Statistical Analysis of Wastewater Discharge in Yunnan Province 2015-2020

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Abstract: Yunnan Province is endowed with abundant water systems and resources. In recent years, with urbanization, human population, social and economic progress fastening, water environment problem is becoming increasingly serious. Therefore, this study proposes the coordinated development of social economy and water environment in Yunnan Province. According to the situation of wastewater discharge in Yunnan Province, the main sources of wastewater discharge and the main factors affecting urban wastewater discharge in recent years are analyzed. Statistical analysis results show that wastewater discharge in Yunnan Province in the past five years mainly came from domestic wastewater (8,891,023,700 tons), followed by industrial sewage (1,984,587,500 tons). Through cluster analysis, 16 cities in Yunnan Province were finally divided into four categories, with Kunming as category 1, Qujing as category 2, Lijiang, Nujiang, Diqing, Baoshan, Chuxiong, Lincang, and Xishuangbanna as category 3, and other cities category 4. In recent years, wastewater discharge in Kunming and Qujing City has been on the rise, probably due to large population density and high demand for domestic water, the concentration of high water-consuming industries such as mining and metallurgy, and defects in wastewater and sewage treatment technology.

1 INTRODUCTION

There are many rivers and lakes in Yunnan Province. The water resources developed are about 153.381 billion cubic meters, accounting for 5.46% of the national water resources in China. However, affected by geographical and natural environment, water resources distribution is uneven [1], Worse still, as urbanization increases, urban population grows, pollution intensifies, water quality deteriorates, river runoff decreases, lakes shrink, which worsens the water environment [2]. Since 1992, Yunnan Province has been committed to water environment protection, and the overall water quality has improved year by year. However, as Yunnan Province is located in inland China, the waste water discharge mainly depends on inland lakes [3], and the self-purification capacity of water is very limited, there is a relatively serious water pollution problem. Therefore, with a view to achieving the coordinated development of social economy and water environment in Yunnan Province, this study plans to adopt multiple statistical factor analysis and cluster analysis methods to study how to reasonably recycle water resources, analyze the main factors affecting wastewater discharge in cities, find solutions to effectively improve wastewater treatment, and propose effective suggestions for water environment protection and wastewater discharge treatment in Yunnan Province.

2 DATA SOURCES AND SELECTION OF POLLUTION INDICATORS FOR WASTEWATER DISCHARGE

2.1 Data Sources

The wastewater discharge data in this study comes from the “Yunnan Statistical Yearbook” and the

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water quality evaluation index data from "Yunnan Province Environmental Status Bulletin" and "Yunnan Province Plateau Lake Water Quality Monthly Report".

2.2 Selection of Pollution Indicators for Wastewater Discharge

According to the Comprehensive Sewage Discharge Standard implemented by China in 1998, a total of 6 wastewater discharge pollution targets were selected: X1 total wastewater discharge, X2 domestic sewage discharge, X3 COD discharge from domestic sewage, X4 industrial wastewater discharge, X5 chemical oxygen demand (COD) emissions, and X6 urban sewage discharge.

3 RESEARCH METHODOLOGY

According to the selected 6 wastewater discharge pollution indexes, the wastewater discharge in Yunnan Province is analyzed by SPSS26.0.

3.1 Factor Analysis

Factor analysis was used to reduce the dimension of multiple sewage discharge standards. In other words, through the study of the correlation between a set of indicators, a linear model is synthesized into a few comprehensive common factors, and the original variables are represented by these comprehensive factors. So, the variables and factors representing most of the index information are easy to study [4].

3.2 Cluster Analysis

Cluster analysis is to classify uncategorized observation units or variables with similar characteristics according to the principle of "object by object clustering". Normally, the Ward's method [5] can classify the observation units or variables based on the factor analysis.

4 RESULTS

4.1 Factor Analysis Results

According to the model and principle of factor analysis, factor analysis of main pollution indexes of wastewater discharge in 16 cities of Yunnan Province was performed by SPSS26.0. Factor analysis hypothesis test was carried out on the collected variable data. First, the KMO test value of variable data is 0.746>0.5. Bartlett's Approximate Chi-Square is 2201.565, If the df (degree of freedom) is 15, the significant difference is 0. Therefore, when α=0.05, the original hypothesis is rejected. It can be considered that the correlation coefficient matrix is significantly related to the unit matrix. There is a positive linear correlation between variables. Factor analysis of variable data can be carried out (see table 1, table 2 for detail).

Table 1: KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.746
Bartlett's Test of Sphericity	Approximate Chi-Square	2201.565
	df	15
	Sig.	0.000

Table 2: Correlation matrix.

