Modelling for Arsenic's transferring process in Jiaozhou Bay

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Abstract. This paper quantified the horizontal and vertical transferring processes of As in Jiaozhou Bay using investigation data in April and August 1988. Results showed that the horizontal absolute loss amounts of As contents in surface waters were 0.10-1.42 μg L^{-1}, and the horizontal relative loss amounts in surface waters were 7.04%-25.00%, respectively. The horizontal absolute loss amounts of As contents in bottom waters were 0.04-1.00 μg L^{-1}, and the horizontal relative loss amounts in bottom waters were 2.85%-41.66%, respectively. The vertical absolute dilution amounts of As contents were 0.02-0.28 μg L^{-1}, and the vertical relative dilution amounts were 1.78%-16.66%. The vertical absolute accumulation amounts of Pb contents were 0.10-0.86 μg L^{-1}, and the vertical relative accumulation amounts were 7.35%-35.83%. During the transferring processes through the bay mouth, no matter from the internal waters to the open water, or from the open waters to the internal waters, As contents in both surface and bottom layers were decreasing in a certain degree. The changes of As contents in surface and bottom waters were determined by the transferring distance of As in surface waters.

1 Introduction

The excessive existence of As in the environment is harmful to organism and ecosystem since As is high toxic ([1-2]). Many marine bays have been polluted by As due to the rapid development of industrial economic and the increase of population size ([3-6]). Understanding the transferring processes of As in marine bays is essential to pollution control. Jiaozhou Bay is a semi-closed bay located in Shandong Province China, and has been polluted by various pollutants including As after the rapid increasing of industry the past three decades ([1-2]). This paper quantified the horizontal and vertical transferring processes of As in Jiaozhou Bay using investigation data in April and August 1988. The aim of this paper was to better understand the transporting processes of As in marine bay, and provide basis for scientific research and environment remediation.

2 Materials and method

2.1 Study area

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 km^2 and 7 m, respectively. The bay mouth is very narrow (3 km), and is connected to the Yellow Sea in the south (Fig. 1). There are a dozen of rivers including Dagu River, Haibo Rriver, Licun Rriver, and Loushan Rriver etc., all of which are seasonal rivers ([7-8]).

2.2 Data collection

In April 1988, As's contents in surface and bottom waters were measured in Site D5 in the east of bay, in Site A5 in the bay mouth, and in Site A1 in the open waters, respectively (Fig. 1). In August 1988, As's contents in surface and bottom waters were measured in Site B5 in north of the bay, in Site A5 in the bay mouth, and in Site A1 in the open waters, respectively (Fig. 1). As in waters was sampled and monitored follow by National Specification for Marine Monitoring ([9]).
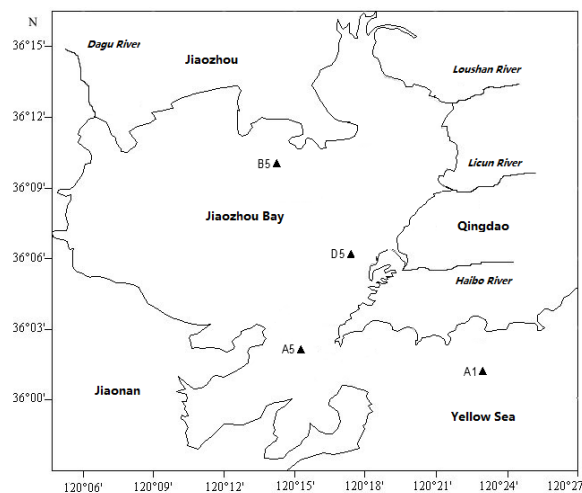

Fig. 1. Geographic location and monitoring sites in Jiaozhou Bay.

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2.3 Modelling for horizontal transferring processes of As

By means of the water exchange via the bay mouth, substance's contents in waters in Jiaozhou Bay were changing continuously ([4-6], [10]). Supposed that certain substance's contents in surface and bottom waters in the bay are A and a, in the bay mouth are B and b, and in the open waters are C and c, respectively.

In surface waters, and from the inner of the bay to the open waters, substance's contents are changing, and the calculation formula for transferring process is:

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

where, D is the horizontal absolute loss amount in surface waters from the inner of the bay to the open waters, E is the corresponding horizontal relative loss amount in surface waters.

In surface waters, and from the open waters to the inner of the bay, substance's contents are changing, and the calculation formula for transferring process is:

$$F=B-C, \quad G=(100\times|B-C|/\max(B, C))\% \quad (2)$$

where, F is the horizontal absolute loss amount in surface waters from open waters to the inner of the bay, G is the corresponding horizontal relative loss amount in surface waters.

In bottom waters, and from the inner of the bay to the open waters, substance's contents are changing, and the calculation formula for transferring process is:

$$d=a-b, \quad e=(100\times|a-b|/\max(a, b))\% \quad (3)$$

where, d is the horizontal absolute loss amount in bottom waters from the inner of the bay to the open waters, e is the corresponding horizontal relative loss amount in bottom waters.

