

DING DING¹, HUIWEN ZHOU¹, WEI YU¹, TIANYI DU¹

RESEARCH ON WATER QUANTITY AND QUALITY MODEL OF THE LANGFANG SECTION OF THE CHAOBAI RIVER BASED ON MIKE11

The water quality of the Chaobai River in Langfang section is relatively poor throughout the year. The water environmental capacity is almost zero, and the surface water is severely polluted, with ammonia nitrogen, total phosphorus, and chemical oxygen demand identified as the primary pollution indicator. This study adopts MIKE11 software to simulate and analyze the water quality and water quantity dynamics of the Langfang section of the Chaobai River. Model parameters are meticulously calibrated and rigorously verified based on the measured hydrological and water quality data collected from the river. The simulation results effectively reflect the actual spatiotemporal characteristics of water quality and quantity within the river reach. The findings of this research can provide a reliable scientific basis and strong technical support for the comprehensive improvement of the ecological environment and the restoration of water functions in the Langfang section of the Chaobai River, thereby contributing to the sustainable development of the regional water ecosystem.

1. INTRODUCTION

Langfang City is located between Beijing and Tianjin, in the mid-downstream of the Haihe River Basin, northeast of the North China Plain, which is a serious resource-type water shortage area. With the development of economy, the acceleration of urbanization and the substantial increase in energy consumption, protecting water resources and improving surface water quality have become the top priority of society. As one of the main rivers in Langfang City, the Chaobai River is in the east of Beijing and Hebei Province. Its upper reaches consist of the Chaohe River in the east and the Baihe River in the west. The Langfang section is in the lower reaches of the Chaobai River, with a total length of about 28.9 km. The water area of the Langfang section of the Chaobai River undertakes the domestic sewage and industrial wastewater of Beijing all year round. Due to the low

¹Civil Engineering Department, North China Institute of Aerospace Engineering, Langfang 065000, China, corresponding author H. Zhou, email address: jane860523@126.com

precipitation, the water quality is poor from January to May, and the comprehensive pollution index is high. After entering June, when the flood season comes, the water quality is better due to the dilution and purification of the river water by the increase in precipitation, the superstandard multiple of pollutants quickly becomes smaller, and the comprehensive pollution index is relatively low. After the flood season, with the rapid decrease of precipitation, the concentration of pollutants increases, the water quality deteriorates, and the comprehensive pollution index also increases gradually. In particular, the data of ammonia nitrogen in recent years are all higher than the permissible concentration for class V water (the worst water class).

The Chaobai River is a seasonal river, and in non-flood season, it mainly carries local sewage and sewage from upstream Beijing. The increase in precipitation can dilute and purify the river water, and the water quality is better. On the contrary, when precipitation decreases, the water quality becomes poor. There are Sanhe Rubber Dam and Sanhe Yanjiao sewage treatment plants in the Chaobai River. According to the survey data of the sewage outlet of the river in the past years, the main pollution indicators are ammonia nitrogen, chemical oxygen demand (COD), total phosphorus, and the other indicators have different degrees of exceeding the standard. By using MIKE11 software to simulate and analyze the water quantity and water quality of the Langfang section, this study reveals the spatiotemporal distribution characteristics of water environment and provides scientific basis for pollution control and ecological restoration [1, 2].

2. WATER QUALITY ANALYSIS AND MODELING METHODS

Li et al. [3] selected the reclaimed water recharge reach of the Chaobai River in Beijing as the research object and analyzed the water quality in different seasons by means of cluster analysis, discriminant analysis and factor analysis. The results show that the water in the study area is seriously polluted by nitrogen and phosphorus, and the water quality varies in different seasonal scales and is affected by reclaimed water replenishment and wetland purification at spatial scales. Li et al. [4] used WASP7.3 water quality model to simulate the water environmental quality in Chengde section of the Chaobai River Basin, and the study clarified the variation law of water environmental quality in Chengde section of the Chaobai River basin. The results show that domestic source pollution contributes the most to ammonia nitrogen concentration in Chaohe River basin. Taking Miyun Reservoir of Beijing and its upstream and downstream the Chaobai River basin as the research object, Hu [5] analyzed the water quality change and its influencing factors through the measurement of water quality indicators and ecological environment investigation. The results show that the water quality of the upper reaches of Miyun Reservoir meets the requirements of drinking water source, and the water quality of individual observation points is different under the influence of the environment. However, some water

quality indicators at downstream sampling sites, such as dissolved oxygen, ammonia nitrogen and total phosphorus, perform better, and the water quality is mainly affected by the environmental governance factors of river channels, indicating that the treated middle water is helpful to improve the ecological environment as landscape water. Qi et al. [6] used the MIKE11 model to establish a hydrodynamic model of the upper reaches of the Hunjiang River from the Northwest Chha Reservoir to the upper reaches of the Huanren Reservoir. Through the simulation of historical floods in 1957 and 2010, the results show that the one-dimensional model has high accuracy and can be used to deduce flood surface lines of other design standards. And the coupling of one- and two-dimensional models is used to simulate the evolution of trough flood. Girbaciuc et al. [7] applied Mike 11 to simulate the amount and quality of water in the Gladna River and Lake Surdod. The results show that, based on the observed values, the model can capture the water quality of the river and can be used to predict the impact of certain pollutants on the Gladna River and Lake Surdod in the future. At the same time, “what if” analysis can be carried out to help decision makers choose the best adaptation strategy. Kanda et al. [8] calibrated the model using discharge and water quality data for 2009 and simulated dissolved oxygen and BOD in the middle part of Lake Victoria after verifying the model with March–April 2013 data. The results show that the model has good performance, with coefficient of determination (R^2), between 0.845 and 0.995, Nash–Sutcliffe efficiency between 0.748 and 0.993, and percentage deviation between 0.7% and 0.9%. The calibration and verification deviations of conductivity, dissolved oxygen and BOD are all less than 10%. Zhang [9] used MIKE software to simulate the hydrology, water quantity, and physical and biochemical processes, on the basis of various water quality biochemical indexes in the Fudian to Tieling section of the Liaohe River Basin. The research results showed that it was feasible to use MIKE software to establish a hydrodynamic model of the Liaohe River Basin and had application advantages in the simulation of the Liaohe River Basin. Xiong et al. [10] continuously monitored surface water and groundwater quality in the source area of the South-to-North Water Diversion Project. The results show that the water quality of the South-to-north water diversion project is excellent. Meanwhile, the mass concentrations of K^+ , Cl^- , HCO_3^- , TH (total hardness), NO_2^- -N and NH_3 -N in groundwater decreased significantly, while pH value increased. Wang et al. [11] established a water quality simulation model for the Jingshi section of the Middle Route of the South-to-North Water Transfer Project based on the hydrodynamic module and convective diffusion module of the MIKE11 model, and on this basis built a transport and diffusion model of pollutants from sudden water pollution accidents in the simulation section. Combined with GB3838-2002 *Standard for Surface Water Environmental Quality* and the simulation results, the pollutants were controlled. The safety of water supply quality can be ensured by opening the drain gate and discharging the pollutants.

