Modeling for horizontal and vertical migration of Pb in marine bay

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Abstract. This paper quantified the horizontal and vertical migration processes of Plumbum (Pb) in Jiaozhou Bay in 1989. Results showed that the horizontal absolute loss amounts of Pb were1.07-8.70 μg L-1, and the horizontal relative loss amounts were 9.70%-57.35%. The vertical absolute dilution amounts of Pb were 1.95-8.70 μg L-1, and the horizontal relative dilution amounts were 19.30%-57.35%. The vertical absolute accumulation amounts of Pb were 1.07 μg L-1, and the vertical relative accumulation amounts were 9.70%. During the migration processes, Pb contents in both surface and bottom waters were decreasing in a certain degree during the horizontal migration process. The horizontal loss amounts were very 52.78%-57.35% in July, yet was very low in April. Meanwhile, the horizontal dilution amounts were also relative high as 47.60%-52.86%. In April, Pb was mainly sourced from river runoff, and there was high sedimentation process in the bay center. In July, Pb was mainly sourced from river runoff and atmosphere deposition, and there were high sedimentation processes in the bay center and the bay mouth.

1. Introduction

Pb has been widely used in many industries such as smelting, instrument and apparatus, brine electrolysis, and a large amount of Pb-containing wastes were generated and discharged to the environment along with the rapid development of industries[1-2]. However the waste treatment in many countries and regions is always lagging [3-4]. In nowadays, many marine bays have been polluted by Pb since ocean is the sink of pollutants [5-6]. Pb in the environment is harmful to organism and ecosystem and could be persistent in the environment [3-4]. Quantifying the migration processes of Pb is essential to pollution control[7-9].

Jiaozhou Bay is a semi-closed bay located in Shandong Province China, and has been polluted by various pollutants including Pb after the rapid increasing of industry the past three decades [10-11]. This paper quantified the horizontal and vertical migration processes of Pbin Jiaozhou Bay using investigation data in April and July 1989. The aim of this paper was to better understand the transporting processes of Pb in marine bay, and provide basis for scientific research and environment remediation.

2. Materials and method

2.1. 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). The total area and average water depth are 446 km2 and 7 m, respectively. The bay mouth is very narrow (3 km), and is connected to the Yellow Sea in the south. There are a dozen of rivers including Dagu River, Haibo River, Licun River, and Loushan River etc., all of which are seasonal rivers [10-11].

The investigation on Pb in Jiaozhou Bay was carried on by North China Sea Environmental Monitoring Center. In April and July1989, Hg contents in surface and bottom waters were measured in Site 85 and Sit 90 in the bay center and the bay mouth, respectively (Fig. 1). Pb in waters was sampled and monitored followed by National Specification for Marine Monitoring [12].

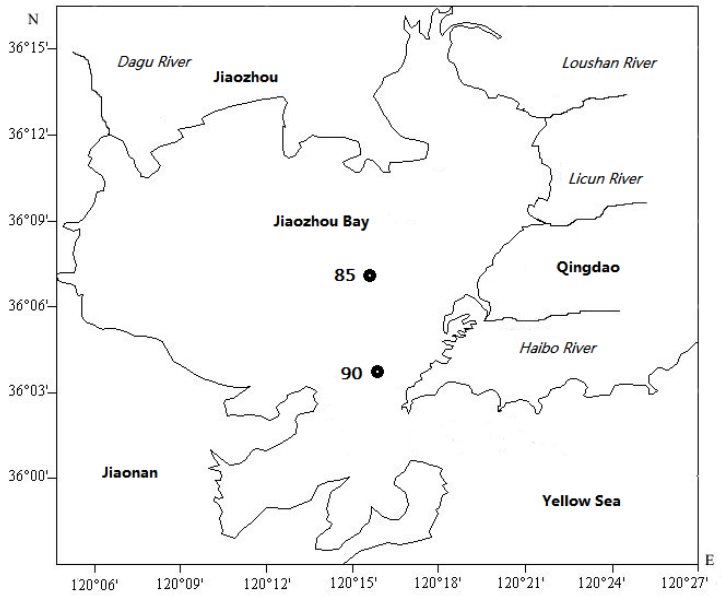

Fig. 1 Geographic location and monitoring sites in Jiaozhou Bay

2.2. Modeling for horizontal migration processes of Hg

The contents of the substances in waters in marine bays were changing continuously water exchange between the open waters and the internal waters in the bay [5-9]. Supposed that Pb contents in surface and bottom waters in the bay center are A and a, in the bay mouth are B and b, respectively.

