Migration paths and laws of Pb from source to ocean

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Abstract. The investigation dataset on Plumbum (Pb) in surface waters in Jiaozhou Bay in May and August 1990 studied the migration paths of Pb from source to ocean. The results unveiled that the major sources were port wharf, river flow, atmosphere deposition and marine current, whose source strengths were 13.39 μg L\textsuperscript{-1}, 12.97 μg L\textsuperscript{-1}, 11.01 μg L\textsuperscript{-1} and 10.82 μg L\textsuperscript{-1}, respectively. This paper revealed that there were three different migration paths which were described by a block diagram model. Finally, the migration laws of Pb from sources to ocean were defined that the loss of Pb contents were increasing along with the increasing of migration path. Ocean was the sink of Pb. During the migration path from source to sink, a part of Pb was storing in water body, while another part was settling and fixing in sea bottom.

1. Introduction
Pb would become the wide use in industry. However, its pollution would become sever and sever with the rapid increasing of industry, resulting in Pb pollution in the environment [1-2]. Pb entered the ocean by source inputs from port wharf, river flow, atmosphere deposition and marine current, etc. [3-4]. Hence, the migration paths of Pb from sources to ocean unveiled the method of the environment to pollution control and environmental remediation. Jiaozhou Bay has a pretty bay. our studies for a long time presented that this bay had showed the pollution process after 1980s through the rapid increasing of industry and economic of these cities around the bay. The investigation dataset on Pb in surface waters in Jiaozhou Bay in May and August 1990 would determine the migration paths of Pb from source to ocean. The paper would look forward to a block diagram model on three different migration paths, and further examine the migration laws of Pb from sources to ocean, describing that the loss of Pb contents were increasing along with the increasing of migration path.

2. Study area and data collection

2.1. Study area. Jiaozhou Bay with total area 446 km\textsuperscript{2} located in the south of Shandong Province, eastern China (35°55′-36°18′ N, 120°04′-120°23′ E) (Fig. 1). There are seasonal rivers into the bay including Dagu River, Haibo River, Licun River, and Loushan River etc.
2.2. Data collection. Dataset on Pb in Jiaozhou Bay from North China Sea Environmental Monitoring Center showed the investigations in May and August 1990. There were 13 sampling sites (2, 53, 54, 55, 56, 57, 58, 59, 60, 61, 2104, 2105 and 2106) in May 1990, compared to 11 sampling sites (52, 53, 54, 55, 57, 58, 59, 60, 61, 2105 and 2106) in August 1990 (Fig. 1). The collection of Pb in surface waters was by National Specification for Marine Monitoring [3].

3. Results and discussion

3.1. Pollution level of Pb. In May and August 1990, Pb contents in surface waters in Jiaozhou Bay were 2.90-13.39 μg L⁻¹ and 2.64-12.97 μg L⁻¹, respectively. The Sea Water Quality standard GB 3097-1997 provides standard lines for Pb (Table 1). In May 1990, the coastal waters in the east of the bay in May 1990 were heavily polluted, the moderate polluted regions were coastal waters in the north and northeast of the bay, as well as the north of the bay mouth, compared to slight polluted in other regions (Fig. 2). In August 1990, the heavy polluted regions were occurring in the northeast of the bay, the bay center and the south of the bay mouth, while in other regions were moderate polluted (Fig. 2). In general, the pollution level of Pb in Jiaozhou Bay was heavy in 1990.

| Class | I   | II  | III | IV  |
|-------|-----|-----|-----|-----|
| Standard line/μg L⁻¹ | 1.00 | 5.00 | 10.00 | 50.00 |