The above literature mainly describes a series of studies on the water quality of different rivers and the analytical methods or models used. These studies not only focus on seasonal changes in water quality but also delve into spatial differences in water quality

and influencing factors. By using statistical methods such as cluster analysis, discriminant analysis and factor analysis, as well as water quality models such as WASP7.3, MIKE11 and MIKE, researchers can more accurately grasp the changing rules of water quality, identify major pollution sources, and evaluate the effects of different treatment measures.

Government agencies such as the Water Resources Management Authority and the National Environmental Management Authority shall strictly implement effluent discharge standards, supervise industrial enterprises to follow regulatory requirements and ensure that industrial enterprises and sewage treatment plants comply with the maximum allowable limits of BOD and improve their treatment efficiency. The maximum allowable value of BOD and the improvement of the efficiency of the wastewater treatment plant, thereby improving the water quality of the Nzoya River, which is of great importance to the local environment. The water quality of the Nzoya River is important to the overall management of the Lake Victoria watershed.

Although previous studies have extensively applied models like MIKE11 and WASP to evaluate water quality in various river basins, most of them focused on general pollution trends or single water quality indicators. The main aim of this paper is to construct a comprehensive hydrodynamic and water quality model specifically for the Langfang section of the Chaobai River using MIKE11. The originality of this study lies in its targeted focus on the unique reclaimed water replenishment characteristics of this specific river reach, providing high-resolution simulations of multiple pollutants (COD, $\text{NH}_3\text{-N}$, and total phosphorous (TP)) to support precise local water environment management.

3. METHODS

Construction of MIKE11 model. After the pollutants enter the water body, they are affected by hydraulic, hydrologic, physical, chemical, ecological, climate and other factors in the process of migration, resulting in the transport, mixing, decomposition, degradation and dilution of pollutants. Water quality model is a mathematical description of the law of pollutant change in water environment and the relationship between influencing factors. MIKE software is a newly launched comprehensive software product for water environment simulation, which can provide powerful functional support for the study of river hydrodynamics and environmental simulation. It takes river as the starting point, simulates regional hydrological characteristics, and conducts overall water environment management, analysis and calculation for the region [12, 13].

This project uses MIKE11 software to simulate and analyze the water quality and quantity of the Langfang section of the Chaobai River, rates the parameters of the model according to the actual hydrological data of the river, verifies the model of the Langfang section of Chaobai River, and then obtains the simulation effect and the characteristics of the water quality and quantity of the river section. The aim is to provide scientific basis

and technical support for the comprehensive improvement of river ecological environment and the restoration of aquatic environmental functions in the Langfang section of the Chaobai River.

Profile of MIKE11 software. The water quality model is mainly represented by research of developed countries such as Europe and America, and the water quality analysis model program is the most widely used at present. It can be used in decision-making systems under different environmental pollution conditions to analyze and predict various water quality changes caused by natural and man-made pollution and can simulate the migration and transformation of conventional and toxic pollutants based on river hydrodynamic laws and one-dimensional unsteady flow models [14]. Our country attaches increasing importance to environmental governance technology, and domestic environmental scholars have done a lot of work in water quality model research. Water quality model is mainly used in water quality management planning, water environment pollutant simulation and prediction, water quality evaluation, and water quality monitoring network design. At present, the application of MIKE11 software has developed rapidly and has been widely used in many large hydraulic and hydrological projects both domestically and internationally [15–22].

The MIKE11 hydrodynamic model (HD) is used to build a one-dimensional hydrodynamic model, in which the MIKE11 hydrodynamic model is based on the Saint–Venant equation and the energy equation for the hydrodynamic simulation of river channels and the calculation of structures, and the Abbott–Ionescu six-point finite difference scheme is used for the solution [23, 24]. The formula is as follows:

$$\begin{aligned} \frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} &= q \\ \frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} \left(\alpha \frac{Q^2}{A} \right) + gA \frac{\partial h}{\partial x} + g \frac{Q|Q|}{C^2 AR} &= 0 \end{aligned} \quad (1)$$

where Q is the section flow, m^3/s , A is the river crossing section area, m^2 , q is the single width flow rate of the source and sink, m^2/s , x and t are distance coordinates and time coordinates respectively, h is the water level, m . C is the Xie CAI coefficient, R is the hydraulic radius, m , g is the gravitational acceleration, m/s^2 , α is the momentum correction factor.

The convection diffusion module (AD) is a tool to simulate the convection diffusion process of soluble and suspended substances in water. It is applied to the convection diffusion equation according to the hydrodynamic conditions generated by HD. In the calculation process, a constant attenuation coefficient is set to simulate non-conservative substances and the process of convection and diffusion of substances in water bodies, so MIKE11 AD can be used as a simple water quality model. MIKE11 AD is built based on MIKE11 HD. MIKE11 HD should be built first, and AD parameters and water quality

boundary should be defined based on it [25]. The basic equation of one-dimensional river water quality model is as follows:

$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \partial \left(AD \frac{\partial C}{\partial x} \right) = -AKC + C_2 q \quad (2)$$

There are two parameters to be determined in the water quality equation: diffusion coefficient D , m^2/s , and comprehensive attenuation coefficient K , $1/day$.

Model construction. MIKE11 model consists of five files: River Network, Cross sections, Boundary data, HD Parameters and AD Parameters. The construction process of each file is presented in the following chapters.

The center line vector data of the simulated river reach was obtained from Orwei Map based on the remote sensing image of the earth and the earth map. After processing by ArcGIS software, it was imported into MIKE11 software to generate Network file. The projection coordinate set is WGS_1984_UTM_Zone_50N. As shown in Fig. 1, the horizontal and vertical axes represent the Easting (X) and Northing (Y) coordinates (in meters), respectively, which define the spatial location of the river network. The total length of the whole course is 28,924.58 m.

