

*Original Research*

# The Temporal Variation and Flood Determined the Characteristics of the Water Quality Pattern in Danjiangkou Reservoir, China

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## Abstract

As the water source of the Middle Route of China's South-to-North Water Transfer project, the change of water quality of Danjiangkou Reservoir has been attracting much attention. This study aimed to obtain the annual water quality pattern and influencing factors of Danjiangkou Reservoir by means of multivariate analysis and correlation analysis using monthly data surveyed in 2021. The results of PCA and RDA variation partition analysis showed that the water quality of Danjiangkou Reservoir was mainly affected by temporal factors, and the spatial effect was limited. The trajectory analysis results revealed that the unusual floods in the current years have specific impacts on water quality in Danjiangkou Reservoir at the temporal and spatial scales. The results of Pearson and Mantel correlation test indicated that the inflow and water level affected the spatial-temporal pattern of reservoir water quality mainly via the  $\text{NO}_3^-$  and  $\text{PO}_4^{3-}$ . With the global change i.e. extreme flood, this research would provide a basis for the decision-making of management empirically.

**Keywords:** Danjiangkou Reservoir, water quality, spatial-temporal pattern, flood

## Introduction

Access to safe, clean, and affordable drinking water is a fundamental right that is essential for public health [1]. However, factors such as global population growth, food demand, industrialization, urbanization, and climate change are posing significant threats to the availability of freshwater resources worldwide [2].

Despite efforts to reduce pollution, improve wastewater treatment, and the restore rivers, lakes and reservoirs in China, archiving good quality for water reminds a challenge [3, 4]. Poor water quality exacerbates China's water scarcity and regional inequality [5], making it increasingly necessary to rely on reservoirs and lakes with better water quality and inter-regional water transfer projects to meet the demands for drinking water supply [6, 7].

The Middle-Route of the South-to-North Water Diversion Project of China (SNWDPC) is the world's largest inter-basin water diversion project and has

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effectively alleviated the severe water shortage in North China. As the water source of SNWDPC, the Danjiangkou Reservoir has provided more than 51.8 billion m<sup>3</sup> of water resources via 1276 km open canal and benefited over 85 million inhabitants in the water receiving area since 2014. It has become the primary domestic source of domestic water for 24 cities including the major municipalities of Beijing and Tianjin. Therefore, it is of crucial importance to protect the water quality and aquatic ecosystem health of the Danjiangkou Reservoir [8].

Multivariate statistical techniques, including cluster analysis (CA), principal component analysis (PCA), and discriminant analysis (DA), have become increasingly popular in recent years to evaluate surface water quality [9-13]. These techniques are also useful for assessing spatial or temporal variations that may be due to natural or anthropogenic factors and possibly linked to seasonality [14].

Previous studies on the Danjiangkou Reservoir mostly focused on normal or low water storage level conditions. However, during the research period of this study, the reservoir was operated at its historical highest water level for an extended period. Thus, it is of great significance to investigate the changes in the water quality and factors that influence them under such conditions. The objective of this paper is to use multivariate statistical techniques to assess temporal variations in the water quality of the Danjiangkou Reservoir and examine the impact of flooding on typical water quality parameters. The results could provide valuable insights for water quality agencies to effectively allocate their resources to combat severe water pollution.

## Material and Methods

### Study Area and Sampling Sites

The Danjiangkou reservoir is the source of China's SNWDPC, located on the border of Henan and Hubei Province. In 2021, We collected surface water samples monthly at Sihekuwan (SHKW), Taijiu (TJH), Langhekou (LHK) and Baqian (BQ) along the main river from the end to the head of the dam (Fig. 1). Each month, we collected a total of 2 L raw water, 0.5 m under the surface, via the 5 L standard water sampler. 0.5 L water was filtered through a 1.2 μm-pore Whatman GF/C membrane filter, and the membrane was kept in a previously acid-washed 2 mL plastic tube for suspended Chlorophyll *a* (Chl *a*) concentration analysis; Another 0.5L water was acidified with sulfuric acid to pH = 2 for chemical oxygen demand (COD<sub>Mn</sub>), total nitrogen (TN) and total phosphorus (TP) analysis; The last 1L water was transported to the laboratory and stored under 4°C for total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP), ammonia nitrogen (NH<sub>4</sub><sup>+</sup>), nitrate nitrogen (NO<sub>3</sub><sup>-</sup>), nitrite nitrogen (NO<sub>2</sub><sup>-</sup>), Phosphate (PO<sub>4</sub><sup>3+</sup>) and silicate (SiO<sub>4</sub><sup>-4</sup>) analyses. The standard techniques used for measuring these water quality parameters are following the "Environmental quality standards for surface water (GB 3838-2002)".

Water temperature (WT), pH, dissolved oxygen (DO), Electronic Conductivity (EC), total dissolved solid (TDS), and Turbidity (Turb) were measured using EXO3 (YSI Inc., Yellow Springs, Ohio, USA); Secchi depth (SD) was determined with a black and white Secchi disk (diameter = 20 cm). The above physico-chemical characteristics were determined for all the samples.

