Evaluation and variation trend of groundwater quality in the area around Poyang Lake

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Abstract: Aiming to study the current situation and variation trend of groundwater quality in the area around Poyang Lake, the single factor index method was used to systematically analyze 19 indicators of 242 groundwater samples in the study area. Results showed that the overall quality of groundwater in the area around Poyang Lake is poor, with Type III water accounting for 19.01%, Type IV water accounting for 36.36% and Type V water accounting for 44.63%, without Type I and Type II water. The Ammonia Nitrogen index of groundwater in Poyang Lake showed a trend of improvement. The Nitrate and Sulfate index showed a trend of deterioration year by year, on the contrary. And the Hardness, Mineralization degree, Oxygen Consumption and Chloride index showed a trend of stability year by year.

1. Introduction
Groundwater is an important part of water resources which is an important natural resource to support economic and social development, and the key element to maintain a good ecological environment. It plays a very important role in urban water supply, rural drinking water, farmland irrigation and industrial production[1]. However, a series of groundwater quality problems may arise under certain geological conditions or improper use and management [2]. In recent years, the degradation of groundwater quality caused by human activities such as cross-basin water transfer, excessive fertilization, random accumulation of surface waste and tailings has attracted attention [3-4]. It is very urgent to carry out groundwater quality evaluation and trend analysis.

Poyang Lake area is a special economic zone with the important strategic conception of protecting ecology and developing economy. It belongs to the plain river network area with developed water system and interlaced river network. Duo Chaomei et al. [5] divided groundwater quality region in Poyang Lake region, and put forward preliminary opinions on the rational development and utilization of groundwater resources by discussing the main water quality characteristics of various areas. However, with intensive human activities such as irrigation, shipping, water system connectivity engineering, urbanization construction and water conservancy projects in the region, the original surface-groundwater circulation system has been changed, which makes the transformation relationship between surface water and groundwater complicated and has a great impact on the regional groundwater quality components. In recent years, relevant scholars studied the characteristics of groundwater quality in Poyang Lake region from different perspectives. Li et al. [6] analyzed the groundwater quality parameters through the comprehensive fuzzy evaluation method of water quality,
and studied the influence of natural factors and human factors on the groundwater quality of Poyang Lake by calculating the sum of pollutant fluxes. Based on the measured water quality and water level data, Liu Fagen [7] used different methods to analyze the temporal and spatial variation characteristics of Poyang Lake water quality under water level change. LI Bing et al [8] investigated 11 groundwater quality parameters in 15 sampling points of Poyang Lake by fuzzy variable assessment model (IFVE), and found that sewage discharged into the lake may affect the water quality and hydrological conditions of Poyang Lake. Given the multiple components of groundwater quality in the plain river network area and the complexity of influencing factors, the single factor index method is used here to conduct a comprehensive analysis of the groundwater quality in the study area, reveal the variation of relevant parameters of groundwater quality, and explore the reasons for the formation of groundwater quality status. This article also aims to provide a scientific basis for the ecological environment protection of regional groundwater resources.

2. Study area
Poyang Lake is the largest freshwater lake in China, located in the south bank of the middle and lower reaches of the Yangtze River. The basin area is 162225 km², of which 156743 km² is located in Jiangxi Province, accounting for 96.6 % of the whole basin. According to the division of water resources in the national water resources comprehensive planning, the Poyang Lake and its surrounding plain areas are divided into the Poyang Lake surrounding lake area, including the area between the Waizhou Hydrological Station of the Ganjiang River, the Lijiadu Hydrological Station of the Fuhe River, the Meigang Hydrological Station of the Xinjiang River, the Shizhenjie Hydrological Station of the Le'an River, the Guxian Ferry Hydrological Station of the Changjiang River, the Yongxiu Hydrological Station of the Xiushui River and the Hukou Hydrological Station of the Hukou County. The area in Jiangxi Province is 20190 km² (the scope of this study).

The strata in this area are well developed. Except for the lack of Lower Devonian, Middle Jurassic and Upper Tertiary, all other strata are exposed. According to the characteristics of sedimentary formation, the area is divided into three sedimentary areas: north, middle and south. The northern region (Xiushui Basin – north of Duchang) is dominated by shallow marine sand shale and carbonate rocks; In the central region (between the north and south regions), the pre-Sinian marble-shallow metamorphic rock series, fluvial-lacustrine red molasses and Quaternary loose deposits are mainly; South area (Xishan, south of Ruihong-Boyang), the former Sinian shallow metamorphic rock series, Late Paleozoic marine-continental coal-bearing sand shale, carbonate rocks, continental clastic rocks. According to the differences of rock formation types, porosity, water content and groundwater dynamic conditions, the water-bearing rock group can be divided into loose rock pore water-bearing rock group, carbonate fracture cave water-bearing rock group, red bed fracture pore water-bearing rock group and bedrock fracture water-bearing rock group[9].

