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DYNAMIC VARIATION OF WATER QUALITY IN WEST LAKE AND MULTIVARIATE ANALYSIS OF ITS PRIMARY FACTORS

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Abstract: Dynamic variation of water quality in West Lake is analyzed based on the data of 1995. Principal Component Analysis is used to reveal the mutual relationships of various factors. It is shown that there exists an obvious special and temporal variation in the main factors of water quality. Annual values of TP, TN, and Chl.a fluctuate seasonally. In addition, Chl.a has a synchronous variation with water temperature, although being lagged a little, and closely relates to TP and TN. SD has a good negative relation with Chl.a. The results from Principal Component Analysis show that SD, Ec, Tw, pH and Chl.a are the most influential factors in water quality of the West Lake.

Key Words: West Lake, dynamic variation of water quality, principal component analysis.

Introduction

West Lake, a famous resort lake both at home and abroad despite its small water volume, has undergone serious eutrophication due to industrial waste water, farming effluents, the city domestic sewage entering it, a rapid development in tourism, etc. As a result, the amount of nutrient salts has increased and the water quality has deteriorated. It is therefore important for us to monitor and analyze the present situation, along with dynamic variations of the water quality, in order to gain a better understanding of the mechanism of eutrophication in West Lake and be able to predict trends in the variation of the water quality.

In this paper, the spatial and temporal variation in the main factors of water quality based on data collected in 1995 are analyzed, and the functions and relationships among the primary factors by multivariate analysis are discussed.

Sampling points and methods

The West Lake was divided into five sections by Su Causeway and Bai Causeway (L. Yue, L. Beili, L. Xili, L. Xiao nan and L. Wai; Fig. 1). According to the distribution of the five lake areas, the surrounding vicinities, and the pleasure-boat lines, we established 8 sampling points (Fig.1). A sampling tool was ;used to sample the water at each point, and analyses were carried out the same day. The measurements included physical, chemical, biological factors of water quality, along with some other parameters.

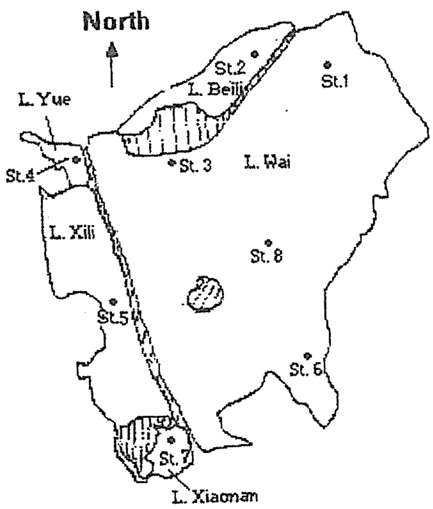

Fig.1 Sampling points in West Lake

Results and discussion

Figure 2 shows the variation in the annual mean values of main water quality factors at each sampling point. Figures 2A and 2B reflect the variation of total phosphorus concentration (TP) and total nitrogen concentration (TN) , respectively, at the sampling points. The values of TP and TN at point 4 (L.Yue) are higher, as Lake Yue is situated at the site of an inlet channel, whereby a large amount of polluted water inters this point. While the value of TP at point 7 (L. Xiao nan) is lower for the water-drawing (the value of TP in Qiantang River is lower than in West Lake). Figure 2D reflects the variation of Chl.a at each sampling point. The highest value was founded at point 2 (L. Beili). This is a result of a slowed water flow in Lake Belie as a dead space of water-drawing. The lowest Chl. A value occurred at point 8, and is a result of the water-drawing. Figures 2D, 2E, "F reveal a small variation in DO, EC, pH values, respectively, at the sampling points. Therefore, with respscti to TP, TN and Chl. A at least, the water-drawing can improve the water quality.

The temporal variation of TP and TN at points 2, 7 and 8 can be seen clearly in Fig. 3. The variation of TP and TN at each of these points have large fluctuations. For point 2, TP was generally higher in April and December. This was also the case for point 7, but not for point 8. The different trends in TP values observed for point 8 could have been due to the water-drawing. At each point, the TN values were lower during April and May.

