

## Vertical variation and migration of Pb in Jiaozhou Bay waters

Dongfang Yang<sup>1,2,4,a</sup>, Sixi Zhu<sup>1,2</sup>, Danfeng Yang<sup>3</sup>, Fengyou Wang<sup>1,2,b,c</sup> and Yunjie Wu<sup>1,2</sup>

<sup>1</sup>Research Center for Karst Wetland Ecology, Guizhou Minzu University, Guizhou Guiyang, Guizhou Guiyang, China;

<sup>2</sup>College of Chemistry and Environmental Science, Guizhou Minzu University, Shanghai, 550025, China;

<sup>3</sup>College of Information Science and Engineering, Fudan University, Shanghai, 200433, China;

<sup>4</sup>North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China.

<sup>a</sup>dfyang\_dfyang@126.com; <sup>b</sup>Corresponding author: <sup>c</sup>wangfy2001@yahoo.com.cn

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**Abstract.** Based on the investigation data on Pb in waters in 1984, were analyzed the horizontal distribution, seasonal variation and settling process of Pb in water in the bay mouth of Jiaozhou Bay, eastern China. Results showed that the seasonal variations of Pb contents in surface waters and bottom waters were consist, and were in order of summer > autumn. In spatial scale, the migration and sedimentation distances of Pb were determined bay Pb contents in waters, and the spatial sedimentaion processes could be revealed by the horizontal distributions of Pb. In vertical scale, Pb contents in surface and bottom waters were closed in cased of low Pb contents in waters, while in case of high Pb contents in waters the differences of Pb contents in surface and bottom waters were relative high. In generally, the seasonal variations and vertical distributions of Pb in waters were indicating the horizontal water's effect and vetical water's effect, and were reveal the horizontal migration and horizontal sedimentation processes of Pb.

### Introduction

A large amount of Pb-containing wastes were generated from industries of metallurgical, salt electrolysis, appliance industry etc., as well as automobile exhaust, coal electricity plant, etc., and the marine bay could be polluted by Pb by means of river flow and atmosphere deposition [1-6]. Hence, it is necessary to understand the migration processes of Pb in marine bay.

Jiaozhou Bay is a semi-closed bay located in Shandong province, eastern China, and had been polluted by various pollutants including Pb [1-6]. This paper analyzed the contents, seasonal variations, vertical and horizontal distributions of Pb based on investigation dada on Pb in Jiaozhou Bay, and tried to provide scientific background and basis for provide basis for Pb pollution control and environmental remediation.

### Material and method

Jiaozhou Bay (35°55'-36°18' N, 120°04'-120°23' E) is a semi-closed bay located in the south of Shandong Province, eastern China (Fig. 1). The total area, average water depth and bay mouth depth 446 km<sup>2</sup>, 7m and 3 km, respectively. This bay was arounded by Qingdao City, Jiaozhou City and Jiaonan City in the east, north and west, respectively, and was connected to Yellow Sea in the south. The bay has more than ten inflow rivers, including Haibo Rriver, Licun Rriver and Loushan Rriver etc., all of which have seasonal features [7-8].

The data was provided by North China Sea Environmental Monitoring Center. The survey was conducted in July and October 1984. Pb in surface waters in six sampling sties (Site 2031, Site 2032 and Site 2033) (Fig. 1) were sampled and monitored follow by National Specification for Marine Monitoring [9].

