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Analysis of the Causes of Cyanobacteria Bloom: A Review

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Abstract: Among water blooms, cyanobacteria bloom occurs over the widest range and is much more harmful than other blooms. Its occurrence in inland water bodies is affected by many factors, such as meteorology, hydrology, and human activities. Therefore, the study of the causes of cyanobacterial bloom has become a major focus of scholars. The China Knowledge Network Journal Database contains 143 papers from China and abroad from the years 2004 to 2019 that are relevant to the study of cyanobacteria bloom. We begin by analyzing keywords in these studies and creating a keyword distribution map which indicates the factors related to the blooms. Based on parameters such as the frequency of words appearing in the text, the full text of each of the 143 papers is analyzed to form a word cloud created by a program written in Python language. After irrelevant terms are eliminated, the word cloud map can reveal potential factors that were not identified by keywords alone. After completing this macro analysis, we examined approximately 100 related papers from the China Knowledge Network Journal Database and Web of Science Database published from 2014 to 2019. Finally, we summarize the main reasons for the outbreak of water blooms. The factors causing blooms can be divided into natural factors and human factors. Among the natural factors are illumination, water temperature and nutrient salt conditions. The human factors are generally related to large-scale water conservancy projects. This paper analyzes and summarizes these factors, and provides a reference to aid in the prevention and treatment of algal blooms. The information in the paper has a certain practical significance for the protection of water environments.

Key words: algae bloom; eutrophication; literature measurement; temperature

1 Introduction

Water bloom refers to a disastrous ecological phenomenon consisting of algae or zooplankton in freshwater, or explosive growth and high concentrations of bacteria, causing discoloration of water bodies (Wang, 2015; Zhou, 2016). Among the various kinds of blooms, cyanobacteria bloom has the widest range, causes the most harm, and represents the greatest danger to human health.

With the eutrophication of water bodies becoming an increasingly serious problem in recent years, more and more water bodies have bloomed. Statistical standards for bloom indicate that water bloom occurs when the water color changes significantly or algae density is greater than 10^7 Pcs L^{-1} (Xiong et al., 2015). The statistics for pollutant levels in China's major rivers in April 2019 are shown in Fig. 1 (EB/OL 2019). The second survey of the status of lakes in China shows that 138 sections of the eastern plain lake area, the northeast plain and mountain lake area, and the Yungui Plateau lake area are larger than 10 km^2, and that 85.4% of the lakes exceed the eutrophication standard. The eutrophication degree of lakes is shown in Table 1; 40.1% of the lakes meet the criteria for severe eutrophication. These data show that cyanobacteria blooms in lakes in China are a grave problem, one that urgently needs a solution.

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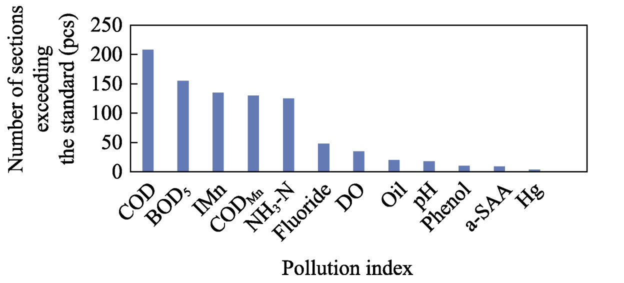

Fig. 1 The pollution index statistics of major rivers in China in April 2019

Table 1 Classification of the eutrophication degree of lakes in China

Degree	Total phosphorus (mg m^{-3})	Total nitrogen (mg m^{-3})	Chlorophyll α (mg m^{-3})
Oligotrophic	<15	<400	<3
Middle nutrition	15–25	400–600	3–7
Eutrophication	25–100	600–1500	7–40
Overnutrition	>100	>1500	>40

2 Bibliometrics and visualization analysis

In order to summarize the causes of outbreaks of cyanobacteria bloom, to begin this paper uses the bibliometrics method and a Python word cloud to analyze the keywords and full text of research papers.

2.1 Key words analysis

This section is based on data from the China Journal Full-text Data-base (CNKI) data for the years 2004 to 2019. Search conditions are theme = 'water bloom' and 'cause'; theme = 'cyanobacteria bloom' and 'mechanism'; theme= 'cyanobacteria bloom' and 'reason'; Excluding non-academic articles and duplicate articles such as conference or newspaper summaries, 143 literature samples were selected.