3. Sample collection and testing
The groundwater sampling points are distributed in the Poyang Lake area, and 242 groups of groundwater samples are collected. The groundwater samples are from civilian wells or conventional monitoring wells. The distribution map of sampling points is shown in Figure 1. The collection, preservation and delivery of water samples are strictly in accordance with HJ / T164-2004 "Technical specification for groundwater environmental monitoring." Groundwater sample test was completed by Jiangxi Provincial Geological and Mineral Testing Center. The test items included pH, hardness, mineralization degree, K⁺, Na⁺, Ca²⁺, Mg²⁺, HCO₃⁻, Cl⁻, SO₄²⁻, NH₄⁺, NO₃⁻, NO₂⁻, F⁻.
Figure 1. Sampling point distribution

4. Results and discussion of groundwater quality evaluation

4.1. Descriptive statistical analysis

4.1.1. Single index evaluation result.
As showed in Table 1, the variation range of pH value in groundwater samples was 3.91~12.25, with an average value of 6.45, which was generally weakly acidic. The hardness varied from 7 to 745 mg/L with an average of 135 mg/L, and the proportions of ultra-soft water, soft water, micro-hard water, hard water and ultra-hard water were 37.2 %, 27.7 %, 28.1 %, 4.5 % and 2.5 %, respectively. The range of mineralization degree was 30-1346 mg/L, and the average value was 223 mg/L. Except for individual sampling points, they were all less than 1 g/L, belonged in sweet water. The content of Fe, Mn and Ammonia Nitrogen varies widely, and the standard deviation is relatively high, indicating that these indicators have large dispersion in space, and the enrichment degree in local areas is high.

Table 1. Statistics of characteristic parameters of shallow groundwater quality around Poyang Lake

| Projects | pH   | Hardness | Mineralization degree | Fe   | Mn   | Ammonia Nitrogen | NO$_2^-$ | NO$_3^-$ |
|----------|------|----------|-----------------------|------|------|------------------|----------|----------|
| Maximum  | 12.25| 745.00   | 1346.00               | 26.8 | 8.04 | 113.10           | 6.85     | 316.00   |
| Minimum  | 3.91 | 7.00     | 30.00                 | 0.02 | 0    | 0                | 0        | 0.02     |
| Average Value | 6.45 | 135.00   | 223.00               | 0.48 | 0.31 | 0.60             | 0.10     | 31.10    |
| Standard Deviation | 1.07 | 109.81   | 161.09               | 2.29 | 0.82 | 7.27             | 0.54     | 39.76    |
| Coefficient of Variation | 0.17 | 0.82     | 0.72                 | 4.73 | 2.66 | 12.15            | 5.50     | 1.28     |
4.1.2. Comprehensive evaluation results.

The comprehensive quality of groundwater in Poyang Lake area is generally poor. There were 242 monitoring wells selected in this evaluation, and no Class I and II water. There were 46 monitoring wells with Class III water quality, accounting for 19.01% of the total. There were 88 monitoring wells with Class IV water quality, accounting for 36.36% of the total; There were 108 monitoring wells with Class V water quality, accounting for 44.63% per cent of the total, as showed in Figure 2.

![Figure 2. Comprehensive evaluation results of groundwater quality around Poyang Lake](image)

The main exceeding standard factor of Class V water were pH, Mn and Nitrate. Among them, 33.06% of the monitoring wells were Nitrate, 16.53% were pH and 4.96% were Mn. The main exceeding standard factor of Class IV water were pH, Fe, Mn, Ammonia Nitrogen and Nitrate. Among them, 34.71% of the monitoring wells were pH value, 30.17% were Mn, 12.40% were Fe, 11.98% were Nitrate and 4.55% were Ammonia Nitrogen. In summary, there were five main indicators that cause the deterioration of groundwater quality in the study area, namely pH, Ammonia Nitrogen, nitrate, Fe and Mn. Among them, pH and Nitrogen were the most important indicators to determine the category of groundwater quality.

