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Detection and Control Method of Odours in Water Sources of Taihu Lake Based on Regression Analysis

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The corruption of water quality is caused mostly by the volatile odorous substances from the metabolism of bacterial algae in the water. Therefore, the monitoring of odorous substances plays a certain role in controlling water quality. In order to solve the problem that the current detection means is not effective, in this paper, the instrument analysis method and regression analysis method were combined to establish a model of odour detection and early warning control. This model can make real-time analysis of water quality, ensuring early warning of algal bloom etc., reducing water pollution, and guaranteeing the cleanliness of water resources. Then, through simulation of the cyanobacterial bloom process in Taihu Lake, the feasibility of this model was validated. It's found that the variations of β-ionone and methyl isopropanol (MIB) have a good indication of that in algae concentration, that is, when these two organic matters in the water quality of Taihu Lake changes abnormally, it indicates that there may be the abnormality of algal bloom. It has very important practical significance to use this model for control the water quality of Taihu Lake.

1. Introduction

In the past two hundred years, human society has experienced rapid development. Meanwhile, the natural environment has also suffered the most serious damage in history, with problems such as climate warming, water pollution, and resource depletion etc. (Hageskal et al., 2009; Motum, 2007). In particular, water pollution caused by human beings has a serious impact on human health. Now about 1.1 billion people worldwide lack safe drinking water, and 5,000 children on average die every day from drinking unclean water.
The main cause of water pollution is the disorderly discharge of industrial and agricultural wastewater and domestic sewage, resulting in eutrophication of water, increased organic matter content, excessive levels of heavy metals, and transitional breeding of algae and other organisms (Hayes et al., 2010; De Carvalho et al., 2004), so how to ensure the safety of drinking water has become the focus of attention. At the earliest time, people judged the quality of water quality mainly through taste and smell. Zoteman performed statistics on water-sensitive indication and odour types, as shown in Table 1.

Table 1: Sensitive indication and odour type of drinking water quality

Type	Chemical compound	Threshold of odour concentration /$mg \cdot L^{-1}$
Bad taste	Geosmin	$15x10^{-6}$
Chemical substances	Ethyl acetate	4.3
Mold taste	Chlorine	$25x10^{-4}$
Chlorine flavour	Hypochloric acid	0.32
Phenolic flavour	2,4- two chlorophenol	$2x10^{-3}$
Mildew	2,4,6- chloromethyl ether	$3x10^{-8}$

The odour generated by water quality is mainly the environmental event caused metabolites of algae, e.g., the common soil odour and musty smell are volatile organic compounds that are metabolized by actinomycetes and algae. Hageskal et al. (Watson, 2004; Suffet et al., 1999) have successively studied the causes and detection methods of odours, and achieved certain results. Stellacci et al. (Stellacci et al., 2010; Zaitlin and

Watson, 2006) monitored the development of cyanobacteria by remote sensing data and water temperature environmental factors, finding that 24-30°C is the optimal temperature range for cyanobacterial outbreaks, and cyanobacteria production is inhibited above 30°C.

The monitoring and control of water quality should be real-time and accurate (Yoosook and Maneeintr, 2018). At present, the monitoring methods adopted at home and abroad are mainly divided into sensory analysis and instrumental analysis. In this paper, the instrument analysis method combined with the mathematical regression analysis method was selected to establish a model of odour detection and early warning control, which can make real-time analysis of water quality, ensure the early warning of algae etc., reduce the factors of water pollution, and guarantee the cleanliness of water resources (Birungi and Chirwa, 2018).

2. Odour monitoring model

In terms of water quality monitoring, the current analytical methods are ineffective (Davies et al., 2004), and it is difficult to handle the abnormal changes in water quality in advance. Based on the long-term odour monitoring data of Taihu Lake raw water and the algae concentration at the corresponding time, this paper establishes an odour-monitoring model to simulate and predict the water quality, and deal with the occurrence of abnormal events such as algal bloom in advance. This has a positive effect on improving the safety of Taihu Lake.