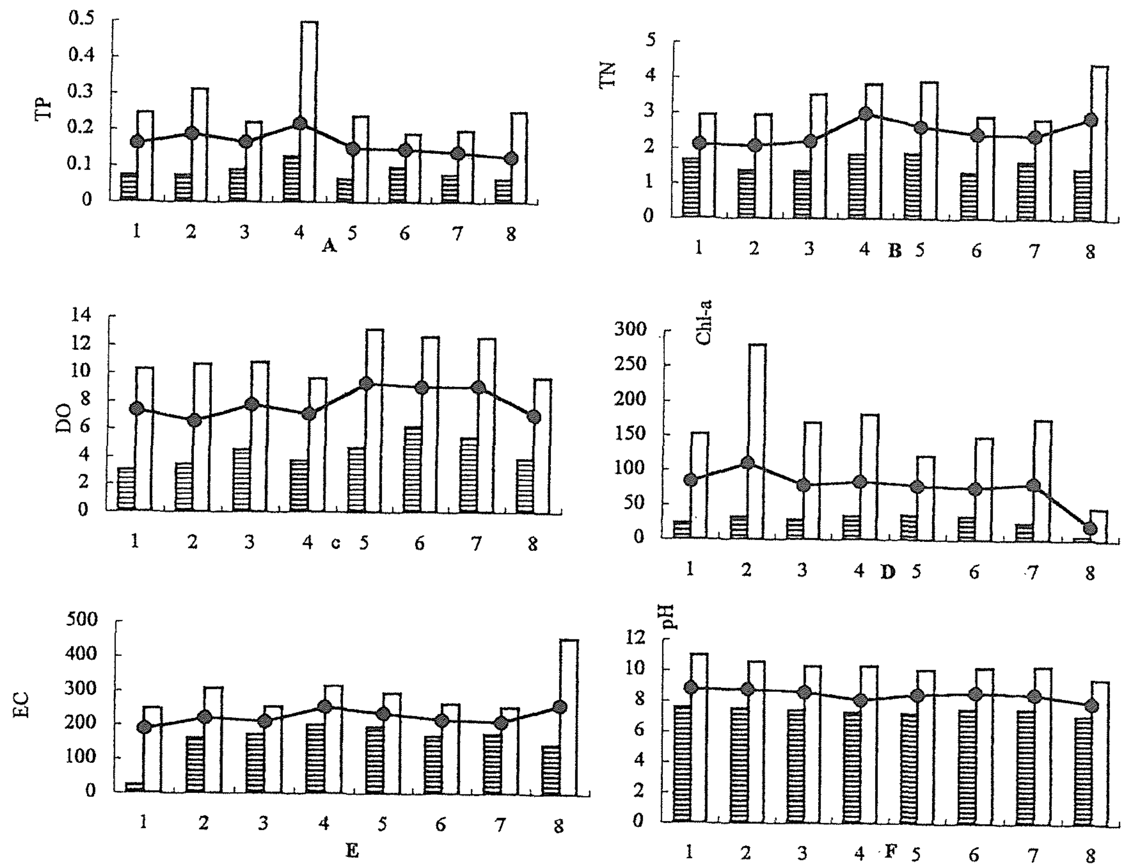

Figure 2. Variation of annual mean values of main water quality factors at each sampling point

