The research on *Nelumbonucifera* for eutrophication control in Wuliangsuhailake Inner Mongolia, China

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Abstract. In order to study the effect on *Nelumbonucifera* (common name: lotus) for eutrophication control in Wuliangsuhai lake inner Mongolia, an enclosure of 2000m² was established in the southeast of Wuliangsuhlake. In the paper, the changes on water quality and phytoplankton abundance were monitored before planting lotus, after. Purpose of the study is to investigate the influence of lotus on improving water quality, restoration of water environment, and so on. The results were shown below. Firstly, Planting lotus was significant for removal of total nitrogen and total phosphorus in water. Total nitrogen removal rate was more than 25%. Total phosphorus removal rate was more than 30%. Secondly, dissolved oxygen concentrations in August increased by 39.31 percent. The Simultaneously, compared with the control (in April), the pH value was 8.0 in August (the flowering period) and declined by 10.11 percent. In this salinity, lotus had a strong salt tolerance and grew normally. Lastly, the biomass of phytoplankton was inhibited after planting lotus, especially for the inhibition of green algae growth. Studies on water bodies restoration under planting lotus in Wuliangsuhai lake have not been reported. Therefore, planting lotus will provide a new idea and theoretical reference for improving the eutrophication of Wuliangsuhailake.

1. Introduction

In the world, lake water pollution has been a serious water environmental problem. China is also facing the problem of serious water shortages, especially in the lake water resources[1]. Wuliangsuhailake is located in the western Inner Mongolia, China. It is the most typical shallow grass-algae lakes in arid zone of Inner Mongolia, where the problem of eutrophication is very serious[2]. In the 1970s, Kichuth who is German scholar proposed the root zone theory, and pointed out that planting aquatic plants can improve the water environment. This conclusion has been concerned around the world[3]. Since then, water pollution problems have been widely attention. This idea that the plant in the theory of root zone has a important role to purify sewage is widely recognized[4]. Currently, the approach on the application of aquatic plants to control water pollution problems has achieved initial success in parks, reservoirs and lake. Especially in the park, research results are mostly on planting lotus to purify water quality[5-7]. A large number of studies have shown that aquatic plants play an important role in purifying water quality, such as *Lotus*, *Nymphaeae tetragona*, *Nipharpumuilum*, and so on[8]. Lotus under reasonable planting density is helpful to control eutrophication[9]. In recent years, research on using plant measures to purify water quality in Wuliangsuhai lake has been shown that reed planting reduced water eutrophication[10]. However, Research on the ability of lotus to purify water quality is rare in Wuliangsuhailake. In this paper, experimental studies were conducted on planting lotus in different growth periods to influence the
water quality parameters and phytoplankton community. The study has begun to take shape that planting lotus to purify water quality, improve water eutrophication and ecological wetlands. But studies on water bodies restoration under planting lotus in Wuliangsuhai lake have not been reported. Planting lotus will provide a new idea and theoretical reference for improving the eutrophication of Wuliangsuhai lake.

2. Materials and methods

2.1. Test purposes
The purpose of the trial is to reveal the effect of lotusin different growth stages on water purification capacity and phytoplankton community in Wuliangsuhai lake.

2.2. Test area overview
Wuliangsuhai lake is located in Wulatqianqi county in Inner Mongolia, China. It is China's eighth largest freshwater lake. It is the most typical shallow grass - algae lakes in arid zone of Inner Mongolia, where the problem of eutrophication is very serious. It is also the largest natural wetland at the same latitude on the earth. It plays a very important role to water retention, water storage and water diversion on the upper reaches of the Yellow River. In recent years, the water environment is very serious in Wuliangsuhai lake. The following aspects have been reflected: (1) Algae growth is abnormal breeding; (2) The lake swamp process is rapidly increasing; (3) The degree of eutrophication of lake water is increasing and water quality is deteriorating; (4) Water level and water depth is at the lower trend; (5) The quantity and quality of species resources are declining; (6) The tourism economy is hampered.

2.3. Monitored parameters and determination methods
The test area is located in a closed enclosure where is in the "two-point tourist area" in Wuliangsuhai lake. The size of the enclosure is 200 m × 10 m × 0.6 m (Length × width × height). Monitored points are three. The way to plant is that rhizome of lotus is pressed into the mud. Then, with the growth of Lotus test indicators are monitored.

