Analysis of Marine environmental impact of shipping bulk liquid chemical spills

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Abstract. This paper analyzes the current transportation status and problems of bulk liquid chemicals in China, and analyzes the impact of typical chemical leakage in Yangkou port on Marine environment. The movement trajectory of Insoluble liquid bulk cargo is greatly affected by meteorological conditions and Marine hydrological conditions after they leak into the sea. The location, tidal period and amount of leakage are the main influencing factors for the difference of environmental risks of chemical leakage.

1. Introduction

More than 30,000 chemicals are currently registered with the International Maritime Organization (IMO). The Group of Marine Pollution Scientists (GESAMP) had identified more than 1400 species by 1990, and the 1992 amendment to Marpol73/78 Annex II identified 596 species that could be transported by bulk chemical vessels at sea, and more than 200 species that are regularly transported by sea[1]. The hazardous characteristics of liquid chemicals include easy combustion, large explosion range, strong reactivity, high toxicity, strong corrosiveness and pollution [2]. The harmfulness of liquid chemicals leakage into the sea to Marine pollution is mainly reflected in the following aspects: bioaccumulation, harm to seafood or human health, harm to biological resources, harm to human health, and the decrease of entertainment value.

As the throughput of bulk liquid chemicals increases, the number of ships loading and unloading increases, and the time of ships in port increases, China's maritime bulk chemical transportation has exposed many serious problems [3]. Bulk chemical species bother much, its physical and chemical properties are different, in view of the liquid chemical pollution diffusion motion forms of different classified: 1. oil and oil chemicals on the surface of the main transport and diffusion in the form of 2 d, 2. easy to melt XuePin in water transport diffusion in three-dimensional form, 3. strong volatile chemicals in the air transport and diffusion of the steam produced, 4. sedimentation type of chemical sedimentation on the bottom to the Marine sediments and the effect of five, the comprehensive chemical - react with air and water[4]. Duarte analyzed the relationship between Marine biodiversity and ecosystem services [5]. Holmlund analyzed the changes in the value of five species of fish released in the waters of the Stockholm Archipelago in the Atlantic Ocean [6]. Xu Congchun et al. discussed the framework system for estimating the service value of Marine ecosystem [7]. Wang Yonghua et al. studied the value of
ecosystem service restoration in Hainan Xincun Bay by questionnaire [8]. At present, the existing research results are lack of recognized and convincing research results. This study mainly studies the damage caused by undissolved chemicals to the Marine environment and ecology.

2. Materials and Methods

2.1. Calculation equation of the insoluble matter
The two-dimensional numerical model MIKE21FM developed by the Danish Institute of Hydraulics was used for the prediction and analysis. The model by adopting the calculation domain, unstructured triangular mesh triangular mesh can better fitting land border, the grid design flexible and can control mesh density at will, the software algorithm is reliable, stable, friendly interface, calculation before and after processing advantages such as powerful function, has been applied in more than 70 countries, hundreds of cases of successful examples, calculation result is reliable, is recognized by the international. The MIKE21FM adopts the standard Galerkin finite element method for horizontal space discretization. In terms of time, the momentum equation and the transport equation are discretized by an explicit upwind difference scheme.

(1) Model governing equation

Mass conservation equation:
\[ \frac{\partial \zeta}{\partial t} + \frac{\partial}{\partial x}(\zeta u) + \frac{\partial}{\partial y}(\zeta v) = 0 \]

Momentum equation:
\[ \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} - \frac{\partial}{\partial x}(\zeta \frac{\partial u}{\partial x}) - \frac{\partial}{\partial y}(\zeta \frac{\partial u}{\partial y}) - f v + g \frac{\nabla u \cdot \nabla v}{C^2} H = -g \frac{\partial \zeta}{\partial x} \]
\[ \frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} - \frac{\partial}{\partial x}(\zeta \frac{\partial v}{\partial x}) - \frac{\partial}{\partial y}(\zeta \frac{\partial v}{\partial y}) + f u + g \frac{\nabla u \cdot \nabla v}{C^2} H = -g \frac{\partial \zeta}{\partial y} \]

