Application of water ecological restoration guided by microbial activation in landscape water

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Abstract. Water eutrophication is one of the difficulties in urban landscape water. In the past period of time, people have been exploring the prevention and control of eutrophication of landscape water. At present, submerged plant restoration, chemical control of algae and physical equipment filtration technology are becoming more and more mature. Among them, submerged macrophyte restoration has become the mainstream technology, but the restoration of submerged macrophytes is faced with the problem of lack of transparency, which leads to the failure of engineering construction. Indigenous microbial activation(IMA) technology has become an effective method to solve this problem. The technology focuses on the water microbial community as the research object. By adding an activator with a suitable concentration gradient to the experimental landscape water, the indigenous microbial community is activated landscape water. The paper analyzed the current landscape water eutrophication technology, summarized the relationship between bacteria and algae, algae and submerged plants, and proposed IMA microbial activation technology. In addition, we share a project case to better illustrate this technology. In the case, IMA equipment was added to the experimental landscape water to study the water environment quality changes before and after the implementation of the project, so as to evaluate the feasibility and technical advantages of IMA technology, and provide technical ideas and data support for landscape water treatment.

1. Introduction

Eutrophication of landscape water is currently one of the main water pollution problems facing the world[1]. Among them, urban landscape water is the main element of urban construction. As the main place for urban residents to live for leisure, it has the characteristics of poor mobility, small water area, poor self-purification ability, and easy to be polluted[2,3]. Once the urban landscape water body appears eutrophication, the algae in the water body will multiply and the color will be green. In severe cases, it will emit foul smell and the death of aquatic organisms. It will lose the ability of the landscape and seriously affect the surrounding natural environment and the living environment of residents[4]. In order to make good use of the functions of urban landscape landscape water and create a beautiful urban environment, we must do a good job in the prevention and control of urban landscape landscape water eutrophication. Controlling the fulminant growth and reproduction of algae is an important issue for effective management of water eutrophication[5]. In recent years, more and more scholars have used ecological technology to restore aquatic ecosystems and restore them to a stable and self-purifying ability. Research on microbial algae control technology based on the aquatic
microecological regulation and the principle of "bacteria and algae interaction" has gradually received attention.

2. Development status of landscape water treatment technology

The essence of water eutrophication is the phenomenon that when the water body contains more nutrients such as total nitrogen, ammonia nitrogen, and total phosphorus, the water quality is reduced and the water body is polluted[6]. When the content of various nutrients in the water body loses its original equilibrium state, the content of algae or other single species in the water body suddenly increases, resulting in the flow of material and energy in the original ecosystem of the water body and the diversity of aquatic species Damaged, unable to maintain the original equilibrium state, and ultimately seriously affect the overall water ecosystem[7].

Nowadays, with the progress of society and the improvement of quality of life, people pay more and more attention to the protection of urban landscape water. Regarding the treatment of water eutrophication, there are many ways, mainly including the following three aspects.

2.1. Reduction and control of external sources

External pollution is an important cause of lake eutrophication. The reduction and control of external sources, in short, is to control external sources and intercept pollution, control the total amount of external pollutants that may enter the lake as much as possible, and keep the amount of external pollutants to a minimum, so that The exogenous nutrient content of the lake is reduced, reducing the pollution load[8]. However, if the lake water body is already at a high degree of eutrophication, it is difficult to effectively improve the status quo only by controlling external pollution.

2.2. Internal source reduction and control

The endogenous pollution of the water body mainly comes from the bottom sludge rich in nutrients in the water body. Therefore, internal source control and reduction are generally adopted to control sediments, such as sediment covering, sediment dredging and many other methods[9]. Among the many methods, the most common, the most applied, and the fastest effective, the most common and extensive technology is sediment dredging technology.

