Source and fate of plumbum in marine bay

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Abstract. Many marine bays bave been polluted by Plumbum (Pb) due to the rapid development of industry and the swift increasing of economic, and therefore understanding the source and fate of Pb is essential to environmental remediation in marine bays. This paper analyzed the source and fate of Pb in Jiaozhou Bay, Shandong Province, eastern China in 1989. Results showed that Pb contents in surface waters in April, July and October 1989 were 5.56-12.59 μg L-1, 1.73-15.17 μg L-1 and 0.50-11.57 μg L-1, and the pollution levels were heavy, moderate and slight/moderate, respectively. The major sources of Pb in this bay were atmosphere deposition, overland runoff and river discharge, and their source strengths were 15.17 μg L-1, 12.59 μg L-1 and 11.57-12.06 μg L-1, respectively. The three source input processes were defined that the longer migration processes, the larger loss of substance's contents. Furthermore, fate of Pb from source to sink was also defined. These migration processes were demonstrated by two block diagrams, which were helpful to better understand the source and fate of Pb in marine bay.

1 Introduction

Plumbum (Pb) is one of the widely used heavy metal elements in industry, agriculture and so on. However, Pb pollution has been one of the critical environmental issues in many marine bays along with the rapid development of economic and population size [1-3]. Understanding the pollution level, distribution, source and fate of Pb in marine bay is essential to marine environmental protection. Jiaozhou Bay is a semi-closed bay located in south of Shandong Peninsula, eastern China. This bay has been polluted by various pollutants including Pb due to the rapid development of industry in since China's Reform and Opening-up [4-6].

This paper analyzed the source and fate of Pb in Jiaozhou Bay, Shandong Province, eastern China in 1989. Results revealed that the pollution levels were heavy, moderate and slight/moderate, respectively. The major sources of Pb in this bay were atmosphere deposition, overland runoff and river discharge. The three source input processes were defined that the longer migration processes, the larger loss of substance's contents. Furthermore, fate of Pb from source to sink was also defined. These findings were helpful to better understand the source and fate of Pb in marine bay.

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 such as Haibo Rriver, Licun Rriver, Dagu Rriver, and Loushan Rriver etc., most of which have seasonal features [7-8].

Data on Pb contents in surface waters in Jiaozhou Bay was provided by North China Sea Environmental Monitoring Center. The survey was conducted in April, July and October 1989. There were 10 sampling sites (04, 05, 06, 84, 85, 86, 87, 88, 89 and 90) in April and July compared to 7 sampling sites (84, 85, 86, 87, 88, 89 and 90) in October (Fig. 1). Surface water samples were collected and measured followed by National Specification for Marine Monitoring [9].

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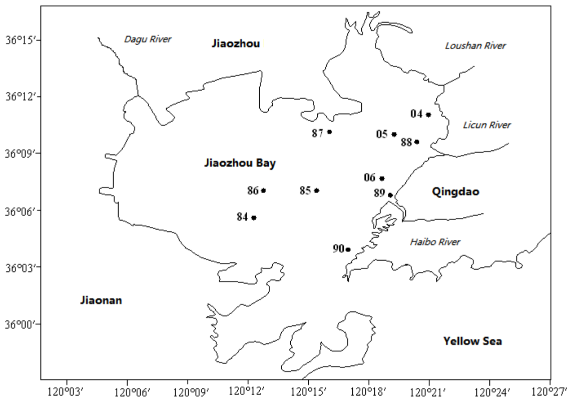

Fig.1 Geographic location and monitoring sites in Jiaozhou Bay

3 Results

Contents and sources of Pb. Pb contents in surface waters in April, July and October 1989 were 5.56-12.59 μg L-1, 1.73-15.17 μg L-1 and 0.50-11.57 μg L-1. In April 1989, high value of Pb contents was in Site 84 in the southwest coast (12.59 μg L-1), and the contour lines were forming a series of parallel lines that decreasing from the southwest to the bay center (9.96 μg L-1), the north coast (6.80 μg L-1) and northeast coast (5.56 μg L-1), respectively (Fig. 2). In July 1989, high value of Pb contents was in Site 85 in the bay center (15.17 μg L-1), and the contour lines were forming a series of semi-circles that decreasing from the bay center to the the north (3.12 μg L-1), east (9.07 μg L-1) and southwest of the bay (1.73 μg L-1), respectively (Fig. 3).Meanwhile, another high value was in Site 04 in the northeast of the bay (12.06 μg L-1), and the contour lines were forming a series of semi-circles that decreasing from the northeast of the bay to the north of the bay (3.12 μg L-1) and to the northeast of the bay (2.95 μg L-1), respectively (Fig. 3). In November 1989, high value of Pb contents was in Site 89 in the estuary of Haibo River in the northeast of the bay (11.57 μg L-1), and the contour lines were forming a series of semi-circles that decreasing from the northeast to the bay center (4.88 μg L-1) and north coast (0.50 μg L-1), respectively (Fig. 4).

