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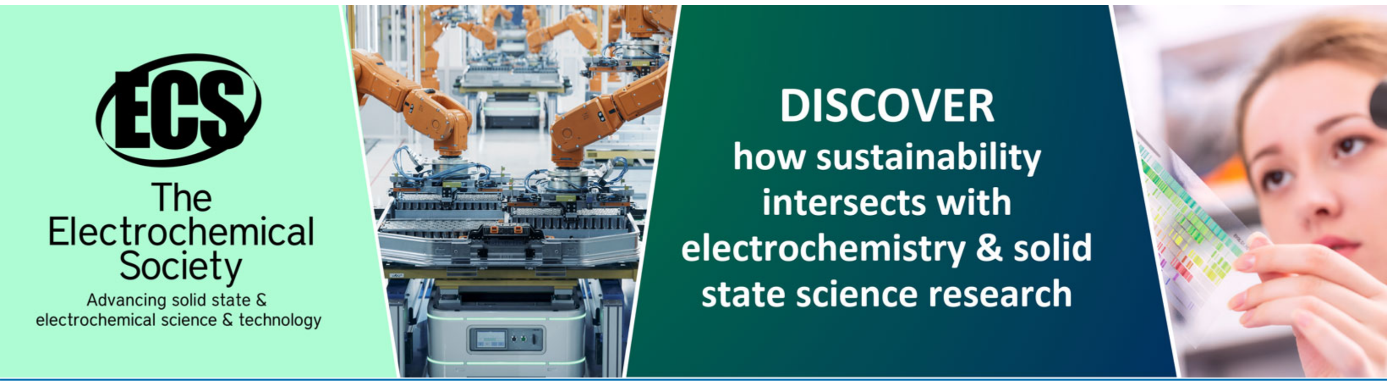

Influencing factors analysis for algal blooms in cold region reservoir

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Abstract. This paper investigated the temporal variations of the phytoplankton biomass along 10 years in the Nierji reservoir located in the northeast of China. The factor analysis was applied to identify significant influencing factors of algal growth. The results demonstrated that total nitrogen (TN) was strongly correlated to phytoplankton in the middle of the reservoir and total phosphorus (TP) showed the same pattern in the outflow of the reservoir. In contrast, water transparency was weakly affected by the production of phytoplankton. Besides, there were annual variations observed for the ratios of TN to TP, while 54.02% of the collected data indicated that TP was limiting the phytoplankton. Keywords: reservoir eutrophication; algal blooms; factor analysis; nutrients

1. Introduction

Phytoplankton biomass is an exemplary phenomenon resulting from excessive growth in nutrients [1]. Meanwhile, the variation of the components of phytoplankton species and biomass in aquatic ecosystems reflect the diverse environments and variations of trophic status [2]. Therefore, ecological variations resulting from the stressors that damage the aquatic ecosystem (e.g. the increase of nutrients) might be evaluated by the behaviors in the phytoplankton composition.

The influence of nutrients on phytoplankton biomass is effected by multi-able environmental factors, such as land utilized, floods, and volume of streams [3]. Besides, it was selected TN: TP ratios as an essential factor for improving Chl-a prediction from TP in classifying lakes through the regression tree frameworks [4]. Also, it was illustrated that the Spatio-temporal variations of water quality and productivity in Lake Nasser's water in Egypt were mainly influenced by the application of fertilizers and environmental conditions, while the contents of Chl-a in the fish pond were higher than those in lake water [5]. Moreover, it was shown that N and P cycles might be coupled in water bodies and stream runoff, but the natural biogeochemical cycles could be altered by human activities around the water body [6]. Therefore, the mechanisms of the influence of environmental factors trigger the algae’s bloom are uncertain at present. However, in the case of the high accuracy of algae predictive, the water environmental management should take countermeasures to decrease algae risk. Thus, the identification, management, and restoration of aquatic resources damaged by eutrophication and maintain valid resources are considered an important first step by defining the nutrient level at ecosystems [7]. This paper studied the temporal variations of the water quality parameters and the productions of phytoplankton biomass from 2006 to 2015 in the Nierji reservoir located in the cold region in northeast China. The relationships between phytoplankton biomass and water quality indicators were determined in the two monitoring sites during seasons.

2. Material and Methods

2.1. Study sites

The Nierji reservoir is a large-scale reservoir in the last gorge of the Nenjiang mainstream river in northeast China, in where air temperatures are from 23.8 ℃ in July to - 25.4 ℃ in January. The total length of the Nierji dam is 7265.553m. The reservoir area of the dam is about 498.33 km^2. The river flood season is from June to September and the else months are the non-flood season, while the maximum average of precipitation and runoff are in July.

