Using Arc GIS to explore the impact of environmental and ecological factors on water body

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Abstract: As water pollution is more and more serious, ArcGIS is proposed to explore the impact of environmental and ecological factors on water. Taking the river water quality as the research object, this paper simulates and analyzes the endogenous and non-point source pollution and water quality through indoor physical model experiment, hydrological and water quality numerical model and water quality numerical model, and analyzes the impact of different environmental changes on river water quality and pollution sources from micro and macro perspectives. The main contents include: experimental study on the influence mechanism of overlying water velocity, disturbance and water temperature on sediment endogenous release, construction and simulation of watershed non-point source pollution model, construction and simulation of watershed river water quality model, as well as the impact of environmental change on river water quality and quantitative analysis of river pollution sources.
Keywords: ArcGIS technology; Environment; Ecological factor; Water body; Water environment quality
Tob Regul Sci.™ 2021;7(6): 6247-6261
DOI: doi.org/10.18001/TRS.7.6.102

0. Introduction

Water is the source of life and the most important natural resource for human development. The quality of water directly affects people's life and the pursuit of beauty. With the development of economy, the increase of human activities, global warming, the increase of extreme environment, water quality problems become more and more obvious. A large number of pollutants containing nitrogen, phosphorus and other nutrients enter the water body. When the pollutants exceed the water environment capacity, the growth of aquatic animals and plants will be abnormal [1]. According to the 2018 National Water Environment Bulletin, among the 1935 water quality monitoring sections, class IV-V and inferior class V accounted for 18.9% and 6.9% respectively; among the 111 major lakes (reservoirs) monitored, class IV-V and inferior class V accounted for 25.2% and 8.1% respectively, and the main pollutants were total phosphorus, chemical oxygen demand and ammonia nitrogen. At the same time, urban rivers and lakes in China are mostly surrounded by blocks, and a large number of pollutants are discharged into the water body, which is also prone to serious eutrophication.

Water pollution sources are mainly divided into external and internal sources. The external pollution is mainly divided into: (1) point source, which mainly comes from urban domestic sewage and industrial pollution discharge. Rural residents are relatively scattered, and domestic sewage is not easy to be treated centrally. (2) Non-point sources mainly come from agricultural runoff pollution, livestock and poultry breeding, aquaculture, etc. In China, the annual use of pesticides is more than 1 million tons, while the plant absorption rate is only 10% ~ 20%. The annual use of chemical fertilizers is more than 40 million tons, and the effective utilization rate is less than 40%. A large number of chemical fertilizers and pesticides are lost in soil and surface water, which poses a serious threat to river water quality [2]. At the same time, the rapid development of animal husbandry also led to a large increase in livestock and poultry excretion, which also made a huge contribution to the nitrogen and phosphorus nutrients in the river. Endogenous pollution mainly comes from sediment (or sediment). Sediment is the terminal point of many pollutants in water. Some pollutants will be adsorbed on the surface of particulate matter, and the other part will directly settle to the bottom of water. Under certain conditions, pollutants can be released from the sediment to the overlying water, becoming the so-called "Secondary Pollution", which is a potential source of water pollution that can not be ignored. The results showed that the internal pollution of West Lake and Chaohu Lake accounted for more than 40% and 20% of the external pollution, respectively, and the contents of nitrogen and phosphorus in Dianchi Lake were even more than 80% in the sediments [3]. Guanting Reservoir in Beijing and Shenzhen reservoir are relatively good reservoirs for water quality protection. They are still faced with the problem of seasonal variation of water quality caused by endogenous pollution. Endogenous pollution has become one of the hot issues of water environment research in the world.

In recent years, the state has attached great importance to the control of water pollution discharge and the protection of drinking water sources. The pollution discharge has been controlled to a certain extent. The proportion of point source pollution in water pollution is gradually decreasing, and non-point source pollution has gradually become the number one pollution source of water environmental degradation.

In order to improve the quality of surface water, it is necessary to find out the size of various source strengths, control the pollutants from the source, and reasonably plan the necessary discharge methods. Both internal and external pollution, including the self-purification ability of surface water, are closely related to external environmental factors [4]. Based on this, this paper analyzes the internal pollution of water body, non-point source pollution of river basin and water quality of river through the experiment of sediment internal release mechanism, coupling watershed hydrological and water quality mathematical model and surface water quality migration and transformation mathematical model. Different environmental scenarios are set up and simulated to explore the effects of different environmental conditions on the endogenous release of sediment and the water quality of the river. Quantitative analysis of river water pollution sources and formulation of reasonable discharge planning provide a scientific basis for water pollution remediation and control, which is of great significance for the protection of water quality in water supply source areas and the sustainable development of water environmental functions [5].