4.2. Status analysis of pollutants

4.2.1. Analysis of groundwater pH value exceeding standard.

In this groundwater quality evaluation, the pH value of groundwater around Poyang Lake is mainly between 5.5 and 8.5, and a small part is less than 5.5. The background value of groundwater pH environment in Poyang Lake area is basically between 5.94 and 6.81, and a few regions are between 6.81 and 7.90. The range of pH value of groundwater in Poyang Lake becomes larger, the main reason of the exceeding standard pH value was the acidizing tendency of groundwater.

In recent years, the process of industrialization and urbanization in Jiangxi Province has accelerated, and a large number of fossil fuels such as coal, oil and natural gas have been burned. The coal contains sulfur, and a large amount of sulfur dioxide is generated in the combustion process. In addition, the high temperature in the coal combustion process makes nitrogen and oxygen in the air become nitric oxide, which is converted into nitrogen dioxide and acid rain. It causes coal-fired or sulfuric acid pollution and reduces the pH value of groundwater in the Poyang Lake region [10].

In summary, the exceeding standard pH value of groundwater in Poyang Lake area is mainly affected by natural background value and acid rain.

4.2.2. Analysis of Nitrogen pollution in groundwater.

The groundwater quality assessment of the Poyang Lake area shows that NH4\(^+\) content between 0mg/L and 113.10mg/L, NO3\(^-\) content between 0.02mg/L and 316.00mg/L, NO2\(^-\) content between 0mg/L and 6.85mg/L; The environmental background value of NH4\(^+\) in groundwater in Poyang Lake area is
basically distributed in 0.023 mg/L and 0.159 mg/L. The environmental background value of NO3--N in groundwater is basically distributed in 0.204 mg/L and 14.942 mg/L. The environmental background value of NO2--N in groundwater is basically distributed in 0.002 mg/L and 0.30 mg/L. The background values are lower than the III water standard of *Groundwater quality standard* (GB/T14848-2017). In this groundwater quality evaluation, the values of each factor were higher than those of natural background values.

According to the complexity and diversity of nitrogen pollution sources in groundwater, the pollution sources can be divided into point source pollution and non-point source pollution [11]. The point source pollution in Poyang Lake area includes industrial sewage, urban sewage, septic tanks in suburban areas, leakage of sewage pipelines, and leakage of farm animal farms. Non-point source pollution includes atmospheric nitrogen deposition, sewage irrigation, and application of nitrogen fertilizer and organic fertilizer. Compared with the two classes of pollution, non-point source pollution covers a wider range and is more difficult to control. Non-point source pollution has the characteristics of randomness, time-space, universality and hysteresis [12]. Nitrogen will undergo mineralization, adsorption, ammoniation, nitrogen fixation and nitrification in the groundwater cycle, which makes it more difficult to control.

In summary, the exceeding standard nitrogen in groundwater around Poyang Lake is mainly affected by atmospheric nitrogen deposition and artificial discharge.

4.2.3. Analysis of Fe and Mn Exceeding Standard in Groundwater.

The groundwater quality assessment of the Poyang Lake area shows that Fe content in 0.02 mg/L~26.80 mg/L, Mn content in 0 mg/L~8.04 mg/L; The environmental background values of Fe and Mn in groundwater of Poyang Lake were 0.02 mg/L~0.734 mg/L and 0.0007 mg/L~0.250 mg/L, respectively. The numerical range of Fe and Mn content is larger than the natural background value, and the coefficient of variation is larger.

The high content of Fe and Mn in groundwater around Poyang Lake is mainly related to the reduction environment, acidic conditions and iron content in the medium. The alluvial-lacustrine aquifer and the overlying clay soil are rich in iron and manganese components. At the same time, the aquifer generally has a binary structure. The vertical infiltration of atmospheric precipitation is weak, and hypoxia and rich in organic matter form a reducing environment, which reduces the Eh value. There are relatively stable high-valent iron and manganese oxides in the medium, which are reduced to soluble salts of low-valent iron and manganese, and a large number of Fe2+ and Mn2+ are dissociated, increasing the content of Fe2+ and Mn2+ in groundwater [13]. The iron-manganese minerals in soil can be considered as an important source of iron and manganese in groundwater, and the input of inorganic salt is mainly the input of total nitrogen. Therefore, it is necessary to reasonably control the fertilization of crops and change the irrigation mode of crops.

In summary, the exceeding standard Fe and Mn in groundwater in Poyang Lake Rim Lake area is mainly affected by natural background values and human agricultural activities.

