The Transport Process of PHC Content at Sea

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Abstract: According to the investigation data of Jiaozhou Bay in May, August and October of 1991, the transport process of PHC content of oil spill in Jiaozhou Bay was studied in this paper. In May, the point 2016 in eastern bay was the source point of oil spill, with PHC content of 0.157 mg/L, forming a series of concentric circles with different gradients. PHC content decreased from 0.157 mg/L in the center to 0.015 mg/L in bay center, 0.025 mg/L in northwestern bay, 0.042 mg/L in northeastern bay, and 0.024 mg/L in southeastern bay. Based on the horizontal absolute loss speed model of matter content, the horizontal absolute loss speed of PHC content at surface was 2.00 ydfr from eastern bay center to bay center, 1.94 ydfr in northwestern bay, 2.76 ydfr in northeastern bay and 4.95 ydfr in southeastern bay. Whereas, based on the horizontal relative loss speed model of matter content, it was 12.78 ydfr, 12.35 ydfr, 17.63 ydfr and 31.53 ydfr, respectively. Therefore, taking the central point 2016 as the source point of oil spill, its PHC content decreased to the periphery, and its horizontal absolute and relative loss speed was 1.94-4.95 ydfr and 12.35-31.53 ydfr, respectively. It was in the order of northwestern bay, bay center and northeastern bay and southeastern bay from low to high. According to the horizontal loss speed model of Yang Dongfang matter content, the transport process of PHC content decreasing to the periphery along with the gradients could be calculated in a quantitative way.

1. Introduction
In Jiaozhou Bay, oil spill frequently occurs by a large number of ships in oil storage bases. Then, PHC, formed the high-content area in the source point of oil spill and decreased to the periphery. In this way, PHC content could be transported to the entire bay [1-11]. In this paper, according to the investigation data of Jiaozhou Bay in 1991, the PHC content, horizontal distribution and source were analyzed, the water quality, source and source amount of PHC were studied, and source and pollution of PHC were determined, to provide scientific theoretical reference for protecting marine environment and maintaining the sustainable development of the ecology.

2. Investigation Waters, Materials and Methods
2.1 Natural environment of Jiaozhou Bay
Jiaozhou Bay, located in southern Shandong Peninsula, is a typical semi-closed bay. The geographical location is 120°04′-120°23′E, 35°58′-36°18′N. Bounded by the line connecting Tuandao Cape and Xuejiadao Island, it connects with Yellow Sea, covering an area of about 446km², with the average depth of about 7m. There are dozens of rivers reaching the ocean in Jiaozhou Bay, among of which, the rivers with a larger volume of runoff and sand content include Dagu River, Yang River, Haibo River in Qingdao, Licun River, Loushan River and so on. These rivers are seasonal streams, and hydrological
characteristics vary seasonally [12, 13].

2.2 Materials and methods
The materials about Cd in Jiaozhou Bay waters in May, August and October of 1991 was provided by North China Sea Environment Monitoring Center, State Oceanic Administration. 13 sites were established for sampling in Jiaozhou Bay: 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 2104, 2105 and 2106, shown in Figure 1. Samplings were performed for three times in May and August in 1990, respectively. According to the depth of water, sampling and survey were conducted (surface and bottom layers were sampled when the depth of water is more than 10m, but just surface layer when less than 10m). The survey on Cd of Jiaozhou Bay waters was in accordance with national standard method, which was included in The Specification for Marine Monitoring (1991) [14].

3. Results

3.1 The source
In May, PHC content reached 0.157mg/L in site 2016 in eastern center, forming a series of concentric circles with different gradients there. It decreased from the center to 0.015mg/L in bay center, 0.025mg/L in northwestern bay, 0.042mg/L in northeastern bay and 0.024mg/L in southeastern bay, shown in Figure 2. PHC content was high in eastern bay center, indicating that it was transported by oil spill. Further, whether the horizontal loss amount of the transport of same PHC contents in different directions were consistent were studied.
3.2 The distance between central site to surrounding sites

In May, in central waters of eastern bay, taking site 2016 as the center, site 55 was in bay center, 57 in northwestern bay, 2015 in northeastern bay and 59 in southeastern bay, and PHC contents were obtained in these five sites, shown in Figure 3.

| Site  | Longitude  | Latitude  | PHC content (mg/L) |
|-------|------------|-----------|--------------------|
| 2016  | 120°19′ 0" | 36°08′0"  | 0.157              |
| 55    | 120°15′18" | 36°07′06" | 0.015              |
| 57    | 120°16′ 0" | 36°10′06" | 0.025              |
| 2015  | 120°20′ 0" | 36°10′0"  | 0.042              |
| 59    | 120°19′12" | 36°06′42" | 0.024              |

