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POLLUTION RESISTANCE AND REMOVAL EFFICIENCY OF MESOPHYTIC PLANTS OF POLLUTED WATER BODIES

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Abstract

With the development of cities and economic growth, the eutrophication of urban park landscape water has become a hot topic in environmental governance and research at home and abroad. Using indoor water pollution simulation experiments, the decontamination and pollution resistance performance of six aquatic plants were studied. The research results found that all six aquatic plants can reduce the pH value of eutrophic water bodies. The pH of the *Lythrum salicaria* L. (Q) and *Iris tectorum* Maxim (Y) treatment systems was the lowest which are 7.34 and 7.48, respectively. They were significantly lower than the control group (CK). The content of nitrogen and phosphorus elements were reduced by six types of plants in the wastewater. After the completion of the experiment, the total nitrogen (TN) removal efficiency of Y was as high as 66.2%, and its content decreased from 9.49 to 3.21 mg/l. The removal rates of total phosphorus (TP) by six types of plants ranged from 59.1 to 81.3% and they were significantly higher than the CK. Among them, the removal rate of TP in wastewater by Y treatment exceeded 80%, which is superior to other plants and significantly different from CK. After the completion of the experiment, the content of chlorophyll a (chl a) in the water treated with Y was the lowest (6.6 mg/l). It was significantly lower than the other treatments ($P < 0.05$). The contents of chl a in Y decreased by 37.1% compared to the initial level. Compared to CK, it is was 54.1% lower and the content of chl a in CK showed an increasing trend with time delay. Overall analysis shows that the microsystems formed by the six plants all have a certain improvement effect on water quality, effectively inhibiting the proliferation of algae in eutrophic water bodies. Among them, planting iris has the best effect.

Introduction

In recent years, with the development of the global economy and agriculture, as well as the improvement of people's living standards, industrial wastewater, agricultural wastewater, and domestic wastewater have all increased dramatically. Therefore, the prevention and maintenance of water pollution has become a hot topic in ecological restoration and research both domestically and internationally. Previous studies have shown that the conditions for eutrophication in water bodies are that the total nitrogen content is greater than 0.3 mg/L and the total phosphorus content is greater than 0.02 mg/L (Li *et al.* 2004, Liu *et al.* 2020). According to existing data of Ansai *et al*. (2020), closed water bodies in Chinese cities are prone to secondary pollution after restoration, which will cause economic losses to the people and greatly damage the diversity of the ecosystem, seriously damaging the living environment. The main reason for secondary pollution is the continuous discharge of substances such as total nitrogen (TN) and total phosphorus (TP) into parks and rivers, while water bodies lack long-term pollution removal capabilities. Therefore, in the process of ecological landscape construction, efficient removal of eutrophic substances from

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water bodies is an urgent development need for building a good living environment both domestically and internationally. Compared with traditional physical and chemical remediation methods, biological remediation methods have significant advantages. On the one hand, it is more conducive to operation under low input conditions, and on the other hand, it can maintain plant diversity and form a good habitat. The key element of this technology is the suitable aquatic plants. Aquatic plants are not only a landscape component of the living environment. Aquatic plants can also utilize their own growth needs to absorb a large amount of nitrogen and phosphorus substances, thereby reducing the content of pollutants such as nitrogen and phosphorus in water bodies (Wang *et al.* 2014, Xu *et al.* 2023).