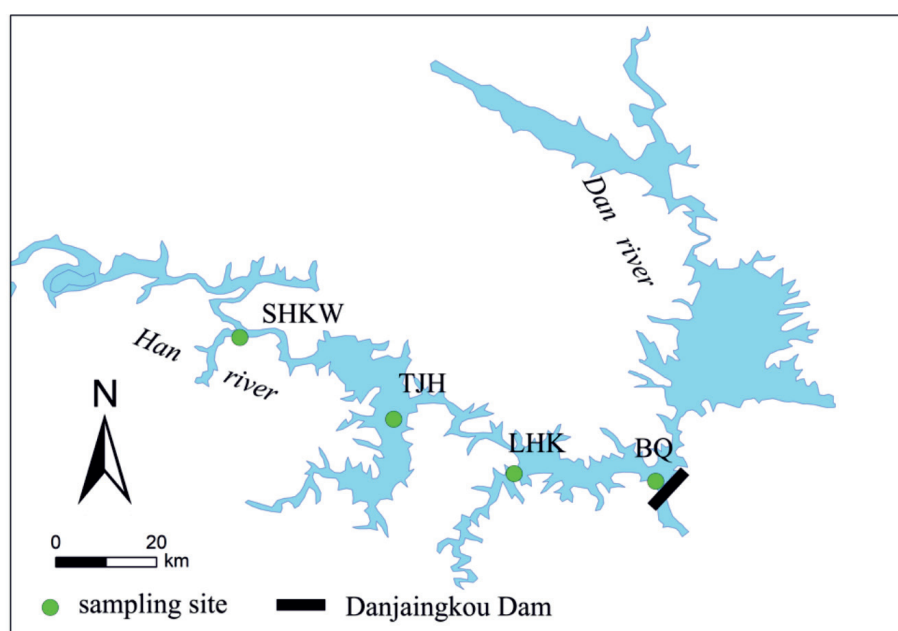


Fig. 1. Map of sampling sites. SHKW is for Sihekuwan, TJH is for Taijiu, LHK is for Langhekou and BQ is for Baqian.

## The Data Statistical Analysis

The multivariate analysis methods of PCA and RDA/VPA were used to analyze the temporal and spatial pattern of the physico-chemical parameters in Danjiangkou Reservoir. The matrix of Euclidean distances was calculated and then Trajectory analysis was applied to analyzing the trend and degree of water quality changing at different sampling sites in a year. Pearson and Mantel analysis were used to analyze the relationship between various environmental factors and between hydrological conditions and environmental factors, respectively. All analysis methods were implemented in R language (Version 4.2.0), and PCA, RDA and VPA were conducted with package *factomineR* and *factoextra*. The Trajectory analysis was calculated using the package *ecotraj*, and Pearson and Mantel correlation were calculated using the package *linkET* [15].

## Results

### Hydrological Parameters

According to the Water Resources Monitoring Bulletin, the monthly water level was 161.3 m before July and increased to 168.82 m from August to December, reaching a historic high of 170 m in October and November. The average inflow of Danjiangkou reservoir was low from January to June at around 960.5 m<sup>3</sup>/s and increased rapidly in July, reaching a peak of about 8470 m<sup>3</sup>/s in September. However, while the water level remained high, the average inflow decreased to about 1000 m<sup>3</sup>/s in the last two months (Fig. 2).

### Spatial and Temporal Variation of the Physico-Chemical Parameters

Table 1 lists the range and average values of physico-chemical parameters for each site. Since there was an increase in the inflow, the period from August to October was designated as the “Flood season” of 2021,

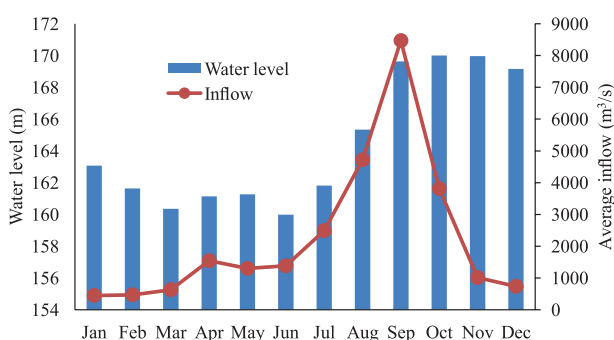


Fig. 2. Water level and average inflow of Jan to Dec, 2021 in Danjiangkou Reservoir.

while January to July was classified as the “Before flood season”, and November to December as the “After flood season”.

Most of the nutrients of nitrogen, including TN, NO<sub>3</sub><sup>-</sup>, NO<sub>2</sub><sup>-</sup>, and NH<sub>4</sub><sup>+</sup>, showed the highest average value at site SHKW, while the other three sites possessed an approximate value. In contrast, the nutrients of phosphorus, such as TDP, did not show significant difference among site SHKW, TJH, BQ (0.030-0.054 mg/L), but were higher than those of site LHK (0.017 mg/L). The spatial distribution of SiO<sub>4</sub><sup>-4</sup> was similar to that of nitrogen nutrients (Table 1).

There was no significant difference in WT, DO, COD<sub>Mn</sub> and pH among the four sites. On the other hand, EC and TDS showed similar patterns with nitrogen nutrients, and Turb showed similar patterns with phosphorus nutrients. The concentration of Chl *a* decreased along the main river of the reservoir, from 6.552 mg/L to 2.713 mg/L. Meanwhile, the SD showed an almost opposite trend with Chl *a*, increasing from 2.4 m to about 3.0 m (Table 1).

It's evident that the concentration of nutrients such as phosphorus, nitrogen, and silicon and COD<sub>Mn</sub> increased during the flood season, and SD, DO and pH decreased. Among the three time periods, with Chl *a* and DO parameters displayed a significant difference, with Chl *a* increasing during the Flood season and decreasing during the After flood season, while the DO showed an opposite trend (Fig. 3).

### Multivariate Analysis of Physico-Chemical Parameters

The PCA results indicate that samples from different months were clustered together in different quadrants, with October to January in the third quadrant; February and March in the fourth quadrant; samples from April to July in the first quadrant, and August to September in the second quadrant. Additionally, the results showed that the site SHKW was distinct from the other three sites, which had overlapping data points in the plots (Fig. 4a).

