Journal of Advances in Social Sciences

2026, Volume 2, Issue 2 | ISSN 3105-899X | eISSN 3105-9007


# Investigation and Analysis of the Water Environment Status of Qinghai Lake and Its Surrounding Wetlands

**Zesheng Xian[1,2], Shufen Chen[1]***

[1]School of Municipal and Environmental Engineering, Shandong Jianzhu University; Jinan, China

[2]Institute of Hydrobiology, Chinese Academy of Sciences; Wuhan , China

**Received**
2026-3-8
**Accepted**
2026-4-23
**Published**
2026-4-28

**Corresponding Author**
Shufen Chen*
Email: 11339@sdjzu.edu.cn

**DOI**: https://doi.org/10.65192/g0m4f835



**Abstract**

Qinghai Lake is the largest inland saltwater lake in China and also an important ecological security barrier in the northeastern Qinghai-Tibet Plateau. To reveal the characteristics of its water environment changes, this study set up sampling points in typical areas including the main lake area, estuary areas and surrounding sub-lakes of Qinghai Lake during the dry season (May) and wet season (August-September) in 2019 and 2024, respectively, to carry out synchronous collection and monitoring analysis of water quality samples, compare the differences of water environment in different periods and regions, and explore the input sources and influencing factors of nitrogen and phosphorus nutrients. The results showed that the physical and chemical conditions of the main lake area of Qinghai Lake were generally excellent, with indicators showing significant seasonal differentiation and the overall nutritional level being low. However, the total nitrogen content showed an increasing trend, and the problem of continuous input of nitrogen and phosphorus in the basin became prominent. The concentrations of nitrogen and phosphorus in the in-flowing rivers, surrounding sub-lakes and wetlands were generally higher than those in the main lake area, which were the main input sources of nitrogen and phosphorus nutrients in Qinghai Lake. The concentrations of nitrogen and phosphorus presented obvious seasonal characteristics: total phosphorus was higher in the dry season and total nitrogen was higher in the wet season, and their contents were affected by multiple factors such as surface runoff, human activities and biological activities. The results of this study can provide basic data and theoretical support for ecological protection, nitrogen and phosphorus pollution prevention and control, and scientific water resources management in the Qinghai Lake basin.

**Keywords**
Qinghai Lake; Surrounding wetlands; Temporal and spatial variation; Water environment

## 1. Introduction

Qinghai Lake is located in the northeastern part of the Qinghai-Tibet Plateau (36°32′–37°15′ N, 99°36′–100°47′ E) and is the largest inland saltwater lake in China. Zhang et al. (2020) proposed that, as a regional ecological barrier, it is not only an important stopover and breeding ground for migratory birds from Central Asia to India, an important water conservation area and water-vapor circulation channel in western China, but also a crucial water body maintaining ecological security in the northeastern part of the Qinghai-Tibet Plateau and a natural barrier preventing the eastward spread of desertification in western China, with important ecological and strategic significance.

Affected by global climate change and regional human activities, the Qinghai Lake ecosystem is facing multiple environmental pressures. With the continuous intensification of tourism development, domestic sewage and solid waste directly pose a threat to the coastal water environment. Non-point source pollution generated by agricultural activities around the lake enters the lake area through in-flowing rivers, affecting the supply process and distribution characteristics of lake nutrients. Wang et al. (2024) found that climate warming leads to increased water temperature and evaporation, which exacerbates changes in lake hydrological rhythms and ecological processes. Deng et al. (2023) proposed that the combined effect of multiple pressures not only affects the water environment quality of the lake area and increases the risk of water eutrophication, but also adversely affects plankton, benthos and waterbird habitats, ultimately threatening the long-term stability of the health and biodiversity of the Qinghai Lake aquatic ecosystem.

In addition, Yang et al. (2025) noted that Qinghai Lake is a closed inland lake on the QinghaiTibet Plateau. Characterized by high altitude, low temperature, and a relatively simple biological community structure, its ecosystem exhibits weak selfregulation capacity and high vulnerability to degradation. Once impaired, ecological restoration is extremely difficult and cannot be achieved in the short term. Accordingly, systematic monitoring and research on the water environment of Qinghai Lake are urgently needed to reveal its spatiotemporal dynamics and provide a scientific basis for formulating targeted protection and management policies.

The lake surface of Qinghai Lake is at an altitude of 3196 m, with a lake area of about 4400 $km^2$ and an average water depth of 21 m, belonging to a typical plateau closed inland lake ecosystem. The lake area has a plateau continental climate with obvious regional differences in temperature: the annual average temperature in the east and south is 0.3~1.1℃, and that in the west and north is -0.8~0.6℃. The precipitation is uneven in time and space, with an annual average precipitation of 336.7 mm, mainly concentrated in May-September, and the annual evaporation is as high as 1584 mm.

The main in-flowing rivers in the lake area include the Buha River and Shaliu River, and the water body replacement cycle of Qinghai Lake is about 22 years. The total annual water supply of Qinghai Lake is 3.493 billion $m^3$, including 1.335 billion $m^3$ of runoff supply, 1.557 billion $m^3$ of precipitation supply and 401 million $m^3$ of groundwater supply; the annual evaporation is 3.93 billion $m^3$, with a net annual water loss of 437 million $m^3$.

The total area of the surrounding wetlands of Qinghai Lake is about 4952 $km^2$, including estuary wetlands, lakeside marshes, tidal flat wetlands and other types, which are important habitats for water birds.