2.3. Biological treatment measures

In the water ecosystem, aquatic organisms will absorb and use the nitrogen and phosphorus elements in the water body for their own survival, absorption of nutrients, and cycle metabolism. Biological treatment measures are to use the characteristics of aquatic organisms in the water to achieve the goal of reducing the content of nutrients such as total nitrogen, total phosphorus, and ammonia nitrogen in the water[10].

There are three main biological treatment measures. The first is the microbiological method: the use of effective groups of effective microorganisms in the water By adopting relevant technologies to activate, mix and cultivate the effective population of microorganisms, and through the use of effective microorganisms through microbial methods, the phenomenon of eutrophication of water can be effectively and quickly improved[11]. The second is the biological manipulation method: the mechanism of action is to use the lake’s own biota and the common adjustment of the habitat of the biota to maintain the relationship between various species in the system, and to a large extent reduce the amount of some plankton types. The third is the aquatic plant restoration method: a wide variety of aquatic plants in the aquatic ecosystem can improve the purification of water.

In many engineering construction, the restoration of submerged plant system to restrain eutrophication of landscape water is the most common technical measure. However, the restoration of submerged plants is often limited by the lack of transparency in the initial stage of construction. In order to solve this problem, engineers usually add PAC or PAM to the project water to achieve the treatment effect. However, this method is not effective in large landscape water. It is necessary to find an efficient biological treatment technology to provide good environmental conditions for submerged
plant restoration. Professor Chai Xiaoli of Tongji University invented the indigenous microbial activation technology guided submerged plant restoration technology, which effectively solved this problem.

3. Water ecosystem restoration based on IMA

3.1. Technical principle
Microbial activation is one of the main forms of the microbial method: according to the biofilm water treatment technology, an improved suspended filler is used to activate native microorganisms, cultivate dominant bacteria species in the water body, and make them multiply, and then release with the microcirculation of the water body into the water body, change the ecological balance of the original microorganisms, improve the environmental condition of the water body, and repair the polluted water body[12].

3.2. Technical characteristics
The traditional water treatment method is to first purify, treat, and then introduce into the water body. The IMA microbial activation engineering technology utilizes water microcirculation, where local microorganisms multiply in large numbers, break the balance of the original water body, and convert the entire water body into a bioreactor system to improve the water body in situ[13]. The microorganisms cultivated by the IMA microbial activation engineering technology can assist in degrading the pollutants in the bottom sludge and inhibit the release of nutrients contained in the bottom sludge, thereby effectively avoiding the outbreak cyanobacteria due to eutrophication, and this method of biological dredging[14] does not require the use of mechanical labor and other methods to reduce labor.

3.3. The relationship between microorganisms and algae in water
Traditional biological algae control methods mainly include filter-feeding fish algae control, aquatic plants algae control, and microbial algae control. It is a relatively economical and safe method for algae control[15]. Since the 1960s, microorganisms have been used to remove harmful blooms and cyanobacteria in landscape water. As potential organisms for the prevention and control of cyanobacteria blooms, microorganisms have attracted more and more researchers' attention[16]. Microbial control cyanobacteria technology is an ecological restoration technology that uses bacteria, fungi, viruses, protozoa and actinomycetes to control algal blooms to solve water environmental problems. Bacteria dissolve algae in two ways: direct or indirect action. Fungi mainly dissolve algae by secreting antibiotic substances and parasitic on algae cells. Viruses mainly dissolve the host algae cells by direct infection. Actinomycetes mainly inhibit the growth of various blooms of cyanobacteria by secreting antibiotics, enzyme inhibitors, alkaloids and other algae-lysing active substances. Protozoans control the population density of algae through feeding behavior. Compared with a single strain, the overall effect of the microbial flora has more advantages in controlling cyanobacteria blooms and purifying water quality[17]. Chen Jian[18] added the selected and cultivated indigenous microbial flora to the enclosed water body. After 4 days, the cyanobacteria biomass was reduced by more than 70% without a rebound. At the same time, the concentration of nitrogen and phosphorus in the water body also dropped rapidly. Deng Jianming[19] put an enriched and screened high-efficiency algae-lysing bacteria group into the water body, and found that it has a significant algicidal effect on both Microcystis aeruginosa and Nodularia.

