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Research Article

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Analysis of principal components of pollution in Baiyangdian

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ABSTRACT

The pollution of lakes in water valley is particular because of the influence of the characteristic of upriver contamination. Taking Baiyangdian，which is a typical shallow weedy lake in the north of China, as a research object，combining the measured water quality data with the spatial data，using the method of Principal Components Analysis based on factor analysis，the water quality parameters of Baiyangdian are summarized into five principal components, namely the index of eutrophication, the index of organic pollution, the index of acid and alkali，the index of algae quantity and the index of plant growing environment. The meaning of each principal component and the pollution mechanism of Baiyangdian are analyzed in this paper to provide scientific basis for the reasonable utilization and the pollution control of Baiyangdian.

Key words: weedy lake; Baiyangdian; principal components analysis; water quality index; eutrophication

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INTRODUCTION

Lake ecosystem, as an important part of aquatic ecosystem, provide necessary water resources and materials for the economic development and people's lives. However, as the increasing of population and developing of agriculture and industry, in one hand, lots of pollutants and nutrients from agriculture, industry and municipal sewage are discharged into the lake continually. On the other hand, people damage the environment seriously through inning of the lake, construction of dams and water gates, and unreasonable aquaculture, which decrease the output approaches of nutrients and weaken the self-adjusting ability of lake ecosystem[1]. It results in wealthy of nutrients, worsen of water, degenerate of environment, damage of lake ecosystem, etc., which cause huge lost for people's production and lives. Therefor, it is significant to study pollution mechanism of lakes for controlling and improving the environment of lakes.

Water pollution of lakes are impacted by various factors. Lake is a complicated system composed by various water quality indexes and each index can reflect the pollution condition in a certain respect. For example, lake rutrophication[2-6], salinization[7-8] and organic pollution[9], etc. In order to study the water environment of lakes clearly and accurately, we should be familiar with various pollution mechanism of lakes and in the basis to conduct assessment and simulation for various pollutions[10]. This paper takes Baiyangdian for example, select those parameters which can reflect the water quality characteristic from numerous parameters, adopt principal component analysis method to find out the main drive factors to illustrate the mechanism of pollutions. This will be significant for maintaining the healthy life and environment of lakes and preventing the water quality from pollution and degradation.

EXPERIMENTAL SECTION

General introduction of the research area

Baiyangdian is a natural big lake in north China, which is in the middle of Daqing river system. The location of Baiyangdian is 40km far from Baoding city with central geographical coordinates of east longitude of 115°38'～116°07' and north latitude of 38°43'～39°02'. The length of Baiyangdian is 39.5km from east to west and 28.5km from south to north, the gross area is 362km^2. Inside of Baiyangdian there are 143 shallow lakes and more than 3700 of ditches which connect and communicate with each other to form a particular landform. The reed fields, acreages and villages account for 46.95% of the gross area, while the water surface accounts for 53.05%. In water areas, ditches water surface accounts for 7.4% while shallow lakes water surface accounts for 41.1%.

Baiyangdian belongs to eastern monsoon, warm temperate and semiarid region, with remarkable continental climate characteristic and four distinct seasons. The annual average temperature is 7.3～12.7℃, the average annual rainfall is 522.7mm, the annual average water evaporation is 1369mm, and the annual average frost-free period is 203d. The water pollution of Baiyangdian can be divided into two major categories of point source and area-source pollution according to the different way of discharge. Point pollutions mainly come from Fu River, White Ditch, Yin River, Cao River and Tang River, in which the pollution of Fu River is most serious. Area-source pollutions mainly include agricultural pollution sources and life pollution sources such as domestic sewage and garbage, etc[11]. In order to recognize various pollution mechanism more clearly, it needs to select several representative lakes of Baiyangdian to conduct comprehensive water monitors.

Monitoring points and monitoring indexes

By means of investigation and research the distribution of pollutions in Baiyangdian, select 8 representative sampling sites to monitor for long term. These 8 monitor points are Nanliuzhuang, Shaochedian, Wangjiazhai, Guangdian, Zaolinzhuang, Quantou, Caiputai and Duancun. The monitor time is in the midmonth during Jan-Oct in 2009. The distribution of sampling sites in Baiyangdian shows in fig.1. Take use of GPS to ensure that the sampling site is consistent each time.

