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# Purifying Effects of Nitrogen in Wangyu River Water through Natural Wetlands

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**Abstract.** In order to study the purifying effects and influences on nitrogen caused by natural riparian wetlands in the river course, Cao Lake and Ezhen Lake in Wangyu River were selected as the main research regions. Samplings in the transfer period with a large flow in May, 2010 were taken in the sites over the whole wetland area and along the main river course, respectively. Observations on the physicochemical indexes such as water temperature, pH, dissolved oxygen(DO), turbidity, suspended solid(SS), total nitrogen (TN), total dissolved nitrogen(DTN), ammonia, nitrate and nitrite were performed to analyze the concentration and chemical forms variations, regional difference of nitrogen nutrient in the river water column. Results are showed as follows: (1) As the water flowed through Cao Lake and Ezhen Lake, the TN, DTN and nitrate showed a trend of descending (descending proportion: 10.45%, 17.85%, 7.62% in Ehen Lake, 9.09%, 7.17%, 7.60% in Cao Lake). The overall removal effects of nitrogen in Ezhen Lake was better than that in Cao Lake, but the retaining effect of ammonia in Cao Lake was better than that in Ezhen Lake. (2) The nitrogen existed in the water mainly in the forms of DTN and the rates on TN were 88.0% and 91.4%, respectively, higher than that of particle nitrogen, but the rates would decrease for the sedimentation of particle nitrogen in the vertical distribution.(3) Water temperature, pH and DO were the dominant factors that affected the purifying effects of nitrogen in the riparian areas. The research showed the obvious retaining effects of nitrogen and evident influences on the nutrients forms variations in the river water column. The results could provide theoretical foundation and technical support for nitrogen purification in the river course.

## Introduction

With important ecological functions and values, wetlands have attracted more and more attention in the global biochemical cycle[1]. Natural wetlands were attached great importance to for the dual effects of natural resource management and environment protection in the wastewater purification process[2]. Meanwhile, eutrophication has become a major environmental problem in the lakes which is called the "ecological carcinoma"[3]. The lake riparian areas, which connects the lake aquatic ecosystem and the terrestrial ecosystem, is the last protection barrier of lakes where the riparian wetlands system can remove the pollutants such as organics and nutrients in the runoff effectively[4].

Many experts had studied the purification effects of nitrogen and phosphorus by constructed wetlands in recent years, for examples, Douglas J. Spieles et al.[5] carried out researches on the effects of season and hydrologic and chemical loading on nitrate retention in constructed wetlands; Cheng et al.[6] explained the function and problems of aquatic plants in the process of purification by constructed wetlands; Chen et al.[7] studied the application of constructed wetlands on the ecological restoration of river channels. Besides, some foreigners did researches with the combination of wetlands system and advanced monitoring methods, Masayuko Itoh et al.[8] evaluated the nitrogen transformation and influencing factors in a natural wetland using dual-isotope analysis of nitrate; Atreyee Sims et al.[9] studied the temporal and spatial distribution of ammonia-oxidizing archaea and bacteria in natural wetlands and used the ratio as an indicator to monitor the oligotrophic conditions.

However, because of the big difference between natural and constructed wetlands on plant communities and internal structures, the studies on purification effects of pollutants in river channels by natural wetlands were insufficient with large liquidity.

Natural wetlands in Ezhen Lake and Cao Lake in Wangyu River which was an important channel from Yangtze River to Lake Taihu were selected as the main regions in this research to observe the concentration and chemical forms variations, regional difference of nitrogen in the water column. The purification effects and mechanism of nitrogen in natural wetlands was also studied to provide the theoretical foundation and technical support for the related research in the future.

## Materials and methods

**Study area**. Wangyu River is designed as a main water channel in the Water Transfer Project from Yangtze River to Lake Taihu in which the two important natural wetlands were located, i.e., Ezhen and Cao (Fig.1). The south-north length and east-west width of Ezhen Lake are about 3.0km and 2.9km, respectively. The lake area is 5.4km$^2$ where the purse-net mariculture was stopped since 2009 and the structure is compact with many aquatic plants such as lemna minor and reed. In contrast, there were many purse-net mariculture regions in Cao Lake whose area and average water depth are 4.5km$^2$ and 2.2m, respectively.

