Constructing Urban Building Water Environment Governance through Digital Art-Enhanced Big Data Visualization

Chunguang Jia[1*] and Yunqi Jia[2]

[1]Department of Environmental Arts, Jilin Jianzhu University, Changchun, Jilin, 130000, China
[2]Department of Architecture, University of Nottingham Ningbo China, Ningbo, Zhejiang, 315199, China
sayyj2@nottingham.edu.cn

Corresponding Author: Chunguang Jia, ccum@163.com

Abstract. This paper studies the visualization of urban water environment governance based on big data analysis. The nonlinear compensation model based on neural network aims at the error in the process of water quality prediction, and describes the migration and transformation of pollutants in the river water environment by analyzing the causes of river pollution. Establish a visual management system for urban water environment governance. After pretreatment, take it as input data, input it in the training model, and make a prediction. The visual simulation results of the case show that the relationship between runoff and rainfall can be described by runoff coefficient, and the calculated runoff coefficient is 0.326. The improvement rate of ammonia nitrogen in the same water period changes slightly, while the improvement rate of different rivers and different river sections varies greatly, with the change range of more than 25%-93%. It is necessary to strengthen the comprehensive analysis and application ability of big data, continuously improve the systematization, scientification, refinement and visualization level of water environment monitoring, and provide strong support for scientific management of ecological environment.□

Keywords: Big data; Water environment governance; Visualization;Constructing Urban Building; Digital Art-Enhanced.
DOI: https://doi.org/10.14733/cadaps.2024.S11.176-189

1 INTRODUCTION

The society created civilization and produced cities at the same time. In recent years, due to the rapid economic development, the global urbanization process has been accelerated. As an important infrastructure of a city, drainage pipe network collects and transports urban sewage and runoff generated by urban rainfall and snow melting, which has dual functions of environmental protection and urban disaster reduction [7].Water environment improvement projects mainly include river comprehensive improvement, rainwater and sewage diversion pipe network construction, etc. As an important part of it, pipe network construction has many problems, such as numerous participating units, complex data, difficult management and operation, etc., which makes it difficult to control the construction progress and give quick and effective feedback to the problems encountered in the construction process. Among them, the discharge of urban point sources, mainly domestic sewage and industrial wastewater, has been effectively controlled in recent years with the improvement of sewage collection rate and sewage discharge standards. Urban non-point source pollution driven by rainfall has gradually become the main or dominant part of urban water pollution discharge [10],[15].

Water environment is a "public good", because its attribute can't completely exist as a market system, so the government is its direct responsible person and duty-bound. At present, the problems faced by China's water environment governance have something in common: first, the water environment pollution caused by the increasing industrialization of urban economic development is difficult to be effectively curbed; second, the people's awareness and requirements for their own environment, especially the water environment closely related to daily life, are getting higher and higher [18],[19]. China's local government's comprehensive environmental governance capacity still has a lot of room for improvement. The government must straighten out its own environmental governance system and mechanism, come up with practical public policies, and build a scientific and efficient public supply model to rectify the current widespread water pollution problems. However, due to the diversity and complexity of rivers, there are many related plans and methods for harnessing rivers. If only tables, words and other methods are used to count river conditions, loopholes will inevitably appear, which will affect the process of harnessing water pollution and even deepen water pollution. Therefore, it is particularly important to comprehensively deal with relevant river basin information on the basis of traditional methods and modern computer technology [2]. digital art to address water-related challenges in urban areas.

Environmental big data refers to the application of the core concepts and key technologies of big data to the environmental field, and the collection, integration, storage, analysis and application of massive environmental data [17],[5]. It is of great significance to the government, enterprises and the public to analyze the data by using algorithm models and display and publicize the data results through visualization and other technologies to support environmental quality assessment and planning, and it also has the characteristics of large amount of data, weak regularity and wide division, which are basically consistent with the characteristics of big data. This paper studies the visualization of urban water environment governance based on big data analysis. The successful implementation of this project can provide a scientific basis for the municipal government to treat the water environment in Chengdu, and relieve the restriction of water environment problems on the urban economic development. The water environment of most cities in China is polluted to varying degrees, so the work of this paper is of great significance for popularization.

2 RELATED WORK

Water resources have the characteristics of mobility and integrity, so no subject can fully possess the right to own water resources. Water environment exists in the field of people's production and life, which is an indispensable part of people's life and occupies an important position. Liu et al. pointed out that the main water problems faced by developing countries in the process of urbanization are water shortage, high cost, capital, management, water sanitation and concepts, etc. At the same time, they pointed out that it is arduous and long-term to solve these problems, and it is necessary to rely on the comprehensive development of social economy and culture and scientific planning and management [11]. Pavlidis et al., on the basis of analyzing the relationship between supply and demand and management of the existing urban water system, proposed to strengthen the systematic, efficient and circular construction of urban water [13].

