Water quality change in Nanchong section of Jialing River Basin based on multivariate statistical analysis

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ABSTRACT

To better understand the temporal and spatial variation characteristics of water quality of the Jialing River and its main influencing factors, this work adopted the methods of cluster analysis and discriminant analysis of multivariate statistical analysis and collected the monitoring data of five main sections (Liduzhen, Xiaodukou, Wencheng, Shaxi, Caihongqiao) of the Nanchong section of the Jialing River from 2011 to 2019. The results showed that the overall water quality of Jialing River Basin is clearly demarcated before and after 2017. pH, dissolved oxygen, chemical oxygen demand permanganate index, and ammonia nitrogen (NH_3–N) are the main influencing factors that distinguish the water quality in different periods. After 2017, the water quality of the Langzhong section of the Jialing River is generally in good condition, and the content of reducing pollutants and nitrogen-containing pollutants in the water body is showing a downward trend. Taking 2015 as the boundary, the main water quality influencing factors of Xichong River after 2015 (Caihongqiao monitoring point), a tributary of Jialing River, are pH and NH_3–N. However, the current trend of water pollution in the Nanchong section of the Jialing River still exists. According to the water quality analysis results of the Nanchong section of the Jialing River Basin (Xiaodukou and Liduzhen monitoring points), the concentration of NH_3–N in the water body increased after 2017, indicating that the Nanchong section of the Jialing River will be more affected by nitrogen pollutants after 2017.

Keywords: Jialing River Basin; Water quality parameters; Multivariate statistical analysis; Cluster analysis; Discriminant analysis; Temporal and spatial variation

1. Introduction

Multivariate statistical technology is an effective method to analyze the temporal and spatial changes of water quality, and has been widely used in practical applications [1–3]. Łukasz et al. [4] studied the changes of water quality parameters of Turava Reservoir (TR), Marapanu River below Turava Reservoir (BTR) and above Turava Reservoir (ATR) through multivariate statistical analysis. Huang et al. [5] evaluated the water quality data of 8 sections from Nuozhadu and Jinghong reservoir area to Guanlei in the lower reaches of Lancang River by using comprehensive pollution index method, cluster analysis and spatio-temporal difference study. Wunderlin et al. [6] used cluster analysis (CA), principal component analysis (PCA), and discriminant analysis (DA) to evaluate the spatial and temporal changes in the water quality of Suquia River. Cristiane et al. studied the surface water quality of 65 monitoring points in Verjas River Basin through multivariate statistical analysis and nonparametric test.

The Jialing River is the largest tributary in the upper reaches of the Yangtze River. It originates from Dawang Mountain in the Qinling Mountains, Fengxian County, Shaanxi Province, flows southwest through Shaanxi, Gansu,

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Sichuan, and Chongqing, and joins the Yangtze River in Chongqing. The basin area is nearly 160,000 km², with a total length of 1,119 km [8]. The middle reaches of the Jialing River flows through Nanchong in the northeastern part of Sichuan Province, which is the second most populous city in Sichuan Province. In recent years, the agriculture, industry, tourism and other industries of Nanchong City have led to rapid economic development. The scale of urbanization has continued to expand. And the urban population has increased as well. Industrial, agricultural and domestic pollution sources have directly or indirectly polluted the water quality of some river basins [9].

According to government statistics, the total wastewater discharge in Nanchong City from 2011 to 2019 showed an upward trend, with an increase of 19.41%, of which domestic and agricultural sources were the main sources of water pollution in the Jialing River of Nanchong [10]. Therefore, based on the monitoring data of the five main sections of the Nanchong section of the Jialing River from 2011 to 2019, and combined with the background of the "Ecological Barrier Construction of the Upper Yangtze River", "Construction of Shelterbelt System in the middle and upper reaches of the Yangtze River" and "Natural Forest Protection" projects, this research analyzed the characteristics of water quality distribution and influencing factors and provided a reference for the environmental protection department to formulate comprehensive treatment measures to prevent, control, and solve water pollution in the Nanchong section of the Jialing River.

2. Research location and materials

2.1. Research location

With subtropical humid monsoon climate in most areas and four distinct seasons and abundant rainfall, Jialing River is located at latitude 30°35′~31°51′ north and 105°27′~106°58′ east diameter The annual precipitation is mainly from May to October, of which July–September precipitation accounts for more than 50% of the annual capacity [11,12]. As an important river in northeastern Sichuan [13], Jialing River serves as a water source for drinking and production in Nanchong City, Sichuan Province. According to the meteorological observation data for many years, the annual average temperature in Nanchong is 17.1°C. The temperature is the highest in summer, and the annual average value is 26.2°C; the temperature is the lowest in winter, and the annual average value is 7.3°C; The temperature in spring and autumn is close to 17.3°C~17.4°C. The average annual rainfall in Nanchong is 1,016.8 mm. Affected by the monsoon, the rainfall in summer is the most, with an annual average of 547.2 mm, accounting for 53.8% of the annual precipitation; Winter is the least, with an annual average of 45.0 mm, accounting for only 4.4% of the annual precipitation; The precipitation in spring and autumn is close to 226.4~275.4 mm [14]. Jialing River enters Sichuan through Guangyuan City, with the Bailong River joining in Zhaohua District, flows south to Langzhong City (in Nanchong City), and flows into Liemian Town, Guang'an City (outbound) through Jialing District of Nanchong City [15,16].

2.2. Monitoring parameters

From January 2011 to December 2019, Nanchong environmental monitoring center collected water samples of Jialing River once a month from Liduzhen, Xiaodukou, Wencheng, Shaxi and Caihongqiao (Fig. 1). The 10 selected parameters according to the sampling continuity of the monitored point includes pH, dissolved oxygen (DO), five-day biochemical oxygen demand (BOD_5), chemical oxygen demand permanganate index (COD_{Mn}), ammonia nitrogen ($NH_3–N$), chemical oxygen demand (COD_{Cr}), total phosphorus (TP), total arsenic, fluorine chemicals, fecal coliforms. The collection, storage and analysis of water samples are in compliance with the relevant requirements of the "Surface Water and Wastewater Monitoring Technical Specification Requirements". Through the analysis of these indicators, it is possible to effectively understand the water quality status and take treatment measures to ensure the stability of the ecosystem. Table 1 shows the specific methods, which are derived from Chinese national standards, and Table 2 shows the environmental quality standards for surface water [17].