2.1 Monitoring model

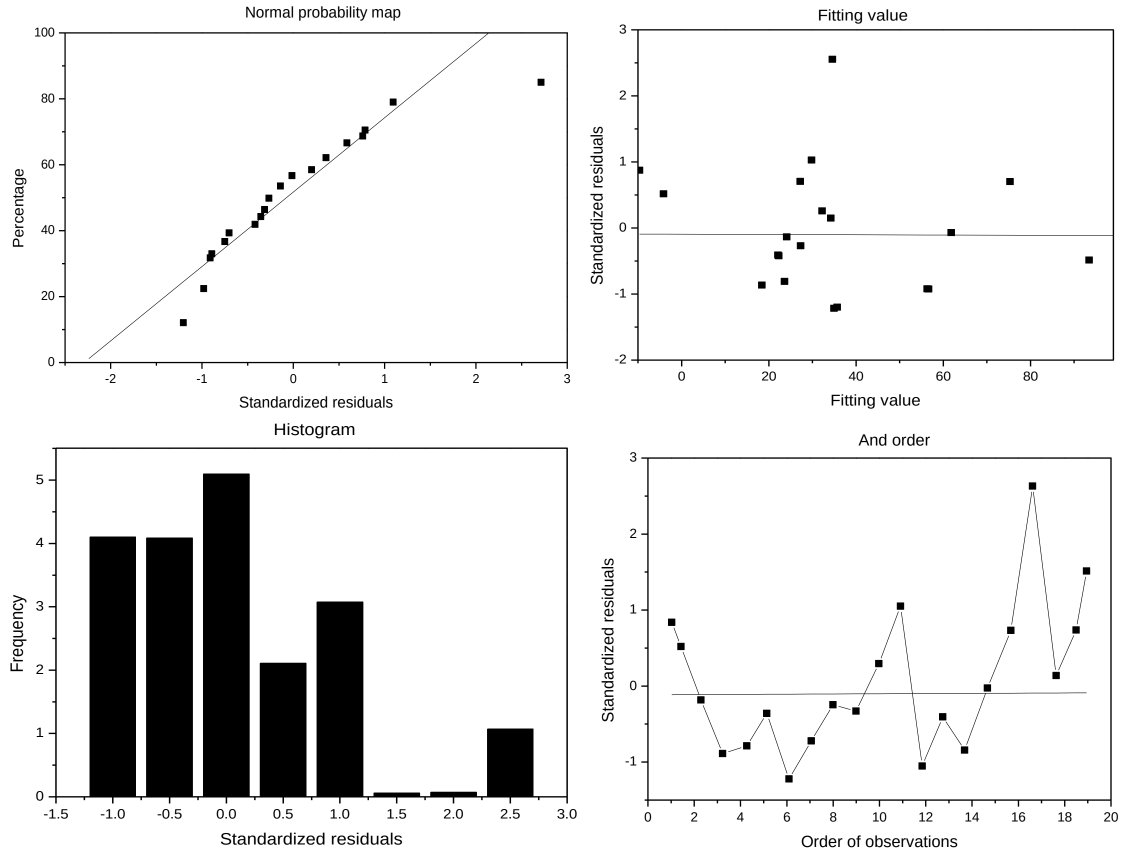

Figure 1: Multiple regression analysis residual graph

Taking the concentration of each odorous substance as the independent variable (such as α-cedrol, β-cyclocitral, β-ionone, dimethyl sulphide (DMS), dimethyl disulphide (DMDS), dimethyl trisulfide (DMTS), 2-methylisoborneol (MIB), geosmin, and m-xylene (MX)), and the α-chlorophyll concentration as the dependent variable, the MINITAB system was used to perform multiple linear regression analysis on each parameter and then establish a detection and control model for water odorous substances in Taihu Lake. Fig.1 shows the regression analysis residual graph of the model.

