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Research Article

Fuzzy Evaluation of Water Quality Based on Micronucleus Technology of *Vicia faba* Root Tip

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By establishing a fuzzy mathematical evaluation model based on physical and chemical indicators, this paper investigates the genetic toxic pollution of Chaohu Lake in 2016 through the micronucleus technology of the *Vicia faba* root tip and evaluates the water quality of Chaohu Lake. The results show that, in recent years, the overall water quality of the lakes around Chaohu has improved slightly, but the pollution levels of some areas (such as Nan Fei He and Shi Wu Li He) are still serious. The results can also provide a more reliable theoretical basis for the planning and management of environment protection.

1. Introduction

In recent years, the pollution status of water quality has been mostly based on conventional physical and chemical indicators, but it is hard to fully reflect the mixed effect of pollutants using the existing physical and chemical detection technology [1–4]. The plant genetic toxicity test can be widely used in the toxicological detection of important pollutants in water samples without knowing the chemical composition because of its short time consumption, low cost, and high sensitivity [5–9]. The micronucleus test of the *Vicia faba* root tip is a plant genetic toxicity experiment [10–13]. This experiment has been widely used as a standard method in water environment monitoring and listed in the "Water and Wastewater Monitoring and Analysis Method" [14].

Chaohu Lake, located in the central part of Anhui Province and on the north bank of Yangtze River, is one of China's five major freshwater lakes. In the past two decades, the pollution of Chaohu Lake has become increasingly serious. The discharge of various factories and enterprises and urban sewage along Chaohu Lake has led to the eutrophication of water quality and the frequent outbreak of cyanobacteria, making it the most serious eutrophic water body in China. One of them has substantially affected the water security of surrounding residents. The whole Chaohu Lake is divided into east and west lakes. From the characteristics of Chaohu Lake and the pollution sources of the rivers entering the lake, the source of pollution in the west district is more than that in east district, especially in the mouth of Nan Fei He in the west district. This channel directly accepts a large number from Hefei City. Industrial wastewater and domestic sewage have formed a total discharge channel into Chaohu Lake.

This paper starts from the aspect of water environment detection, chooses the root tip of *Vicia faba* as the experimental material, selects the water body of the main river of Chaohu Lake as the sample, analyzes the data through the micronucleus experiment and fuzzy comprehensive evaluation method, compares the physical and chemical indicators of water quality, and comprehensively evaluates the water quality of Chaohu Lake.

2. Materials and Methods

2.1. Main Materials and Reagents

2.1.1. Collection of Water Samples. According to the main rivers entering the lake and the key pollution sources [14], six sampling points were set in the east and west lakes; the data segment was selected as the monitoring data from April to August in 2016 (see Table 1).

2.1.2. Test Materials and Reagents. The test materials used are as follows: commercially available high-quality green skin broad beans, medical ethanol (95%), hydrochloric acid

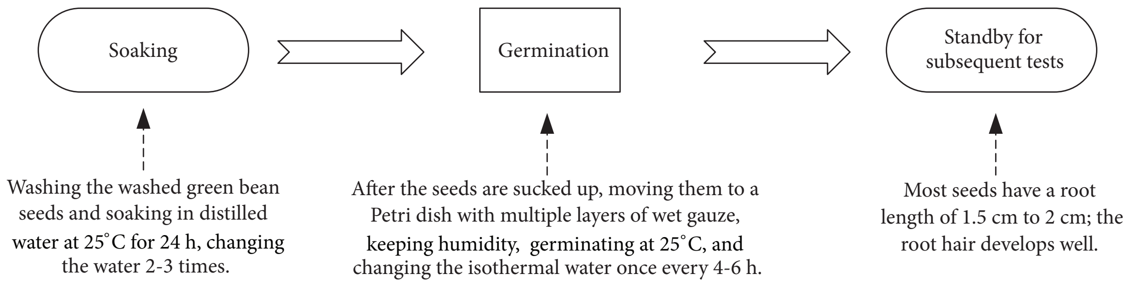

Figure 1: Soaking and germination.

Table 1: Entering positions of the lake.

W1	Nan Fei He	W4	Shi Dui Du Kou
W2	Shi Wu Li He	W5	Yu Xi He
W3	Hang Beng He	W6	Zhe Gao He

(1 mol/L), and Carnot's fixed solution (anhydrous ethanol: glacial acetic acid = 3:1).