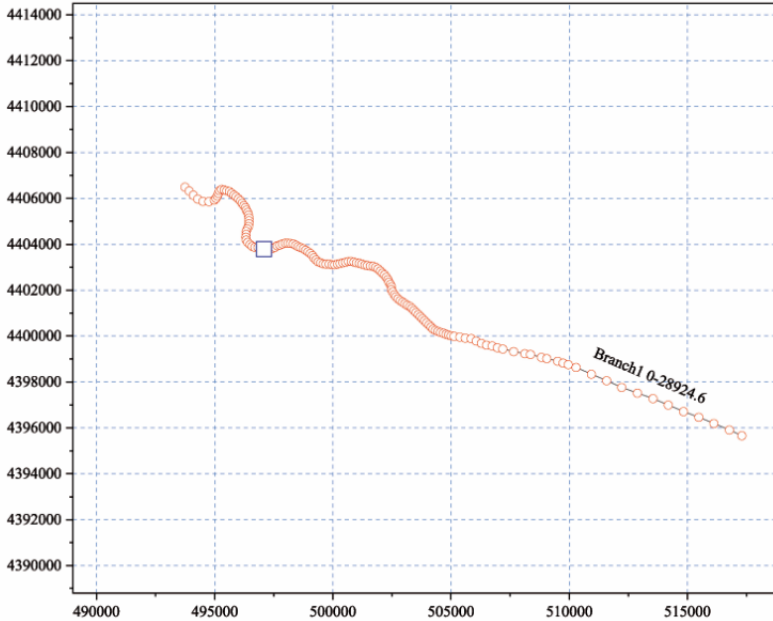


Fig. 1. Spatial distribution of the simulated river reach center line in WGS_1984_UTM_Zone_50N coordinate system (X and Y axes represent Easting and Northing coordinates meters)

Overview of the entire section of the Chaobai River in Langfang are as follows: longitude: 116°45'E to 117°12'E, latitude: 39°36'N to 40°00'N. Commonly used hydrological station Ganshui Dam Station has the following coordinates: 116.95°E, 39.76°N. The dam is located 6053 m downstream from the starting point of the river section. The structure consists of a broad-crested weir and a culvert system. The weir serves as a roadway with a crest elevation of 17.4 m and a bottom elevation of 11.2 m, spanning a width of approximately 300 m. Under normal operating conditions, the weir typically remains unsubmerged. To simulate energy losses accurately, a flow resistance coefficient of 0.5 was applied. Additionally, the hydraulic facility includes a culvert system comprising 42 circular pipes, each with a diameter of 1.2 m. These parameters were defined based on the engineering design data to ensure the model reflects the actual hydraulic behavior of the facility.

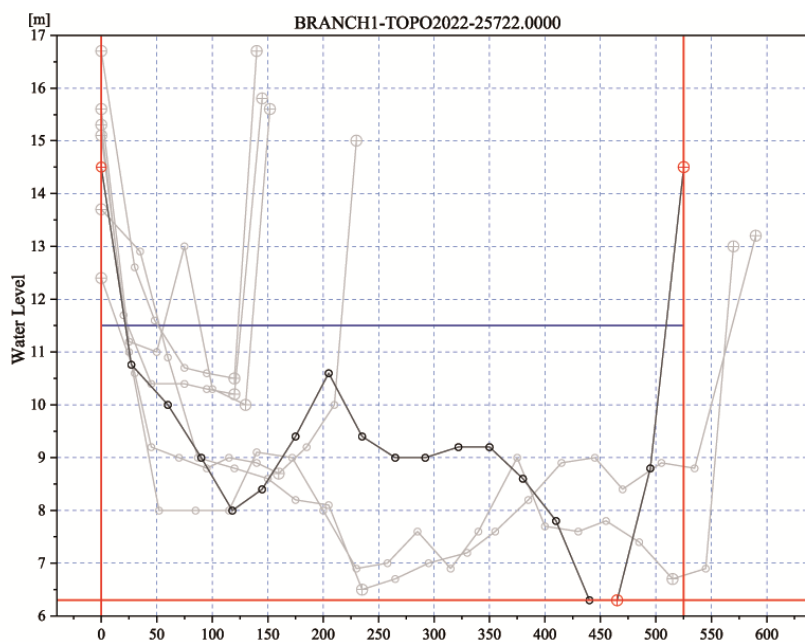


Fig. 2. Representative river cross-section showing the bed elevation and the design water level (blue line)

Due to the lack of measured river cross-section data, Digital Elevation Model (DEM) data with a resolution of 30 m were obtained from the geospatial data cloud. ArcGIS software was utilized to extract the river width and elevation profiles for each section. Subsequently, the extracted data were imported into MIKE 11 to generate the cross-section files. Figure 2 illustrates a representative cross-section derived from this process, where the blue horizontal line indicates the design water level.

In this study, boundary conditions were defined for both hydrodynamic and water quality simulations. The upstream boundary was established at the starting point of the first river section as a flow boundary, utilizing measured discharge data from January to December 2019 obtained from the Hydrology Bureau. The downstream boundary was located at the end point of the reach and defined as a water level boundary. Due to the absence of a hydrological station near the downstream end, measured water level data were unavailable. Considering the hydraulic regulation by slices and dams in the reach, which maintains a relatively stable tailwater level, the downstream water level was set to a constant value of 10 m based on the terrain elevation of the outlet cross-section.

For the water quality simulation, concentration boundaries were specified at both the upstream and downstream ends. Time-series concentration data for three key pollutants – chemical oxygen demand (COD), ammonia nitrogen ($\text{NH}_3\text{-N}$), and total phosphorus (TP) – were imported via external text files (TS1 format). These files provided the temporal variation of pollutant concentrations corresponding to the simulation period, ensuring that the water quality model accurately reflected the inflow and outflow conditions.

Initial conditions for the hydrodynamic simulation were defined to ensure numerical stability during the model spin-up period. It is important to distinguish between water level (the absolute elevation of the water surface relative to a datum) and water depth (the vertical distance from the riverbed to the water surface). In this study, the initial condition was set based on water depth. A uniform initial water depth of 0.1 m was applied across the entire computational domain. This non-zero value serves as a “warm start” condition, preventing numerical errors associated with dry beds or zero-depth calculations in the early stages of the simulation. Other hydrodynamic parameters, such as bed resistance (Manning’s coefficient n) and eddy viscosity, were retained at their default values or calibrated against observed data, specifically setting Manning’s n to 0.025 for the main channel.

Water quality simulation focused on three key pollutants: COD, $\text{NH}_3\text{-N}$, and TP. Initial conditions for these parameters were established based on the mean values of field measurements collected in 2019 as follows: 33.2 mg/dm^3 for COD, 1.1 mg/dm^3 for $\text{NH}_3\text{-N}$, and 0.0 mg/dm^3 for TP.

