Numerical simulation of the effects of Yangtze River runoff on pollutant transport and diffusion in the Yangtze River estuary

Zhuoyu Ren¹, Kai Li², Songlin Han*¹, Jibin Han¹

¹Changjiang River Scientific Research Institute, Wuhan, 430010, China.
²Water Resources Department (Transboundary river management department), Changjiang River Scientific Research Institute, Wuhan 430010, China

*Corresponding author’s e-mail: 539751685@qq.com.

Abstract. The coastal-estuary area is one of the areas most seriously affected by human activities, and the quality of the water environment has received extensive attention from society and scholars. In order to analyze the characteristics of pollutant transport in the Yangtze River Estuary, a two-dimensional hydrodynamic model of the Yangtze River Estuary waters was established, and the model was verified using measured hydrological data. On this basis, the effects of the dilution and diffusion of pollutants (COD) under different runoff rates are studied and the transport characteristics of the pollutants of the Yangtze River estuary are studied. The results show that after the calculation reaches a relatively stable level, the concentration at the measuring point of the pollutant input from the Yangtze River in the high and low water period is about 6mg/L and 1.2mg/L, which is diluted by 42.9% and 88.6% respectively compared with the pollutant concentration at the discharge outlet. When the sewage is discharged from the sewage outlet, the highest COD concentration does not exceed 3mg/l during the high and low water periods, indicating that the sewage discharged from the planned sewage project will not have a serious impact on water quality.

1. Introduction

A series of studies have been carried out on the water environment process of the Yangtze River estuary at home and abroad. According to the three-dimensional governing equation of tidal unsteady flow, Liu Zilong et al. carried out three-dimensional mathematical simulation of the Yangtze River tidal current [1]. Zhu Yuliang et al. established a mathematical model of three-dimensional nonlinear baroclinic water salinity in the Dajiang Estuary and applied it to the calculation of saltwater intrusion in the Yangtze River estuary [2]. Li Tilai et al. established a three-dimensional power flow mathematical model of the Yangtze Estuary boundary fitting coordinates [3].

Although many studies have been carried out on the hydrodynamic and pollutant transport characteristics of the Yangtze River estuary in the past [4-8], with the development and deepening of research methods, there are still many problems worthy of further discussion. Previous studies have mainly focused on the study of the dilution and diffusion of pollutants discharged from the sewage outlets of the Yangtze River estuary, but the research on the impact of the discharge of sewage from the Yangtze River estuary was insufficient. It is of practical significance to study the impact of the pollutants discharge of sewage from the Yangtze River estuary on the marine environment.
2. Information and methods

2.1 Hydrodynamic model

This paper uses MIKE21 to simulate the hydrodynamic characteristics of the study area. The model is based on the three-way incompressible and Reynolds value-averaged Navier-Stokes equations, and is subject to the Boussinesq assumption and hydrostatic pressure assumptions.

\[ \frac{\partial h}{\partial t} + \frac{\partial}{\partial x} (hu) + \frac{\partial}{\partial y} (hv) = 0 \]

(1)

\[ \frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \frac{1}{Re} \nabla^2 \mathbf{u} + g \nabla \eta \]

(2)

\[ \frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} = -\nabla p + \frac{1}{Re} \nabla^2 \mathbf{v} + g \nabla \eta \]

(3)

Where

\[ \eta \] is the water level.
\[ d \] is the static water depth.
\[ u \] and \[ v \] are the velocity components in the x and y directions, respectively.
\[ S_{xx}, S_{xy}, \text{and } S_{yy} \] are radiative stress components.
\[ (u,s,vs) \] is the source water flow rate.
\[ T_{ij} \] is a horizontal viscous stress term.

The frequent exchange of water between the Yangtze River estuary and Hangzhou Bay is carried out. In order to provide a reasonable boundary condition for the numerical simulation of the Yangtze River estuary, this paper studies the Yangtze River estuary and Hangzhou Bay as a whole, and the calculation area includes the Yangtze River estuary, Hangzhou Bay and their adjacent waters. It is about 280 km long from north to south and about 250 km from east to west. The model calculation uses a cold start with zero initial water level and flow rate. The model's open boundary tide level data is provided by the MIKE Global Tide model. The measured daily discharge at Datong station is taken as the discharge boundary condition of the Yangtze River estuary and the discharge of the Qiantang River is the mean annual discharge of wet year.

2.2 Model verification

In order to verify the simulation accuracy of the model, using the measured tide data of three temporary tide stations and the measured current data of the three tide stations during the spring tide and neap tide period compare with the model calculation results. The position of the station is shown in Figure 1.
The comparison between the simulation results of tide level and the measured data is shown in Figure 2, and the comparison between the simulation results of the flow velocity and flow direction and the measured data is shown in Figure 3. The solid line in the Figure represents the analog value, and the scattered points represent the measured value.

![Figure 2: Comparison between computed and observed tide level at six station](image1)

![Figure 3: Verification of flow magnitude and direction of eight stations](image2)

As can be seen from Figure 2 and 3, the calculated value of tidal level at each tidal station is in good agreement with the measured value, and the calculated results of flow rate and flow direction are in good agreement with the measured values.
agreement with the measured data as a whole, thus correctly describing the changes of ebb and flow in different time periods of the sea area.