**Sampling arrangement.** In order to study the purifying effects of nitrogen by natural riparian wetlands in the river course, two samplings were taken in 6$^{th}$ and 21$^{st}$, May, 2010, respectively. The temporal water transfer flows were larger compared to those in other periods which were 1700wm$^3$/d and 1750wm$^3$/d, respectively. The first sampling was carried out over the whole wetland areas at 13 sites (E1-E13) in Ezhen Lake and at 10 sites (C1-C10) in Cao Lake, respectively, to observe the physicochemical indexes and nitrogen concentrations in two riparian areas. The second sampling was carried out at 4 sampling sites (e1-e4 in Ezhen Lake; c1-c4 in Cao Lake) along the center flow lines in two riparian areas from the entrance to the exit with stratified operations in three different depths.

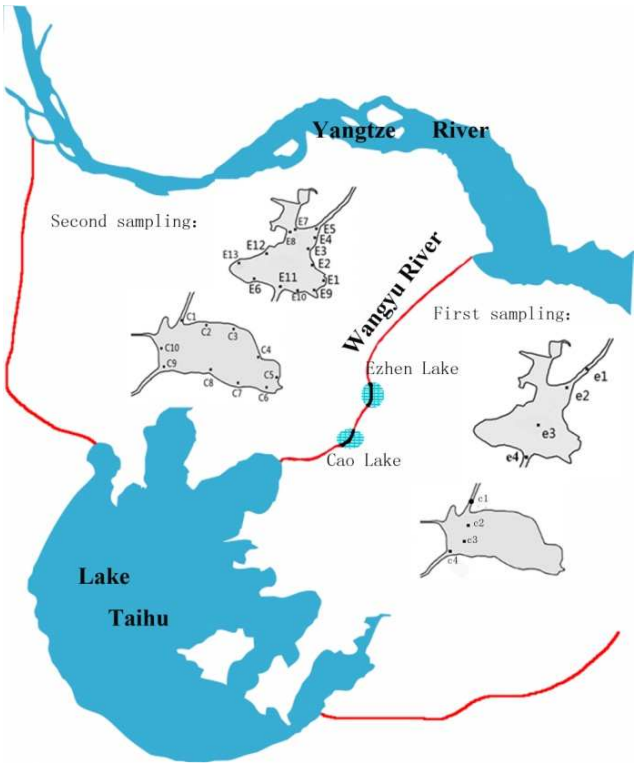


Fig.1 Sampling sites location

**Analytical methods.** The physicochemical indexes and water quality indexes were both analyzed in this research, among which the portable instruments were used to measure the physicochemical indexes including water temperature, conductivity, pH, transparency, turbidity and DO in field. The

water quality indexes comprised of chlorophyll a, suspended solid (SS), total nitrogen (TN), dissolved total nitrogen (DTN), ammonia, nitrate and nitrite were determined in the laboratory according to the national standard methods.

All the analyses were carried out in triplicate and the average of the results were taken as the final value. The experimental data was processed using Excel 2007 and SPSS 16.0 for Windows software with SEM less than 10% of the parallel samples.

## Results and discussion

**Physicochemical characteristics of overlying water**. The physicochemical indexes have a great influence on the forms variations and concentration distributions of nutrients in the water. The average values of the field observation data in two samplings was shown in Table 1.

Table 1 Physicochemical indexes in the water of riparian areas

| physicochemical indexes | Ezhen Lake | | | | Cao Lake | | | |
|---|---|---|---|---|---|---|---|---|
| | May 6 | | May 21 | | May 6 | | May 21 | |
| | range | average | range | average | range | average | range | average |
| Temperature[$^{o}$C] | 24.0-24.5 | 24.3 | 23.1-24.5 | 23.8 | 19.9-22.7 | 21.3 | 22.9-25.3 | 24.1 |
| pH | 8.02~8.38 | 8.20 | 7.86-8.77 | 8.32 | 7.78-8.48 | 8.13 | 8.21-8.33 | 8.27 |
| DO[mg/L] | 6.8~8.1 | 7.4 | 5.3-7.1 | 6.2 | 4.9-7.4 | 6.2 | 6.6-8.5 | 7.6 |
| Turbidity[NTU] | 37.2~42.5 | 39.6 | 18.5-58.0 | 38.3 | 24.8-59.2 | 42.0 | 30.7-40.8 | 35.7 |
| Transparency[cm] | 39-42 | 40.5 | 27-55 | 41 | 26-44 | 35.0 | 38-44 | 41.0 |
| SS[mg/L] | 6.0~26.7 | 16.4 | 5.0-28.0 | 16.5 | 6.2-30.4 | 18.3 | 5.0-29.0 | 17.0 |