Key words present a high-level summary of the topic of a thesis. Using CNKI's bibliometric analysis function, the key words of the selected literature items were distributed according to word frequency, and terms like "cyanobacteria bloom", "water bloom outbreak" and "analysis" were removed because these are not directly related to the causes of blooms. A keyword distribution map (Fig. 2) was drawn to identify the factors influencing blooms.

We see in Fig. 2 that keywords such as eutrophication, temperature, nutrients and algae cells appear frequently, and suggesting that these are related to the occurrence of water bloom.

2.2 Full text analysis

In this section a Python word cloud method is created and the full text of the 143 articles is analyzed, in an effort to reveal underlying factors that the keywords have not identified.

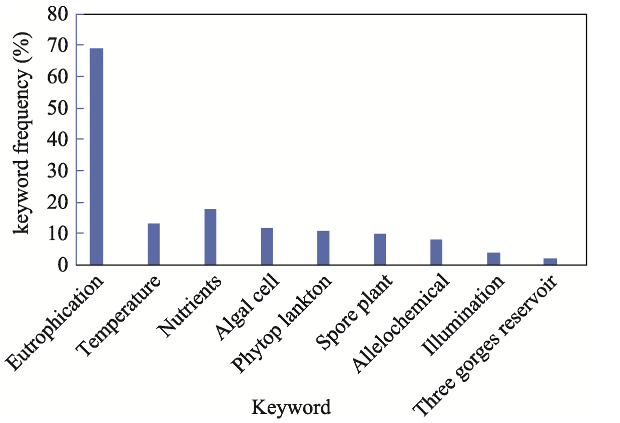

Fig. 2 Key words distribution map of factors influencing water bloom

The word cloud uses words as the basic unit to display text more intuitively and artistically. The authors of this article used the word cloud module in the Python programming language to generate word clouds for text. Python can draw word clouds based on parameters such as the frequency of occurrence of words in text, and the shape, size and color of the word cloud can be set. Irrelevant terms such as "Taihu Lake", "concentration", "aquatic", "cyanobacteria" can be removed. The resulting word cloud is as follows (Fig. 3):

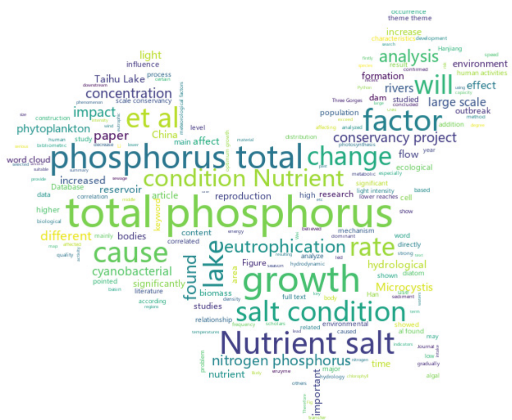

Fig. 3 Word cloud map of factors influencing water bloom

We can see in Fig. 3 that the terms "total phosphorus" and "salt condition" appear very frequently. This information combined with the analysis of previous keywords allows us to conclude that factors such as total phosphorus are associated with the occurrence of water bloom.

3 Analysis of the causes of water blooms

After completing the macroscopic analysis, we use data from the China Journal Full-text Database (CNKI) and SCIE in the Web of Science database for the years 2014 to 2019 as the source. The search conditions we apply to this data are theme = 'water bloom' and 'cause'; theme = 'cyanobacteria bloom' and 'mechanism'; theme = 'cyanobacteria bloom' and 'reason'; After excluding non-academic articles and duplicate articles such as conference or newspaper summaries, we selected the top 40 papers based on their relevance rankings. After tracing the literature citations, nearly 100 articles were read and analyzed.

Xu and Zhang (2019) found that outbreaks of water bloom were the result of the combined effects of water-related environmental factors (such as total nitrogen, total phosphorus, pH, dissolved oxygen, etc.) and meteorological factors. Su et al. (2012) found that algal blooms were the result of a combination of environmental factors. It is generally believed that the mechanisms behind cyanobacteria bloom are affected by three key factors: 1) suitable light and water temperature; 2) excessive intake of certain nutrients (such as nitrogen or phosphorus concentrations in water); 3) conditions of slow water flow (Li et al., 2016; Hang et al., 2019; Yang et al., 2019).

