The spreading process of Pb in Jiaozhou Bay

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Abstract. This paper analyzed the contents, horizontal distributions, sources and spreading process of Pb in Jiaozhou Bay, China based on investigation data on Pb in surface waters in 1985. Results showed that Pb contents were 11.4-42.8 μg L^{-1}, and were confirmed with Grade IV in according to Chinese Sea Water Quality Standard (GB 3097-1997), indicated that the pollution level of Pb was very heavy. Overland runoff and stream flow were the two major sources of Pb, and the source strength of overland runoff was stronger. Even the pollution source was playing a role of 'point source', Pb could be spreading to the whole bay, and to the open waters. The loss of Pb during the spreading process in the bay was 44.8%, and from the bay to the open waters was 23.5%. The spreading processes confirmed the point of view that the ocean had the characteristic of homogeneity. We found that the Pb contents were easy to be spreading, under same time and same conditions, the bigger spreading space the higher spreading rate. Hence, the reduction of emission of Pb was necessary, and the transfer process of Pb should be given close attention to.

Introduction

A lot of Pb-containing waste gas and waste water were discharged to the environmental along with the rapid increasing of industry and agriculture, and the ocean was received and polluted by Pb via river flow discharge, atmosphere deposition etc [1-6]. Pb is stable and persistent in the environment, and were making risks to the ecological environment and human health due to the high toxicity. Hence, understanding the pollution level, source and transfer process of Pb is essential to environmental protection in marine bay. Based on investigation data on Pb contents in surface waters in April, July and October 1985, the aim of this paper was to analyze the contents, horizontal distributions, pollution sources and spreading processes of Pb in Jiaozhou Bay, Shandong Province, China, and to provide basis to pollution control and environmental remediation in this bay.

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. This bay is a typical of semi-closed bay. 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 [7-8].

The investigation on Pb in surface waters in Jiaozhou Bay was carried on in April, July and October 1985 in six investigation sites namely 2031, 2032, 2033, 2034, 2035 and 2047, respectively

(Fig. 1). Pb in surface and bottom waters were sampled and monitored follow by National Specification for Marine Monitoring [9].

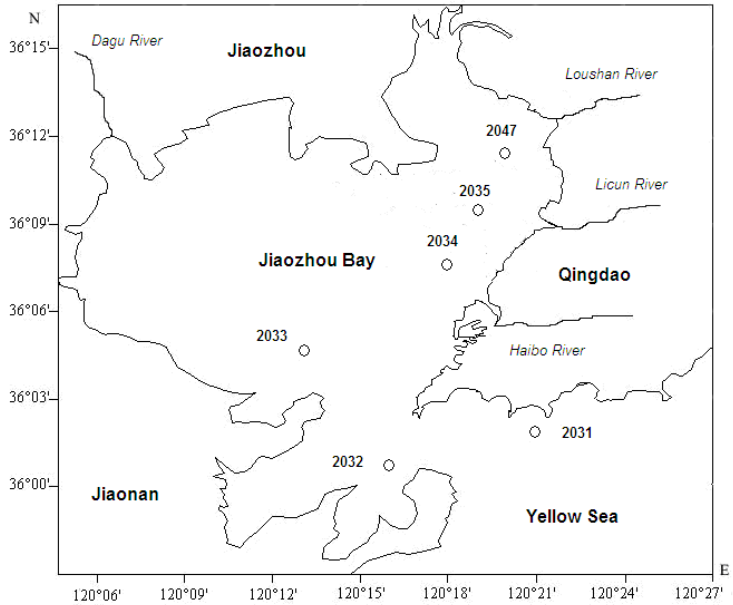

Fig. 1 Geographic location and sampling sites in Jiaozhou Bay

Results

Contents of Pb. The guide line of Pb contents of Grand I, Ⅱ, III and IV in Chinese Sea Water Quality Standard (GB 3097-1997) are 1.00 μg L^{-1}, 5.00 μg L^{-1}, 10.00 μg L^{-1} and 40.00 μg L^{-1}, respectively. Pb contents in surface waters in April, July and October 1985 were 12.61-25.82 μg L^{-1}, 23.60-42.81 μg L^{-1} and 11.40-22.73 μg L^{-1}, respectively (Table 1), and were confirmed with Grade IV in according to Chinese Sea Water Quality Standard (GB 3097-1997). In generally, Pb contents ranged from 23.60-42.81 μg L^{-1} in the whole year and the pollution level of Pb in different seasons in 1985 were very heavy.