The decontamination mechanism of aquatic plants is to use their own tissues and organs such as roots, stems, and leaves to absorb organic matter and nutrients from the water (Kadlec *et al.* 2002). Most aquatic plants need to absorb and utilize nutrients such as nitrogen and phosphorus throughout their entire life cycle, so the removal of nitrogen and phosphorus from water is not only efficient but also sustainable. In addition, aquatic plants convert substances that cause eutrophication in the water into other substances that maintain plant life through absorption and decomposition, which can be consumed and transformed during the continuous growth process of plants (Odoh *et al.* 2019). Planting aquatic plants can compete with algae for nutrients and produce a certain shading effect, hindering the rapid reproduction and growth of algae (Shi *et al.* 2020). At the same time, aquatic plants form independent growth zones through rapid tillering and reproduction, thereby gaining a competitive advantage in the co growth process with algae, accelerating growth metabolism, inhibiting the growth metabolism of surrounding algae substances, and forming a virtuous cycle (Alahuhta *et al.* 2020). However, currently, most of the landscape construction processes in human settlements mainly focus on the requirements of urban landscape aesthetics, with relatively little consideration given to the decontamination performance of aquatic plants. In some studies, it has also been found that both aesthetics and practicality can be emphasized in urban landscape construction. For example, Cai *et al.* (2019) fully considered the ornamental and practical aspects of plants in the construction of wetland landscapes in northern Jiangsu. At present, research on efficient and sustainable decontamination of practical plant species needs to be further strengthened. Existing studies have mostly selected single species of aquatic plants as materials (Zhang *et al.* 2014, Zhang *et al.* 2016, Fan *et al.* 2017), especially research on the purification effect of different life forms of aquatic plants on eutrophic urban river water bodies is still relatively scarce. In view of this, this study selected six common urban landscape plants and simulated the eutrophic urban river water environment under indoor conditions. Plant species with efficient pollution removal and algae inhibition abilities were screened out to provide support for building a beautiful living environment.

Materials and Methods

By investigating the types of aquatic landscape plants in Xi'an, Shaanxi Province, six plant species were selected as the research objects. They are spiked loosestrife herb (*Lythrum salicaria* L.), cattail (*Typha orientalis* Presl), water bamboo taro (*Thalia dealbata*), Lotus (*Nelumbo* SP.), giantreed rhizome (*Arundo donax var. versiocolor* Stokes) and Iris (*Iris tectorum* Maxim).

The experiment was conducted from May to July 2023 at the Artificial Climate Laboratory of the Institute of Geosciences and Urban Rural Development. The experimental temperature was maintained at 28-31 ℃ during the day and 18-21 ℃ at night. Relative humidity was 72 ± 5%.

The size of the experimental box is 35 cm x 45 cm x 60 cm. Seven groups of plants were set up, each of which was planted with six types of plants, namely the spiked loosestrife herb (Q), the cattail group (X), the water bamboo taro group (Z), the lotus group (H), the giantreed rhizome group (L), the iris group (Y), and the planless group (CK). Each group was repeated three times. Firstly, fill the experimental pot with sediment to a depth of 23 ± 0.5 cm, which serves as the substrate for plant rooting. Wash the roots of the plants with distilled water and cultivate them in distilled water for two days. Transplant well growing plants into an experimental pot, lay about 1 cm thick gravel on the surface, and then add eutrophic water to a depth of 28 centimeters. After the plants grow well, collect water samples to determine the initial values. The pH value is 7.7. Dissolved oxygen (DO), the total nitrogen and total phosphorus were 3.64, 9.7 and 1.5 mg/l, respectively. The frequency of water sample collection during the experiment is 10 days each time.

The determination method of chlorophyll a: using spectrophotometry (Streibig *et al*. 2002). DO and pH were measured using a portable measuring instrument. The determination method of TN is to use alkaline potassium persulfate oxidation ultraviolet spectrophotometry. TP was determined by ammonium molybdate spectrophotometry (Editorial Committee of the State Environmental Protection Administration 2002). At the same time, the elimination rate of nitrogen and phosphorus in the water is calculated based on the initial and final concentration changes of nitrogen and phosphorus.

Results and Discussion

Fig. 1 shows that at the end of the experiment, the pH of CK treatment was 8.24, significantly higher than its plant treatment group ($P < 0.05$), and higher than the initial value of the experiment. There is a significant change in pH in the water body after planting plants. Previous studies have also shown that plants can utilize their own characteristics to exchange ions with water, thereby changing the pH of the water (Liu *et al*. 2021, Ma *et al*. 2023, Lewis *et al*. 2023). In this experiment, the pH of the water body planted with the spiked loosestrife herb decreased the most significantly, reaching 7.34, indicating neutrality. Next was the Iris group (7.48), and both showed a significant decrease compared to CK ($P < 0.05$). Throughout the entire experimental period, pH showed an overall downward trend. In the early stages of planting, there was an increase, but after July 15th, there began to be a downward trend.