2.2 Regression equation

The mathematical expression of this model is given as:

$$Y_{\alpha\text{-chlorophyll}}=0.4-0.00062\times C_{\text{dimethyl sulfide}}+0.14\times C_{\text{dimethyl disulfide}}+2.5\times C_{\text{m-xylene}}+0.16\times C_{\beta\text{-ionone}}-0.39\times C_{\alpha\text{-cedrol}} \quad (1)$$

It can be seen from formula (1) that dimethyl sulfide, dimethyl disulfide, m-xylene, β-ionone, and α-cedrol play a positive role in the growth of algae and can be used as the key factors for monitoring and judging algae growth condition. That is, when the concentrations of dimethyl disulfide, meta-xylene, and β-ionone are abnormally increased, or the concentrations of dimethyl sulfide and α-cedrol are abnormally lowered, abnormal growth of algae may occur.

3. Empirical analysis

3.1 Analysis of experimental data

A part of the water plant was selected as the experimental test area, and the test was divided into four areas, each of which was 30m×60m in size. The first, second, and third are test areas, and the fourth is the control area. The Taihu Lake water with different algae content was injected into four areas, and the water quality and cyanobacterial growth in each area were monitored. The collection time was set between 9:00 and 11:00 am at 3 collection points for each area. The collection quantity at each collection point should not less than 350mL. After mixing, 1000mL was selected for analysis. The results are as follows.

3.1.1 Variation of α-chlorophyll concentration

Fig.2 shows the variation trend of α-chlorophyll concentration with the sampling date. It can be seen from the figure that the third and fourth areas have the highest concentration on the first day, then decrease rapidly, and slightly increase until the fourth day; while the concentrations in the first and second areas are low, at the small range of change. This is consistent with the actual growth of cyanobacteria: in the first 6 days, the temperature was high, and the cyanobacteria bloomed; on the 7th-10th day the rainstorm occurred, and the cyanobacteria outburst was suppressed; in the last two days the cyanobacteria settled.

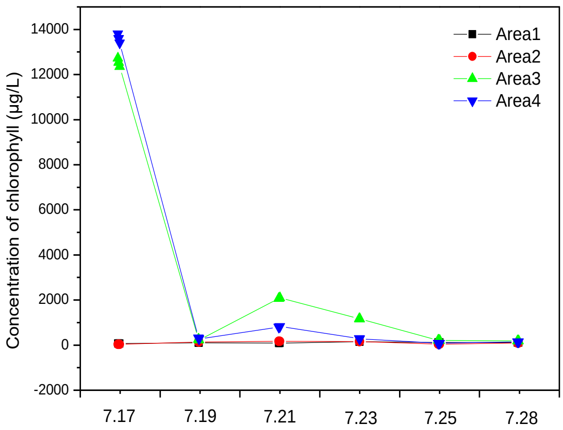

Figure 2: Variation of chlorophyll concentration in different areas

3.1.2 Variation of dimethyl sulfide concentration

The cyanobacteria bloom produces a large amount of algae spoilage. It can be seen from Fig. 3 that the concentration of dimethyl sulphide (DMS) increases when the cyanobacteria are spoiled, then decreases due to the suppression of the bloom, and reaches the highest on the 3rd-7th day.

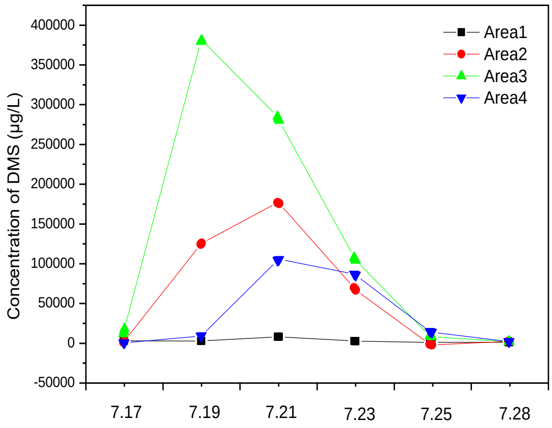

Figure 3: Variation of two methyl sulphur in different areas

3.1.3 Variation of dimethyl disulfide concentration

Dimethyl disulfide (DMDS) with the taste of rotten vegetables is a factor that causes the decomposed odour of algae. Fig.4 shows the variation of DMDS concentration with time, indicating that on the fifth day the second region has the highest peak, and at other times, the DMDS concentration of each area does not change much with lower concentration.