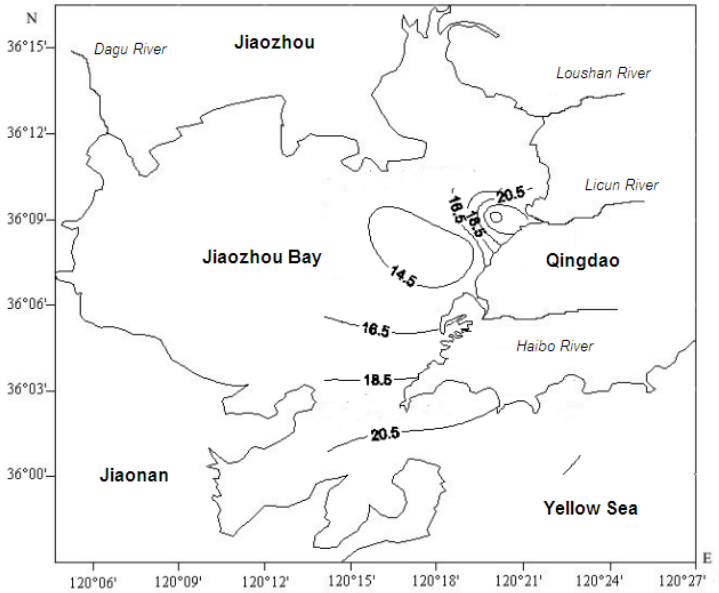

Fig. 2 Horizontal distribution of Pb contents in April 1985 in Jiaozhou Bay/μg L^{-1}

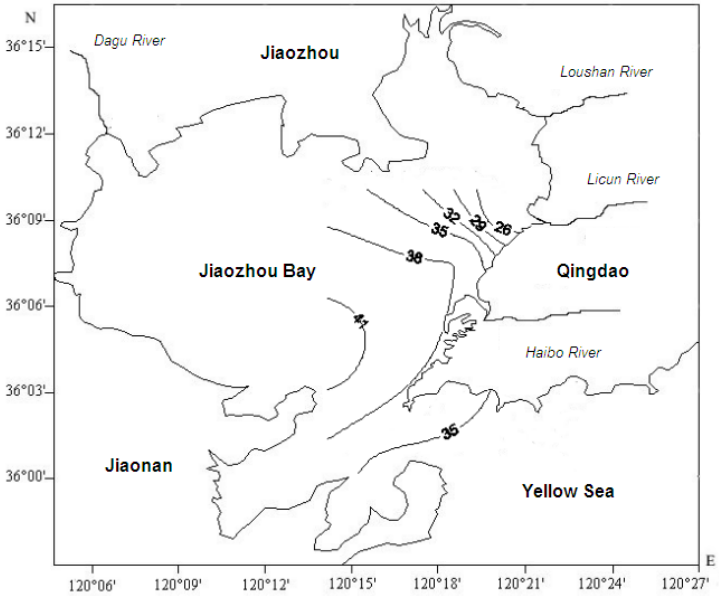

Fig. 3 Horizontal distribution of Pb contents in July 1985 in Jiaozhou Bay/μg L^{-1}