According to the research, there were little difference between two samplings for the water environmental characteristics and the main water physicochemical indexes were not significantly different between the layers (Table 1). The average values of water temperature and pH in Ezhen Lake in two samplings were 24.3℃, 23.8℃ and 8.20, 8.32, respectively, higher than the indexes in Cao Lake. Large DO was observed both in Ezhen Lake and Cao Lake, the average value was higher in Ezhen Lake in 6$^{th}$ May (7.4mg/L) and the average value was higher in Cao Lake in 21$^{st}$ May (7.6mg/L). While the turbidity variations in Ezhen Lake in two samplings were not big, the turbidity values of Cao Lake showed variable changes along the main flow line. It was observed that the average turbidity value at the sites near the center and exit was less of 6.2-9.4NTU than that before the entrance which meant the silt sedimentation and water transparency improvement caused by the wider area and lower velocity. The SS values in Ezhen Lake in two samplings were 16.4mg/L and 16.5mg/L, respectively, less than those in Cao Lake. Meanwhile, the obvious descent of SS was observed when Wangyu River flowed through Ezhen Lake from the 21.3mg/L at the entrance to the 11.3mg/L at the exit which indicated that the natural wetlands played an important role in the removal process of suspended matters.

**Nitrogen distribution in the riparian areas**. The nitrogen concentration variations and distribution characteristics in the surface overlying water were shown in Fig.2 according to the analysis of the first sampling.

The TN concentration ranges in two lakes were 2.74-3.41mg/L and 1.41-2.46mg/L, respectively. The nitrogen existed mainly in the forms of DTN and nitrate while the ammonia content was low in the water column. The rates of DTN on TN, nitrate on DTN and ammonia on TN in Ezhen Lake and Cao Lake were 85.9%-90.0% and 84.9%-97.8%, 72.8%-89.6% and 72.5%-99.2%, 2.0%-13.8% and 1.9%-15.0%, respectively. When the water channel flowed into Cao Lake from Ezhen Lake, the average rate of dissolved organic nitrogen (DON) on DTN increased from 1.8% to 4.3%, but the average rate of nitrate on DTN decreased from 71.2% to 69.5%. It was the bloom of blue-green algae in the summer period and the subsequent decomposition of dead algae residues on

the sediment surface that led to the improvement of DON, which was consistent with the results in the research of the dissolved nitrogen variations in the water-sediment interface during the period of algae bloom by Jiangxia et.al[10].

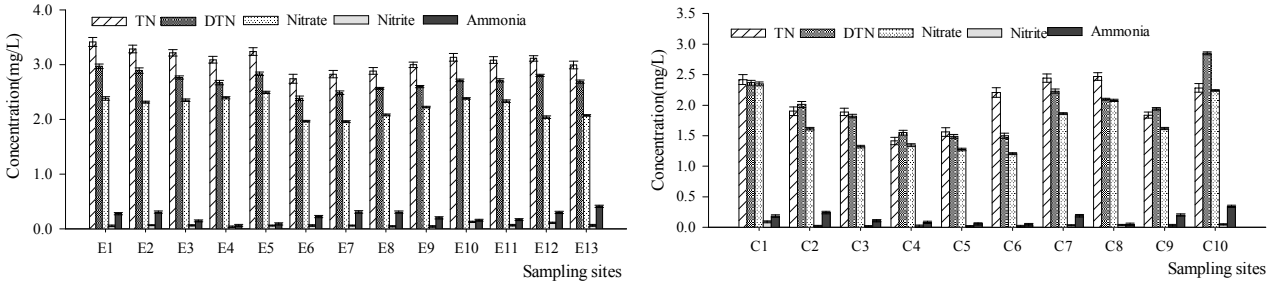


Fig.2 Concentration and distribution of nitrogen in the surfacr water of riparian areas