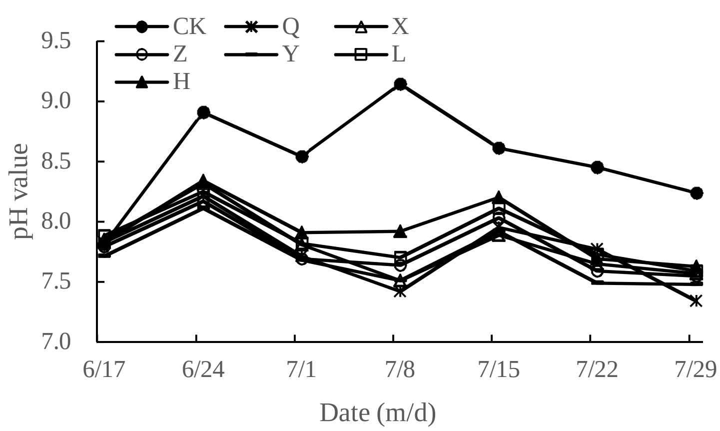

Fig. 1. Changes in pH value of microsystem water by different emergent plants.

From Fig. 2, CK shows a slow downward trend throughout the entire cycle. The DO of the plant group shows a slight fluctuation in the early stage and a significant increase after July 1st, indicating that planting plants can effectively increase the content of dissolved oxygen in water, which is consistent with existing research results (Wei *et al.* 2023). At the end of the experiment, Y has the highest dissolved oxygen content, reaching 8.74 mg/l. Compared to CK, it has increased by about three times. And all plant groups were significantly higher than CK. This may be due to the rapid growth of plants, which generate a large amount of oxygen through respiration, thereby increasing the content of dissolved oxygen in the water.

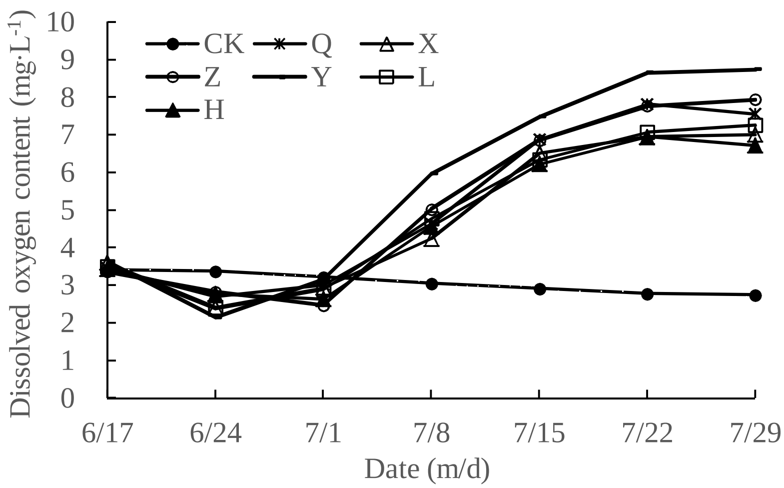

Fig. 2. Changes of dissolved oxygen in microsystems water by different emergent plants.

The total nitrogen variation chart in Fig. 3 shows a significant difference between the total nitrogen content and CK under different plant treatments. The water sample results on July 29th showed that the average total nitrogen content of each treatment was 4.01 mg/l, and the removal rate of total nitrogen by each treatment was 46.8-66.2%. The average removal efficiency of TN reached 57.2%. The total nitrogen content of Y is the lowest, at 3.21 mg/l, a decrease of 66.2% from the initial value of 9.49 mg/l. From the trend analysis in Fig. 3, the total nitrogen content of the water body showed a continuous decrease and gradually stabilized after planting plants. The possible reason is that in the early stage, plants are in a period of vigorous growth and need to absorb a large amount of nutrients, while in the later stage, plant growth stops or even decays, resulting in slow nutrient absorption and a tendency for total nitrogen to stabilize (Gaballah *et al.* 2020).