Test methods on water quality indicators[11]. Ammonium Molybdate Spectrophotometry method of GB11893-89 was used to determine the total phosphorus content total. Potassium persulfate Alkaline Digestion - UV method of GB11894-89 was used to determine the total nitrogen. Membrane Electrode methods was used to determine dissolved oxygen. Dilution and Inoculation method of GB11901-89 was used to determine Biochemical Oxygen Demand (BOD₅) and Micro reflow - potassium dichromate spectrophotometric method was used to Chemical Oxygen Demand (COD₅).

Method for determination of phytoplankton biomass are as follows. First, the qualitative samples of phytoplankton were harvested with "∞" shape with 25 # biological net at 0.5 m below the surface of the water body. Then, the sample was placed in a sample bottle and fixed by using a formaldehyde solution with a volume fraction of 1%. The sample was brought back to the laboratory. After standing concentrated, species identification and quantitative counting are carried out.

During the four growth periods of the lotus, the test parameters were monitored. Four growth periods were respectively floating leaves (April 15, 2017), the first leaf stage (June 1), the third leaf stage (June 20), and flowering period (August 15). Before planting lotus (April 15, 2017) in situ water quality was tested and the results were taken as a comparison of test water quality indicators and abundance of phytoplankton. Each sample is repeated three times, and take the average as the final result.

2.4. Data analysis
Using SAS 9.0 software to data parallax analysis[12].
3. Results and analysis

3.1. Change of total nitrogen and total phosphorus content under planting lotus

As can be seen from Figure 1, the difference of among treatments was significant at p < 0.05. That the contents of total nitrogen and total phosphorus in water showed a decreasing trend after planting lotus. Compared with the control (in April), April > May > June > July > August. The average removal rate of total nitrogen during the growth period was 1.49%, and the removal rate of total nitrogen was more than 25% in the late growth period. The average removal rate of total phosphorus during the growth period was 28.13%, and the removal rate of total phosphorus was more than 30% in the late growth period. The reason can be seen that with the normal growth of lotus leaves are lush and density is enhanced. The result is lotus has the ability to effectively reduce the total nitrogen and total phosphorus content in water.

![Figure 1. Change of TN and TP content under planting lotus.](image)

3.2. Change of DO and pH under planting lotus

Seen from Figure 2 that the difference of among treatments was significant at p < 0.05. Dissolved oxygen concentrations in water were increasing trend after planting lotus in the different growth period. Compared with the control (in April), dissolved oxygen concentrations in August increased by 39.31 percent. This result is that with the growth of lotus concentration of nitrogen and phosphorus decreased. A large number of microbial reproduction was inhibited. Thereby consumption of dissolved oxygen was reduced. However, respiration of lotus release large quantities of oxygen into the atmosphere. As a result, the content of dissolved oxygen in the water body was increasing.

With the growth of lotus, the pH value in the water body slowly declined. Compared with the control (in April), the pH value was 8.0 in August (the flowering period) and declined by 10.11 percent. This result was better and indicated that lotus can grow in high salinity water and it has a strong salinity resistance.

![Figure 2. Change of DO and pH under planting lotus.](image)
3.3. Change of BOD$_5$ and CODcr under planting lotus

According to the experimental design planting area of lotus is 667 m$^2$, and the area of purified water is 2,000 m$^2$. According to the following formula actual reductions of BOD$_5$ and CODcr is calculated.

\[
\text{Actual reductions} = \frac{\text{Measured value after purification} - \text{Initial control value}}{\text{Planting area}} \times \text{Volume of purified area}
\]  

(1) 

It can be seen that the difference of among treatments was significant at p < 0.05. That the contents of BOD$_5$ and CODcr in water showed a decreasing trend after planting lotus. Compared with the control (in April), April > May > June > July > August. By analysis, lotus in the flowering period had the strongest purification ability to BOD$_5$ and CODcr in water. After planting 1m$^2$ lotus, the content of the reduced BOD$_5$ was 8.99 g and the CODcr content was 7.62 g. As can be seen from Figure 3 that with the growth of lotus, the contents of BOD$_5$ and CODcr in water were declining. Especially in the fall flowering the trend was more significant. Compared to the control, BOD$_5$ removal rate was 26.32%, and CODcr was 39.60%.

