Application of Systematic Management in Ecological Environment Restoration of "Plant - Net - River and Lake": A Case Study of the Shiwuli River Basin

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Abstract: The current basin water ecological environment management technology is inefficient due to the complexity and diversity of the cities. In pursuit of targeting the problems faced by the primary basin water ecological environment, the Basin of Shiwuli River, the first tributary of Chaohu Lake, was taken as the research object. Using the existing basin water ecological environment control engineering measures, and the concept of systematic management and principle of simultaneous development of project and research, the research objectives and contents of the water ecological environment systematic management of the Shiwuli river basin were proposed in this paper. Our work establishes a technical platform for ensuring the stability and long-term maintenance of qualified water in the basin.

1 INTRODUCTION

The Shiwuli river rises from the southeastern foot of the Dashu mountain, and is a primary tributary of the Chaohu Lake. This river is located in the southwest of Hefei City and flows through High-tech, Shushan, Jingkai, Baohe, and Binhu New regions of Hefei. It is not only the main channel of regional drainage, but also an important landscape river channel and ecological economic belt of the city. Meanwhile, the Shiwuli river basin is also an important section of the comprehensive National Science Center, made-in-China 2025 pilot demonstration city, international metropolitan area, Chaohu Lake ecological civilization pioneering demonstration area, and new highland of the inland development. In 2017, the fourth environmental protection supervision group of the Central Committee pointed out that "the water environmental protection situation of Chaohu Lake basin is severe, and the pollution load of runoffs flowing into the lake is large. The water quality of Shiwuli, Nanfei, and Pai rivers is at class V for a long time, and the pollution load of these three rivers is huge." The Shiwuli river undertakes the important task of urban flood drainage (Lu, 2019) and thereby plays an important role in the social and economic development of Hefei. Also, it plays the role of the urban sewage receiving water body of Hefei (Tian et al., 2019). This river is an important source of water pollution load of the Chaohu Lake. As a result, the treatment of water ecological environment in the Shiwuli river basin is particularly important.

For the realization of the long-term, stable, and qualified water ecological environment management objectives of the Shiwuli river basin, the present study was envisaged to identify comprehensively analyze the current water ecological environment problems of the Shiwuli river, and systematically categorize the basin water ecological environment management measures. By employing the basin systematic management concepts of overall basin research, comprehensive management, entire process control, and all-round connection (Peng, 2019), and following the principle of simultaneous development of project and research, the present study proposed the research objectives and contents of water ecological environment management of the Shiwuli river basin.

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2 SURVEY OF THE STUDY AREA

The trunk stream of the Shiwuli river from the Swan lake dam to the entry point of Chaohu Lake is 22.9 km long, with a basin area of 106.6 km^2, including 26.6 km^2 of economic development zone in the upstream part of the Tangxi river. The geographical location is shown in Figure 1. Swan lake and Kuang river are located in the upstream section of Shiwuli river. The primary tributaries, including Xuxiao, Weixi, Xingfuqu, and Wangniangou rivers, are located on the left bank of the middle and lower reaches of the basin. In addition, five overflow dams have been currently built on the trunk stream to regulate the river level, and a wetland project is built near the entry point of the Chaohu Lake to degrade the water pollutants.

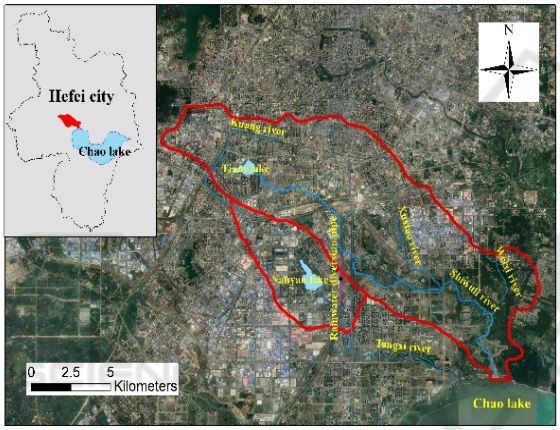

Figure 1: Geographical location of the Shiwuli river basin.

From the perspective of landform, the Shiwuli river basin is at high altitude in the northwest and at low altitude in the southeast (Figure 2 (a)), with geographical elevations of -25 to 75 m. Low mountains and hills as well as low-lying plain with rivers and lakes are the dominant two landforms. According to the land use types in the basin in 2018 (Figure 2 (b)), the urban land is the principal land use type in the basin, and accounts to 72%. From the perspective of hydrometeorology, the Shiwuli river basin has a subtropical humid monsoon climate, with an average temperature of 16.5°C (from 1990 to 2019) and an average annual evaporation capacity of 835 mm. The daily precipitation data provided by the Hefei Station (Figure 3) shows that the average annual precipitation is 1018.8 mm, and the precipitation is concentrated in April to August, of which the precipitation accounts for 62.18% of the annual value.