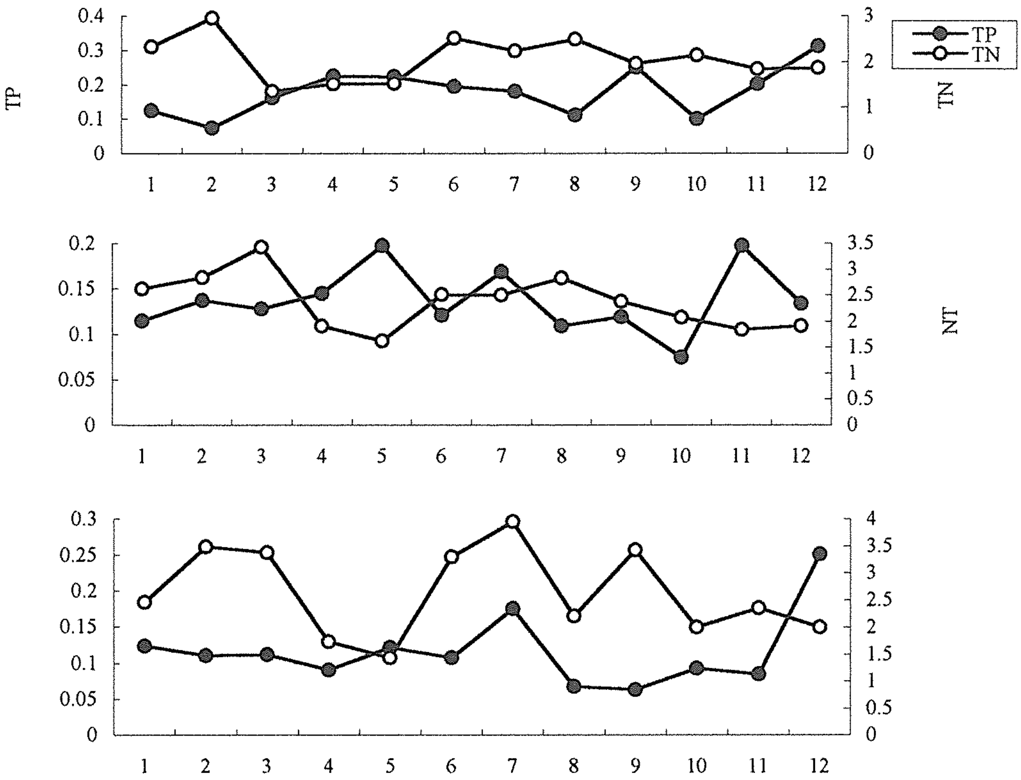

Fig.3 Temporal variation of TP and TN at points 2, 7 and 8

Figure 4 shows the temporal variation of Chl.a and SD at point 7. It is apparent that their values have fluctuated greatly. The opposing trends in their values show their negative relationship. This is due to the occurrence of a great amount of nutrient salts, resulting from the luxuriant growth of algae, increasing Chl.a values while simultaneously reducing SD values.

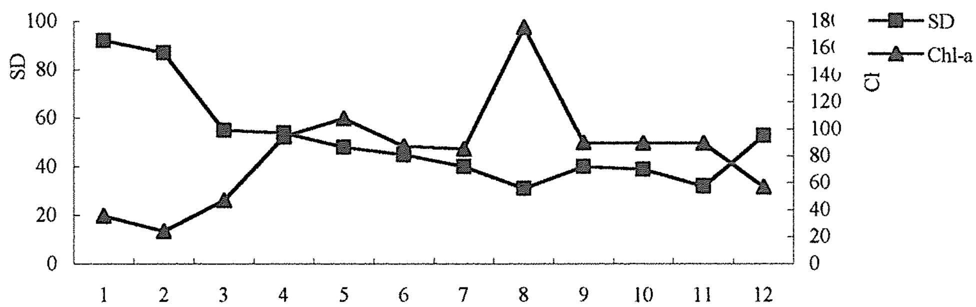

Fig.4 Temporal variation of Chl-a and SD at point 7

Figure 5 shows the temporal variation of Chl.a at points 2, 7 and 8, along with the waters' temperature, Tw. For each point, Chl.a revealed a great monthly variation, peaking in April, August and October, while its lowest value occurred in February. This was a synchronous to the variation in the water temperature, although slightly lagged.