With the development of Internet, the breakthrough of IT technology, and the proposal of big data, environmental big data provides a new direction and technology for the solution of major water pollution source evaluation and prediction. Yuan et al. used relevant statistical mathematical models and theories to accurately calculate relevant results from a mathematical point of view [20]; Bai et al. evaluated the comprehensive quality of groundwater in shallow water environment by establishing an attribute recognition model based on entropy weight [1]. Kyei et al. used the method of classifying pollutants first, then studying them in detail to comprehensively treat water pollution, and finally counted out the research results [8]. The corresponding warning mechanism and virtual object are formed by processing a series of data, and then combined with the previous water pollution factors and modern data analysis, it contributes to solving the complexity and severity of water pollution problems.

In order to establish a reasonable water quality model, it is necessary to analyze the evolution law of migration and transformation among various pollutants in water body according to specific hydrological characteristics (such as water flow rate, water flow rate, distribution, etc.), and comprehensively use the knowledge of mathematics, chemistry and physics to describe the concentration distribution of pollutants. Sanchez et al. established a mathematical model of urban water environment connecting water quality, and used it to simulate the movement of sediment in the estuary. The results show that the model has high reliability [14]. Liu et al. considered the influence of wind on water environment and established a two-dimensional water quality model based on the closed boundary caused by wind. In order to improve the management efficiency and save the management cost of reclaimed water utilization, developed countries attach great importance to sewage reuse and visualization construction of reclaimed water utilization [9]. Dai et al. made use of the network analysis function and topology function of GIS, combined GIS with gravity flow sewage pipe network design program to describe the basin condition of underground pipe network, customized the pipe network, and determined the location of sewage pumping station and the route of pressure pipe [4]. Suni et al. set the initial conditions (water depth, discharge and other information), then calculated the mathematical model by computer to get the results, then compiled the results into a text file according to the sequence of flood evolution, and finally combined the calculated results with the pre-established three-dimensional scene by programming, and achieved the effect of flood simulation visualization by controlling the response program [16].

3 RESEARCH METHOD

3.1 Visualization Model of Urban Water Environment Management

The processing flow of environmental big data is generally divided into data acquisition and preprocessing, data storage, data analysis and result visualization. Through sensor, web, bar code, mobile terminal and other data acquisition technologies, and integrated and extracted. Machine learning, big data mining and other methods are used to analyze the monitoring data of water environment quality in the basin, to intelligently identify the water environment risk in the basin, to use a variety of numerical models and a large number of data technologies for assessment and prediction, and to make effective decisions. The data of environmental management business is a kind of data of pollution control to improve the quality of water environment [12],[6]. A large amount of data from the Internet further enriches the contents of the above data. Through multi-factor joint evaluation, space-time analysis and other means, we can gain insight into the new decision-making ability of watershed water environment quality management. Water environment management mainly includes analysis and tracing of water environment pollution, prediction of water environment sensitive points, prediction and early warning of water environment quality, etc.□

Through the big data management cloud platform, the data can be analyzed, compared, summarized and classified, and then transmitted to the client. Because of the big data processing management platform, it is connected with the Internet. Therefore, when the big data management cloud platform is running, first of all, we should ensure the security of information, pay attention to the stability, security, timeliness, authenticity and document shaping of information transmission, and provide reliable data support for data processing.

As an important part of ecological environment big data, surface water environmental quality big data is the general name of numbers, words, tables, graphs and other information that characterize the surface water environmental quality and the types, quantities, quality, temporal and spatial distribution and change rules of its related environmental factors [3]. The complex internal factors and a large number of external factors of surface water system jointly determine its quality. For big data analysis of surface water environmental quality, it is necessary to identify these influencing factors first.

In this paper, the correction factor method is used to correct the rainfall data R converted from radar reflectivity by using the rainfall data G observed by the rainfall station. The basic formula is:

$$R_1(i,t) = R_0(i,t) \cdot B \tag{1}$$

$$B = f(G, R_0) \tag{2}$$

$R_0(i,t)$ is the rainfall (uncorrected) converted from reflectivity at i rainfall station at time t; $R_1(i,t)$ is at the rainfall station i at time t, and the corrected reflectivity is converted into rainfall; B is the correction factor.

When preprocessing the data, it is important to sort out the data and discretely deal with all the monitoring factors of major water pollution sources. In this paper, PKI method is used to discretize the continuous numerical attribute with equal frequency, and MapReduce is used to calculate, and the minimum and maximum values of this pollution factor attribute are obtained, from which the discretization interval width W can be obtained.

$$S \times t = N \tag{3}$$

$$W = \frac{\max - \min}{t} \tag{4}$$

S is the discrete interval size; t is the number of intervals; N is the total number of samples. The maximum value of sample attribute is represented by $\max$, and the minimum value of sample attribute is represented by $\min$.