On the other hand, the content of various forms of nitrogen in the water of Ezhen Lake showed obvious trends of descending when the river course flowed from E5 at the entrance to E6 near the exit, indicating the good purifying effects of nitrogen in the water column by Ezhen Lake. In this research, large amounts of emergent plants such as reed and cattails were observed near E6 site. Besides, the emergent plants with large biomass were fit for the surface flow wetlands and the assemblies of various aquatic plants could improve the purification effects compared to the single species[12], therefore, the concentrations of TN and DTN at E6 site showed the minimum values. Similarly, the nitrogen concentrations along the flow lines of C1-C4 and C1-C9 in Cao Lake also showed the obvious trend of descending, but the ammonia cotent had a slight increase when Wangyu River was just entering into Cao Lake compared to that in the upstream sites, i.e., from 0.17mg/L to 0.19mg/L.

As a key parameter, the water depth of the wetlands had a great influence on the hydraulic retention time (HRT), physicochemical environment, aquatic plants and even the microorganisms among them, thus affecting the nitrogen forms distributions and purification effects[13]. The concentration variations and distribution characteristics of nitrogen in different water depths along the center flow line of Ezhen Lakein the second sampling were shown in Fig.3.

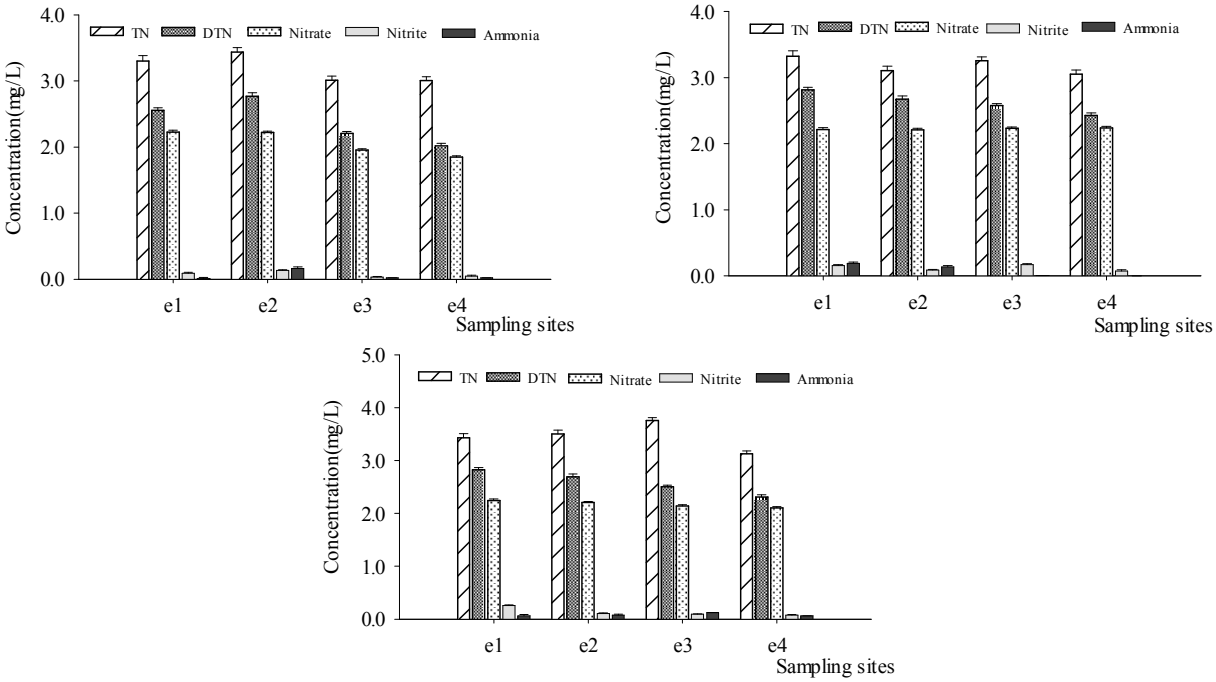


Fig.3 Distribution of nitrogen in the different water depths of Ezhen Lake

There were little difference of climates and water environmental characteristics between the two samplings, therefore, the average concentrations of nitrogen in the surface water were not significantly different in Ezhen Lake.The concentration ranges of TN, DTN and nitrate were 3.05-3.32mg/L, 2.42-2.82mg/L and 2.21-2.24mg/L, respectively. Because of the vessels nearby, the ammonia content had a slight increase in the center when the river course flowed through Ezhen Lake, but the nitrogen concentrations showed an obvious trend of descending compared to those at the entrance in different water depths.