2.2. Data analysis method

The environmental indicators used in the analysis mainly include the chlorophyll-a (Chl-a); total nitrogen (TN), total phosphorus (TP), Secchi depth (SD), permanganate index (PMI) in the two water quality-monitoring sites: Site A is located in the outflow of the reservoir; Site B is located in the middle of the reservoir.

In order to find the relatively important influencing factors on phytoplankton biomass, the factor analysis method was used in this study for reducing dimensions of multivariate factors. This method was applied in the case with many variations that correlated with each other. Therefore, we combined these variations into a smaller number of potential factors. The Kaiser-Meyer-Olkin (KMO) and Bartlett's test were adopted to prove whether the database is suitable for the factor analysis method (KMO>0.5, significant<0.05). The maximum likelihood (ML) factor analysis was considered to determine the number of factors in different spatial scales by its goodness-of-fit test (significant <0.05). The eigenvalue of every factor was measured by its contribution ratio in the original matrix variance. The varimax rotation was performed on the original loading matrix to simplify the correlation data of the component [8,9].

3. Results and discussion

3.1. Temporal variation of Chl-a and TN/TP

As illustrated in Fig.1(a), The highest values of Chl-a specified in the latest five years with the average values of 7.133 ug/l and 9.313 ug/l in the site A and site B, respectively. The ten-year span showed the lower average Chl-a concentrations of 7.05 ug/l and 7.96 ug/l in the site A and site B, respectively, because of the lower average values of Chl-a that observed in the first five years. The Chl-a content started to increase steadily year by year in the two sites after installing the wastewater outlet on upstream of the reservoir. The average air temperature in the non-flood season is lower than that those in the flood season, which was inadequate for the growth of phytoplankton. Thus, the general concentrations of Chl-a in the non-flood season were relatively low, while the increase of water temperature and rainfall in the flood season would promote the activity of phytoplankton, accelerate the migration and transformation of nutrients, and provide an impetus for the growth of phytoplankton [10].

As illustrated in Fig.1 (b), the average values of TN/TP (in concentrations) along the ten years were 8.89:1 and 10.81:1 in site A and site B, respectively. Therefore, TP is limiting the growth of phytoplankton based on the empirical previous studies that illustrated TP limits the growth of phytoplankton when TN/TP (in concentrations) is higher than 7.2:1, otherwise, TN would limit the growth of phytoplankton [11]. However, there were 44.81% and 45.34% of the collected data recorded that TN is the limiting factor of phytoplankton in site A and site B, respectively. Moreover, most of them were detected before 2011, indicating that the first five years observed that TN was limiting the algal growth, and after 2011, the growth of algae was limited by TP. While the highest TN/TP value of 37.5 in site A was in 2012 and the highest TN/TP value of 50.66 in site B was in 2014. On the other hand, the lowest TN/TP values of 2.671 and 2.205 in site A and site B, respectively were in 2010.

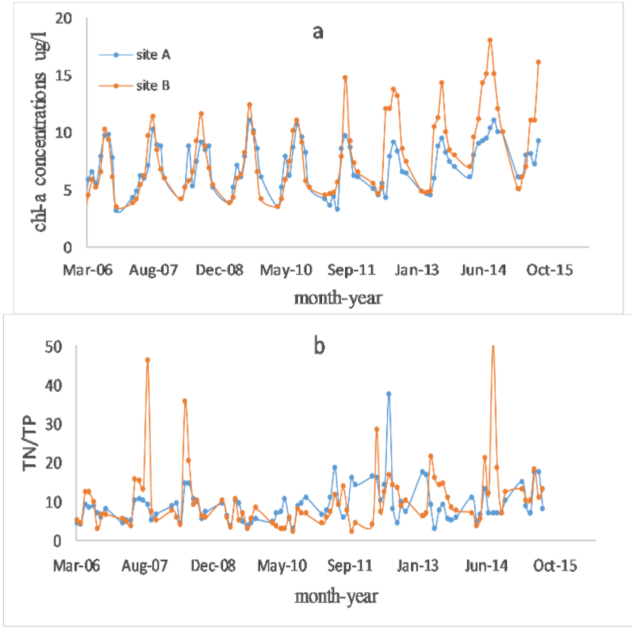

Figure.1. temporal variations of Chl-a and TN/TP.

3.2. Factor analysis of water quality parameters

Rotated factor matrix, KMO, and Bartlett's test indicated that the factor analysis method is valid for the database as illustrated in Table 1. Two components factors were selected to affect phytoplankton biomass in site B during the flood season, which covered 47.02% of the original matrix variance. For other spatial and seasonal scales, three components factors were determined to affect phytoplankton biomass. In site A, the top three factors covered 53.14% and 49.95%, of the original matrix variance during the flood season and the non-flood season, respectively. While the top three factors in site B covered 40.65% of the original matrix variance during the non-flood season.