The core water quality goal of Qinghai Lake is to maintain the natural state of the lake water quality, and the in-flowing rivers and surface water around the lake stably meet the Class III standard and above.

## 2. Materials and Methods

### 2.1 Study Area and Sampling Point Layout

#### 2.1.1 Sampling time

This study investigated the water environment status of Qinghai Lake and its surrounding wetlands during the dry season (May, thawing period ) and wet season (August~September) in 2019 and 2024, respectively. These two periods can reflect the key transition nodes of the lake hydrological cycle and ecological system, so as to find out the current water environment status and linkage relationship between the main and tributaries of in-flowing rivers, sub-lakes and the main lake area in the basin.

#### 2.1.2 Survey area and sampling point layout

The survey scope includes: the main lake area of Qinghai Lake, the estuary areas of 7 main in-flowing rivers (including Buha River, Shaliu River, Quanji River, Heima River, Caiji River and Daotang River), and 4 main sub-lakes (including Jinshawan, Gahai, Erhai and Yueya Lake).

17 sampling points were set up in the main lake area: mainly in the lake center and open water areas with large water depth, less interference from human activities and relatively stable water environment, which can represent the overall water quality of the lake. 15 sampling points were set up in the estuary area: located at the confluence of main in-flowing rivers such as Buha River and Shaliu River with the lake, where the input of terrestrial nutrients is concentrated, mainly reflecting the impact of basin input on the lake water environment. 18 sampling points were set up in the surrounding wetlands: covering typical wetlands such as Erhai and Gahai, as well as lakeside marshes, tidal flat areas and nearshore tourist areas, mainly reflecting the water area characteristics of the surrounding wetlands and the interference of tourism activities on the nearshore water environment. The survey area and sampling point layout are shown in Figure 1.

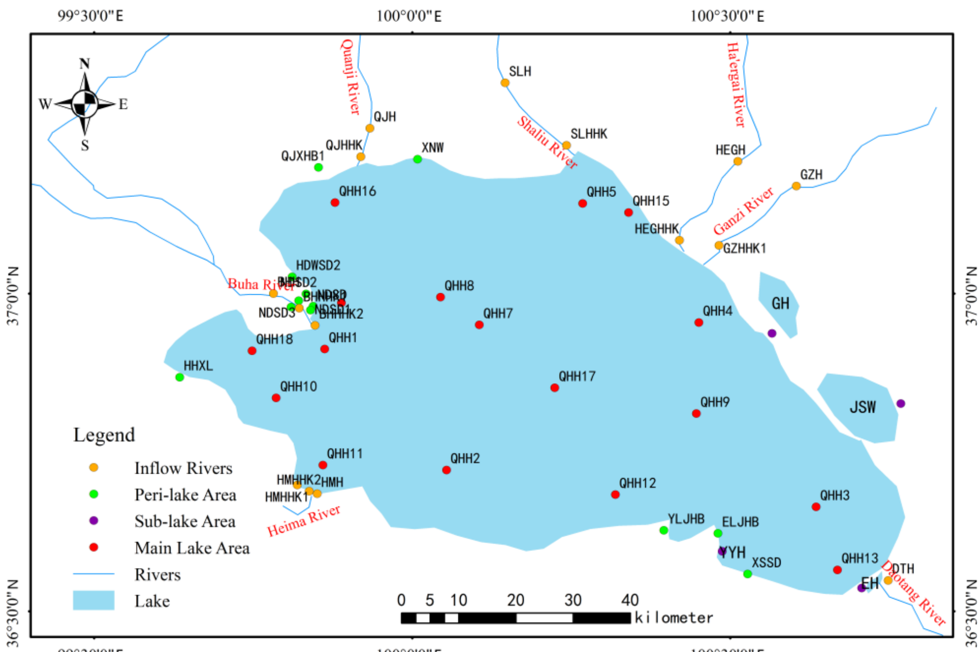


Figure 1. Layout of the survey area and sampling points

### 2.2 Water Environment Investigation Methods

Surface water samples were collected with reference to the Technical Specification for Surface Water Quality Monitoring (HJ 91.2—2022). Indicators such as water temperature, transparency, turbidity, dissolved oxygen, pH value, electrical conductivity and salinity were measured on site. 1 L of surface water sample was collected at each sampling point, placed in sample bottles, stored in low temperature and dark conditions, and brought back to the laboratory as soon as possible for the analysis of conventional water quality indicators such as total nitrogen, total phosphorus, ammonia nitrogen, nitrate nitrogen, dissolved phosphorus, permanganate index, chloride and chlorophyll. Preservation and transportation: the samples were stored at 4℃ after sampling and sent to the laboratory for analysis within 24 hours.