3. Research method

This study uses multivariate statistical analysis, which requires water quality parameter indicators to be normally distributed or close to normal distribution [28–30]. Therefore, it first verifies the distribution characteristics of water quality indicators before analysis. Since different water quality indicators differ in value and unit of measurement, the data in the process of standardized systematic cluster analysis also helps to improve their
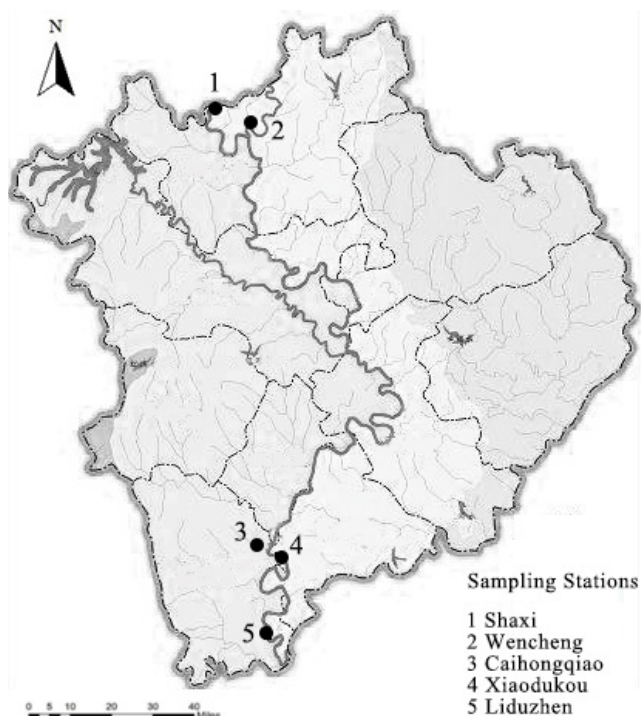

Fig. 1. Monitoring section of Nanchong section of Jialing River.

credibility [31,32]. All mathematical and statistical calculations in this study were performed by using IBM SPSS Statistics 23.0. All of the main water quality parameters conform to the normal distribution [33].

CA is a relatively common exploratory method, which is generally divided into variable clustering (R-type clustering) and sample clustering (Q-type clustering) [34]. The principle behind this analysis is to gather similar objects according to the degree of closeness between variables or samples, and gradually aggregate until they are aggregated into one category to form a pedigree diagram. For water quality evaluation, CA generally divides the monitoring sites or monitoring time into different categories based on the similarity of water quality data. Therefore, the water quality data of the monitoring points or monitoring time in the same group possess great similarities. There are great differences in water quality data between different groups [35,36]. In this study, the Euclidean square distance method and the Wald minimum variance method were applied to systematically cluster the time similarity of the Nanchong section of the Jialing River Basin.

DA is a multivariate statistical method that classifies research objects under the conditions of classification and identification, and establishes a discriminant method suitable for the research objects in the Nanchong section of the Jialing River Basin. The discriminant function (DF) is based on certain criteria, and uses a large amount of raw datas to find the undetermined coefficients in the DF [35]. Compared with cluster analysis, discriminant analysis first distinguishes the classification of samples. At the same time, DF can be used to identify the properties of samples and identify significant pollution parameters. The expression is as follows:

$$f(G_i) = k_j + \sum_{j=1}^{n} w_{ij} p_{ij} \tag{1}$$

where "i" is the number of group types (G), "n" is the pollution parameter of the number of group types, "w_{ij}" is the weight coefficient, "p_{ij}" is the concentration of the main pollution index, "f" is DF, and "k_j" is the inherent constant of each group [30]. The discrimination criterion can be divided into distance discrimination and Fisher discrimination. The verification methods of direction finding effect include self-verification and external verification, sample dichotomy and cross-validation. Discriminant analysis is usually performed on test data using standard, forward and backward methods. The results are applied to the spatial analysis of water quality, and the optimal DF and matrix are obtained, which are used to verify the results of the cluster analysis and identify the key pollutants at each monitoring point [37]. In this study, stepwise model was applied to process the raw data to determine the clusters in the CA, and to evaluate the temporal changes in the watershed based on discriminant variables. The monitoring period (time) was set as grouping variable, and the measurement parameter set as independent variable.

4. Results and discussion

4.1. Water quality analysis of Shaxi monitoring point

According to the water quality monitoring data of the Shaxi monitoring point on the main stream of the Jialing River, the pedigree map obtained through CA can divide the area into three time period groups with the same physical and chemical characteristics from 2011 to 2019, The

Table 1
Monitoring methods of water quality parameters

Project	Monitoring method	Method source
pH	Portable pH meter method	Water and Wastewater Monitoring and Analysis Methods (Fourth Edition) [18]
DO	Electrochemical probe method	HJ 506-2009 [19]
BOD$_5$	Water quality five-day biochemical oxygen demand (BOD$_5$) determination Dilution and inoculation method	HJ 505-2009 [20]
COD$_{Mn}$	Water quality – determination of permanganate index acid method	GB 11892-1989 [21]
NH$_3$–N	Nessler reagent spectrophotometry	HJ 535-2009 [22]
COD	Water quality – determination of chemical oxygen demand dichromate method	HJ 828-2017 [23]
TP	Water quality – determination of total phosphorus-ammonium molybdate spectrophotometric method	GB 11893-1989 [24]
As	Water quality – determination of arsenic atomic fluorescence method	HJ 694-2014 [25]
Fluoride	Water quality – determination of fluoride ion selective electron method	GB/T 7484-1987 [26]
Fecal coliforms	Water quality – determination of fecal coliforms multi-tube fermentation method	HJ/T 347-2007 [27]

first group is 2011–2012, the second group is 2013–2016, and the third group is 2017–2019. As shown in Table 2, the Wilk Lambda value of DF is very small (0.001) while the chi-square value is high (30.351). The classification function coefficient of temporal DA indicated that DO and COD_{Mn} are the most important water quality parameters that distinguish the first, second and third groups, and can be used to explain the time distribution characteristics of water quality (Fig. 2).

