

Quantification of vertical and horizontal loss of Hg in Jiaozhou Bay 1988

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Abstract. This paper quantified the horizontal and vertical loss of Hg in Jiaozhou Bay based on investigation data on surface and bottom waters in six sampling sites in April and July 1988. Results showed that the horizontal absolute loss amounts of Hg contents in surface and bottom waters were 0.004-0.048 $\mu\text{g L}^{-1}$, and the horizontal relative loss amounts of Pb contents were 8.16-64.00%, respectively. The vertical absolute dilution amounts of Pb contents were 0.000-0.008 $\mu\text{g L}^{-1}$, and the vertical relative dilution amounts were 0.00-16.32%. The vertical absolute accumulation amounts of Pb contents were 0.003-0.042 $\mu\text{g L}^{-1}$, and the vertical relative accumulation amounts were 6.25-56.00%. During the transporting process through the bay mouth, no matter from the internal waters to the open water, or from the open waters to the internal waters, the loss of Hg at horizontal direction could be 8.16-64.00%. In case of the horizontal loss of Hg in surface waters was relative high/low, the horizontal loss of Hg in bottom waters would be also relative high/low. The changes of Hg contents in surface and bottom waters were determined by the migration distance of Hg in surface waters.

1. Introduction

A great deal of Hg-containing waste gas, water and castoff were generated and discharged to the environment along with the rapid development of industrial economic and the increase of population size [1-2]. The excessive existence of Hg in the environment is harmful to organism and ecosystem since Hg in one of the most critical toxic heavy metal elements [3-5]. Nowadays, many marine bays have been polluted by Hg, and understanding the migration processes of Hg in marine bays is essential to pollution control [6-8].

Jiaozhou Bay is a semi-closed bay located in Shandong Province China, and has been polluted by various pollutants including Hg after the rapid increasing of industry the the past three decades [9-11]. This paper quantified the horizontal and vertical loss of Hg in Jiaozhou Bay based on investigation data on six sampling sites in April and July 1988. The aim of this paper was to better understand the transporting processes of substance 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 [12-13]. The investigation on Hg in bottom waters in Jiaozhou Bay was carried on in April and July 1988 in six monitoring sites (Fig. 1). Hg in bottom waters was sampled and monitored follow by National Specification for Marine Monitoring [14].

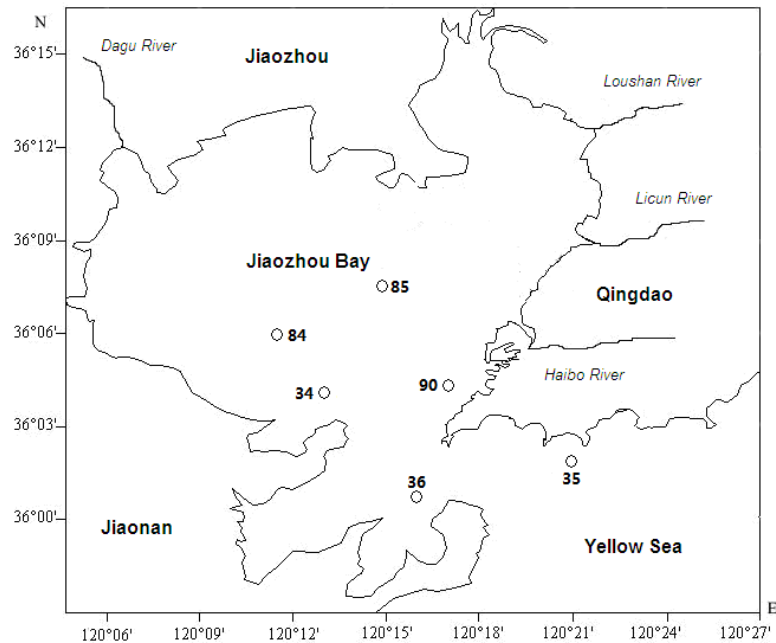


Fig.1 Geographic location and monitoring sites in Jiaozhou Bay

2.2 Quantification the horizontal loss of Hg.

By means of the water exchange, substance's contents in waters were changing continuously [15-18]. Supposed that certain substance's content in surface waters in the outer side of the bay mouth in Jiaozhou Bay was A , and in the inner side of the bay mouth was B . For surface waters and from the outer side to the bay mouth, the calculation formula for horizontal loss of substance's content is:

