

Research on numerical method for multiple pollution source discharge and optimal reduction program

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Abstract. In this paper, the optimal method for reduction program is proposed by the nonlinear optimal algorithms named that genetic algorithm. The four main rivers in Jiangsu province, China are selected for reducing the environmental pollution in nearshore district. Dissolved inorganic nitrogen (DIN) is studied as the only pollutant. The environmental status and standard in the nearshore district is used to reduce the discharge of multiple river pollutant. The research results of reduction program are the basis of marine environmental management.

1. Introduction

With the rapid development of marine reclamation in nearshore district, the environmental pollution and ecological disaster has been influencing the regional sustainable development. Environmental management has been facing new challenges due to the new demand of environment and economy. So the emission-reduction study of marine pollutant source is meaningful for guiding the environmental management, protection and industry upgrades.

The emission-reduction of pollutant source discharge has been studied and applied widely for recent decades, such as the proportion method, the cost minimum method, the contribution rate method, and the economic maximum method [1], etc. The above mentioned methods have been used to the emission reduction of pollutant source widely [1].

In this paper, a numerical model is applied to simulate the pollutant distribution of nearshore district in Xuwei Jiangsu of China by tidal and transport model. Dissolved inorganic nitrogen (DIN) is studied as the only pollutant owing to its higher rate of excessive standard. An optimal reduction program of multiple river pollution sources could be obtained by the optimal algorithm.

2. Methodology

2.1 Hydrodynamics model

A hydrodynamic model is employed for simulating the current field changes in this paper and triangle mesh technique is applied for close to complex coastline. The two dimension model could be obtained by integration among the water depth based on five aspects as follows:

- (1) Sea water is a homogeneous, incompressible, viscous fluid.
- (2) The Coriolis force and gravity force are considered in the model.



- (3) The wind stress of the free surface and the bottom friction force are considered in the model.
 (4) Assumption of hydrostatic pressure.
 (5) Assumption of Boussinesq.

The governing equation of this two dimension model is as follows:

Continuity equation:

$$\frac{\partial h}{\partial t} + \frac{\partial(Hu)}{\partial x} + \frac{\partial(Hv)}{\partial y} = 0 \quad (2.1)$$

Motion equations:

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + g \frac{\partial h}{\partial x} - fv + g \frac{u\sqrt{u^2 + v^2}}{C^2 H} = 0 \quad (2.2)$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + g \frac{\partial h}{\partial y} + fu + g \frac{v\sqrt{u^2 + v^2}}{C^2 H} = 0 \quad (2.3)$$

Where h is the water level, H is the water depth, u and v are the component of current velocity in the x and y direction, f is the Coriolis coefficient, C is the Chezy coefficient, t is time, g is the gravity acceleration.

Open boundary conditions:

$$\eta = \eta(x, y, t) \quad (2.4)$$

Close boundary conditions:

$$V_n = 0 \quad (2.5)$$

Initial conditions:

$$\begin{aligned} U(x, y, \sigma, t_0) &= U_0(x, y, \sigma) \\ V(x, y, \sigma, t_0) &= V_0(x, y, \sigma) \\ \eta(x, y, t_0) &= \eta_0(x, y) \end{aligned} \quad (2.6)$$

2.2 Convection and diffusion model

A convection and diffusion model is employed to simulate the pollutant distribution in the marine district by the equation (7).

$$\frac{\partial}{\partial t}(hc) + \frac{\partial}{\partial x}(uhc) + \frac{\partial}{\partial x}(vhc) = \frac{\partial}{\partial x}(h \cdot D_x \cdot \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(h \cdot D_y \cdot \frac{\partial C}{\partial y}) - F \cdot h \cdot c + S \quad (2.7)$$

Where C is the concentration of pollutant, D_x, D_y is the diffusion coefficient in the x and y direction, F the linear coefficient, S is the pollution source.

2.3 GAs

The genetic algorithm [2-3] is a global random search method. The optimal solution could be obtained by the biological process of selection, crossover and mutation.

2.4 Calculated method of reduction

The total pollutant amount is estimated by equation (8) based on the pollution source flux and the concentration of gauge station in the estuary.

$$S = \sum_{i=1}^n V_i \times Q_i \quad (2.8)$$

Where S is the total pollutant amount, V_i is the pollution source flux of the i th pollution source, Q_i is the concentration of gauge station in the i th estuary.