The total phosphorus change chart in Fig. 4 shows that the trend of total phosphorus change in the water system after planting aquatic plants is basically consistent with total nitrogen. The research results of Chen *et al.* (2022) indicate that planting plants can significantly reduce the total phosphorus content in water, which is consistent with the results of this study. The average removal rate of total phosphorus in each experimental group is 70.5%. Among them, Y treatment had the best clearance effect, reaching up to 81.2%. On July 29th, the total phosphorus content in the water was only 0.21 mg/l.

Based on a comprehensive analysis of the trends in total nitrogen and total phosphorus, the Iris (Y) treatment group showed the best effect in eliminating nitrogen and phosphorus in water.

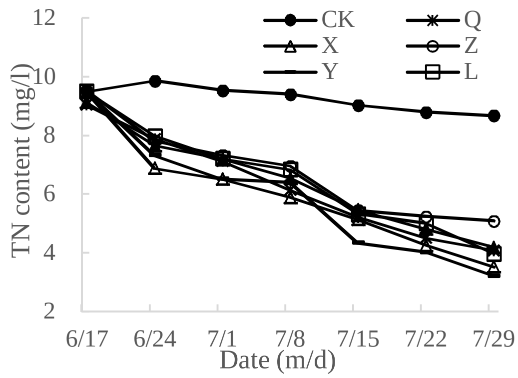

Fig. 3. Changes of TN content in the water.

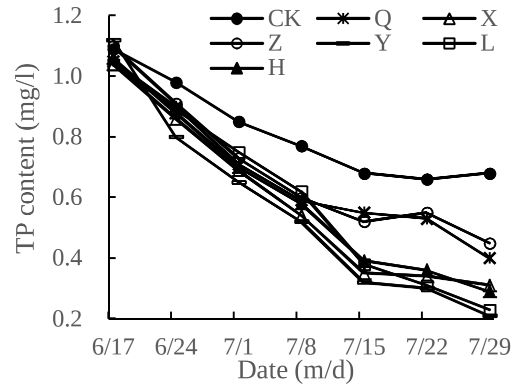

Fig. 4. Changes of TP content in the water.

Fig. 5 shows that the chl a content in the water treated with CK gradually increases, while the chl a content in the water treated with planting plants shows an overall downward trend. At the beginning of the experiment, the trend of chl a content changes in different plant species of water bodies are inconsistent. Among them, after planting cattail (X), the giantreed rhizome (L), and lotus (H), the chl a content in the water body shows an increase decrease, while after planting the spiked loosestrife herb (Q), the water bamboo taro (Z), and iris (Y), the chl a content in the water body shows a decrease increase decrease. Among them, the decrease in chla content is most significant in Y treatment. On July 29th, the content of chl a in the water treated by Y has dropped to 6.6 mg/l. Compared to the initial value of 10.5 mg/l, it decreases by 37.1%. Compared to CK, it decreases by 54.1%. And it reaches a significant difference with CK ($P < 0.05$). A comprehensive analysis of the chl a changes in the plant group and CK group water reveals that the growth of plants absorbs a large amount of nutrients in the water, competing for the nutrients needed for algae reproduction in the water, thereby limiting algae reproduction (Feng *et al.* 2018, Rodrigo *et al.* 2018). In water bodies without plant groups, algae have no competitors and can rapidly reproduce by utilizing nutrients in the water, thereby increasing the content of chl a in the water.