3.1 The influence of light on water bloom

Light radiation provides metabolic energy for algal photosynthesis, affects the rate of photosynthetic carbon fixation, and also affects algae cell respiration intensity and energy levels. In addition, light induces the formation of certain products such as carotene in cells (Gao et al., 2006). The paper by Domingues (Rita et al., 2015; Rita et al., 2017) and other studies have confirmed that the growth of phytoplankton and cyanobacteria in water is greatly affected by light intensity. They also note that eutrophication in lagoons is not a serious problem, but if the light intensity is appropriate, it may lead to algae growth. Lu et al. (2017) studied the correlation between cyanobacteria blooms and meteorological factors, and found that the frequency of cyanobacterial blooms in Dian Chi Lake was significantly correlated with the cumulative number of sunshine hours and rainfall factors. Lewis et al. (2000) found that the growth of algae in the Orinoco River needs to receive sufficient light intensity, and the depth and transparency of the river affect the growth of algae by affecting the distribution of light in the water.

Illumination is one of the important indicators for phytoplankton photosynthesis and for evaluations of water environment quality (Jiang et al., 2019a). Phytoplankton, in which algae plants use photosynthesis to absorb and transmit light energy through chlorophyll, plays an important role in energy conversion and materials circulation in lake ecosystems (Qin et al., 2011). The light intensity has a direct relationship with the formation of water blooms. Cui et al. (2016) and other studies have shown that the effect of light is mainly reflected by changes of the photosynthetic rate of algae with light intensity. Different types of algae have different levels of photosensitivity to light intensity.

3.2 The influence of water temperature on water bloom

Water temperature is a necessary condition for photosynthesis of algae. It determines the rate of enzyme reaction in cells, and temperature is an important condition for the work of biological enzymes. If the temperature is too low, the fluidity of cell membrane is poor, and this makes the algae cells slow down the intake of nutrients. At the same time, the activity of the enzymes is low under low temperature conditions, the electron transfer rate is slowed down, and the metabolic rate of algae is low. Appropriate water temperature conditions are a necessary condition for cyanobacterial bloom. The growth rate of cyanobacteria increased with the increase of water temperature. When the temperature reached 20 ℃ or more and the water temperature was 25–35 ℃, the probiotic single-cell algae speed became slower than that of cyanobacteria (Zhang, 2019). Cyanobacteria are not likely to grow explosively on a large scale under normal temperature conditions. Only when the hot season is underway, does the growth rate advantage of cyanobacteria become apparent. Temperature is one of the main factors in the outbreak of cyanobacteria. Temperature changes lead directly to changes in water temperature, and these changes affect various physical and chemical properties, reaction rates and biological activities of river waters. Suitable water temperature affects the metabolism and reproduction of algae, thereby accelerating the process of eutrophication and increasing the risk of blooms (David et al., 1996). The effects of short- and long-term climate change on phytoplankton dynamics in aquatic ecosystems have received widespread attention in the past few decades. Temperature changes have a significant impact on the growth and distribution of aquatic organisms. Within a certain temperature range, the metabolic rate of algae accelerates and the growth and reproduction rate increase (Zhang, 2017).

Many studies have confirmed that the meteorological factors likely to have an important impact on cyanobacterial growth and bloom formation include temperature (Anna et al., 2014; Li et al., 2016a). Jeremy et al. (2018) found that the biomass of cyanobacteria increased with temperature. When the water temperature was higher than 18 ℃, the biomass of cyanobacteria decreased rapidly with the increase of temperature, and the algal toxin increased gradually at high temperatures. Xia (2014) argued that different species of planktonic algae were affected by environmental factors, such as water temperature, and that chlorophyll a is only related to abundance when the dominant algae species are stable and single. Based on frequent, long-term field observations of large areas of Taihu Lake, Li et al. (2016b) found that moderate temperatures were beneficial to the formation of cyanobacteria blooms.