The max allowable discharge amount is calculated by equation (9).

$$P_y = \sum_{i=1}^n Sh_i^j \times St_j \Big|_{j=1,2,\dots,m} - P_e \quad (2.9)$$

Where P_y is the max allowable discharge amount, Sh_i^j is the share ratio of the j th marine element for the i th pollution source, St_j is the environmental quality standard of the j th marine element, P_e is the exchanging flux. The share ratio is obtained by the calculation of tidal and transport model.

The reduction amount is calculated by equation (10).

$$X = S - P_y \quad (2.10)$$

Where X is the reduction amount of pollution source.

3. Case study

3.1 Research district

A coastal region of Xuwei in the Jiangsu province, China is studied in this paper. The main four pollution sources are considered named that the Shaoxiang river, the Paidan river, the Guanhe river and the discharge outlet of the Xuwei sewage treatment plant, which is shown in the figure 1. The four control gauge stations are selected in the nearshore district for the pollutant reduction, which is shown in the figure 1.

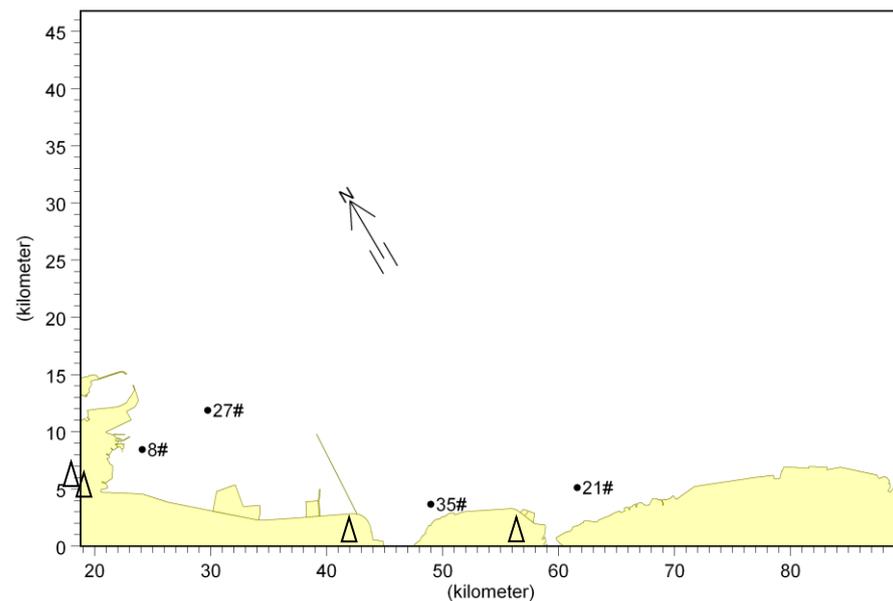


Figure 1: The control gauge station for pollutant reduction

3.2 Research results

The tidal current field is simulated by the hydrodynamics model, which is shown in the Figure 2.

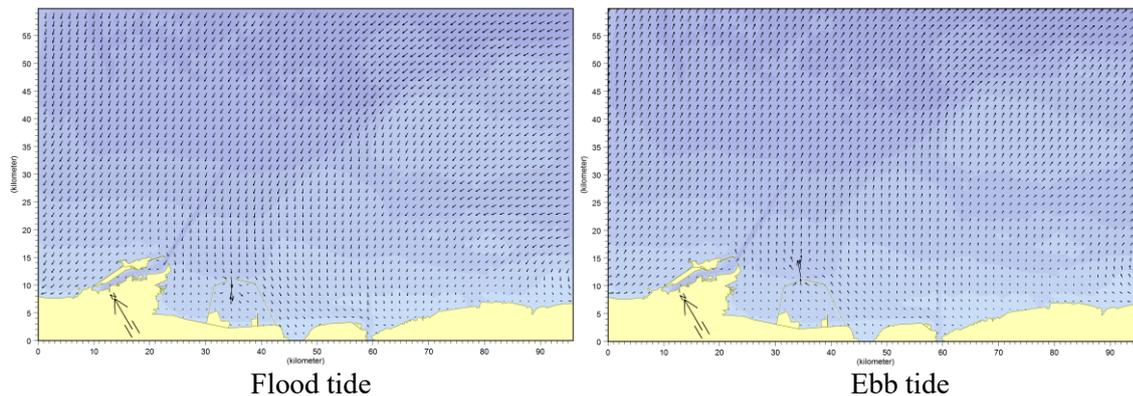


Figure 2: The simulated results of tidal current field.

