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Development and Sustainable Utilization of Marine Resources Considering Numerical Simulation

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Abstract: The sea is the source of life, and oil spills caused by human activities, such as ship collision and leakage of offshore drilling platforms, will cause great damage to the marine environment. When an oil spill accident occurs, accurate simulation and prediction of the trajectory and fate of the oil spill will provide effective help for the subsequent accident treatment, so as to minimize environmental pollution. This paper mainly studies the development and sustainable utilization of marine resources taking numerical simulation into account. This paper first analyzes the impact of oil spill on the environment, establishes a mathematical model of oil spill spread drift based on the oil particle model, and embeds the behavior and destination expression of oil spill into the mathematical model framework of oil spill pollution. The feasibility and applicability of the model are verified by simulation experiments under different working conditions.

1. Introduction

The ocean accounts for 71% of the earth's surface and is an important part of the earth system on which human beings depend for survival. The ocean is a treasure house of resources, rich in water resources, responsible for the circulation of global water resources, and even affecting global climate change to a great extent. There are a large number of phytoplankton in the ocean, and the amount of oxygen produced by photosynthesis accounts for about 70% of the global oxygen production [1-2]. The ocean is rich in mineral resources, such as combustible ice, oil, sodium, magnesium, calcium and other chemical elements, which are far greater than those mined on land. The oil spill at sea will cause serious damage to the marine environment. First of all, oil leakage will cause damage to the marine ecological environment. The oil film covering the surface of seawater hinders the exchange between air and water, reduces the photosynthesis of light and phytoplankton in water, and thus reduces the production of oxygen in water. Some oil spills

dissolve in water, and harmful substances can cause fish poisoning and even death. More seriously, some harmful substances will remain in the organism by eating fish, shrimp and shellfish [3]. When humans eat contaminated marine objects, they can cause serious harm to health. The marine oil spill will also affect human social and economic activities, including tourism, fishery and industry, causing huge economic losses to human beings [4].

With the continuous development of computer technology, numerical simulation is widely used in the study of oil spill behavior and fate. At present, oil spill models are mainly divided into two categories, namely, Eulerian Lagrangian theoretical model and random sampling statistical method [5]. The random sampling statistical method adds the calculation of the random diffusion of spilled oil on the basis of the Eulerian Lagrangian theoretical model, uses random numbers to simulate the movement of the oil film in the three-dimensional expansion scale, and mainly solves the expansion of the oil film according to the turbulence intensity and time scale [6]. The movement of spilled oil generally includes diffusion, drift, evaporation, dissolution, emulsification and sedimentation [7]. After the oil spill is released, the diffusion process is the main movement process of the oil spill, and its diffusion is related to the type of oil, wind, tide, temperature and other factors. Some scholars have studied the aggregation and dispersion of oil droplets under the action of breaking waves, and combined and compared oil with different properties and different breaking wave heights [8]. Other scholars have simulated the oil spill in the Persian Gulf, taking into account the movement of oil particles under the influence of wind, tide and temperature, and verified the simulation results [9].

The numerical simulation of oil spill risk and the study of influencing factors play an important role. The study of influencing factors can help relevant departments predict the diffusion range of oil spill according to the environmental conditions of the accident place. The numerical simulation can predict the transport trajectory of oil particles, providing basic data for predicting the impact range of the accident.

2. Oil Spill Model Considering Numerical Simulation

2.1. Impact of Oil Spill on Environment

In recent years, the frequent offshore oil leakage accidents have become one of the main reasons threatening China's marine ecological security. According to China's state of the Marine Environment Bulletin, land-based pollution sources are the main factors leading to environmental pollution and ecological damage in offshore waters [10]. Among them, oil leakage is the biggest threat, and oil pollution will cause different harm to different objects in the marine environment:

(1) Biological hazard

Oil pollution will cause low temperature reaction to seabirds and marine mammals. When oil and water are mixed, a "mousse" substance will be formed, which will adhere to feathers and fur [11-12]. The feathers of birds are an insulator when they are filled with air and can maintain the body temperature of birds. When birds are stained with oil, not only will their feathers lose their insulating ability, but also they will die of hypothermia. Oil leakage will also increase predation, and the weight of feathers and fur will increase after they are stained with oil, making it difficult for birds to escape from predators. If they were covered with enough oil, they might eventually be drowned [13]. On the other hand, birds may be poisoned or damage their internal organs, such as red blood cells, liver and immune system, due to ingestion of oil. The oil vapor in the process of oil evaporation may cause damage to the eyes and lungs of animals. If there is enough vapor, it may cause irreparable damage to marine mammals.