Overall, these findings suggested that the temporal changes in the physico-chemical parameters, such as seasonal variations and hydrological events, have a greater impact on the physico-chemical parameters of the reservoir compared to the spatial differences among sampling sites. The lack of spatial variation among sites THJH, LHK, and BQ may indicate that the environmental conditions in these areas are relatively homogeneous (Fig. 4b).

RDA variance partition analysis was performed for the environmental conditions based on the temporal variables of months and the spatial variables of sampling sites. The result further confirmed that the dominance of temporal variation in driving changes of physico-chemical parameters annual alteration (82.45%), and the spatial variation only explained 2.62%, whereas the rest 14.93% were remain unknown (Fig. 5).

Table 1. Spatial distribution of environmental parameters in Danjiangkou Reservoir.

|                                       | SHKW         |         | TJH           |         | LHK           |         | BQ            |         |
|---------------------------------------|--------------|---------|---------------|---------|---------------|---------|---------------|---------|
|                                       | Range        | Average | Range         | Average | Range         | Average | Range         | Average |
| TN (mg/L)                             | 1.258~2.428  | 1.711   | 1.120~1.694   | 1.429   | 1.068~1.918   | 1.403   | 0.991~1.599   | 1.301   |
| TP(mg/L)                              | 0.004~0.125  | 0.034   | 0.006~0.154   | 0.032   | 0.007~0.059   | 0.027   | 0.005~0.139   | 0.040   |
| NO <sub>3</sub> <sup>-</sup> (mg/L)   | 0.991~1.834  | 1.459   | 0.965~1.501   | 1.188   | 0.886~1.655   | 1.159   | 0.804~1.411   | 1.118   |
| NO <sub>2</sub> <sup>-</sup> (mg/L)   | 0.001~0.048  | 0.014   | 0.0004~0.023  | 0.008   | 0.001~0.018   | 0.008   | 0.002~0.021   | 0.008   |
| NH <sub>4</sub> <sup>+</sup> (mg/L)   | 0.037~0.206  | 0.093   | 0.018~0.241   | 0.088   | 0.041~0.182   | 0.097   | 0.049~0.192   | 0.104   |
| PO <sub>4</sub> <sup>3+</sup> (mg/L)  | 0.0005~0.031 | 0.010   | 0.0001~0.022  | 0.009   | 0.0002~0.032  | 0.011   | 0.0001~0.044  | 0.013   |
| TDN (mg/L)                            | 1.130~2.171  | 1.629   | 1.105~1.648   | 1.348   | 0.981~1.759   | 1.312   | 0.945~1.594   | 1.266   |
| TDP (mg/L)                            | 0.004~0.196  | 0.032   | 0.004~0.201   | 0.030   | 0.005~0.046   | 0.017   | 0.002~0.468   | 0.054   |
| SiO <sub>4</sub> <sup>-4</sup> (mg/L) | 3.815~11.184 | 8.225   | 3.559~10.902  | 7.224   | 3.046~10.66   | 7.669   | 2.273~10.420  | 7.491   |
| WT (°C)                               | 8.938~29.807 | 18.338  | 10.705~29.544 | 19.114  | 11.183~30.222 | 19.403  | 11.181~29.356 | 18.933  |
| DO (mg/L)                             | 5.710~11.160 | 9.575   | 6.210~12.260  | 9.667   | 6.720~11.280  | 9.541   | 6.240~11.760  | 9.443   |
| CODMn (mg/L)                          | 1.381~4.950  | 2.615   | 1.161~3.383   | 2.209   | 1.220~8.222   | 2.944   | 1.18~8        | 2.853   |
| EC (μS/m)                             | 195.2~322.9  | 236.383 | 186.5~249.1   | 216.717 | 178.9~245.6   | 209.483 | 182.8~251.3   | 216.225 |
| TDS (mg/L)                            | 155~193      | 176.500 | 141~181       | 159.500 | 141~167       | 152.833 | 143~174       | 159.833 |
| Turb (mg/L)                           | 1.17~20.06   | 5.422   | 0.44~31.35    | 6.601   | 0.26~11.11    | 3.868   | 0.56~27       | 6.292   |
| pH                                    | 7.74~8.9     | 8.401   | 7.96~8.87     | 8.417   | 7.9~8.88      | 8.385   | 7.89~8.83     | 8.372   |
| SD (m)                                | 0.5~4.8      | 2.4     | 0.5~6.1       | 2.9     | 0.8~7.9       | 3.1     | 0.5~6.4       | 2.9     |
| Chl <i>a</i> (μg/L)                   | 1.181~7.772  | 3.290   | 0.510~12.280  | 3.902   | 0.532~11.137  | 3.486   | 0.460~4.781   | 2.713   |

### Affecting Factors of the Water Quality

Trajectory analysis was conducted to explore the monthly variation trend of different locations throughout the year. The results show that axis 1 of PCoA explained 62%, while axis 2 explained 16% of the variation, totaling to 78%. The trajectory analysis effectively captured the time-series regulation of water quality in the four survey sites of Danjiangkou Reservoir within 12 months. Initially, the sample points from TJH and LHK in the reservoir were mixed from January to July with little fluctuation. However, with a significant increase in water inflow in the reservoir (Fig. 2), sample points from August to September moved rapidly along the first axis, indicating that the physico-chemical parameters were greatly affected by the flood. Specifically, sample points from SHKW (black arrow in Fig. 6a) showed a longer step from August to September compared to other sites, while the sample points from BQ (green arrow in Fig. 6a) showed less impact from the flood.

To identify the contributing factors to the water quality succession in main area of the reservoir, PCA was conducted on variables from sites excluding SHKW (Fig. 6b). It can be observed that the WT, SiO<sub>4</sub><sup>-4</sup>, pH were the top three contributing factors to the water quality succession, while the TP, TDP, Chl *a* showed less contribution.