In surface waters, and from the bay center to the bay mouth, the calculation formula for migration process is:

$$D=A-B, \qquad E=(100\times \mid A-B \mid /\max(A, B))\% \tag{1}$$

where, D is the horizontal absolute loss amount in surface waters, E is the horizontal relative loss amount.

In bottom waters, and from the bay center to the bay mouth, the calculation formula for migration process is:

$$d=a-b, \qquad e=(100\times \mid a-b \mid /\max(a, b))\% \tag{2}$$

where, d is the horizontal absolute loss amount in bottom waters from the bay center to the bay mouth, e is the horizontal relative loss amount.

2.3. Modeling for vertical migration processes of Pb

Supposed that Hg contents in surface and bottom waters in Site *n* in the bay center are *A* and *a,* respectively. From surface waters to bottom waters, the calculation formula for this migration process is:

$$V_{na}=A-a, \quad V_{nr}=(100\times \mid A-a \mid /\max(A, a))\% \tag{3}$$

where, Vna is the horizontal absolute dilution amount from surface waters to bottom waters, Vnr is the horizontal relative dilution amount. While from bottom waters to surface waters, Vna refers to the horizontal absolute accumulation amount, and Vnr refers to the horizontal relative accumulation amount.

3. Discussion and discussion

3.1. Horizontal and vertical processes of Pb.

The horizontal migration process of Pb in surface waters were calculated in according to Pb contents in Site 85 and Site 90. The horizontal losses of Pb in surface and bottom waters were calculated by Eq. (1) and Eq. (2), respectively. The vertical migration processes of Pb in Site 85 in the bay center and Site 90 in the bay mouth were calculated by Eq. (3).

In the internal waters of Jiaozhou Bay, Pb was mainly sourced from river runoff, and Pb contents were decreasing from the high value region to peripheral zones by means of marine current and tide. In April 1989, along with the flow direction of marine current from the bay mouth to the bay center, the horizontal losses of Pb in surface and bottom waters were 9.70% and 19.30%, respectively (Fig. 2).

In the bay center the vertical accumulation amount was very low as 1.38%, and in the bay mouth the vertical dilution amount was relative low as 26.11% (Fig. 2). In July 1989, along with the flow direction of marine current from the bay mouth to the bay center, the horizontal losses of Pb in surface and bottom waters were 89.13% and 29.41%, respectively (Fig. 3). In the bay center the vertical accumulation amount was very high as 1.38%, and in the bay mouth the vertical dilution amount was also relative high as 59.33% (Fig. 3).

In general the horizontal absolute loss amounts of Pb were 1.07-8.70 μg L-1, and the horizontal relative loss amounts were 9.70%-57.35%. The vertical absolute dilution amounts of Pb were 1.95-8.70 μg L-1, and the horizontal relative dilution amounts were 19.30%-57.35%. The vertical absolute accumulation amounts of Pb were 1.07 μg L-1, and the vertical relative accumulation amounts were 9.70%.

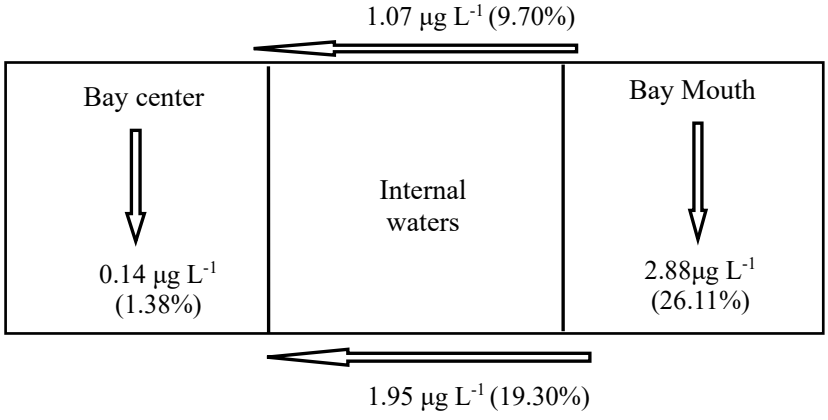

Fig. 2 Block diagram model for horizontal-vertical changes of Pb in Jiaozhou Bay in April 1989