		Total wastewater discharge (X1)	Domestic sewage discharge (X2)	COD discharge from domestic sewage (X3)	Industrial wastewater discharge (X4)	COD (X5)	Urban sewage discharge (X6)
Correlation	Total wastewater discharge (X1)	1.000	0.993	0.914	0.847	0.882	0.993
	Domestic sewage discharge (X2)	0.993	1.000	0.886	0.779	0.833	0.990
	COD discharge from domestic sewage (X3)	0.914	0.886	1.000	0.877	0.963	0.891
	Industrial wastewater discharge(X4)	0.847	0.779	0.877	1.000	0.940	0.823
	COD (X5)	0.882	0.833	0.963	0.940	1.000	0.860
	Urban sewage discharge (X6)	0.993	0.990	0.891	0.823	0.860	1.000

The ratio of common factor variance extracted is shown in table 3. The information extraction of six evaluation indexes is above 90%, and the effective information of variable data is retained, which indicates that the evaluation of wastewater discharge in Yunnan Province greatly reduces the complexity of the original data. The two common factors extracted are the total amount of wastewater discharge and the discharge of domestic sewage. The contribution rates of factor variance before rotation is 91.537%, 6.162%, 50.877%, and 46.822%, respectively, and the cumulative contribution rate is 97.699% (see table 4 for details)

Table 3. Proportion of variance of common factor.

Communalities		
Total wastewater discharge (X1)	Initial	Extraction
Domestic sewage discharge （X2）	1	0.997
COD discharge from domestic sewage (X3)	1	0.999
Industrial wastewater discharge(X4)	1	0.951
COD (X5)	1	0.982
Urban sewage discharge (X6)	1	0.991

Extraction Method: Principal Component Analysis

As shown in figure 1, the horizontal coordinate represents the number of principal components and the vertical coordinate the eigenvalues, from which we can see that the contribution rate of different indicators is greater than 1, and the eigenvalue of the second index is between 0-1.

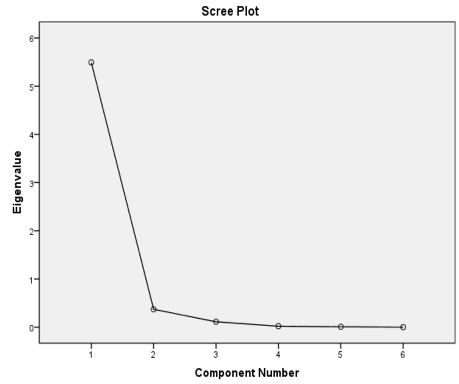

Figure 1: Scree plot of wastewater and major pollutants in Yunnan Province.

Table 4. Total variance explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	of Variance%	Cumulative%	Total	of Variance%	Cumulative%	Total	of Variance%	Cumulative%
1	5.492	91.537	91.537	5.492	91.537	91.537	3.053	50.877	50.877
2	0.370	6.162	97.699	.370	6.162	97.699	2.809	46.822	97.699
3	0.111	1.858	99.557						
4	0.019	0.320	99.877						
5	0.007	0.123	100.000						
6	5.690E-006	9.483E-005	100.000						

Extraction Method: Principal Component Analysis.

The factor load matrix is shown in table 5. The factor load matrix reflects the total amount of wastewater discharge, the total amount of munici pal sewage discharge, the COD discharge from domestic sewage, and the discharge from COD, and industrial wastewater in Yunnan Province. T heir respective expressions can be written as foll ows:

total wastewater discharge=×component1-0.184×c omponent2;

0.981 Municipal sewage discharge=×component1-0.228×component2;

0.969 COD discharge=0.963×component1+0.120×component2;

domestic sewage discharge=×component1-0.291×c omponent2;

0.956COD=0.954×component1COD=0.269×compo nent1COD=component2;

wastewater discharge=0.916×component1+0.335×c omponent2.

Table 5. Factor load matrix.

	Component	
	1	2
Total wastewater discharge (X1)	0.981	-0.184
Domestic sewage discharge （X2）	0.969	-0.228
COD discharge from domestic sewage (X3)	0.963	0.120
Industrial wastewater discharge(X4)	0.956	-0.291
COD (X5)	0.954	0.269
Urban sewage discharge (X6)	0.916	0.335

The factor load matrix after maximum variance rotation is shown in table 6. The information of each variable is extracted more fully after the m aximum variance rotation. The total amount of wastewater discharge and domestic sewage disch arge are extracted as common factors. Compone nt1 mainly explains the domestic sewage dischar ge, urban sewage discharge, and wastewater disc harge, while component2 mainly explains the ind ustrial wastewater discharge, COD, and domestic sewage discharge.

