Yang’s Marine Bay Phenomenon for Cr

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Abstract. Taking chromium (Cr) in waters in Jiaozhou Bay in August 1981 as an example, this paper analyzed the horizontal and vertical loss processes of Cr, as well as the vertical dilution. Results showed that from waters in the outer side of the bay mouth to the bay mouth, the absolute loss amount in surface and bottom waters, the relative loss amount in surface and bottom waters were very low as 0.00 μg L⁻¹ and 0.08 μg L⁻¹, 0.00% and 19.51%, respectively. From waters in the bay mouth to the inner side of the bay mouth, the absolute loss amount in surface and bottom waters, the relative loss amount in surface and bottom waters, and the vertical dilution amount were very low as 0.24 μg L⁻¹ and 0.19 μg L⁻¹, 57.14% and 57.57%, respectively. In waters from the outer side of the bay mouth to the bay mouth, there was little settlement, yet in waters from the bay mouth to the inner side of the bay mouth, there were rapid settlement processes and the settlement amounts were more than 50%. The marine bay is playing a role of a crock, and the bay mouth is the mouth of the crock. Once the substances have been entering the crock, the settlement processes would be very rapid. This is Yang’s Marine Bay Phenomenon.

1. Introduction
Many marine bays have been polluted along with the rapid development of industry and economic in the past several decades [1-3]. By means of horizontal and vertical water’s effects, pollutant contents were changing continuously during the horizontal and vertical migration processes[3-6]. Understanding the horizontal and vertical loss processes of pollutants in marine waters is essential to environmental protection and remediation. By taking Cr in Jiaozhou Bay as an example, this paper provided horizontal and vertical loss modeling methods on matter content in marine bay. Furthermore, this paper provided Yang’s Marine Bay Phenomenon for substance contents in marine bay waters. The research results revealed the horizontal and vertical loss during the process in marine bay, and provided scientific basis for research on the migration process of pollutants in marine bay.

2. Materials and method
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 (Fig. 1). 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 Rriver, Licun Rriver, and Loushan Rriver etc., all of which are seasonal rivers [7-8]. Dataset on Cr in Jiaozhou Bay was provided by North China Sea Environmental Monitoring Center. The investigations were carried on in August 1981 in 30 sampling sites (Fig. 1). Cr in waters was monitored follow by National Specification for Marine Monitoring [9].

![Fig. 1 Geographic location and sampling sites of Jiaozhou Bay](image)

**Modeling for horizontal loss in surface waters.** The contents of the substances in waters in marine bays were changing continuously water exchange between the open waters and the internal waters in the bay [5-6]. Supposed that substance contents in surface and bottom waters in the outer side of bay center are \( A \) and \( a \), in the bay mouth are \( B \) and \( b \), and in the inner side of bay mouth are \( C \) and \( c \), respectively.

In surface waters, and from the bay mouth to the outside of the bay mouth, the calculation formula for migration process is:

\[
D = A - B, \quad E = \left(100 \times \frac{|A - B|}{\max(A, B)}\right)\%
\]

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

In surface waters, and from the bay mouth to the inside of the bay mouth, the calculation formula for migration process is:

\[
F = B - C, \quad G = \left(100 \times \frac{|B - C|}{\max(B, C)}\right)\%
\]

where, \( F \) is the horizontal absolute loss amount in surface waters, \( G \) is the horizontal relative loss amount.

**Modeling for horizontal loss in bottom waters.** In bottom waters, and from the bay mouth to the outside of the bay mouth, the calculation formula for migration process is:

\[
d = a - b, \quad e = \left(100 \times \frac{|a - b|}{\max(a, b)}\right)\%
\]

where, \( d \) is the horizontal absolute loss amount in surface waters, \( E \) is the horizontal relative loss amount.
amount.
In bottom waters, and from the bay mouth to the inside of the bay mouth, the calculation formula for migration process is:
\[ f = b - c, \quad g = (100 \times \frac{|b - d|}{\max(b, c)})\% \]  
(4)
where, \( f \) is the horizontal absolute loss amount in surface waters, \( g \) is the horizontal relative loss amount.

Modeling for vertical loss in waters. Supposed that substance contents in surface and bottom waters in Site \( n \) in the bay center are \( A \) and \( a \), respectively. From surface waters to bottom waters, the calculation formula for this migration process is:
\[ V_{na} = A - a, \quad V_{nr} = (100 \times \frac{|A - a|}{\max(A, a)})\% \]  
(5)
where, \( V_{na} \) is the horizontal absolute dilution amount from surface waters to bottom waters, \( V_{nr} \) is the 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 horizontal relative accumulation amount.

