

Research on Key Pollutant Reduction Program of Environmental control in a Small River Basin of Guangxi

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Abstract. In order to strengthen the prevention and control of water pollution in rural rivers, it is necessary to analyze the pollution causes in detail, calculate the pollutant reduction amount and put forward the comprehensive treatment measures. Aiming at the small basin of a county in the southwest Guangxi, this paper carried out the comprehensive improvement of water environment, including specifically investigation the water pollution degree of the basin, calculating present pollution load and water environment capacity, and proposing pollutant reduction targets in accordance with the requirements for water quality targets. The basin has poor water quality background and is seriously polluted by rural living pollution sources, livestock and poultry breeding pollution sources and planting pollution sources, in order to solve these problems, the water quality assurance project, rural living sewage governance project and large-scale livestock and poultry breeding pollution governance project are put forward. Through project quantity accounting and pollutant reduction calculation, the water quality target can be achieved.

1 Introduction

Rural rivers are important natural resources for rural development, and have extremely important ecological functions as an important part of large and medium-sized rivers. However, with the rapid development of rural society and economy, the ecological environment of small basin in rural areas deteriorates sharply, resulting in a number of pollutant water quality indicators exceed the standard, and directly affect the quality of life of people on both sides of the river. It is urgent to strengthen the prevention and control of water pollution in rural rivers. For polluted rivers, pollutant reduction should be calculated according to the current pollution load and water environment capacity to provide a reference for integrated governance measures in small basins [1-2].

It is necessary to calculate the water environment capacity and the target reduction amount in order to formulate a more targeted implementation plan of comprehensive water environment improvement in small basin. At present, there are many studies on the calculation of pollution load reduction. Taking the comprehensive improvement of water environment in the river basin as an example, Huang comprehensively considered the estimation method of water capacity and the control of discharge reduction target, and carried out the calculation research on water environment capacity and the target reduction amount using one-dimensional

calculation mode [3]. According to the small basin river system situation and characteristics of different river water quality, Zhang et al calculated the water environment capacity through basin segmentation, carried out calibration and validation of hydrological model parameters based on the measured data, proposed the method for calculating water environment capacity of river segments in small basin area, and determined the pollutant reductions, so as to formulate key project measures to reduce pollutants, and ensure that the water quality of the whole line is up to standard [4]. In this study, the pollution status and pollution load of a small rural basin in southwest Guangxi were calculated and analyzed, the water environment capacity was calculated according to the water quality target, the target reduction amount of pollutants was determined, pollutant reduction measures were proposed and the target accessibility analysis was carried out to ensure the river water quality target. This study will not only provide a reference for the calculation of water environment capacity and pollutant reduction targets in river basin, and provide technical support for the comprehensive remediation of water environment in small river basin, but also is of great significance to solve the problems of river water environment and eliminate the inferior class V water bodies in rivers.

2 Materials and methods

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2.1 Study area

Taking a small river basin in southeastern Guangxi province as the study area, it includes four rivers (hereinafter referred to as Four Rivers): YQ River, LW River, DB River and BML River. Four Rivers have a basin area of 303 km², a river length of 68.3 km, which flows through 29 administrative villages in 3 towns.

2.2. Calculation method of the amount of pollutant source into the river

(1) Township living sewage

Township living sewage treatment project is point source pollution discharge, whose pollutant discharge calculation formula is:

$$W_i = C_i \times Q \times 10^{-3} \quad (1)$$

Where, W_i is the pollutant discharge of township sewage treatment plant (kg/m), C_i is the discharge concentration of pollutants from the township sewage treatment plant (mg/L), and Q is the discharge of township sewage treatment plant (m³/d).

(2) Rural living sewage

Based on the number of rural populations in the basin, the output of living sewage in the basin is calculated by using the pollution coefficient method [4-6].

$$W_{living} = \alpha_i \times N_{agriculture} \times 10^{-3} \quad (2)$$

Where, W_{living} is the discharge of rural living pollutants (kg/d), $N_{agriculture}$ is the number of rural population (person), and α_i is the rural living sewage discharge coefficient (g/person·day).

(3) Non-point source of living garbage

$$W_i = \gamma_i \times M \quad (3)$$

Where, W_i is the discharge of living waste pollutants i (kg/d), and γ_i is the conversion coefficient of pollutant discharge in garbage.

(4) Livestock and poultry breeding pollution sources

$$W_{Livestock} = \alpha_2 \times N_{pig} \times 10^{-3} \quad (4)$$

Where, $W_{Livestock}$ is the discharge of livestock and poultry breeding pollutants, N_{pig} is the number of converted active pigs (head), and α_2 is the sewage discharge coefficient of livestock and poultry (g/head·day).