Petra et al. (2016) pointed out that the growth rate of cyanobacteria increased significantly when the temperature exceeded 25 ℃, and that its optimum growth temperature is 27 ℃ to 37 ℃. Jung et al. (2009) studied the environmental factors affecting diatom blooms in the lower Han River of South Korea. It was found that the growth of diatoms in eutrophic rivers is mainly limited by water temperature and silicate content. Zhu et al. (2019) analyzed the environmental factors, the annual average of RDA, and water blooms of Taihu Lake in 2011–2017, concluded that the high temperature in 2017 increased the density of microcystis in Taihu Lake. The rich material foundation has created suitable conditions for large-scale blooms. With respect to the influence of temperature on blooms in Chaohu Lake, Jiang et al. (2019b) showed that algae concentrations varied in different temperature regions, which was caused by changes in the growth rate of cyanobacteria at different temperatures. When the temperature was below 29 ℃, the growth rate of cyanobacteria increased as the temperature increased. Therefore, when the temperature is higher than 20 ℃, the initial algae concentration increases significantly faster than the temperature below 20 ℃. When the water temperature exceeds 29 ℃, the higher the temperature, the faster the algae concentration decreases. This may be because at temperatures above the optimum temperature for algae growth, the growth rate decreases while the metabolic death rate increases, and this causes the algae concentration to decrease.

Li et al. (2014) and others have noted that Taihu Lake is located in a subtropical zone. The lake does not freeze over completely in winter, and this helps the cyanobacteria to survive in winter. As temperatures rise in spring, cyanobacteria biomass increases steadily, becoming the dominant species in the water body, and this causes blooms. Paerl et al. showed that the optimum temperature for growth is 27–37 ℃, while for most other phytoplankton the optimal temperature for growth is between 20–25 ℃; for example, the optimum growth temperature of diatom is 17–22 ℃. Hans et al. (2014), Hang et al. (2019) and other studies have shown that temperature has an important effect on the resilience of growth and bloom formation, and large-scale outbreaks of cyanobacteria in Tai-hu Lake. Findings indicate that high temperatures inhibit cyanobacterial blooms to a certain extent. Dong and Li (2016) found that the water temperature on the surface of the Xiao River gradually increased during the seasonal change from spring to summer. The average surface temperature of the Gao-yang and Shuang river sections was 21–23 ℃, and this led to the accelerated growth of microcystis that gradually accumulated on the surface layer. Simon et al. (2008) studied the water bloom in the Hunter River in Australia. When the water temperature exceeded 23 ℃ and the flow rate was lower than 400 $m^3 d^{-1}$, the dominant algae in the water bloom event, which lasted for more than 12 days, were Cyclotella meneghiniana and Nitzschiasp. The redundancy analysis showed that water temperature was positively correlated with the biomass of the two algae and negatively correlated with the flow.

3.3 The influence of nutrient content on water blooms

The nutrient contents of water are the material basis for the growth and reproduction of cyanobacteria. Nutrients determine the speed of cyanobacterial reproduction and have a crucial impact on the occurrence of blooms. According to the pre-mainstream view, the key factors leading to eutrophication of river water include the nutrient salt load and hydrological conditions (Allison, 2014). Nitrogen and phosphorus are essential nutrients for the growth of cyanobacteria. Han et al. (2016) have shown that the release of nutrients such as nitrogen and phosphorus accumulated in sediments provides an important source of nutrients for algae growth in water, and is an important predisposing factor for the continued eutrophication of water bodies. At the same time, the ratio of nitrogen to phosphorus in water has a significant effect on the reproduction of cyanobacteria. It is generally believed that when TN:TP<29, cyanobacteria will dominate in the algae population (Smith, 1983). The exact relationship of nutrients to cyanobacterial reproduction and water bloom formation varies from lake to lake (Zhang and Cheng, 2011; Wu et al., 2013). Algae cells acquire and store nutrients at the bottom of the habitat or in the free state for their own growth in water bodies (Grover et al., 2017). When the growth environment conditions are satisfied to a certain extent, whether nutrients such as nitrogen and phosphorus are abundant becomes the main controlling factor for population growth and reproduction and quantity. The random movement of the population is the same as the diffusion rate of nutrient salt, and causes changes to nutrients such as nitrogen and phosphorus in different areas of the body of water, and this, in turn, causes corresponding changes in the growth and reproduction of the planktonic algae that feeds on these nutrients.