Because there are usually nonlinear characteristics in water environment, the nonlinear theories and methods commonly used to analyze water environment include: neural network theory, grey system theory, information theory, projection pursuit technology, fractal theory, chaos theory and so on. Because rivers are usually located in urban residential areas, and a large amount of domestic sewage and industrial wastewater are discharged intensively, the dissolved oxygen concentration in rivers is seriously insufficient, which makes the prediction error of linear differential equation model in such rivers larger. The nonlinear compensation model based on neural network aims at the error in the process of water quality prediction, and describes the migration and transformation of pollutants in the river water environment by analyzing the causes of river pollution.

For different neural networks, such as BP neural network. Then:

$$F_1 = \left(R_{i-1}, R_{i-2}, \cdots, R_{i-n}\right) = \sum_{i=1}^{n} \alpha_{i,L} h\left(\sum_{j=1}^{n} \omega_{i,j} - \theta_{j,L}\right) \tag{5}$$

$$F_2 = \left(R_{i-1}, R_{i-2}, \cdots, R_{i-n}\right) = \sum_{i=1}^{n} \alpha_{i,O} h\left(\sum_{j=1}^{n} w_{i,j} - \theta_{j,O}\right) \tag{6}$$

α, ω, w is the weight coefficient of neural network, and θ is the threshold.

In the future, the data collected by the sensors of major water pollution monitoring points in the city will be collected in this big data platform, and the traditional database matching with the sensors will be installed in this server. In order to store the collected data forever, the Sqoop big data synchronization software will be used to synchronize the data in the receiving server in the HBase database of the big data platform at regular intervals.

The big data analysis process of surface water quality consists of factor identification, data selection, data collection, data collation, correlation analysis, model verification and result application. The visual management system of urban water environment management mainly consists of data input function, data management function, data query function and authority management function. The overall framework of the system is shown in Figure 1.

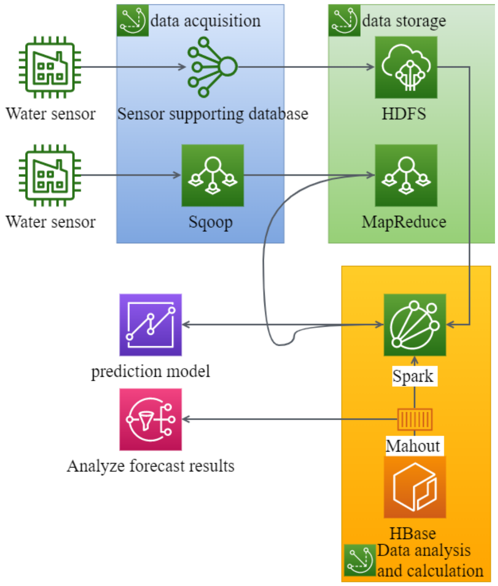

Figure 1: Overall Framework of Visual Management System for Urban Water Environment Management.

Future big data processing will process more data. According to the cluster size, batch processing time can be divided into minutes to hours. If there is an analysis need, real-time data can be obtained in the data center. After preprocessing, it can be used as input data, which can be input in the training model to make predictions.

3.2 Main Function Realization

Visual browsing of reclaimed water utilization. This part mainly relies on ArcGIS Server technology, and carries out front-end development based on Flex platform. WebGIS realizes the networking of GIS, and users can perform common GIS operations such as factor query, statistics, positioning and spatial analysis of reclaimed water utilization information without installing complex client software, thus solving the limitations of traditional desktop GIS management. This part realizes the spatial visual browsing, query and analysis of related geographical elements such as reclaimed water treatment stations, reclaimed water pipelines, reclaimed water intake points, etc. At the same time, the spatial information and attribute information of underground pipelines are provided from many aspects and angles, which provides necessary basic information and technical support for the treatment of emergency accidents such as pipeline burst and the investigation of major accidents in urban safe operation. Using database technology, access and manage the spatial data of pipeline data to ensure the security of data.

Establishment of dynamic water environment. In the simulation of urban water environment, the characteristics and current situation of water environment are highlighted. Therefore, the performance of water is particularly important, which mainly involves the performance of water quality, quantity and pollutants. In the simulation results of urban water environment, the water level changes with the seasons, and there are three water periods: low water period, normal water period and high water period. In order to cooperate with the analysis of simulation results, the method of changing water color is adopted to reflect the change of water quality, so as to visualize the non-visual results. According to the simulation results, the color of urban rivers is changed in real time, and different water quality is reflected by different urban river colors. The changed urban river colors and textures act together to show the water surface effect.