Improved basic fuchsin: the order of configuration is (1) stock solution A (3 g basic fuchsin + 100 ml 70% ethanol, which can be stored for a long time); (2) stock solution B (10 ml A solution + 90 ml 5% phenol aqueous solution, which with a brown bottle can be stored for 2 weeks); (3) stock solution C (55 ml B solution + 6 ml glacial acetic acid + 6 ml 38% formaldehyde, which can be stored for a long time); (4) 10-20 ml C solution + 90-80 ml 45% acetic acid + 1.5 grams of sorbitol, placed for 2 weeks after use.

We also used a manganese sulfate solution (480 g/L) and an alkaline potassium iodide solution (500 g NaOH + 150 g KI); the rest of the reagents are of analytical grade; all water is double distilled water.

2.2. Main Instruments and Equipment. The main instruments and equipment used were as follows: HQ30D portable dissolved oxygen measuring instrument, HZQ-F120 type full temperature shaking incubator, sunny optical microscope ST60-24B1, 752 type ultraviolet spectrophotometer, 101A-2 type electric blast drying box, BS224S type electronic precision balance (accuracy 0.0001 g), and other instruments and equipment commonly used in laboratories.

2.3. Test Methods

2.3.1. Micronucleus Test of Vicia faba Root Tip

(1) Soaking Seeds and Germination. The flowchart of soaking and germination is shown in Figure 1.

(2) Exposure. Three seeds with well-developed root tips and the same root length were selected and placed in a Petri dish containing (make sure that the root tip should be immersed in the water all the time). The processing lasts for 6 h. The same processing using distilled water was set as the control group.

(3) Apical Cell Fixation. The treated seeds were immersed in distilled water 2-3 times and then placed in a covered Petri dish with freshly laid gauze and cultured for 22 h to 24 h according to the above conditions. Then, the roots of 1 cm length at the tip of the apex were fixed with Carnot's fixative for 24 h, then replaced with a 70% ethanol solution, and stored in a refrigerator at 4°C for later use.

(4) Dyeing. The fixed young roots were digested with distilled water, soaked in 1 mol/L HCl, and hydrolyzed in a 60°C water bath for 10-15 min. They were further immersed in distilled water, stained with modified basic fuchsin [11] for 20 min in the dark, and finally rinsed with distilled water.

(5) Production. The root tip was placed on the slide and blotted dry. 1 mm of the apex of the root tip was removed and the remaining part (approx. 1 mm) was left on the slide. The crossover method was used for tableting.

(6) Microscopic Examination and Micronucleus Identification Standards. The microscopic examination was carried out by means of a low-power microscope and a high-power microscope. Micronucleus identification standard: separated from the main nucleus and with a size of about 1/3 of the main nucleus is the micronucleus; the micronucleus coloration is generally shallower than the main nucleus, and the shape is mostly circular, elliptical, or irregular. Three root tips were reviewed at each treatment, and about 1000 cells were examined at each root tip. From that we get the following:

$$\begin{aligned}&\text{Micronucleus percentage MCN‰}\\&\quad=\frac{\text{number of cells observed in micronucleus}}{\text{total number of cells observed}}\\&\qquad\times 1000‰,\\&\text{Pollution index PI}\\&\quad=\frac{\text{sample measured MCN‰ average}}{\text{control MCN‰ average}}.\end{aligned} \tag{1}$$

2.3.2. Physical and Chemical Testing Indicators. According to the pollution status of Chaohu Lake, this paper mainly selects five representative water quality indicators of dissolved oxygen (DO), oxygen consumption (COD_{Mn}), organic nitrogen (NH_3-N), total phosphorus (TP), and total nitrogen (TN) as evaluation factors, in collecting water samples, transportation, storage, inspection, and data processing, according to

Table 2: Determination standard methods.

Indicator	Determination standard method
DO	Electrochemical probe method HJ 506-2009
COD_{Mn}	Permanganate index GB/T11892-1989
NH_3-N	Salicylic acid spectrophotometry HJ 536-2009
TP	Ammonium molybdate spectrophotometric method GB/T 11893-1989
TN	Alkaline potassium persulfate digestion UV spectrophotometry HJ636-2012

the requirements of the corresponding standard methods (see Table 2).

2.3.3. Fuzzy Comprehensive Evaluation Method

(1) Concept of the Fuzzy Comprehensive Evaluation Method. Fuzzy comprehensive evaluation refers to the use of fuzzy mathematics to perform simple analysis, judgment, and evaluation of those problems with fuzziness. It is to turn qualitative problems into quantitative problems.