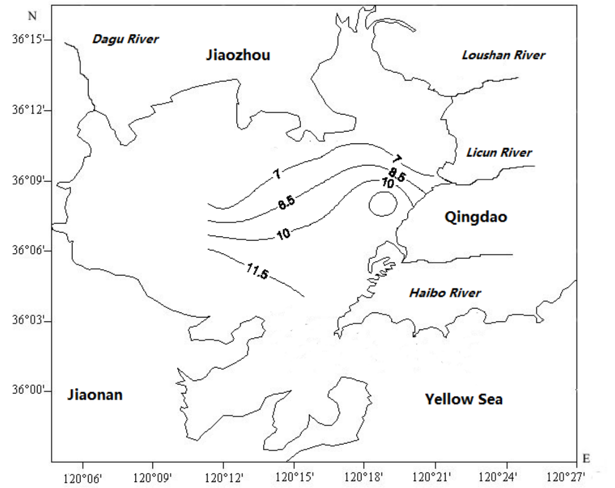

Fig. 2 Horizontal distribution of Pb in surface waters in Jiaozhou Bay in April 1989/μg L-1

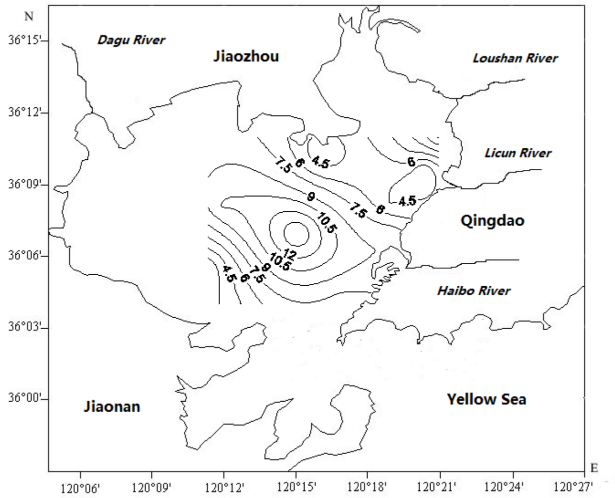

Fig. 3 Horizontal distribution of Pb in surface waters in Jiaozhou Bay in July 1989/μg L-1

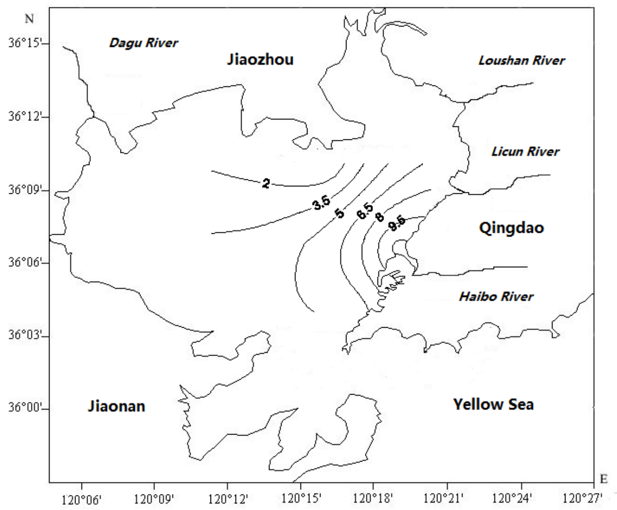

Fig. 4 Horizontal distribution of Pb in surface waters in Jiaozhou Bay in October 1989/μg L-1

4 Discussion

Pollution level of Pb. In Chinese Sea Water Quality Standard (GB 3097-1997), there are 4 classes of water quality, and for Pb the guide lines for Class I, II, III and IV (Table 1). In April 1989, Pb contents were 5.56-12.59 μg L-1. There was a rectangular high value region (between Site 84, 85, 89 and 90) in the southwest of the bay in where Pb contents were 9.83-12.59 μg L-1 and the water quality was moderate polluted as Class IV (Fig. 5), while in the other regions was slight polluted as Class III. In July 1989, Pb contents were 1.73-15.17 μg L-1. There were one high value region around Site 85 and 86 in the bay center in where Pb contents were 10.16-15.17 μg L-1 and the water quality was heavy polluted as Class IV (Fig. 6). Another high value region around Site 04 in the northeast of the bay in where Pb contents were 12.06 μg L-1 and the water quality was heavy polluted as Class IV. Pb contents in the north, east and southwest of the bay were 1.73-9.07 μg L-1, and water quality of Pb was slight polluted in Class II to III. This indicated Pb contents were decreasing along with the increase of distance of the high value region. In October 1989, Pb contents were 0.50-11.57 μg L-1. There was a high value region in the estuary of Haibo River in where the high value of Pb contents was 11.57 mg L-1 and the water quality was moderate polluted as Class IV. Meanwhile, Pb contents were decreasing along with the flow direction of Haibo River. In general, the pollution level of Pb in 1989 was moderate/heavy, and the spatial variations were significant.