From Table 3, the step-by-step model processing only requires two main water quality indicators to construct DFs. Its discrimination ability will not be significantly reduced as a result.

The average DO in the third group (8.81 mg/L) is higher than the average DO in the first group (7.44 mg/L) and the second group (7.47 mg/L), which belongs to the second category of surface water environmental quality standards. DO is a comprehensive indicator to measure river water quality. It is mainly related to factors such as atmospheric reoxygenation, organic matter degradation, nitrification, photosynthesis, sediment oxidation, and microbial respiration. It is the basis for natural river water self-purification and maintaining ecological balance [38]. Among them, the third group belongs to class I of surface water environmental quality standards, and the first and second groups belong to class II; The average COD_{Mn} (1.79 mg/L) of the third group is significantly lower than that of the first group (2.33 mg/L) and the second group (2.68 mg/L), belonging to the first category of surface water environmental quality standards. The index of permanganate directly reflects the degree of water pollution by various reducing substances [39]. The
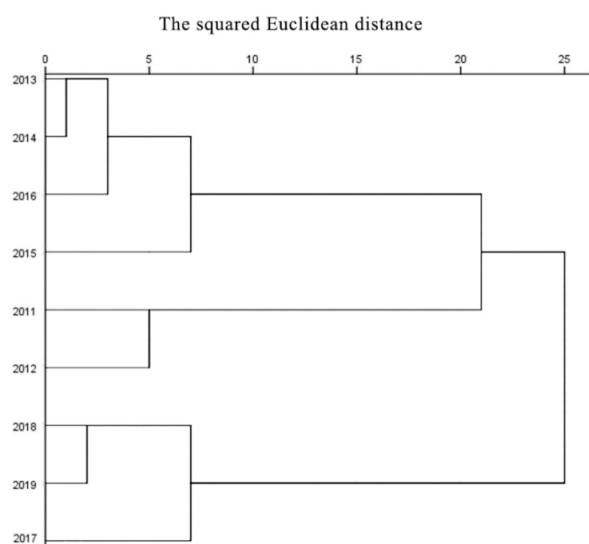
degree of water pollution in the third group was significantly lower than that of the first and second groups (Fig. 3).

4.2. Water quality analysis of Wencheng monitoring point

According to the water quality monitoring data of the Wencheng monitoring point of the Dong River, a tributary of the Jialing River, the pedigree map obtained through CA can divide the basin from 2011 to 2019 into three groups with the same physical and chemical characteristics, that is, three time periods. The first group is 2011 and 2012, the second group is 2013–2016, and the third group is 2017–2019. As shown in the Table 4, the Wilk Lambda value of DF is very small (0.001), the chi-square value is high (28.938). The classification function coefficient of the temporal DA shows that pH, COD_{Mn} are the most important water quality parameters that distinguish the first, second and third groups (Fig. 4).

From Table 5, it can be concluded that the step-by-step model processing only requires three main water quality indicators to construct DFs. Its discrimination ability will not be significantly reduced as a result.

The average pH of the third group (8.10) is higher than that of the second group (7.89) and the first group (7.94), which meets the surface water environmental quality standards (6–9). Generally speaking, the pH value of the river is 7.5~8.5, which is slightly alkaline, which is beneficial to fish and other aquatic organisms and the water environment; The average COD_{Mn} of the third group (2.06 mg/L) is lower than that of the second group (2.93 mg/L) and the first group (2.40 mg/L) and it belongs to the first category of surface water environmental quality standards. COD_{Mn} reflects the degree of water pollution by various reducing substances [39]. The degree of water pollution in the third group is significantly lower than that of the first and second groups (Fig. 5).

4.3. Water quality analysis of Caihongqiao monitoring point

According to the water quality monitoring data of the Caihongqiao monitoring point of the Xichong River, a tributary of the Jialing River, the pedigree map obtained through CA can divide the basin from 2011 to 2019 into two groups with the same physical and chemical characteristics,

Fig. 2. Periodic cluster analysis pedigree of Shaxi monitoring point.

Table 3
Classification function coefficients

Parameter	Group		
	First group	Second group	Third group
DO	5,880.876	5,838.814	7,263.003
COD_{Mn}	3,741.913	3,724.696	4,607.921
Constant	–12,366.663	–11,965.599	–15,297.365

Table 2
Wilk's Lambda and chi-square values

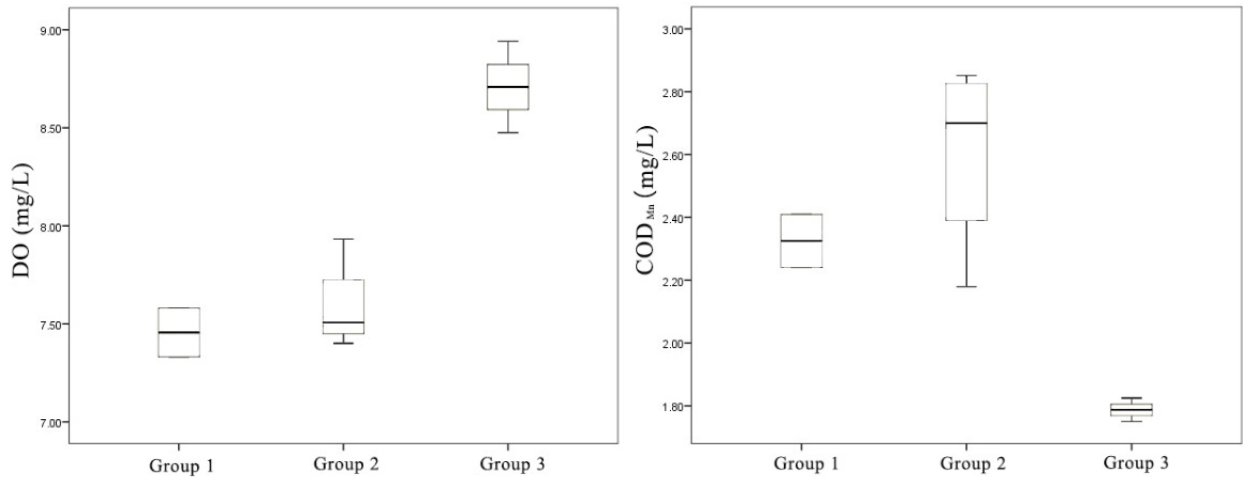| Fun.(s)	Wilk Lambda	Chi-square	Degree of freedom	Significance
1 to 2	0.001	30.351	10	0.001
2	0.112	8.749	4	0.068

Fig. 3. DO and COD_{Mn}.

