Effect on coastal environment of Ptot emission of wastewater

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Abstract: The article analyses and predicts the hydrodynamic feature of study area on the basis of Mike3 numerical model. By means of 3D numerical simulation of the problem of ocean dumps from offshore industries, computation on Ptot emission of wastewater is used on the pollutant. Research shows that the results reflected the rules of transportation and diffusion of Ptot in the tidal water area bitterly.

1. Introduction
The sewage point B3 locates in Guangxi Tieshan Bay. The position of study area is shown in Figure 1. Tieshan Bay is a table-land and submerged-valley bay in the funnel shape with north-south orientation. It is the depression structure drowned by the lifted sea level in the post frozen age, so it has 40km long (from the bay’s top to the shoal) and 3~4km narrow tidal channel[1].

![Figure 1 - The position of study area](image-url)
2. Mathematical Model

2.1 Research methods

It is applied by the Estuarine and Coastal Ocean Model (Mike). This model can simulate tide, waves, tidal current, water quality and ecology in coastal and estuary areas. Hydrodynamic module is built on the basis of N-S equations, used finite difference (semi-implicit) numerical solution of the σ coordinate equations for the discrete solution. Continuity equation for three-dimensional flow motion, momentum equation, mass conservation equations and convection-diffusion equations refer in the literature [2]. Mike water quality model [3] is based on hydrodynamic simulation; make use of the principle of conservation of mass, considering the transportation and the distribution of the material due to convection, turbulent diffusion [4] and so on, to calculate the concentration of the diffusion of pollutants.

2.2 model of material transport and diffusion

Mike water quality model[5] based on hydrodynamic simulation is to calculate the concentration of the diffusion of pollutants in the sea area, making use of the principle of conservation of mass, considering the transportation and the diffusion of the material due to convection, turbulent diffusion and so on.

The formula of material transport and diffusion is described as follows:

\[ \text{C-concentration of contamination; } u,v,w-\text{velocity of flow in direction of x,y,z; } K_H, A_H-\text{diffusion coefficient in vertical and horizontal direction, } H-\text{depth; } Q-\text{source and sink of contamination.} \]

1) Initial conditions

The main purpose of this paper is to analyze the distribution of the concentration of the pollutants. The water quality simulation is mainly incremental calculation. There is no regional pollution sources in the area of simulating, assuming that no sources of pollution outside the region in the simulation; only along the open boundary there is material transportation. So the simulation generalized the concentration for the boundary, to determine the initial concentration of the environment as \( c(x, y, z, 0) = 0 \).

2) Diffusion coefficient

We selects the horizontal and vertical diffusion coefficient according to turbulent diffusion theory and the amendment to the measured data; degradation coefficient \( K \) and current characteristics, type and quantity of marine life, sea gas exchange rate, pollutant concentration and water temperature and other factors, refer to the home and abroad manual. \( K \) is actually taken to be constant in the model, and when the water temperature is in the range 10~28°C, the degradation factor \( K \) values ranges from 0.02~0.07 d\(^{-1}\). According to the specific circumstances of the Northern Gulf, the author selects the water is 21°C in the research area, and the coefficient \( K \) is 0.03 d\(^{-1}\).

3) Technical processing

As 2D Water Quality Model generalizes the average of vertical diffusion in calculation, its result is the average value of vertical line; as 3D calculation has considered the horizontal and vertical diffusion, the result is more similar to the process of physical diffusion in the space. How to measure the influence of small-scale dispenser’s hole distance on the water quality model is the key issue of numerical simulation in the calculation of the large-range flow field, as the dispenser in real engineering is less than 100m long, and the hole distance would be less than 2m; when the situation that sewage in all sewage outfalls is discharged is directly simulated, there will be large number of grids, and the calculation will take a long time; when all sewage is considered to be discharged from one outfall, it won’t comply with the actual situation.

According to the diffuser length, putting posture in the sea area and gridding space, this paper generalizes the quantity of hole distance from the number of grid nodes that the dispenser has passed through, so it meet the demands of calculative accuracy and conforms to the sewage’s 3D porous diffusion situation in the sea. To reach the accurate analysis and judgement for the pollutants’ space-time distribution characters and environmental influence after the mixation by turbulent
fluctuation and the transport diffusion, this paper has chosen the chemical oxygen demand (Ptot) in the water quality monitoring as the predictor for the establishment, prediction and analysis of 3D Water Quality Model.