Table 1 Guide lines for Pb in Chinese Sea Water Quality Standard (GB 3097-1997)

Class	I	II	III	IV
Guide line/μg L-1	1.00	5.00	10.00	50.00

Sources of Pb. Pb contents in surface waters were impacted by source input directly, and the major sources could be defined in according to the spatial distribution of Pb content. In April 1989, high value region was in the southwest coast, and therefore overland runoff was the major source of Pb in April 1989 (Fig. 2), whose source strength was 12.59 μg L-1. In July 1989, high value regions were in the bay center and the estuary of Loushan River, and therefore atmosphere deposition and river discharge were the major sources of Pb in April 1989 (Fig. 3), whose source strength were 15.17 μg L-1 and 12.06 μg L-1, respectively. In October 1989, high value regions was in the estuary of Loushan River, and therefore river discharge were the major source of Pb in April 1989 (Fig. 3), whose source strength was 11.57 μg L-1. In general, the major sources of Pb in this bay were atmosphere deposition, overland runoff and river discharge, and their source strengths were 15.17 μg L-1, 12.59 μg L-1 and 11.57-12.06 μg L-1, respectively (Table 2). It should be noticed that the source strengths of the three major sources were all higher than10.00 μg L-1, and could be considered as heavy polluted in according to Chinese Sea Water Quality Standard (GB 3097-1997) (Table 1 and Table 2).

Table 2 Source strengths of Pb in Jiaozhou Bay 1989

Source	Overland runoff	River discharge
Source strength/μg L-1	12.59	11.57-12.06
Water quality	Class IV	Class IV

Fate of Pb. There was three major Pb sources in Jiaozhou Bay, resulting in different "source to sink" fate. Firstly, for river discharge, the anthropogenic Pb was ransported to bay waters directly. Secondly, for overland runoff, the anthropogenic Pb was washing from the land surface by means of rainfall-runoff, and then was transported to rivers, and was finally discharged to bay waters. Thirdly , for atmosphere deposition, a part of the anthropogenic Pb could be inputted to the bay waters directly, and another part was was washing from the land surface by means of rainfall-runoff, and then was transported to rivers, and was finally discharged to bay waters (Fig. 6). The source strength of atmosphere deposition was highest compared to overland runoff and river discharge (Table 2), and therefore the Pb contents contributed by atmosphere deposition was decreasing along with the increasing of travel distance. That was the feature of the migration process of substance in marine bay. Furthermore, the fate of Pb could be defined that, anthropogenic Pb was discharged to land and air, and then was transported to marine bay by means of overland runoff, river discharge and atmosphere deposition, and was travelled through water body, and was stored in sea bottom finally (Fig. 7). Environmental risks were occurring during the "source to sink" fate, and the targeted countermeasures should be putted into effect during the process.

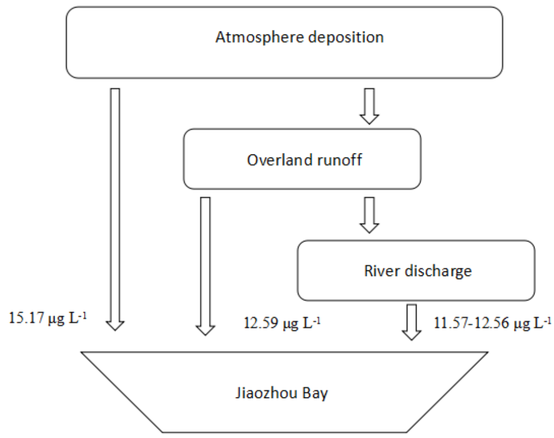

Fig. 6 The "source to sink" fate of Pb from atmosphere deposition

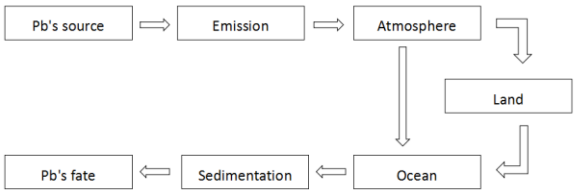

Fig. 7 The block diagram of Pb's fate

5 Conclusion

Pb contents in surface waters in April, July and October 1989 were 5.56-12.59 μg L-1, 1.73-15.17 μg L-1 and 0.50-11.57 μg L-1. The pollution level of Pb in 1989 was moderate/heavy, and the spatial variations were significant. The major sources of Pb in this bay were atmosphere deposition, overland runoff and river discharge, and their source strengths were 15.17 μg L-1, 12.59 μg L-1 and 11.57-12.06 μg L-1, respectively. FThe fate of Pb could be defined that, anthropogenic Pb was discharged to land and air, and then was transported to marine bay by means of overland runoff, river discharge and atmosphere deposition, and was travelled through water body, and was stored in sea bottom finally. Environmental risks were occurring during the "source to sink" fate, and the targeted countermeasures should be putted into effect during the process.

Acknowledgment

This research was sponsored by Doctoral Degree Construction Library of Guizhou Nationalities University, 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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