The Pearson analysis revealed significant positive correlations of TP with COD<sub>Mn</sub>, SiO<sub>4</sub><sup>-4</sup>, PO<sub>4</sub><sup>3+</sup> ( $p < 0.01$ ) and Turb ( $p < 0.05$ ), while significant negative correlations were found with DO, pH, SD ( $p < 0.01$ ) and NH<sub>4</sub><sup>+</sup> ( $p < 0.05$ ). Furthermore, the Mantel test was conducted to assess the correlation between individual environmental factor and monthly averages of inflow and water level (Fig. 7). The results showed that inflow was significantly correlated with the concentration of TDS, NO<sub>3</sub><sup>-</sup> and COD<sub>Mn</sub>, while the increase of water level was correlated with the concentration of PO<sub>4</sub><sup>3+</sup>.

### Discussion

#### Spatial-Temporal Patterns of Physico-Chemical Parameters in Danjiangkou Reservoir

Danjiangkou Reservoir is a long and narrow riverine reservoir, and the inflow of water mainly comes from the mainstream, Han River, which contributed up to 88%. Therefore, the spatial-temporal patterns of physico-chemical parameters in Han River represent the reservoir [16]. Comparison of different environmental parameters at each site and in each flood period, Before, During and After the Flood Season, suggested a distinct pattern in Danjiangkou reservoir, in which the temporal

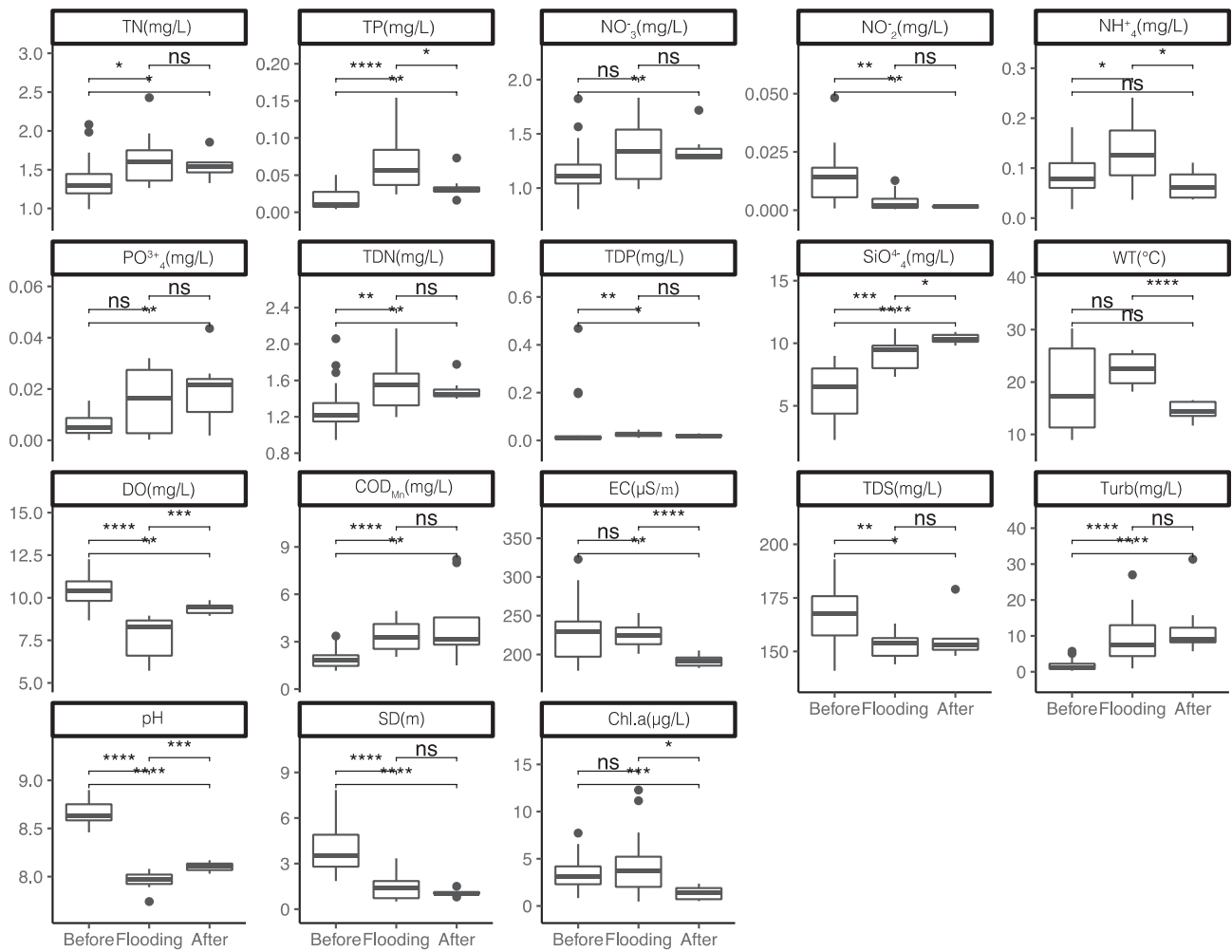


Fig. 3. The environmental parameters of different period in Danjiangkou Reservoir. Group “Before” indicates Jan to July, group “Flooding” indicates Aug to Oct, and “After” indicates Nov to Dec; “ns”, “\*”, “\*\*”, “\*\*\*” and “\*\*\*\*\*” indicates the p value of the “t-test” was >0.05, ≤0.05, ≤ 0.01, ≤ 0.001, and ≤ 0.0001.