At the same time of model development, many countries have achieved fruitful results in water environment management and prevention. Forst of Belgium first put forward the concept of water environmental capacity in the 1930s, that is, the maximum amount of pollutants that a water body can receive without external damage [6]. Since the 1970s, countries around the world have gradually introduced pollution control policies, among which the total maximum daily load (TMDL) policy of the United States is more advanced, and it is also widely used in the United States and many countries. Since the 1970s, China has also started the research of water quality management in basin. In the initial stage of implementation, the main methods are terminal treatment, concentration control, etc., but this method will cause a large number of low concentration pollutants discharge and the accumulation of source pollution. After years of policy adjustment and the development of pollution control research, the total amount control target has gradually changed from multi index control to individual index control, and the measures have changed from city and region control unit to basin control unit to implement water environment quality management, around water quality simulation, water environment function zoning, water environment capacity calculation and so on [7], so as to gradually form a relatively complete basin water quality management and control system. China's total amount control management is mainly divided into three categories, including industry total amount control, target total amount control and capacity total amount control. Industry total amount control is based on the rational use of energy resources to limit the total amount of pollutants discharged by various industries, so that the total amount of pollutants discharged reaches the standard. The target total amount control is to control the limited discharge of water pollution according to the water quality management regulations by taking the environmental management target as the control base point and the input quantity of pollutants carried by the water body as the target. The control target of this method is simple, the environmental data is fully utilized, and the process is simple, which is the main method of pollution control and management in China. However, there are some problems in the target total amount control method, including the poor correlation between water quality target and pollutant prevention and control, the inter basin pollution disputes in administrative region, and the difference between the total amount of control and allowable emission determined by environmental target, etc. The total capacity control is based on the environmental quality standards. According to the water quality standards to control the total amount of pollution emissions, the pollutant emissions and environmental capacity are estimated, and the pollutant emissions are reasonably distributed, to reduce and control the load of pollutants, so as to manage the pollution. The estimation of environmental capacity and pollutant allocation are the core process of total capacity control, which is also our main the research focus of pollution control in China [8].

Based on the current situation of basin water environment research at home and abroad, it can be seen that although there are corresponding researches on sediment endogenous, non-point source pollution and water environment pollution in the basin, most of these researches focus on single factor or single pollution source, and there are deficiencies in the research on basin as a whole and the impact of environment on pollution source change [9]. In recent years, extreme weather caused by climate change has a huge impact on the water environment. However, previous studies on the non-point source pollution of basin and water environment model have underestimated this aspect. Most studies only use the simulation results after verification to allocate pollution emissions, ignoring the differences between environmental change and seasonal change.

In view of the impact of non-point source pollution and endogenous pollution on water environment quality and the difficulty of control, this paper discusses the mechanism of endogenous release of sediment and the release law under different environmental conditions by combining indoor mechanism test, hydrological and water quality numerical model of non-point source in the basin, water environment numerical model of the basin water body and water environment management. The non-point source pollution model and water environment model of Rappahannock River Basin are used to predict the impact of various environmental and ecological factors on water environment quality; the pollution sources of Rappahannock River Basin are analyzed to provide theoretical basis for water pollution control and management.

1. Construction of hydrological and water quality model

The non-point source pollution has great harm to the water body of the basin, which will cause the increase of the content of pollutants in the water body, resulting in the deterioration of water quality and eutrophication of the water body. Compared with point source pollution, non-point source pollution has a wide range and strong randomness, which is difficult to monitor [10]. Therefore, it is a very good research method to build hydrological and water quality model of the basin, which can simulate and predict the migration and source strength of pollutants into the river, quantify the pollutants in the river basin, and provide help for water quality evaluation, water quality improvement and restoration of river basin. The research object of this paper is the Rappahannock River Basin in the United States. The terrain distribution of the basin is mainly mountainous and woodland, less agricultural land, and higher degree of urban and rural mixing. The HSPF hydrological and water quality mathematical model has a good degree of terrain simulation and strong applicability for this type of terrain. In this study, HSP is selected from SWAT and HSPF water quality models. Therefore, HSPF is used to model the non-point source pollution of the Rappahannock River Basin in the United States, and to simulate the pollutant index of the main stream of the Rappahannock River.