Figure 2 shows the tidal current field. Compared with the field data and the research results [4], the hydrodynamics characteristics is same as the actual condition. So the model is credible for the pollutant concentration distribution simulation.

Based on the hydrodynamic model, a convection and diffusion model is employed for simulating the pollutant diffusion. The four pollution sources are selected and input into the model respectively. Through the numerical simulation, the pollutant distribution is obtained.

Through the pollutant concentration distribution, the share ration of different pollution source for different control gauge station is computed, and then, the max allowable discharge amount and the optimal reduction amount could be simulated and obtained by the GAs.

The discharge amount of pollution source after reduction is input into the convection and diffusion model for judging the effect of reduction (in Figure 3), compared with the actual condition (in Figure 4).

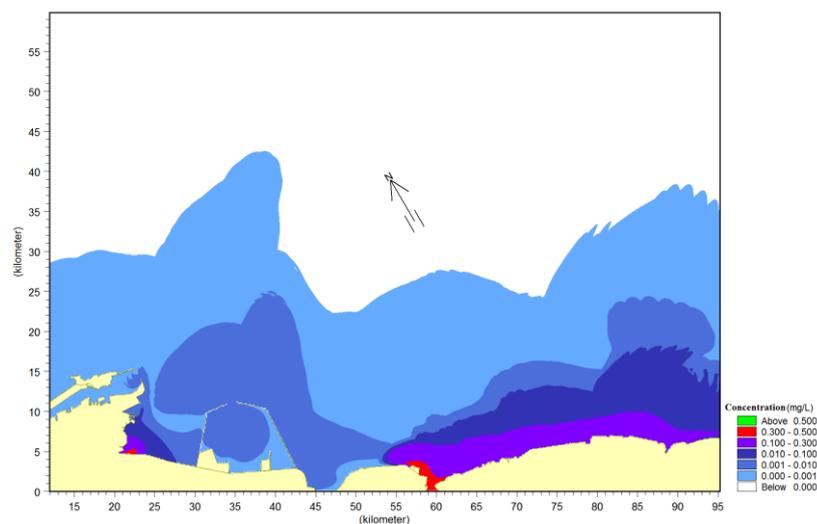


Figure 3: The pollutant concentration distribution after reduction.

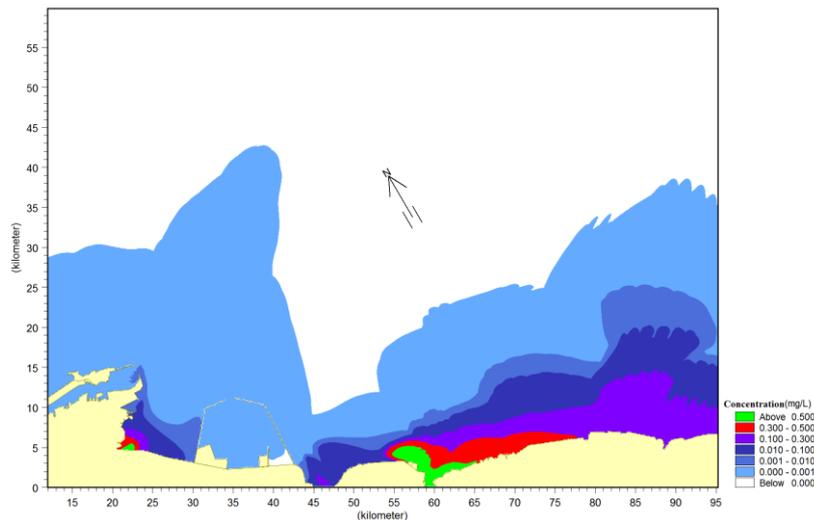


Figure 4: The pollutant concentration distribution before reduction.

Through the comparison the Figure 3 and 4, the high concentration district has decreasing obviously after reduction, which shows the pollution source reduction is very meaningful for marine environment and ecology protection.

4. Conclusion

In this paper, the hydrodynamics model and convection and diffusion model are employed for the process simulation of multiple river pollution discharge. The optimal method for reduction program is proposed by the nonlinear optimal algorithms. A case study by four main pollution sources in Jiangsu province, China is used to calibrate the method. The research results show that the reduction program is the basis of marine environmental management and it's very meaningful for marine environment and ecology protection.

Acknowledgments

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