In the water environment simulation system, floating objects in the river can't pass through the river bank and disappear. When users roam, the viewpoint should not pass through trees and walls. When the roaming range is limited, it is forbidden to move forward when reaching the boundary, so collision detection is needed. According to the shape and state of the object, by taking the maximum and minimum values of x, y, z in the world coordinate system, the highest and lowest boundary points can be obtained, thus establishing the bounding box.

After the corresponding bounding box is established for each object, the collision between the two bounding boxes can be easily tested according to the distance between the corresponding center points of the two objects and the three-dimensional dimension (w, h, d) of their bounding boxes. For example, consider that two objects and, the three-dimensional dimensions of their respective bounding boxes are $(w_a, h_a, d_a),(w_b, h_b, d_b)$, respectively, collide when the following conditions are met at the same time:

$$1_x \leq \frac{w_a + w_b}{2} \tag{7}$$

$$1_y \leq \frac{h_a + h_b}{2} \tag{8}$$

$$1_z \le \frac{d_a + d_b}{2} \tag{9}$$

$1_x, 1_y, 1_z$ is the x, y, z component of the distance between two center points. For some objects, the enclosing ball can also be used, and the enclosing ball of the object is the external ball of the object.

In the simulation of urban water environment, the human landscapes of rivers and banks to be displayed are basically static objects. By applying the above methods, the houses and trees are sorted in a certain order, the range values of adjacent objects are selected, and then whether the viewpoint moves or not is judged, and detection is carried out according to the current position of the viewpoint. The process is shown in Figure 2 below.

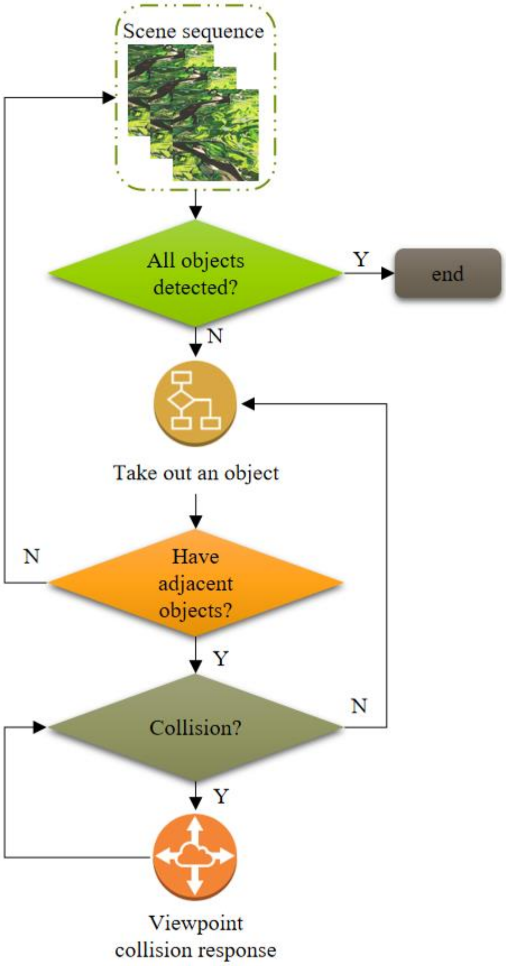

Figure 2: Collision Detection of Viewpoint Based On.

This part is mainly based on ArcObjects component library for secondary development of functions, and develops professional functions according to actual needs. For example, the tracing of pollution sources, the delineation of influence areas, the generation of emergency routes, etc. In addition, the specific flow direction and network analysis can also be used as auxiliary support in the planning, design and engineering transformation of the pipe network. Provide support for emergency dispatch: by using the network analysis function, the best dispatch scheme for dealing with accidents (dangerous situations) can be quickly determined. Provide support for planning and design: provide reliability reference for planning and design of new pipelines, and ensure the rationality of planning and design.

In this study, the method similar to surface deposition is used to define the deposition and scouring rate of pipe network. The basic assumption is that the distribution of pollutants in water and sediment is determined by the balance between sedimentation and scouring, in which the sedimentation rate is constant, while the scouring rate is related to the pipeline velocity. The specific expression is as follows:

$$\frac{dc}{dt} = \frac{r_{wash} - r_{set}}{h + H_{\min}} \tag{10}$$

According to the rules of the actual drainage network, the final discharge port of the pipeline can only be connected to the sewage treatment plant, the chestnut station and the river channel. If this rule is not met, we think that there is a problem with the pipeline data in this section, and it needs to be surveyed and corrected. Effective use of the upstream and downstream tracking functions of GIS can provide a range of reference for decision makers in time, so as to determine the accident source and the strategy of isolating pollution sources in time, thus greatly improving the efficiency of drainage work.

4 ANALYSIS AND DISCUSSION OF RESULTS

The sewage treatment system is time-varying and nonlinear, and the scale and scope of sewage treatment data have far exceeded human intuition. On the basis of analyzing the interrelations and elements of the system, and then carrying out quantitative analysis or experiments to obtain the objective information.

