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Spatial-Temporal Variation Characteristics and Cause Analysis of Water Quality in Yinma River Basin

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Abstract In order to comprehensively understand the water quality in Yinma River Basin, and to analyze the spatial-temporal variation characteristics of water quality over the years and the causes of water pollution, 15 sections were selected in the Yinma River Basin. Based on the water quality monitoring data in the past decade, 7 evaluation indexes including dissolved oxygen (DO), 5-day biochemical oxygen demand (BOD_5), permanganate index (COD_{MN}), chemical oxygen demand (COD), ammonia nitrogen (NH_4-N), total phosphorus (TP) and total nitrogen (TN) were determined, according to the *Environmental Quality Standard for Surface Water* (GB3838-2002) and the historical monitoring data of rivers. The water quality of 15 sections in Yinma River Basin was comprehensively evaluated, and the water quality categories and the evolution of river water quality were analyzed. The pollution sources of Yinma River Basin were analyzed, and the constructive countermeasures were put forward according to the conclusions.

Key words Yinma River, Water quality, Characteristic, Cause analysis

1 Introduction

Yinma River is a primary tributary of the second Songhua River, originating in the southeast side of Laoyeling along Hadaling Mountain in Yitong County. It falls into Yitong River in Kaoshan Town, Nong'an County, and flows into Songhua River in the southeast of Hongshileitun in Kaoshan Town. The river is 386.80 km long, with a drainage area of 17 400 km^2 (including the Yitong River with an area of 9 300 km^2). Tributaries of Yinma River Basin with an area of more than 1 000 km^2 include Shuangyang River, Chalu River, Wukai River and Yitong River[1].

2 Evaluation of water quality in Yinma River Basin

2.1 Water quality monitoring and evaluation methods

2.1.1 Implementation standard of water quality monitoring. The surface water testing method in the *Surface Water Environmental Quality Standard* (GB2828-2002) was adopted, and the specific testing standard is shown in Table 1.

2.1.2 Water quality evaluation method. The pollutant overproof value, the water quality grading standard and the contribution of pollutants to the total pollution are linked by fuzzy comprehensive evaluation method. The specific steps are as follows.

(i) Establish evaluation object set $U=\{u_1, u_2, u_3, \cdots, u\}$. In this study, $u=\{DO, BOD_5, COD_{MN}, COD, NH_4\text{-}N, TP, TN\}$.

(ii) Establish water quality evaluation grades. The water quality evaluation grade is $L=\{I, II, III, IV, V\}$.

(iii) Establish membership function.

$$U(X)=\begin{cases}1 & 0\leqslant X\leqslant a_1\\ \dfrac{a_2-X}{a_2-a_1} & a_1<X\leqslant a_2\\ 0 & X>a_2\end{cases}$$

(iv) Establish fuzzy matrix. Through the membership function, the membership relationship of the i^{th} single index to the j^{th} grade water quality is calculated by the measured value, and the matrix is obtained.

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j}\\ r_{21} & r_{22} & \cdots & r_{2j}\\ \vdots & \vdots & \vdots & \vdots\\ r_{i1} & r_{i2} & \cdots & r_{ij}\end{bmatrix}$$

(v) Establish weight matrix. $A=\{a_1, a_2, a_3, \cdots, a_n\}$

(vi) Calculate evaluation results.

$W=A\times R.$

2.2 Evaluation of water quality in Yinma River Basin

Fifteen monitoring sections were selected from Yinma River Basin for evaluation[2]. The perennial water quality of the three sections of Shitoukoumen Reservoir was evaluated as grade III, and the perennial water quality of the other three monitoring sections was inferior grade V. The superstandard multiple of pollutants in Changling section successively were NH_4-N > TP > BOD_5 > COD > COD_{MN}. In 2009, NH_4-N, TP and BOD_5 exceeded the standard by 9.9, 3.6 and 0.6 times, while in 2013, NH_4-N, TP and COD_{MN} exceeded the standard by 8.3, 2.2 and 0.1 times, respectively. In 2018, NH_4-N, TP and COD_{MN} exceeded the standard by 6.7, 2.3 and 0.5 times, respectively. In general, although the superstandard multiple of pollutants had decreased, there was no change in indicators of pollutants in different years, and there was