Fuzzy comprehensive evaluation relies on the membership theory to transform problems between qualitativeness and quantitativeness [1, 3, 15]. The fuzzy matrix is a model that reflects the influence of the membership degree of each factor on the evaluation level. The membership degree can be used as the numerical index and standard function of the evaluation index. In general, the form of the function is different, and the degree of membership of the evaluation level is also different. Comprehensively speaking, it not only reflects strong systemicity, but also makes the evaluation results clearer. It can also construct a model for the ambiguity problem and give a solution.

(2) General Steps for Fuzzy Comprehensive Evaluation

(1) Constructing fuzzy comprehensive evaluation set: to a certain extent, the appropriateness of the evaluation index selection may affect the result, large or small, so it is necessary to construct an evaluation index system

(2) Constructing weight vector: the weight vector is constructed by expert experience or an AHP analytic hierarchy process

(3) Constructing the evaluation matrix: the construction of the membership function will have a certain impact on the construction of the evaluation matrix

(4) Synthesizing the evaluation matrix and weights

3. Results and Analysis

3.1. Comprehensive Evaluation of Water Quality in Chaohu Lake

3.1.1. Constructing the Fuzzy Comprehensive Evaluation Set. The fuzzy comprehensive evaluation set U involves six parameters, including five indicators introduced in Section 2.3.2 and one micronucleus test pollution index PI, which is given in point (6) of Section 2.3.1,

$$U = \{DO,\ NH_3 - N,\ COD_{Mn},\ TP,\ TN,\ PI\}. \quad (2)$$

According to the National Surface Water Environmental Quality Standard [14] (GB3838-2002), an evaluation rating set is established:

$$V = \{\mathrm{I},\ \mathrm{II},\ \mathrm{III},\ \mathrm{IV},\ \mathrm{V}\}. \quad (3)$$

Evaluation rating is based on the degree of water pollution, so both are ambiguous concepts. The indicators in Table 3 are the lowest limit values in the evaluation criteria [14], and the genetic pollution index PI sets the corresponding pollution level according to the "National Biotechnology Testing Specification – Broad Bean Root Tip Micronucleus Technology."

3.1.2. Constructing Weight Vector. Based on the sampling data of Chaohu Lake water quality, a fuzzy weight set is constructed, and its line chart is shown in Figure 2.

Take the dissolved oxygen (DO) index in the W1 area as an example:

Average of the evaluation criteria:

$$\frac{7.5 + 6 + 5 + 3 + 2}{5} = 4.7. \quad (4)$$

The measured average concentration is 6.6, and the combined weights are

$$a_{DO} = \frac{6.6}{4.7} = 1.404. \quad (5)$$

Similarly, the weights of other indicators in the W1 area are as follows:

$$\begin{aligned} a_{NH_3-N} &= \frac{2.49}{1.03} = 2.41, \\ a_{COD_{Mn}} &= \frac{6.408}{7.4} = 0.866, \\ a_{TP} &= \frac{0.173}{0.077} = 2.241, \\ a_{TN} &= \frac{1.513}{1.04} = 1.454, \\ a_{PI} &= \frac{3.28}{2.33} = 1.408. \end{aligned} \quad (6)$$

The weight is important in the specified range [0, 1], normalized, i.e.,

$$\begin{aligned} A_i &= \frac{a_i}{\sum_i^n a_i}, \\ \sum_i^n A_i &= 1. \end{aligned} \quad (7)$$

Table 3: Standard values of the parameters in the quality standard.

Indicators	DO	NH_3-N	COD_{Mn}	TP	TN	PI
I	7.5	0.15	2	0.01	0.2	<1.5
II	6	0.5	4	0.025	0.5	1.5
III	5	1.0	6	0.05	1	2
IV	3	1.5	10	0.1	1.5	3.5
V	2	2.0	15	0.2	2	>3.5

Table 4: Weight values of each parameter.