First-order decay constants (attenuation coefficients) were applied to simulate the natural degradation of pollutants. Based on literature data and model calibration, the decay rates were determined as follows: 0.0008 1/day for COD, 0.0004 1/day for $\text{NH}_3\text{-N}$, and 0.0003 1/day for TP. These coefficients represent the combined effects of biological decomposition and sedimentation under the local environmental conditions.

4. RESULTS AND DISCUSSION

To verify the reliability of the model, it must be calibrated, and the river hydrodynamics and water quality must be calibrated. For calibration, the data from January to December 2019, and partial independent data were used.

4.1. HYDRODYNAMIC SIMULATION

The hydrodynamic simulation was conducted for the period from 1 January 2019 to 1 January 2020, with a computational time step of 2 minutes. The model successfully reproduced the hydraulic characteristics of the Chaobai River Reach.

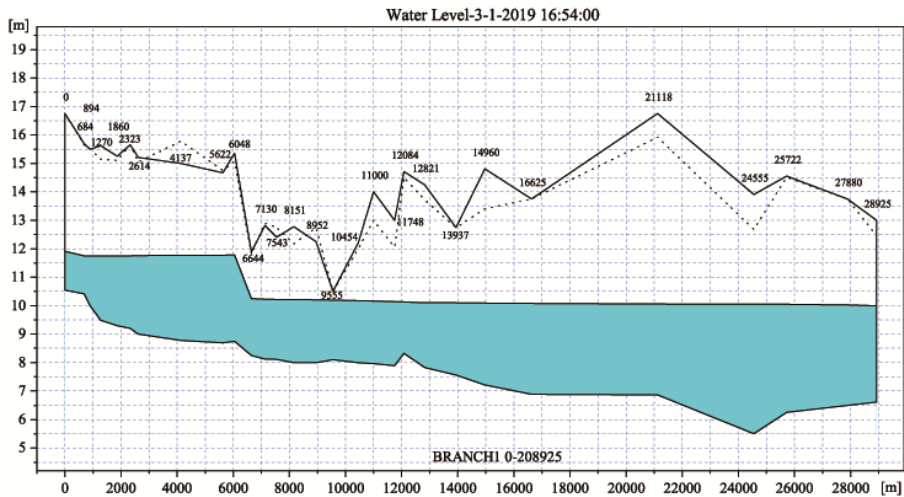


Fig. 3. Longitudinal profile of simulated water level along the Chaobai River reach (0–8000 m) on 15 May 2019; solid line: simulated water surface elevation, dotted line: riverbed elevation, cyan area: water depth distribution

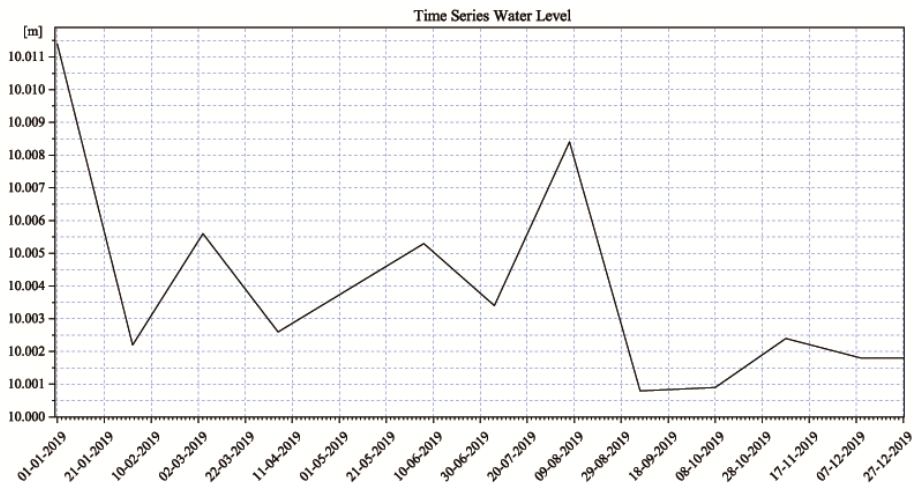


Fig. 4. Temporal variation of the simulated water level at a representative cross-section in the downstream reach (Jan. 2019–Jan. 2020), the peak in May corresponds to snowmelt runoff, low values in July–August reflect dry season conditions

Figure 3 illustrates the longitudinal profile of the water level along the simulated river reach at a specific timestamp (a representative high-flow period). The solid black line represents the simulated water surface elevation, while the dotted gray line indicates the riverbed elevation. The shaded cyan area denotes the water depth distribution. As shown in the figure, the water level fluctuates significantly along the longitudinal distance 8000 m, reflecting the complex topography and flow conditions within the study area.

To analyze the temporal dynamics, a representative cross-section located in the downstream reach was selected for detailed analysis. Figure 4 presents the time series of water level variations in this section during the simulated period. The results show distinct seasonal fluctuations, with peak water levels occurring in May and minimum levels observed during the dry season (July–August).

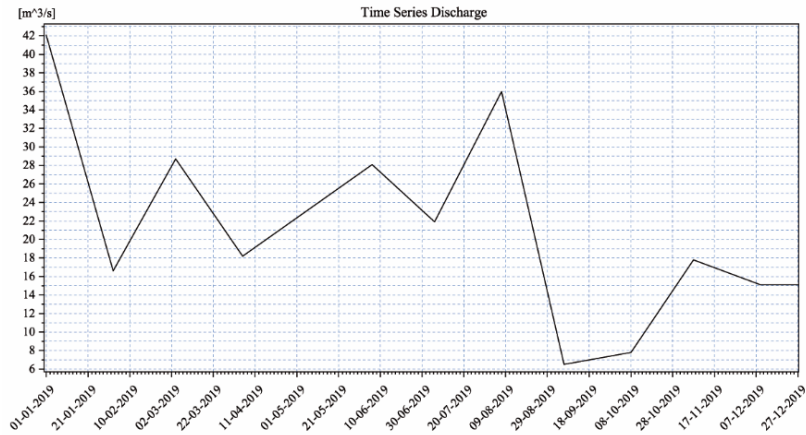


Fig. 5. Simulated discharge hydrograph at the same representative cross-section as Fig. 4; flow peaks coincide with water level peaks, indicating strong hydraulic coupling