Through the constructed drainage model, this paper estimates the pollution load of urban point source and non-point source in the case area, and identifies the emission characteristics of different pollutants. Through the constructed drainage system model of the case area, the selected 10 typical rainfalls are taken as rainfall inputs, and the non-point source pollution load caused by rainfall runoff (including sewage overflow, etc.) can be calculated by comparing with the situation in dry season. The calculation results under each rainfall are shown in Table 1 and Table 2 below, and the pollution load is shown in Figure 3.

Rainfall scene	*Rainfall (mm)*	*Volume of runoff($10^4 \cdot t$)*	*Overflow amount of sewage($10^4 \cdot t$)*
R1	*49.457*	*46.423*	*1.918*
R2	*73.631*	*33.722*	*1.369*
R3	*31.629*	*67.548*	*2.673*
R4	*68.033*	*61.376*	*3.268*
R5	*44.194*	*73.076*	*2.324*
R6	*66.601*	*30.946*	*2.481*
R7	*19.845*	*39.138*	*2.141*
R8	*49.501*	*59.283*	*0.634*

R9	*33.151*	*69.302*	*2.292*
R10	*15.469*	*18.625*	*3.971*

Table 1: Runoff simulation results.

Rainfall scene	*COD*	*TN*	*TP*	*NH3-N*
R1	*2.972*	*0.083*	*3.739*	*15.211*
R2	*3.907*	*0.207*	*4.145*	*18.256*
R3	*4.017*	*0.175*	*4.214*	*13.161*
R4	*1.981*	*0.129*	*5.63*	*8.798*
R5	*3.87*	*0.298*	*5.471*	*13.942*
R6	*2.223*	*0.125*	*5.146*	*12.294*
R7	*1.806*	*0.206*	*4.084*	*16.944*
R8	*2.238*	*0.349*	*4.513*	*10.091*
R9	*1.841*	*0.284*	*4.272*	*17.926*
R10	*2.932*	*0.323*	*2.924*	*16.849*

Table 2: Pollution Simulation Results.

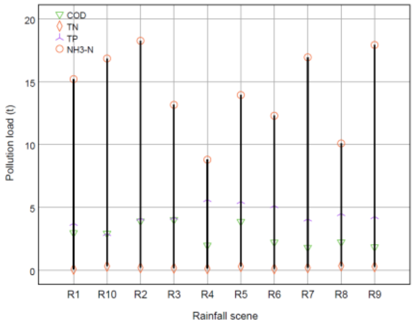

Figure 3: Pollution Load Diagram.

In order to estimate the pollution discharge load in different years, based on the above results, this paper identifies the relationship between rainfall, rainfall runoff and non-point source pollution load. From the above simulation results, the relationship between runoff per unit area and rainfall is shown in Figure 4 below.

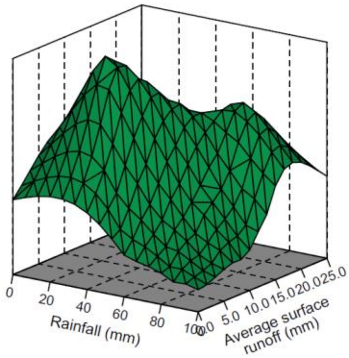

Figure 4: Relationship Between Rainfall and Average Surface Runoff.

It can be seen from the figure that the relationship between runoff and rainfall per unit area is basically linear. Therefore, the relationship between runoff and rainfall can be described by the runoff coefficient, which is calculated as 0.326. It should be noted that the runoff coefficient here is lower than the general runoff coefficient in urban areas, because the runoff here refers to the amount of rainwater and combined sewage discharged into the downstream water body by the drainage pipe network after the rainfall occurs, and some combined sewage is discharged after being treated by the sewage treatment plant. This part is regarded as urban point source pollution, so it is not calculated here.

The main purpose of establishing the water environment decision simulation service system in the central city of the city is to provide medium and long-term services for urban water environment management. However, in the face of the current severe situation of urban water pollution, the most urgent task is to provide decision-making support for the water environment of the central city to reach the standard according to the functional areas.

After the comprehensive improvement of the designed urban water environment is completed, the water quality of the main river tributaries will reach the standard, and the pollution load discharged into the urban water environment will be reduced accordingly. In order to make the input data of three water periods general, the statistical values of monitoring data and historical data are used here. Through simulation, the comparison curve of the effect before and after comprehensive improvement of urban water environment is shown in Figure 5.