3. Results
Horizontal loss of Cr. The horizontal migration process of Cr in surface waters in Jiaozhou Bay were calculated in according to Cr contents in Site A1 in the outer side of the bay mouth and Site A5 in the bay mouth. The horizontal migration process of Cr in bottom waters in Jiaozhou Bay were calculated in according to Cr contents in Site A5 in the bay mouth and Site A8 in the inner side of bay mouth. The horizontal losses of Cr in surface and bottom waters were calculated and listed in Table 1.

| Direction         | Surface waters | Bottom waters |
|-------------------|---------------|--------------|
| Site A5 to A1     | \( D / \mu g L^{-1} \) | \( E /\% \) | \( d / \mu g L^{-1} \) | \( e /\% \) |
| Horizontal loss   | 0.00          | 0.00         | 0.18          | 19.51      |
| Site A1 to A5     | \( F / \mu g L^{-1} \) | \( G /\% \) | \( f / \mu g L^{-1} \) | \( g /\% \) |
| Horizontal loss   | 0.24          | 57.14        | 0.19          | 57.57      |

Vertical loss of Cr. The vertical migration process of Cr in waters in Jiaozhou Bay were calculated in according to Cr contents in Site A1 in the outer side of the bay mouth, and Site A5 in the bay mouth, and Site A8 in the inner side of the bay mouth, respectively. The horizontal losses of Cr in surface and bottom waters were calculated and listed in Table 2.

| Site  | \( V_{na} / \mu g L^{-1} \) | \( V_{nr} /\% \) |
|-------|-----------------|-----------------|
| A1    | 0.01            | 2.38            |
| A5    | 0.09            | 21.42           |
| A8    | 0.04            | 22.22           |

4. Discussion
Vertical and horizontal loss of Cr. The vertical and horizontal loss during migration process of substances in marine bay were determined by source input and vertical and horizontal water’s effect [10-14]. From the outer side of the bay mouth to the bay mouth, the horizontal absolute and relative loss amounts of Cr in surface waters were 0.00 \( \mu g L^{-1} \) and 0.00\%, while from the bay mouth to the inner side of the bay mouth were 0.24 \( \mu g L^{-1} \) and 57.14\%, respectively (Table 1). It could be found that the settlement of Cr in surface waters in the open waters were little, yet in surface waters in waters inside the bay were huge (Fig. 2). From the outer side of the bay mouth to the bay mouth, the
horizontal absolute and relative loss amounts of Cr in bottom waters were 0.08 μg L^{-1} and 19.51%, while from the bay mouth to the inner side of the bay mouth were 0.19 μg L^{-1} and 57.57%, respectively (Table 1). It could be found that the settlement of Cr in bottom waters in the open waters were little, yet in bottom waters in waters inside the bay were huge (Fig. 2). However, by means of tide and marine current, there was little accumulation of Cr in the outer side of the bay mouth, bay mouth and the inner side of the bay mouth. Meanwhile, the vertical dilution amount of Cr in the outer side of the bay mouth was as low as 2.38%, while in the bay mouth and the inner side of the bay mouth was relative high as 21.42%-22.22% (Fig. 2). The fact indicated that there was little settlement of Cr in waters in the outer side of the bay mouth, yet the settlement was enhancing once Cr was transporting from the open waters to the inside of the bay. In general, the vertical losses of Cr in different location were different since the hydrogeologic environment and hydrodynamic conditions were different.

**Fig. 2 Block diagram model for horizontal-vertical loss of Cr in August 1981 in Jiaozhou Bay**

**Yang’s Marine Bay Phenomenon.** In according to the vertical and horizontal loss of Cr in Jiaozhou Bay, it could be found that from waters in the outer side of the bay mouth to the bay mouth, the absolute loss amount in surface and bottom waters, the relative loss amount in surface and bottom waters were very low as 0.00 μg L^{-1} and 0.08 μg L^{-1}, 0.00% and 19.51%, respectively. However, from waters in the bay mouth to the inner side of the bay mouth, the absolute loss amount in surface and bottom waters, the relative loss amount in surface and bottom waters, the vertical dilution amount were very low as 0.24 μg L^{-1} and 0.19 μg L^{-1}, 57.14% and 57.57%, respectively. Furthermore, the vertical dilution in waters in the outer side of the bay mouth was as low as 2.38%, compared to 21.42%-22.22% in waters in the inner side of the bay mouth. In general, in waters from the outer side of the bay mouth to the bay mouth, there was little settlement. However, in waters from the bay mouth to the inner side of the bay mouth, there were rapid settlement processes and the settlement amounts were more than 50%. The marine bay is playing a role of a crock, and the bay mouth is the mouth of the crock. Once the substances have been entering the crock, the settlement processes would be very rapid. This is Yang’s Marine Bay Phenomenon.

5. Conclusions

From waters in the outer side of the bay mouth to the bay mouth, the absolute loss amount in surface and bottom waters, the relative loss amount in surface and bottom waters were very low as 0.00 μg L^{-1} and 0.08 μg L^{-1}, 0.00% and 19.51%, respectively. From waters in the bay mouth to the inner side of the bay mouth, the absolute loss amount in surface and bottom waters, the relative loss amount in surface and bottom waters, the vertical dilution amount were very low as 0.24 μg L^{-1} and 0.19 μg L^{-1}, 57.14% and 57.57%, respectively.

In waters from the outer side of the bay mouth to the bay mouth, there was little settlement, yet in waters from the bay mouth to the inner side of the bay mouth, there were rapid settlement processes
and the settlement amounts were more than 50%. The marine bay is playing a role of a crock, and the bay mouth is the mouth of the crock. Once the substances have been entering the crock, the settlement processes would be very rapid. This is Yang’s Marine Bay Phenomenon.

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