The use of microorganisms to control algae is cheap, specific, safe, and maintains the ecological balance of landscape water. It is a promising method for repairing and purifying eutrophic.

3.4. The relationship between microorganisms and submerged plants
Aquatic plants are an important part of the water ecosystem, and the microbial system attached to the surface of submerged plants is also an important part of aquatic ecology. The activation of indigenous
microorganisms by submerged plants refers to the restoration or reconstruction of aquatic vegetation that pollutes landscape water to provide attachment substrates for water microorganisms, provide habitats and refuges for aquatic animal communities, improve water transparency and dissolved oxygen environment, and activate beneficial microbial communities in water, and strengthen the self-purification ability of landscape water[20-21].

Related experimental studies have shown[22] that in the submerged plant-microbe system, microorganisms play a key role in reducing nitrogen and phosphorus in water, and the direct absorption contribution rate of plants to nitrogen and phosphorus is 1.5%~13.3% and 2.2%~13.2%, the synergistic contribution rate of activating the microbial community through habitat improvement is 22.5%~29.9% and 10.1%~20.6%. Aquatic plants provide microbial attachment substrates, improve the oxygen environment of the water body (roots, stems, leaves), activate indigenous microorganisms and improve the structure and composition of the microbial community. The growth of aquatic plants directly absorbs and roots fixation, reducing the pollution of landscape water and sediments Material content and internal pollution release. The restoration or reconstruction of aquatic plants is often used as a core technology for eutrophication treatment, black and odorous water treatment, water ecological restoration, wetland restoration and other water environmental protection and treatment.

3.5. Current research results and successful application cases of IMA
In the application of IMA engineering technology, appropriate in-situ activation measures should be selected according to the service function of the water body, supplemented by aeration and oxygenation, growth promoters, etc., as appropriate, to optimize the microbial community structure and maintain the ecological integrity of the ecosystem.

At present, the IMA microbial activation project has been implemented in many southern cities, and good governance results have been achieved. For example, in the Daoxianglou Hotel in Hefei, the capital of Anhui Province[22], there is a landscape water body of about 10,000 square meters. One month after the IMA microbial activation project was treated, the water pollution in the hotel was basically eliminated. In Niushou Mountain Park in Nanjing, Jiangsu[23], the water body in the park is also seriously polluted. After one week of treatment by IMA microbial activation engineering technology, the water body condition has been greatly enhanced, and the water body transparency has also been improved. Junzhu River, located in the main urban area of Mawei, Fujian, its open channels and branch canals are black and smelly landscape water[24]. The IMA microbial activation project has also been implemented. With the stable operation of the IMA system, the local beneficial microbial communities have been significantly expanded. The number of consumer communities at the top of the food chain in Hanoi has increased significantly, water quality has gradually improved, and the water has increased its ability to withstand sudden pollution., the restoration goal of the water ecosystem has gradually achieved results.

4. Engineering application of IMA in Lotus Lake

4.1. Project Overview
The landscape water of the Lotus Lake is located inside the Lotus community of Shenzhen. The surrounding area of the project is a residential area with no obvious external source pollution. The water area is about 8000 square meters, the average water depth is 2m, and the deepest point can reach 4.5m. According to water quality monitoring, the total nitrogen is as high as 5mg/L. The eutrophication of the water is serious, and the algae erupts in some areas, which has caused the deterioration of water quality in the past, the smell of the water and the pollution of the atmospheric environment, which seriously affected the lives of nearby residents. The water quality is poor, and the pollutants exceed the self-purification capacity of the water, leading to the degradation of the water ecosystem.
According to the environmental investigation of Lotus lake, it has good ecological restoration conditions in general. The project design team set up two ima microbial activation systems in Lotus Lake to remove total nitrogen and total phosphorus in the water, control algae, and the IMA provide good environmental conditions for the restoration of submerged plants, improve the water quality of the project and present the beautiful water landscape.