Table 4
Wilk's Lambda and chi-square values

Fun.(s)	Wilk Lambda	Chi-square	Degree of freedom	Significance
1 to 2	0.001	28.938	10	0.001
2	0.067	10.795	4	0.029
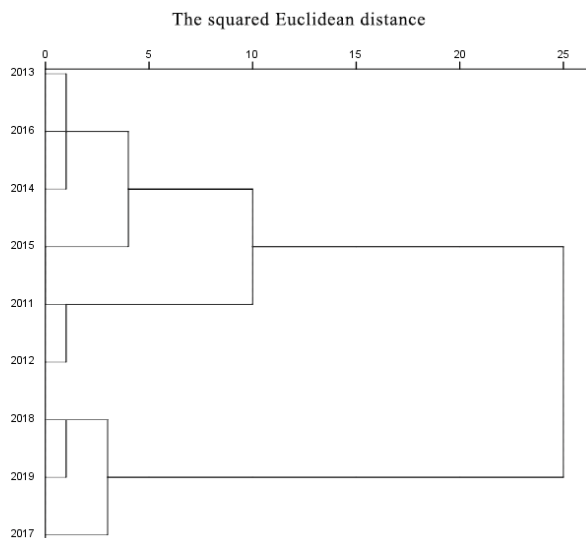
Fig. 4. Periodic cluster analysis pedigree of Wencheng monitoring point.

Table 5
Classification function coefficients

Parameter	Group		
	First group	Second group	Third group
pH	2,047.377	2,080.554	2,071.534
COD_{Mn}	227.778	267.863	243.943
Constant	−12,063.112	−13,606.678	−14,892.613

Table 6
Wilk's Lambda and chi-square values

Fun.(s)	1
Wilk Lambda	0.046
Chi-square	10.751
Degree of freedom	7
Significance	0.150

that is, two time periods. The first group is from 2011 to 2014, and the second is from 2015 to 2019. As shown in the Table 6, the Wilk Lambda value of DF is very small (0.046), and the chi-square value is high (10.751). The classification function coefficient of temporal DA shows that pH and NH_3–N are the most important water quality parameters that distinguish the first and second groups (Fig. 6).

It can be concluded from Table 7 that the stepwise model processing only requires two main water quality indicators

construct to DFs. Its discrimination ability will not be significantly reduced as a result.

The average pH of the second group (8.35) is slightly higher than that of the first group (8.22), which meets the environmental quality standards of surface water (6–9). As mentioned earlier, the pH value of the river is 7.5~8.5, which is slightly alkaline, which is beneficial to fish and other aquatic organisms and the water environment; The average NH_3–N of the second group (0.581 mg/L) was significantly lower than that of the first group (1.225 mg/L), NH_3–N in rivers mainly comes from nitrogen-containing
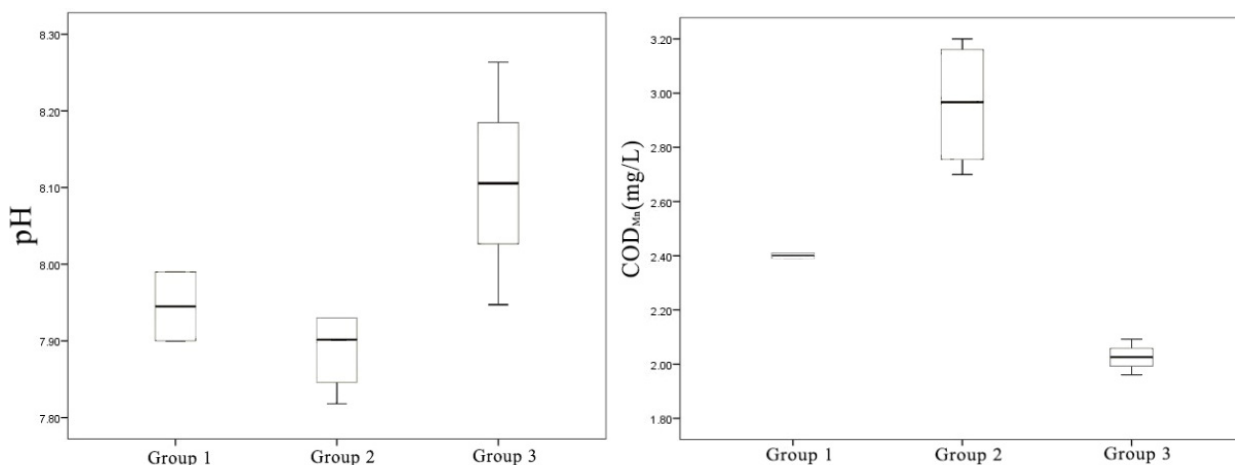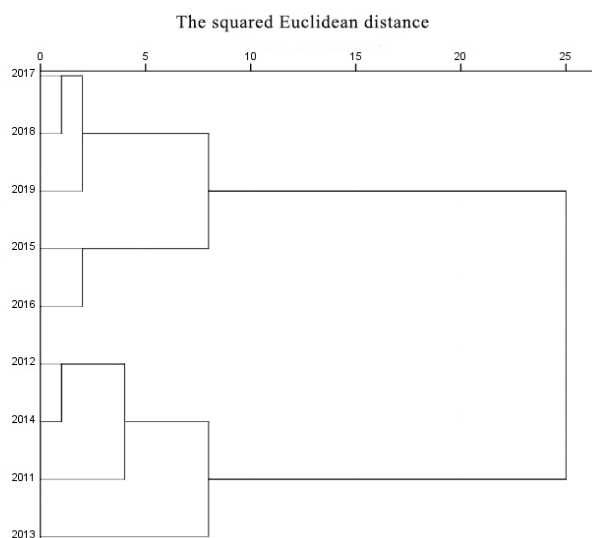
Fig. 5. pH and COD_{Mn}.