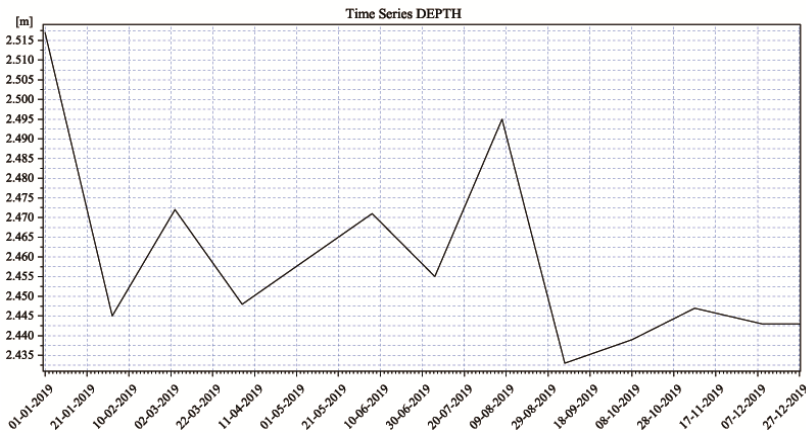


Fig. 6. Simulated water depth variation at the representative cross-section; depth changes mirror water level fluctuations, confirming model consistency in capturing hydraulic dynamics

Correspondingly, Fig. 5 displays the flow discharge variation in the same section. The discharge pattern closely follows the water level trends, validating the model's ability to capture the unsteady flow characteristics. Furthermore, Fig. 6 depicts the changes in water depth over time. The synchronization between water level, discharge, and depth confirms the hydraulic consistency of the simulation results across different parameters.

Considering the self-purification capacity of the river system, a water quality model was established to simulate the temporal and spatial variation of the COD, $\text{NH}_3\text{-N}$, and TP. The model dynamically simulates pollutant transport, diffusion, and attenuation processes in real time, providing scientific support for water quality improvement strategies, sewage outlet optimization, and environmental emergency response planning.

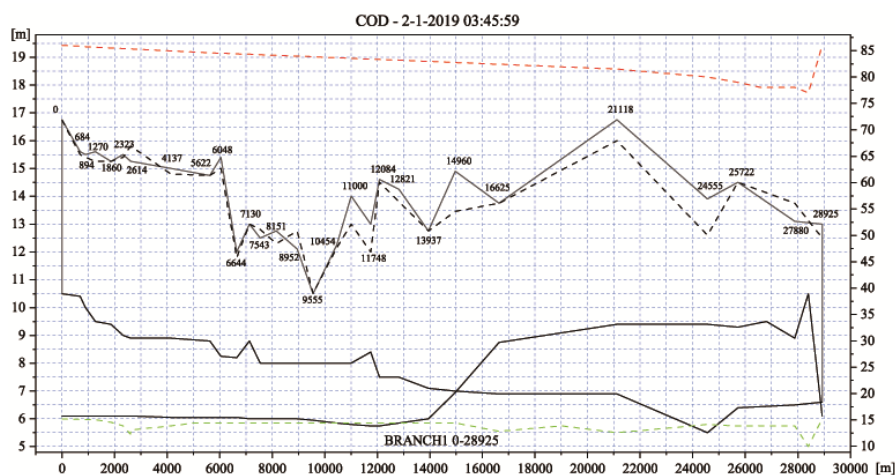


Fig. 7. Longitudinal profile of simulated COD concentration along the Chaobai River reach (0–8000 m) on 15 May 2019; solid black line: COD concentration, dotted gray line: riverbed elevation, cyan area: water depth

Simulation results reveal distinct spatiotemporal patterns across the study reach. As shown in Fig. 7, the longitudinal profile of COD concentration at a representative cross-section on 15 May, 2019, exhibits significant spatial heterogeneity. The solid black line represents the simulated COD concentration (mg/dm^3), while the dotted gray line indicates the riverbed elevation (m). The shaded cyan area denotes the water depth distribution. The fluctuation in COD levels along the river distance (0000 m) suggests localized pollution inputs or varying hydraulic conditions affecting pollutant dispersion.

The temporal variation of COD at a specific monitoring point is illustrated in Fig. 8. The X-axis represents the simulation time from January 2019 to January 2020, and the Y-axis indicates the COD concentration (mg/dm^3). A significant peak is observed around mid-year, likely corresponding to increased runoff or discharge events during the wet season, followed by a gradual decline as the flow stabilizes.

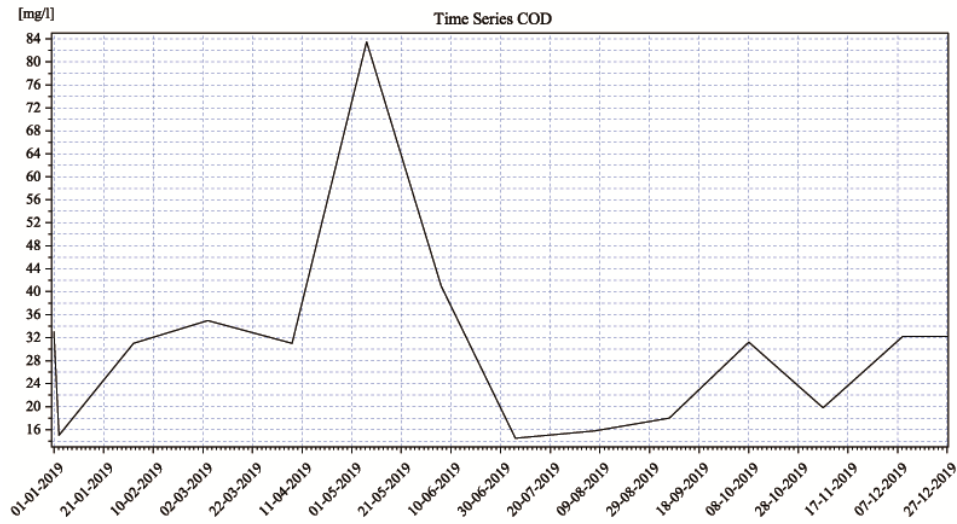


Fig. 8. e Tmporal variation of simulated COD concentration at a raepresentive cross-section during the simulation period (Jan. 2019–Jan. 2020); *X*-axis – date, *Y*-axis – COD concentration in mg/dm³

Similar spatial distribution characteristics were observed for NH₃-N. Figure 9 displays the longitudinal profile of NH₃-N concentration. The continuous red line represents simulated concentration, while the dotted lines indicate the background values or threshold limits. The profile shows a general decreasing trend downstream, reflecting the river’s self-purification capacity and dilution effects.

