Yang’s marine bay filtration phenomenon on substance’s content

Dongfang Yang1,2,3, a, Sixi Zhu1,2, Ming Wang1,2, Yunjie Wu1,2, Xiaoye Gao1,2

1Research Center for Karst Wetland Ecology, Guizhou Minzu University, Guizhou Guiyang, Guizhou, China;
2College of Chemistry and Environmental Science, Guizhou Minzu University, Shanghai, 550025, China;
3North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China.
adfyang_dfyang@126.com

Abstract. This paper established definition and formula for horizontal and vertical changes of substance’s contents were established, and provided a case study on plumbum (Pb) contents in Jiaozhou Bay 1987. Results showed that the horizontal absolute loss amounts of Pb contents in surface and bottom waters were 0.06 to 20.66 μg L⁻¹, and the horizontal relative loss amounts of Pb contents were 2.30 to 83.84%, respectively. The vertical accumulation amounts of Pb contents were 0.00 to 8.61 μg L⁻¹, and the vertical accumulation amounts were 0.00 to 68.38%. The vertical dilution amounts of Pb contents were 0.00 to 13.56 μg L⁻¹, and the vertical dilution amounts were 0.00 to 55.03%. The bay mouth was playing a role of a filter. Pb contents were difficult to be transported from the open waters to the bay, and were difficult to be transported from the bay to the open waters. This phenomenon determined by the special geographic and geomorphic conditions of the bay, was named as Yang’s marine bay filtration phenomenon.

1. Introduction
Pb has been widely used in industry, agriculture and everyday life, and Pb pollution has been one of the critical environmental issues since the rapid increasing of industrialization and urbanization. Nowadays, many marine bays had been polluted by Pb, and understanding the transporting processes of Pb in marine bays is essential to pollution control [6]. This paper established definition and formula for horizontal and vertical changes of substance’s contents were established, and provided a case study on plumbum (Pb) contents in Jiaozhou Bay 1987. Both the horizontal and vertical changes of Pb contents were quantified, and the filtration effect of the bay mouth on substance’s contents was defined. Furthermore, Yang’s marine bay filtration phenomenon on substance’s content was found. These research results were helpful to better understand the transporting processes of substance in marine bay.

2. Methodology
Definition and formula for horizontal change of substance’s content. By means of the water exchange, substance’s contents in waters were changing continuously [10-12]. For a marine bay, supposed that certain substance’s contents in surface waters in the outer side of the bay mouth, the center of the bay mouth and the inner side of the bay mouth are C, B and A, respectively, while in bottom waters are a, b and c, respectively (Fig. 1).
Fig. 1 Schematic diagram of the geographic location and substance’s contents in waters

For surface waters and from the outer side to the bay mouth, the calculation formula for horizontal change of substance’s content is:

$$D = A - B, \quad E = (100 \times \frac{|D|}{\max(A, B)})\%$$  \hspace{1cm} (1)

where, $D$ is the horizontal absolute loss amount in surface waters, $E$ is the horizontal relative loss amount in surface waters. $D > 0$ indicates that substance’s content in surface waters was losing along with the migration process from the outer side of the bay mouth to the bay mouth, $D < 0$ indicates that substance’s content in surface waters was increasing along with the migration process from the outer side of the bay mouth to the bay mouth, and $D = 0$ means little loss in surface waters.

For surface waters and from the inner side to the bay mouth, the calculation formula for horizontal change of substance’s content is:

$$F = C - B, \quad G = (100 \times \frac{|F|}{\max(B, C)})\%$$  \hspace{1cm} (2)

where, $F$ is the horizontal absolute loss amount in surface waters, $G$ is the horizontal relative loss amount in surface waters. $F > 0$ indicates that substance’s content in surface waters was losing along with the migration process from the inner side of the bay mouth to the bay mouth, $F < 0$ indicates that substance’s content in surface waters was increasing along with the migration process from the inner side of the bay mouth to the bay mouth, and $F = 0$ means little loss.