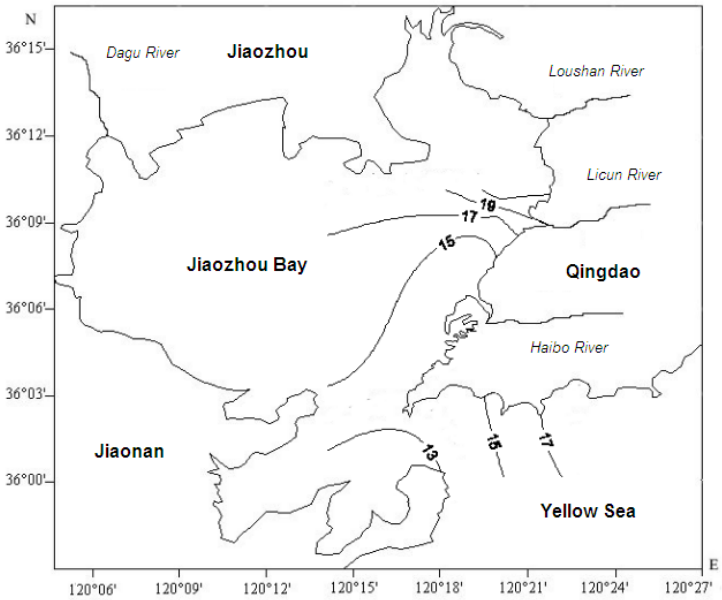

Fig. 4 Horizontal distribution of Pb contents in October 1985 in Jiaozhou Bay/μg L^{-1}

Table 1 Pb contents in surface water in Jiaozhou Bay in April, July and October 1985

Time	April	July	October
Content/μg L^{-1}	12.61-25.82	23.60-42.81	11.40-22.73
Grade	IV	IV	IV

Horizontal distributions of Pb. In April, there was a high value zone in the coastal waters in the northeast of the bay, and the highest value (25.82 μg L^{-1}) was occurring in Site 2035 in the estuary of Licun River (Fig. 2). The contour lines were forming a series of semi-concentric circles, which were decreasing from the high value center to the bay mouth (17.97 μg L^{-1}). In July, the highest value (42.81 μg L^{-1}) was occurring in Site 2033 in the coastal wasters in the southwest of the bay (Fig. 3). The contour lines were forming a series of semi-concentric circles, which were decreasing from the high value center to in the northeast to the bay mouth (33.47 μg L^{-1}), and to the open waters (32.73 μg L^{-1}). Meanwhile, the contour lines were decreasing from the high value center to in the estuary of Haibo River (37.51 μg L^{-1}) and Licun River (23.60 μg L^{-1}). In October,

the highest value (22.73 μg L^{-1}) was occurring in Site 2047 in the estuary of Loushan River in the northeast of the bay (Fig. 4). The contour lines were forming a series of semi-concentric circles, which were decreasing from the high value center to in the estuary of Licun River (16.67 μg L^{-1}) and Haibo River (13.79 μg L^{-1}).

Discussion

Water quality. Pb contents ranged from 23.60-42.81 μg L^{-1} in different season, and were confirmed to Grade IV, indicated that the pollution level of Pb in different seasons in 1985 were very heavy. In April, Pb contents ranged from 12.61-25.82 μg L^{-1}, and the water quality was as worse as Grade IV in the whole study area. Pb contents were higher than 12.61 μg L^{-1} from the inside of the bay, the bay mouth and the open waters, indicated that the waters were heavy polluted. The highest Pb content (25.82 μg L^{-1}) was occurred in the estuary of Licun River. In July, Pb contents ranged from 23.60-42.81 μg L^{-1}, and the water quality was as worse as Grade IV in the whole study area. Pb contents were higher than 23.60 μg L^{-1} from the inside of the bay, the bay mouth and the open waters, indicated that the waters were heavy polluted. The highest Pb content (42.81 μg L^{-1}) was occurred in the coastal waters in the southwest of the bay. In October, Pb contents ranged from 11.40-22.73 μg L^{-1}, and the water quality was as worse as Grade IV in the whole study area. Pb contents were higher than 11.40 μg L^{-1} from the inside of the bay, the bay mouth and the open waters, indicated that the waters were heavy polluted. The highest Pb content (22.73 μg L^{-1}) was occurred in the estuary of Loushan River. For seasonal variation, Pb contents were in order of July>April>October, yet all of the seasons were heavy polluted.

Source of Pb. There was a high value region in the estuary of Licun River in the northeast of the bay, indicated that stream flow was the major source of Pb in April, and the source strength was 25.82 μg L^{-1}. The high value region in July was occurred in the coastal waters in the southwest of the bay, indicated that overland runoff was the major source of Pb in July, and the source strength was 42.81 μg L^{-1}.The high value region in October was occurred in the estuary of Loushan River, indicated that stream flow was the major source of Pb in October, and the source strength was 22.73 μg L^{-1}. It could be found that overland runoff and stream flow were the major sources of Pb, and their source strengths were 42.81 μg L^{-1} and 22.73-25.82 μg L^{-1}, respectively (Table 2). The source strengths of overland runoff and stream flow were higher than the guide line of Pb of Grade III, and were belong to Grade IV, and the pollution level of overland runoff is more heavy than stream flow.