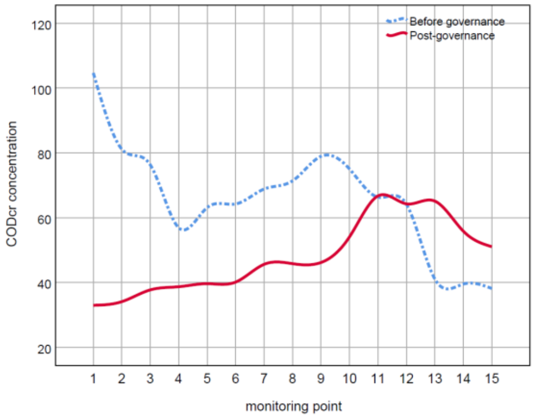

Figure 5: Changes of CODcr Concentration Before and After Comprehensive Improvement of Urban Water Environment.

From the simulation results, it can be seen that after the comprehensive improvement of urban water environment, the water quality at the outlet section of urban water environment is obviously improved, and it has been close to the third class standard of surface water. However, due to the large amount of sewage discharged from sewage plants at the outlet of the main city and the poor water quality of the river water in the case area, the water quality at the outlet of the main city, that is, the neutralization section, is still higher than the five-category standard of surface water. It is suggested to strengthen the management of urban water environment. Further treatment of sewage from sewage treatment plant.

Error compensation first needs to determine the number of neurons, because the number of neurons will affect the calculation speed of system simulation and prediction. If there are too many neurons, it is not conducive to network training. If there are too few neurons, it will affect the prediction accuracy of the model. A reasonable number of neurons should make the model calculation more effective without affecting the prediction accuracy.

In the reconstructed phase space, it can be considered that each neuron in the single layer of neural network represents one dimension of the phase space, so its solution space is the same. The BOD observation data of the upstream and downstream monitoring points in the case area for 20 consecutive days are shown in Figure 6.

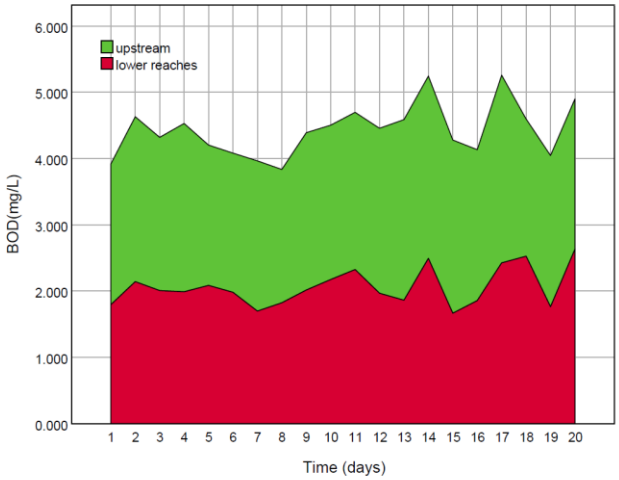

Figure 6: Chart of BOD Observation Data for 20 Consecutive Days.

The formation of water environmental problems is a comprehensive presentation of a series of factors such as history, politics, economy and humanities. In terms of work orientation, it is necessary to shift the focus of water environment governance from water body perception and water quality indicators to water environment quality and water ecological restoration, systematically plan and arrange long-term treatment measures such as river network connection, rainwater and flood management, source control, rainwater and sewage diversion, ecological restoration, etc., and build a long-term mechanism that links construction, management, maintenance and operation with each other to achieve the effect of water-city integration and harmony between people and water. It is necessary to further revise and improve the urban water system planning, urban flood control and drainage planning, formulate urban drainage planning as soon as possible, and earnestly enhance the scientific nature of water environment governance in the light of the economic and social development planning and the overall urban planning.

After the comprehensive renovation of the center, the reduction of ammonia nitrogen concentration in relevant sections in four different water periods is shown in Figure 7. Figure 7 shows that the improvement rate of ammonia nitrogen in different water periods changes slightly, while the improvement rate in different river sections varies greatly, ranging from 25% to 93%. Therefore, the project has obvious reduction effect on ammonia nitrogen index in the central city river.

Actively guide and encourage social forces to widely participate in publicity, river patrol, river cleaning and other activities, and further explore and expand more forms and channels of participation. The first is to implement the project contract mode.