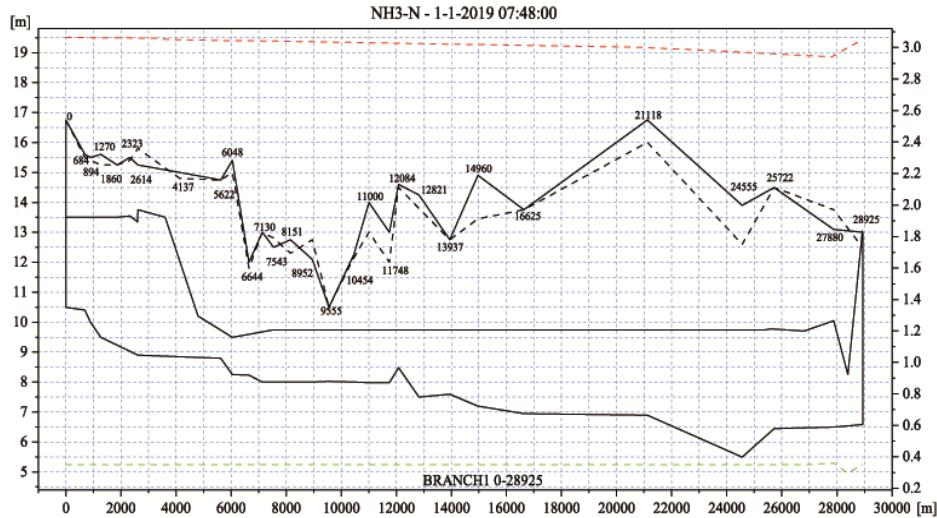


Fig. 9. Longitudinal profile of simulated ammonium nitrogen (NH₃-N) concentration along the river reach; solid red line – simulated concentration, dotted lines – threshold limits

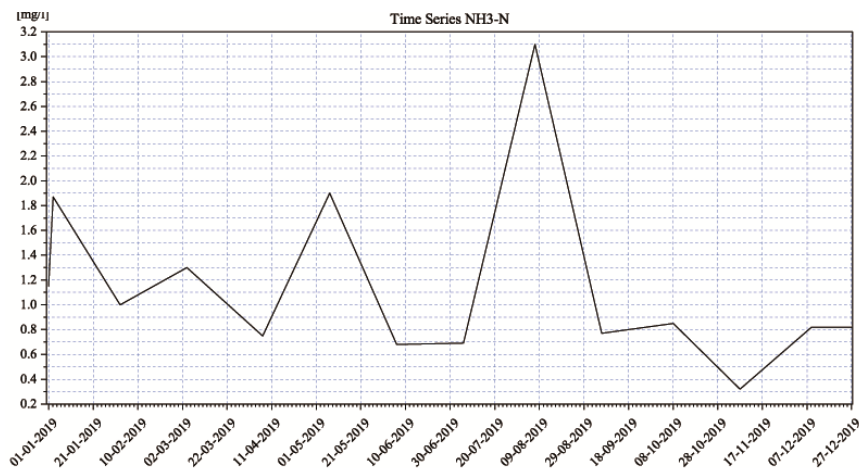


Fig. 10. Temporal variation of simulated ammonium nitrogen ($\text{NH}_3\text{-N}$) concentration at the representative cross-section; X -axis – date, Y -axis – concentration in mg/dm^3

The time-series analysis for ammonium nitrogen is presented in Fig. 10 as the concentrations over the one-year simulation period. Peaks in ammonium levels coincide with periods of low flow or high temperature, which may enhance biological activity or reduce dilution capacity.

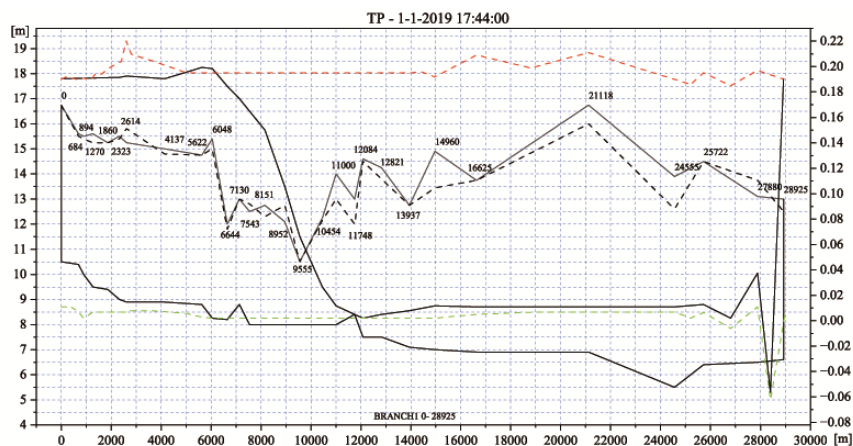


Fig. 11. Longitudinal profile of simulated total phosphorus (TP) concentration along the river reach; solid line – simulated TP concentration

Figure 11 shows the longitudinal profile of TP. The solid line indicates the simulated TP concentration, showing a strong correlation with the hydraulic gradient. High concentrations are observed in the upstream sections, gradually attenuating towards the downstream areas.

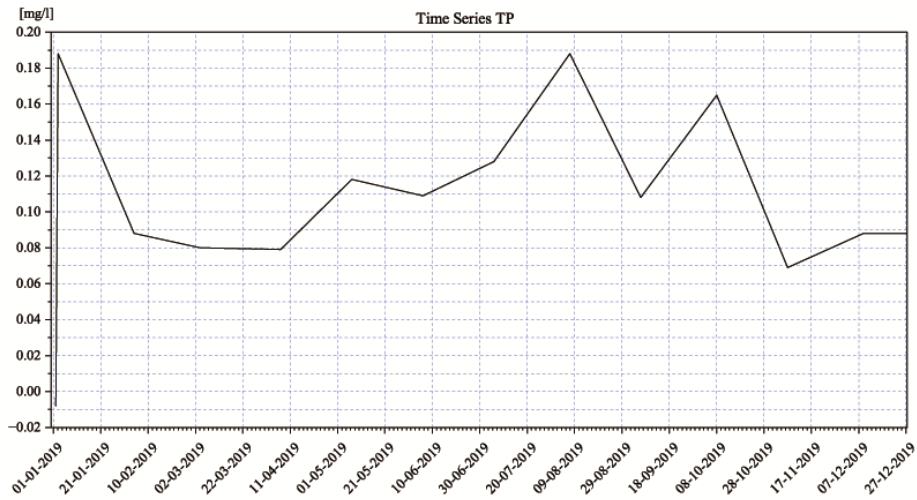


Fig. 12. Temporal variation of simulated total phosphorus (TP) concentration at the representative cross-section; X-axis – date, Y-axis – concentration in mg/dm³

The temporal dynamics of TP are depicted in Fig. 12. The plot highlights seasonal fluctuations, with higher concentrations typically occurring during dry seasons when dilution is minimal. This data is crucial for identifying critical periods for water quality management.