Contribution of various principal components:

Principal Component	Tw	SD	DO	Ec	pH	TP	TN	Chl-a	charact-eristic value	accumulation contribution
	Principal component coefficient									
First	-0.45	0.48	0.28	0.44	-0.42	-0.13	0.07	-0.32	3.90	0.49
Second	0.10	0.07	0.08	0.12	0.21	-0.64	0.64	0.33	1.64	0.69
Third	-0.21	-0.23	0.66	0.27	0.25	0.09	-0.32	0.47	1.09	0.83
Fourth	-0.35	0.07	-0.28	0.28	0.34	0.61	0.46	0.13	0.57	0.90

Table 2. Principal components analysis at point 7

	Tw	SD	DO	Ec	pH	TP	TN	Chl-a
Tw	1.00							
SD	-0.73	1.00						
DO	-0.26	0.16	1.00					
Ec	-0.84	0.64	0.17	1.00				
pH	0.64	0.64	0.21	-0.51	1.00			
TP	-0.03	-0.13	-0.23	0.02	-0.10	1.00		
TN	0.03	0.30	-0.05	0.31	-0.05	-0.43	1.00	
Chl-a	0.75	-0.76	-0.48	-0.73	0.46	0.02	-0.22	1.00

Contribution of various principal components:

Principal Component	Tw	SD	DO	Ec	pH	TP	TN	Chl-a	charact-eristic value	accumulation contribution
	Principal component coefficient									
First	0.47	-0.45	-0.15	-0.45	0.36	0.04	-0.14	0.46	3.81	0.48
Second	0.16	0.03	0.38	-0.03	0.33	-0.66	-0.52	-0.08	1.53	0.67
Third	0.13	0.12	-0.72	0.04	-0.33	-0.16	0.52	0.22	1.23	0.82
Fourth	0.15	-0.15	0.005	0.33	0.39	0.63	0.50	-0.18	0.63	0.89

Table 3. Principal components analysis at point 8

	Tw	SD	DO	Ec	pH	TP	TN	Chla
Tw	1.00							
SD	-0.61	1.00						
DO	-0.64	0.41	1.00					
Ec	-0.13	-0.43	0.06	1.00				
pH	0.33	-0.29	0.04	0.05	1.00			
TP	-0.27	-0.19	0.34	0.62	-0.20	1.00		
TN	0.22	-0.06	0.22	0.08	0.09	-0.07	1.00	
Chl-a	0.73	-0.44	-0.79	0.04	0.05	-0.22	-0.08	1.00

Contribution of various principal components:

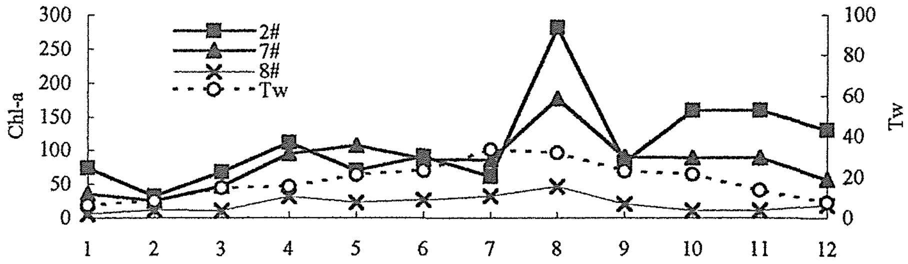

Fig.5 Monthly variation of Chl-a and water temperature (Tw) at points 2, 7 and 8

Figure 6 shows the relationship between Chl.a and TP. From this figure, a relationship between Chl.a and TP is not obvious. If we analyze the yearly average for each monitoring point, however, Chl.a and TP appear to have a good correlation. Point 2 was the exception, and is shown in Fig. 6b. While TP of point 2 is very high, Chl.a does not appear to increase with it, suggesting that point 2 (L. Beili) is affected by the pollution water and the slow water flow.