![Figure 3. Change of BOD$_5$ and CODcr under planting lotus.](image)

3.4. Change of algal cell density under planting Lotus

During the observation period, samples of algal phytoplankton were observed five times. Identification results contained Chlorophyta, Bacillariophyta, Cyanophyta, Euglenophyta and Euglenophyta. Among them, the number of Chlorophyta is the largest. There were 36 genera and 43 species. This amount was 38.05 percent of the total species number of algae.

Seen from Figure 4 that with the growth of lotus the biomass of algae in water showed a decreasing trend. Wherein the cell density of Chlorophyta reduced significantly.

It can be seen that the inhibitory effect of lotus on green algae cells was better. Chlorophyta is the dominant species in the blooms in Wuliangsuhai lake. The reduction of chlorophyta has an important effect on the inhibition of bloom.
4. Conclusions

- The difference of among treatments was significant at $p < 0.05$. That the contents of total nitrogen and total phosphorus in water showed a decreasing trend after planting lotus. Compared with the control (in April), April > May > June > July > August. The removal rate of total nitrogen is more than 25%, and the removal rate of total phosphorus is more than 30% after planting lotus. The effect of lotus purifying water quality is obvious.
- Dissolved oxygen concentrations in water were increasing trend after planting lotus in the different growth period. Compared with the control (in April), dissolved oxygen concentrations in August increased by 39.31 percent.
- With the growth of lotus, the pH value in the water body slowly declined. Compared with the control (in April), the pH value was 8.0 in August (the flowering period) and declined by 10.11 percent. This result was better and indicated that lotus can grow in high salinity water and it has a strong salinity resistance.
- After planting 1 m$^2$ lotus, the content of the reduced BOD$_5$ is 8.99 g and the COD$_{cr}$ content is 7.62 g. The contents of BOD$_5$ and COD$_{cr}$ in water are declining.
- To a certain extent, lotus can inhibit phytoplankton biomass, especially for the growth of green algae. The reason is that there is competition in the living environment, on the other hand the allelopathic effect of lotus has a certain inhibitory on algae. It can be seen that the inhibitory effect of lotus on green algae cells was better. Chlorophyta is the dominant species in the blooms in Wuliangsuhai lake. The reduction of chlorophyta has an important effect on the inhibition of bloom.

5. Discussions

A large number of studies have shown that aquatic plants have a significant effect on eutrophication. Among them, the effect of *Lotus* on purifying water quality is more obvious.

*N. nucifera* and *C. alternifolius* showed the successful removal of phosphorus from domestic wastewater[13]. The increase of phosphorus in both *N. nucifera* and *C. alternifolius* shows that phosphorus was taken up from domestic wastewater by the plants[14]. The aquatic plant species are effectively reliable indices as water status indicators. Their ability in taking up metal and toxic pollutants has shown their level of strength as well as tolerance in any concentration levels[15]. The dominant green algae (Chlorophyta) and blue-green algae (Cyanophyta) turned into green algae and diatoms before and after planting *Nelumbonuciferae* in Baiyangdian Lake. And the eutrophication levels of the water were from severe to moderate[16] and after the planting lotus the total nitrogen, total...
phosphorus and ammonia nitrogen in the water body have obvious are renovated and algae growth is also inhibited. These conclusions are consistent with the results of this study.

However, in Inner Mongolia Wuliangsuhailake the research on planting lotus to contaminate water quality is still in the preliminary stage. The test area is located in the northern cold regions of China. Climate characteristics follow that vary between temperatures of morning and evening is widely. Water temperature is relatively low. Sunshine time is relatively inadequate. The above characteristics led to further research needs to be done on the selection of species of large, deep-water planted lotus. In addition, the pH value of Wuliangsuhailake is alkaline, and it is the focus of further study on select the salt-tolerant lotus to large area planting.

In short, the study has begun to take shape that planting lotusto purify water quality, improve water eutrophication and cological wetlands. Because of studies on water bodies restoration under planting lotus in Wuliangsuhailake have not been reported. Planting lotus will provide a new idea and theoretical reference for improving the eutrophication of Wuliangsuhailake.

Acknowledgment
Fund Project: 1. Inner Mongolia Science and Technology Project: Study on the Mechanism of Migration and Transformation of Phytoplankton and Pollutants in Ice – season; 2. Inner Mongolia Technical College of Mechanics & Electrics Science Fund.

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