For bottom waters and from the outer side to the bay mouth, the calculation formula for horizontal change of substance’s content is:

$$d = a - b, \quad e = (100 \times \frac{|d|}{\max(a, b)})\%$$  \hspace{1cm} (3)

where, $d$ is the horizontal absolute loss amount in bottom waters, $E$ is the horizontal relative loss amount in bottom waters. $d > 0$ indicates that substance’s content in bottom waters was losing along with the migration process from the outer side of the bay mouth to the bay mouth, $d < 0$ indicates that substance’s content in bottom waters was increasing along with the migration process from the outer side of the bay mouth to the bay mouth, and $d = 0$ means little loss in bottom waters.

For bottom waters and from the inner side to the bay mouth, the calculation formula for horizontal change of substance’s content is:

$$f = c - b, \quad g = (100 \times \frac{|f|}{\max(b, c)})\%$$  \hspace{1cm} (4)

where, $f$ is the horizontal absolute loss amount in bottom waters, $g$ is the horizontal relative loss amount in bottom waters. $f > 0$ indicates that substance’s content in bottom waters was losing along with the migration process from the inner side of the bay mouth to the bay mouth, $f < 0$ indicates that substance’s content in bottom waters was increasing along with the migration process from the inner side of the bay mouth to the bay mouth, and $f = 0$ means little loss in bottom waters.

**Definition and formula for vertical change of substance’s content.** 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 (Fig. 1).

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

\[ V_{na} = A - a, \quad V_{nr} = \left(100 \times \frac{|V_{na}|}{\max(A, a)}\right)\% \]  

(5)

where, \( V_{na} \) is the horizontal absolute change amount in waters, \( V_{nr} \) is the horizontal relative change amount in waters. \( V_{na} > 0 \) is the horizontal absolute dilution amount, indicates that substance’s content in waters was losing along with the migration process from surface waters to bottom waters, \( V_{na} < 0 \) is the horizontal absolute accumulation amount, indicates that substance’s content in waters was increasing along with the migration process from surface waters to bottom waters, and \( V_{na} = 0 \) means little change in waters.

3. Case study

**Study area and data collection.** Jiaozhou Bay (120°04′-120°23′ East, 35°55′-36°18′ North) is located in Shandong Province, eastern China (Fig. 2). It is a semi-closed bay with the total area, average water depth and bay mouth width of 446 km², 7 m and 3 km, respectively. There are more than ten inflow rivers such as Haibo River, Licun River, Dagu River, and Loushan River [12-13]. The data was provided by North China Sea Environmental Monitoring Center. The survey on Pb was conducted in May, July and November 1987. Surface and bottom water samples in three stations (i.e. 2031, 2032 and 2033) were collected and measured followed by National Specification for Marine Monitoring [9].

![Fig.2 Geographic location and monitoring sites in Jiaozhou Bay](image-url)

**Calculation results of horizontal and vertical changes of Pb.** Jiaozhou Bay (120°04′-120°23′ East, 35°55′-36°18′ North) is located in the south of Shandong Province, eastern China. In accordance to the geographic location and monitoring sites (Fig. 2), Sites of 2033, 2032 and 2031 are located in the inner side, middle and outside of the bay mouth, respectively (Fig. 1). By means of the calculating formulas (i.e., Eq. (1) to Eq. (4)), the horizontal absolute and relative loss amounts of Pb in surface and bottom waters in Jiaozhou Bay in 1987 were calculated in listed in Table 1 and Table 2, respectively. By means of the calculating formulas of Eq. (5), the horizontal changes of Pb in waters in Jiaozhou Bay in 1987 were calculated in listed in Table 3. It could be seen from Table 1 and Table 2 that, in May, July and November 1987, the horizontal absolute loss amounts of Pb contents in surface and bottom waters were 0.06 to 20.66 µg L⁻¹, and the horizontal relative loss amounts of Pb contents were 2.30 to 83.84%, respectively. It could be seen from Table 3 that, the vertical accumulation amounts of Pb contents were 0.00 to 8.61 µg L⁻¹, and the vertical accumulation amounts were 0.00 to
68.38%. Meanwhile, the vertical dilution amounts of Pb contents were 0.00 to 13.56 μg L⁻¹, and the vertical dilution amounts were 0.00 to 55.03%. The horizontal changes of substance’s contents revealed the horizontal loss effect, while the vertical changes of substance’s contents revealed the dilution effect and accumulation effects.