Table 6. Rotated component Matrix 6a.

	Component	
	1	2
Total wastewater discharge (X1)	0.893	0.449
Domestic sewage discharge （X2）	0.858	0.504
COD discharge from domestic sewage (X3)	0.837	0.544
Industrial wastewater discharge(X4)	0.432	0.874
COD (X5)	0.504	0.853
Urban sewage discharge (X6)	0.614	0.752

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 3 iterations.

The principal component conversion matrix is shown in table 7. The principal component conversion matrix reflects the relationship between the principal components before and after rotation, so the principal components before and after rotation can be converted by transforming the matrix.

Table 7: Component transformation matrix.

Component	1	2
1	0.724	0.690
2	-0.690	0.724

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

The standardized factor score coefficient matrix is shown in table 8. The linear combination of principal components about each variable can be given by standardized factor score coefficient matrix, and further clustering analysis is carried out. $F_1 = 0.179X_1 + 0.174X_2 + 0.167X_3 + 0.175X_4 + 0.174X_5 + 0.176X_6$

Table 8. Component score coefficient matrix.

	Component
	1
Total wastewater discharge (X1)	0.179
Domestic sewage discharge （X2）	0.174
COD discharge from domestic sewage (X3)	0.167
Industrial wastewater discharge(X4)	0.175
COD (X5)	0.174
Urban sewage discharge (X6)	0.176

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization

4.2 Cluster Analysis Results

The total amount of wastewater discharge, domestic sewage discharge, domestic sewage COD discharge, urban sewage discharge, industrial wastewater discharge and chemical oxygen demand (COD) discharge were numbered in the systematic cluster analysis according to six wastewater pollution discharge indexes in Yunnan Province. After 15 steps, it was finally merged into a class (see table 9 for details).

Table 9. Agglomeration schedule.

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	5	7	0.043	0	0	10
2	6	15	0.108	0	0	6
3	4	9	0.193	0	0	5
4	3	14	0.326	0	0	10
5	4	8	0.458	3	0	8
6	6	16	0.639	2	0	11
7	11	13	0.972	0	0	9
8	4	12	1.446	5	0	11
9	10	11	2.347	0	7	12
10	3	5	3.870	4	1	12
11	4	6	7.294	8	6	13
12	3	10	13.120	10	9	13
13	3	4	24.600	12	11	14
14	2	3	41.866	0	13	15
15	1	2	90.000	0	14	0

According to figure 2, 16 cities in Yunnan Province can be divided into the following four categories according to six wastewater discharge pollution indicators: ① Kunming; ② Qujing; ③ Lijiang, Nujiang, Diqing, Baoshan, Chuxiong, Lincang, Xishuangbanna; ④ Zhaotong, Pu’er, Yuxi, Dehong, Wenshan, Dali, Honghe.

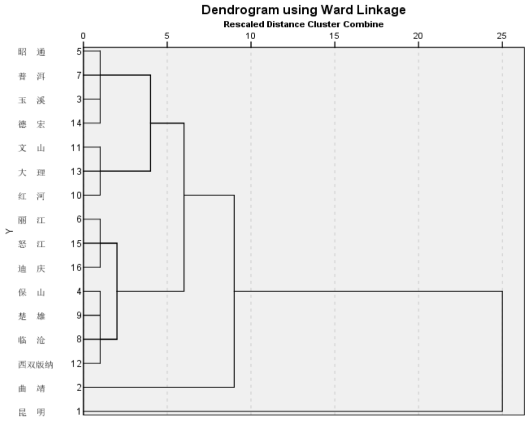

Figure 2. Cluster analysis tree map of wastewater and major pollutants in Yunnan Province.

5 CONCLUSION

The factor analysis results show that the total amount of wastewater discharge has been increasing year by year, among which the proportion of public domestic sewage continues to increase, becoming the main source of water resources pollution in Yunnan Province. The reason may be that since the reform and opening-up, Yunnan, bordering south and southeast Asia, has been committed to economic and social development. Its total population increased from 46,016,300 in 2010 to 48,583,000 in 2020; its urban population rose from 11,111,300 to 14,310,730; its population density from 116.6 to 123.3 persons per square kilometer. Among the six wastewater discharge pollution indicators, the total wastewater discharge and domestic wastewater emissions have the greatest impact on water environmental pollution, followed by industrial sewage and other pollutants. The reason may be due to the weak development of state-run enterprises in Yunnan Province and rapid growth of highly polluted industries discharging more industrial sewage and requiring large water consumption.