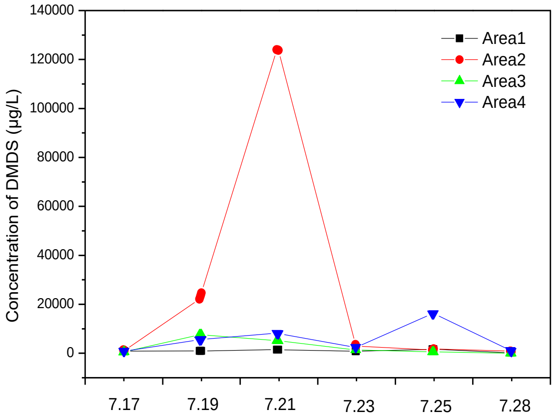

Figure 4: Variation of dimethyl disulfide concentration in different areas

3.1.4 Variation of m-xylene concentration

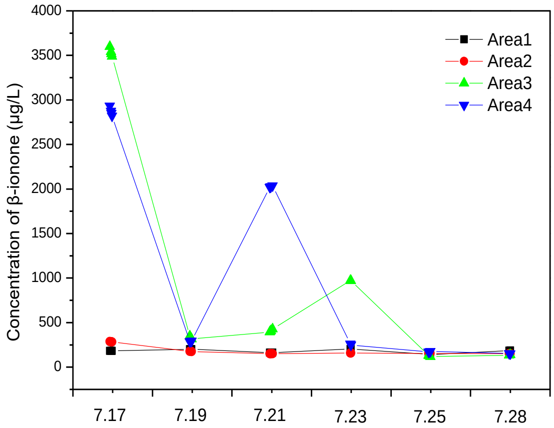

Figure 5: Variation of β-violet concentration in different areas

Fig. 5 shows the variation of the β-ionone concentration in each area. The concentration is the largest at the initial stage, the lowest on the third day, and rises on the fifth day, and then decreased again. Therefore, the variation of β-ionone concentration can be used as an indicative factor for the growth of algae.

3.1.5 Variation of α-cedrol concentration

The variation of α-cedrol concentration in each area is shown in Fig. 6. Except for the fourth region, the variation of α-cedrol concentration in other areas and the overall content were all low.

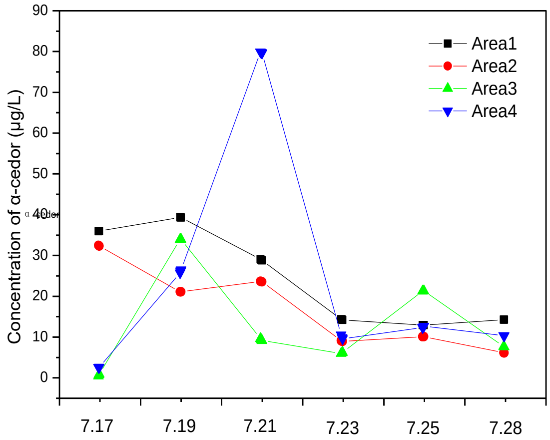

Figure 6: Variation of α-cedor concentration in different areas

3.2 Odour substance monitoring model for algae growth

The experimental data was analysed by the odour monitoring model and then the regression equation was obtained. The result is shown in Fig.7. It can be seen from the figure that except for the first area with better prediction, the other three areas cannot predict algae growth through the variation of odorous substances. Therefore, it is necessary to re-establish the model for the 2nd, 3rd, and 4th area.