4.2. HYDRODYNAMIC RATE

General water level parameters are determined for hydrodynamic rates (i.e., parameters governing flow velocity, discharge, and water surface elevation dynamics). There is a hydrographic station in the simulated river reach, where measured water level data are found. The hydrographic station is located at 6053 m of the river reach, and the model has a section at 6048 m of the river reach. Therefore, the section water level data at 6048 m of the model is extracted and compared with the measured data. Since there is only one set of data in the measured data every month, the data at the corresponding time point is extracted from the simulated data, and then the analysis is carried out, as shown in Table 1.

Table 1

Simulated and measured water level values

Date	Actual value [m]	Simulatedvalue [m]	Absolute error [%]
4 Jan. 2019	11.99	11.7619	1.9
13 Feb. 2019	11.61	11.5997	0.1
5 Mar. 2019	11.81	11.6593	1.3

Table 1

Simulated and measured water level values

Date	Actual value [m]	Simulatedvalue [m]	Absolute error [%]
3 Apr. 2019	11.63	11.5708	0.5
5 May 2019	12.25	11.6114	5.5
12 Jun. 2019	11.8	11.6449	1.3
3 Jul. 2019	12.03	11.6073	3.6
6 Aug. 2019	11.44	11.7245	2.4
3 Sept. 2019	11.23	11.4541	-2.0
10 Oct. 2019	11.26	11.446	1.6
5 Nov. 2019	11.91	11.5607	3.0
4 Dec. 2019	11.7	11.5448	1.3

Through comparative analysis, the absolute simulation error is less than 6%, the Nash-Sutcliffe efficiency coefficient (NSE) is 0.88, and the determination coefficient R^2 is 0.90, so the calibrated model is reliable and can be used for research simulation.

4.3. WATER QUALITY

The COD simulated value was extracted from the section at 6048 m of the river reach and compared with the measured value (Table 2). The average error is less than 8%, and the maximum error is less than 17%, $R^2 = 0.92$, $NSE = 0.89$. The COD pollutant model was reliable.

Table 2

COD simulated and measured values

Date	Actual value [mg/dm ³]	Simulated value [mg/dm ³]	Absolute error [%]
4 Jan. 2019	15	16.172	7.25
13 Feb. 2019	32	32.9529	2.89
5 Mar. 2019	36	35.4016	1.69
3 Apr. 2019	32	31.5125	1.55
5 May 2019	86	83.4966	3.00
12 Jun. 2019	42	36.018	16.61
3 Jul. 2019	15	17.9834	16.59
6 Aug. 2019	16	15.8064	1.22
3 Sept. 2019	20	18.7285	6.79
10 Oct. 2019	34	32.1602	5.72
5 Nov. 2019	20	20.5873	2.85
4 Dec. 2019	34	30.9475	9.86

NH₃-N simulated values were extracted from the section at 6048 m of the river reach and compared with the measured values (Table 3). The average error is less than 11%, $R^2 = 0.87$, NSE = 0.84. The NH₃-N pollutant model is reliable.

Table 3

Simulated and measured values of NH₃-N concentration

Date	Actual value [mg/dm ³]	Simulated value [mg/dm ³]	Absolute error [%]
4 Jan. 2019	1.92	1.8201	5.49
13 Feb. 2019	1.02	1.1299	9.73
5 Mar. 2019	1.33	1.3069	1.77
3 Apr. 2019	0.758	0.7738	2.04
5 May 2019	1.93	1.9	1.58
12 Jun. 2019	0.661	0.6574	0.55
3 Jul. 2019	0.667	0.6606	0.97
6 Aug. 2019	3.06	3.0184	1.38
3 Sept. 2019	0.8	1.0698	25.22
10 Oct. 2019	0.894	0.8615	3.77
5 Nov. 2019	0.322	0.3607	10.73
4 Dec. 2019	0.839	0.7439	12.78

The TP simulated value was extracted from the section at 6048 m of the river reach and compared with the measured value (Table 4). The maximum error is less than 9%, $R^2 = 0.94$, NSE = 0.92. The TP pollutant model was reliable.

Table 4

TP simulation and measured values

Date	Actual value [mg/dm ³]	Simulated value [mg/dm ³]	Absolute error [%]
4 Jan. 2019	0.19	0.1809	5.03
13 Feb. 2019	0.09	0.0855	5.26
5 Mar. 2019	0.08	0.0796	0.50
3 Apr. 2019	0.08	0.0794	0.76
5 May 2019	0.12	0.1188	1.01
12 Jun. 2019	0.11	0.1136	3.17
3 Jul. 2019	0.13	0.1267	2.60
6 Aug. 2019	0.17	0.1689	0.65
3 Sept. 2019	0.11	0.1171	6.06
10 Oct. 2019	0.17	0.1649	3.09
5 Nov. 2019	0.07	0.0768	8.85
4 Dec. 2019	0.09	0.0864	4.17

5. CONCLUSIONS

With economic development, accelerating urbanization, and a substantial increase in energy consumption, the protection of water resources and the prevention of surface water pollution have become top priorities for society. The Chaobai River is one of the main rivers in Langfang City. Water pollution and water shortage will affect the ecological environment around the river. Through the establishment of water quantity and water quality model, the water level and discharge of the river can be accurately predicted, as well as the water quality of each section, which will provide important data support and guarantee for the water ecological construction and restoration advocated by the country. The river network, hydrodynamic and water quality model established by MIKE11 model adopted in this paper can all reflect the pollution situation of the studied river reach, and the following conclusions can be drawn:

- The MIKE11 hydrodynamic module was used to simulate the one-dimensional model of the Langfang section of the Chaobai River. The simulated river flow fitted well with the measured process line, the simulated water level results were consistent with the measured process line crest, and the errors were all within the allowable range. The simulated water level error is less than 6%, $NSE > 0.85$, $R^2 > 0.90$. The simulation results were reliable and reasonable. The results show that as long as the hydrologic and topographic data are sufficient, the hydrodynamic model of the Langfang section of the Chaobai River established by MIKE software has a good simulation effect, and the model can be applied to predict the water quality and quantity of the Langfang section of the Chaobai River, so as to determine and take effective treatment measures, and provide a feasible reference for future study.