Fig. 6. Periodic cluster analysis pedigree of Caihongqiao monitoring point.

pollutants in sewage. It comes from livestock and poultry breeding, industrial wastewater, detergents and chemical fertilizers. It is the main oxygen-consuming pollutant. Excessive concentration can lead to eutrophication and poisoning of water bodies. Aquatic organisms will destroy the ecological and environmental functions of water bodies in severe cases [40] (Fig. 7).

4.4. Water quality analysis of Xiaodukou monitoring point

According to the water quality monitoring data at the Xiaodukou monitoring point, on the main stream of the Jialing River, the pedigree map obtained through CA can divide the basin from 2011 to 2019 into three groups (time periods) with the same physical and chemical characteristics. The first group is 2011–2012, the second group is 2013–2016, and the third group is 2017–2019. As shown in the Table 8, the Wilk Lambda value of DF is very small (0.000),

Table 7
Classification function coefficients

| Parameter	Group	
	First group	Second group
pH	6,472.074	6,378.481
NH_3–N	649.395	668.404
Constant	−29,090.121	−28,188.401

the chi-square value is high (32.579). The classification function coefficient of the temporal DA indicates that pH and NH_3–N are the most important water quality parameters that distinguish the first, second and third group (Fig. 8).

It can be concluded from Table 9 that the stepwise model processing only requires two main water quality indicators to construct DFs. Its discrimination ability will not be significantly reduced as a result.

The average pH of the third group (8.33) is higher than that of the second group (8.17) and the first group (8.26), which meets the surface water environmental quality standards (6–9); The average NH_3–N of the third group (0.339 mg/L) is higher than that of the second group (0.178 mg/L) and the first group (0.214 mg/L), which belongs to the second category of surface water environmental quality standards. In the third group, the water body was more affected by nitrogen-containing pollutants than the previous two groups (Fig. 9).

4.5. Water quality analysis of Liduzhen

According to the water quality characteristics of the Liduzhen monitoring point of the Jialing River and the pedigree map obtained through CA, we can divide the basin from 2011 to 2019 into three groups with the same physical and chemical characteristics. The first group is 2011-2012, the second group is 2013–2016, and the third group is 2017–2019. As shown in the Table 10, the Wilk Lambda value of DF is very small (0.003), and the chi-square value is high (19.981). The classification function coefficient of the
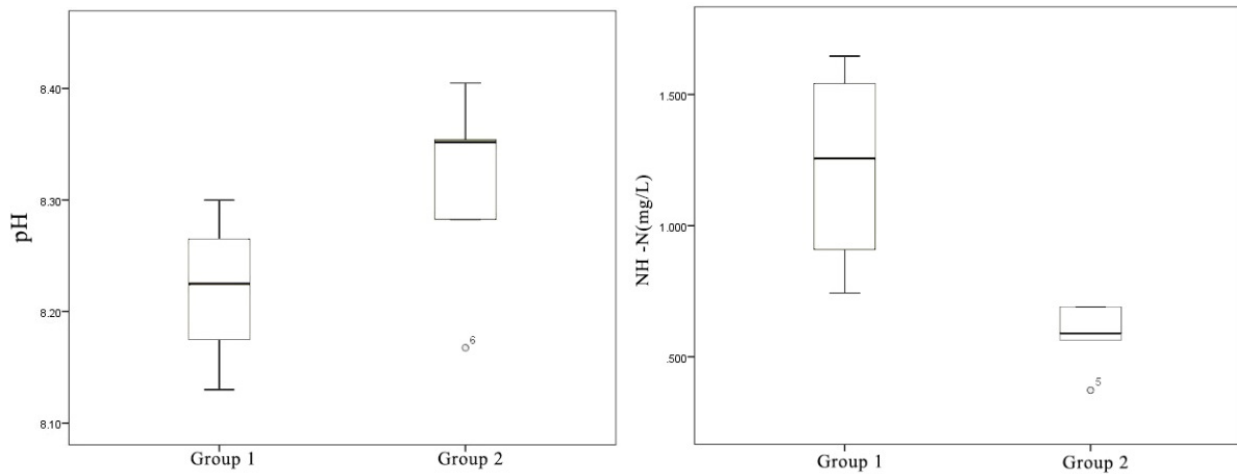
Fig. 7. pH and NH$_3$–N.

Table 8
Wilk's Lambda and chi-square values

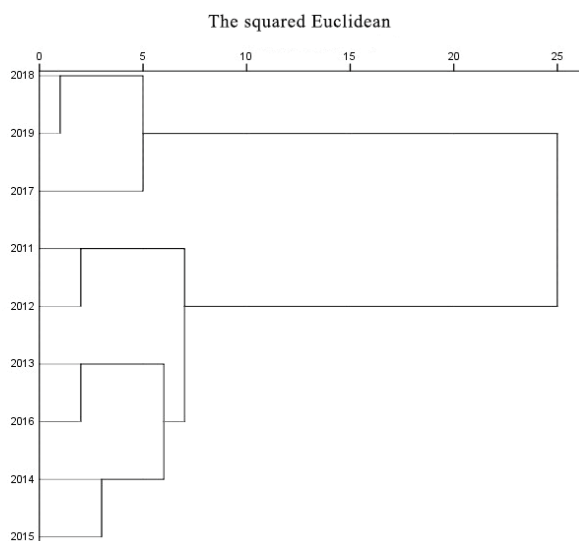| Fun.(s)	Wilk Lambda	Chi-square	Degree of freedom	Significance
1 to 2	0.000	32.579	12	0.001
2	0.205	5.551	5	0.352

Fig. 8. Periodic cluster analysis pedigree of Xiaodukou monitoring point.

temporal DA indicates that pH and NH$_3$–N are the most important water quality parameters that distinguish the first, second and third group (Fig. 10).

From Table 11 it can be concluded that the step-by-step model processing only requires three main water quality indicators to construct DFs. Its discrimination ability will not be significantly reduced as a result.

