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Methods to address the problem of algal bloom in Lake Taihu

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Abstract:

Algal blooms in eutrophication are a severe problem all over the world and would lead to plenty of negative impacts, such as affecting the quality of water badly. In China, many water bodies, including Lake Taihu, are severely affected by this problem. Therefore, this article will focus on Lake Taihu, and aim to analyze different methods to address the algal bloom. The purpose of the article is to find out the most effective and suitable way to solve the problem of algal bloom in Lake Taihu.

Keywords: Algal bloom, utrasonic treatment, bioremediation.

1. Introduction

1.1 Eutrophication

China has about one-third of its water mainly distributed in the Yangtze River. Eutrophication is one of the major pollution problems in Chinese environment, which will lead to abundant of severe issues to ecosystem. Taihu Lake is a end part of Yangtze River. Taihu Lake has a serious and consistent algae bloom and Eutrophication issues. Eutrophication is a problem in river or ocean areas that are rich in diverse nutrients, like phosphorus, nitrogen, and so on [1]. In some situations, the farmlands or industries will also leak out a lot of nutrient pollution to pollute outside environmental water. Overabundance of these nutrients in the water will spur the untamed development of creature, like algae, disrupting the natural ecosystem's equilibrium and causing a host of other ecological issues.

1.2 The impact of algal bloom

The primary source of water eutrophication was human activity-induced nutrient pollution of lakes and other bodies of water, particularly with nitrogen and phosphorus. Plankton and algae multiplied quickly as a result of eutrophication, which left the oxygen low [2]. Despite Richard A. Vollenweider's discovery in 1967 that the primary cause of eutrophication was excessive nutrient input in the surroundings, the origin of eutrophication remained unknown even in the middle of the 20th century, despite Einar Naumann's initial discovery in the early 1900s [3]. Urbanization-related sewage flow and human activity exacerbate the eutrophication process [4].

In the past 20 years, with the increase of eutrophication and associated harmful cyanobacterial blooms, Taihu Lake has been damaged by a large number of cyanobacterial blooms and their toxic metabolites [5].

According to Mohamed M. Dorgham, eutrophication could lead to algal blooms and reduced water transparency, resulting in a lack of oxygen due to the inability of plants on the lake floor to perform photosynthesis [6]. At the same time, eutrophication could cause cyanobacteria to proliferate dramatically, resulting in the release of harmful cyanobacteria blooms (CyanoHAB), which could cause serious environmental hazards [7] and have high prevalence [8][9] and serious economic consequences [10]. According to Mishra, some cyanobacteria produce toxins that are harmful to humans and could produce pathological symptoms if humans are exposed to them, such as fatigue, headache, diarrhea, vomiting, and throat irritation [11].

1.3 The difference in policy between China and America

There is a significant difference between China and the US when it comes to environmental policy. Although China has strict policies regarding environmental pollution, the government often does not enforce these laws strictly. As a result, many companies in China choose to pay fines while continuing to pollute water with substances like phosphorus. In contrast, in the US, many companies, such as General Electric, need to spend money to control pollution and improve the condition of rivers if they discharge pollutants into them.

2. Methods used in the past

2.1 Physical method: Dissolved Air Flotation (DAF)

DAF is a process to treat polluted water and remove suspended matter like solids, oils, and algae from the water. DAF needs to be run by the machine to dissolve air into the water under pressure and release the pressurized water, which will form lots of tiny bubbles [12]. Then, the bubbles will attach algae, solids, or other contaminants to make them float to the water surface, and contaminants can be quickly gathered to make it easily skim off.

2.1.1 Process

In order to demonstrate the benefits of the dissolved air flotation methods, there are some experiments to compare dissolved air flotation versus sedimentation. There are two steps of the process, pre-concentration and dewatering. During the experiment, the first step is to dry sample content of 1 to 6%. The second step can use devices of centrifugation to do the final work of the dry sample content of about 20% [13][14][15].

Comparing the sedimentation and DAF in the process of two steps, the experimental data shows that the sedimentation costs less and has high energy efficiency, but sedimentation also shows a slower process than DAF to make the particle settle together and always contribute to a loose sludge with high water content.