HSPF model is embedded in BASINS platform, which was developed by EPA in 1988, and the latest version is BASINS4.5. BASINS mainly includes four important parts: GIS integrated analysis tool, tool analysis software, watershed hydrological model and decision support analysis tool [11]. The time-series data structure used by BASINS and HSPF is wdm format file. WDMUtil is an effective analysis and processing tool for wdm data embedded in BASINS. However, in the latest version of BASINS, WDMUtil has been removed. As an alternative, SARA time-series tool is used to process data in this study. SARA time-series tool supports viewing, analyzing, transforming and generating time-varying environmental data. SARA is designed to process large input and output files of HSPF, and can be used for other time series data [12]. SARA is used to process and edit the meteorological data and point source data needed by HSPF model, and store them in wdm format file. Meteorological data include rainfall, evapotranspiration, air temperature, dew point temperature, wind speed, cloud cover; point source data include runoff, sediment, nitrogen and phosphorus and other water quality indicators. Each kind of data has its own specific data set in HSPF model.

WinHSPF is the internal component of the model, which is the visual interface of software running produced by the combination of HSPF model and Windows system. WinHSPF completes the simulation by generating, operating and modifying uci file. uci file is the core file of HSPF model, which stores the pre-processing data and the parameter data set in this model construction. The main modules of HSPF model include hydrological and water quality simulation module in permeable area, hydrological and water quality simulation module in impervious area and surface water simulation module [13]. The auxiliary module consists of sequence data conversion module, sequence data writing module, sequence data operation module and optimization management module.

The construction of HSPF model needs a lot of spatial data and time-series data. Spatial data include DEM, water system map, soil type and land use type. These data can be processed by ArcGIS, and then the raster data and vector layer are imported into BASINS for data preprocessing [14]. Time-series data is the necessary data of HSPF model. It is necessary to edit the meteorological data, hydrological data and water quality data by using time-series data processing software SARA. The data obtained are stored in wdm format file. The spatial data is connected with meteorological data, hydrology and water quality data through BASIN, and jumped to HSPF interface, to set up each module, and run the model to generate uci file. The uci file not only connects the data preprocessing results, but also saves the parameter settings of the model simulation. The simulation results of HSPF model can be visually analyzed by various kinds of drawing software, and the parameters calibration, sensitivity analysis and simulation prediction of water quality indexes such as runoff, sediment and nitrogen and phosphorus can be carried out [15]. The flow chart of the model is shown in Figure 1.

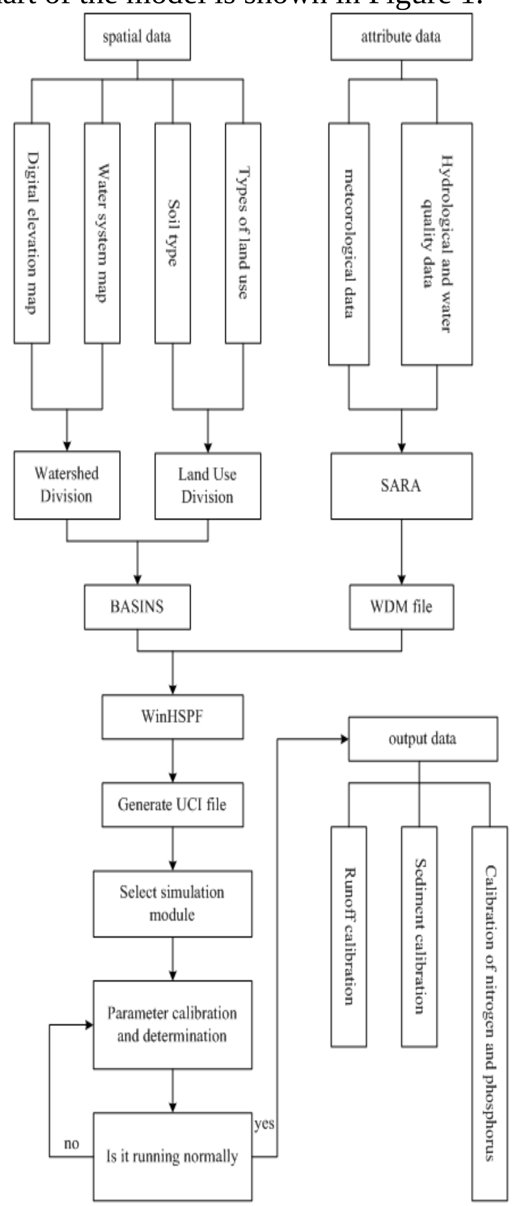


Figure 1 Flow chart of building HSPF model

2. Construction of water quality model

The migration and transformation of water pollutants have a significant impact on the survival of human beings and aquatic animals and plants. In addition to the indoor mechanism test, it is an important process of water protection and pollution control to study the migration and transformation of river water quality in large scale through numerical model. The hydrological and water quality model of the Rappahannock River Basin in the United States has been constructed, which provides a quantitative basis for non-point source pollution into the river. Next, the WASP model of water quality migration and transformation in Rappahannock river will be built to lay the foundation for the simulation and prediction of the spatial and temporal distribution of river pollutants [16].