(5) Planting

Agricultural non-point source pollution includes farmland surface runoff pollution and farmland solid waste pollution.

Farmland surface runoff pollution discharge calculation formula is:

$$W_{farmland\ surface\ runoff} = A_{farmland} \times \varphi_i / 1000 \quad (5)$$

Where, farmland surface runoff pollution discharge is the product of farmland area ($A_{farmland}$) and pollutant loss coefficient (φ_i) within the basin [5-6].

Farmland solid waste pollutants are mainly plant residues from agricultural production:

$$W_{Farmland\ solid\ waste} = 30\% \times A_{farmland} \times \varepsilon \times \alpha_3 \quad (6)$$

Where, $A_{farmland}$ is the farmland area in the basin. ε is the solid waste coefficient from farmland. α_3 is the main pollutants content of farmland solid waste non-point source (α_3).

(6) Soil erosion pollution

The calculation formula of soil erosion pollution source discharge is:

$$W_{soil\ erosion} = 25\% \times A_{total} \times \mu \times \alpha_4 \quad (7)$$

Where, A_{total} is the total area of the basin (km²). μ is the soil erosion modulus. α_4 is the content of pollutants in sediment.

The formula for calculating the amount of pollutants inflow into the river is:

$$W = \sum (W_i \times \beta_i) \quad (8)$$

Where, W is the amount of pollutants inflow into the river (kg/d), i is the type of pollution source, W_i is the discharge of pollutants from all pollution sources (kg/d) and β_i is the river inflow coefficient of all pollution sources [7-8].

2.3 Pollution capacity calculation method

The environmental capacity calculation formula is:

$$W = 365 \times 0.0864 \times Q_h \times [C_s \times \exp(K \times L / 86400u) - C_0] \quad (9)$$

Where, W is the environmental capacity, t/a, Q_h is the river flow during dry season, m³/s, C_s is the standard concentration of river water quality control, mg/L, K is the comprehensive degradation coefficient of pollutants, 1/d, L is river spacing, m, u is the river velocity, m/s and C_0 is the river background concentration, mg/L.

The pollutant reductions can be calculated as follows:

$$X = P - W \quad (10)$$

Where, X is the pollutant reduction target (t/a), P is the amount of pollutants into the river (t/a) and W is the environmental capacity (t/a).

3 Results & Discussion

3.1 Water environment quality

According to the analysis of water quality monitoring data of the Four rivers in 2019, the water quality of the four rivers in 2019 was inferior class V, which all did not meet the water environment function requirements (class V standard), and the main exceeding factors were

ammonia nitrogen and total phosphorus. In YQ River, LW River, DB River and BML River, the average annual exceeding multiple of ammonia nitrogen was 15.75, 3.09 and 2.93 times, respectively (the average

annual exceeding multiple of ammonia nitrogen in BML River reached the standard), and the average annual exceeding multiple of total phosphorus was 2.86, 3.45, 2.96 and 1.4 times, respectively.

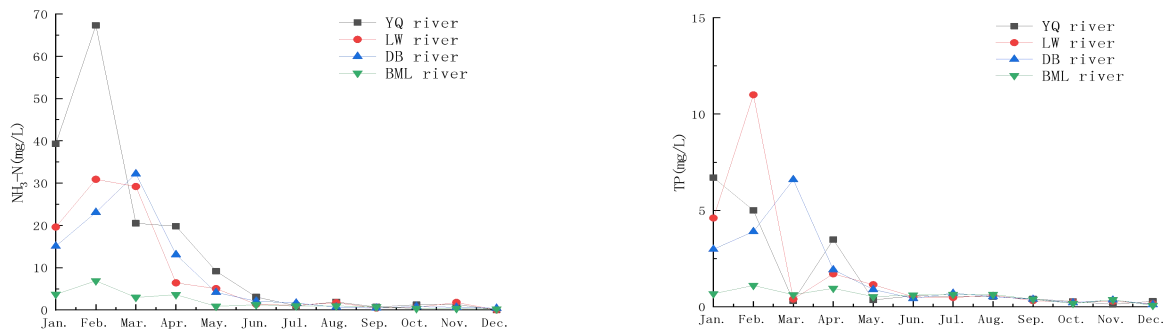


Fig. 1. Concentrations of ammonia nitrogen (left) and total phosphorus (right) of Four Rivers in 2019

3.2 Pollutants calculation results

The discharge load of pollutants is calculated based on the statistical data of 2019. The results are shown in Table 1. The discharge of COD, NH₃-N, TN and TP are 8827.21 t/a, 259.72 t/a, 916.17 t/a and 189.54 t/a, respectively. Generally speaking, livestock and poultry pollution sources are the main pollution sources.