Table 1. Analysis methods, detection limits and basis standards of various water quality indicators

| Monitoring Indicator | Analysis Method | Detection Limit (Unit: NTU, mg/L, μS/cm) | Basis Standard |
|---|---|---|---|
| Water temperature | Thermometer method | - | SL58 - 2014 |
| pH value | Electrode method | - | GB/T 6920 |
| Dissolved oxygen | Electrochemical probe method | 0.1 | GB/T 11913 |
| Salinity | Conductance method | 0.01 | GB/T 13073 |
| Permanganate index | Acidic/alkaline method | 0.5 | GB/T 11892 |
| Total nitrogen | Alkaline potassium persulfate digestion-ultraviolet spectrophotometry | 0.05 | GB/T 11894 |
| Ammonia nitrogen | Nessler's reagent spectrophotometry | 0.025 | HJ 535 |
| Nitrate nitrogen | Ultraviolet spectrophotometry | 0.08 | HJ/T 346 |
| Total phosphorus | Ammonium molybdate spectrophotometry | 0.01 | GB/T 11893 |
| Soluble phosphate | Ammonium molybdate spectrophotometry | 0.01 | GB/T 11893 |

Restricted by sampling accessibility, there were missing sampling points for the water environment indicators in the main lake area of Qinghai Lake in 2019: no samples were obtained at QHH18 in the dry season, and no samples were collected at QHH8 and QHH10 in the wet season (Figure 1); in addition, Ganzi River, Ha'ergai River and the surrounding wetlands were not included in the monitoring objects in that year. The monitoring data in 2024 were complete without missing, the names and units of each indicator were unified, and no abnormal values were found after inspection by the 3σ rule. The specific analysis methods, detection limits and basis standards are shown in Table 1.

### 2.3 Analysis Indicators

To compare the changes of water environment quality of Qinghai Lake in recent years and clarify the impact of surrounding wetlands and in-flowing rivers on the main lake water body, this study focused on analyzing the differences of main water environment indicators in the main lake area of Qinghai Lake between 2019 and 2024. In view of the variety of water environment indicators and complex variation characteristics, 9 key indicators such as permanganate index, total phosphorus, total nitrogen and ammonia nitrogen were selected for comparative analysis to highlight the core evolution law of water quality.

## 3. Survey Results and Analysis

### 3.1 Water Environment Characteristics of the Main Lake Area of Qinghai Lake

#### 3.1.1 Physical and chemical indicators of the water body in the main lake area

The water quality detection results of dissolved oxygen (DO), pH, salinity and temperature in the main lake area during the wet and dry seasons in 2019 and 2024 are shown in Figure 2.

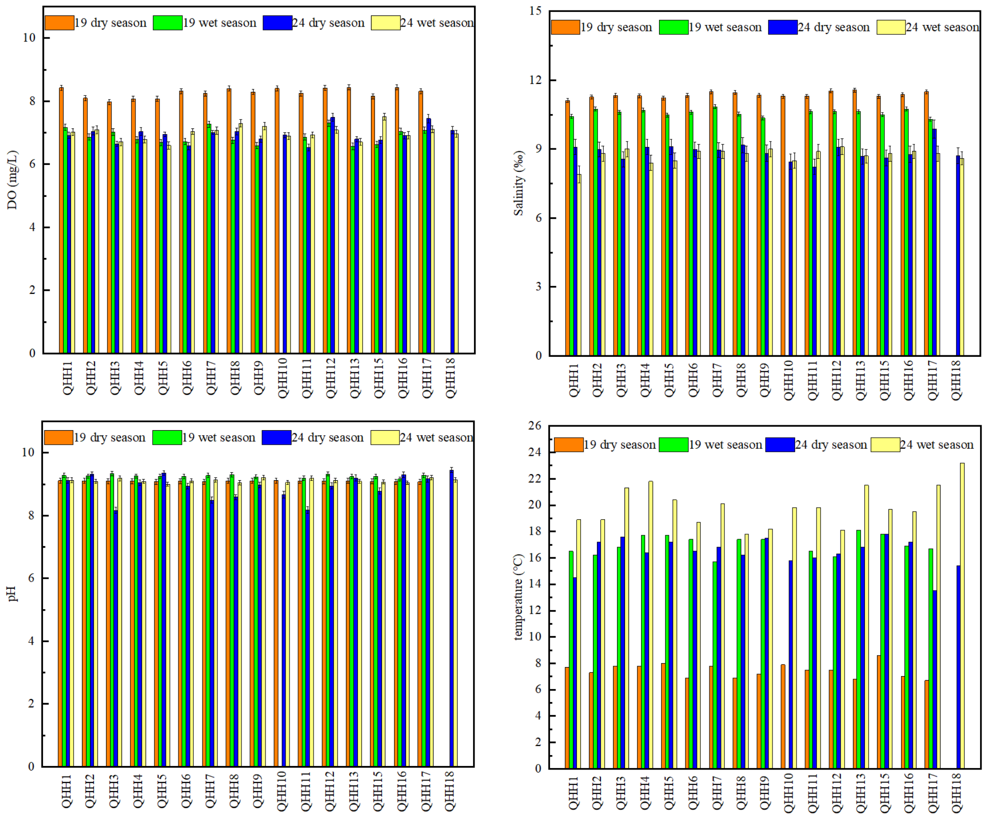


Figure 2. Water quality detection results of DO, pH, salinity and temperature in the main lake area

### *Dissolved Oxygen (DO)*

The concentration of dissolved oxygen (DO) in Qinghai Lake was generally at a good level, all superior to the Class III limit of the surface water environmental quality standard (Figure 2). On the one hand, the overall water quality of Qinghai Lake was good, and the concentration of oxygen-consuming pollutants in the water was low (Figure 3, CODMn detection results), resulting in a high saturation of dissolved oxygen. On the other hand, the saturated dissolved oxygen concentration was negatively correlated with water temperature. The dissolved oxygen concentration at each sampling point in the dry season of 2019 exceeded 8 mg/L. Compared with the dry season of 2024 (average water temperature 16.4℃), the water temperature in the dry season of 2019 (average water temperature 7.5℃) was lower (Figure 2), leading to a higher dissolved oxygen concentration. In conclusion, the dissolved oxygen concentration in Qinghai Lake was significantly regulated by water temperature.