2.1 Design of model structure

WASP model is a box type dynamic model, which can simulate the temporal and spatial changes of water quality of rivers, lakes and reservoirs. The model divides the water body into grids, and simulates the water quality of one-dimensional, two-dimensional and three-dimensional through the connection of grids, including point source, non-point source pollution load and boundary exchange [17]. WASP model mainly includes river network generalization, hydrodynamic input, water quality transformation and environmental toxicology. The model framework of WASP8 is shown in Figure 2.

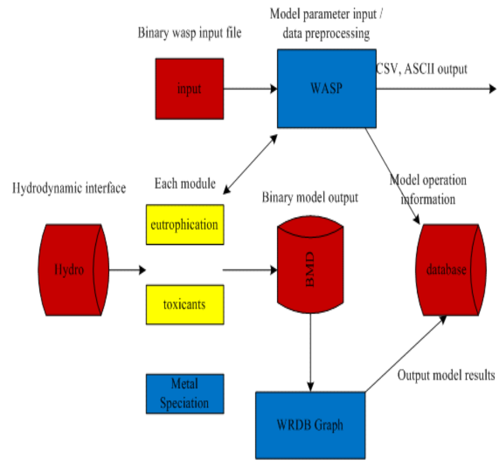


Figure 2 WASP8 model framework

WASP is based on hydrodynamic equation to realize the continuous simulation of nutrients in water, which can track the spatiotemporal changes of various water quality components from input to output [18]. The WASP model needs eight data inputs to simulate nutrients, including simulation and output control, river information, boundary conditions, point source load, hydrodynamic parameters, model constants, time-series function and initial nutrient concentration.

After importing the data required by WASP, HSPF and WASP have been coupled, and can output the pollutant concentration of each river section under the condition of inputting non-point source pollution. Next, the parameters need to be adjusted, and the model is verified by the measured data, so that the model can be constructed reasonably. In this study, helium nitrogen, nitrate nitrogen, total nitrogen, total phosphorus, chlorophyll a and dissolved oxygen are calibrated [19].

The calibration of parameters is very important for the success of WASP simulation. In this study, the trial method is used to set the initial parameters and adjust the trial parameters repeatedly within the range [20].

2.2 Calibration of model parameters

2.2.1 Nitrogen

The main parameters of nitrogen module are shown in Table 1.

Table 1 Main parameters of nitrogen module calibration

Parameter symbol	Parameter definition	Unit	Parameter range	Parameter value
K12	The nitrification rate of ammonia nitrogen at 20°C	d^{-1}	0.01-0.31	0.05
K12T	Temperature coefficient of nitrification	-	0-1.07	0.08
KNIT	Oxygen limited semi saturation constant of nitrification	$mgO_2 \cdot L^{-1}$	0.1-30	2
K2D	The rate of denitrification at 20°C	d^{-1}	.01-0.2	0.08
K2DT	Temperature coefficient of denitrification	-	0-1.07	1.05
KNO3	Oxygen limited semi saturation constant of denitrification	$mgO_2 \cdot L^{-1}$	0.1-2	1
K71	Mineralization rate of dissolved organic nitrogen at 20°C	d^{-1}	0.01-0.2	0.05
K71T	Temperature coefficient of organic nitrogen mineralization	-	0-1.08	0.08
FON	The ratio of endogenous respiration / death of phytoplankton to organic nitrogen, and	-	1	1

	the default value is 1			

2.2.2 Phosphorus The main parameters of phosphorus module are shown in Table 2.

Table 2 Main parameters of phosphorus module calibration

Parameter symbol	Parameter definition	Unit	Parameter range	Parameter value
K83	Mineralization rate of dissolved organic phosphorus at 20℃	d^{-1}	0.01-0.22	0.2
K83T	Temperature coefficient of organic phosphorus mineralization	-	0-1.08	0.2
FOP	The ratio of endogenous respiration / death of phytoplankton to organic phosphorus, and the default value is 1	-	1	1