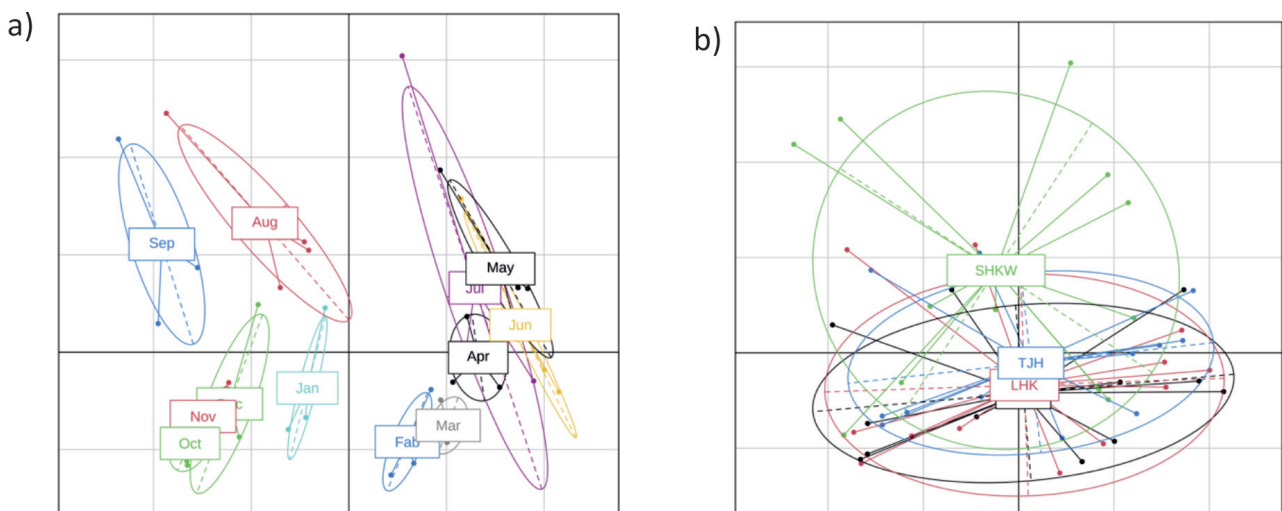


Fig. 4. The PCA results of the environmental parameters in Danjiangkou Reservoir.



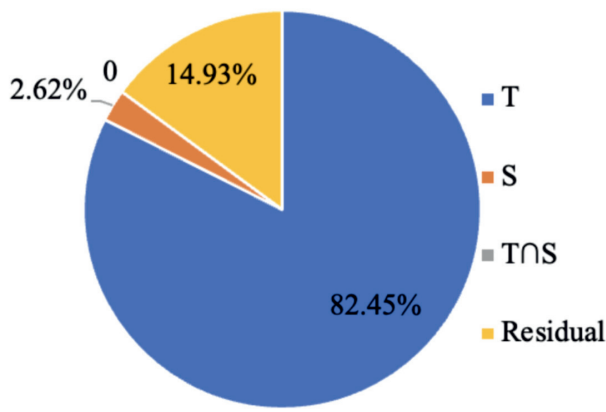


Fig. 5. The contribution of temporal and spatial variation on the physico-chemical parameters annual alteration (T: temporal; S: spatial; T∩S: both temporal and spatial explained; Residual: Unexplained).

variation explained most of the total variation rather than the spatial variation.

The upstream received large amount of rainfall, which caused the formation of floodwater mixed with pollutants that run into the Reservoir. This had a profound impact on the water quality at both temporal and spatial scales [17]. As a result, the transparency (SD) of the SHKW sample site was the lowest, and gradually increased to about 3 m at BQ sample site, due to the slowing down of water velocity. The turbid water caused a decrease in SD and an increase in EC, TDS, and nitrogen concentration at the SHKW site, while the other three sites archived less effect because of their great distance. It can be confirmed that the less spatial difference in Danjiangkou Reservoir were contributed from flood, rather than the local environment.

Phosphorus and nitrogen are drivers of eutrophication in aquatic lakes and reservoirs systems [18], and both nutrients are influenced by flood and water level regime [19-20]. The distribution of nitrogen

and silicon decreased from the end to the head of the reservoir, while the spatial difference of phosphorus was not significant. This may be due to the self-cleaning processes such as dilution and sedimentation in the reservoir water [21]. In addition, the decreased inflow after the Flood season, coupled with the effect of temperature reduction, led to a decrease in phosphorus concentration to the level observed before Flood Season. Since temperature and key nutrient element are widely known to be the main contributors of algae growth [22-23], the level of Chl *a*, which represents the growth of freshwater algae, decreased in Danjiangkou Reservoir.

Based on the given statement, it appears that there was no decrease in the concentration of nitrogen in the reservoir area during the “After flood” season. This could be due to the high water level operating in the reservoir during that year, which resulted in some coastal areas being soaked in water for an extended period. As a result, there was a continuous leaching of nitrogen in the form of  $\text{NO}_3^-$ , which helped to maintain the nitrogen concentration at the level of the flood season.

It is worth noting that high levels of nitrogen in water can lead to eutrophication, which can cause harm to aquatic ecosystems. Therefore, it is essential to monitor the levels of nitrogen in water bodies and take appropriate measures to prevent excessive leaching of nitrogen into the water.

Based on the given statement, it appears that the annual succession of Danjiangkou Reservoir is mainly explained by temporal variation, similar to the previous study conducted at Tangpu Reservoir [24]. However, the difference is that Danjiangkou Reservoir was affected by floods both temporally and spatially in a certain year, which could have an impact on the reservoir’s ecological succession.