(2) Offshore hazards

The oil spill damage in offshore shallow water areas is usually caused by the mixing of oil into

the ocean by wave action or the use of dispersants. Under normal circumstances, the dilution capacity of the ocean itself is sufficient to reduce the oil concentration in the water below the harmful level [14]. However, for the light toxic substances that have been diffused or in major leakage accidents, the oil pollution near the shore has been diffused by the wave action, which may cause the death of marine organisms, such as shellfish and coral.

(3) Shoreline hazards

The closer the oil spill is to the coastline, the greater the damage to the marine ecological environment. The diversity and richness of ecosystems in coastal waters are far greater than those in the open sea. Oil contamination will seriously damage fish eggs and larvae, causing deformities. Algae is an important role in the water environment system, and oil spill will also pollute algae. If the oil spill cannot be controlled quickly, there will always be oil pollution on the beach and below the sea surface, which will have a serious impact on cave marine organisms such as crabs in the next decade or so, and these cave marine organisms are the food source of other animals. If this cycle continues, the toxicity will last for many years [15].

2.2. Numerical Simulation Model of Oil Spill

In this paper, the oil particle model of oil spill pollution based on Lagrange theory is used for modeling. First, the oil spill is generalized by the oil particle model, and the oil spill is dispersed into a certain number of oil spill particles, each of which represents a certain amount of oil spill. The oil spill film is an oil spot particle cluster composed of a large number of oil particles. The oil particle model uses Lagrange random walk method and particle cloud principle to describe the diffusion and drift process of spilled oil. It regards the diffusion and drift of oil film as the superposition effect of many oil particles moving under the action of external driving force. It summarizes and simulates the drift and diffusion characteristics of oil film by calculating the hydrodynamic parameters of individual oil particles [16-17]. The oil particle model can better reflect the development process of oil spill, so it is widely used in the numerical simulation of oil spill [18].

In this paper, the oil particle model is realized by the additional volume parameter method. If the particle diameter of the ith oil particle is Di, the volume is:

$$V_i = \frac{\pi}{6}(d_i)^3 \tag{1}$$

The percentage fi of the volume of the oil particles in the total volume of the whole oil film is:

$$f_i = \frac{\frac{\pi}{6}(d_i)^3}{\sum_{k=1}^{n}\frac{\pi}{6}(d_k)^3} \tag{2}$$

Where: n - total number of oil particles.

The characteristic volume of a single oil particle is:

$$V_i = f_i V_0 \tag{3}$$

Where: V0 - initial volume of spilled oil.

(1) Extension process

When the spilled oil enters the water, the oil film will quickly spread around under the action of gravity, inertia, viscosity and surface tension. In the initial period of time, the expansion of the

spilled oil is the most important behavior process. According to the Fay theory, the expansion can be divided into three stages: gravity inertial force expansion stage, gravity viscous force expansion stage and surface tension viscous force expansion stage. This paper mainly considers the expansion of oil film under the action of gravity and viscous force, that is, the optimized Fay theoretical gravity viscous force formula is used to calculate the expansion of oil film:

$$\frac{dA}{dt} = K_0 A^{1/3} (\frac{V_0}{A})^{4/3} \tag{4}$$

Where: a - oil film surface area, m2; T-Time; K0 - oil film area growth rate, taken as 150 / S; V0 - oil spill volume.

(2) Drift process

After the oil spill occurs, the oil film will expand itself and drift and diffuse under the driving of external forces such as water, waves and wind. The drift process includes translation process and random diffusion process. The diffusion process of oil particles in water is a random turbulent dispersion process. In this paper, the method of generating random numbers is used to calculate the possible diffusion distance of oil particles in the horizontal direction in each time step.

(3) Oil particle model

With the proposal of the concept of "oil particles" in the 1980s, the oil spill model based on "oil particles" became the mainstream. Using the "oil particle" model framework, a large number of simulation studies on marine oil spill pollution have been carried out; At the same time, domestic oil spill numerical simulation research is also very active.

Most oil spill models basically rely on experience to determine the number of particles. In order to reduce the influence of human subjective factors on oil film dissection, a formula for determining the number of oil particles in the process of oil film granulation is proposed. According to the characteristics of oil particles and the characteristics of the water area, the following formula can be used to calculate the number of oil particles contained in the oil film in shallow water:

$$n = \frac{S}{S_i} = [\frac{1}{\gamma(a/kh)}]^2 = (\frac{\pi dh}{\gamma a \lambda}) \tag{5}$$

Where, l is the length of the long axis of the leaked spilled oil under gravity in Δ t time; γ Is the influence coefficient of oil viscosity on the number of oil particles, ranging from 0 to 1. The greater the viscosity, the greater the coefficient. In the process of oil spill granulation, the number of particles is determined by the oil film area, oil viscosity and wave factors. The oil film area s is the expanded area of the leaked oil in Δ t time. Different oil products have different viscosity. Wave disturbance is the decisive factor to determine the number of oil particles. The motion of the oil film after the oil particles are divided is transformed into the motion of these particles.