The main reasons that livestock and poultry breeding has become the main source of pollution are first, the proportion of large-scale breeding is low, where in the first quarter of 2020, the current amount of B county is 413,000, while the amount of large-scale breeding is only 81,000. Second, the aquaculture methods in breeding farms below large scale are backward, where traditional aquaculture accounts for a large proportion and environmental pollution

governance level is backward. Third, as a traditional industry in county, breeding supports the lives of local people. Whereas there are a large number of breeding farms below large scale, it is difficult to regulate the discharge of breeding pollution, and the pollution of livestock and poultry has not formed a special supervision and management system, thus livestock and poultry breeding pollution has become one of the main factors affecting the regional water environment quality in B County.

Soil erosion pollutant discharge is large, among which COD discharge is 2022t/a, ammonia nitrogen discharge is 259.72t/a, total nitrogen discharge is 916.17t/a, and total phosphorus discharge is 189.54t/a.

Table 1. Statistics of pollution source discharges in Four Rivers’ basin in 2019

Pollution sources		COD (t/a)	Ammonia nitrogen (t/a)	Total nitrogen (t/a)	Total phosphorus (t/a)
Living sewage	Rural living sewage	547.45	54.30	121.47	17.35
	Township living sewage	26.18	2.62	7.85	0.26
Living garbage	Rural living garbage	77.39	1.55	2.32	3.87
	Township living garbage	5.15	0.10	0.15	0.26
Livestock and poultry breeding	Livestock and poultry breeding below large scale	2452.21	39.07	151.27	18.80
	Large-scale livestock and poultry breeding	3114.84	83.76	114.32	16.56
Planting industry	Fertilizer loss pollution	265.46	11.68	113.30	2.46
	Farmland solid waste	316.54	66.64	102.18	28.88
Soil erosion	Soil erosion	2022.00	0.00	303.30	101.10
Totally		8827.21	259.72	916.17	189.54

According to formula (1)-(8), the total amount of COD pollutants into the river is shown in Fig.2, among which the pollutants discharge from large-scale livestock and poultry breeding accounts for the highest proportion of 44.42%. The total amount of ammonia nitrogen pollutants into the river is 246.88t/a, where the pollution sources from large-scale livestock and poultry breeding accounts for the highest proportion of 30.87%. Again, the total amount of total phosphorus discharge is 91.83t/a, where the pollution sources from planting industry accounts for 35.92%.

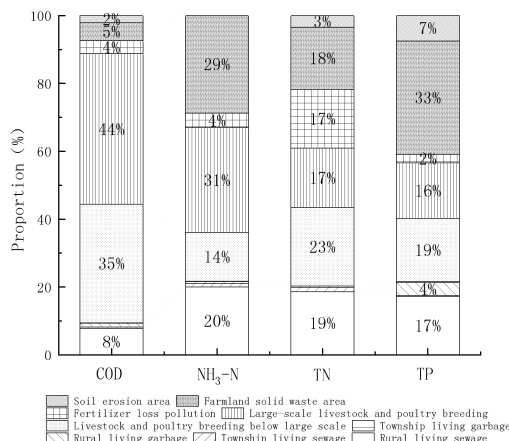


Fig. 2. Proportion of main pollution sources into the river in Four Rivers' basin

3.3. Analysis of pollutant reduction targets

The river flows in each section are measured data in dry season, which are 0.34, 0.48, 0.64 and 0.17 m³/s respectively. According to Formula (9), the environmental capacities of COD, ammonia nitrogen and total phosphorus are 474.64, -549.33 and -86.15 t/a respectively. The reduction amount can be calculated from the difference between river inflow amount and environmental capacity, the results are shown in Fig.3.

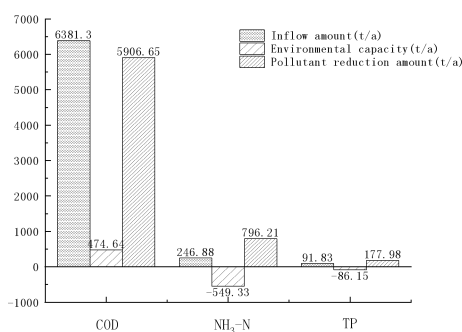


Fig. 3 The pollutant reduction in the basin

3.4 Project reduction program

In order to improve pollution control requirements, the following reduction principles shall prevail, the key pollution sources are first reduced, pollutants in the

control unit must be reduced, key sources are emphatically reduced, and livestock and poultry breeding source is the focus to reduce. The Pollutant reductions of comprehensive treatment projects in four rivers' basin was shown in Tab.3.