Temporal variation refers to changes that occur over time, such as seasonal changes, while spatial variation refers to changes that occur across space,

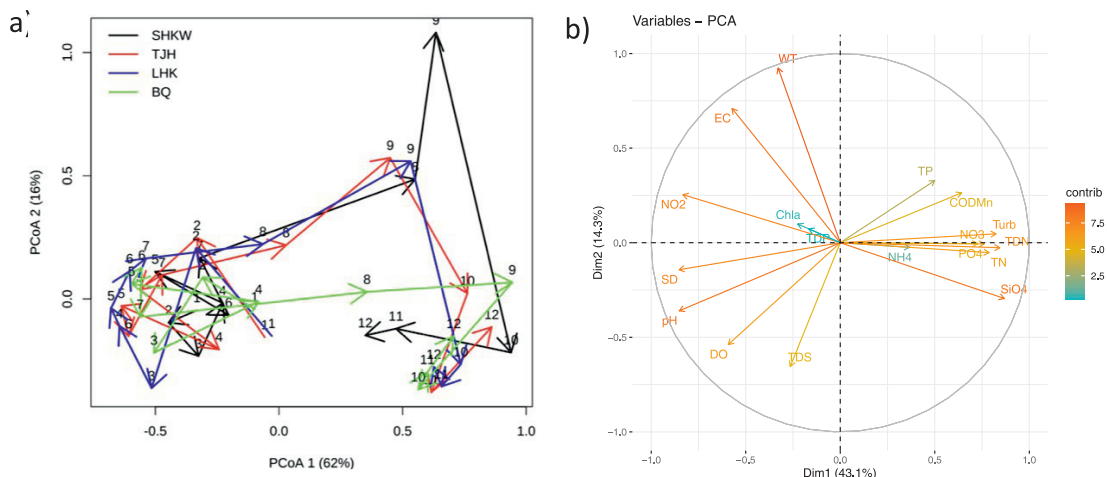


Fig. 6. The effecting factors based on trajectory analysis and PCA.

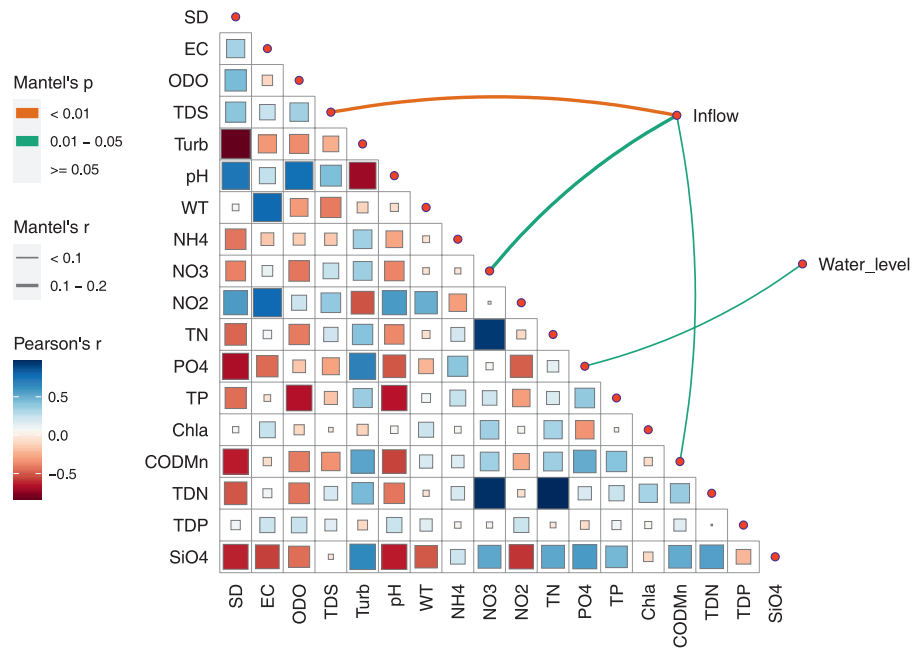


Fig. 7. The Pearson correlation between environmental parameters and Mental test between each hydrological parameter with environmental parameter.

such as changes in different areas of a reservoir. The impact of floods on the reservoir’s ecology could have both temporal and spatial components, affecting the reservoir’s ecological succession in various ways.

### The Affecting Factors of the Water Quality Pattern in Danjiangkou Reservoir

Danjiangkou Reservoir is the important water source of the south-north water diversion in China, and its water quality and the factors that affect it have received widespread attention [25-27]. In many reservoirs across China, phosphorus is considered the primary determinant of water quality [12, 28-30]. Studies have shown that the total phosphorus concentration in China’s reservoirs ranges from 0.02 to 0.21 mg/L, with a decreasing trend [31]. For example, Li et al. [32] found that the average annual TP and TN in the Three Gorges Reservoir were about 0.15 mg/L and 1.5 mg/L, respectively. Phosphorus was found to be the limiting factor for phytoplankton growth (represented by Chl *a*) in all seasons. Cao et al. [25] noticed a significant relation between water quality and parameters such as DO, Turb, Cl<sup>-</sup> and NO<sub>3</sub><sup>-</sup>, but not with TN or TP. This finding indicates that the reservoir dispatching, fertilizer utilization, and rock weathering have an impact on the water quality. Li et al. [33] focused on the changes in different ion concentrations in water from 2004 to 2014, revealing the long-term effects of rock weathering and human activities on the water quality in Danjiangkou Reservoir.