2.2.3 Dissolved oxygen The main parameters of dissolved oxygen module are shown in Table 3.

Table 3 main parameters of dissolved oxygen module

Parameter symbol	Parameter definition	Unit	Parameter range	Parameter value
OCRB	Oxygen carbon ratio of phytoplankton	$mgO_2 \cdot mgC^{-1}$	2.67	2.67
K2	Atmospheric reoxygenation rate of water body at 20℃	d^{-1}	Dobbins formula	0.03
K2T	Temperature correlation coefficient of reoxygenation rate	-	0-1.03	1.02
SOD	Sediment oxygen	$g \cdot m^{-2} \cdot d^{-1}$	0.1-4	1

	consumption rate			
SODT	Temperature correlation coefficient of SOD	-	0-1.1	1.08
KD	The degradation rate of CBOD at 20℃	d^{-1}	0.01-0.3	0.1
KDT	Temperature coefficient of CBOD degradation rate	$mgC{\cdot}L^{-1}$	0-1.07	1.05
KBOD	Half saturation constant of CBOD		0.1-3	2

3. Scenario prediction of impact of environmental and ecological factors on water quality

Through the coupling construction of two sets of numerical models (HSPF and WASP), the non-point source pollution in the basin is successfully connected with the water body, and the water quality of Rappahannock River is simulated and verified. In the case of global warming, extreme weather is increasing day by day, regional temperature and rainfall may be abnormal, and temperature will synchronously affect water temperature, while rainfall will directly affect river flow and velocity. Therefore, the WASP model, which has been calibrated and verified, is used to synchronously set different temperature, water temperature, river flow and other scenarios based on the original data, to explore its impact on river water quality.

In view of the fact that the annual average temperature change of 5 ℃ in the Rappahannock River is the limit, setting the changes of 1 ℃, 2 ℃ and 5 ℃ can provide certain reference value for future climate change. Based on the actual simulation results, the external temperature and the river water temperature in the upper reaches of the Rappahannock River are increased by 1 ℃, 2 ℃ and 5 ℃ and decreased by 1 ℃, 2 ℃ and 5 ℃ respectively, including the original conditions, and seven scenarios are set. The results of the reach 1 (the downstream boundary of this simulation) and the reach 15 (the midstream position of the river in this simulation) are compared.

The dissolved oxygen content of reach 1 and reach 15 under different temperature conditions is shown in Figure 3. There is a significant change from July to September in 2011, and there is no significant difference in the rest of the time, which indicates that although the change of temperature changes the oxygen consumption rate in the water, the rate of water reoxygenation also changes, reaching a certain degree of balance.