3. Environmental Variable Impact Test

The marine environment is complex and changeable. Simply simulating the movement of oil particles under ordinary working conditions can not meet the need to provide theoretical support for emergency measures. Exploring the impact of different environmental variables on the movement of oil spills, combining them into a variety of working conditions to study the impact of each factor on the diffusion trajectory of oil film and the amount of residual oil on the surface can take corresponding first aid The clean-up measures provide reliable theoretical support. Based on the numerical simulation model, this paper adopts the control variable method to combine the environmental variables in a variety of ways to simulate the movement trajectory of oil particles under various working conditions. From the simulation results, it explores the impact of different

environmental variables on oil film transport, and whether there is superposition or offset between environmental variables, so as to establish a clear impact matrix.

4. Analysis of Test Results

4.1. Time Factor

The combination of working conditions for exploring time factors is shown in Table 1:

Table 1. Time factor working condition combination

Working condition	Time	Wind speed	Wind direction
1	24H	7m/s	50 °
2	48H	7m/s	50 °
3	72H	7m/s	50 °

In order to explore the influence of time factors on the spread range of oil spills, three groups of experiments were set up. Each group of experiments included at least one complete flood tide ebb tide cycle, and the influence of other variables was excluded as far as possible.

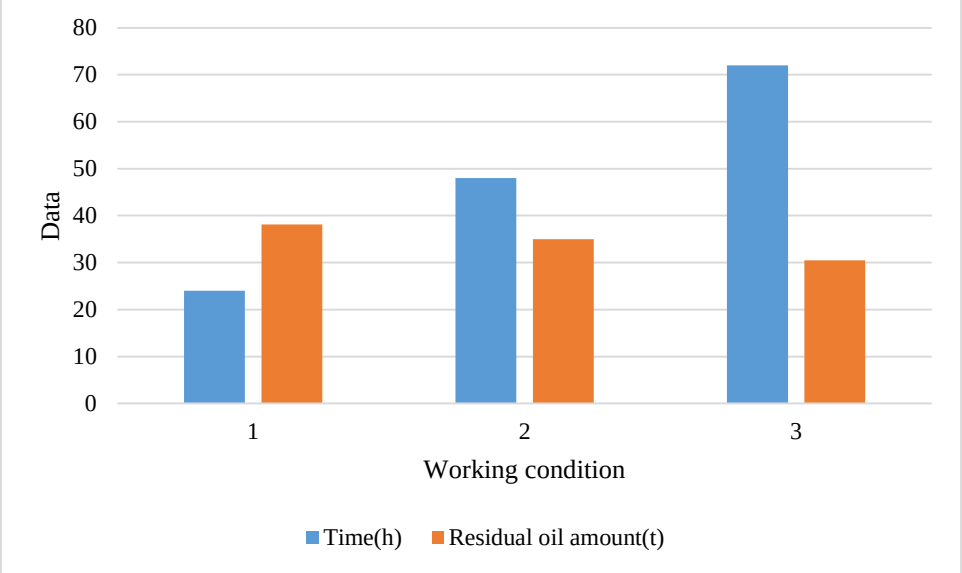

Figure 1. Residual oil volume map

As shown in Fig. 1, with the increase of the time when the oil is discharged into the sea, the diffusion range is obviously larger, the amount of residual oil on the surface is smaller and smaller, and the reduction speed is faster. The diffusion speed is also faster. It can be seen that the evaporation speed of surface oil is accelerated with the increase of the diffusion area, and the diffusion speed is also gradually accelerated with the expansion of the area. Therefore, the evaporation speed in 24-48 hours is less than that in 48-72 hours.

4.2. Wind Condition Factor

Table 2. Table of parameters of wind speed conditions

Working condition	Time	Wind speed	Wind direction
1	48H	3m/s	Northeaster
2	48H	5m/s	Northeaster
3	48H	9m/s	Northeaster

As shown in Table 2, there are three groups of wind speed experiments. The parameters of each group are the same except the wind speed. The simulation duration is 48 hours. The wind speeds of the three groups are 3m / s, 5m / s and 9m / s respectively, and the wind direction is northeast.