Although the total phosphorus concentration in Danjiangkou Reservoir is at the lowest level

among deep water reservoirs in China, the risk of eutrophication and algae bloom cannot be ignored [34]. Similar to previous studies [20], phosphorus from upstream tributary watersheds remained relatively high and stable in the head area of reservoir, which increase the high risk of eutrophication. In the present study, Chl *a* was significantly positively correlated with nitrogen (including TN, TDN, and NO<sub>3</sub><sup>-</sup>), but negatively correlated with orthophosphate (PO<sub>4</sub><sup>3+</sup>), which may be influenced by the unusual flood in this year. Research has shown that utilization of agricultural land and seasonal precipitation jointly promoted the dry deposition of NH<sub>4</sub><sup>+</sup> in dissolved inorganic nitrogen (DIN) in Danjiangkou Reservoir, thereby increasing the risk of water pollution [27]. However, Chen et al. [26] assessed the risk of eutrophication in Danjiangkou Reservoir through a 3D model based on hydrodynamic conditions (EFDC) and found that even when TN increased by 50%, it did not pose an obvious threat to the bloom risk in the Reservoir.

The spatial-temporal patterns in the Danjiangkou reservoir could be attributed to its spatial structure and seasonal hydrological conditions. As a riverine reservoir system, spatial heterogeneity was concealed by temporal heterogeneity [24]. The water quality pattern was mainly determined by temperature and other seasonal parameters. With the influence of global warming [35], nutrients were dissolved in rainwater and formed as turbid water flowed into the river from the end to the head of the reservoir. This reminds us that the precipitation and runoff are major causes of eutrophication risk in Danjiangkou Reservoir. Therefore, further long-term monitoring and research

are needed to address the spatial-temporal variation of water quality in Danjiangkou Reservoir.

### Conclusions

The main conclusions may be summarized as follows.

i. The unusual flood in this year affected the pattern of water physical and chemical parameters both at spatial and temporal scales.

ii. Phosphorus loading from precipitation and runoff still was the risk of eutrophication even though the low concentration.

iii. Seasonal variation and unusual flood shaped the water quality parameters in 2021.

In conclusion, routine monitoring in temporal change is more important than in spatial variation in riverine reservoirs e.g. Danjiangkou reservoir with a limited budget. Furthermore, variation in reservoir hydrological regimes caused by events such as floods or heavy rainfall also have a dramatic impact on its water quality.

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### Conflict of Interest

The authors declare no conflict of interest.

### References

- WHO. Guidelines for drinking-water quality: fourth edition incorporating the first addendum. Geneva, **2017**.
- ÖZDEMİR A. A Framework for Drinking Water Basin Protection. *Water and Environment Journal*, **35** (4), 1362, **2021**.
- WANG H.N., YU X.X. A Review of the Protection of Sources of Drinking Water in China. *Natural Resources Forum*, **38** (2), 99, **2014**.
- WU J.Y. Challenges for Safe and Healthy Drinking Water in China. *Current Environmental Health Reports*, **7** (3), 292, **2020**.
- MA T., SUN S., FU G.T., HALL G.W., NI Y., HE L.H., YI J.W. Pollution Exacerbates China's Water Scarcity and Its Regional Inequality. *Nature Communications*, **11** (1), 650, **2020**.
- GUO, Z.F., BOEING W.J., BORGOMEIO E., XU Y.Y., WENG Y. Linking Reservoir Ecosystems Research to the Sustainable Development Goals. *Science of The Total Environment* **781** (4), 146769, **2021**.
- ZHANG Y.L., DENG J.M., QIN B.Q., ZHU G.W., ZHANG Y.J., JEPPESEN E., TONG Y.D. Importance and Vulnerability of Lakes and Reservoirs Supporting Drinking Water in China. *Fundamental Research*, March, in press. **2022**.
- JIANG Y.Q., HE K., LI Y.Y., QIN M.Q., CUI Z.Z., ZHANG Y., YAO Y.L., CHEN X.N., DENG M.J., GRAY A., LI B.L. Driving Factors of Total Organic Carbon in Danjiangkou Reservoir Using Generalized Additive Model. *Water*, **14** (6), 891, **2022**.
- LI X., LI P.J., WANG D., WANG Y.Q. Assessment of Temporal and Spatial Variations in Water Quality Using Multivariate Statistical Methods: A Case Study of the Xin'anjiang River, China. *Frontiers of Environmental Science & Engineering*, **8** (6), 895, **2014**.
- GU Q., ZHANG Y., MA L.G., LI J.D., WANG K., ZHENG K.F., ZHANG X.B., LI S. Assessment of Reservoir Water Quality Using Multivariate Statistical Techniques: A Case Study of Qiandao Lake, China. *Sustainability*, **8** (3), 243, **2016**.
- ZEINALZADEH K., REZAEI E. Determining Spatial and Temporal Changes of Surface Water Quality Using Principal Component Analysis. *Journal of Hydrology: Regional Studies*, **13** (C), 1, **2017**.
- VAROL M. Spatio-Temporal Changes in Surface Water Quality and Sediment Phosphorus Content of a Large Reservoir in Turkey. *Environmental Pollution*, **259**: 113860, **2020**.
- YANG W.J., ZHAO Y., WANG D., WU H.H., LIN A.J., LI H. Using Principal Components Analysis and IDW Interpolation to Determine Spatial and Temporal Changes of Surface Water Quality of Xin'anjiang River in Huangshan, China. *International Journal of Environmental Research and Public Health*, **17** (8), 2942, **2020**.
- WOLDEAB B., BEYENE A., AMBELU A., BUFFAM I., MERETA S.T. Seasonal and spatial variation of reservoir water quality in the southwest of Ethiopia. *Environmental monitoring and assessment*, **190** (3), 1, **2018**.
- HUANG H.Y. linkET: Everything is Linkable. R package version 0.0.3. **2021**.
- WEI M.J., DUAN P.F., GAO P.C., GUO S.L., HU Y.X., YAO L.G., LI M. Exploration and Application of Hydrochemical Characteristics Method for Quantification of Pollution Sources in the Danjiangkou Reservoir Area. *Journal of Hydrology*, **590** (2-4), 125291, **2020**.
- LI S.Y., JIANG H., XU Z.F., ZHANG Q.F. Backgrounds as a Potentially Important Component of Riverine Nitrate Loads. *Science of The Total Environment*, **838** (4), 155999, **2022**.
- MARIEL B.A., MARTIN M.I., JORGE R.Z., FERMIN C.S., VILACLAR A.G., ANDREA G.A., MIROSLAV, M. ROCIO A.H., SALVADOR S.C., PATRICIA V., ARANTXA S.R., JOSE Q.T., EMILIANO M.R., JULIO D.V., JULIO L.G., OSCAR G.N., ROBERTO G.D. Nitrogen and Phosphorous Retention in Tropical Eutrophic Reservoirs with Water Level Fluctuations: A Case Study Using Mass Balances on a Long-Term Series. *Water*, **14** (14), 2144, **2022**.
- YU J.H., ZHANG Y.S., ZHONG J.C., DING H., ZHENG X.Z., WANG Z.Y., ZHANG Y.L. Water-Level Alterations Modified Nitrogen Cycling across Sediment-Water Interface in the Three Gorges Reservoir. *Environmental Science and Pollution Research*, **27** (1), 1, **2020**.