While the average content of nitrate in the surface water was relatively low which was 2.2mg/L, the average concentrations of TN and nitrate in the middle-level water were the highest in Ezhen Lake which were 3.45mg/L and 2.58mg/L, respectively. The rates of DTN on TN would decrease for the sedimentation of particle nitrogen in the vertical distribution, for instance, the decline percentages of DTN at e1 near the entrance and at e4 near the exit were 7.3% and 12.4%, respectively. However, the rate of DTN on TN in the middle-level water at e2 had a slight increase because of the sediment resuspension. With the flowing of Wangyu River, there was a rising trend of average rates of nitrate on DTN and the rate in the bottom water reached the highest at 86.8%.

**Comparative analyses on the purifying effects of nitrogen in the riparian wetlands.** The average nitrogen concentrations in different water depths were taken to analyze the purifying effects by riparian wetlands in Ezhen Lake and Cao Lake along the center flow lines (Table 2), nitrogen removal rate = (content at the entrance - content at the exit)/content at the entrance.

Table 2 Nitrogen concentration variations in the water along the riparian wetlands

| Indexes (mg/L) | e1 | e2 | e3 | e4 | Removal rate (%) | c1 | c2 | c3 | c4 | Removal rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| TN | 3.35 | 3.35 | 3.34 | 3.00 | 10.45 | 2.86 | 2.99 | 2.84 | 2.60 | 9.09 |
| DTN | 2.73 | 2.71 | 2.43 | 2.25 | 17.58 | 2.37 | 2.19 | 2.33 | 2.20 | 7.17 |
| Nitrate | 2.24 | 2.21 | 2.09 | 2.07 | 7.62 | 2.18 | 2.06 | 2.16 | 1.98 | 7.60 |
| Ammonia | 0.09 | 0.14 | 0.02 | 0.12 | -33.33 | 0.12 | 0.14 | 0.09 | 0.08 | 33.33 |
| Nitrite | 0.17 | 0.11 | 0.1 | 0.11 | 35.30 | 0.11 | 0.06 | 0.14 | 0.07 | 36.40 |

The results showed that the removal rates of TN, DTN, nitrate and nitrite in Ezhen Lake were 10.45%, 17.58%, 7.62% and 35.30%, respectively; the retaining rates in Cao Lake were 9.09%, 7.17%, 7.60% and 36.40%, respectively, indicating the good removal effects of nitrogen nutrients in the river course by natural riparian wetlands and the better purifying efficiency in Ezhen Lake. The possible reasons were: 1) the region of natural wetlands in Ezhen Lake was mainly located along the sides of Wangyu River which could enable the wetlands function better; however, only a small part of wetlands in Cao Lake was located near the adjacent river which would not be beneficial for the purification of nitrogen in the river course; 2) since the plants could absorb the ammonia and nitrate directly in the water column and the nitrogen nutrients would be removed with the phytosynthesis and harvest of the plants in the water column, the greater aquatic plants growth in Ezhen Lake could facilitate the better purifying effects of dissolved nitrogen; 3) the nitrogen loading could be increased with the afflux of outside pollutants in Cao Lake caused by the large areas of purse-net mariculture regions along the sides of the center line. It is noting that while the retaining rate of ammonia nitrogen in Cao Lake was 33.33%, the content of ammonia nitrogen fluctuated and had a large increase of 33.33% at c4 near the exit when Wangyu Rive flowed through Ezhen Lake, indicating the better purifying effect of ammonia nitrogen in Cao Lake.

According to the analysis of the purification in the vertical distribution, certain retaining effects of nitrogen nutrients in both different depths in the wetlands were observed among which the removal efficiency in the bottom water were the highest where the rates for TN, DTN and nitrate were 9.0%, 21.1% and 17.1%, respectively. It is because that the vigorous physiological activity and multispecies of microorganisms could increase the removal capability of the natural wetlands in the bottom[14].