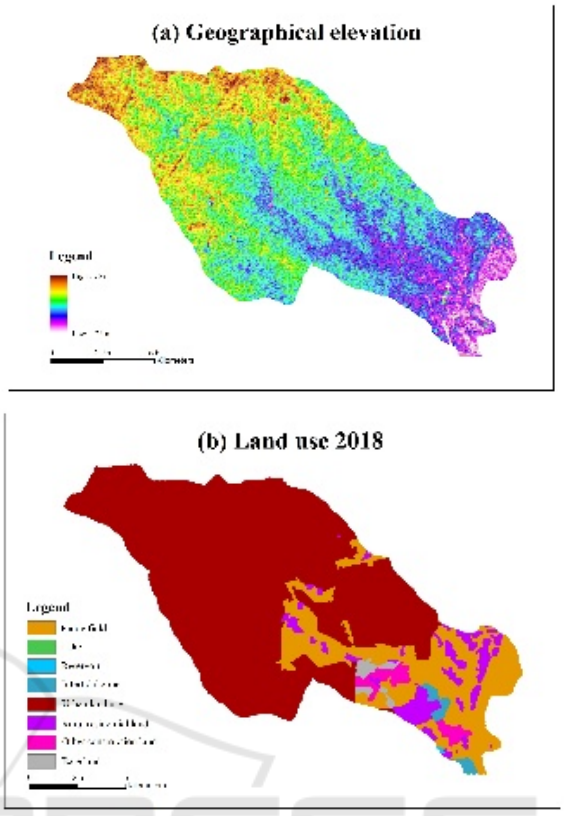

Figure 2: Geographical elevation and spatial distribution of the land use types in the Shiwuli river basin.

3 CURRENT PRIMARY WATER ECOLOGICAL ENVIRONMENT PROBLEMS

Shiwuli river is the primary tributary of the Chaohu Lake. Under the influence of the rapid development of urban society and economy and the construction of upstream lakes and reservoirs, the water quality of the Shiwuli river was at the class-V level before 2017. It has gradually evolved into an urban sewage receiving water body with an extreme lack of ecological base flow. This change not only affected the production and living conditions of the residents along the river, but also led to a great impact on the water environment quality of Chaohu Lake (Tian, 2018). In view of this adverse situation, since 2018, the Hefei municipal government constructed a series of treatment projects, and the pollution load into the river and lake was reduced. The water quality monitoring data of each section showed that the water quality of the Shiwuli river was improved (Wu et al., 2015). However, the current engineering measures

cannot ensure the long-term, stable qualified water quality in each control section. The primary water ecological environment issues include the follows.

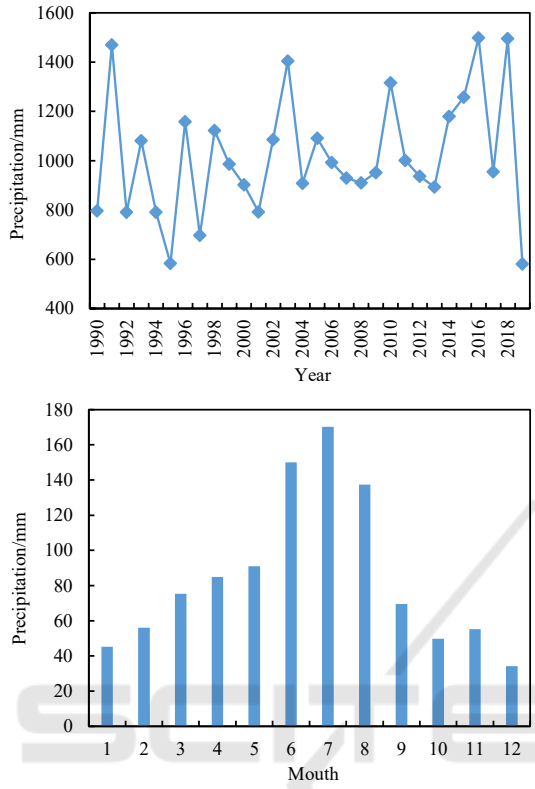

Figure 3: Annual and monthly precipitation in the Shiwuli river basin from 1990 to 2019.