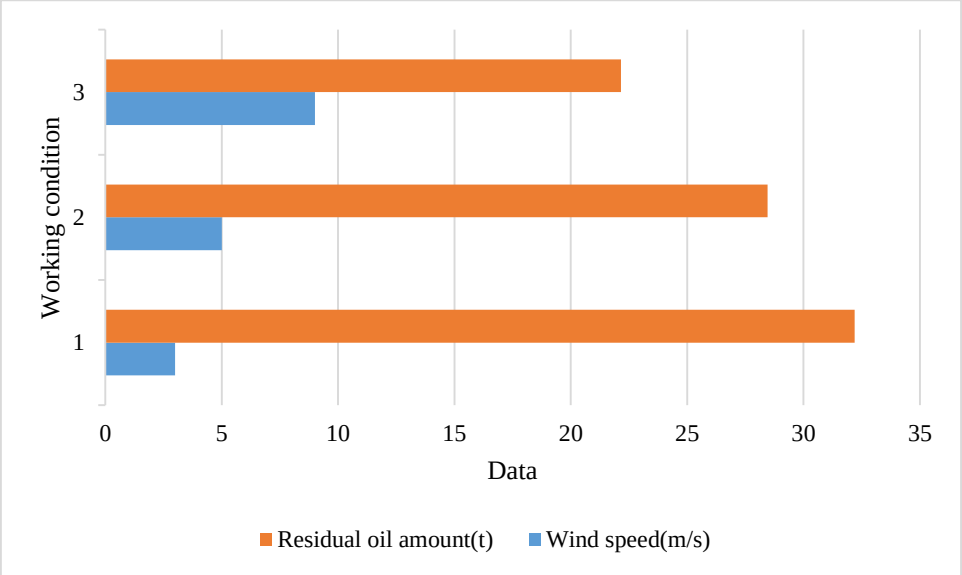

Figure 2. Residual oil at sea surface after 48 hours at the three wind speeds

As shown in Fig. 2, with the increase of wind speed, the amount of residual oil on the sea surface per unit time becomes significantly smaller. Without taking artificial measures, the larger the surface wind speed is, the less the residual oil is. Since the oil on the sea surface is mainly removed by evaporation in natural circumstances, it can be concluded that the larger the surface wind speed of the oil film on the sea surface, the greater the evaporation per unit time, the greater the diffusion speed of the oil film, and the increase of the area of the oil film will also accelerate the evaporation, The superposition of the two effects is the main reason why the wind speed has such a great influence on the diffusion and evaporation of oil spills.

4.3. Tidal Current Factors

Table 3. Experimental results of wind regime and tidal current

Working condition	Tide flow	Direction of the wind	Time	Sweep the sea area
1	Southwest to Northeast	Southwest	48h	612.56km2
2	Northeast to Southwest	Southwest	48h	349.05km2

As shown in Table 3, when the wind direction is close to the tidal current direction (recorded as the favorable wind direction), the diffusion speed of the oil film on the sea surface per unit time is significantly faster than when the two directions are opposite (recorded as the unfavorable wind direction). Therefore, it can be concluded that the tidal current and the wind direction have an overlapping or counteracting effect on the diffusion of oil spills, which is specifically reflected in that when the tidal current direction is close to the sea surface wind direction, the two will accelerate the diffusion speed of the oil film, When the two directions are opposite, the wind direction will prevail, but the wind force will weaken, which is obviously not as fast as the diffusion

speed in the favorable wind direction. At the same time, it can also be seen that the effect of wind on the diffusion and evaporation of oil film is obviously stronger than that of tide and time.

5. Conclusion

The research content of this paper is to simulate the diffusion movement of oil spill on the sea surface and the influence of environmental variables on its movement. As we all know, oil spill accident is one of the main factors of marine pollution, and its harm has affected the marine ecological environment, industrial production, aquaculture, fishery and tourism. The difficulty of decontamination and oil absorption, and the investment of a large number of equipment and manpower have made the maritime departments and environmental protection organizations of various countries headache. Moreover, the harmful substances in crude oil cause irreversible damage to many marine organisms, Once the pollutants are dispersed to the nature reserve, they may even cause the extinction of some species. Through the research and investigation of the marine oil spill accident, this paper decided to take a Strait as the research sea area to simulate the diffusion and drift trajectory of the oil film on the sea surface after the oil spill accident occurred in this sea area, and analyzed and tested the main variables (wind, tide and time) one by one to study the impact of each variable on the oil spill.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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