Based on the cluster analysis method, the total amount of wastewater discharge and domestic sewage discharge obtained from factor analysis were classified into 16 cities in Yunnan Province. The first category is Kunming, which has a large population density and produces more domestic wastewater and industrial sewage than other cities. The second category is Qujing City [6]. There are many industrial and mining enterprises and industrial parks, most of which are heavily polluted and high-water-consuming industries such as thermal power generation, coal, machinery, chemical industry, metallurgy, and so on. The third category is Lijiang, Nujiang, Diqing, Baoshan, Chuxiong, Lincang, Xishuangbanna, and the fourth category is Zhaotong, Pu’er, Yuxi, Dehong, Wenshan, Dali, Honghe. The population density in these areas is relatively balanced, and the domestic sewage and industrial wastewater produced are less than that in Kunming and Qujing. The main source of wastewater discharge is domestic sewage, which has a trend of yearly increase, followed by industrial wastewater. The discharge of industrial wastewater in 2018 appeared in a significant decline mode, and then began to grow slowly.

With the continuous urban expansion in Yunnan Province, urban population, discharge of domestic wastewater and industrial sewage produced by cities, as well as total wastewater and main pollutants increase. It mainly results from the lack of effective planning and reasonable control of urban domestic sewage, the low wastewater treatment rate of factories, and excessive discharge or discharge. It then leads to the continuous deterioration of water environment and continuous pollution of water resources [7].

At present, China’s own core technology and complete set equipment for efficient wastewater treatment are still mainly dependent on imports. What’s more, the research and development of research institutes, and wastewater treatment technology evaluation system is not perfect, leading to a lack of universality in evaluation technology and standards.

6 RECOMMENDATIONS

First, the rapid development of social economy, the improvement of public living standards and the acceleration of the industrialization process will all increase the urban wastewater discharge and pose some threats to water resources protection. Secondly, the water environmental pollution control in Yunnan Province mainly relies on the self-purification capacity of water bodies. However, limited by geographical factors, the self-purification capacity of some river basins began to diminish. Worse still, the lack of surrounding environmental infrastructure construction and the imperfect urban drainage pipe network, the rivers entering the lake have become the main sewage channel for wastewater discharge. Therefore, focusing on the source to control wastewater and pollution discharge, and striking a balance between urban economic development and environmental protection is one of the key approaches for water resources and environmental protection.

According to the latest statistics, as of 2019, 194 enterprises in Yunnan Province have obtained sewage treatment qualifications. Among them, the number of wastewater treatment facilities in industrial enterprises increased by 1.39 times; the number of urban sewage treatment plants increased by 4.67 times. The treatment method of wastewater and pollutants has changed from the most basic physical method to the use of microorganisms to remove dissolved organic matter and colloidal substances in sewage and improve the discharge of public domestic wastewater and enterprises to the standard rate. However, due to the high treatment cost, difficulty in ensuring the effect, and unstable operation, the treatment of high-concentration pollutants and organic wastewater is still relatively difficult. Therefore, it is suggested that Yunnan Province should adopt professional and strong treatment level technical methods for enterprises with large industrial sewage discharge and introduce high-end and fine automatic wastewater treatment integration and control technology, to ensure it matches the process and equipment operation. Special technical evaluation indicators should be formulated for some regions and enterprises with difficult processing. The close combination between the overall environmental protection strategy and environmental science and technology development strategy should be done to meet the requirements of environmental supervision and achieve scientific and technological progress and the development of environmental protection industry.

Government departments should improve the supervision capacity of water environment protection, beef up environmental monitoring team and standardization construction, improve fundamental conditions for environmental monitoring, upgrade environmental supervision agency equipment, increase energy conservation and emission reduction, promote water protection publicity, improve public environmental awareness, encourage the public to maximize the recycling of domestic water [8], reduce domestic sewage discharge, and formulate corresponding sewage discharge indicators and regulations to ensure that plant production and public sewage discharge do not exceed environmental capacity.

In promoting the development of prefectures and cities in Yunnan Province, we must pay attention to the protection of the ecological environment. We should increase the government ’ s capital investment in the field of water conservancy construction and water environment protection, mobilize enterprises to strengthen their pollution prevention and control efforts, strengthen the construction of safe water network and water pollution prevention and control in key river basins, prefectures and cities, optimize the water pollution prevention and control system by using the system engineering, and recycle urban waste water resources as much as possible, We also call for strengthening the formulation and implementation of relevant laws and regulations for key polluting enterprises, and advocating scientific governance by introducing artificial intelligence and big data into the environmental monitoring platform – a water environment protection and management platform integrating the province ’ s water environment quality testing and water environmental pollution early warning.

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