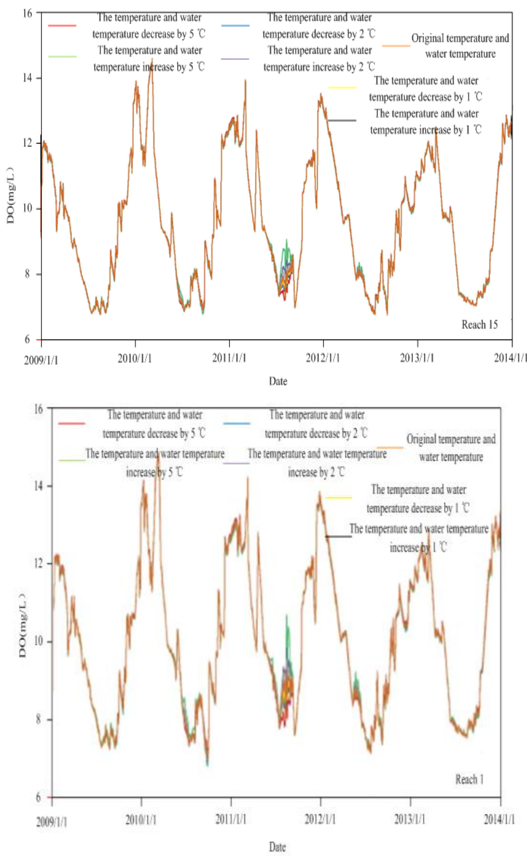


Figure 3 Simulation results of dissolved oxygen at different temperatures

The change of temperature can only change the transformation of ammonia nitrogen, nitrate nitrogen and organic nitrogen, and the transformation of organic phosphorus and inorganic phosphorus. The total nitrogen and total phosphorus do not change under different temperatures. Therefore, the water quality parameters only list the simulation results of ammonia nitrogen and nitrate nitrogen, as shown in Figure 4 and Figure 5. It can be seen that the concentrations of ammonia nitrogen and nitrate nitrogen decrease with the increase of temperature, while the contents of ammonia nitrogen and nitrate nitrogen increase slightly with the decrease of temperature. Compared with the change of nitrate nitrogen, the difference of ammonia nitrogen is more obvious, indicating that ammonia nitrogen is more easily affected by temperature. However, the two water quality indexes are significantly different from July to September in 2011 at different temperatures, which indicate that dissolved oxygen is the main factor leading to nitrogen transformation. Dissolved oxygen increases with the increase of temperature at this time, while ammonia nitrogen decreases significantly. However, the corresponding nitrate nitrogen does not increase, but decreases with the increase of temperature, which indicates that the increase of temperature also promotes the transformation of nitrate nitrogen into other forms of nitrogen.