	W1	W2	W3	W4	W5	W6
DO	0.144	0.088	0.277	0.300	0.457	0.343
NH_3-N	0.246	0.234	0.160	0.064	0.055	0.069
COD_{Mn}	0.088	0.119	0.133	0.168	0.168	0.147
TP	0.229	0.221	0.147	0.166	0.077	0.176
TN	0.149	0.210	0.150	0.142	0.079	0.118
PI	0.144	0.127	0.132	0.159	0.163	0.147

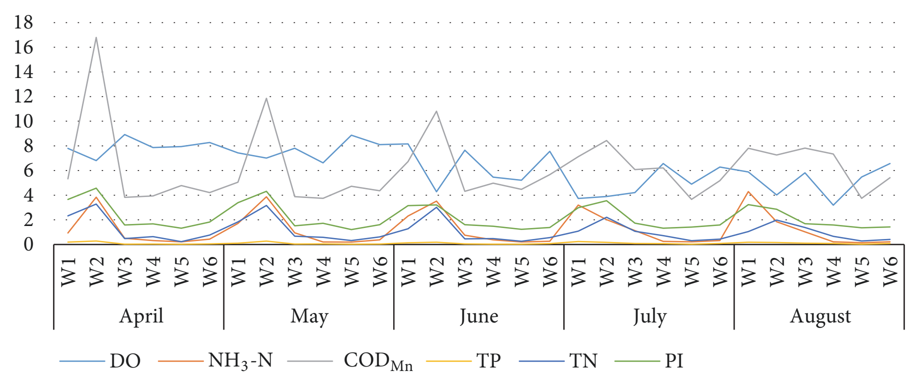

Figure 2: Water quality sampling data of Chaohu Lake.

After normalization, the weight value of the W1 area is

$$A = (0.144, 0.246, 0.088, 0.229, 0.149, 0.144). \quad (8)$$

Similarly, the weight values of other monitoring points can be obtained, as shown in Table 4.

3.1.3. Constructing the Evaluation Matrix R. Taking the DO of the W1 area as an example, the membership degree of the DO is calculated.

Membership function belonging to the first-grade water quality:

$$r_{ij} = \begin{cases} 0, & c_i \le s_{i,j-1} \text{ or } c_i \ge s_{i,j+1} \\ \dfrac{c_i - s_{i,j-1}}{s_{ij} - s_{i,j-1}}, & s_{i,j-1} < c_i < s_{ij} \\ \dfrac{s_{i,j+1} - c_i}{s_{i,j+1} - s_{ij}}, & s_{ij} < c_i < s_{i,j+1} \\ 1, & c_i = s_{ij}, \end{cases} \quad (9)$$

where evaluation matrix R=$(r_{ij})_{6\times5}$; r_{ij} is the element of R on the ith column and jth row; s_{ij} is the standard values shown in Table 3; c_i is the ith element's actual measured value given in Figure 2.

From the above calculation process, a single factor fuzzy evaluation set corresponding to each factor can be obtained:

$$R_{W1} = \begin{bmatrix} 0.4 & 0.6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0.898 & 0.102 & 0 \\ 0 & 0 & 0 & 0.27 & 0.73 \\ 0 & 0 & 0 & 0.974 & 0.026 \\ 0 & 0 & 0.147 & 0.853 & 0 \end{bmatrix}. \quad (10)$$

Then, the matrix R and the weight set A are combined to obtain a comprehensive water quality evaluation vector of the Chaohu W1 into the lake. By adopting the same method, the water quality evaluation vector of other lake entrances in Chaohu Lake can be obtained.

$$\begin{aligned} B_{W1} &= A \cdot R_{W1} \\ &= (0.144, 0.246, 0.088, 0.229, 0.149, 0.144) \end{aligned}$$

Table 5: Comprehensive evaluation results.

Position	I-level	II-level	III-level	IV-level	V-level	Evaluation results
W1	0.058	0.086	0.100	0.339	0.417	V
W2	0	0.018	0.070	0.094	0.817	V
W3	0.107	0.363	0.445	0.029	0.160	III
W4	0.199	0.477	0.301	0.013	0.064	II
W5	0.547	0.143	0.210	0.099	0.055	I
W6	0.315	0.345	0.236	0.042	0	II

$$\cdot \begin{bmatrix} 0.4 & 0.6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0.898 & 0.102 & 0 \\ 0 & 0 & 0 & 0.27 & 0.73 \\ 0 & 0 & 0 & 0.974 & 0.026 \\ 0 & 0 & 0.147 & 0.853 & 0 \end{bmatrix}$$

$$= (0.058, 0.086, 0.100, 0.339, 0.417)$$

$$B_{W2} = A \cdot R_{W2}$$

$$= (0.088, 0.234, 0.119, 0.221, 0.210, 0.127)$$

$$\cdot \begin{bmatrix} 0 & 0.203 & 0.797 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0.793 & 0.207 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= (0, 0.018, 0.070, 0.094, 0.817)$$