The average pH of the third group (8.32) is higher than that of the second group (8.19) and the first group (8.20),

Table 9
Classification function coefficients

Parameter	Group		
	First group	Second group	Third group
pH	209,972.967	205,732.965	220,283.137
NH$_3$–N	470,971.780	461,084.807	495,004.788
Constant	−772,478.923	−741,416.941	−849,789.196

which meets the surface water environmental quality standards (6–9); The average NH$_3$–N of the third group (0.22 mg/L) is higher than that of the second group (0.18 mg/L) and lower than the first group (0.23 mg/L). It belongs to the second group of surface water environmental quality standards in the period of the third group, the water body is affected by nitrogen-containing pollutants less than the first group period, but greater than the second group (Fig. 11).

Through the integration of multiple statistical analysis of monitoring data from 2011 to 2019, it showed that except for the Xichong River (Caihongqiao monitoring point) branch, the overall water quality of the Jialing River Basin is clearly demarcated around 2017, pH, DO, COD$_{Mn}$ and NH$_3$–N are the main influencing factors of water quality in different periods. After 2017, the water quality of the Langzhong section of the Jialing River is generally in good condition, and the content of reducing pollutants and nitrogen-containing pollutants in the water body is showing a downward trend. Taking 2015 as the boundary, after 2015, the main water quality influencing factors of Xichong River (Caihongqiao monitoring
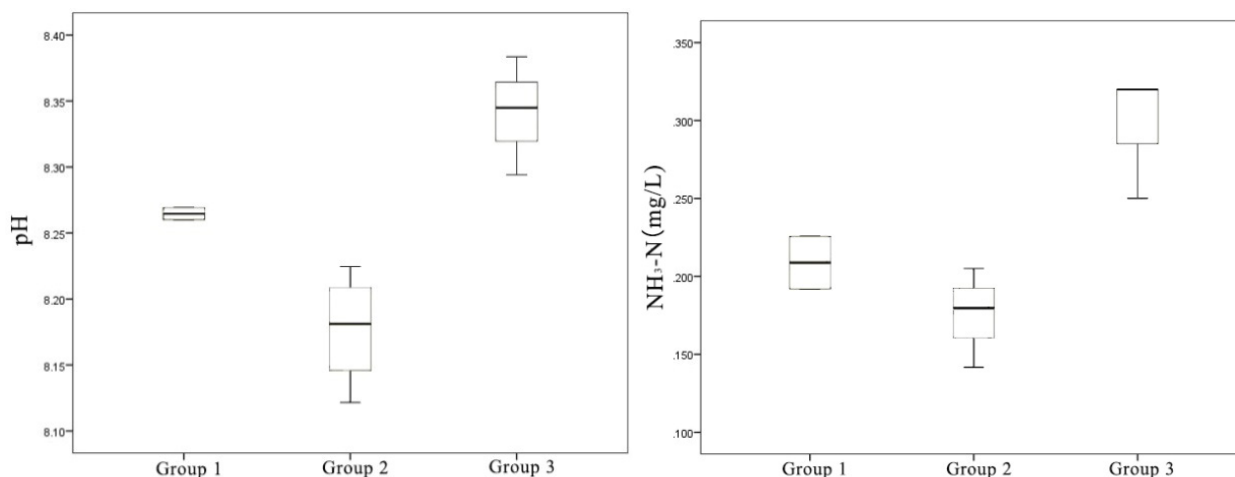
Fig. 9. pH and NH$_3$–N.

Table 10
Wilk's Lambda and chi-square values

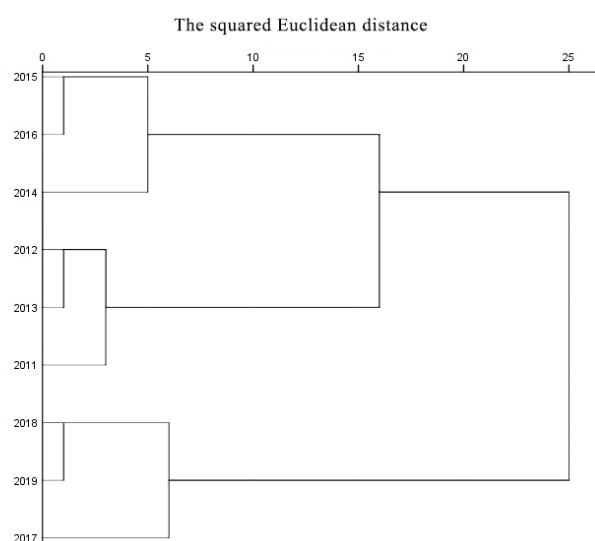| Fun.(s)	Wilk Lambda	Chi-square	Significance	Spatial
1 to 2	0.003	19.981	12	0.067
2	0.174	6.118	5	0.295

Fig. 10. Periodic cluster analysis pedigree of Liduzhen monitoring point.

point), a tributary of Jialing River, are pH and NH$_3$–N. NH$_3$–N is the main oxygen consuming pollutant. Too high concentration will lead to water eutrophication and poisoning, and its content shows a downward trend, which is inseparable from the high attention and effective management of the black and smelly water body of Xichong River by the government and relevant departments. However, the current trend of water pollution in the Nanchong section of the Jialing River still exists. According to the water

Table 11
Classification function coefficients

Parameter	Group		
	12,396.904	12,186.169	12,103.812
pH	17,996.957	17,584.043	17,516.538
NH$_3$–N	−91,322.369	−87,857.038	−8,6212.798
Constant	12,396.904	12,186.169	12,103.812

quality analysis results of the Nanchong section of the Jialing River Basin (Xiaodukou and Liduzhen monitoring points), the concentration of NH$_3$–N in the water body increased after 2017, indicating that the Nanchong section of the Jialing River will be more affected by nitrogen pollutants after 2017. The following picture shows the discharge indicators of waste water from the Jialing River system in Nanchong City from 2013 to 2018 (Fig. 12). With rapid economic development of Nanchong in recent years, the urban population has grown greatly, and the discharge of waste and sewage from the Jialing River system has also increased year by year. As a result, the situation of nitrogen-containing pollutants in the Nanchong section of the Jialing River has not been thoroughly settled. Therefore, the control of NH$_3$–N need to be enhanced.