$$D=A-B, \quad E=(100 \times |D| / \max(A, B))\% \quad (1)$$

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

Supposed that certain substance's content in bottom waters in the outer side of the bay mouth in Jiaozhou Bay was a , and in the inner side of the bay mouth was b . For bottom waters and from the outer side to the bay mouth, the calculation formula for horizontal change of substance's content is:

$$d=a-b, \quad e=(100 \times |d| / \max(a, b))\% \quad (2)$$

where, d is the horizontal absolute loss amount in bottom waters, e is the horizontal relative loss amount in bottom waters.

2.3 Quantification the vertical loss of Hg.

For a certain sampling site (n) in a marine bay, supposed that substance's contents in surface waters and bottom waters are A and a , respectively.

From the surface waters to bottom waters, the calculation formula for vertical change of substance's content is:

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

where, V_{na} is the horizontal absolute change amount in waters, V_{nr} is the horizontal relative change amount in waters.

3. Results and discussion

3.1 Horizontal and vertical loss of Hg.

Supposed that Site 35 in the outer side of the bay mouth and Site 34 in the inner side of the bay mouth were simplified as *A* and *B*. Taken from *A* to *B* as the direction, the horizontal loss of Hg in Jiaozhou Bay 1988 could be calculated and listed in Table 1. It could be seen from Table 1 that Hg contents in both surface and bottom waters were changing so much after transporting through the bay mouth [10]. The vertical loss of Hg in both surface and bottom waters in Jiaozhou Bay 1988 were calculated and listed in Table 2. It could be found that Hg contents in both surface and bottom waters were also changing so much during the vertical transporting process [11-13].

Table 1 Horizontal loss of Hg in Jiaozhou Bay 1988

Month	Surface waters		Bottom waters	
	$D/\mu\text{g L}^{-1}$	$E/\%$	$d/\mu\text{g L}^{-1}$	$e/\%$
April	-0.004	8.16	0.007	14.58
July	0.006	18.18	0.048	64.00

Table 2 Vertical loss of Hg in Jiaozhou Bay 1988

Month	Location	$V_{na}/\mu\text{g L}^{-1}$	$V_{nr}/\%$
April	Outer side	-0.003	6.25
	Inner side	0.008	16.32
July	Outer side	-0.042	56.00
	Inner side	0.000	0.00

In the inner side of the bay mouth of Jiaozhou Bay, Hg contents were relative high by means of the input of overland runoff and river flow. In waters in the bay mouth, Hg contents were decreasing continuously by means of tide and marine current, and were migration from the high value region in the bay center to the edge. In April 1988, from the inner side of the bay mouth to the outer side of the bay mouth, the horizontal relative loss amount of Hg in surface waters was 8.16%, while in bottom waters was 14.58% (Fig. 2). The vertical relative dilution amount of Hg in the inner side of the bay mouth was 16.32%, while in the outer side of the bay mouth was relative low as 6.25% (Fig. 2). In April 1988, from the outer side of the bay mouth to the inner side of the bay mouth, the horizontal relative loss amount of Hg in surface waters was 18.18%, while in bottom waters was as high as 64.00% (Fig. 3). The vertical relative dilution amount of Hg in the outer side of the bay mouth was relative high as 56.00%, while in the inner side of the bay mouth was little (Fig. 3).

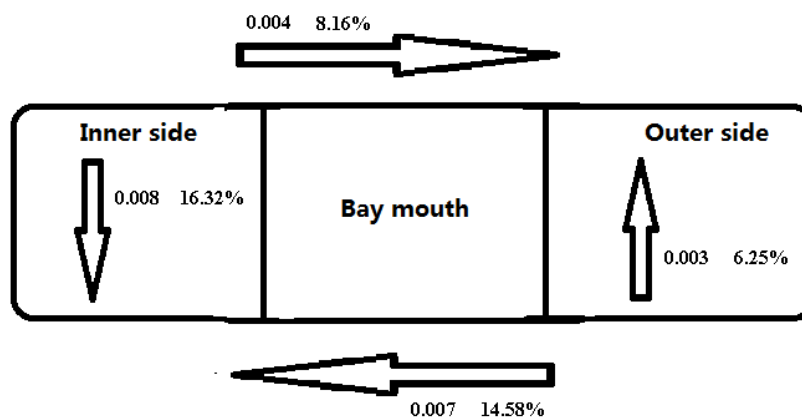


Fig. 2 Block diagram model for horizontal-vertical changing of Hg in Jiaozhou Bay in April 1988

