A web-site system to simulate sudden water pollution accidents

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Abstract. In this paper, a two-dimensional water quality analytical model of pollutant concentration is used to simulate and respond to sudden water pollution accidents. The two-dimensional water quality model uses river flow rate, the distance from the river point to the place where the pollutant occurred, the pollutant discharge amount, time and other parameters to calculate the river pollutant concentration in the simulated time range of each point of the river. Therefore, through the system designed in this paper, the location of the accident, the amount of pollutants and other information will be collected in time after the accident, and the concentration of pollutants in Jinhua River will change with time in the future. The system will assess the water quality of the section and provide an effective means for the decision-making department to provide scientific basis for emergency response and treatment.

1. Introduction

Water pollution prevention and control is centered on improving the quality of the water environment. In accordance with the principles of "priority for water conservation, spatial balance, system governance, and implementation of both forces", the principle of "safety, cleanliness, and health" is implemented, source control is strengthened, water and land resources are coordinated, and both rivers and seas are taken into consideration. The implementation of sub-basin, sub-regional, and stage-by-stage scientific governance of rivers, lakes, and seas will systematically advance water pollution control, water ecological protection, and water resources management [1]. The objectives of the water pollution control action are as follows[2]: By 2020, the national water environmental quality will be gradually improved, serious pollution of water bodies will be greatly reduced, the level of drinking water safety and security will continue to increase, groundwater over-production will be strictly controlled, and groundwater pollution will intensify. Initially curbed, the environmental quality of the offshore waters has stabilized, and the water ecological environment conditions in the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Pearl River Delta have improved. By 2030, it will strive to improve the overall quality of the water environment in the country and restore the functions of the water ecosystem. By the middle of this century, the quality of the ecological environment has been comprehensively improved and the ecosystem has achieved a virtuous circle.

Water pollution is divided into sudden water pollution and persistent water pollution. Sudden water pollution has sudden and serious consequences, which will cause varying degrees of ecological, environmental, social, and human health losses [3-5].
Sudden water pollution accidents are a kind of environmental disasters. According to statistics, water pollution accidents account for 50% to 60% of the total environmental accidents after 2000. Most of them are caused by natural disasters, mechanical failures and human factors. The pollution source deviates from the normal operating conditions and suddenly discharges pollutants and enters the water body through various channels, thereby causing an accident of water environment pollution.

With the increasing scope and scale of modern industrial production, the production, storage, transportation and use of various chemicals and dangerous goods have increased greatly, and the potential danger sources of accidents have also increased, and the threat to the water environment has become more and more significant.

At present, China has done a lot of research on the simulation of sudden water pollution accident simulation and early warning systems, including GIS-based water quality simulation system and sudden accident water quality mathematical model.

Therefore, in order to further strengthen urban water pollution prevention and control work, improve urban surface water environment quality, and ensure urban drinking water safety [6-8], this paper designs and develops a WebGIS-based simulation system for sudden water pollution accidents. The system utilizes a two-dimensional water quality river pollutant diffusion analytical model, and calculates the pollutant concentration, the discharge position, the discharge time and other calculation parameters, and simulates the change of pollutant concentration in the Jinhua River in the future, and through pollution. The object analysis model predicts the adverse effects of changes in river pollutant concentration on the water quality of important sections, and provides scientific basis and technical support for the treatment of sudden water pollution accidents, and realizes the intelligent treatment of sudden water pollution accidents in rivers.

2. Water pollution in Jinhua City
Since the reform and opening up, while Jinhua City was rapidly developing its economy, the water environment also paid a heavy price. In 2012, one-third of the surface water in Jinhua City was inferior V-class, one-third was close to inferior V-class, and only one-third reached the water quality standard of Class III. In June 2013, Jinhua City implemented the general strategy of "promoting transformation and upgrading with water" by the provincial party committee and the provincial government. In February 2014, the province’s "Wuxhui Gongzhi" site meeting was held in Jinhua City, fully launching the "fight for water". Up to now, all ten outbound market sections of Jinhua City have been stable in surface water category III, and the water quality of 42 surface water sections has reached Class IV or above (40 in Class I-III and 2 in Class IV, compared to the same period in 2014, I - Class III increased by 24, Class IV decreased by 5, Class V decreased by 4, and Class V reduced by 15), and the deterioration of the inferior Class V section was completely eliminated. A historic breakthrough was made in water quality improvement; the public satisfaction reached 98%.