- Based on the established one-dimensional hydrodynamic model, a water quality model was added to simulate and calculate the changes of COD, NH_3-N and TP in the river over time. The model ran well and the results were consistent with the theory, indicating that MIKE11 software could be used to determine the water quality of the Langfang section of the Chaobai River.

- According to the simulation results, it is suggested to strengthen the interception of pollution sources in dry seasons, increase ecological water replenishment, optimize the dispatch of rubber dams, and focus on controlling ammonia nitrogen and total phosphorus loads, so as to effectively improve the water quality of the the Langfang section of the the Chaobai River.

To sum up, MIKE software can achieve good results in the process of simulating water quality, providing scientific basis and technical support for the overall improvement of river ecological environment and the restoration and construction of water function in the Langfang section of the Chaobai River, and at the same time providing scientific basis for optimizing the sustainable utilization of water resources, bringing huge economic and environmental benefits to society. It has great popularization and application value.

ACKNOWLEDGEMENTS

This project is supported by the Science and Technology Research Project of Colleges and Universities of Hebei Province (Project No. ZC2023139, *Model Study of Water Quantity and Quality in the Lower Reaches of the Longhe River*), the Science and Technology Research Project of Housing and Urban and Rural Construction of Hebei Province (Project No. 172, *Carbon Emission Reduction Technology Research of Urban Sewage Systems*), and the Research Project of Hebei University of Applied Technology (Project No. JY2023182, *Research on Student-Centered Teaching Methods*).

REFERENCES

- [1] WANG Q., *Prediction of water temperature as affected by a pre-constructed reservoir project based on MIKE11*, J. Clean Soil, Air, Water, 2013, 41 (11), 1039–1043. DOI: 10.1002/clen.201200066.
- [2] CHIBOLE K., SITTERS C., *Development of a hydrodynamic model for River Sosiani*, J. Environ. Earth Sci., 2013, 3 (9), 29–30.
- [3] LI H., DI Y., LI D., LIAN J., GUO X., *Spatial and temporal variation of water quality in a wetland-reclaimed water-supplied purification urban river: Case study in Chaobai River of Beijing*, Res. Environ. Sci., 2017, 30 (10), 1542–1552. DOI: 10.13198/j.issn.1001-6929.2017.02.93 (in Chinese). .
- [4] LI H., LI Q., WANG H.H., et al., *Research on domestic source ammonia nitrogen pollution in Chengde Section of Chaobai River Basin*, J. Urban Constr. Theory, 2016, 13, 3001 (in Chinese).
- [5] HU Y.K., *Water quality analysis and environmental influencing factors in Miyun Reservoir Basin of Chaobai River*, J. Water Res. Dev. Manage., 2016, 4, 63–67 (in Chinese).
- [6] QI W.B., DING M., *Application of one-dimensional numerical simulation of Hunjiang River channel in Jilin Province based on MIKE11 model*, J. Jilin Water Conservancy, 2017, 8, 34–37 (in Chinese).
- [7] GIRBACIU A., GIRBACIU C., PETCOVICI E., DODOCIOIU A.M., *Water quality modelling using MIKE 11*, J. Rev. Chim., 2015, 66 (8), 1206–1211. DOI: 0.37358/Rev.Chim.1949.
- [8] KANDA E.K., KOSGEI J.R., KIPKORIR E.C., *Simulation of organic carbon loading using MIKE 11 model: A case of River Nzoia, Kenya*, J. Water Pract. Technol., 2015, 10 (2), 298–304.
- [9] ZHANG S., *Research on establishing water quality model of Liaohe River Basin based on MIKE software*, D. Northeastern University, 2013 (in Chinese).
- [10] XIONG X.Y., LIU L.C., GUO M.L., *Analysis on groundwater quality of Chaobai River water source of South-to-North Water Diversion project*, J. Beijing Water Res., 2018, 3, 13–16. DOI: 10.19671/j.1673-4637.2018.03.004 (in Chinese).
- [11] WANG X.W., CHEN J.J., ZHENG H.L., *Study on transport and diffusion of pollutants from sudden water pollution accident in Jingshi Section of Middle Route of South-to-North Water Transfer Project*, J. Water Res. Prot., 2015, 31 (06), 103–108. DOI: 10.3880/j.issn.1004-6933.2015.06.017.
- [12] KEILHOLZ P., *Water supply and distribution in the ancient Decapolis city of Gadara*, J. Water History, 2017, 9 (2), 147–168.
- [13] YOUSEFI P., NASER G., MOHAMMADI H., *Surface water quality model: Impacts of influential variables*, J. Water Res. Plan. Manage., 2018, 144 (5), 04018015.
- [14] WANG Y., *Application of MIKE11 water quality model in water quality improvement scheme of river basin: A case study of Shending River in Shiyan City*, J. Guangdong Chem. Ind., 2011, 12 (9), 169–171 (in Chinese).
- [15] GUO Z., TANG X.W., *Change based on MIKE model and water quality improvement assessment*, J. Water Res. Dev. Manage., 2022, 12, 45–52 (in Chinese).
- [16] CHI J., SUN Y., ZHANG Y., et al., *MIKE11 model in water quality research of Songhua River in Jiamusi City*, C./IOP Conference Series: Earth and Environmental Science. IOP Publishing, 2020, 526 (1), 012054.

-
- [17] LI Q., GUO S., ZHANG R., YAN X., ZHANG X., *Application of MIKE11 model in the study of water quality improvement in the Pearl River Delta network area*, J. China Rural Water Res. Hydr., 2023, 5, 10–16.
 - [18] KANDA E.K., KIPKORIR E.C., KOSGEI J.R., *Modelling of nitrates in River Nzoia using MIKE 11*, J. Water Pract.Technol., 2017, 12 (1), 217–223.
 - [19] GIRBACIU A., GIRBACIU C., ROSU S., *Water quality modeling of Bega River using MIKE 11*, J. Mater. Plast., 2016, 53 (3), 533–536.
 - [20] WANG L.Y., *Study on the application of Denmark MIKE11 hydrodynamic module in river network simulation*, J. China Water Transp. (Acad. Ed.), 2007, 7 (2), 106, 107.
 - [21] GU J.R., XU Z.X., LIN W.Q., *Establishment and application of hydrodynamic model of Suzhou River System*, J. Shanghai Environ. Sci., 2002, 21 (10), 606–609.
 - [22] LIANG J., YANG Q., SUN T., et al. *MIKE 11 model-based water quality model as a tool for the evaluation of water quality management plans*, J. Water Sup.: Res. Technol. AQUA, 2015, 64 (6), 708–718.