Where: \( \zeta \) —— water level,
\( h \) —— static depth,
\( H \) —— total water depth, \( H = h + \zeta \),
\( u, v \) —— the average vertical velocity in X and Y directions, respectively,
\( g \) —— acceleration of gravity,
\( f \) —— Coriolis force parameter \( f = 2 \omega \sin \varphi \) \( \varphi \) is to calculate the geographical latitude of the sea area,
\( CZ \) —— Xie Cai coefficient, \( n \) is Manning coefficient,
\( \epsilon_x, \epsilon_y \) —— Is the viscosity coefficient of horizontal vortex in x and y directions.

(2) Determinate solution conditions
\[ \zeta(x, y, t) \big|_{t=0} = \zeta(x, y, t_0) = 0 \]
\[ u(x, y, t) \big|_{t=0} = v(x, y, t) \big|_{t=0} = 0 \]

2.2. Ship Leakage Source Analysis

According to the Technical Code for Risk Assessment of Marine Environmental Pollution from Ships (Trial), the oil overflow of the most likely shipwreck accident, the maximum oil overflow and the worst case oil overflow are predicted by the main ship type and the largest ship type respectively.

The oil overflow of the most likely shipwreck accident is mainly predicted according to the oil load of the main ship type, and the oil overflow of the most likely shipwreck pollution accident is predicted according to the oil leakage of one or two oil tanks. The maximum oil overflow of the most likely shipwreck accident is predicted according to the maximum oil carrying capacity of the ship type and the total oil leakage of one or two oil tanks or oil tanks; The worst-case oil spill is predicted based on the maximum oil load of the ship type and the total loss of cargo oil or fuel.
For chemicals, transport mainly for 5000 - ton ship, this according to the environmental risk assessment technical guideline of the construction projects and the water environment of oil spill risk assessment technical guideline (JT/T 1143-2017), "TABLE c. 1 products tanker freight rate statistics, 3000 ~ 5000 tonnage single cargo oil amount is 255 ~ 531 m³, real load rate is calculated at 90%, a side tank leakage in all less than 478 m³.

2.3. Leakage condition determination
According to the cargo types in Yangkou Port and water quality standards, this paper selects phenol as the representative undissolved substance for calculation. The calculation conditions and the location of leakage points are listed in Table 1.

According to surrounding environment sensitive target, in this project are surrounding the status quo of culture zones, southeast to cold sand important fishing area, the west for some coastal wetlands, the north for some greater respectively antiquata national aquatic germ plasm resources, therefore the forecast analysis of adverse selection of wind speed is based on a chemical leak location selection and leak current moment, finally choose the combination of the most unfavorable conditions, as shown in table 1, adverse wind speed for a maximum of five wind, about 10.7 m/s. The wind direction was combined with the different locations of the predicted points and the target distribution of protection (west breeding, south breeding and north germplasm resources protection zone). The combination of east wind, north wind and south wind combined with the combination of ebb and flow tide was respectively selected for prediction.

Table.1 Calculation conditions and the location of leakage points.

| Location of leakage points | The tide | The wind speed(m/s) | Sweep the sea area(km²) |
|---------------------------|---------|---------------------|------------------------|
| Wharf apron               |         |                     |                        |
| The summer wind often     |         |                     |                        |
| At high tide              | 3.8     |                     | 306.8                  |
| Ebb tide                  | 3.8     |                     | 316.4                  |
| The winter wind often     |         |                     |                        |
| At high tide              | 3.8     |                     | 268.2                  |
| Ebb tide                  | 3.8     |                     | 298.4                  |
| Adverse wind              |         |                     |                        |
| At high tide              | 10.7    |                     | 330.1                  |
| Ebb tide                  | 10.7    |                     | 59.9                   |

3. Results & Discussion

3.1. Results
In the prediction, the drift and diffusion of the chemical leakage along with the water flow are analyzed, and the results are listed in Table 2.