5. Conclusion

This paper used the monitoring data of water quality of the Nanchong section of the Jialing River Basin from 2011 to 2019, and also employed multivariate statistical analysis
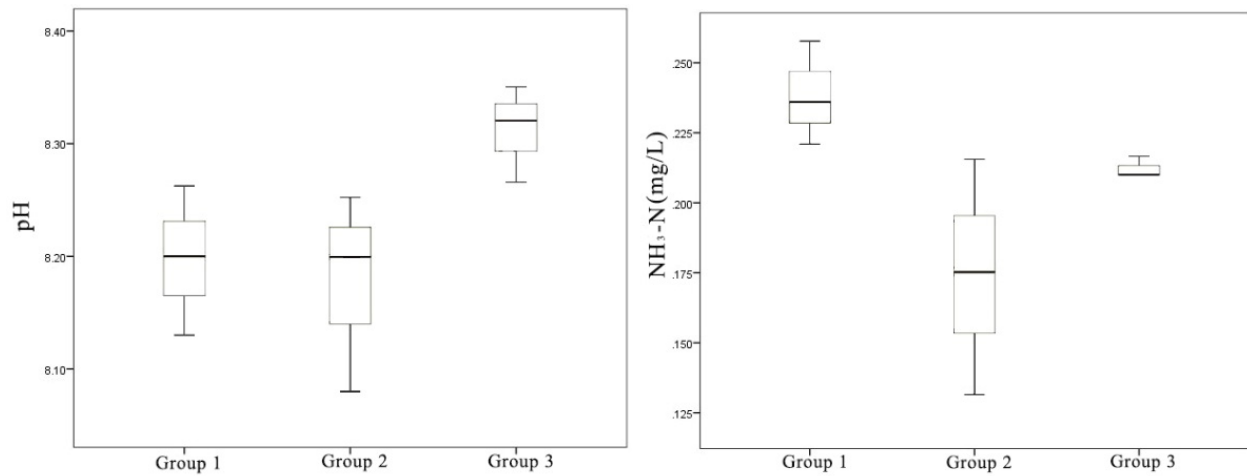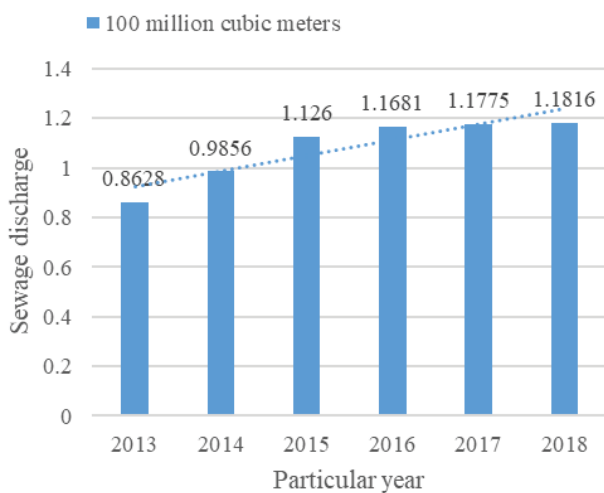
Fig. 11. pH and NH$_3$–N.

Fig. 12. Discharge of waste and sewage from the Jialing River system in Nanchong City from 2013 to 2018.

methods to analyze the time changes of the water quality in the basin, which improves public awareness of the changes of water quality related to spatial and temporal variation in the Nanchong section of the Jialing River Basin, and provides scientific basis to water quality management and protection in the basin.

During the period 2011–2019, the main influencing factors of the water quality of the Jialing River (Nanchong section) are pH, DO, COD$_{Mn}$ and NH$_3$–N. Among them, the annual average water quality indicators of the Langzhong main stream of the Jialing River Basin (Shaxi monitoring point), the Langzhong tributary of the Jialing River Basin (Dong River, Wencheng monitoring point) and the tributary of the Nanchong section of the Jialing River Basin (Xichong River, Caihongqiao monitoring point) shows a positive trend; while the results of main stream of the Jialing River (Xiaodukou and Liduzhen monitoring points) show that it has been greatly affected by nitrogen containing pollutants after 2017, and nitrogen containing pollutants in the Nanchong section of the Jialing River system are showing an increasing trend.

By categorizing pollution sources, it can provide reference basis for the government to prevent and control water pollution in the Nanchong section of the Jialing River Basin and to protect relevant ecosystems. So according to the current situation, two suggestion was given (1) Nanchong City should strengthen the water quality monitoring of the Nanchong section of Jialing River and strictly manage the sewage discharge into the river and lake. (2) Local government has to accelerate the process of environmental protection publicity and environmental education, improve the quality of the general public to consciously protect the environment, mobilize enthusiasm, and give full play to its supervisory role.

References

[1] K.P. Singh, A. Malik, S. Sinha, Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques—a case study, Anal. Chim. Acta, 538 (2005) 355–374.

[2] J. Wang, L. Da, K. Song, B.-L. Li, Temporal variations of surface water quality in urban, suburban and rural areas during rapid urbanization in Shanghai, China, Environ. Pollut., 152 (2008) 387–393.

[3] T.M. Qian, Multivariate statistical analysis of water quality in main and tributary stream of Qiantangjiang River in Hangzhou, Environ. Monit. China, 31 (2015) 74–77.

[4] G. Łukasz, W. Mirosław, P. Krzysztof, K. Andrzej, Determination of changes in the quality of surface water in the river—reservoir system, Sustainability, 13 (2021) 3457–3457.

[5] K. Huang, K.D. Fu, R. Zhu, Spatial-temporal distribution of water quality in the lower Lancang River based on multivariate statistical analysis, Water Resour. Res., 10 (2021) 53–62.

[6] D.A. Wunderlin, M.P. Díaz, M.V. Amé, S.F. Pesce, A.C. Hued, M.A. Bistoni, Pattern recognition techniques for the evaluation of spatial and temporal variations in water quality. A case study: Suquía River Basin (Córdoba–Argentina), Water Res., 35 (2001) 2881–2894.