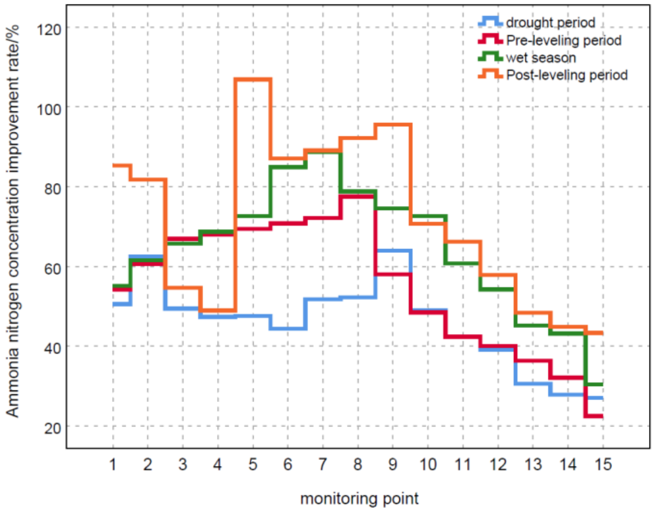

Figure 7: Ammonia Nitrogen Concentration of Main Rivers in Each Water Period is Reduced After Comprehensive Improvement of Urban Water Environment.

While solving the shortage of funds for volunteer teams and social organizations, we will effectively enhance the effectiveness of publicity and education and the scientificity of government decision-making. Water environmental governance is a highly professional work, and the degree of specialization of participants determines the effectiveness of participation. According to the characteristics of different stages and different participating groups, organize the popularization and training of necessary knowledge and skills, provide their necessary knowledge and skills reserves, and continuously improve the specialization degree of participants. Establish a contribution point system for water control. For the participants in water environment control, a point system is implemented according to their participation time and activity types. According to the number of points, corresponding incentives are given, such as rewards in kind and free access to social services, so as to effectively mobilize the enthusiasm of social forces to participate in water environment control.

Big data technology can identify environmental risks timely and accurately, and promote the precision of environmental management. Constantly improving the means of environmental data generation, adopting modern scientific and technological monitoring means such as automatic hydrological and water quality monitoring station, remote sensing monitoring and video monitoring. Accelerate the short board of monitoring network construction, explore multiple application scenarios of big data, and develop and innovate more data applications, scientification, refinement and visualization of water environment monitoring, so as to provide strong support for scientific management of ecological environment.

5 CONCLUSION

Water resources have the characteristics of mobility and integrity, so no subject can fully possess the right to own water resources. Water environment exists in the field of people's production and life, which is an indispensable part of people's life and occupies an important position. The visual management system of urban water environment management mainly consists of data input function, data management function, data query function and authority management function. The visual simulation results of the case show that the relationship between runoff and rainfall can be described by runoff coefficient, and the calculated runoff coefficient is 0.326. The improvement rate of ammonia nitrogen in the same water period changes slightly, while the improvement rate of different rivers and different river sections varies greatly, with the change range of more than 25%-93%. It can convey the simulation results to decision makers intuitively and clearly, which is the purpose of this simulation decision support system.

Chunguang Jia, https://orcid.org/0009-0003-8806-098X
Yunqi Jia, https://orcid.org/0009-0009-2350-4838

ACKNOWLEDGEMENTS

Key technologies and application demonstration of human settlements water environment monitoring in new urban areas， Jilin Provincial Science and Technology Development Plan Project(2020).

REFERENCES

[1] Bai, Z.; Zhao, H.; Velthof, G. L.; Oenema, O.; Chadwick, D.; Williams, J. R.: Designing Vulnerable Zones of Nitrogen and Phosphorus Transfers to Control Water Pollution In China, Environmental Science & Technology, 52(16), 2018, 8987-8988. https://doi.org/10.1021/acs.est.8b02651
[2] Chen, L.; Xu, G.; Rui, Z.; Alshawabkeh, A. N.: Demonstration of a Feasible Energy-Water-Environment Nexus: Waste Sulfur Dioxide for Water Treatment, Applied Energy, 250(1), 2019, 1011-1022. https://doi.org/10.1016/j.apenergy.2019.05.108
[3] Cui, J.; Duan, L.; Zhou, L.; Zhao, C.: Effects of Air Pollution Control Devices on the Chlorine Emission From 410 t/h Circulating Fluidized Bed Boilers Co-Firing Petroleum Coke and Coal, Energy & Fuels, 32(4), 2018, 4410-4416. https://doi.org/10.1021/acs.energyfuels.7b03106
[4] Dai, L.; Lu, Q.; Zhou, H.; Shen, F.; Huang, H.: Tuning Oxygenated Functional Groups on Biochar for Water Pollution Control: a Critical Review, Journal of Hazardous Materials, 420(1), 2021, 126547. https://doi.org/10.1016/j.jhazmat.2021.126547
[5] Fischer, A.; Wezel, A. V.; Hollender, J.; Cornelissen, E.; Hofman, R.; Peter, V.: Development and Application of Relevance and Reliability Criteria for Water Treatment Removal Efficiencies of Chemicals of Emerging Concern, Water Research, 161(15), 2019, 274-287. https://doi.org/10.1016/j.watres.2019.05.088
[6] Ge, B.; Ren, G. N.; Zhao, P. F.; Jin, C. Y.; Zhang, Z. Z.: Preparation of Superhydrophobic Cds Cotton Using Visible Light Response and its Application for the Control of Water Pollution, Science China Technological Sciences, 62(12), 2019, 2236-2242. https://doi.org/10.1007/s11431-019-9560-7
[7] Hilares, R. T.; Singh, I.; Meza, K. T.; Andrade, G. C.; Tanaka, D. P.: Alternative Methods for Cleaning Membranes in Water and Wastewater Treatment, Water Environment Research, 2022(4), 2022, 94. https://doi.org/10.1002/wer.10708
[8] Kyei, C.; Hassan, R.: Managing the Trade-Off Between Economic Growth and Protection of Environmental Quality: the Case of Taxing Water Pollution in the Olifants River Basin of South Africa, Water Policy, 21(2), 2019, 277-290. https://doi.org/10.2166/wp.2019.190
[9] Liu, W. S.; Guo, M. N.; Liu, C.; Yuan, M.; Chen, X. T.; Huot, H.: Water, Sediment and Agricultural Soil Contamination from an Ion-Adsorption Rare Earth Mining Area, Chemosphere, 216(12), 2019, 75-83. https://doi.org/10.1016/j.chemosphere.2018.10.109