The main monitor items can be divided into outdoor monitor indexes and indoor experiments. Outdoor monitor indexes include sampling site, sampling time, weather describe, surroundings describe and photos, water temperature, air temperature, water length, transparency, plant types, pH and DO. Indoor experiment items include TN, TP, NH_4^+-N, NO_3^--N, COD, BOD_5, chl-a, etc. The sampling sites are determined by GPS; the transparency is determined by Sai's Pan; The water temperature, pH and DO are tested by WTW (Multi350i/SET, made in Germany); NH_4^+-N is tested by Nessler colorimetric method; TN is tested by alkaline potassium persulfate oxidation method and ultraviolet spectrophotometry; TP is tested by potassium persulfate and Mo-Sb colorimetry; NO_3^--N is tested by ultraviolet spectrophotometry; COD is tested by COD tacheometer(CTL-12); chl-a is tested by ultraviolet spectrophotometry after filtered by 0.45um filter membrane and extracted by acetone.

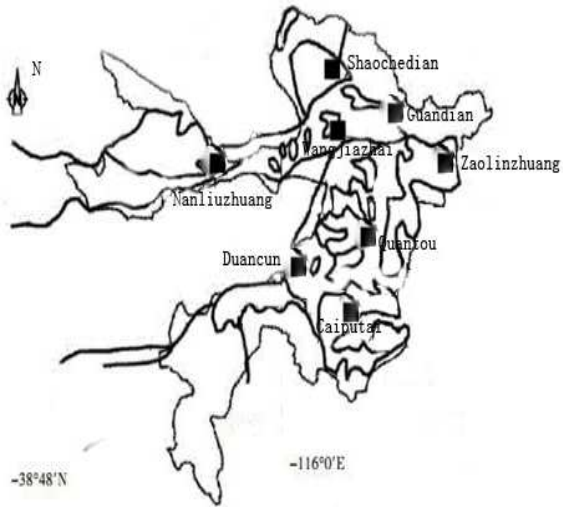

Fig.1 Distribution of water monitor in Baiyangdian

Process of principal components analysis

The purpose of principal components analysis is to combine the indexes to be several few overall targets (that are principal components), to simplify and enhance the reliability of results in use of liner transformation [12-14]. The

methods of PCA for lake pollutions are: Assume that p index variables of n sampling sites such as x_i (i=1，2，…，p)have been given, construct the principal components of water quality analysis. At first, study the correlation ships of p pollution indexes, construct p overall indexes that are irrelevant such as y_i (i=1，2，…p). Secondly, select few m overall indexes from those p indexes whose accumulative variance contribution rate are greater than 80% and which can reflect most information that provided by original indexes. Then quantified and comparable assessments of sampling water can be realized finally.

Analysis and discuss of the research results

This paper adopted the data of 80 samples from 8 sample sites during January to October 2009, select 10 main indexes from 24 water indexes that can reflect the water quality and morphological of lakes to conduct principal of lakes to conduct principal component analysis. Monitoring data of each sample are showed in Table 1.

Tab.1 Basic information of water monitoring data

Monitor indexes	minimum	maximum	Mean value
pH	7.78	8.88	8.18
transparency/m	15.00	200.00	67.97
DO/mg·L^{-1}	3.80	22.10	8.17
permanganate Index /mg·L^{-1}	4.80	13.80	9.07
BOD/mg·L^{-1}	2.00	3.90	2.48
TN/mg·L^{-1}	0.60	29.80	3.50
NH_4^+-N /mg·L^{-1}	0.13	23.90	2.45
NO_3^--N /mg·L^{-1}	0.08	1.49	0.21
TP/mg·L^{-1}	0.02	1.33	0.15
chl-a/mg·L^{-1}	0.52	26.40	4.53

Tab.2 Results of principal components analysis

principal components	Characteristic value	Variance contribution rate/%	Accumulative variance contribution rate/%
1	2.854	31.708	31.708
2	2.113	23.478	55.186
3	1.026	11.398	66.584
4	1.023	11.368	77.952
5	0.992	11.018	88.969
6	0.771	8.565	97.534
7	0.216	2.399	99.933
8	0.006	0.067	100.000
9	0.000	0.000	100.000

Tab.3 Coefficient matrix between the principal components and water indexes

water indexes	principal components				
	1	2	3	4	5
TN	0.961	0.176	-0.002	-0.067	-0.076
NH_4^+-N	0.943	0.173	-0.013	-0.078	-0.102
TP	0.787	0.320	0.151	-0.192	-0.069
BOD	0.220	0.954	0.051	0.100	0.120
permanganate Index	0.220	0.954	0.051	0.100	0.120
Chl-a	0.032	0.068	0.983	-0.054	0.154
DO	-0.147	0.153	-0.055	0.975	-0.004
pH	-0.141	0.185	0.166	-0.004	0.958
NO_3^--N	0.530	0.258	-0.004	-0.051	-0.012