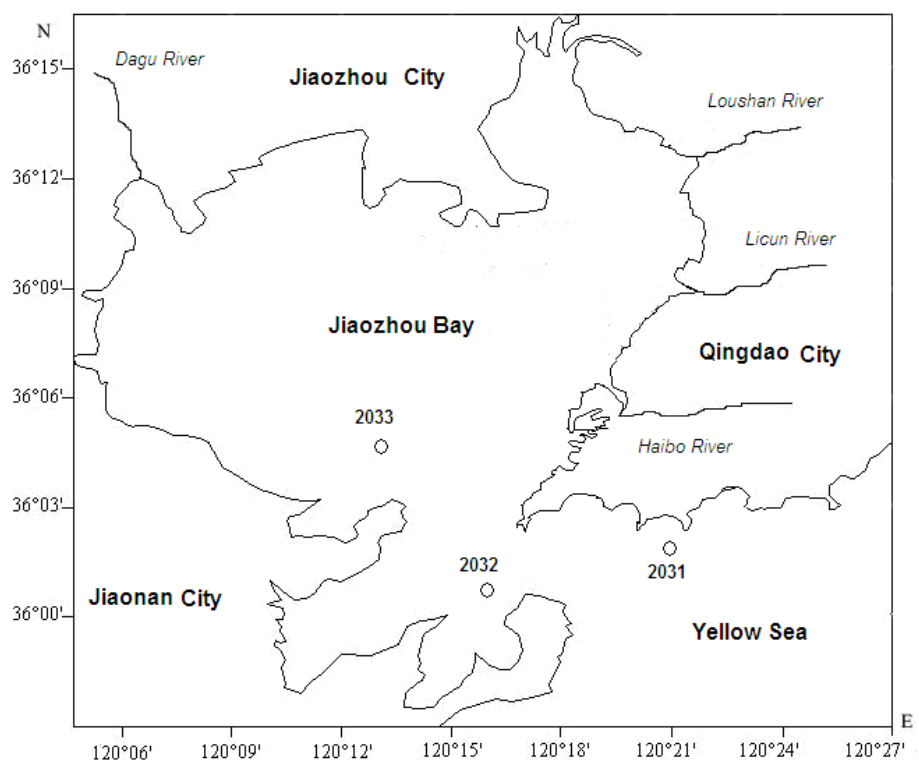


Fig.1 Investigation sites in Jiaozhou Bay

## Results

**Seasonal variations of Pb.** Pb contents in surface waters in July and October in the bay mouth of Jiaozhou Bay in 1984 were  $9.34\text{--}36.00\ \mu\text{g L}^{-1}$  and  $0.80\text{--}1.24\ \mu\text{g L}^{-1}$ , respectively, while in bottom waters were  $7.15\text{--}17.34\ \mu\text{g L}^{-1}$  and  $1.33\text{--}2.25\ \mu\text{g L}^{-1}$ , respectively. July and October could be defined as summer and autumn in study area. Hence, Pb contents in surface waters and bottom waters were consist and were in orders of summer > autumn. Meanwhile, it could be found that Pb contents in bottom waters were higher (or lower) in case of higher (or lower) Pb contents in surface waters.

**Hozizontal distributions of Pb.** Among the three sampling Sites, Site 2033 was located in the inside of the bay mouth, Site 2032 was located in the middle of bay mouth, and Site 2031 was located in the outside of the bay mouth. In July, Pb contents in surface waters were decreasing from the inside to the outside of the bay mouth, while in bottom waters were increasing from the inside to the outside of the bay mouth. In October, Pb contents in surface waters were increasing from the inside to the outside of the bay mouth, while in bottom waters were decreasing from the inside to the outside of the bay mouth.

**Vertical variations of Pb.** In order to reveal the vertical variations of Pb, the contents in surface waters in the three sampling sites were subtracted by which in bottom waters. For the whole year, the subtraction of Pb contents in surface from which in bottom waters ranged from  $-8.00\text{--}28.71\ \mu\text{g L}^{-1}$ . In July, the differences were ranging from  $-0.80$  to  $28.71\ \mu\text{g L}^{-1}$ , while in October were  $-1.45$  to  $-0.09\ \mu\text{g L}^{-1}$  (Table 1). The differences in two of the three sampling Sites were positive in July, while both two Sites were negative (Table 1).

Table 1 Results of subtracting Pd contents in surface waters from which in bottoms in the three sampling sites in July and October 1984

Month	Site 2031	Site 2032	Site 2033
July	Negative	Positive	Positive
October	Negative	Negative	

## Discussion

**Settling process of Pb.** Pb contents in waters were changing a lot once were transferring across water body by means of vertical water's effect. In summer, the activities of zooplankton and phytoplankton were increasing, which were able to enhancing the adsorption capacity of suspended particulate matters due to the large production of colloid [8]. A large amount of Pb was absorbing and settling to the sea bottom under the force of gravity and current [1-6]. Hence, the migration processes of Pb were the continuous sedimentation of Pb from surface waters to bottom waters.

**Seasonal variations of Pb.** Pb contents in both surface and bottom waters in July and October were in orders of summer > autumn. The reason was that river flow from adjacent regions of Jiaozhou Bay was the major Pb source, whose source strength was relative high in summer, and was relative low in autumn. By means of vertical water's effect [10] and Pb contents in waters, the sedimentation of Pb was higher in summer than in autumn, and Pb contents in bottom waters were higher in summer than in autumn. It could be further concluded that Pb contents in bottom waters were determined by which in surface waters.

**Spatial variations of Pb.** Pb in Jiaozou Bay was mainly sources from river flow, whose source strength was more strong in summer than in autumn. In July, the source strength of Pb was relative high and Pb in surface waters were decreasing from the inside of the bay mouth to the outside of the bay mouth. However, the sedimentation of Pb was also stronger in July, and a large amount of Pb could be transferred to the bay mouth and the outside of the bay mouth via water exchange. Hence, Pb in bottom waters were increasing from the inside of the bay mouth to the outside of the bay mouth along with the flow direction. The source strength of Pb in October was relative low in October, and was even lower than the background pollution level of Pb in marine current. Hence, Pb in surface waters was decreasing from the inside of the bay mouth to the outside of the bay mouth. However, due to the sedimentation of Pb, a big part of Pb was settled and accumulated in bottom waters, and Pb in bottom waters were increasing from the inside of the bay mouth to the outside of the bay mouth. In case of low Pb contents, the loss of Pb was little. In case of high Pb contents, the loss of Pb was  $1.33 \mu\text{g L}^{-1} - 0.80 \mu\text{g L}^{-1}$  to  $36.00 \mu\text{g L}^{-1} - 17.34 \mu\text{g L}^{-1}$ , that was  $0.53 \mu\text{g L}^{-1}$  to  $18.66 \mu\text{g L}^{-1}$ . In generally, the impact distances and horizontal distributions of the pollution source of Pb were determined by the source strengths, and the spatial variations of Pb were determined by the pollution strengths and the vertical water's effect.