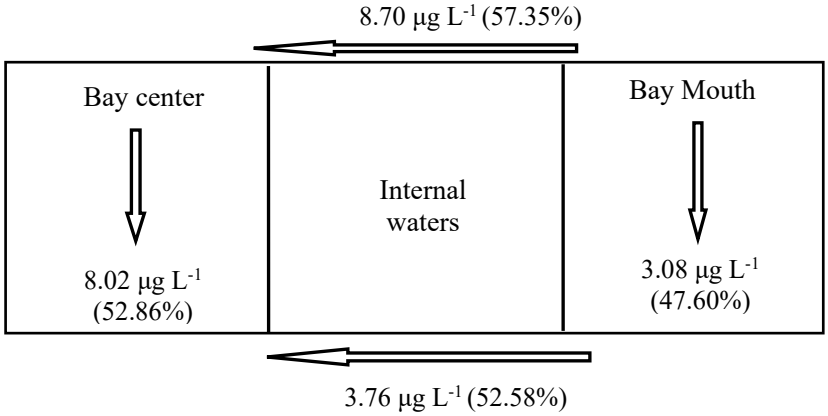

Fig. 3 Block diagram model for horizontal-vertical changes of Pb in Jiaozhou Bay in July 1989

3.2. Horizontal loss of Pb. Pb

contents would be changing a lot during the horizontal migration process. In April 1989, from the bay mouth to the bay center, the horizontal loss of Pb in surface waters was very low as 9.70% (Table 1). In July 1989, from the bay center to the bay mouth, the horizontal loss of Pb in surface waters was relative high as 57.35% (Table 1). No matter from the bay center to the bay mouth, or from the bay mouth to the bay centers, Pb contents in surface waters were decreasing in a certain degree of 9.70%-57.35%.

In April 1989, from the bay mouth to the bay center, the horizontal loss of Pb in bottom waters was very low as 19.30% (Table 1). In July 1989, from the bay center to the bay mouth, the horizontal loss of Pb in bottom waters was relative high as 52.58% (Table 1). No matter from the bay center to the bay mouth, or from the bay mouth to the bay centers, Pb contents in bottom waters were decreasing in a certain degree of 19.30%-52.58%.

Hence, no matter from the bay center to the bay mouth, or from the bay mouth to the bay centers, Pb contents were decreasing in a certain degree. In case of the loss rate of Pb in surface water was relatively high, the loss rate of Pb in bottom water would also be relatively high, and vice versa.

Table 1 Horizontal loss of Hg in surface and bottom waters in Jiaozhou Bay 1989

Water layer	Time	Starting point	End point	Horizontal loss/%
Surface water	April	Bay mouth	Bay center	9.70
	July	Bay center	Bay mouth	57.35
Bottom water	April	Bay center	Bay mouth	19.30
	July	Bay center	Bay mouth	52.58

3.3.Vertical loss of Pb.

Pb contents were also changing a lot during the vertical migration process. In April 1989, Pb contents in surface and bottom waters were relatively high as 9.96-11.03 μg L-1 and 8.15-10.10 μg L-1, respectively. This indicated that Pb contents in April 1989 were relatively low. In the bay center, the vertical accumulation amount was relatively low as 1.38%, while in the bay mouth the vertical dilution amount was also relatively low as 26.11%. In general, the contents of Pb in April were relatively low, resulted in the vertical loss amounts of Pb were also relatively low.

In July 1989, Pb contents in surface and bottom waters were relatively high as 6.47-15.17 μg L-1 and 3.39-7.15 μg L-1, respectively. This indicated that Pb contents in July 1989 were relatively high. In the bay center, the vertical dilution amount was relatively high as 52.86%, the vertical dilution amount was also relatively high as 47.60%. In general, the contents of Pb in April were relatively high,

resulted in the vertical loss amounts of Pb were also relatively high. In case of the loss rate of Pb in surface water was relatively high, the loss rate of Pb in bottom water would also be relatively high, and vice versa.

The vertical dilution and accumulation amounts of Pb indicated that, the vertical accumulation process was only occurring in the bay mouth and the value was as low as 1.38%. However, in July, the horizontal dilution amounts were as very high as 52.78%-57.35%.

4. Conclusions

The horizontal and vertical migration processes of Pb in Jiaozhou Bay 1989 were quantified. The horizontal absolute loss amounts of Pb were 1.07-8.70 μg L-1, and the horizontal relative loss amounts were 9.70%-57.35%. The vertical absolute dilution amounts of Pb were 1.95-8.70 μg L-1, and the horizontal relative dilution amounts were 19.30%-57.35%. The vertical absolute accumulation amounts of Pb were 1.07 μg L-1, and the vertical relative accumulation amounts were 9.70%.

No matter from the bay center to the bay mouth, or from the bay mouth to the bay centers, Pb contents in surface waters were decreasing in a certain degree of 9.70%-57.35%. No matter from the bay center to the bay mouth, or from the bay mouth to the bay centers, Pb contents in bottom waters were decreasing in a certain degree of 19.30%-52.58%.

The vertical dilution and accumulation amounts of Pb indicated that, the vertical accumulation process was only occurring in the bay mouth and the value was as low as 1.38%. However, in July, the horizontal dilution amounts were as very high as 52.78%-57.35%.

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