Table 2 The source strength of different Pb sources in Jiaozhou bay

Source	Overland runoff	Stream flow
Source strength/μg L^{-1}	42.81	22.73-25.82
Grade	IV	IV

Spatial spreading of Pb. In July, the highest value (42.81 μg L^{-1}) was occurring in Site 2033 in the coastal wasters in the southwest of the bay, and were forming a series of semi-concentric circles, indicated the pollution sources was playing a role of 'point source'. The contents were decreasing from the high value center to the bay mouth (33.47 μg L^{-1}), and to the open waters (32.73 μg L^{-1}) (Fig. 3), indicated that Pb was spreading from the pollution source to the bay mouth rapidly via tide, and to the open waters rapidly via ocean current. Pb contents were decreasing form the high value center (42.81μg L^{-1}) to the open waters (32.73 μg L^{-1}) gradiently, and the loss of Pb was 42.81 μg L^{-1}-32.73 μg L^{-1} = 10.08 μg L^{-1}, and the loss rate was 10.08/42.81 = 23.54%. Meanwhile, Pb contents were decreasing gradiently form the high value center (42.81 μg L^{-1}) to the bay mouth (37.51 μg L^{-1}), and the estuary of Licun River (23.60 μg L^{-1}). These indicated that Pb was spreading from the pollution source to the estuary of Haibo River by tide and marine current rapidly, and was spreading from the pollution source to the estuary of Licun River by tide and marine current rapidly. During the spreading from the high value center to the estuary of Licun River, the loss of Pb was 42.81 μg L^{-1}- 23.60 μg L^{-1} = 19.21 μg L^{-1}, and the loss rate was 19.21/42.81 = 44.8%. In according

to the horizontal distribution of Pb, it could be found that Pb was able to spread to the whole bay even to the open waters. The loss rate during the spreading in the bay was 44.8%, while from the bay to the open waters was 23.54%. These founding confirmed that the ocean had the characteristic of homogeneity by means of tide and marine current. Tide and marine are stirring and transporting all of the substances in the ocean, leading to the homogeneous distribution of the contents of the substances in marine waters [10]. Hence, Pb contents in Jiaozhou Bay were ranging from 23.60-42.81 μgL^{-1}, and were revealing the homogeneous distribution characteristic of substances in the ocean.

Pb pollution in overland runoff. In July, the highest value (42.81 $\mu g\ L^{-1}$) was occurring in Site 2033 in the coastal wasters in the southwest of the bay, indicated the pollution level of Pb in overland runoff was very high, and the land around Jiaozhou Bay was polluted by Pb seriously. That was the evidence that a lot of waste gas/waster was generated and discharged to the environment and was remained in the land surface. The source strength of overland runoff was 42.81 $\mu g\ L^{-1}$, which was more higher than the source strength of stream flow (22.73-25.82 μgL^{-1}), indicated that a big part of Pb was transported to the bay by overland runoff before it was transported to the stream. In generally, Pb was easy to be transported. Thus, under same time and conditions, the bigger spreading space the higher spreading rate.

Conclusions

Pb contents in surface waters in different were confirmed with Grade IV, and the pollution level of Pb in different seasons in 1985 were very heavy. Overland runoff and stream flow were the major sources of Pb, and their source strengths were 42.81 $\mu g\ L^{-1}$ and 22.73-25.82 $\mu g\ L^{-1}$, respectively. Pb was able to spread to the whole bay even to the open waters. The loss rate during the spreading in the bay was 44.8%, while from the bay to the open waters was 23.54%. These founding confirmed that the ocean had the characteristic of homogeneity by means of tide and marine current. Pb was easy to be transported that, under same time and same conditions, the bigger spreading space the higher spreading rate. In order to prevent environment pollution, people should pay more attention to the transfer process and reduce the discharge of Pb.

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