To further improve the water pollution situation in Jinhua City, a sudden water pollution accident simulation system was developed. Government personnel can simulate, predict, and analyze sudden water pollution at the Web site.

3. Sudden water pollution accident simulation system

3.1. Two-dimensional water quality model
Any pollutant discharged into the water body satisfies the basic equation of migration and transformation derived from the conservation of mass. For general inland shallow water rivers, it can be considered that there is no mass concentration gradient in the vertical direction. The water quality model can mainly consider the mass concentration changes along the flow direction and the lateral direction. The equation of the two-dimensional water quality model is as follows:

\[
\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} + v \frac{\partial C}{\partial y} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} - kC + \sum S
\]  

(1)
where \( C \) is the mass concentration of pollutants in the river, \( mg/L \); \( t \) is time, \( s \); \( k \) is the degradation coefficient, \( s^{-1} \); \( x, y \) are the longitudinal and lateral distances respectively, \( m \); \( u, v \) are the water flow velocity components in the direction \( x \) and \( y \), respectively, \( m/s \); \( D_x, D_y \) are the turbulent diffusion coefficients in the \( x \) and \( y \) directions, respectively, \( m^2/s \); \( \sum S \) is the sum of all internal sources and sinks.

The actual river is not an infinite water body, but is constrained by the two banks and the bottom of the river. The diffusion of pollutants in the water flow is restricted by the boundary and produces reflection. According to river width, hydraulic characteristics and discharge position, reflection can be divided into single-sided reflection and bilateral reflection. In this paper, the bilateral reflections on both sides of the strait are considered, and the equation is solved by Laplace transform and its inverse transformation. The initial conditions are: \( x = 0, C = C_0; t \to \infty, C = 0 \). If the accident occurs at the origin of the coordinate, the analytical solution of the equation can be obtained:

\[
C(t) = \frac{M}{(4\pi rt)(D_x, D_y)^2} \exp\left(-\frac{(x-ut)^2}{4D_x t}\right) \exp\left(-\frac{(y-vt)^2}{4D_y t}\right) \exp(-kt) + C_0
\]  

where \( C(t) \) is the concentration of river pollutants at \((x,y)\) at time \( t \); \( M \) is the emissions for pollutants; \( h \) is the water level; \( D_x, D_y \) are the turbulent diffusion coefficients in the \( x \) and \( y \) directions, respectively; \( u, v \) are the flow rates in the \( x \) and \( y \) directions, respectively; \( k \) is the degradation coefficient; and \( C_0 \) is the base concentration.

### 3.2. Input parameters

The mathematical principle of the sudden water pollution accident simulation is based on the two-dimensional water quality model and the convection diffusion model. It is necessary to input simulation parameters such as: simulation time, pollution source information, and hydrological conditions. Table 1 shows the list of input parameters.

#### Table 1. Input parameters.

| Calculation parameters | Unit |
|------------------------|------|
| Simulation start time  | /    |
| Simulation end time    | /    |
| Pollution longitude    | /    |
| Pollution emission latitude | / |
| Contaminant category   | /    |
| Pollutant emissions    | t    |
| Degradation coefficient| 1/d  |
| Turbulent diffusion coefficient \( D_x \) | \( m^2/s \) |
| Turbulent diffusion coefficient \( D_y \) | \( m^2/s \) |
| Background concentration| \( mg/L \) |
| South Wangjing flow    | \( m^3/s \) |
| Longyou flow           | \( m^3/s \) |
| Liantangkou flow       | \( m^3/s \) |