### *Salinity*

The salinity in the main lake area of Qinghai Lake was generally higher in the dry season than in the wet season, and the salinity in 2019 was significantly higher than that in 2024. The salinity in the lake estuary area was slightly lower than that in the central lake area, and this spatial difference was more significant in the wet season (Figure 2). The salinity difference between dry and wet seasons was mainly controlled by the dilution effect of exogenous freshwater input in the wet season. In addition, the salinity of Qinghai Lake in 2024 decreased compared with that in 2019, reflecting that under the background of climate change in recent years, the precipitation in some areas of the basin has increased, and the supply of main inflowing runoffs such as Buha River and Shaliu River has risen, thus producing a dilution effect on the lake water salinity.

### *pH*

The water body in the main lake area of Qinghai Lake was weakly alkaline on the whole, with small spatial differences in pH values at each sampling point and no obvious seasonal differences between dry and wet seasons (Figure 2). Compared with ordinary freshwater bodies, the pH value of the main lake area of Qinghai Lake was slightly higher, but it was still at a low level compared with other saltwater and brackish lakes on the Qinghai-Tibet Plateau. The pH value was slightly higher in the wet season, which may be related to the enhanced photosynthesis of phytoplankton in summer.

### *Temperature*

Water temperature is an important environmental factor affecting the changes of lake water environment. It indirectly dominates the temporal and spatial distribution characteristics of water quality indicators by regulating the physical and chemical processes of water bodies and microbial metabolic activities. Under the background of global climate change, the regional air temperature fluctuates significantly. The water temperature in the dry season of 2019 was significantly lower than that in 2024 (Figure 2), and the difference in water temperature further had an important impact on the temporal and spatial changes of key water quality indicators such as dissolved oxygen (DO) and ammonia nitrogen.

Based on the above analysis results of physical and chemical indicators of the water body, it can be seen that the physical and chemical conditions of the water body in Qinghai Lake were generally excellent, and each indicator showed significant seasonal differentiation characteristics.

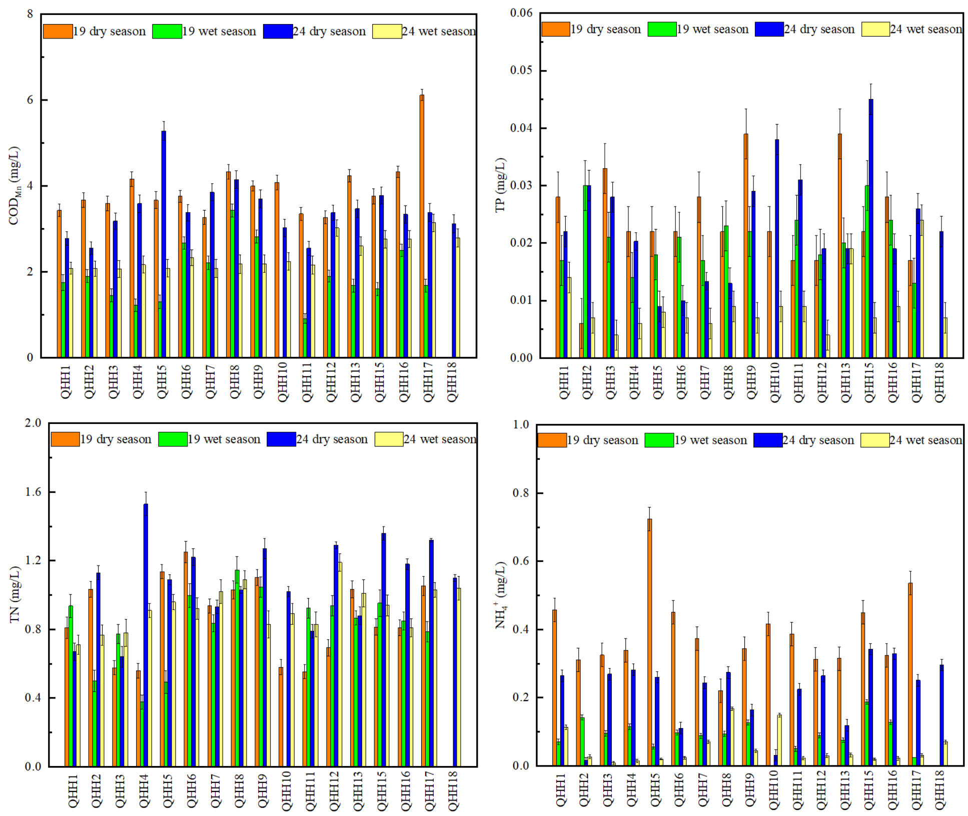


Figure 3. Detection results of CODMn, TP, TN and ammonia nitrogen in the main lake area

3.1.2 Nutritional indicators of the water body in the main lake area

Carbon, nitrogen and phosphorus are the most important nutrient elements in the ecosystem, and their concentrations determine the health status of the aquatic ecosystem. The water quality detection results of CODMn, total phosphorus (TP), total nitrogen (TN), ammonia nitrogen, etc. in the main lake area during the wet and dry seasons in 2019 and 2024 are shown in Figure 3.