4.2. Project technical scheme
According to the results of the preliminary site survey and test, the goal is to control the total pollution of the project area through the treatment of point source, non-point source, and endogenous pollution, and build a complete water ecosystem in the water body, so that it has good self-purification ability and has a certain degree After being polluted, it can recover itself in a short period of time, and has better landscape and ecological functions.

The project specifically adopts the method of "perfecting water ecosystem technology", making full use of the self-purification mechanism of healthy landscape water in nature, restoring and rebuilding the water body food chain, strengthening the decomposition of water body pollutants and the removal of nutrients such as nitrogen and phosphorus, so that the landscape water body always tends to be oligotrophic Chemical state, maximize the water body's own immunity and self-purification ability; at the same time, widely use the ornamental effects of various aquatic plants. The construction of aquatic ecosystem mainly includes the construction of aquatic vegetation system, the stocking of aquatic animals, the construction of water micro-ecosystem and the later maintenance of the ecosystem.

According to the current situation of the project, it is necessary to install two microbial activation equipment in the lake to improve the microbial activity of the water body, provide a better source of microorganisms for the lake area, and improve the self-purification ability of the lake area.

At the same time, in order to better realize the restoration of water ecosystem, after the installation of IMA equipment, 85.3% of submerged plants (Vallisneria and Malayan Potamogeton) were restored in the lake. In addition, 320kg silver carp, 80kg bighead carp and 120kg bellamya aeruginosa were added into the lake.

4.3. Process operation effect
The operation results show that with the stable operation of the IMA system, the local beneficial microbial communities have been significantly expanded, the number of consumer communities at the top of the food chain in the water has increased significantly, the water quality has gradually improved, According to the analysis of water quality testing data provided by Tsinghua University, the main water quality indicators have reached the class II water quality of GB3838-2002 after the implementation of the project. The transparency of the lake water reaches 2.0 ~ 2.5m, and the water ecosystem is gradually improved and maintained stable.
5. Conclusion

The comprehensive treatment of eutrophic landscape water in my country has achieved initial results. Practice has shown that the restoration of aquatic ecosystems is a key measure to continuously improve the quality of eutrophic landscape water. The water ecosystem restoration technology with IMA as the core can better promote the local beneficial microorganisms to become a dominant community, build a stable water ecosystem, and effectively improve the removal of river pollutants. The engineering application represented by the Lotus Lake shows that the water environment governance system with IMA as the core can gradually improve water quality, improve the stability of the water ecological environment, and achieve continuous improvement and stable maintenance of water quality. IMA is one of the effective technical means to prevent and control the eutrophication of landscape water in China in the future. It solves the problem of insufficient transparency of submerged plant restoration or difficult to maintain the later construction achievements, and has a good application space.

References

[1] Hong Lu, Jianying Yan, Yimin Zhang, et al. Artificial media abounding attached to the purification effect of organisms on nutrient-rich water bodies[J]. Journal of Ecology and Rural Environment, 2011, 27(3):76-81.

[2] Zhuojun Mo. A preliminary exploration of the nutrient-rich pollution and treatment technology of urban landscape water bodies[J]. Guangdong Chemical Industry, 2010, 37(7):239-240.

[3] Baoqing Shan, Honglei Liu. On-site experimental study of biological/ecological technology to repair water bodies in urban landscapes[J]. Journal of Environmental Engineering, 2008(05):128-132.

[4] Aihuan Gao, Hongying Li, Haifu Guo. The causes, hazards and prevention measures of the nutrient-rich water body[J]. Journal of Zhaoqing College, 2005, 26(5):41-44.

[5] Xiaoping Li. Research and management of the nutrionalization of lakes in the United States[J]. Journal of Nature, 2002, 24(2):63-68.