The DAF is a way to use the system of tank with pressure to fill air into it, and the pressurized water will be added to a flotation tank bottom containing the microalgal substance with tiny bubbles. Thus, the DAF can efficiently skim off the surface. Compared to the process of sedimentation, the DAF shows that it is faster and generates the higher solids content sludge [16][17][18][19].

2.1.2 Advantages and Disadvantages

While the DAF system has some applications in sludge thickening, DAF can perform better than sedimentation in different environmental conditions. DAF can remove the algae efficiently in the water without releasing stink and toxins into the water. However, the DAF system cost is higher than the sedimentation system because of the demand of expensive devices that need pressure vessels and add more energy to the DAF system. In the harvesting system and process, DAF also has more important benefits than sedimentation. The rates of DAF was higher and was compared to sedimentation experiments may promote smaller system in working space and eliminate the cost. Experiment shows that DAF as opposed to sedimentation can get reduce costs of equipment and eliminate requirement of energy with a larger scale [17][18][20].

2.2 Physical Method: Ultrasonic Radiation

Ultrasonic radiation is a new idea for how to treat the water that is suffering from algae in the lake. It will remove harmful algae blooms using ultrasonic radiation. In this method, it was concluded that using frequencies of 20-90 kHz, densities of 0.0005-0.1 W/mL, and durations of 0.5-10 minutes achieves an 87.6% removal rate which is highly energy efficient.

2.2.1 Process

Ultrasonic treatment is a new technique that has been developed recently to battle algae, especially *Microcystis aeruginosa.* This method effectively removes algae from water bodies by using short-duration, low-frequency, low-density ultrasonic waves.

The ultrasonic equipment emits 20 kHz sound waves into the water, generating cavitation bubbles that disrupt algae cellular structures through rapid pressure and temperature changes.

Two stages make up the therapy: a one-minute initial vibration and a second treatment given after 12, 24, and 36 hours to evaluate the overall impact on the number of algae decreased and the amount of chlorophyll. The effectiveness of treatments is assessed by comparing clearance rates under various circumstances, which leads to a lot of findings for controlling toxic algal blooms. In summary, while the efficacy and environmental safety of the ultrasonic algae removal method are noteworthy, there are some issues that need to be resolved for the approach to be successfully applied and for the long-term control of dangerous algal blooms.

2.2.2 Advantages and Disadvantages

Ultrasonic treatment offers several benefits for managing harmful algal blooms. It effectively reduces harmful algae, like Microcystis aeruginosa, enhancing water quality. This method is environmentally friendly, avoiding harmful chemical use and maintaining ecosystem health. Additionally, ultrasonic treatment can be cost-effective,

especially in terms of energy efficiency, potentially lowering operational expenses compared to traditional chemical methods. Its versatility allows application across various water bodies, including lakes, reservoirs, and wastewater facilities.

However, ultrasonic radiation also has some problems. For example, its biggest problem is that it requires a large amount of electricity, in this situation the ultrasonic radiation can only be used for cleaning some small swimming pools. Due to the physical properties if people require ultrasonic radiation to work as normal cleaning ways it needs to use a lot more power and at the same time, the time required for cleaning will increase significantly.

2.3 Bioremediation

The value of bioremediation in the treatment of eutrophic water bodies came to the attention of an increasing number of specialists and academics in the 1970s [22]. The value of bioremediation in the treatment of eutrophic water bodies came to the attention of an increasing number of specialists and academics in the 1970s [22]. The way that aquatic plant species degrade the nutrients in a body of water varies. The remediation of eutrophic water bodies was significantly aided by the appropriate aquatic plant selection [23]. Therefore, the selection of aquatic plants typically adheres to the following principles: the plants must be able to grow normally in a variety of water environments and be able to adapt to them; they also need to be able to withstand certain diseases and insects; the plants' roots need to be dense [24][25]; the plants should be able to grow naturally in the wild; and finally, the plants should be simple to maintain and manage.

2.3.1 Past experiment demonstration

Based on the research of P. Nascimento et al., they first identified the plants that need to be adopted for biological remediation, which are macrophytes. So they chose *I. pseudacoros, A. lanceolatum, A. plantago-aquatica, W. arrhiza, L. punctata, L. minor T. latifolia and, N. officinale* conducted the experiment.