Table 1 Horizontal absolute loss amount and horizontal relative loss amount of Pb in surface waters in Jiaozhou Bay 1987

| Direction      | Month | D/μg L⁻¹ | E/%   |
|----------------|-------|----------|-------|
| From A to B    | May   | -0.65    | 25.00%|
|                | July  |          |       |
|                | November | 20.66 | 83.84%|
| Direction      | Month | F/μg L⁻¹ | G/%   |
| From C to B    | May   | -0.42    | 13.90%|
|                | July  | 3.26     | 14.80%|
|                | November | -11.20 | 73.78%|

Table 2 Horizontal absolute loss amount and horizontal relative loss amount of Pb in bottom waters in Jiaozhou Bay 1987

| Direction      | Month | F/μg L⁻¹ | G/%   |
|----------------|-------|----------|-------|
| From A to B    | May   | -0.73    | 28.07%|
|                | July  |          |       |
|                | November | -1.51 | 11.99%|
| Direction      | Month | F/μg L⁻¹ | G/%   |
| From C to B    | May   | -0.06    | 2.30% |
|                | July  | 4.57     | 23.22%|
|                | November | 2.59 | 17.06%|

Table 3 Horizontal changes of Pb in waters in Jiaozhou Bay in 1987

| Month | Location    | Vna/μg L⁻¹ | Vnr   |
|-------|-------------|------------|-------|
| May   | Outer side  | 0.08       | 4.10% |
|       | Middle      | 0.00       | 0.00% |
|       | Inner side  | 0.48       | 15.89%|
| June  | Outer side  | 6.91       | 31.38%|
|       | Middle      | -8.61      | 68.38%|
|       | Inner side  | 0.00       | 0.00% |
| November | Outer side  | 13.56      | 55.03%|
|       | Middle      | -8.61      | 68.38%|
|       | Inner side  | 0.00       | 0.00% |

Yang’s marine bay filtration phenomenon. By means of water’s effect (i.e., horizontal water’s effect and vertical water’s effect), substance’s contents were changing along with the transporting process [11-13]. In according to the horizontal loss amounts (Table 1 and Table 2), it could be found that from the outer side of the bay mouth to the middle of the bay mouth, that was from the transporting process of from the open waters to the insider of the bay, the horizontal relative loss amounts of Pb could be as high as 83.84%. Meanwhile, from the inner side of the bay mouth to the middle of the bay mouth, that was from the transporting process of from the insider of the bay to the open waters, the horizontal relative loss amounts of Pb could be as high as 73.78%. The bay mouth was playing a role of a filter, and a big part of Pb contents were filtering by the bay mouth. This phenomenon determined by the special geographic and geomorphic conditions of the bay, was named as Yang’s marine bay filtration phenomenon. This phenomenon further revealed that, in waters outside of the bay mouth, the vertical relative dilution amount of Pb could be as high as 55.03%. It was indicated that a big part of Pb was diluting due to the torrential marine current in the bay mouth, which
was resulting in high sedimentation rate of Pb in the bay mouth. Hence, Pb contents were difficult to be transported from the open waters to the bay, and were difficult to be transported from the bay to the open waters.

4. Conclusions
Definition and formula for horizontal and vertical changes of substance’s contents were established, and a case study on Pb contents in Jiaozhou Bay were provided in this paper. The horizontal absolute loss amounts of Pb contents in surface and bottom waters in Jiaozhou Bay were 0.06 to 20.66 μg L⁻¹, and the horizontal relative loss amounts were 2.30 to 83.84%, respectively. The vertical accumulation amounts of Pb contents were 0.00 to 8.61 μg L⁻¹, and the vertical accumulation amounts were 0.00 to 68.38%. Meanwhile, the vertical dilution amounts of Pb contents were 0.00 to 13.56 μg L⁻¹, and the vertical dilution amounts were 0.00 to 55.03%. The bay mouth was playing a role of a filter, and a big part of Pb contents were filtering by the bay mouth. This phenomenon determined by the special geographic and geomorphic conditions of the bay, was named as Yang’s marine bay filtration phenomenon. In general, Pb contents were difficult to be transported from the open waters to the bay, and were difficult to be transported from the bay to the open waters.

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