Conduct KMO and Bartlett test before principal components analysis. The F value of Bartlett test is 0 which indicated that the data are from normal distribution totality; the value of KMO test is 0.726 which indicated that the data available can be conducted as principal components analysis. Conduct principal components analysis in use of SPSS software [15]. Enter the data into SPSS form and adopt the factor analysis function to get the results that are showed in table 2. The results demonstrated that the accumulative variance of the first 5 principal components reached 88.969%, which indicated that the data include almost all the information of those 10 indexes. The first principal component is the most important and its variance contribution rate is 31.708%. Table 3 showed the factor loading matrix between the principal components and the water indexes, from which we can see that the most relevant factors with the first principal components are TN, TP, NH_4^+-N, NO_3^--N. The correlation coefficient with TN is 0.961 which illustrated that nitrogen is the nutrient element limiting the eutrophication of the lake. The four nutrients indexes are positive loading. The first principal components indicated that the increasing of nitrogen and phosphorus as the nutrient sources of hydrobios resulted in the eutrophication of the lake. The first principal components included the key factors of the lake's eutrophication, and the variance contribution rate is 31.708% which is greater than other factor's, so this principal component can reflect the level of the lake's eutrophication. Define the first principal component as the characteristic index of eutrophication.

The second principal components are of relative higher correlation coefficient with BOD_5 and COD_{Mn}, which reflect the situation of organic pollution in Baiyangdian. Organic pollution is one of the most important environmental problems in Baiyangdian. The variance contribution rate reaches 23.478% which is only next to the first principal components. So define the second principal component as the organic pollution index of the lake.

The third principal component is of high correlation coefficient with chorophyll, which reflect the bios character of the lake's alga. According to the results of investigation for the lakes, the annual average value of the index that indicate the alga's growth of all the lakes that is in the situation of eutrophication is in higher level. OECD stipulated the dividend standard of chorophyll in eutrophicative lakes. It is eutrophication lake when its chorophyll is higher than 78mg/L. The average value of chorophyll in Baiyangdian is lower than the standard, but in other scientific researches Baiyangdian has been demonstrated as eutrophication. And in general alga-eutrophication lakes, the chorophyll has relative high correlation coefficient with nutrient elements. In this case, the chorophyll should be with TN and TP in one team. But Baiyangdian is a typically grass lake, and most of the nitrogen and phosphorus are used by aquatic plants which results the amount of alga is small. According to the data analysis of site investigation, there is a strong association between the biomass of submerged plants and nutrient elements. So the chlorophyll in the water of Baiyangdian didn't appear in the same principle components with TN and TP. Define the third principal component as the biomass index of water alga. The forth principal component has a relative larger correlation coefficient with DO. The amount of DO has a directive impact on the environment of the plants' growth. The underwanter creatures will consume a vast of oxygen, and the DO decreases with the increasing of the biomass. Define the growth environment of plants as the forth principal component. The fifth principal component has a relative larger correlation coefficient with pH. The pH reflects the acidity-alkalinity of water, it plays an action of control in redox reaction. Additionally, pH has a big impact on Ca^{2+} of lake water which define the chemical stability of lake water system. The pH of most of water area in Baiyangdian is about 8 and it accords with the characteristic of alkalescent in entrophication lakes. Define the acidity-alkalinity index as the fifth principal component.

CONCLUSION

According to the principal components analysis we got 5 principal control factors in Baiyangdian at present. Firstly, the water quality is controlled by eutrophication indexes, that is TN, TP, NH_4^+-N and NO_3^--N which were defined as the first principal component and secondly the organic pollution indexes. There are mainly two kinds of pollutions in Baiyangdian: eutrophication and organic pollution. The rutrophication is most serious and it is the primary cause of water change in Baiyangdian. The later 3 principal components are alga biomass indexes, growth environment indexes and water acidity-alkalinity indexes, which are focus on the characteristic indexes of the lake itself. When do the research of assessing the lake water pollution condition and building the water environment models, abiotic environment such as water chemical and water morphology are not only been considered, but also the biology characteristic of water pollution should be considered. Combine these factors and do research in basis of mastering the pollution mechanism of lakes, and this is the effective approach to judge the pollution conditions of lake's water overly.

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