First, they needed to make the plant powder, so they placed the plants in a solution of seven parts methanol to three parts of water, ensuring that the plants would dissolve completely. After that, the excess magazines are removed from the water by vacuum filtration. Then a rotary evaporator is used to remove excess water, and you end up with plant powder.

As for how to simulate water eutrophication, the method they chose was to artificially grow cyanobacteria and test the restorative effects of these plants. First, culture medium were used to cultivate the *Chrysosporum ovalisporum* CYN producing strain (LEGE X-001) for a duration of one month.

To prevent contamination, all culture manipulations were carried out in sterile environments. For calculating the concentration of cyanobacteria cells, an optical density calibration curve was established. By measuring the absorbance at 420 nm of seven distinct known C. ovalisporum cellular amounts in the growing medium, the calibration curve was generated.

After the preparation work was completed, the main experiment was ready to proceed. The plant extract powder was scattered into the cyanobacteria community. Different plant extract concentrations were added.

The result is illustrated in figure 1 below, which depicts the relationship between each concentration of plant extract powder and the number of cyanobacteria. According to the conclusion, *L.punctata* has the best function of repairing cyanobacteria [26].

Others have made similar discoveries, Ke et al used plants *Cannaceae, Phyllostachys heteroclada Oliv., Ipomoea aquatica Forssk., Oryza sativa L., Lolium perenne L., Hordeum vulgare L., Triticum aestivum L., Medicago sativa L.* After treatment, the water surface sensitivity is improved, the odor is controlled, the transparency is increased from 5 cm to more than 11 meters in the best time, ammonia nitrogen and total phosphorus are reduced by 4 times and 11 times, COD and DO are significantly improved, and fish crustaceans appear. That result proves the efficacy of aquatic bioremediation in eutrophic water.