Bowes et al. (2012) analyzed water blooms along the Danube River in Hungary and the Kennet River in Australia. The study found that the relationship between nitrogen and phosphorus nutrients in the water and the chlorophyll α concentrations of algae were not unique, and showed different correlation characteristics under different hydrological conditions. Li et al. (2016) found that the higher content of PO_4^{3-}-P in water is beneficial to microcystis as the dominant algae, and to the bacteria associated with cyanobacterial outbreaks. Wei (2015) and other studies of Gao-yang Ping Lake on the Tun-xi River pointed out that nutrient flux is significantly and positively correlated with water flow. The higher the water level, the greater the amount of backwater and the more phosphorus from outside is introduced, the more likely a bloom is to erupt. In their study of Hongze Lake, Liu and Cao (2014) found that when a body of water body is in a closed state that is not conducive to the evacuation of nutrients, eutrophication is more likely to occur.

Zhu et al. (2019) studied the effects of typhoon processes and found that the release of nutrients from the sediments of Taihu Lake during the time a typhoon goes across the lake may cause an increase of bloom areas. Yang et al. (2016) believed that extreme strong winds and rainy weather caused sediment re-suspension and a large amount of nutrients in the surrounding basin to flow into the waters of Tai-hu Lake, causing the growth of microcystis biomass that led to an increase in water bloom area. Lee et al. (2014) studied the effects of the hydraulic characteristics of artificial seawater canals in Songdo City, South Korea, had on the growth trend of algae in rivers. The study found that the density of algae in rivers is usually closely related to hydrological conditions and nutrient intake. Xin et al. (2019) compared the recent case of severe diatom blooms in the lower reaches of the Han River in the early spring of 2018 with historical data, and found that the root cause of severe diatom blooms was higher nitrogen and phosphorus nutrients and lower flow conditions. Dai et al. (2017) found that the formation of water blooms was closely related to the concentration of nutrients in water, especially the levels of nitrogen and phosphorus. Ma et al. (2015) confirmed that increasing the amount of nitrogen in Taihu Lake could promote the growth of all phytoplankton, keep the size of microcystis unchanged, and increase the microcystis population in all phytoplankton biomass. Adding phosphorus will cause microcystis to form a smaller population.

At present, much of the research concerned with the mechanisms that form water blooms are focused on the relationship between nutrients such as nitrogen and phosphorus and algae growth. Xu et al. (2014) showed that the size and composition of the cyanobacteria in Taihu Lake gradually increased as nutrient concentrations of $TN \leqslant 10$ mg L^{-1} and $TP \leqslant 0.5$ mg L^{-1} also increased. Leibig's law of the minimum identifies phosphorus as the main factor controlling the growth of algae in most lakes (Kong and Song, 2011). Numerous studies have shown that N and P are essential nutrients for the growth of microcystis, and the amount of these two nutrients has an important influence on the growth of microcystis. Occurrences of water bloom are definitely related to nitrogen and phosphorus nutrients. In addition to total nitrogen and total phosphorus concentrations, the ratio of nitrogen to phosphorus in water is also related to the occurrence of water blooms.

3.4 The influence of hydraulic engineering on water bloom

The development of water conservancy projects can change hydrological situation, and such changes have caused an increase of water blooms on rivers. Changes in hydrological situation caused by development of water conservancy projects is an important application basis for the cross-sectional study of water conservancy and environment (Zhang et al., 2017). China has undergone a period of water conservancy development in recent decades. During this period, Xiaolangdi, Gezhouba and other major water conservancy projects have been completed and put into operation, bringing great benefits and convenience to the country's social economy and people's lives. However, these large-scale water conservancy projects are having an increasingly significant impact on the large-scale hydrological cycle in China's river basins and regions. The interactions between large- scale river blooms and hydrology, water environments and water ecology are raising new scientific issues that urgently needed study and exploration (Fang et al., 2013; Rui et al., 2016).

Given the way water conservancy projects have been developed, river-type reservoirs form unique geographical environments and hydrological conditions, and have unique hydrodynamic change characteristics: Due to the influence of the upstream inflow and the periodic change of the water level before the dam, the river pattern shows periodic changes dominated by lake shape or river flow pattern at different periods (Dai et al., 2015). The impact is reflected by two factors related to water quality and hydrological pattern: 1) interference from human activities, including industrial and agricultural wastewater discharge; and 2) the implementation and construction of water conservancy projects may change the original downstream form or path of the river. In some cases, a large "dead water zone" has been created in the river, with water features similar to those of lakes or reservoirs. Such zones weaken a river's self-purification capacity (Wang et al., 2009). After examining the research into the causes of river blooms connected with water conservancy projects during the past five years, it was determined that experts and scholars from China and abroad have carried out studies on large-scale watershed ecological problems. Some scholars have pointed out that large-scale water conservancy projects, and especially the construction of dams, have a very significant impact on the structure of river plankton (Li et al., 2016).