20. CHEN S.B., CHEN L., GAO Y., GUO J.S., LI L.F., SHEN Z.Y. Larger Phosphorus Flux Triggered by Smaller Tributary Watersheds in a River Reservoir System after Dam Construction. *Journal of Hydrology*, **601** (3), 126819, **2021**.
21. XU J.X. The Influence of Dilution on Downstream Channel Sedimentation in Large Rivers: The Yellow River, China. *Earth Surface Processes and Landforms*, **39** (4), 450, **2014**.
22. WANG H., WU Q., HAN Y.P. Effects of Drying-Flooding Alternation on Sediment-Water Nitrogen Fluxes in Hydro-fluctuation Belt of the Danjiangkou Reservoir. *Water, Air, & Soil Pollution*, **233** (3), 1573, **2022**.
23. ZHANG, X., FENG B.F., ZHANG J., XU Y.S., LI J. NIU W.J., YANG Y.F. The Detection of Flood Characteristics Alteration Induced by the Danjiangkou Reservoir at Han River, China. *Water*, **13** (4), 496, **2021**.
24. MA P.M., SHI L.D., ZHANG J.F., HU J.X., ZHAO X.F. Succession of Phytoplankton Assemblages and Its Influencing Factors in Tangpu Reservoir, Zhejiang Province. *Environmental Science*, **37** (12), 4560, **2016**.
25. CAO Z.X., BO W., XIAO Y.H., WU M.H., TAN X., ZHANG Q.F., WANG D.Z. Exploring the Impact of Landscape Ecological Risk on Water Quality in the Danjiangkou Reservoir, China. *Earth and Space Science*, **9** (9), e2022EA002363, **2022**.
26. CHEN, L.B., YANG Z.F., LIU H.F. Assessing the Eutrophication Risk of the Danjiangkou Reservoir Based on the EFDC Model. *Ecological Engineering*, SI: Function, Restoration, and Ecosystem Service of Riverine Wetlands in Temperate Zone, **96**, 117, **2016**.
27. GUO X.M., ZHANG Q.M., ZHAO T.Q., JIN C. Fluxes, Characteristics, and Influence on the Aquatic Environment of Inorganic Nitrogen Deposition in the Danjiangkou Reservoir. *Ecotoxicology and Environmental Safety*, **241**, 113814, **2022**.
28. KARAMOZ M., TAHERIYOUN M., SEYEDABADI M., NAZIF S. Uncertainty Based Analysis of the Impact of Watershed Phosphorus Load on Reservoir Phosphorus Concentration. *Journal of Hydrology*, **521**, 533, **2015**.
29. LIU F., HUANG T.L., SHI J.C. Phosphorus fractions in sediment and its relationship with phosphorus in interstitial water of a source water reservoir. *Chinese Journal of Environmental Engineering*, **10** (12), 7119, **2016**.
30. ZHANG S.Y., ZENG Y.H., ZHA W., HUO S.L., NIU L.H., ZHANG X.F. Spatiotemporal Variation of Phosphorus in the Three Gorges Reservoir: Impact of Upstream Cascade Reservoirs. *Environmental Science and Pollution Research*, **29** (37), 1, **2022**.
31. WANG J.F., CHEN J.N., CHEN Q., JIN Z.X., ZENG H.X. Biogeochemical cycling of phosphorus in deep-water reservoirs. *Quaternary Sciences*, **41** (4), 1192, **2021**.
32. LI Z., MA J.R., GUO J.S., PAERL H.W., BROOKES J.D., XIAO Y., FANG F. OUYANG WJ., and LU L.H. Water Quality Trends in the Three Gorges Reservoir Region before and after Impoundment (1992-2016).” *Ecohydrology & Hydrobiology*, **19** (3), 317, **2019**.
33. LI S.Y., CHEN Y., ZHANG Q.F. 11-Year Change in Water Chemistry of Large Freshwater Reservoir Danjiangkou, China. *Journal of Hydrology, Investigation of Coastal Aquifers*, **551**, 508, **2017**.
34. WANG, Z.Q., LIU X.X., YAO Z.H., YAO L.G., CHANG Y., LIU Z.C., CAO L.H. Endogenous Release of Nitrogen and Phosphorus in the Danjiangkou Reservoir. *Environment Science*, **40** (11), 4953, **2019**.
35. SINHA E., MICHALAK A., BALAJI V. Eutrophication Will Increase during the 21<sup>st</sup> Century as a Result of Precipitation Changes. *Science*, **357** (6349), 405, **2017**.