***Permanganate Index (CODMn)***

In terms of spatial distribution, except for the QHH17 sampling point where the permanganate index once exceeded 6 mg/L, the overall water quality of Qinghai Lake was superior to the Class III limit of the Surface Water Environmental Quality Standard, and the water quality at some sampling points even reached the Class I standard in the wet season. In terms of temporal variation, compared with 2019, the permanganate index of the lake showed an overall downward trend in 2024 (Figure 3). The above results indicate that the content of oxygen-consuming pollutants in the Qinghai Lake basin is generally at a low level.

***Total Phosphorus (TP)***

The phosphorus content in the lake was generally at a good level. In terms of temporal variation, the total phosphorus concentration in Qinghai Lake was slightly higher in the dry season than in the wet season. The total phosphorus in the water body basically met the Class III water quality requirements of the Surface Water Environmental Quality Standard (GB 3838-2002) in the dry season, while the total phosphorus concentration was generally superior to the Class II standard in the wet season; compared with 2019, the total phosphorus concentration showed a slight increasing trend in 2024 (Figure 3).

***Total Nitrogen (TN) and Ammonia Nitrogen***

In terms of spatial distribution, the total nitrogen concentration at more than 50% of the sampling points in the main lake area of Qinghai Lake was greater than 1 mg/L, and the water quality was inferior to the Class III standard of the Surface Water Environmental Quality Standard. In terms of temporal variation, compared with 2019, the total nitrogen content of the lake showed an overall increasing trend in 2024, increasing in both wet and dry seasons except for individual sampling points, with a particularly significant increasing trend in the dry season (Figure 3).

There was a great difference in the ammonia nitrogen content of Qinghai Lake between dry and wet seasons, with the ammonia nitrogen concentration in the dry season significantly higher than that in the wet season (Figure 3). At lower water temperatures, the weak biological nitrification reaction may increase the ammonia nitrogen concentration in Qinghai Lake, and Qinghai Lake just experiences a process of water temperature changing from high to low from winter to summer.

Based on the above analysis results of nutritional indicators of the water body, it can be seen that the overall nutritional level of the main lake area of Qinghai Lake was low, but the nitrogen and phosphorus in the basin still showed a continuous input trend, which needs to be focused on.

In view of the generally good physical and chemical conditions of the water body in the main lake area of Qinghai Lake, the following part focuses on analyzing the main input sources of nitrogen and phosphorus, including the nitrogen and phosphorus input characteristics of in-flowing rivers and surrounding sub-lakes in the lake area. The above areas are significantly affected by human production, living and tourism activities.

### 3.2 Comparison of Nitrogen and Phosphorus between the Main Lake Area and Inflow Estuaries of Qinghai Lake

The main water recharge source of Qinghai Lake is the inflowing rivers, including the Buha River, Shaliu River, Quanjing River, and Heima River. Although the Daotang River does not directly discharge into Qinghai Lake, it eventually flows into Erhai Lake, an important sub-lake of Qinghai Lake. Therefore, the Daotang River is included in the analysis as an inflowing river. The measured concentrations of total nitrogen (TN) and total phosphorus (TP) in the main lake area and river inflow estuaries during the wet and dry seasons of 2019 and 2024 are shown in Figure 4.

#### 3.2.1 Total phosphorus (TP)

During the survey period, the total phosphorus concentration of each in-flowing river was significantly higher in the dry season than in the wet season. Among them, the total phosphorus concentration at some points of the Heima River was higher than 0.6 mg/L in the dry season of 2019, and the total phosphorus concentration of the Daotang River could also reach more than 0.5 mg/L in the dry season of 2024; while the total phosphorus concentration of in-flowing rivers decreased significantly in the wet season, and the water quality was all superior to the Class II standard of the Surface Water Environmental Quality Standard (Figure 4).

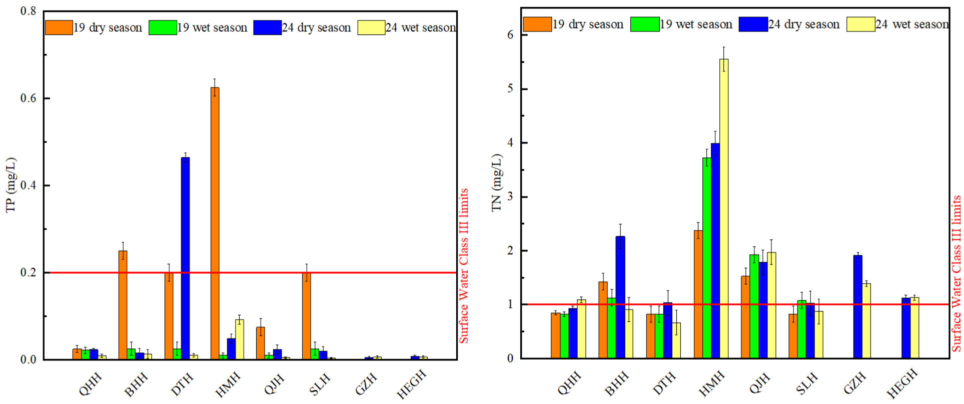


Figure 4. Comparison of total nitrogen and total phosphorus between the main lake area and inflow estuaries of Qinghai Lake

The reasons for the high total phosphorus concentration in the dry season mainly include the following three aspects: 1) The small runoff of rivers in the dry season leads to the concentration and enrichment of pollutants; 2) The grassland vegetation coverage is low in the dry season, the soil and water conservation capacity of the surface is weak, and the slope erosion effect is significant, which makes the phosphorus in the soil more likely to enter the river with runoff; 3) The sewage discharged into the river channel from the production and living activities of residents along the river is difficult to be fully diluted and diffused due to insufficient water volume in the dry season.