**Influence factors on nitrogen purification.** The distributive characteristics and transformation processes of nitrogen nutrient were influenced by various factors, in other words, they were related to both the external pollution sources and the environmental, nutritious and biological factors in the

water column. The various forms of nitrogen in the water in the riparian areas were subjected to SPSS 17.0 for Windows by Pearson correlation analysis with the main aquatic environmental factors in this research (Table 3).

Table 3 Correlation between nitrogen and environment factors in the riparian wetlands

| Indexes | TN | DTN | Ammonia | Nitrate | Nitrite | DON |
|---|---|---|---|---|---|---|
| Water temperature | 0.343** | 0.297* | -0.063 | 0.133 | -0.017 | 0.605** |
| DO | -0.548* | -0.685* | -0.488** | -0.265* | 0.409* | -0.783* |
| pH | -0.330** | -0.453* | -0.406* | -0.401** | 0.154 | -0.033 |
| Conductivity | 0.636** | 0.253 | 0.508* | 0.279 | -0.307 | 0.760* |
| Turbidity | -0.512* | -0.511* | -0.006 | -0.399* | -0.09 | -0.368 |
| Transparency | 0.599** | 0.586* | 0.19 | 0.261 | -0.177 | 0.251 |

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed)

It was known that the main aquatic environmental factors both had influence on the nitrogen distribution and transformation processes and water temperature, pH and DO were the dominant factors that affected the purifying effects in the riparian areas.

The increase of water temperature within certain ranges could facilitate the activity of microorganisms and photosynthesis of plants to improve the purifying effects by wetlands. The analysis results showed that water temperature was significantly related to the content of TN, DTN and DON in this research and the average water temperature in Ezhen Lake was higher than that in Cao Lake, indicating the probable better retaining effects of nitrogen. Meanwhile, DO value was negatively correlated to the content of nitrite, DO and pH values were significantly negatively correlated the content of TN, DTN, ammonia and nitrate. In this research, the slightly alkaline water (average range: 8.12-8.37) in Wangyu River was suitable for the growth of blue-green algae with little ammonia volatilization and strong ammonification. Besides, the average pH value in Ezhen Lake was higher and showed large variations along the center flow line, so the concentration of ammonia increased near the exit. According to the relative researches, while the higher DO values could promote the chemical mineralization of organics, the lower DO values could restrain the nitrification and transform the organic nitrogen nutrients to ammonia in the sediments. Therefore, the average DO value was more than 6.0mg/L in both Ezhen Lake and Cao Lake in this research, indicating the great restriction of denitrification.

The good effects and strong persistence of nitrogen removal were observed in this study and the nitrogen loadings in Ezhen Lake and Cao Lake could be reduced effectively by the natural riparian wetlands through multiple methods such as volatilization, ammonification, nitrification and aquatic plants assimilation. The nitrification and denitrification were usually the main removal methods of nitrogen in the soil and rhizosphere in the wetlands, but in this research the denitrification was greatly restricted by the large DO values.

## Conclusions

Through two samplings in Ezhen Lake and Cao Lake and experiments, the purification effects and transformation principles of nitrogen by natural riparian wetlands in the river course in Wangyu River were studied in this research, the results are as follows:

(1) The content of various forms of nitrogen could be obviously retained or removed when Wangyu River flowed through the two natural riparian wetlands. As the water flowed through Cao Lake and Ezhen Lake, the TN, DTN and nitrate showed a trend of descending (descending proportion: 10.45%, 17.85%, 7.62% in Ehen Lake, 9.09%, 7.17%, 7.60% in Cao Lake).

(2) Besides the greater growth of aquatic plants in Ezhen Lake, the main region of wetlands was mostly located along the adjacent river areas, so the better removal effects of TN, DTN and nitrate were observed in Ezhen Lake. The nitrogen loading in Cao Lake could increase with the afflux of outside pollutants caused by the large areas of purse-net mariculture regions along the sides of the center line.

(3) The nitrogen loadings in Wangyu River were reduced by the natural wetlands through multiple methods such as volatilization, ammonification, nitrification and aquatic plants assimilation. In the purifying precess, water temperature, pH and DO were the important influence factors.

Since the different water flows and seasons could affect the purification and tranformation of nitrogen in the water column, while the two samplings in this research were operated just in the period of large water flows in Wangyu River, some conclusions need further study and practical verification.

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