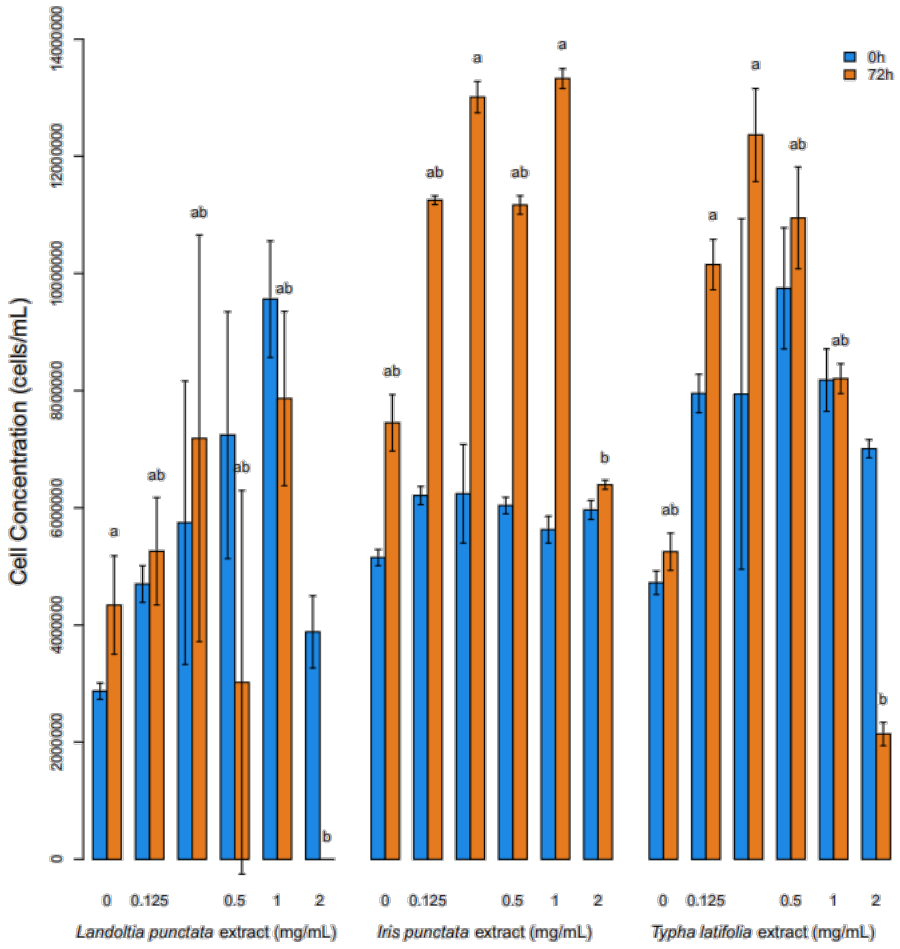

Figure 1. Bar graph displaying the means ± standard deviation of the quantities of Chrysosporum ovalisporum cells obtained from bioassays using Landoltia punctata extract, Iris punctata root extract, and Typha latifolia leaves extract. [26].

2.3.2 Specific methods of bioremediation

The plants commonly used for bioremediation are large aquatic plants, and these plants are generally emergent plants, ensuring that they have full access to the bottom of the water body. Larger emergent plants first on the shore can be planted directly in the center of the lake. Without careful management, aquatic plants can absorb excess nitrogen and phosphorus, and some aquatic plants can also release substances that kill cyanobacteria. By simply ensuring that plants grow properly and do not rot away on a daily basis, eutrophic water and cyanobacteria blooms can be restored [26].

2.4 Chemical Method: Potassium Permanganate

Adding potassium permanganate—a kind of chemical compound and effective heterogeneous oxidant that can be seen as an algicide—can be a feasible treatment [27]. The principle of using it to kill the algae is pretty simple. Oxidation would result from the potassium permanganate's reaction with both the organic and inorganic substances when it was added to water. Algae's cell walls and membranes undergo damage by this oxidative process, disrupting their biological balance. In addition, cell lysis is the result of this oxidation process harming the proteins and lipids in the cell membranes [27][28].

2.4.1 Process

To use the potassium permanganate to reduce the number of algae, the researchers need to do the assessment first. They need to determine the extent, density, and specific species present in the cyanobacteria bloom, and measure the pH, temperature, and nutrient level of the water [29]. Next, the right potassium permanganate dosage needed to be determined based on the assessment. To make a solution that is conveniently utilized and well-controlled, the researchers needed to dilute the potassium permanganate with water. Then, they need to distribute the solution evenly by using boats or other floating platforms equipped with injectors. In the next step, the researchers need to

monitor the water quality and cyanobacteria levels following application in order to evaluate the initial efficacy. There are three types of monitoring: immediate, short-term, and long-term [29]. For immediate monitoring, as soon as potassium permanganate is added, it is crucial to verify the water purity and cyanobacteria level, make sure the chemical is applied correctly, and look for any immediate effects on aquatic life and water quality. Over the following few days, short-term monitoring should be conducted to see if the treatment is successful in lowering the amount of algae present and to look for any short-term negative effects on the environment, including any possible effects on creatures that are not the intended target. Long-term monitoring is necessary to evaluate the long-term impact on the health of aquatic ecosystems and water quality. This means monitoring the water body's overall wellness as well as keeping a watch out for any potential algal bloom recurrence. [29][30].

2.4.2 Advantages and Disadvantages

Adding potassium permanganate has two sides. For the benefits, the cost of the potassium permanganate is pretty low and potassium permanganate is so easy to be applied [28][30]. Also, while potassium permanganate kills the algae in the water, it can control the pathogens, such as some kinds of bacteria and viruses, in water as well [30]. Additionally, employing potassium permanganate reduces the danger of hypoxia for aquatic creatures because it has a lower oxygen demand than other approaches and doesn't considerably lower the dissolved oxygen levels in the water [29]. As for the disadvantages, potassium permanganate can only be considered a type of temporary solution. Since it can only be used to kill algae rather than reducing the amounts of phosphorus and nitrogen in the water, it cannot be used to effectively solve the problem of algal bloom. Furthermore, since potassium permanganate can change the pH of the water and possibly create conditions that are unfavorable for aquatic life, it would harm organisms that are not the intended target. In addition, the health of individuals would be affected by potassium permanganate, such as causing skin irritation, respiratory issues, toxicity if swallowed or inhaled, and other issues. People must exercise caution when using, storing, or applying potassium permanganate, for example, as it can burn and cause blindness if it comes into contact with the skin or eyes.