**The regional variations of Pb.** The subtractions of Pb contents in surface waters from which in bottom waters were changing along with time in different seasons. Once Pb was inputted to the bay, Pb was originally arrived at the surface waters, and than was settling to the bottom waters rapidly and continuously. Hence, the exist and distributions of Pb contents in bottom surface and bottom waters were also changing. In July, the source strength of Pb to the bay was relative high, and in input of Pb to the bay was also very high. Pb contents in surface waters in the bay were higher than in bottom waters. However, the big part of Pb had not been transferred to the bay mouth yet in July, and Pb contents in surface waters in regions in the outside of the bay mouth were still lower than in bottom waters. In October, both the source strength and input of Pb were relative low, yet and sedimentation and accumulation of Pb were continuous with time, and Pb contents in surface waters in regions in the inside, middle and outside of the bay mouth were lower than in bottom waters. The regional variations of Pb in Jiaozhou Bay were similar with PCH, which could be confirmed by the block diagram model [11-12].

## Conclusion

Pb contents in surface waters and bottom waters were consist in the bay mouth of Jiaozhou Bay in 1984 and were in orders of summer > autumn. Pb contents in bottom waters were determined by which in surface waters. In spatial scale, the impact distances and horizontal distributions of the pollution source of Pb were determined by the source strengths, and the spatial variations of Pb were determined by the pollution strengths and the vertical water's effect. In variation scale, the variations of Pb contents in surface and bottom waters in the bay mouth in July and October were

consist, which was determined by the rapid and continuous sedimentation of Pb. In vertical scale, the loss of Pb was little in case of low Pb contents, while was very big in case of high Pb contents, indicated that Pb in surface waters could be removed by water body rapidly, and there were inconsistencies of Pb in surface and bottom waters. In regional scale, in summer, a large amount of Pb in this bay was inputted from river flow, and Pb contents in surface waters were higher than in bottom waters in the inside of the bay mouth, yet were reverse in regions in the outside of the bay mouth. In autumn, the input of Pb was little, yet and sedimentation of Pb was continuous, and Pb contents in surface waters in regions in the middle and outside of the bay mouth were lower than in bottom waters. Both seasonal variation and spatial migration of Pb in Jiaozhou Bay were determined by both vertical water's effect and horizontal water's effect.

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## References

- [1] Yang D F, Su C, Gao Z H, et al.: Chinese Journal of Oceanology Limnology, Vol. 26(2008), p. 296-299.
- [2] Yang DF, Guo JH, Zhang YJ, et al.: Journal of Water Resource and Protection. Vol. 3(2011), p. 41-49.
- [3] Yang DF, Zhu SX, Wang FY, et al.: Applied Mechanics and Materials, Vols. 651-653 (2014), p. 1419-1422.
- [4] Yang DF, Geng X, Chen ST, et al.: Applied Mechanics and Materials, Vol. 651-653 (2014), p. 1216-1219.
- [5] Yang DF, Ge HG, Song FM, et al.: Applied Mechanics and Materials, Vol. 651-653 (2014), p. 1492-1495.
- [6] Yang DF, Zhu SX, Wang FY, et al.: Applied Mechanics and Materials, Vol. 651-653 (2014), p. 1292-1294.
- [7] Yang DF, Chen Y, Gao ZH, et al.: Chinese Journal of Oceanology and Limnology, Vol. 23(2005), p. 72-90.
- [8] Yang DF, Wang F, Gao ZH, et al. Marine Science, Vol. 28 (2004), p. 71-74. (in Chinese)
- [9] China's State Oceanic Administration: The specification for marine monitoring (Ocean Press, Beijing 1991), p.1-300. (in Chinese)
- [10] Yang DF, Wang FY, He HZ, et al.: Proceedings of the 2015 international symposium on computers and informatics, Vol. (2015), p. 2655-2660.
- [11] Yang DF, Gao ZH, Cao HR, et al.: Coastal Engineering, Vol. 27 (2008), p. 65-71.
- [12] Yang DF, Gao ZH, Sun PY, et al.: Coastal Engineering, Vol. 28 (2009), p. 69-77.