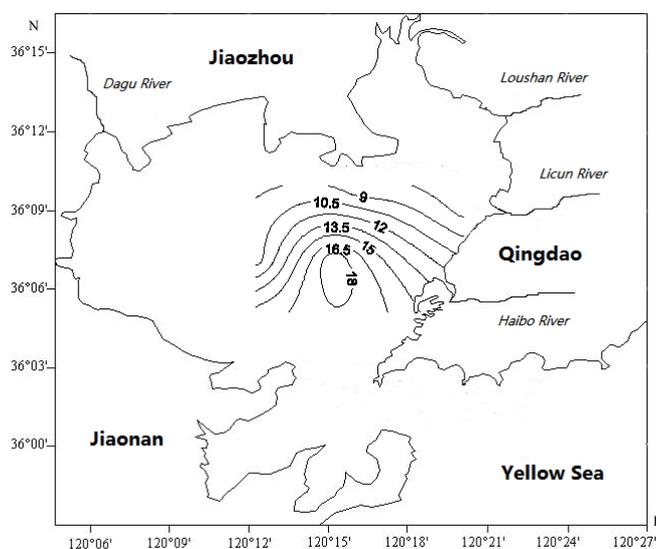


Fig. 4 Horizontal distribution of Pb contents in surface waters in Jiaozhou Bay in October 1988  $\mu\text{g L}^{-1}$

Table 1 Guidelines for Pb in Sea Water Quality Standard (GB3097-1997)

Class	I	II	III	IV
Pb content/ $\mu\text{g L}^{-1}$	1.0	5.0	10.0	50.0

#### 4.2 Pollution source of Pb

The horizontal distribution of Pb contents in surface waters was the important evidence to identify the source of Pb. In April 1988, high value region of Pb contents in surface waters was occurring in the coastal waters in the southwest of the bay, indicated that atmospheric deposition was the major Pb source (Fig. 2), and the source strength was  $24.61 \mu\text{g L}^{-1}$ . In July 1988, high value region of Pb contents in surface waters was occurring in the open waters and were decreasing along with the flow direction of marine current, indicated that marine current was the major Pb source (Fig. 3), and the source strength was  $38.62 \mu\text{g L}^{-1}$ . In October 1988, high value region of Pb contents in the center of the bay, indicated that atmospheric deposition was the major Pb source (Fig. 4), and the source strength was  $19.30 \mu\text{g L}^{-1}$ . Hence, the major Pb sources in this bay were atmospheric deposition, and marine current, whose source strengths were  $19.30\text{-}24.61 \mu\text{g L}^{-1}$  and  $38.62 \mu\text{g L}^{-1}$ , respectively. In according Sea Water Quality Standard (GB3097-1997) (Table 1), the pollution levels of the source strengths were all (Class IV), indicated that the pollution degrees of these sources were serious. The source strengths of atmospheric deposition were  $19.30\text{-}24.61 \mu\text{g L}^{-1}$ , indicated that the source strengths were stable and strong. Ocean is the sink of pollutants. The pollution level of Pb in open waters of Jiaozhou Bay was heavy, and the marine current had been one of the major Pb source, and the marine bays in the world would be finally polluted by means of ocean current. In general, the pollution level of Pb in this bay in 1988 was moderate to heavy, and the source control measurements were necessary.

#### 5. Conclusion

Pb contents in surface waters in Jiaozhou Bay in April, July and October 1988 were  $5.52\text{-}24.61 \mu\text{g L}^{-1}$ ,  $7.66\text{-}38.62 \mu\text{g L}^{-1}$  and  $6.89\text{-}19.30 \mu\text{g L}^{-1}$ , respectively. The pollution level of Pb in Jiaozhou Bay in 1988 was moderate to heavy, and were showing temporal and spatial heterogeneity. The major Pb sources in this bay were atmospheric deposition, and marine current, whose source strengths were  $19.30\text{-}24.61 \mu\text{g L}^{-1}$  and  $38.62 \mu\text{g L}^{-1}$ , respectively. The source strengths of atmospheric deposition were  $19.30\text{-}24.61 \mu\text{g L}^{-1}$ , indicated that the source strengths were stable and strong. The pollution level of Pb

in this bay in 1988 was moderate to heavy, and the source control measurements were necessary.

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