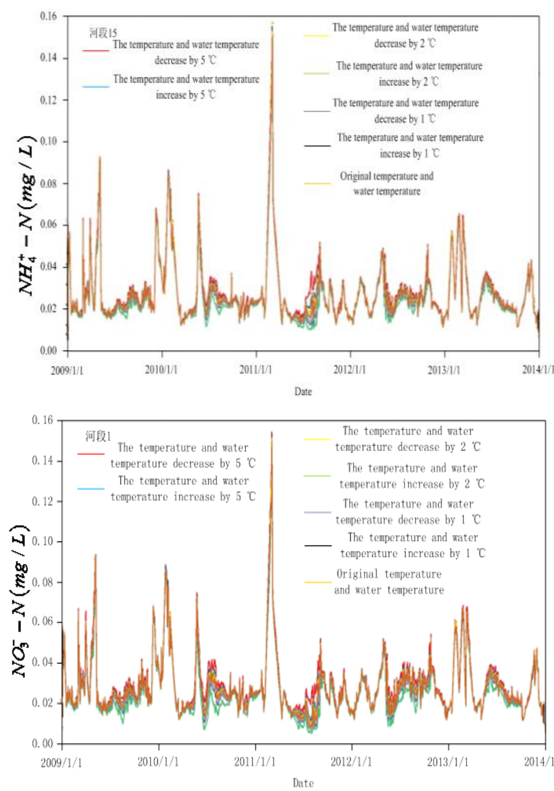


Figure 4 Simulation results of ammonia nitrogen at different temperatures

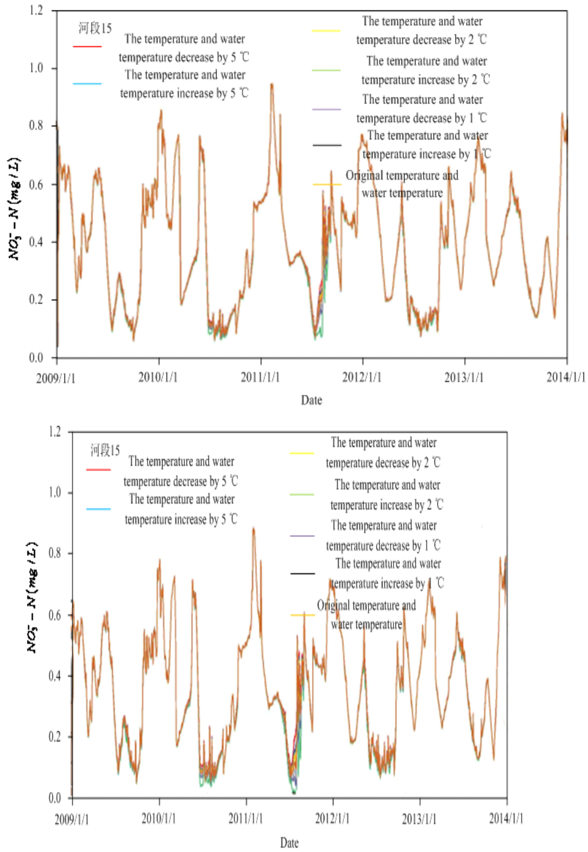


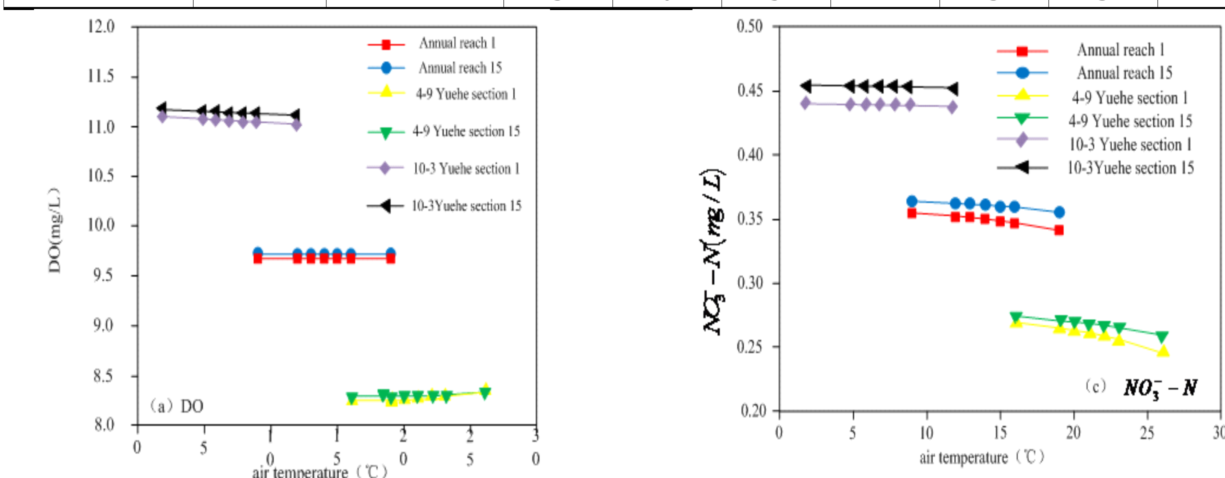
Figure 5 Simulation results of nitrate nitrogen at different temperatures

The effect of temperature has different results in different seasons. There is almost no difference under the condition of low temperature in winter, but the difference is obvious in the summer when the temperature is higher. It shows that there are different effects of basic temperature on water quality for temperature change. Therefore, the whole year is divided into two parts, April to September is summer, and October to march is winter. The results are shown in Table 4 and Figure 6. Because the water temperature data of upstream boundary conditions are discontinuous scattered points, the average value is not representative, and the temperature data is daily average temperature, so the average values listed in Table 4 and Figure 6 are the average values of temperature.

Table 4 Results of different working conditions

Classification	Reach	Index	T-5	T-2	T-1	T	T+1	T+2	T+5
The whole year		Temperature	9.0	12.0	13.0	14.0	15.0	16.0	19.0
	$1(mg·L^{-1})$	DO	9.676	9.667	9.666	9.667	9.668	9.671	9.682
		NH_4^+-N	0.0295	0.0282	0.0278	0.0272	0.0267	0.0262	0.0245
		NO_3^--N	0.3545	0.3520	0.3509	0.3497	0.3483	0.3467	0.3412
	$15(mg·L^{-1})$	DO	9.723	9.715	9.713	9.712	9.712	9.713	9.721
		NH_4^+-N	0.0272	0.0263	0.0260	0.0257	0.0253	0.0249	0.0237
		NO_3^--N	0.3637	0.3621	0.3615	0.3607	0.3599	0.3589	0.3553
April to September		Temperature	16.1	19.1	20.1	21.1	22.1	23.1	26.1
	$1(mg·L^{-1})$	DO	8.252	8.260	8.267	8.276	8.287	8.300	8.346
		NH_4^+-N	0.0275	0.0256	0.0250	0.0243	0.0235	0.0228	0.0203
		NO_3^--N	0.2690	0.2645	0.2626	0.2604	0.2579	0.2551	0.2454
	15(mg·	DO	8.280	8.284	8.287	8.292	8.298	8.306	8.339

	L-1)	NH_4^+-N	0.0253	0.0241	0.0236	0.0231	0.0226	0.0221	0.0204
		NO_3^--N	0.2733	0.2706	0.2695	0.2682	0.2667	0.2650	0.2585
October to March		Temperature	1.9	4.9	5.9	6.9	7.9	8.9	11.9
	1(mg·L-1)	DO	11.107	11.081	11.072	11.063	11.055	11.047	11.024
		NH_4^+-N	0.0315	0.0308	0.0305	0.0302	0.0299	0.0296	0.0287
		NO_3^--N	0.4404	0.4398	0.4396	0.4393	0.4391	0.4388	0.4375
	15(mg·L-1)	DO	11.171	11.151	11.145	11.139	11.132	11.126	11.109
		NH_4^+-N	0.0291	0.0286	0.0285	0.0282	0.0280	0.0278	0.0272
		NO_3^--N	0.4545	0.4540	0.4539	0.4537	0.4535	0.4533	0.4524