In bottom waters, and from the open waters to the inner of the bay, substance's contents are changing, and the calculation formula for transferring process is:

$$f=b-c, \quad g=(100\times|b-c|/\max(b, c))\% \quad (4)$$

where, f is the horizontal absolute loss amount in bottom waters from open waters to the inner of the bay, g is the corresponding horizontal relative loss amount in bottom waters.

2.4 Modelling for vertical transferring processes of As

Supposed that certain substance's contents in surface and bottom waters in Site n in the bay are A and a,

respectively. From surface waters to bottom waters, the calculation formula for this transferring process is:

$$V_{na}=A-a, \quad V_{nr}=(100\times|A-a|/\max(A, a))\% \quad (5)$$

where, V_{na} is the horizontal absolute dilution amount from surface waters to bottom waters, V_{nr} is the corresponding horizontal relative dilution amount. While from bottom waters to surface waters, V_{na} refers to the horizontal absolute accumulation amount, and V_{nr} refers to the corresponding horizontal relative accumulation amount.

3 Results

3.1 Horizontal loss of As in surface and bottom waters

In April 1988, As's contents in surface and bottom waters were measured in Site D5 in the bay, in Site A5 in the bay mouth, and in Site A1 in the open waters, respectively. In August 1988, As's contents in surface and bottom waters were measured in Site B5 in the bay, in Site A5 in the bay mouth, and in Site A1 in the open waters, respectively. In according to Eq. (1) and (2), the horizontal loss of As in surface waters were calculated listed in Table 1. In according to Eq. (3) and (4), the horizontal loss of As in bottom waters were calculated and listed in Table 2.

Table 1. Horizontal loss of As in surface waters in Jiaozhou Bay 1988

	From D5 to A5		Form A1 to A5	
Month	D/µg L^{-1}	E/%	F/µg L^{-1}	G/%
April	-0.14	8.33	1.42	25.00
August	0.10	7.04	0.20	15.15

Table 2. Horizontal loss of As in bottom waters in Jiaozhou Bay 1988

	From B5 to A5		Form A1 to A5	
Month	d/µg L^{-1}	e/%	f/µg L^{-1}	g/%
April	1.00	41.66	0.04	2.85
August	0.36	20.00	0.34	23.61

3.2 Horizontal loss of As in surface and bottom waters

In April 1988, vertical loss of As's contents in waters were calculated in Site D5 in the bay, Site A5 in the bay mouth, and in Site A1 in the open waters, respectively. In August 1988, vertical loss of As's contents in waters were calculated in Site B5 in the bay, Site A5 in the bay mouth, and in Site A1 in the open waters, respectively. In according to Eq. (5), the vertical loss of As in waters were calculated and listed in Table 3.

Table 3. Vertical loss of As in waters in Jiaozhou Bay 1988

Time	Sampling Site	V_{na}/μg L-1	V_{nr}/%
April	D5	-0.86	35.83
	A5	0.28	16.66
	A1	-0.10	7.35
August	B5	-0.38	21.11
	A5	-0.12	8.33
	A1	0.02	1.78

4 Discussion

4.1 Horizontal and vertical changes of As

In April 1988, the horizontal absolute loss amount in surface waters from the bay mouth to the open waters was as high as 25.00%, while the horizontal absolute loss amount in bottom waters from the inner of the bay to the bay mouth was as high as 41.66% (Fig. 2). There were accumulation processes in the inner of the bay and the open waters, and the relative accumulation amounts were 35.83% and 7.35%, respectively, while in the bay mouth there was dilution process, with a relative dilution amount of 16.66% (Fig. 2).
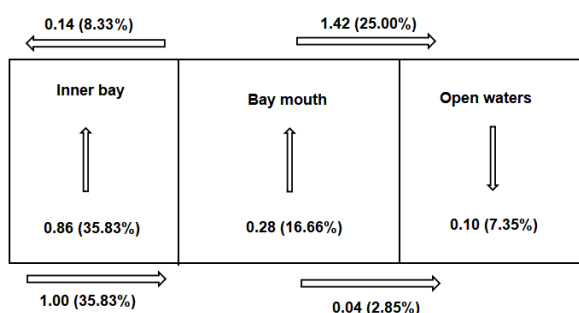

Fig. 2. Block diagram model for horizontal-vertical changes of As in Jiaozhou Bay in April 1988.

In August 1988, the horizontal absolute loss amount in surface waters from the bay mouth to the open waters was as high as 15.15%, and the horizontal absolute loss amount in bottom waters from the bay mouth to the open waters was as high as 23.61% (Fig. 3). There were accumulation processes in the inner of the bay and the bay mouth, and the relative accumulation amounts were 21.11% and 8.33%, respectively, while in the open waters there was dilution process, with a relative dilution amount of 1.78% (Fig. 3).
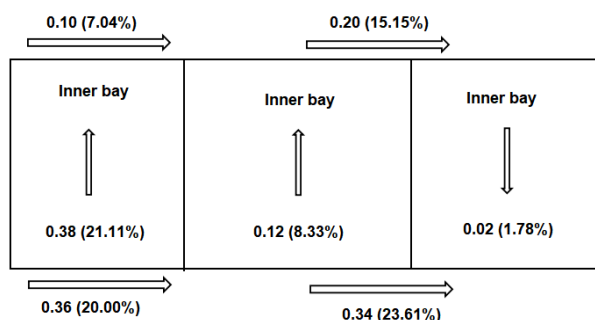

Fig. 3. Block diagram model for horizontal-vertical changes of As in Jiaozhou Bay in August 1988.