3.1 Lack of Initial-Stage Rainwater Pollution Treatment Capacity

Besides agricultural non-point source pollution, the urban surface runoff pollution has become the second largest non-point source pollution, and 80% of the pollutants in a single precipitation event get entrained in the rainwater at the initial stage (Shen et al., 2020). In order to reduce the pollution load from Tangxi river in the Chaohu Lake, the rainwater at the initial stage from the upstream economic development zone of Tangxi river was discharged into the middle part of Shiwuli river. It has been reported that the instant contents of COD, NH_3-N, and total phosphorus (TP) in the initial-stage rainwater transferred from the upstream section of Tangxi river reached 452, 5.8, and 4.8 mg/L, respectively, and the average contents reached to 85.52, 2.15, and 0.59 mg/L, respectively, far higher than the levels specified in the class-V water standard (Zhou et al., 2017). The existing project treatment measures, including the urban land use, roads, residential areas, and other facilities constructed in the Shiwuli river basin, did not completely take the urban non-point source pollution control measures into account, and these facilities insufficiently retain the rainwater in the initial stage. In addition, the Shiwuli sewage plant with a total capacity of 200000 m^3/d has been operated in the basin. Also, the Hudaying sewage plant with a capacity of 100000 m^3/d is under construction. Considering the sewage transferred from the west to the east to the Wangxiaoying sewage plant, the capacity can only meet the regional sewage treatment requirement. The space accommodating the initial-stage rainwater is insufficient, and the initial-stage rainwater treatment capacity is low.

3.2 Potential Risk of Pollutants Released from the River Sediment

The sediment pollution of the Shiwuli river is relatively severe (Li et al., 2019), and a gush of black lump from the sediment of some river sections was observed in summer due to anaerobic fermentation. It has been reported that the contents of total organic matter, total nitrogen, and total phosphorus in the sediment of the Shiwuli river trunk stream reached 5.32%, 2352.04 mg/kg, and 982.83 mg/kg, respectively (Wang, 2016). According to the standards of the “Investigation and Evaluation of Sediment Pollution Situations of National Rivers, Lakes and Reservoirs”, the levels of total organic matter and total nitrogen in the sediment of Shiwuli river should not exceed class IV, and level of total phosphorus should be in class II. Overall, the results indicate that the sediment pollution was severe in the Shiwuli river.

3.3 Insufficient Ecological Base Flow Supply

Because the Shiwuli river basin is a relatively small urban region with a developed pipe network, the natural runoff supply is not stable in a year, and the river water is difficult to be self-sufficient. Currently, thanks to the Swan lake water replenishment project, Chaohu Lake ecological water replenishment project, and urban reclaimed water, the situation of insufficient ecological base flow of Shiwuli river has been effectively mitigated. However, generally speaking, the problem of insufficient ecological base flow of the Shiwuli river has not been addressed continuously and stably, especially in the upper reaches of the Shiwuli River, of which the base flow mainly depends on the irregular discharge from the

Swan lake overflow dam. And, the slope upstream is steep, so it is very easy to dry in dry seasons.

3.4 Insufficient Tributary Regulations

The primary tributaries of the Shiwuli river include the Xingfuqu, Wangniangou, Xuxiaohe and Xuxi rivers that are located on the left bank of the middle and lower reaches. They receive the urban and rural domestic sewage and agricultural irrigation residual water, and the pollution load is large. The distance between the intersection of the trunk-stream-tributary and the entry point of Chaohu Lake was 16.40, 12.36, 9.49, and 4.66 km, respectively. This reflects that the flow of pollutants in the trunk stream of the Shiwuli river takes a short time, without complete degradation. Therefore, it is necessary to promote the comprehensive treatment of the tributaries in the middle and lower reaches of the Shiwuli river.

3.5 Poor Linkage of Management Regime

Currently, the water environment management regime of the Shiwuli river basin lacks linkage, and the principle is not systematic enough. The water environment treatment project can hardly be developed in accordance with the concepts of source control, process blocking, and end-of-pipe treatment. The problems mainly lie in the emergent treatment of sudden water pollution accidents, optimal dispatch of river water quantity and quality, and tracing of excess pollutants in the river.

4 BASIN WATER ECOLOGICAL ENVIRONMENT CONTROL PROJECT

Since 2015, many departments of Hefei explored the transformation of Chaohu Lake treatment from point, line, to surface. In 2016, the Hefei municipal government announced the construction of short-term and long-term projects of the "Scheme of Requirement Reaching of Shiwuli River Water Body" to the society. To date, some projects have been implemented and have played an active role in restoration and pollution control of the water quality of the entire Shiwuli river basin (Chen et al., 2018). However, the existing engineering measures cannot essentially compensate for the historical damage to the water ecological environment in the Shiwuli river basin, and the water ecological environment can be merely treated in limited zones of the basin and the end of the river. Both the implementation scopes of engineering measures as well as the blocking and control of pollutant transport processes are insufficient. For the benign cycling of the water ecological environment of Shiwuli river basin with a possible self-recovery and stable maintenance, the Hefei municipal government has carried out the first Shiwuli river basin management project, and the construction of some of the projects has begun. The ongoing and incoming projects and engineering measures in the Shiwuli river basin are listed as follows:

The ongoing projects include the bid submission process in the phase-I project and construction of new phase-III project of the Shiwuli river sewage plant, economic development zone, sewage transfer project, Swan lake upstream water transfer and make-up project, Shiwuli river estuary wetland project, initial-stage rainwater regulation and storage project at the Beijing-Taiwan expressway, community reconstruction pilot project for sponge city, and sewage interception project at the Qimen road outlet.