$$B_{W3} = A \cdot R_{W3}$$

$$= (0.277, 0.160, 0.133, 0.147, 0.150, 0.132)$$

$$\cdot \begin{bmatrix} 0.587 & 0.413 & 0 & 0 & 0 \\ 0 & 0.26 & 0.74 & 0 & 1 \\ 0 & 0.41 & 0.59 & 0 & 0 \\ 0 & 0 & 0.804 & 0.196 & 0 \\ 0 & 0.356 & 0.644 & 0 & 0 \\ 0 & 0.748 & 0.252 & 0 & 0 \end{bmatrix}$$

$$= (0.107, 0.363, 0.445, 0.029, 0.160)$$

$$B_{W4} = A \cdot R_{W4}$$

$$= (0.300, 0.064, 0.168, 0.166, 0.142, 0.159)$$

$$\cdot \begin{bmatrix} 0 & 0.94 & 0.06 & 0 & 0 \\ 0.63 & 0.37 & 0 & 0 & 1 \\ 0 & 0.38 & 0.62 & 0 & 0 \\ 0 & 0 & 0.92 & 0.08 & 0 \\ 0 & 0.754 & 0.246 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$= (0.199, 0.477, 0.301, 0.013, 0.064)$$

$$B_{W5} = A \cdot R_{W5}$$

$$= (0.457, 0.055, 0.168, 0.077, 0.079, 0.163)$$

$$\cdot \begin{bmatrix} 0.907 & 0.093 & 0 & 0 & 0 \\ 0.886 & 0.114 & 0 & 0 & 1 \\ 0 & 0.13 & 0.87 & 0 & 0 \\ 0.333 & 0.667 & 0 & 0 & 0 \\ 0.733 & 0.267 & 0 & 0 & 0 \\ 0 & 0 & 0.39 & 0.61 & 0 \end{bmatrix}$$

$$= (0.547, 0.143, 0.210, 0.099, 0.055)$$

$$B_{W6} = A \cdot R_{W6}$$

$$= (0.343, 0.069, 0.147, 0.176, 0.118, 0.147)$$

$$\cdot \begin{bmatrix} 0.907 & 0.093 & 0 & 0 & 0 \\ 0.051 & 0.049 & 0 & 0 & 0 \\ 0 & 0.518 & 0.482 & 0 & 0 \\ 0 & 0 & 0.76 & 0.24 & 0 \\ 0 & 0.886 & 0.114 & 0 & 0 \\ 0 & 0.878 & 0.122 & 0 & 0 \end{bmatrix}$$

$$= (0.315, 0.345, 0.236, 0.042, 0). \tag{11}$$

3.1.4. Synthesis of Evaluation Matrix and Weights. According to the calculation results of the above fuzzy matrix, the fuzzy comprehensive evaluation results of the monitoring points of each lake entrance of Chaohu Lake can be obtained, as shown in Table 5.

3.2. Analysis of Water Quality Evaluation Results. According to the comprehensive evaluation results in Table 5, it can be seen that the main lakes in Chaohu Lake are polluted to varying degrees. The water of the Nan Fei He and the Shi Wu Li He is seriously polluted, but the water quality of other monitoring points is higher than that of previous years. The situation has a certain degree of improvement, which also shows the government's comprehensive management of Chaohu Lake Basin in recent years [16].

In order to ensure the sustainable use of water resources and that the virtuous cycle continues—the Nan Fei He and the Shi Wu Li He both pass through the urban area of Hefei and have a great impact on the lives of residents—it is necessary to increase pollution control and rectification efforts and to find better governance measures.

There are many reasons for the pollution in Chaohu Lake, but most of the reasons are sewage discharge from agriculture and enterprises. From the perspective of agriculture, in order to obtain a better harvest, farmers will spray pesticides and fertilizers in the process of planting crops. These polluted waters will eventually gather in Chaohu Lake. After a long period of time, the water quality of Chaohu Lake will be destroyed. Therefore, the government should actively guide and vigorously promote the development of green agriculture and manage it from the origin. From the perspective of the enterprise, many heavy industrial enterprises in the industrial park directly discharge untreated wastewater to the surrounding lake entrance area, so that the nutrients of the lake body of Chaohu Lake rise to a high point, thereby increasing the outbreak of cyanobacteria. Therefore, it is necessary to increase the pollution control and punishment of this type of enterprises. At the same time, it is also possible to improve the pollution status of Chaohu Lake Basin by planting water plants and exerting the ability of plants to purify water bodies.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Supplementary Materials

Water quality sampling data of Chaohu Lake. *(Supplementary Materials)*

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