Supposed the distance between site 2016 to site 55 is L₁, according to 1°=1858m, so it can be calculated by Equation (1).
\[ L_1^2 = [(18-15+60/60-18/60) \times 1858]^2 + [(7-7+60/60-6/60) \times 1858]^2 \]

\[ L_1 = 3.80 \times 1858 = 7075.05 \text{ (m)} \]  

Supposed the distance between site 2016 to site 57 is \( L_2 \), according to \( 1' = 1858 \text{ m} \), so it can be calculated by Equation (2).

\[ L_2^2 = [(19-16+0/60-0/60) \times 1858]^2 + [(8-10+0/60-6/60) \times 1858]^2 \]

\[ L_2 = 3.66 \times 1858 = 6803.93 \text{ (m)} \]  

Supposed the distance between site 2016 to site 2015 is \( L_3 \), according to \( 1' = 1858 \text{ m} \), so it can be calculated by Equation (3).

\[ L_3^2 = [(19-20+0/60-0/60) \times 1858]^2 + [(8-10+0/60-0/60) \times 1858]^2 \]

\[ L_3 = 2.23 \times 1858 = 4154.61 \text{ (m)} \]  

Supposed the distance between site 2016 to site 59 is \( L_4 \), according to \( 1' = 1858 \text{ m} \), so it can be calculated by Equation (4).

\[ L_4^2 = [(19-19+0/60-12/60) \times 1858]^2 + [(8-6+0/60-42/60) \times 1858]^2 \]

\[ L_4 = 1.44 \times 1858 = 2686.07 \text{ (m)} \]  

### 3.3 The horizontal loss speed model of Yang Dongfang matter content

The model proposed by the author includes the absolute and relative loss speed model.

Supposed that matter content at surface layer decrease from a in A point to b in B point, the distance between A to B is \( L \), and the horizontal absolute loss speed is \( V_{asp} \), so the absolute one model was \( V_{asp} = (a-b)/L \). Suppose the relative loss speed is \( V_{rsp} \), so the relative one model was \( V_{rsp} = [(a-b)/a]/L = (a-b)/a \ L \).

Spatially, this model displayed the absolute loss amount and relative loss amount of unit distance in the transport of matter content in horizontal plane.

### 3.4 The simplification of unit

The units of absolute and relative loss speed were complicated, thus, it was necessary to simplify the units. \( \times 10^{-5} \text{(mg/L)/m} \) was called Yang Dongfang number, simplified as ydf.

For instance, the absolute loss speed of \( V_{asp} = 30.84 \times 10^{-5} \text{(mg/L)/m} \) could be called as 30.84 ydf, and the relative one of \( V_{rsp} = 7.78 \times 10^{-5} \text{(mg/L)/m} \) could be called as 7.78 ydfr.

Then, in any waters, the unit of horizontal loss amount of any matter content could be calculated by ydfa and ydfr.

### 3.5 The horizontal loss speed from eastern center to bay center

In May, PHC content reached 0.157 mg/L in site 2016 in eastern center, indicating that it was transported by oil spill. It decreased to 0.025 mg/L in site 57 in northwestern bay.

According to the model proposed, the absolute and relative loss speed of PHC content were calculated as \( V_{asp} = (0.157-0.025)/6803.93 = 1.94 \times 10^{-5} \text{(mg/L)/m} \) and \( V_{rsp} = 12.35 \times 10^{-5} \text{(mg/L)/m} \) respectively.

Hence, in northwestern bay, the absolute loss speed was 1.94 ydf and relative loss speed was 12.35 ydfr from site 2016 to 57.

### 3.6 The horizontal loss speed from eastern center to northeastern bay

In May, PHC content reached 0.157 mg/L in site 2016 in eastern center, indicating that it was transported by oil spill. It decreased to 0.042 mg/L in site 2105 in northeastern bay.

According to the model proposed, the absolute and relative loss speed of PHC content were calculated as \( V_{asp} = (0.157-0.042)/4154.61 = 2.76 \times 10^{-5} \text{(mg/L)/m} \) and \( V_{rsp} = 17.63 \times 10^{-5} \text{(mg/L)/m} \) respectively.
Hence, in northeastern bay, the absolute loss speed was 2.76 yd fa and relative loss speed was 17.63 ydfr from site 2016 to 2015.

3.7 The horizontal loss speed from eastern center to southeastern bay
In May, PHC content reached 0.157mg/L in site 2016 in eastern center, indicating that it was transported by oil spill. It decreased to 0.024 mg/L in site 59 in northeastern bay.

According to the model proposed, the absolute and relative loss speed of PHC content were calculated as \( V_{asp} = \frac{(0.157-0.024)}{2686.07} = \frac{4.95\times10^{-5}(mg/L)}{m} = 4.95 \text{ yd/fa} \) and \( V_{rsp} = \frac{12.78\times10^{-5}(mg/L)}{m} = 31.53 \text{ yd/fr} \), respectively.