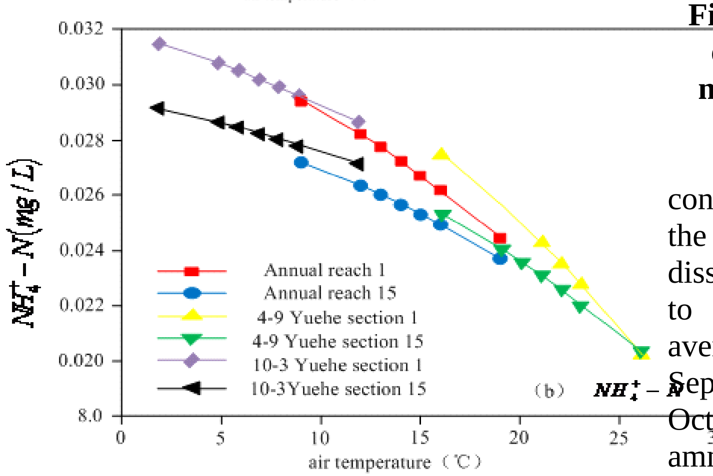


Figure 6 Correlation between dissolved oxygen / ammonia nitrogen / nitrate nitrogen and temperature in different seasons

The difference of dissolved oxygen content in different seasons is obvious, but the change of temperature has little effect on dissolved oxygen content, which may be due to the setting of model parameters. The average temperature from April to September was much higher than that from October to March, and the concentration of ammonia nitrogen and nitrate nitrogen showed different results. At any temperature, the content of ammonia nitrogen in reach 15 is lower than that in reach 1, while nitrate nitrogen is higher than that in reach 1, which indicates that with the river moving downstream, nitrate nitrogen gradually transforms to ammonia nitrogen. On the other hand, non-point source pollution in the downstream carries more ammonia nitrogen, which exceeds the self-purification capacity of the river, resulting in the increase of ammonia nitrogen. From the overall trend, with the increase of temperature, the concentrations of ammonia nitrogen and nitrate nitrogen show a downward trend, and with the increase of temperature, the decline rate is gradually increasing. The lower the temperature is, the greater the difference of ammonia nitrogen concentration between reach 15 and reach 1 is. With the increase of temperature, the difference is narrowing. The average concentration of nitrate nitrogen in summer is much lower than that in winter. Even though the average temperature is similar to that in the whole year, the concentration of nitrate nitrogen is also significantly different, which indicates that temperature is not the only factor affecting nitrate nitrogen concentration. Only focusing on the temperature condition, it can be seen that the sensitivity of reach 1 and 15 to temperature change is higher in summer, with the further increase of temperature, the concentration difference of reach 1 and 15 increases from step to step; but in winter, the sensitivity is lower, the concentration change range of reach 1 and 15 is small, and the difference is almost unchanged.

3. Conclusions

In this paper, Arcgis is used to explore the impact of environmental and ecological factors on water body. The WASP model is used to simulate different environmental conditions. Different simulation conditions are set for the temperature. The results show that the impact of temperature change is different when the basic temperature is different. There is no significant difference in nutrient content when the temperature is lower, but it has a great influence on nutrient content when the temperature is higher. The average temperature is about 14 ℃, which is the most stable temperature of DO. When the average temperature is higher than 14 ℃, the DO content increases with the increase of temperature. When the average temperature is lower than 14 ℃, the DO content decreases with the increase of temperature. The increase of temperature will lead to the gradual decrease of ammonia nitrogen and nitrate nitrogen concentration, and the decrease rate is also gradually increasing. When the average temperature changes 5 ℃, the annual average fluctuation of ammonia nitrogen reaches more than 10%, and the average temperature from April to September is 21.1 ℃. When the average temperature changes 5 ℃, the fluctuation of ammonia nitrogen reaches 16.58%. The prevention and control of ammonia nitrogen pollution in summer should be paid more attention than in winter. Nitrate nitrogen is less affected by temperature, and the maximum fluctuation is only 2.41% when the average temperature changes 5 ℃.

Acknowledgements

General project of Jiangsu Provincial College Students' Practical Innovation Training Program: Ecological Restoration and Landscape Improvement Design of Green Shipping Demonstration Section of the Northern Jiangsu Section of Beijing-Hangzhou Canal -- Taking Huaian Section as an Example "SCX2015"

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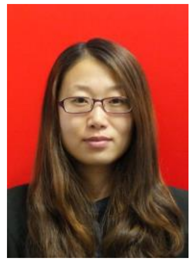

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