3. Methods would be used in the future

Electroporation is a relatively recent technique that is suggested to be used for algae removal. In order to remove algae from a cell, a process known as electroporation creates holes in the cell membrane of the algae [31]. Because of electrophoretic force, charged ions inside and outside the cell move and rearrange on both sides of the membrane bilayer, creating a potential across the membrane under an external electrical field [32][33]. Water molecules move through the lipid bilayer as a result of this potential, forcing the lipids to reposition their heads in the direction of the water molecules and causing holes to form in the membrane [34]. A specific electrical voltage has the potential to permanently harm cell membranes and reduce their function [35].

Several studies have researched the effective methodology of electroporation on algae cells. An experiment conducted by Wang determined the lethal electroporation threshold (LET)-- the minimum amount of electric field that causes algae death-- of Staphylococcus epidermidis [35]. Researchers applied 100 voltages to the algae and concluded that LET for S. epidermidis is 29.50 ± 0.16 kV/cm. In different electricity fields, the required LET may vary. In this case, electroporation in Taihu Lake needs to be measured depending on the electric field created by the realistic equipment. Furthermore, the algae in the Taihu Lake are mainly cyanobacteria, which are different from *S. epidermidis*, so the effective LET of cyanobacteria should be tested and modified before use.

Another study by Bai suggests an optimal temperature and time for electroporation [36]. Researchers selected several temperatures and observed the change in the structure of the nanomaterials on the electrodes and the effect of algae inhibition. The result demonstrated that electroporation works best at 400°C. Moreover, the studies showed that when hydraulic retention time (HRT), the time of electroporation, is greater than 10 seconds, the algae growth can be significantly inhibited [36]. This study achieved the goal of damaging the algae cell membrane at a low voltage of 2V for 10 seconds, which provides a convenient and beneficial condition for treating algal bloom by using electroporation.

Previous studies have shown that this method only used 0.014 kWh/kg of energy while using 2V and 10s, which is energy-effective and environmentally friendly since it will not produce any toxic substances like chemical methods do [36]. On the other hand, there are few studies analyzing and verifying the effectiveness of electroporation, discouraging the immediate use of electroporation at Taihu Lake. The actual electroporation protocol needs to be measured locally, which requires further experiments and time. In addition, the optimal temperature of electroporation is 400°C, indicating more equipment is required in order to heat up the environment.

4. Discussion

By combining the methods of ultrasonic treatments and bioremediation, the problem of algal bloom in Lake Taihu can be addressed greatly because of their complementary characteristics. The ultrasonic treatments are a kind of short-term way and would reduce the activity of algae by upsetting the cell architecture of algae. Also, it is quite suitable to be used in Lake Taihu, since it would bring great results in the low-depth water body. For bioremediation, it is a relatively long-term way and would solve the problem fundamentally, since it can absorb excess nutrients like phosphate and nitrogen. In this case, the water quality can be enhanced, and algal blooms can be prevented from happening again. Therefore, the combination of these two methods can be seen as a comprehensive and sustainable solution, providing high efficiency and environmental safety.

However, this combination has its limitations. The application of the ultrasonic method is restricted to certain types of water and algae. In other words, the effectiveness of ultrasonic at Taihu Lake is waiting to be further verified by sampling local water and cyanobacteria in studies. Another consideration is the limited funds provided by the government. Usually, only a single treatment is allowed by the government for treatment since it is cheaper than two treatment combinations. Plus, the equipment of ultrasonic is relatively more expensive than other methods. Future studies may improve this flaw, providing this combination with a wider application aspect. Lastly, bioremediation may involve the danger of invasive species as it brings new plants to the lake. Therefore, the selection of plants needs to depend on the local ecosystem and policy.

5. Conclusion

In conclusion, the problem of algal bloom is quite severe, people need to find an effective and suitable way to address this problem as soon as possible. According to this article, the suitable way is the combination of ultrasonic treatments and bioremediation, which is a comprehensive and sustainable solution and can solve the problem fundamentally. Also, it can provide high efficiency and environmental safety.

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