Hence, in northeastern bay, the absolute loss speed was 4.95 yd/fa and relative loss speed was 31.53 yd/fr from site 2016 to 2015.

4. Discussion

4.1 The variation of horizontal content from the same source
In May, PHC content reached 0.157mg/L in site 2016 in eastern center, forming a series of concentric circles with different gradients there. It decreased from the center to 0.015mg/L in bay center, 0.025mg/L in northwestern bay, 0.042mg/L in northeastern bay and 0.024mg/L in southeastern bay, shown in Figure 2.

Based on the horizontal absolute loss speed model of matter content, the horizontal absolute loss speed of PHC content at surface was 2.00 yd/fa from eastern bay center to bay center, 1.94 yd/fa in northwestern bay, 2.76 yd/fa in northeastern bay and 4.95 yd/fa in southeastern bay. Whereas, based on the horizontal relative loss speed model of matter content, it was 12.78 yd/fr, 12.35 yd/fr, 17.63 yd/fr and 31.53 yd/fr, respectively. Therefore, taking the central point 2016 as the source point of oil spill, its PHC content decreased to the periphery, and its horizontal absolute and relative loss speed was 1.94-4.95 yd/fa and 12.35-31.53 yd/fr, respectively. The results are shown in Table 2.

4.2 The characteristics of PHC content values from the same source
In the same period, from the same starting point to different ending points, PHC contents were same in the starting point, and the absolute loss amounts in unit distance were different. In May, in eastern Jiaozhou Bay, from eastern center to northwestern bay, the absolute loss value of 1.94 yd/fa was the lowest, indicating that there was no influence and disturbance from PHC content, and the absolute loss speed pf PHC was the lowest. Whereas, from eastern center to southeastern bay, the absolute loss value of 4.95 yd/fa was the highest, indicating that there was great influence and disturbance from the input of Haibo River, and the absolute loss speed of PHC was the highest.

The absolute loss speed of PHC content was in the order of northwestern bay, bay center and northeastern bay and southeastern bay from low to high, and the relative loss speed of PHC content was in the same order, which was inconsistent with the order of PHC content: bay center<southeastern bay<northern bay=northeastern bay from low to high.
A series of concentric circles with different gradients were formed in eastern center as the source point of oil spill with the content of 0.157mg/L. PHC content decreased to the periphery, and the order was bay center<southeastern bay<northwestern bay<northeastern bay from low to high, inconsistent with the absolute and relative loss speed. PHC content displayed the value from the same point of oil spill to the waters, and the absolute and relative loss speed described the process value from the same point of oil spill to the waters.

4.3 The transport process in a quantitative way
A series of concentric circles with different gradients were formed in eastern center as the source point of oil spill with the content of 0.157mg/L. PHC content decreased to bay center, northwestern bay, northeastern bay and southeastern bay, with a variation range of 0.015-0.157 mg/L. Its horizontal absolute and relative loss speed was 1.94-4.95 yd/da and 12.35-31.53 yd/dr, respectively. The high value indicated the influence of river flow, however, low value showed that there was no influence from any source. Thus, according to horizontal loss speed model of Yang Dongfang matter content, the transport process of PHC content decreasing to the periphery along with the gradients could be calculated in a quantitative way.

5. Conclusion
In May, PHC content reached 0.157mg/L in site 2016 in eastern center, forming a series of concentric circles with different gradients there. It decreased from the center to 0.015mg/L in bay center, 0.025mg/L in northwestern bay, 0.042mg/L in northeastern bay and 0.024mg/L in southeastern bay, shown in Figure 2.

Based on the horizontal absolute loss speed model of matter content, the horizontal absolute loss speed of PHC content at surface was 2.00 yd/da from eastern bay center to bay center, 1.94 yd/da in northwestern bay, 2.76 yd/da in northeastern bay and 4.95 yd/da in southeastern bay. Whereas, based on the horizontal relative loss speed model of matter content, it was 12.78 yd/dr, 12.35 yd/dr, 17.63 yd/dr and 31.53 yd/dr, respectively. Therefore, taking the central point 2016 as the source point of oil spill, its PHC content decreased to the periphery, and its horizontal absolute and relative loss speed was 1.94-4.95 yd/da and 12.35-31.53 yd/dr, respectively.

A series of concentric circles with different gradients were formed in eastern center as the source point of oil spill with the content of 0.157mg/L. PHC content decreased to the periphery, and the order was bay center<southeastern bay<northwestern bay<northeastern bay from low to high, inconsistent with the absolute and relative loss speed. PHC content displayed the value from the same point of oil spill to the waters, and the absolute and relative loss speed described the process value from the same point of oil spill to the waters.

Therefore, according to horizontal loss speed model of Yang Dongfang matter content, the transport process of PHC content decreasing to the periphery along with the gradients could be calculated in a quantitative way.

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