#### 3.2.2 Total nitrogen (TN)

Compared with the main lake area, the total nitrogen concentration of each inflowing river except the Daotang River was generally high, among which the Heima River had the highest concentration (Figure 4), which was particularly prominent in the wet season of 2024. The total nitrogen of the Heima River could reach more than 5 mg/L in the wet season, with the water quality being inferior Class V. In contrast, the total nitrogen concentrations of the Buha River and Shaliu River were slightly lower, but due to their larger runoff, the two rivers had a higher nitrogen input flux to Qinghai Lake.

As the two rivers with the largest inflow into Qinghai Lake, the Buha River and Shaliu River both flow through urban areas and are significantly affected by human production and living activities; at the same time, the inflow estuary sections of the two rivers both pass through grassland distribution areas, and the leaching effect of the grassland ecosystem also provides a continuous nitrogen input for the rivers.

Based on the comparison results of nitrogen and phosphorus between the main lake area and inflow estuaries, it can be seen that the nitrogen and phosphorus concentrations of the inflowing rivers of Qinghai Lake (especially the Heima River, Buha River and Shaliu River) were significantly higher than those of the main lake area, making an important contribution to the nitrogen and phosphorus input in the basin. The nitrogen and phosphorus concentrations of inflowing rivers showed obvious seasonal characteristics: the content of total phosphorus was high in the dry season and the content of total nitrogen was high in the wet season. Based on the results of this study, surface runoff scouring and urban sewage discharge are both important nitrogen and phosphorus sources of the inflowing rivers of Qinghai Lake.

3.3 Comparison of Nitrogen and Phosphorus between the Main Lake Area and Sub-lakes as well as Surrounding Wetlands of Qinghai Lake

3.3.1 Comparison of nitrogen and phosphorus between the main lake area and sub-lakes of Qinghai Lake

Several sub-lakes are distributed around Qinghai Lake. In this study, four typical sub-lakes were investigated, including Erhai Lake with freshwater recharge, Gahai Lake without freshwater recharge, Jinsha Bay (which was once separated from the main lake of Qinghai Lake but has gradually become connected again), and Yueya Lake located in the Yilangjian grassland.The measured results of total nitrogen (TN) and total phosphorus (TP) in the main lake area and river inflow estuaries during the wet and dry seasons of 2019 and 2024 are shown in Figure 5.

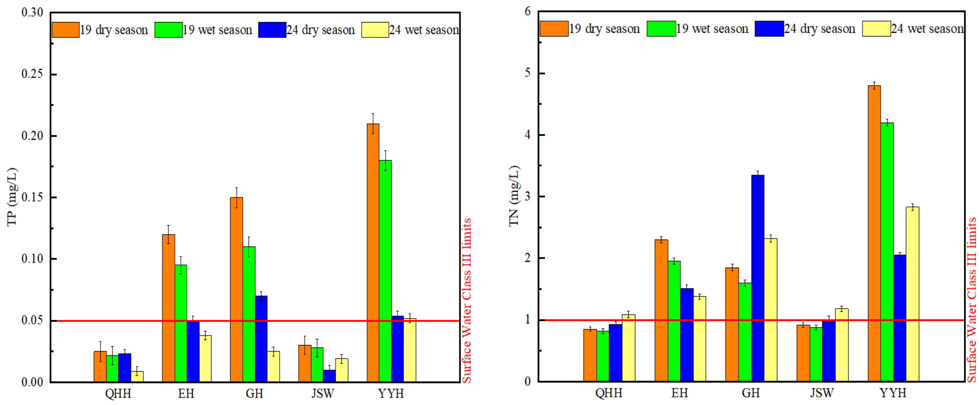


Figure 5 Comparison of total nitrogen and total phosphorus between the main lake area and sub-lakes of Qinghai Lake

### *Total phosphorus (TP)*

In terms of total phosphorus, the total phosphorus concentrations of Gahai, Yueya Lake and Erhai were significantly higher than those of the main lake area. Among them, the total phosphorus concentration of Yueya Lake was the highest in both the dry and wet seasons of 2019 (Figure 5). The total phosphorus concentrations of Yueya Lake, Erhai and Gahai have all exceeded the Class IV or even Class V limits of the surface water environmental quality standard.

The reason is that the total phosphorus accumulation in Gahai may be caused by material accumulation due to concentration effect, while the total phosphorus in Yueya Lake is more due to the input of cattle and sheep manure around it.

### *Total nitrogen (TN)*

Similar to the temporal and spatial variation of phosphorus, the nitrogen concentrations of these sub-lakes were basically higher than those of the main lake area of Qinghai Lake. Except for Jinshawan, the total nitrogen concentrations of the other three sub-lakes in both dry and wet seasons were much higher than those of the main lake area of Qinghai Lake, among which the total nitrogen concentration of Yueya Lake in 2019 was the highest, reaching 4~5 mg/L, far exceeding the Class V water limit of the surface water environmental quality standard (Figure 5).