Table.2 The affected area and the maximum diffusion distance of phenol leakage.

| Location of leakage points | The tide | Maximum drift distance (km) | The direction of the wind |
|---------------------------|---------|-----------------------------|--------------------------|
| Wharf apron               |         |                             |                          |
| The summer wind often     |         |                             |                          |
| At high tide              | 38.6    | southeast                   |                          |
| Ebb tide                  | 25.1    | southeast                   |                          |
### Chemical diffusion results under constant monsoon in summer

Figure 1~2 shows the influence of chemicals on the water environment under the condition of constant wind in summer after leakage at the wharf front. The influence on the water environment in summer under the condition of constant wind. As can be seen from the chart, the oil film at the beginning of the flood will drift to the current breeding area on the west side 4.5 hours after the spill, and will have a direct impact on important coastal wetlands in the eastern part of the country 5 hours later. Within 72 hours of the spill, the maximum area swept by insoluble products is 306.8km², and the farthest distance from the leakage point is 38.6km. At the beginning of ebb tide, the chemicals mainly drift to the eastern sea, and it will affect the water quality of important fishing areas in the north, such as Dongta Zhonacula Xishaigao National Aquatic Germplasm Resources Reserve and Lanshayang North Water Channel, only 50 hours after the leakage.

|                         | At high tide |          |          |
|-------------------------|--------------|----------|----------|
| The winter wind often   | 22.7         | northwest|
|                         | 41.5         | northwest|
| Adverse wind, south wind| 54.9         |          |
| Adverse wind, east wind | 36.2         |          |
| Adverse wind, northeast wind | Ebb tide | 22.1      |
3.3. Chemical diffusion results under constant monsoon in Winter

Figure 3-4 show the influence of insoluble substances on water environment in winter under normal wind weather conditions. The leakage at the early stage of the flood tide will drift to the current breeding area on the west side 4 hours after the leakage, and will have a direct impact on the important wetlands in the eastern coastal area 5 hours later. Within 72 hours of the leakage, the maximum area swept by the insoluble products is 268.2km², and the farthest distance from the leakage point is 22.7km. At the beginning of ebb tide, chemicals mainly drift to the eastern sea, and chemicals will not affect the surrounding environmental protection targets during the whole process.
3.4. Chemical diffusion results under constant monsoon in Adverse wind

Figure 5-7 for adverse wind conditions of trajectory and impact range, can be seen from the diagram, under the condition of the south wind, unsolvable material can reach the sun island soon, some chemicals and island coastline of adhesion, but there are still a part as the role of flood current and the wind to the north drift, leakage in 13 hours after the pollutants along some greater respectively antiquata national aquatic germ plasm resources of drift to the north, west border will have direct influence the protection of the south goal; Under the unfavorable wind and east wind conditions, the chemicals can reach the current culture area in the west in 3 hours and have a lasting impact on it. In 4 hours, they can reach the important coastal wetlands in the west, and have no effect on the razor clam protection area in the north. Under the action of adverse wind to the northeast, the chemical will have an impact on the current situation of aquaculture on the east side near the shore after 8 hours, and then the chemical port will gradually reach the shore under the action of wind and current.

Figure 4 Chemical film influence process (ebb tide, winter monsoon)

Figure 5 Dispersion Trajectory of Adverse Wind S to Wind (High Tide) (1-72 Hours)
4. Conclusions

According to the prediction of drift track and sweep range of insoluble products after leakage under the condition of constant wind and adverse wind, it can be seen that insoluble products will affect the aquaculture areas and wetlands near shore when risk leakage accident occurs in the stage of high tide. When the risk leakage accident occurs in the ebb tide stage, the insoluble products generally drift to the eastern sea with the effect of wind and ebb tide, and will not have an impact on the national aquatic germplasm resources conservation area of Sinovaconta Sinovaconta Xishitongue. The movement trajectory of Insoluble substance is greatly affected by meteorological conditions and Marine hydrological conditions after they leak into the sea. The location, tidal period and amount of leakage are the main influencing factors for the difference of environmental risks of chemical leakage.
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