3.4.1 Water quality guarantee project

Through pollution load analysis, it can be seen that the internal pollution and planting pollution in the four rivers account for a relatively large proportion. The wetland is constructed to reduce non-point source runoff of rural life, non-point source sediment of farmland agriculture, dissolved nitrogen and phosphorus and other pollutants along the river, and purify the water quality of runoff into the river. The ecological buffer zone has an obvious effect on the removal of nitrogen and phosphorus in agricultural production, and can intercept and absorb 40%-60% of the nutrients absorbed in soil particles. Using artificial floating island, planting willow herb, calamus, reed and other aquatic plants, through the absorption and attachment function of plant roots, the concentration of nitrogen and phosphorus pollutants in the water would be reduced, so as to achieve the effect of purifying water. The serious sedimentation of bottom mud in water body has a certain impact on water body and is also detrimental to industrial and agricultural water consumption. Therefore, it is necessary to carry out dredging treatment project.

3.4.2 Rural living sewage treatment project

At present, there are 484 natural villages in the region that have not carried out rural living sewage treatment project. Through field investigation, it is found that the rural living sewage construction land is insufficient, and the villages are scattered and complex. The living connection rate is insufficient and the living connection is not standardized. In order to solve the above problems, the rural living sewage treatment project needs to reconstruct 326 ecological regulation and storage ponds including the use of waste ponds, and 101 functional wetlands. As to supporting pipe network projects, it constructs new 17km residential pipe network, 31km ecological ditch, 95km culvert repair, 24 hydrolysis acidification tank and contact oxidation tank.

3.4.3 Pollution control project for livestock and poultry breeding below large scale

As to the pollution control project for livestock and poultry breeding below large scale, a total of 1,723 livestock and poultry pollution treatment sites are contained and along with the construction of aerobic composting sites and livestock and poultry wastewater treatment sites in the 'septic tank + oxidation pond' model, the dry manure removal process is promoted in a coordinated manner. Above all, with cross-border four rivers' section water quality requirements (surface water V standard) as the goal, the comprehensive basin

treatment projects of cross-border four rivers. Eventually, after the implementation of all projects, the reduction amount of COD, ammonia nitrogen and total phosphorus is 6434.81 t/a, 635.75 t/a and 368.91t/a respectively, which are all higher than the pollutant reduction target of

5906.65 t/a, 796.21 t/a and 177.98t/a, reaching the overall reduction target. This project is of great significance to solve the problems of river water environment and eliminate the inferior class V water body.

Table 2. Pollutant reductions of comprehensive treatment projects in four rivers' basin

No.	Name	Content	Pollutant reductions (t/a)		
			COD	NH ₃ -N	TP
1 Water quality guarantee project					
1.1	Artificial wetland	A total of 75,700 m ² wetland is constructed.	2399.14	299.71	96.26
1.2	Ecological buffer zone	A total of 58.8km ecological farmland buffer zone is constructed.			
1.3	Artificial floating island	A total of 12,830 m ² artificial floating is constructed.			
1.4	Internal source governance engineering	A total of 11,020m ³ mud is removed and a total of 354,086m ³ aquaculture waste water is treated.			
2 Rural living sewage treatment project					
2.1	Pipe network project	A total of 17km residential pipe network, 31km ecological ditch, and 95km culvert repair, are constructed.	262.26	43.18	30.48
2.2	Living sewage governance	A total of 326 ecological regulation and storage ponds, covering an area of 428 mu, and 101 functional wetlands, covering an area of 406 mu are constructed.			
3 Pollution control project for livestock and poultry breeding below large scale					
3.1	Aerobic fertilizer composting site	A total of 30,860m ³ of manure storage tank for livestock and poultry breeding, 115,725m ³ of compost tank and 7,715m ² of fertilizer warehouse are constructed.	3773.41	292.86	242.17
3.2	Oxidation pond	16457.6m ² oxidation pond is constructed.			
Totally			6434.81	635.75	368.91

4 Conclusion

- (1) The ammonia nitrogen and total phosphorus of Four Rivers is seriously over the standard and the overall water quality is line with the surface water class V standard. The change of water quality is seriously affected by seasons and residents' activities.
- (2) According to the analysis of river inflow, large-scale livestock and poultry breeding and rural living sewage are the main pollution sources.
- (3) Through the implementation of rural sewage treatment projects, livestock and poultry pollution prevention and control projects and other project measures, the pollutants pollution of inflow into the river can be reduced and the overall reduction target can be reached.

Acknowledgments

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