[7] P.C. Cristiane, C.G. Moura, O.S. Corrêa, Assessment of spatial variations in the surface water quality of the Velhas River Basin, Brazil, using multivariate statistical analysis and nonparametric statistics, Environ. Monit. Assess., 191 (2019) 164, doi: 10.1007/s10661-019-7281-y.

[8] S. Zhang, Y. Liu, T. Wang, How land use change contributes to reducing soil erosion in the Jialing River Basin, China, Agric. Water Manage., 133 (2014) 65–73.

[9] X.B. Tang, H. Tang, Y. Wu, Spatio-temporal evolution of water resources pressure in Nanchong City, J. Univ. Chin. Acad. Sci., 33 (2016) 497–504.

[10] M. Li, J. Hu, C. Fan, Analysis on the discharge situation of main water pollutants in Nanchong during the twelfth five-year plan, Green Technol., 2 (2017) 16–17.

[11] B.X. Yang, Q. Liu, T.X. Dong, Functional diversity of soil microorganisms under different land use types in the Jialing River Basin, Soil Water Conserv. Res., 24 (2017) 14–20.

[12] H.M. Du, J.P. Yan, D.X. Yang, Multi-time scale analysis of precipitation changes and droughts and floods in the Jialing River Basin, J. Nat. Resour., 30 (2015) 836–845.

[13] J.Y. Li, Analysis and comprehensive evaluation of water quality monitoring in Nanchong section of Jialing River, Sichuan Environ., 33 (2014) 77–82.

[14] T.J. Xian, Z. He, C.J. Peng, Climatic characteristics of Nanchong City and evaluation of growth adaptability of "Nanchong Citrus", J. Agron., 11 (2021) 74–79.

[15] J. Zhang, T.S. Li, C.Z. Li, Analysis of main pollutants in water quality of Nanchong section of Jialing River, China Environ. Monit., 21 (2005) 88–90.

[16] W.X. Li, Investigation on water quality and pollution discharge in Jialing River Basin, Water Plann. Des., 8 (2015) 37–38.

[17] GB3838-2002, Environmental Quality Standards for Surface Water, State Environmental Protection Administration, China, 2002.

[18] Water and Wastewater Monitoring and Analysis Methods (Fourth Edition), State Environmental Protection Administration, China, 2002.

[19] HJ 506-2009, Water Quality-Determination of Dissolved Oxygen-Electrochemical Probe Method, Ministry of Environmental Protection, China, 2009.

[20] HJ 505-2009, Water Quality-Determination of Biochemical Oxygen Demand after 5 Days (BOD_5) for Dilution and Seeding Method, Ministry of Environmental Protection, China, 2009.

[21] GB 11892-1989, Water Quality-Determination of Permanganate Index, State Environmental Protection Administration, China, 1989.

[22] HJ 535-2009, Water Quality-Determination of Ammonia Nitrogen-Nessler's Reagent Spectrophotometry, Ministry of Environmental Protection, China, 2009.

[23] HJ 828-2017, Water Quality-Determination of the Chemical Oxygen Demand-Dichromate Method, Ministry of Environmental Protection, China, 2017.

[24] GB 11893-1989, Water Quality-Determination of Total Phosphorus-Ammonium Molybdate Spectrophotometric Method, State Environmental Protection Administration, China, 1989.

[25] HJ 694-2014, Water Quality-Determination of Mercury, Arsenic, Selenium, Bismuth and Antimony-Atomic Fluorescence Spectrometry, Ministry of Environmental Protection, China, 2014.

[26] GB/T 7484-1987, Water Quality-Determination of fluoride-Ion Selective Electrode Method, State Environmental Protection Administration, China, 1987.

[27] HJ/T 347-2007, Water Quality—Determination of Fecal Coliform—Manifold Zymotechnics and Filter Membrane, State Environmental Protection Administration, China, 2007.

[28] G. Papatheodorou, G. Demopoulou, N. Lambrakis, A long-term study of temporal hydrochemical data in a shallow lake using multivariate statistical techniques, Ecol. Modell., 193 (2006) 759–776.

[29] N. Cliff, Analyzing multivariate data, Technometrics, 46 (2003) 254–255.

[30] R. Johnson, Applied multivariate statistical analysis, Technometrics, 25 (1982) 385–386.

[31] K.P. Singh, A. Malik, V.K. Singh, D. Mohan, S. Sinha, Chemometric analysis of groundwater quality data of alluvial aquifer of Gangetic Plain, North India, Anal. Chim. Acta, 550 (2005) 82–91.

[32] W.D. Alberto, D.M. del Pilar, A.M. Valeria, P.S. Fabiana, H.A. Cecilia, B.M. de los Ángeles, Pattern recognition techniques for the evaluation of spatial and temporal variations in water quality, a case study: Suquía River Basin (Córdoba–Argentina), Water Res., 35 (2001) 2881–2894.

[33] Y. Yang, Y.Y. Zhou, L.Q. Zhang, Water quality analysis of the Yalong River in Panzhihua, China, Desal. Water Treat., 198 (2020) 53–60.

[34] C. Brown, Applied Multivariate Statistics in Geohydrology and Related Sciences, Springer, Berlin, 1998.

[35] F. Zhou, Z.J. Hao, H.C. Guo, Temporal and spatial distribution patterns of coastal water quality in Eastern Hong Kong, J. Environ. Sci., 27 (2007) 1517–1524.

[36] H.M. Zhou, L.F. Jiang, F.R. Li, Water quality status and cluster analysis of Huaihe River Basin in 2004, Water Resour. Prot., 23 (2007) 60–62.

[37] L.P. Meng, Based on cluster analysis and discriminant analysis method, Environ. Dev., 24 (2012) 193–194.

[38] D.J. Li, The role and analysis of dissolved oxygen in river water pollution, Henan Water Conserv. South-to-North Water Diversion, 14 (2014) 7–8.

[39] T. Yang, Q. Li, Analysis and countermeasures on exceeding standards of pH value and permanganate index in spring of small and medium-sized rivers in North China, China's New Technol. New Prod., 17 (2020) 134–135.

[40] F.J. He, L.Q. Zhang, Y.X. Li, Dynamic changes and influencing factors of permanganate index and ammonia nitrogen in the mainstream of Jialing River in Nanchong City, Sichuan Environ., 37 (2018) 95–101.