[6] Weimin Quan, Lijiao Yan, Zuoming Yu, et al. Advances have been made in the study of the lake's nutrient-rich model[J]. Biodiversity, 2001, 9(02):168-175.

[7] Jiumei Long. Evaluation of the nutritional status of leaping lake and research on ecological management technology[D]. Hunan Agricultural University, 2007.

[8] Shuyuan Tian, Jingfeng Wang, Tiezhu Lang, et al. Aquatic support tube plant treatment of sewage and its comprehensive utilization[J]. Urban Environment and Urban Ecology, 2000(06):54-56.

[9] G Landry M R , Ohman M D , Goericke R , et al. Lagrangian studies of phytoplankton growth and grazing relationships in a coastal upwelling ecosystem off Southern California[J]. Progress in Oceanography, 2009, 83(1-4):208-216.

[10] Todd A. Anderson, Barbara T. Walton. Comparative fate of [14C]trichloroethylene in the root zone of plants from a former solvent disposal site[J]. Environmental Toxicology and Chemistry, 1995.
[11] Wei Huang. Comprehensive treatment of cyanobacteria blooms and water body denutrientization[J]. China's rural water conservancy and hydropower, 2014, 000(004):44-50,54.

[12] Yoshikawa K., Adachi K., Nishijima M., et al. beta-Cyanoalanine Production by Marine Bacteria on Cyanide-Free Medium and Its Specific Inhibitory Activity toward Cyanobacteria[J]. Applied & Environmental Microbiology, 2000, 66(2):718-722.

[13] Šimek K., Pernthaler J., Weinbauer M.G., et al. Changes in bacterial community composition and dynamics and viral mortality rates associated with enhanced flagellate grazing in a mesoeutrophic reservoir[J]. Appl. Environ. Microbiol., 2001, 67(6):2723-2733.

[14] Lili Yang, et al. The effect of microbial bio-active technology on the restoration of water body in Beeling Park, Shenyang[J]. Journal of Liaoning University: Natural Science Edition, 2017, 43(2):79-82.

[15] Lee, T.J., Nakano, K., Matsumara, M. Ultrasonic Irradiation for Blue-Green Algae Bloom Control. Environmental Science and Technology. 2001.

[16] Hongqiang Wang, Baohong Li, Dongling Zhang, et al. Research on biological control techniques for algae[J]. Safety and environmental engineering, 2013, 20(5):38-41.

[17] TAYLOR F J R. Parasitism of the toxin-producing dinoflagellate Gonyaulax catenella by the endoparasitic dinoflagellate Amoebophrya ceratii[J]. Journal of the Fisheries Board of Canada, 1968, 25(10):2241-2245.

[18] Jiahua Yang, Zhihong Guo. Em technology and its application in water environmental protection[J]. Environmental science and technology, 2007, 30(6):112-114.

[19] Jian Chen, Jun Cong, Gaoyun Chen, et al. The use of effective microbiome to control cyanobacteria bloom research[J]. Journal of Environmental Engineering, 2010, 4(1):101-104.

[20] Jianming Deng. Study on the soluble algae effect and its action on copper-green microcystic algae[J]. Chengdu: Chengdu Institute of Biology, Chinese Academy of Sciences, 2009.

[21] Songhe Zhang, Tiantian Zhou, Yuansi Liu. The surface of the four aquatic plants in Xin kaihe is characterized by microbial community[J]. Water conservation, 2020, 36(3):83-88; 104.

[22] Shuquan Jin, Jinbo Zhou, Weihong Bao, et al. Comparison of nitrogen and phosphorus absorption and water purification capacity of 5 kinds of water-sinking plants[J]. Environment Science, 2017, 38(1):156-161.

[23] Hua Zou, et al. Research on clay in-place algae removal techniques[J]. Environment Science, 2009, 30(2):407-410.

[24] Xing Li, et al. Study on the efficacy of manganese copper compound algae remover inactivates copper-green microcystic algae[J]. Journal of Beijing Polytechnic University, 2009, 29(10):910-913.