The primary phase-I treatment projects of the Shiwuli river basin construction include 8 categories and 16 projects, such as urban point source pollution treatment, urban non-point source pollution treatment, endogenous pollution treatment, water replenishment project, river water quality restoration, river ecological buffer zone, river ecological restoration and comprehensive monitoring. The primary projects include the pipe network tracing, investigation, reconstruction project, initial-stage rainwater regulation and storage project at Jinzhai Road and other six sites, garbage collection and disposal project, river sediment treatment project, ecological water replenishment project, ecological buffer zone project, river ecological restoration project, water and soil conservation forest project, oxygenation and aeration project, and the comprehensive river monitoring project.

5 CONCLUSIONS AND RECOMMENDATIONS

Considering the important geographical location and the irreplaceable role of the Shiwuli river basin, and targeting the current water ecological environment problems in the basin, scientific research should play a positive guiding role in the treatment of Shiwuli river water ecological environment by utilizing the water ecological environment control engineering

measures in the basin. By following the principles of simultaneous development of project and research, research on the project optimization and project inspection, the aforesaid objectives can be met.

5.1 Research Objective

Aiming at the current primary water ecological environment problems in the Shiwuli river basin, according to the overall deployment of the basin treatment project, the topics of "what to reduce, where to reduce, how much to reduce, how to reduce, and how to manage the pollutants in the basin" should be taken as the core theme. The control of total maximum daily load (TMDL) of pollutants in the basin and integrated planning of land and water areas (point source, non-point source, and endogenous) should be taken as the basic principles. Subsequently, the research on the entire basin, all-round treatment (engineering and non-engineering measures), and management of all factors should be paid attention. The comprehensive benefits of various ongoing engineering and non-engineering measures in the basin for the improvement of water quality of the Shiwuli river should be systematically analyzed. With these solutions, the objectives of stable qualified water in the basin and its long-term maintenance can be realized, and a model for the treatment of water environment in a highly urbanized basin can be successfully established.

5.2 Research Content

(1) Construction of a water ecological environment model of Shiwuli river basin by coupling the hydrology, hydraulics, water quality, and water conservancy projects

The Shiwuli river is a complex basin, where the water and pipe networks intersect and the urban and agricultural land intersect. The transport of water and pollutants is not only blocked by the initial-stage rainwater regulation and storage projects in the pipe network, but also is regulated by the gate and dam projects in the water network. From the perspective of systematic management of the basin, a reaction chain of the entire process of pollutant generation, pipe network transportation, project regulation, and water network degradation should be established. In addition, the current and upcoming treatment engineering measures should be embedded into the model to quantitatively evaluate the treatment effects of the engineering measures. Furthermore, the quantitative and accurate simulations of the initial-stage rainwater regulation and storage project in the pipe-network model and multi-gate-dam dispatching in the water-network model should be highlighted.

(2) Construction of a technical method for the distribution of the excessive pollution load in the cross-section of the Shiwuli river with coupled natural and social attributes

Based on the successful pollution source discharge management experience for total maximum daily loads (TMDLs), through localization, optimization, and continuous innovation, the breakthrough of the limitations in thinking of current pollution load distribution is essential considering the monotonous factors. There is a need to categorize the response relationship between the basin pollution load and water quality change. The hydrometeorological variation and socio-economic development factors should be also taken into account and the dynamic water environment capacity of water body should be calculate under the influence of multi-factor disturbance. Additionally, there is a need to develop a technical method for the distribution of excessive pollution load in the Shiwuli river basin to provide a practical goal for the basin water quality objective management work.

(3) Research and development of a water ecological environment systematic regulation platform of the Shiwuli river basin with real-time monitoring, accurate simulation, and intelligent mutual feedback

For the informationization, digitization, and intellectualization of the water ecological environment management of the Shiwuli river basin, the basin water ecological environment systematic regulation platform should be developed. Based on the multi-source information fusion, with water ecological environment model as the core and by using the artificial intelligence modules, this platform should be developed. This platform should focus on the issues about the real-time mutual feedback between the measured data and mathematical models. Also, the efficient operation of the platform with multiple objectives needs to be taken into consideration. In addition, the abilities of emergent management of sudden water pollution events, early warning of unqualified water, joint dispatching of the water quantity and quality, and tracing of pollution source in the Shiwuli river basin should be improved.

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