3. Results of Ptot of the sewage numerical simulation

To illustrate the impact of sewage discharge on sea water quality, this article assumes one kind of discharge concentration of Ptot to predict and analyse (according to background information, the background concentration of Ptot is 0.01mg / L). The sewage emissions amount of 109158 m³/d, emission concentration of Ptot of 0.8mg/ L. Projections were calculated by these and superposition of background concentration.

Predicted results shown in Figure2~Figure3 and Table1~Table2. By the results of the simulation tidal flow, the flow around area of sewage outfall is basically alongshore current, so Ptot is basically showing zonal distribution. After sewage from the diffuser into the seawater the results showed that the middle-layer has the largest influence distance and the smallest at the surface-layer. At 0.005mg / L concentration, the middle-layer enveloping is far than the surface about 1147m.

| Emission concentration (mg/L) | Space distribution | Concentration impacted area(m²) |
|------------------------------|-------------------|--------------------------------|
|                              |                   | ≥0.045 mg/L | ≥0.03 mg/L | ≥0.015 mg/L |
| 0.8                          |                   |           |          |          |
| surface-layer                |                   |       | 0.0011   | 0.042     |
| mid-layer                    |                   |       | 0.0058   | 0.34      |
| bottom-layer                 |                   |       |           | 0.0015    |

| Concentration increment (mg/l) | Diffusion direction | ≥0.03 mg/L | ≥0.02 mg/L |
|--------------------------------|---------------------|------------|------------|
|                                 | alongshore   | offshore  | alongshore | offshore  |
| emission concentration (0.8mg/l)| surface-layer |       | 54        | 27        |
|                                 | mid-layer    |       | 140       | 59        |
|                                 | bottom-layer |       |           |           |

| Concentration increment (mg/l) | Diffusion direction | ≥0.005 mg/L |
|--------------------------------|---------------------|------------|
|                                 | alongshore   | offshore  |
| emission concentration (0.8mg/l)| surface-layer | 442       | 110       |
|                                 | mid-layer    | 1589      | 197       |
|                                 | bottom-layer | 58        | 31        |
Figure 2: Ptot each layer’s influence envelope (dashed-line frame is 3-time zoomed image)
4. Analysis of Ptot of the sewage on sea environment

The result of research shows: the overall sewage in surface, medium and bottom layers reciprocates along the coastline in flood and ebb tides, when the range of motion along the vertical coastline is very small, so it is favorable for reducing the pollutants’ influence on the beach and the sensitive areas. Vertically, the concentration of discharged sewage in lift gets continuously lower, and the concentrations in medium and surface layers near the outfalls is relatively the lowest in vertical direction.

Generally, in vertical direction, the concentrations in characteristic layers near the outfalls are different; and as the sewage continues to mix with the nearby seawater, the vertical concentration gradient is larger (the concentration drops quickly). Ptot has little influence scope that violates the seawater-quality standards in every layer, so it won’t produce direct harm to Yinpan marine culture area, dugong nature reserve and mangrove nature reserve.

5. Conclusion

The results show that the hydrodynamic conditions and the pollutant dispersion laws of Guangxi Tieshan Port have the following features:

1) In vertical direction, the concentrations in characteristic layers near the outfalls are different; and as the sewage continues to mix with the nearby seawater, the vertical concentration gradient is larger;

2) Ptot has little influence scope that violates the seawater-quality standards in every layer. From the point of view of the port planning, the greatest influential scope of the pollutant dispersion will not have direct harm on Yinpan marine culture area, dugong nature reserve and mangrove nature reserve;

3) The results of 3D porous diffusion model can more precisely determine whether environmental protection target is influenced by the ocean engineering.

Therefore, the water quality model of Mike is more scientific and accurate, which can be used as a reliable method to study environmental pollution, with its research results contribute to the implementation of marine environmental protection and used as reference for the environmental protection sector.

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