3.3.2 Comparison of nitrogen and phosphorus between the main lake area and surrounding wetlands of Qinghai Lake

In 2024, the surrounding wetlands of Qinghai Lake were added as the survey objects, mainly including Xia she Wetland, Yilangjian Lakeside, Bird Island Wetland, Cormorant Island Wetland, Hadawan Wetland 2, West Ring Lake Road, Quanji Township Lakeside, Erlangjian Lakeside, Fairy Bay, Bird Island Wetland 1, 2, 3, etc. The above surrounding wetlands are significantly affected by human production, living and tourism activities, and have an obvious impact on the nitrogen and phosphorus input process in the basin.The comparison of total nitrogen and total phosphorus between the main lake area and surrounding wetlands of Qinghai Lake in 2024 is shown in Figure 6.

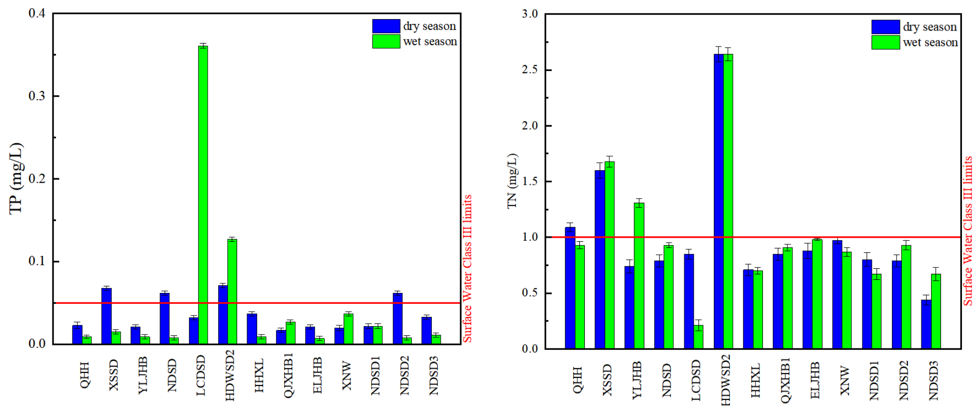


Figure 6 Comparison of total nitrogen and total phosphorus between the main lake area and surrounding wetlands of Qinghai Lake in 2024

### *Total phosphorus (TP)*

It can be seen from Figure 6 that in terms of space, except for Yilangjian Lakeside Wetland, the total phosphorus concentrations of other surrounding wetlands were generally higher than those of the main lake area, and the total phosphorus contents of Xia she Wetland, Bird Island Wetland, Cormorant Island Wetland, Hadawan Wetland 2 and other wetlands exceeded the Class III limit of the surface water environmental quality standard; in terms of temporal distribution, except for Cormorant Island Wetland and Hadawan Wetland, the total phosphorus concentration was generally higher in the dry season than in the wet season.

The phosphorus concentration of Cormorant Island Wetland was particularly high in the wet season, which is mainly due to the combined effect of bird habitats, exogenous input and human activities. This area is a core breeding and habitat area for water birds in Qinghai Lake. A large amount of bird manure produced by high-density birds is directly input into the water body, which is an important natural source of nitrogen and phosphorus in the wetland; at the same time, Cormorant Island is close to the inflow estuary of the Buha River, continuously receiving the input of basin non-point source nutrients carried by the river. In addition, the influence of surrounding tourism development, animal husbandry and human production and living activities further aggravates the exogenous input of nitrogen and phosphorus.

***Total nitrogen (TN)***

In terms of spatial distribution, the total nitrogen concentrations of Xia she Wetland and Hadawan Wetland exceeded 1 mg/L in both dry and wet seasons, higher than the Class III limit of the Surface Water Environmental Quality Standard, among which the total nitrogen concentration of Hadawan Wetland 2 even exceeded 2.5 mg/L, and the water quality reached inferior Class V. In terms of temporal variation, except for Cormorant Island Wetland, Fairy Bay and Bird Island Wetland 1, the total nitrogen concentration of most wetlands was generally higher in the wet season than in the dry season (Figure 6).

The total nitrogen concentration of the surrounding wetlands of Qinghai Lake was generally high, and was more prominent in the wet season, which was mainly affected by grassland leaching driven by strong runoff in the wet season, non-point source pollution input and nitrogen transport by inflowing rivers, superimposed with sewage discharge from surrounding human production, living and tourism activities; in addition, the slow water exchange in wetlands leads to the easy accumulation and enrichment of nitrogen in the area, which together result in a significant increase in the total nitrogen concentration of wetlands in the rainy season.

Based on the comparison results of nitrogen and phosphorus between the main lake area and surrounding wetlands, it can be seen that the nitrogen and phosphorus concentrations of Xia she Wetland, Cormorant Island Wetland and Hadawan Wetland 2 were significantly higher than those of the main lake area. The nitrogen and phosphorus concentrations of the surrounding wetlands showed similar seasonal characteristics to the inflowing rivers: the content of total phosphorus was high in the dry season and the content of total nitrogen was high in the wet season. Due to the close hydraulic connection between the surrounding wetlands and the main lake of Qinghai Lake, the continuous input of nitrogen and phosphorus from the surrounding wetlands will continuously affect the phosphorus concentration of Qinghai Lake in the future.