3.3. Dominant influencing factors of phytoplankton

According to the loading of variations in each component, the influence of different water quality indicators on phytoplankton biomass might be determined, while the first component was significantly correlated to Chl-a in different spatial and seasonal scales. TN was the dominant factor that significantly affects the phytoplankton biomass in the different spatial and seasonal scales except for site A during the flood season. TP was only the dominant factor in site A during the various seasons, and it was not shown as a dominant factor in site B. SD was not the main factor in all spatial and seasonal scales.

As explained above, our results demonstrated that the response of Chl-a to TN, TP, and SD varied in the spatial and seasonal scales. Whereas the variations of the influence of nutrients on the production of phytoplankton biomass refer to significant seasonal variation and the diversity of the human activities around the reservoir along ten years. While pollution from non-point sources included agricultural fertilization, excreta of livestock and wild animals, mineral, urban development, and engineering construction would fluctuate the growth of phosphorus, and nitrogen load over the years, especially those that are caused by the erosion of farmland are quite high, which has a considerable impact on the eutrophication. Meanwhile, the absorption rate of chemical fertilizer in the reservoir area is generally less than 40%, and the residue of them remains in the soil thus lead to release nitrogen and phosphorus to the surface water in the reservoir. The point source of phosphorus and nitrogen often discharge from the domestic sewage and the industrial wastewater, while the domestic sewage, such as washing, bathing, and waste flushing, contains a lot of phosphorus and nitrogen[5,12]. In contrast, SD demonstrated an inverse trend of nutrients, while its impact on phytoplankton was weak. Agriculture activities with the accumulation of abiogenic and biogenic turbidity over many years by increasing and resuspension of sediment and nutrients' loadings can modify the light of the underwater climate[13].

Moreover, light penetration could be reduced by the dominance of surface bloom-forming Cyanobacteria in the reservoir. Thus, the excessive growth of phytoplankton did not affect the decline of SD. PMI was positively correlated with the phytoplankton in site B during the non-flood season. While the oxidation of organics can decrease dissolved oxygen concentration and release CO_2 in the reservoir water, which would provide more nutrients and appropriate carbon sources for the growth of phytoplankton[5]. While there is a positive correlation between TP and PMI in site B during the flood season as shown in Table 1. Suggesting that the local government should pay more attention to reduce nutrient load and organic matters that discharged from the point and the non-point pollutant sources.

Table 1. The KMO and Bartlett's test and Rotated factor matrix of water quality parameters in the various spatial and seasonal scales.

X^2=Bartlett's test; significant of values<0.05 iteration=25.

Sites	Season	KMO	X^2	Factors	Variance %	Chl-a	TN	TP	SD	PMI
Site A	Flood season	0.62	39.93	FAC1	39.01	0.48	0.19	0.85	-0.07	0.31
				FAC2	10.15	0.65	0.21	0.09	-0.67	0.13
				FAC3	3.98	0.41	0.61	0.14	-0.16	0.19
	Non-flood season	0.59	40.22	FAC1	31.91	0.76	0.67	0.73	-0.09	-0.03
				FAC2	15.31	-0.14	-0.14	0.46	0.68	0.04
				FAC3	2.73	-0.27	-0.02	0.10	0.08	0.33
Site B	Flood season	0.55	48.02	FAC1	32.90	0.94	0.80	-0.18	-0.24	0.16
				FAC2	14.11	0.05	-0.26	0.56	-0.16	0.56
	Non-flood season	0.61	27.15	FAC1	29.76	0.60	0.86	0.14	-0.37	0.03
				FAC2	5.98	0.30	0.06	0.54	-0.17	-0.05
				FAC3	4.88	0.42	0.04	-0.06	-0.03	0.42

4. Conclusion

The factor analysis method was used to determine the influence of the environmental factors on phytoplankton and reducing dimensions of multivariate factors. The main results showed that the phytoplankton was higher in the flood season compared with the non-flood season. The potential reasons for the differences in seasonal phytoplankton patterns in the various spatial scales were the fluctuation of the non-point pollution sources of the application of fertilizers and point pollution sources of the domestic sewage, environmental conditions, and large seasonal variations.

The reduction of TN should be prioritized in the middle of the reservoir, while TP should be decreased in the outflow of the reservoir. The water transparency was not affected by the phytoplankton. Indicating that the accumulation of abiogenic and biogenic turbidity by increasing and resuspension of sediment and nutrients' loadings was modifying the transparency.

5. Acknowledgments

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