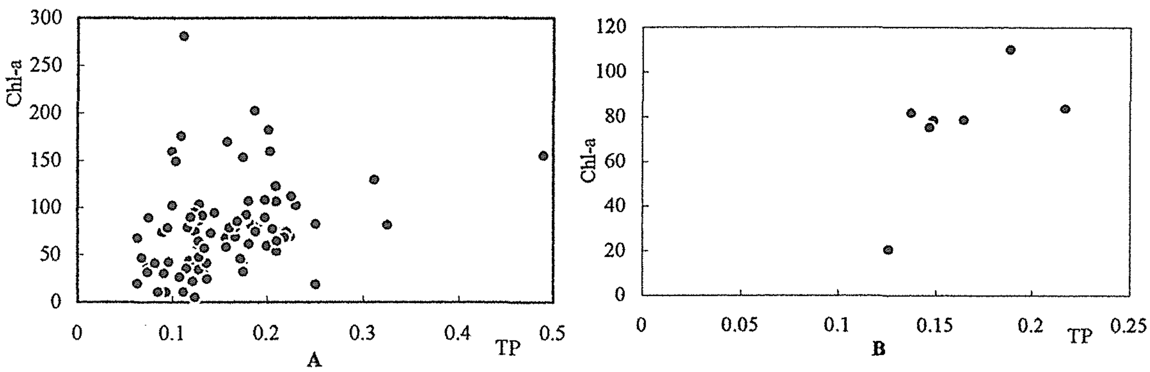

Figure 6. Relationship between Chl-a and TP

Principal component analysis is a statistical method that enables us to reduce the number of variables in a system. The analyses of several main factors presented in the previous section related a complex system to exist, with each factor having undergone a large variation over both the timing and positioning of each sampling point. Multivariate analyses (such as principal component analysis) can be used to determine the mutual relationships between various environmental factors along with each factor's individual impact. The method may be consulted in the references[1-4].

Table 1. Principal components analysis at point 2. (Correlation coefficients)

	Tw	SD	DO	Ec	pH	TP	TN	Chl-a
Tw	1.00							
SD	-0.67	1.00						
DO	-0.65	0.33	1.00					
Ec	-0.86	0.79	0.58	1.00				
pH	0.55	-0.79	-0.26	-0.56	1.00			
TP	0.01	-0.33	-0.19	-0.26	0.13	1.00		
TN	0.07	0.27	-0.03	0.18	0.12	-0.52	1.00	
Chl-a	0.34	-0.64	-0.12	-0.29	0.68	0.12	0.06	1.00

Principal Component	Principal component coefficient Tw	SD	DO	Ec	pH	TP	TN	Chl-a	charact-eristic value	accumulation contribution
Firth	0.53	-0.40	-0.50	-0.001	0.17	-0.16	0.01	0.51	2.97	0.37
Second	-0.04	-0.40	0.13	0.66	0.04	0.61	0.11	0.03	1.75	0.59
Third	0.20	-0.10	0.34	-0.06	0.60	-0.20	0.61	-0.24	1.30	0.75
Fourth	0.13	0.13	-0.05	-0.06	0.64	0.07	0.72	0.15	0.94	0.87

Table 4. Principal components analysis at whole lake

	Tw	SD	DO	Ec	pH	TP	TN	Chl-a
Tw	1.00							
SD	-0.73	1.00						
DO	-0.55	0.44	1.00					
Ec	-0.80	0.72	0.40	1.00				
pH	0.60	-0.70	-0.18	-0.52	1.00			
TP	0.21	-0.43	-0.37	-0.32	0.01	1.00		
TN	-0.19	0.56	0.23	0.53	-0.20	-0.68	1.00	
Chl-a	0.70	-0.75	-0.67	-0.74	0.49	0.34	-0.60	1.00

Contribution of various principal components:

Principal Component	Principal component coefficient Tw	SD	DO	Ec	pH	TP	TN	Chl-a	charact-eristic value	accumulation contribution
First	0.39	-0.42	-0.30	-0.41	0.30	0.24	-0.30	0.42	4.55	0.57
Second	-0.33	0.07	-0.06	0.10	-0.44	0.64	-0.52	0.003	1.39	0.74
Third	0.18	0.22	-0.77	0.13	-0.40	0.008	0.36	0.12	0.89	0.85