## 4. Conclusions

The physical and chemical conditions of the water body in the main lake area of Qinghai Lake are generally excellent, and each indicator shows significant seasonal differentiation characteristics. Among them, water temperature has a significant regulatory effect on indicators such as dissolved oxygen and ammonia nitrogen. Salinity is affected by freshwater dilution in the wet season, being higher in the dry season and lower in 2024 than in 2019. On the whole, there is no water quality condition that seriously threatens the survival of aquatic organisms. The overall nutritional level of the main lake area is low, the permanganate index shows a downward trend, and the total phosphorus concentration basically meets the surface water Class III standard. However, the total nitrogen content at more than 50% of the sampling points is inferior to the Class III standard, and shows an obvious increasing trend in 2024 compared with 2019. The continuous input of nitrogen and phosphorus nutrients in the basin has become the main potential problem of the water environment of Qinghai Lake.

In-flowing rivers are the core input sources of nitrogen and phosphorus nutrients in Qinghai Lake, with their nitrogen and phosphorus concentrations significantly higher than those of the main lake area, and showing obvious temporal and spatial differences and point characteristics: the total phosphorus concentration is significantly higher in the dry season than in the wet season, affected by factors such as runoff concentration, grassland slope scouring and insufficient sewage dilution; the total nitrogen is generally high except for the Daotang River, with the Heima River having the highest concentration and reaching inferior Class V in the wet season of 2024.

The total nitrogen and total phosphorus concentrations of the surrounding sub-lakes of Qinghai Lake are generally higher than those of the main lake area. The nitrogen and phosphorus concentrations of Yueya Lake, Gahai, Erhai and other sub-lakes exceed the surface water Class IV or even Class V limits. Among them, Yueya Lake is significantly affected by the input of livestock manure around it, and Gahai has phosphorus accumulation due to concentration effect. The nutrient accumulation in sub-lakes poses a potential input pressure on the water environment of the main lake area.

The nitrogen and phosphorus concentrations of the surrounding wetlands are generally high, which are important supplementary sources of nitrogen and phosphorus input in Qinghai Lake, and show similar seasonal characteristics to the inflowing rivers: the total phosphorus is higher in the dry season than in the wet season except for Cormorant Island Wetland and Hadawan Wetland, and the total nitrogen is significantly higher in the wet season than in the dry season except for some wetlands. The nitrogen and phosphorus concentrations at points such as Xia she Wetland and Hadawan Wetland 2 exceed the standard for a long time, and the total nitrogen of Hadawan Wetland 2 even reaches inferior Class V.

On the whole, the water environment quality of the main lake area of Qinghai Lake is generally good, but the continuous input of nitrogen and phosphorus from inflowing rivers, surrounding sub-lakes and wetlands has become the main factor affecting the stability of its water environment, and the increasing trend of total nitrogen content needs to be focused on. In view of the characteristics of the plateau closed lake ecosystem of Qinghai Lake with weak self-regulation capacity and great difficulty in restoration, it is necessary to formulate differentiated prevention and control countermeasures for the key input sources and key affected areas of nitrogen and phosphorus pollution in the follow-up, strictly control the sewage discharge from human activities along the inflowing rivers, strengthen the ecological restoration and protection of surrounding wetlands and sub-lakes, and reduce the input of terrestrial nutrients, so as to maintain the long-term stability of the ecological system in the Qinghai Lake basin.

## Acknowledgements

We sincerely thank Researcher Chenxi Wu from the Institute of Hydrobiology, Chinese Academy of Sciences (Director of the Qinghai Lake Plateau Lake Wetland Ecological and Environmental Science Observation Field Station) and his team for their strong support and help in the conduct of this study.

## Funding

There is no funding to report.

## Conflicts of Interest

The author(s) declare no conflicts of interest regarding the publication of this paper.

## Ethics Statement

Not applicable.

## References

Deng, D. & Deng, L. (2023). Spatial distribution characteristics and control countermeasures of nitrogen pollution load in the Qinghai Lake watershed. Environmental Impact Assessment. *45*(3): 84-93. https://doi.org/10.14068/j.ceia.2023.03.014

Fang, J. (2020). *Research on the evolution of hydrological processes and their driving mechanisms in the Qinghai Lake basin under changing environments* (Ph.D. Dissertation). Beijing Forestry University.

Hu, S., Qu, J., Zhang, L. & Zhao, M. (2023). Heavy metal content and resistance gene abundance and their correlation in the surface soil around Qinghai Lake. Environmental Science. *44*(1):336-346. https://doi.org/10.13227/j.hjkx.202202175

Li, G., Li, X. & Zhao, G.(2014). Spatiotemporal characteristics of phenology under the dynamic variation trend of grassland vegetation in the Qinghai Lake watershed. Acta Ecologica Sinica. *34*(11): 3038-3047.

Wang, M. & Wen, L. (2024). Study on water level evolution of Qinghai Lake and its influencing factors. Plateau Meteorology. (3): 561-569.

Yang, J., Jin, X., Jin, Y., et al. (2025). Changes in wetland area and its influencing factors in an alpine inland river basin. Acta Ecologica Sinica. *45*(8): 3684–3699. https://doi.org/10.20103/j.stxb.202409122208

Zhang, C., Ma, M., Zhang, S., et al. (2025). Study on main ecological problems and protection and restoration countermeasures of Qinghai Lake under the background of global warming and wetting. Qinghai Land and Resources Management. (2): 57–61.

Zhang, Y., Bai, W. & Zheng, D. (2020). *Spatial distribution characteristics and genesis analysis of lakes on the Qinghai-Tibet Plateau*. Science Press.