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generally no significant change in water quality in this section[3]. The perennial water quality of Latapao section was inferior grade V, and the superstandard multiple of pollutants successively were NH_4-N > BOD_5 > COD > COD_{MN}. In 2009, NH_4-N, BOD_5 and COD exceeded the standard by 5.8, 0.8 and 0.1 times, while in 2013, NH_4-N, BOD_5 and COD exceeded the standard by 0.5, 0.7 and 0.2 times, respectively. In 2018, NH_4-N, BOD_5 and COD exceeded the standard by 0.5, 0.6 and 0.5 times, respectively. The pollution of indicators in this section was particularly stable, indicating that the surrounding conditions of the basin were stable, and the pollutant concentration had reduced, suggesting that the water quality changed in a better direction. Dehui section is the control section where Yinma River flows into the Second Songhua River, and its perennial water quality was inferior grade V. The superstandard multiple of pollutants successively were NH_4-N > BOD_5 > COD > TP. When analyzing this section, it was found that although the source of pollutants was stable, the NH_4-N indicator showed a turning point. It exceeded the standard by 7.5 times in 2009, which lowered to 1.7 times in 2015, and increased to 5.1 times in 2018, while the water quality was still inferior grade V. Although the other three sections, except the drinking water source control section, were stably controlled in the inferior grade V, it is found that most of the superstandard multiples were slowly decreasing year by year, indicating that the water quality of Yinma River was improving year by year.

Table 1 Main testing items and methods mg/L

No.	Test parameter	Standard code of test method	Main equipment used and serial number
1	Dissolved oxygen (DO)	GB 7489-1987	Brown acid burette
2	Permanganate index (COD_{MN})	GB 11892-1989	Brown acid burette
3	Chemical oxygen demand (COD)	HJ 828-2017	Colorless acid burette
4	5-day biochemical oxygen demand (BOD_5)	HJ 505-2009	Brown acid burette
5	Ammonia nitrogen (NH_4-N)	HJ 665-2013	Continuous flow analyzer SAN + + (151910)
6	Total phosphorus (TP)	HJ 670-2013	Continuous flow analyzer SAN + + (162113)
7	Total nitrogen (TN)	HJ 667-2013	Continuous flow analyzer SAN + + (162113)

3 Analysis of pollution sources in Yinma River Basin

3.1 Research methods According to the water quality sections designed along Yinma River Basin, 15 monitoring points were analyzed throughout 2018. Two Landsat8 image data with a resolution of 30 m in Yinma River Basin in May and September 2018 were selected. Based on geometric correction and atmospheric correction, supervised classification was adopted to extract land use information in the area[4]. According to the classification standard of *Technical Specification for Ecological and Environmental Status Assessment* (HJ192-2015), 7 land cover types including cultivated land, grassland, vegetable land, forest land, urban land, bare land and water body were selected as research objects. Combined with DEM and drainage system distribution, the data of land use types in 7 catchment units were obtained. The industrial proportion, per capita GDP, population density and other data were derived from the *Statistical Yearbook of Jilin Province* and *Changchun Statistical Yearbook* in 2017. A Pearson analysis of water quality and land use in Yinma River Basin was conducted by SPSS 17.0 software[5].

3.2 Relationship between land use and river water quality in Yinma River Basin The extracted land use information map (Fig. 1) was divided according to their functions, and the research area was divided into 7 catchment areas. As shown in Fig. 1, the urban land area of A2 accounted for 52% – 58% of the total area; the cultivated land area and forest land area accounted for 18% – 20% of the total area; and the cultivated land area of A1 and A5 accounted for 48% – 56% of the total area. Generally speaking, the cultivated land area from A1 to A7 accounted for a large proportion. However, the forest land area from A1 to A7 also remained at about 19%, and the proportion of vegetable land and bare land was relatively small. There was a large difference in the proportion of land use type area in the 7 areas.