#### Table 2. Calculation parameters for the example.

| Calculation parameters | value |
|------------------------|-------|
| Simulation start time  | 2018.3.15 00:00:00 |
| Simulation end time    | 2018.3.16 00:00:00 |
| Pollution emission longitude | 119.782011E |
| Pollution emission latitude | 29.107986N |
| Contaminant category   | COD   |
| Pollutant emissions    | 100t  |
| Degradation coefficient| 0.2 1/d |
| Turbulent diffusion coefficient \( D_x \) | 50m^2/s |
| Turbulent diffusion coefficient \( D_y \) | 0.5m^2/s |
| Background concentration| 5 mg/L |
| South Wangjing flow    | 201m^3/s |
| Longyou flow           | 384m^3/s |
| Liantangkou flow       | 230m^3/s |

### 3.3. System interface

The simulation interface of sudden water pollution accident based on WebGIS is shown in Figure 1. The left side is the Zhejiang Tiantian map (centered on Jinhua City), and the right side is the
emergency simulation interface, including the accident condition parameter setting and planning conditions. The program selection, analysis section selection, and result calculation are four parts.

As shown in Figure 1, the accident condition parameter setting page, including time setting (time setting refers to the time from the start of the accident to the end of the simulation), source strength information, pollutant discharge location, pollutant category (common pollutant category) Including COD-Mn, NH3-N), pollutant discharge, water level conditions (automatically match the boundary site after the accident occurred).

As shown in Figure 2, the planning situation plan selection. For the analysis of the section, the corresponding control measures are to increase the upstream flow or change the pollutant discharge. In the custom scheme, the pollutant discharge and flow rate can be selected at the same time. When clicking the pollutant discharge amount, you can input a value. If you click on the flow rate, you can enter the flow value by adding one line below. Two options can be combined.

Figure 1. WebGIS-based simulation interface for sudden water pollution accidents.

Figure 2. the planning situation plan selection.

As shown in Figure 3, analysis section selection. The analysis section includes the national control, provincial control, and handover sections. The user selects some important sections for analysis to facilitate decision-making.
4. Results: an example of application

The simulation system on the sudden water pollution accident covers major rivers in Jinhua City, including Dongyang River, Wuyijiang River, Jinhua River, Lanjiang River and Lancang River. We have used ArcMap to obtain the latitude and longitude of the boundaries of these five rivers in Jinhua. By entering the values of the input parameters listed in section 3.1 the calculation results are displayed visually. The calculation parameters are shown in Table 2 and a typical result is shown in Figure 4.

In addition to monitoring the concentration of pollutants in the entire river, it is necessary to further analyze key river sections. In this system, all national control, provincial control, and cross-section
profiles have been stored in the database. In the system analysis section selection page, the important sections that need to be monitored are selected for analysis. Typical results of this analysis are shown in Figure 5.

[Figure 5. Sudden water pollution accident analysis results for the example considered in this section.]

The analysis results include statistics on whether the section exceeds the standard, exceeds the multiple, and exceeds the duration, and provides a decision-making basis for handling this unexpected accident. E.g:

(1) The relevant departments can use sandbags and other emergency materials to intercept under the contaminants in the shortest possible time to minimize the pollution.

(2) Increase the flow of pollutants upstream of the site of leakage, making the concentration of pollutants in the river drop rapidly. The monitoring and analysis of the water environment in the accident pollution section shall be strictly carried out, and necessary announcements, chemical treatment and other measures shall be taken depending on the situation, and timely notification shall be made to the downstream water plants and relevant local governments in the downstream of the bridge location according to the magnitude of the hazard degree of the incident, and the water source shall be closely monitored for water intake. According to the actual situation, alternative water supply programs should start, such as alternative water supply sources, or emergency supply of urban tankers.
5. Conclusions
The occurrence of sudden water pollution accidents poses a threat to water resources, especially the pollution of urban water sources will directly threaten the safety of urban water supply and the normal operation of urban economic and social systems. Therefore, when a sudden water pollution accident occurs, the temporal and spatial characteristics of the water pollution group, the route of transmission, and the duration of contamination should be simulated, predicted, and analyzed.

The sudden water pollution accident simulation system can promptly predict the occurrence of sudden water pollution accidents in rivers in Jinhua City over a period of time, as well as predict the impact of river water quality, and perform statistical analysis on the calculation results, and propose solutions to water pollution accidents. The scientific proposal provides an effective means of providing scientific basis for the emergency mobilization and processing of decision-making departments.

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