Tables 1, 2, 3 and 4 show the main results of the principal component analyses of points 2, 7 and 8 and of the whole lake, respectively. From Table 1 (for point 2), we can see that there are high positive correlation (>0.58) for SD-Ec, pH-Chl.a and Ec-DO, while Tw-Ec, SD-pH, Tw-SD, SD-Chl.a, Tw-DO and TP-TN have high negative correlation. According to the coefficients of the principal components, which indicate the contribution by each individual factor, Tw, SD, Ec and pH are the factors for the first principal component. Therefore, Tw, SD, Ec and pH are all important factors in the water quality at point 2. For the second and fourth principal components, TP and TN are the obvious key factors. DO and Chl.a play an important role in the third principal component. As the principal components are independent of one another, the different principal components stand for different mechanisms of pollution. The above results indicate that the first principal component for the water quality of point 2 varied dominantly with weather and season fluctuations, while the second and third principal components for the water quality was influenced mainly by the discharging of city waste water.

From the same analysis of point 7 (see Table 2), we can see that Tw-Chl.a, Tw-pH, SD-Ec and SD-pH have high positive correlation, and Tw-SD, Tw-Ec, SD-Chl.a and Ec-Chl.a have even higher negative correlation. This shows that Tw, SD and Ec have a remarkable effect on the growth of algae at point 7.

For the first principal component, the coefficients of Tw, SD, Ec and Chl.a are greatest, indicating that the effect of weather and season on the water quality is dominant. The second, third and fourth principal components all revealed that the discharging of the city waste water was less important to the water quality, perhaps due to point 7 being a greater distance from the lake bank.

Table 3 shows that for point 8 there is a high positive correlation for Ec-TP and Tw-Chl.a, and a high negative correlation for Tw-SD, Tw-DO and DO-Chl.a. The coefficients of Tw, DO and Chl.a are greatest in the first principal component; Ec, TP and SD are the main factors in the second principal component, while the coefficients of pH and TN are the greatest in the third and fourth principal components. Point 8 lies at the entrance of drawing-water, where the water quality is mostly influenced by the Ian Tang River. This Chl.a and TP are the main factors in this area as their values are lower in the Qian Tang River than in the West Lake.

Finally in Table 4, the correlation among each factor studied is shown for the whole lake. Large positive correlation are observed for Tw-Chl.a and SD-Ec and large negative correlation are seen for Tw-SD, Tw-Ec, SD-Chl.a, Ec-Chl.a and SD-pH. The main factors of the first principal component are Tw, SD and Chl.a. The pH, TP and TN are the important factors in the second principal component, while DO and pH are the major influencing factors of the third principal component.

Based on the principal component analyses of the three sampling points and the whole lake, TP and TN were not the main factors of the water quality in the first principal component. On the contrary, Tw, SD, DO and Ec were the main factors. Therefore, it is probable that the high values of TP and TN in the serious eutrophication lake only slightly influenced the water quality.

Conclusions

Using data from 1995, the rule of dynamic variation of water quality and affected factors in West Lake was analyzed. Due to the shortage of long-term-data, the results obtained are preliminary, but the phenomena discovered are nonetheless reasonable. These are presented below.

1. The factors of water quality had both special and temporal variations. Different primary factors were affected at different monitoring points.
2. Chl.a was closely related to TP, TN and Tw. Chl.a had a synchronous variation with water temperature (Tw), although being slightly lagged. Apart for Lake Beili, its correlation with TP was found to be good.
3. SD had an obvious negative correlation with Chl.a, suggesting that Chl.a determined the water transparency.
4. Correlation Analyses and Principal Component Analyses indicated that Tw, SD, Ec, Chl.a, TP and TN were the most important influential factors in the water quality of West Lake. TP and TN were not important factors in the first principal component, however. Thus the high TP and TN in the serious eutrophication lake only slightly influenced the water quality.

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