As shown in Table 2, the area proportion of land use type had different correlation with the water quality of the basin in which it was located. The results showed that urban land use was negatively correlated with DO, which indicated that the impact of urban production and domestic sewage on dissolved oxygen indicator was reflected in the increase of oxygen demanding substances in water after the discharge of urban pollutants, thus reflecting the low measured value of DO[6]. There was significant positive correlation between COD and urban land area, indicating that domestic wastewater produced by urban land use and wastewater produced by urban processing and production would significantly increase water pollution. TP was positively correlated with cultivated land, bare land and vegetable land, indicating that agricultural cultivation and soil leaching would increase the concentration of phosphorus related substances in water. Meantime, TN was significantly positively correlated with cultivated land, bare land and vegetable land, indicating that agricultural cultivation methods, excessive use of pesticides and fertilizers, and agricultural planting types all led to the increase of TP and TN concentrations in water bodies. After pollutants enter the water body, it will easily cause eutrophication of water body, and the aggravation of eutrophication of water body is easy to induce the outbreak of blue-green algae. In 2007, the blue-green algae outbreak in Xinlicheng Reservoir caused water suspension for

45 d, which brought great inconvenience to residents and caused serious economic losses.

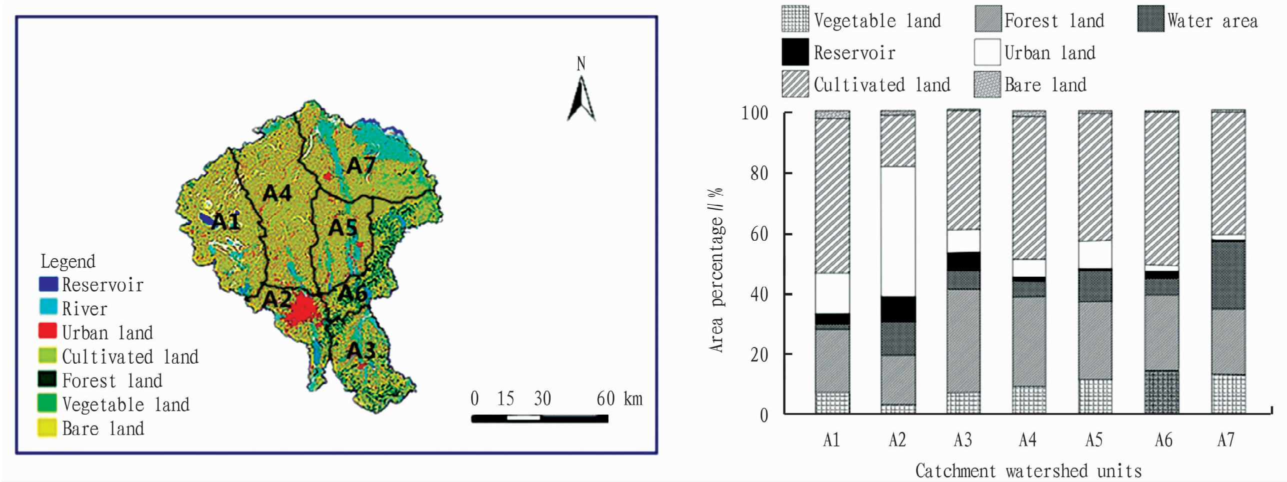

Fig. 1 **Land use type and area ratio in Yinma River Basin**

Table 2 **Correlation between land use pattern and water environment index in 2018**

Land type	DO	BOD_5	COD	TP	TN	pH	Chlorophyll
Cultivated land	0.051	-0.524	-0.401	0.948	0.768	0.182	0.145
Urban land	-0.879	-0.587	0.823	-0.156	0.523	0.175	-0.131
Water body	0.582	-0.814	-0.516	-0.524	0.241	0.181	-0.142
Grassland	0.731	-0.521	-0.271	0.358	0.625	0.162	0.200
Forest land	0.614	-0.633	-0.325	-0.378	0.612	0.085	-0.280
Vegetable land	0.501	-0.504	-0.322	0.087	0.813	0.145	-0.290
Bare land	-0.068	0.165	-0.028	0.083	0.215	0.158	0.322

4 Conclusions and suggestions

The water quality of Yinma River Basin is improving year by year. However, as this basin is the main grain crop growing area in Jilin Province, its pollution is mainly affected by non-point source pollution, with great seasonal effect. Therefore, it is necessary to strengthen the development of agricultural green industry and strengthen the construction of ideology, so as to gradually restore green hills and clear waters. In order to improve the water quality in Yinma River Basin, we should strengthen the control of non-point source pollution and improve the legal system, accelerate the process of agricultural science and technology, develop green agriculture, and carry out special treatment measures in key areas.

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