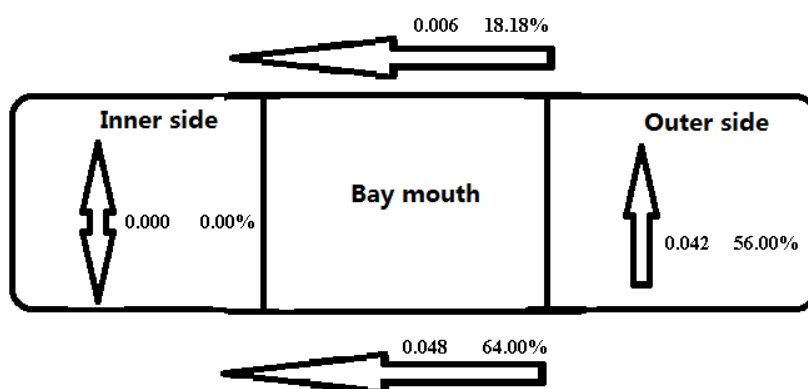


Fig. 3 Block diagram model for horizontal-vertical changing of Hg in Jiaozhou Bay in July 1988

3.2 Horizontal loss of Hg in the bay mouth.

For horizontal loss in surface waters. In April 1988, from the inner side of the bay mouth to the bay mouth and to the outer side of the bay mouth, the horizontal relative loss amount of Hg in surface waters was 8.16%. In July 1988, from the outer side of the bay mouth to the bay mouth and to the inner side of the bay mouth, the horizontal relative loss amount of Hg in surface waters was 18.18%. The horizontal loss of Hg in surface waters was 8.16-18.18%.

For horizontal loss in bottom waters. In April 1988, from the outer side of the bay mouth to the bay mouth and to the inner side of the bay mouth, the horizontal relative loss amount of Hg in surface waters was 14.58%. In July 1988, from the outer side of the bay mouth to the bay mouth and to the inner side of the bay mouth, the horizontal relative loss amount of Hg in surface waters was 64.00%. The horizontal loss of Hg in bottom waters was 14.58-64.00%.

It could be found that no matter from the internal waters to the open waters or from the open waters to internal waters, and no matter in surface waters or in bottom waters, the horizontal loss of Hg was existing objectively in a certain degree (Table 3). In general, if the horizontal loss in surface waters was relative high/low, the horizontal loss in bottom waters would be also relative high/low accordingly.

Table 3 Vertical loss of Hg in Jiaozhou Bay 1988

Water layer	Month	Start point	Passing by	End point	Horizontal loss/%
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Surface	April	Inner side	Bay mouth	Outer side	8.16
	July	Outer side	Bay mouth	Inner side	18.18
Bottom	April	Inner side	Bay mouth	Outer side	14.58
	July	Outer side	Bay mouth	Inner side	64.00

4. Conclusions

The horizontal and vertical loss of Hg contents in Jiaozhou Bay 1988 were quantified. The horizontal absolute and relative loss amounts of Hg contents in surface and bottom waters were 0.004-0.048 $\mu\text{g L}^{-1}$ and 8.16-64.00%, respectively. The vertical absolute and relative dilution amounts of Pb contents were 0.000-0.008 $\mu\text{g L}^{-1}$ and 0.00-16.32%, respectively. The vertical absolute and relative accumulation amounts of Pb contents were 0.003-0.042 $\mu\text{g L}^{-1}$ and 6.25-56.00%, respectively.

No matter from the internal waters to the open waters or from the open waters to internal waters, and no matter in surface waters or in bottom waters, the horizontal loss of Hg was existing objectively in a certain degree. If the horizontal loss in surface waters was relative high/low, the horizontal loss in bottom waters would be also relative high/low accordingly.

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