It can be seen from the overall verification results that the hydrodynamic model can accurately simulate the tidal variation law of the Yangtze River estuary during the observation period, and has high simulation precision. It can be used for numerical simulation of hydrodynamic field near the Yangtze River estuary and provide reliable hydrodynamic conditions for the water quality model.

3. Model calculation and analysis

In order to analyze the transport and diffusion of pollutants in the Yangtze River estuary and the influence of the discharge of sewage from the Yangtze River estuary and the discharge of sewage from the sewage outlet on the marine environment, the influence of different runoff on the diffusion of pollutants was studied. According to the Shanghai Sewage Phase III project, the Yangtze Estuary sewage outlets are located in Shidongkou, Zhuyuan, Bailonggang and Xinhe. The location is located in the south branch, south port and south trough of the Yangtze River along the coast of Shanghai, the sewage is discharged through the bottom of the pipeline into the Yangtze River, the emission form is continuous point source discharge, and the discharge amount is 800000 m$^3$/d, 3.3 million m$^3$/d, 1.7 million m$^3$/d and 1.5 million m$^3$/d, respectively [9]. In the model, four sewage outlets with different runoff are designed as runoff, and the pollution factor is COD. According to the Integrated Wastewater Discharge Standard secondary emission standards, the COD in sewage is no more than 120mg/l, and 100mg/l is taken in this paper.

3.1 Transport and diffusion of pollutants in the Changjiang Estuary

In order to understand the impact of the Yangtze River runoff on the hydrodynamics and pollutant transport in the Yangtze River estuary, the numerical simulation was first carried out for the Yangtze River estuary during the period of high water season. The simulation time was selected from 8:00 on June 1, 2010 to 8:00 on August 15, 2010. Then, the numerical simulation of the Yangtze River estuary during the dry water season was carried out, and the simulation time was selected from 8:00 on December 1, 2009 to 8:00 on March 31, 2010. According to the water quality evaluation of the Yangtze River estuary, the COD value of most water areas is 10~12mg/L. We choose the COD value of the Datong station section of the Yangtze River estuary to be 10.5 mg/L [10].

Figure 4 (a) and (b) respectively give the COD concentration isolines comparison diagram of Yangtze River estuary after self-discharge 10 days and 25 days in the wet and dry water seasons.
According to the result analysis, the point source pollutants discharged from the Yangtze estuary spread downstream under the combined action of runoff and tidal current, and eventually flowed into the offshore sea, and some of the pollutants were dispersed to the north coast of Hangzhou Bay along with the current movement. It can also be seen from Figure 6 that in the discharge of point source pollutants at the mouth of the Yangtze River, the pollutants are more likely to flow into the outer sea during the wet period due to the effect of runoff from the Yangtze river, and the extent of diffusion to the outer sea during the wet period is larger, indicating that the runoff is large and the diffusion is faster and the dilution is higher.

In order to better study the change of background COD concentration in the Yangtze estuary, the COD concentration value of C1 monitoring point is given for analysis, as shown in Figure 5. The location of C1 monitoring point is shown in Figure 6.

It can be seen from Figure 5 that when pollutants are discharged from the Yangtze River Estuary, after the model calculation is stable, the concentration of C1 point in the wet season is about 6mg/ L, which is diluted by 42.9% compared with the pollutant concentration at the discharge outlet. During the dry season, the concentration of C1 was about 1.2mg/ L, which was 88.6% diluted compared with the pollutant concentration at the discharge outlet.

3.2 Transport and diffusion law of pollutants in sewage outlet
The COD values of C1 and C2 monitoring points near the sewage outlet are extracted for comparison and analysis. The distribution of monitoring points is shown in Figure 6. C1 and C2 monitoring COD value is shown in Figure 7.
Figure 7. The change diagram of COD concentration in sewage outlet

It can be seen from Figure 7 that after the calculation reaches relative stability, during the wet season, the maximum COD concentration at the discharge point C1 at the discharge point is 0.5 mg/l, and the maximum COD concentration at the point C2 at the discharge point is 1.4 mg/l, indicating that the pollutants the spread to the sea gradually became more apparent. The COD concentration of the sewage discharge point C1 during the dry season is up to 2 mg/l, but the measurement point of C2 is close to 0 mg/l, which indicates that due to the small amount of upstream water in the dry season, the effect of dilution and diffusion is not obvious. Distributed in the area near the sewage outlet, the pollutants are mainly transported downstream along the water flow, the lateral migration and diffusion effect is small, and the concentration is lower when it reaches the observation point C2. During the high water period, the COD concentration at the measurement point C2 is higher than the measurement point C1. In addition to the pollutants discharged from the Shidongkou, it is mainly because the pollutants discharged from the Zhuyuan, Bailonggang and Xinhe three sewage outlets are rising and falling. The effect of concentration superposition. This shows that the sewage discharged from the four sewage outlets is mainly transported and diffused downstream along the south port. In addition, the highest COD concentration during the high and low water periods does not exceed 3 mg/l, which indicates that the sewage discharged from the planned sewage disposal project will not have a serious impact on the water quality.

4. Conclusion
Through the establishment of the Yangtze river estuary and the hangzhou bay and adjacent waters of the two-dimensional tidal current mathematical model, and the Yangtze estuary and hangzhou bay pollutant diffusion and intersection are simulated. Therefore, it is necessary to take some effective measures to control sea water pollution.

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