[10] Liu, X.; Wu, Y.; He, R.; Jiang, H. L.; Wang, C.: The Stability of Drinking Water Treatment Residue with Ozone Treatment, Environmental Technology, 39(13-16), 2018, 1697-1704. https://doi.org/10.1080/09593330.2017.1337231

[11] Liu, Y.; Lu, H.; Li, Y.; Xu, H.; Yang, Q.: A Review of Treatment Technologies for Produced Water in Offshore Oil and Gas Fields, Science of The Total Environment, 775(7), 2021, 145485. https://doi.org/10.1016/j.scitotenv.2021.145485

[12] Onwe, M. R.; Nwankwor, G. I.; Ahiarakwem, C. A.; Abraham, E. M.; Emberga, T. T.: Assessment of Geospatial Capability Index for Siting Waste Dump/Landfill to Control Groundwater Geopollution Using Geographic Information System (gis) Approach: Case Study of Abakaliki Area and Environs, Southeastern Nigeria, Applied Water Science, 10(1), 2020, 1-19. https://doi.org/10.1007/s13201-019-1087-5

[13] Pavlidis, G.; Tsihrintzis, V. A.: Environmental Benefits and Control of Pollution to Surface Water and Groundwater by Agroforestry Systems: a Review, Water Resources Management, 32(1), 2018, 1-29. https://doi.org/10.1007/s11269-017-1805-4

[14] Sanchez, S.; Tedeschi, E.; Silva, J.; Jafar, M.; Marichalar, A.: Smart Load Management of Water Injection Systems in Offshore Oil and Gas Platforms Integrating Wind Power, Iet Renewable Power Generation, 11(9), 2017, 1153-1162. https://doi.org/10.1049/iet-rpg.2016.0989

[15] Shen, C.; Zhao, Y. Q.; Liu, R. B.; Morgan, D.; Wei, T.: Enhancing Wastewater Remediation by Drinking Water Treatment Residual-Augmented Floating Treatment Wetlands, Science of The Total Environment, 673(10), 2019, 230-236. https://doi.org/10.1016/j.scitotenv.2019.04.035

[16] Sun, Q.; Wang, X.; Wang, L.: Ecological Impact of Watershed Water Pollution Control on Coastal Tourist Scenic Spots, International Journal of Low-Carbon Technologies, 20119(1), 2019, 1. https://doi.org/10.1093/ijlct/ctz060

[17] Sun, Y.; Chen, G.; Xu, Z.: Research Progress of Water Environment, Treatment and Utilization in Coal Mining Areas of China, MeitanXuebao/Journal of the China Coal Society, 45(1), 2020, 304-316.

[18] Wang, Y.; Tavakkoli, S.; Khanna, V.; Vidic, R. D.; Gilbertson, L. M.: Life Cycle Impact and Benefit Tradeoffs of a Produced Water and Abandoned Mine Drainage Co-Treatment Process, Environmental Science and Technology, 52(23), 2018, 13995-14005. https://doi.org/10.1021/acs.est.8b03773

[19] Yang, Y.; Ge, B.; Chen, X.; Yang, W.; Wang, Z.: Impact of Water Vapor Content on Visibility: Fog-Haze Conversion and its Implications to Pollution Control, Atmospheric Research, 256(16), 2021, 105565. https://doi.org/10.1016/j.atmosres.2021.105565

[20] Yuan, Y.; Zhu, H.; Liang, D.: Optimal Control of Groundwater Pollution Combined with Source Abatement Costs and Taxes, Journal of Computational Science, 20(6), 2017, 17-29. https://doi.org/10.1016/j.jocs.2017.03.014