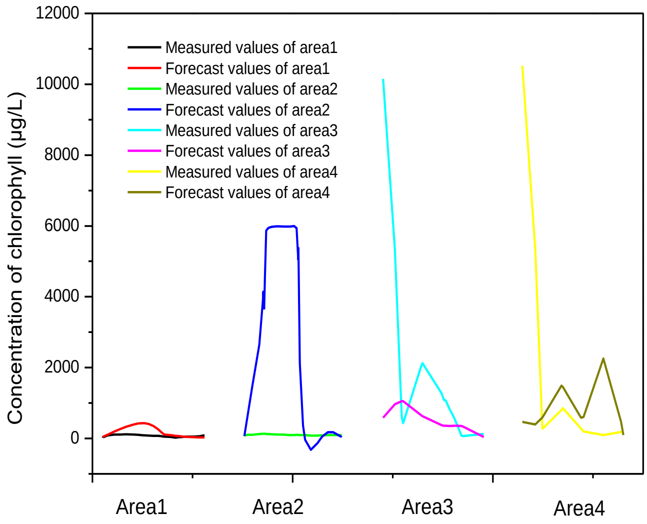

Figure 7: Comparison of measured values and predicted values of chlorophyll concentration

Table 2: Regression equations and related factors in different areas

Area	Regression equation	R^2	Related factors	P value
Second area	$Y_{\alpha\text{-Chlorophyll}}=104.5-0.0003\times C_{DMTS}$	40.6%	DMTS	0.175
Third area	$Y_{\alpha\text{-Chlorophyll}}=708.8-3.77\times C_{\beta\text{-ionone}}$	95.8%	β-ionone	0.001
Fourth area	$Y_{\alpha\text{-Chlorophyll}}=217.4-5.1\times C_{\beta\text{-ionone}}-2.47\times C_{MIB}$	99.6%	β-ionone MIB	0 0

The MINITAB system was used to analyse the odour substance concentration data in the 2nd, 3rd, and 4th areas, and the related regression equation was established, as shown in Table 2, the main influencing factor on the variation of chlorophyll concentration in the second area is DMTS, but the significance is not high; the main influencing factor of the third area is β-ionone, and the level of significance is better; in the fourth area, the main influencing factors are β-ionone and MIB, and the level of significance is the best. The variation of chlorophyll concentration is proportional to that of β-ionone concentration and inversely proportional to the concentration of MIB.

4. Conclusions

Due to the disorderly discharge of industrial and agricultural wastewater and domestic sewage, it has resulted in the eutrophication of water quality, increased organic matter content increased, excessive heavy metal content, and over-proliferation of algae and other organisms, so how to ensure water safety has become the focus of attention. For solving the problem that the current detection means is not effective, in this paper, the instrument analysis method and regression analysis method were combined to establish a model of odour detection and early warning control. This model can make real-time analysis of water quality, ensuring early warning of algal bloom etc., reducing water pollution, and guaranteeing the cleanliness of water resources. Then, through simulation of the cyanobacterial bloom process in Taihu Lake, the feasibility of this model was validated. It's found that the variations of β-ionone and MIB have a good indication of that in algae concentration. It has very important practical significance to use this model for control the water quality of Taihu Lake.

(1) By analysing the odorous substances and chlorophyll concentration in water, the monitoring model of odorous substances and the equation of regression analysis were established. It's found that DMS, DMDS, MX, β-ionone, α-Cedar alcohol plays a positive role in the growth of algae and can be used as an important factor in monitoring and judging the growth of algae.

(2) Through simulating the cyanobacterial bloom process in Taihu Lake, it is found that algae may have an outbreak abnormality when the concentration of β-ionone and MIB changes abnormally, thus, by monitoring the variation of β-ionone and MIB concentration, the abnormal bloom of algae in Taihu Lake can be predicted.

(3) In addition, it has also been found that the variation of volatile sulfur compounds such as DMS, DMDS and DMTS has no significant indication on the growth of algae in Taihu Lake, but it can indicate the specific stage of algal bloom, which also has important practical significance.

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