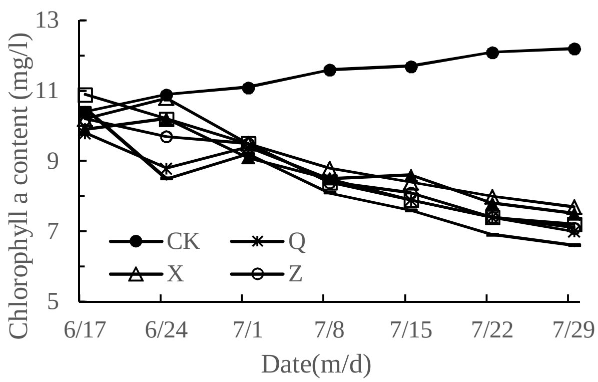

Fig. 5. Changes in chlorophyll a concentration in different emergent plant.

There are significant differences in the number of tillers among the six aquatic plants planted in eutrophic water bodies, but they all grow well. Table1 shows that during the 45 days' experiment, the contents of Pro and MDA in the stems and leaves of the water bamboo taro group, the iris, and lotus were all higher than the initial experimental values. The Pro content of the three plants increased by 62.8, 19.6 and 36.2% , respectively compared to the initial values, and the MDA content increased by 38.4, 39.8 and 23.9%. The content of Pro and MDA in the stems and leaves of the spiked loosestrife herb and the cattail decreased. The trend of changes in Pro and MDA content in the stems and leaves of bamboo is opposite. Pro and MDA are important substances produced by plants to adapt to adversity. The stress resistance substances in the bodies of the spiked loosestrife herb and the cattail decreased, but the number of plant tillers was significantly higher than other treatments. This may be because the nitrogen and phosphorus concentrations in the water did not form their stress, so they can grow and reproduce quickly. The increase of stress resistant substances in the bodies of the three plants, the water bamboo taro, iris, and Lotus, indicates that stress resistance reactions have occurred in eutrophic water bodies, thereby adapting to the eutrophic water environment.

Table 1. Analysis of pollution resistance of different plants in eutrophic water bodies.

Treatment	Proline		Malondialdehyde		Tillering number
	0 d	45 d	0 d	45 d	
Q	102.34	75.61	0.8125	0.6714	22
X	148.30	104.55	1.2451	0.9453	18
Z	18.97	30.89	0.2458	0.4785	11
Y	98.24	117.52	0.2978	0.3744	13
L	32.41	33.24	0.3017	0.1151	17
H	85.21	116.08	0.6528	0.8090	8

Q: the spiked loosestrife herb, X: the cattail, Z: the water bamboo taro, H: the lotus, L: the giantreed rhizome, Y: the iris, and CK: the plantless.

This experiment studied the removal efficiency of six aquatic plants in artificially eutrophic water. It was found that planting plants can stabilize the acid-base environment of the water, reduce the concentration of total nitrogen and total phosphorus in the water, and significantly inhibit the occurrence of algae. A comprehensive comparison of the decontamination efficiency and adaptability of six plants shows that the aquatic plant Iris has a stress response to eutrophic water and can quickly adapt to polluted environments to produce tillering, which is beneficial for removing excess nutrients in eutrophic water and maintaining water quality in the long term.

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References

Alahuhta J, Rosbakh S, Chepinoga V and Heino J 2020. Environmental determinants of lake macrophyte communities in Baikal Siberia. Aquat Sci **82**: 2-13.

Ansai A, Naeem M, and Gill S 2020. Phytoremediation of contaminated waters: an eco-friendly technology based on aquatic macrophytes application. Egyptian J. Aquatic Res. **46**: 471-476.

Cai L, Zhang H and Chen Y 2019. Application of emergent plants and floating leaf plants in the wetland landscape of Northern Jiangsu. Genomics Applied Biol. **38**: 5131-5135.

Chen L, Li CG, Li FM, et al 2022. Summary of plant water purification ability in water ecological restoration. Environ Poll Control. **44**:1079-1084.

Editorial Committee of the State Environmental Protection Administration 2022. Water and Wastewater Monitoring and Analysis Methods (Edition 4). China, Environmental Science Press.

Fan HL, Xie LQ, Song XM 2017. Responses and accumulation features of nitrogen and phosphorus of submerged vegetation under different nutrient levels. Environ. Sci. Technol. **40**: 42-48.