5. Variation trend analysis of groundwater quality

Index of groundwater quality trend analysis can be included Hardness, Mineralization degree, Oxygen Consumption, Ammonia Nitrogen, Nitrate, Fluoride, Chloride, Sulfate.

According to the monitoring value $C_{i1}$ of evaluation index $i$ in $t_1$ year and $C_{i2}$ of evaluation index $i$ in $t_2$ year, the annual variation $\Delta C_i$:

$$\Delta C_i=(C_{i2}-C_{i1})\times(t_2-t_1)$$

The average annual change rate $RC_i$ of the monitoring value of evaluation index $i$ is

$$RC_i=\Delta C_i\times(C_{i1})^{-1}\times100\%$$

Then, the variation trend of evaluation index $i$ is divided into three categories: water quality deterioration ($RC_i>5\%$), water quality stability ($-5\%\leq RC_i\leq5\%$) and water quality improvement.
(\(R_C\) \(<\) -5%). According to the data of groundwater monitoring wells, 10 monitoring wells meeting the evaluation conditions and evenly distributing the long series of water quality monitoring data in the study area were selected for analysis. The change trend results are shown in Table 2.

Table 2. Analysis of water quality variation trend of groundwater monitoring wells

| Monitoring Wells | Hardness | Mineralization degree | Oxygen Consumption | Ammonia Nitrogen | Nitrate | fluoride | Chloride | Sulfate |
|------------------|----------|-----------------------|--------------------|------------------|---------|----------|----------|---------|
| No.1             | -3.03    | -2.57                 | 1.24               | 2.50             | -3.83   | -6.36    |          |         |
| No.2             | -1.01    | -0.33                 | 0.97               | -9.09            | -8.41   | -0.64    | -3.74    |         |
| No.3             | 3.41     | 3.33                  | -1.04              | -9.06            | 5.48    | -1.86    | 5.68     |         |
| No.4             | 1.78     | 2.04                  | 3.54               | -9.06            | -0.63   | -3.36    | 36.36    |         |
| No.5             | 6.24     | -1.94                 | -0.08              | -9.01            | -7.43   | -4.45    | 28.79    |         |
| No.6             | -0.88    | -5.08                 | 5.93               | -9.05            | 93.48   | -0.91    | -6.19    | -8.00   |
| No.7             | -1.93    | 5.53                  | 7.65               | 25.00            | 7.31    | 1.74     | 25.00    |         |
| No.8             | -5.72    | -7.76                 | -4.86              | -7.95            | 41.98   | -8.06    | -8.35    | -8.01   |
| No.9             | 3.12     | 71.59                 | 16.90              |                   |         |         | -2.59    | 4.55    |
| No.10            | 30.74    | 5.24                  | -2.41              | -9.09            | 1.81    | -4.45    | 36.36    |         |

The Ammonia Nitrogen index of groundwater decreased in 6 monitoring wells, showing a trend of amelioration year by year. In recent years, the province has reasonably controlled the fertilization of crops and improved the irrigation methods of crops, implemented a number of specific prevention and control measures of nitrate nitrogen pollution, and managed the ammonia nitrogen pollution of groundwater in the study area in an economic and effective way.

Hardness, Mineralization degree, Oxygen Consumption and Chloride index of groundwater decreased by more than 5 monitoring wells, showing a trend of well stabilization year by year.

Groundwater Nitrate and Sulfate index increased monitoring wells reached 5, showing a trend of deterioration year by year. With the acceleration of industrialization and urbanization in Jiangxi Province, the amount of coal-fired gas fuel in people’s life and production is increasing. The exhaust gas and dust discharged from residential areas, factories and other human activities seriously pollute the atmospheric environment for people to survive. At the same time, due to the occurrence of rainfall process, atmospheric pollutants fall to the ground with rain, causing pollution to groundwater. The indexes of nitrate and sulfate in groundwater around Poyang Lake increased year by year.

6. Conclusions

The comprehensive quality of groundwater in Poyang Lake area is generally poor. Class III water accounts for 19.01%, Class IV water accounts for 36.36% and Class V water accounts for 44.63%. There is no Class I and II water. There are five main indicators that cause the deterioration of groundwater quality in the study area, namely pH value, Ammonia Nitrogen, Nitrate, Fe and Mn.

The indicator of Ammonia Nitrogen in Poyang Lake groundwater are improving year by year, The indicators of Hardness, Mineralization degree, Oxygen Consumption and Chloride are well stable year by year, while the indicator of Nitrate and Sulfate are deteriorating year by year.

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