In surface waters in April and August 1988 in Jiaozhou Bay, the horizontal absolute loss amounts of As＇s contents were 0.10-0.42 μg L⁻¹, and the corresponding relative loss amounts were 7.04%-25.00%. In bottom waters, the horizontal absolute loss amounts of As＇s contents were 0.04-1.00 μg L⁻¹, and the corresponding relative loss amounts were 2.85%-41.66%. The absolute dilution amounts of As＇s contents were 0.02-0.28 μg L-1, and the corresponding relative dilution amounts were 1.78%-16.66%. The absolute acumulation amounts of As's contents were 0.10-0.86 μg L⁻¹, and the corresponding relative dilution amounts were 7.35%-35.83%.

In general, by means of the modelling processes (i.e., Eq. (1) to Eq. (5)), the changes of As＇s contents in transferring processes in Jiaozhou Bay were quantified ([4-6]). Furthermore, the block diagram models were demonstrating the horizontal and vertical changes of As＇s contents visually.

4.2 Horizontal loss of As in the bay mouth

In April 1988, from the inner of the bay to the bay mouth and then to the open waters, the horizontal relative loss amount of As's contents in surface waters were 8.33%-25.00%, while in bottom waters were 2.85%-41.66% (Fig. 2). It could be found that in transferring process from the inner of the bay to the open waters, the horizontal loss amounts in surface waters were relative low, while in bottom waters were relative high.

In August 1988, from the inner of the bay to the bay mouth and then to the open waters, the horizontal relative loss amount of As's contents in surface waters were 8.04%-15.15%, while in bottom waters were 20.00%-23.61% (Fig. 3). It could be found that in transferring process from the inner of the bay to the open waters, the horizontal loss amounts in surface waters waters were relative low, while in bottom waters were relative high.

As a whole, during the transferring processes through the bay mouth, no matter from the internal waters to the open water, or from the open waters to the internal waters, As contents in both surface and bottom layers were decreasing in a certain degree. The changes of As contents in surface and bottom waters were determined by the transferring distance of As in surface waters.

5 Conclusions

The changes of As's contents in transferring processes in Jiaozhou Bay were quantified, and block diagram models were demonstrating the horizontal and vertical changes of As's contents visually. In surface waters in April and August 1988 in Jiaozhou Bay, the horizontal absolute loss amounts of As's contents were 0.10-0.42 μg L⁻¹, and the corresponding relative loss amounts were 7.04%-25.00%. In bottom waters, the horizontal absolute loss amounts of As's contents were 0.04-1.00 μg L⁻¹, and

the corresponding relative loss amounts were 2.85%-41.66%. The absolute dilution amounts of As's contents were 0.02-0.28 μg L^{-1}, and the corresponding relative dilution amounts were 1.78%-16.66%. The absolute acumulation amounts of As's contents were 0.10−0.86 μg L^{-1}, and the corresponding relative dilution amounts were 7.35%-35.83%. During the transferring processes through the bay mouth, no matter from the internal waters to the open water, or from the open waters to the internal waters, As contents in both surface and bottom layers were decreasing in a certain degree. The changes of As contents in surface and bottom waters were determined by the transferring distance of As in surface waters.

Acknowledgments

References

1. D.F. Yang, W.P. Song, S.T. Chen, J.H. Guo, L. Zheng, Coastal Engineering, **31**, 4(2012)

2. D.F. Yang, Y.H. Zhao, Z.G. Piao, Ocean Development and Management, **31**, (2014)

3. D.F. Yang, S.X. Zhu, F.Y. Wang, S.T. Chen, Z.J. Xu, S.X. Zhu, Y.J. Wu, Meterological and Environmental Research, **5**, (2014)

4. D.F. Yang, F.Y. Wang, H.Z. He, Y.J. Wu, S.X. Zhu, Proceedings of the 2015 international symposium on computers and informatics, (2015)

5. D.F. Yang, F.Y. Wang, X.L. ZhaoY.J. Wu, S.X. Zhu, Sustainable Energy and Enviroment Protection, (2015)

6. D.F. Yang, F.Y. Wang, X.Q. Yang, Y.J. Wu, S.X. Zhu, Advances in Computer Science Research, **3252**, (2015)

7. D.F. Yang, Y. Chen, Z.H. Gao, J. Zhang, F. Wang, Chinese Journal of Oceanology and Limnology, **23**, 1(2005)

8. D.F. Yang, F.Y. Wang, Z.H. Gao, W.L. Cui, S.X. Huo, Marine Science, **28**, 6(2004)

9. China's State Oceanic Administration, *The specification for marine monitoring* (Ocean Press, Beijiang, 1991)

10. Yang DF, Miao ZQ, Xu HZ, Y. Chen, J.Y. Sun, Marine Environmental Science, **32**, 3(2013)