Xia et al. (2019) found in a study of the lower reaches of the Han River that upstream water conservancy project construction and a dam led to changes of the hydrological runoff process in the downstream river channel. Xiao et al. (2009) discovered the South-to-North Water Transfer Project led to water quality in the middle and lower reaches of the Han River deteriorating significantly. This water transfer project inevitably contributes to blooms. Zeng et al. (2006) explored the impact of the Three Gorges Dam on aquatic ecosystems, and analyzed the composition and abundance of phytoplankton and the time distribution of water bloom algae in the Three Gorges Reservoir. The results showed that there is a significant negative correlation between the content of phytoplankton and the content of Si, N and P in the Xiangxi River during the rainy season. Lee et al. (2014) used a FLOW-3D hydrodynamic model to identify the influence the hydraulic characteristics of artificial seawater canals in Songdo City, Korea, have on algae growth in rivers. The results show that the location of blooms is affected by stagnant water areas and the effect of the vertical flow rate. Chen et al. (2016) studied the impact of hydropower development projects on ecological environment effects, and explained the mechanisms of hydrodynamics in aquatic ecosystems and technologies for water conservancy regulation of water ecological health of human activities. Liu et al. (2016) found that after the impoundment of the Three Gorges Reservoir, stratified heterogeneous flows, influenced by the temperature differences of dry tributaries and differences in water density, occurred in the tributaries of the Daning River and the Xiangxi River. The hydrodynamic conditions of tributaries of the reservoir bay led to the outbreak of seasonal water blooms. In a study of the Han River basin, Li (2013) concluded that, with the opening of the Han River mainstream dam, the overall index of the Han River Eco-environmental Impact Assessment declined. Jeong et al. (2007) found that dam discharge and precipitation in the upper reaches of the Nakdong River in South Korea were significantly correlated with the retention time of Korean Phytophthora and microcystis aeruginosa in water (Kim et al., 2009). This existence of this phenomenon was confirmed by subsequent studies.

In summary, river-type blooms are a complex multi-factor impact problem, which are often accompanied by the dual effects of strong human activities and climate change (Li et al., 2014).

4 Results

By synthesizing the contents of nearly 100 papers and the information presented Fig. 2 and Fig. 3, this paper roughly divides the causes of cyanobacteria bloom outbreaks into natural factors and human factors. The principal natural factors include light, water temperature and nutrient salt conditions, while human factors are related mainly to the impact of large-scale water conservancy projects. Fig. 4 shows a schematic diagram of the factors causing water bloom outbreaks. Water conservancy projects lead to different degrees of hydrological changes downstream, thus changing the runoff process of river sections in ways that directly affect the downstream water body coefficient, self-purification capacity and sediment adsorption capacity. Illumination (light) and temperature changes directly control changes in water temperature and ecological conditions, affecting the chemical and biological properties of water bodies. The resulting changes in the water environment index affects the distribution and growth of algae in the river. In addition, humans add nutrients to water bodies, increasing the risk of degrading of the ecological environment of river water. It is hoped that the analysis presented here provides a reference for research into the problem of eutrophic algal blooms in lakes and reservoirs.