Feng SG, Xu SJ, Zhang XP, Wang R, Ma X, Zhao ZR, Zhuang GQ, Bai ZH and Zhuang XL 2018. Myriophyllum aquaticum-based surface flow constructed wetlands for enhanced eutrophic nutrient rrmoval-a case study from laboratory-scale up to pilot-scale constructed wetland. Water. **10**: 1391.

Gaballah MS, Abdelwahab O and Barakat KM 2020. A novel horizontal subsurface flow constructed wetland planted with Typha angustifolia for treatment of polluted water, Environ Sci Poll Res Inter, **27**: 28449-28462.

Kadlec RH, Knight R, Vymazal J, Wu SB, Chen ZB, Zhao YQ, Cheng C, Hu Z, Zhuang LL, Guo ZZ, Xie HJ and Zhang J 2002. Constructed wetlands for pollution control. USA: IWA Publishing 2002: 93-102.

Lewis JP, Ryves DB, Søndergaard M, Lauridsen TL, Johansson LS, Tserenpil S, Rasmussen P and Jeppesen E 2023. Nutrients and saltwater exchange as drivers of environmental change in a danish brackish coastal lake over the past 100 years. Water, **15**: 1116.

Liu LS, Huang GX, Wang P, Chu ZS and Li HS 2020. Main problems, situation and countermeasures of water eco-environment security in the Yangtze River Basin., Res. Envir. Sci. **33**: 1081-1090.

Liu YH, Wang ST and Yang QQ 2021. Current status of eutrophication in water bodies at home and abroad and research progress on phosphorus accumulating bacteria. Jiangsu Agric. Sci. **49**: 26-35.

Li ZY, Ding J, and Peng LH 2004. Principles and Methods of Environmental Quality Assessment, Beijing: Chemical Industry Press.

Ma X, Wang Q, Wang H, Li D, Li F, Yu D and Liu C 2023. Effects of disturbance on functional diversity-productivity relationships of aquatic plant communities depend on nutrients and life-forms., Hydrobiologia. **850**: 683-697.

Streibig JC and Olofsdotter M 2002. Joint action of phenolic acid mixtures and its significance in allelopathy research. Phys Plantarum, **114**: 422-428.

Odoh CK, Zabbr YN, Sam K, and Eze CN 2019. Status, progress and challenges of phytoremediation-an African scenario. J Environ Manag **237**: 365-378.

Rodrigo MA, Valentin A, Claros J, Moreno L, Segura M, Lassalle M and Vera P 2018. Assessing the effect of emergent vegetation in a surface-flow constructed wetland on eutrophication reversion and biodiversity enhancement. Ecol Engin **113**: 74-87.

Shi XP, Chen YP, Yan ZQ, Luo YQ, Li YQ, Ding JG and Jie HF 2020. Research progress on plant allelopathy. Biotech Bull **36**: 215-222.

Wang C, Zheng SS, Wang PF and Qian J 2014. Effects of vegetations on the removal of contaminants in aquatic environments: a review. J Hydrodyn Ser B. **26**: 497-511.

Wei JH, Li YY and Yang GR 2023. Characteristics of the impact of water fall mode and aquatic plant on dissolved oxygen content in water body. Chin J. Tropical Agricul. 1-11.

Xu B, Zhang XY, Chang JS, Guo H., Han S and Lee DJ 2023. Remediation of the black-odor water body by aquatic plants with plant growth-promoting Rhizobacteria: Lab and pilot tests. Environ Res **223**: 115462.

Zhang CB, Liu WL, Pan XC, Guan M, Liu SY, Ge Y and Chang J 2014. Comparison of effects of plant and biofilm bacterial community parameters on removal performances of pollutants in floating island systems. Ecol Engin **73**: 58-63.

Zhang HY, Tang YZ and Gu JY 2016. Progress review on the water purification effect of aquatic ecosystems, Environ. Sci. Tech. **39**: 79-86.

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