3.2. Sources of Pb. In May 1990, the highest value of Pb contents was in Site 60 in the north of the bay mouth (13.39 μg L⁻¹), the contour lines of Pb contents were forming a series of semi-concentric circles that decreasing from the high value region to the bay center (4.64 μg L⁻¹) and the south of the bay mouth (4.65 μg L⁻¹) (Fig. 2). In August 1990, the highest value of Pb contents was in Site 2105 in the northeast of the bay (12.97 μg L⁻¹), the contour lines of Pb contents were forming a series of semi-concentric circles that decreasing from the high value region to the southwest of the bay (5.84 μg L⁻¹) and the coastal waters in the estuary of Licun River (3.58 μg L⁻¹) (Fig. 3). Meanwhile, there was
another high value center in Site 55 in the bay center (11.01 μg L⁻¹), the contour lines of Pb contents were forming a series of concentric circles that decreasing from the high value region to the north of the bay (5.84 μg L⁻¹), the east of the bay (6.12 μg L⁻¹), and the southwest of the bay (6.85 μg L⁻¹) (Fig. 2). The horizontal distributions of Pb contents were important evidences for source identification of Pb. In May 1990, high value region was in the north of the bay mouth in where there was the port wharf. This indicated that port wharf was the major Pb sources in May 1990. In August 1990, there were high value regions in the estuary of Loushan River, the bay center, and the bay mouth. This indicated river flow, atmosphere deposition and marine current were the major source of Pb in August 1990. In general, the major sources were port wharf, river flow, atmosphere deposition and marine current, whose source strengths were 13.39 μg L⁻¹, 12.97 μg L⁻¹, 11.01 μg L⁻¹ and 10.82 μg L⁻¹, respectively.

Fig. 2 Horizontal distribution of Pb in Jiaozhou Bay in May 1990/μg L⁻¹
3.3. Migration path of Pb. In consideration that there were four major sources of Pb, there were also four different migration paths of Pb from source to sink. Firstly, Pb was discharged directly to the ocean by means of port wharf, with the source strength of 13.39 μg L⁻¹. Secondly, Pb was discharged to the land and then was discharged to the ocean by means of river flow, with the source strength of 12.97 μg L⁻¹. Thirdly, Pb was discharged to the atmosphere, and then was discharged to the ocean by means of dry and wet deposition, with the source strengths of 11.01 μg L⁻¹. Fourthly, Pb was transported to the may by means of marine current due to the marine pollution, with the source strengths of 10.82 μg L⁻¹. The previous three migration paths could be considered as anthropogenic migration paths. By comparison, the source strength of port wharf was highest, the source strength of river flow was relatively high, while the source strength of atmosphere deposition was relatively low. In general, Pb contents in waters during the migration paths were decreasing along with the migration processes, the longer the migration distance, the bigger loss of Pb content.

3.4. Origin and fate of Pb. Since the source strengths of port wharf, river flow, atmosphere deposition, and marine current were 13.39 μg L⁻¹, 12.97μg L⁻¹, 11.01μg L⁻¹, and 10.82 μg L⁻¹, respectively, and were all higher than 10.00 μg L⁻¹, the pollution level of Pb in Jiaozhou Bay could be considered as heavy polluted. Furthermore, the origin a fate of Pb was described. Firstly, Pb was discharged to atmosphere, land and ocean by anthropogenic activities. Pb could be discharged directly to the ocean, e.g., port wharf. Pb could also be discharged indirectly from origin to land, and then to the ocean via river discharge. Pb could also be discharged indirectly from origin to atmosphere, and then to the ocean via dry and wet deposition. The origin and fate of Pb could be demonstrated by a block diagram model (Fig. 4). From origin to fate, the migration processes were time-consuming and space-consuming. It should be noticed that once Pb in the ocean was in excess of the environment capacity, the ecology and environment would be damaged and polluted.
4. Conclusion

In May and August 1990, Pb contents in surface waters in Jiaozhou Bay were 2.90-13.39 μg L⁻¹ and 2.64-12.97 μg L⁻¹, respectively. The pollution level of Pb in Jiaozhou Bay was heavy in 1990. The major sources were port wharf, river flow, atmosphere deposition and marine current, whose source strengths were 13.39 μg L⁻¹, 12.97 μg L⁻¹, 11.01 μg L⁻¹ and 10.82 μg L⁻¹, respectively.

There were three different migration paths which were described by a block diagram model. Pb contents in waters during the migration paths were decreasing along with the migration processes, the longer the migration distance, the bigger loss of Pb content. Ocean was the sink of Pb. During the migration path from source to sink, a part of Pb was storing in water body, while another part was settling and fixing in sea bottom.

References

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