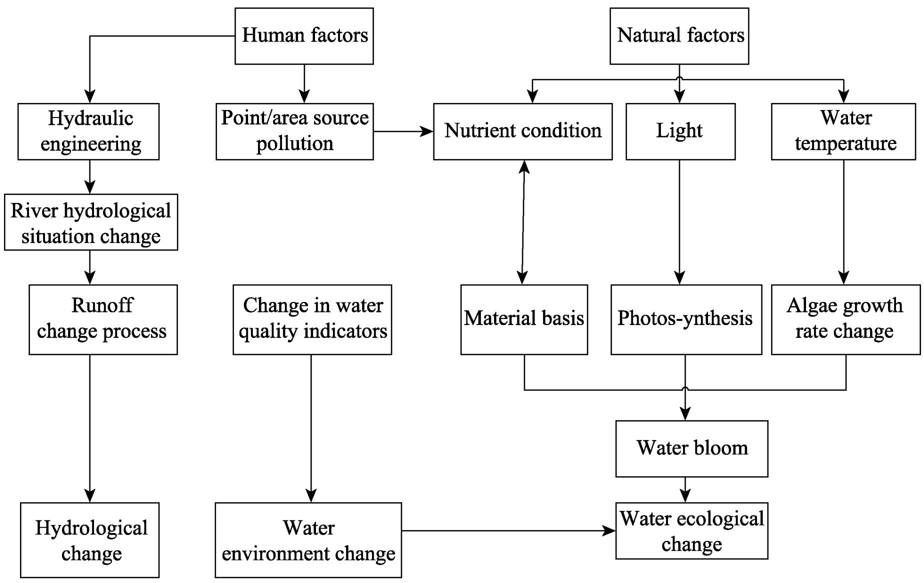

Fig. 4 Schematic diagram of factors affecting the blooms

In view of the above analysis of the causes affecting blooms, such as light, temperature, nutrients, water conservancy projects, etc., several monitoring measures are proposed to help prevent blooms and control the aftermath of blooms.

(1) Nutrient control. Because nutrients enter into lakes and coastal waters through various point and non-point sources, the problem can be solved by reducing the number of external nutrient inputs. This requires control measures for the entire basin.

(2) Water bloom is controlled by hydrodynamics. An occurrence of cyanobacteria bloom needs a certain period of time to develop. Lakes and reservoirs that are static over a long period of time easily develop conditions that lead to the

occurrence of water blooms. Therefore, increasing water flow can shorten retention time, providing a promising mitigation method for stagnant rivers and reservoirs.

(3) Biological control. Increasing the natural enemies of algae that produce water bloom, or reducing the number of fish that eat phytoplankton can change the structure of the food web, control the growth of phytoplankton, and help make lake water cleaner.

(4) From a global human perspective, the most logical step is to curb carbon dioxide and other greenhouse gas emissions to reduce the climate conditions that cause cyanobacteria bloom. This requires the efforts of the entire country and its people.

5 Conclusions

This paper analyzes recent literature from China and abroad about cyanobacteria blooms, explores the laws governing cyanobacterial blooms, and analyzes the factors driving blooms. The results can provide support and guidance for lake protection and governance agencies. The authors believe that hydrological, meteorological and climatic conditions are the main factors driving the occurrence of blooms. Nutrient enrichment is the basis for the growth and reproduction of cyanobacteria and it is the environmental element that must be considered firstly in warning of the risks of water bloom. In addition, human factors produced by water conservancy projects also have an impact on the formation of water bloom. The factors affecting water bloom summarized in this paper are common factors, but the crossover and combination of their actions are not the same in different lakes and reservoirs. Therefore, the causes and mechanisms of eutrophic cyanobacterial bloom in specific water bodies may differ. When discussing the water blooms of specific water bodies, it is necessary to analyze them in detail taking local conditions into consideration.

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基于文献分析的蓝藻水华爆发成因综述

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摘 要：在各种水华当中，蓝藻水华发生的范围最广、危害也更大。内陆水体中，蓝藻水华爆发是导致水体富营养化的一大主因，然而其易受气象、水文、人类活动等多种因素的影响，因此研究蓝藻水华爆发的原因成为学者研究的一大重点。该文基于国内外研究现状，首先对 2004–2019 年间中国知网期刊数据库中 143 篇相关论文，从文章的关键词进行主题分析，初步获取影响水华爆发因素的关键词分布图，然后利用 Python 语言编写程序，利用 Word Cloud 库对这 143 篇论文全文作词云处理，根据文本中词语出现的频率等参数绘制词云，并剔除无关词项，生成词云图，试图揭示关键词尚未覆盖到的潜在因素。宏观上分析之后，本文又调研了 2014–2019 年间，中国知网期刊数据库和 Web of Science 数据库中相关论文，并对检索获取的文献引文进行追溯来补充，分析了领域内的百余篇文章，最终归纳出蓝藻水华爆发的主要原因。研究结果表明水华爆发的因素分为自然因素和人为因素，其中自然因素主要包括光照、水温和营养盐条件，人为因素主要是大型水利工程。该文对这些因素进行了分析总结，并提出相应的综合治理对策，为藻类水华的预防和治理提供了参考，这对水环境的保护有一定的现实意义。

关键词：藻类水华；富营养化；文献计量分析；温度