Research on Water Environment Situation and Regulation Progress of Urban Lakes

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Abstract. Urban lake water environment management and water ecosystem restoration have always been research hotspots at home and abroad. However, there have always been different opinions on the water environment situation and water environment regulation of urban lakes at home and abroad. Based on the investigation of domestic and foreign water environment conditions, this study summarizes the research progress of different control measures of urban lakes and their respective advantages and disadvantages, and combines the research examples of domestic and foreign scholars to systematically analyze and organize the control of major urban lakes, with a view to provide a reference for the evaluation and restoration of urban lakes in the future.

1. Introduction

Domestic lake research mostly focuses on basin-type lakes, such as Taihu Lake, Dianchi Lake, Chaohu Lake, Dongting Lake, Poyang Lake, and there is little research on urban lakes. Urban lakes generally refer to small lakes located in urban or suburban areas of large and medium-sized cities. They have important functions such as regulating microclimate, reducing urban heat island effect, flood storage, providing cultural and sports entertainment, and regulating surface runoff[1-2]. These functions provide multi-dimensional value for economy, society, culture, and nature, and are the basic guarantee for the implementation of urban ecological construction and the implementation of the national ecological civilization top-level design strategy. However, due to the expansion and construction of cities, the impact of residents' lives, and the pollution of point and non-point sources, urban lakes have become one of the most severely affected ecosystems by humans[3]. Therefore, the control of urban lake water environment and the overall understanding of urban lake water environment regulation will play an important role in the water environment restoration of urban lakes in the future.

2. Urban lake water environment situation

The understanding of lake and reservoir ecosystem pollution is relatively early in foreign countries. In the 1940s, Hasler pointed out that with the development of industry and economic growth, the health of lakes and reservoirs will inevitably be affected by it[4].

According to a survey conducted by the United Nations Environment Programme (UNCD), 30%-40% of lakes in the world are affected by eutrophication to varying degrees. 53%, 28%, 48%, and 41% of lakes in Europe, Africa, North America, and South America respectively have different eutrophication phenomena, and 54% of lakes in the Asia-Pacific region are in a state of
eutrophication\cite{5}. Eutrophication is more serious in dry climates\cite{6}, and at least one third of the 800 lakes in Spain are in a state of heavy eutrophication. In South America, South Africa, Mexico and some other places, there have been reports of water weight eutr ophication. There are many lakes in Canada, and most of the lakes with eutrophication are concentrated in densely populated areas, and about 3/4 of the lakes are in a state of eutrophication. 80% of the 96 lakes in European statistics are in a state of eutrophication\cite{7}. The pollution of lakes in Asia varies greatly from north to south, and most of the lakes in the south are more eutrophication, especially in developing countries in Southeast Asia\cite{8}.

At the beginning of the 21st century, the water quality of more than 80% of the lakes in the country was in Grade IV or worse than Grade V, and more than 75% of the lakes had problems with eutrophication\cite{9}. In 2005, in a survey of 133 lakes in my country, more than 85% of lakes were facing eutrophication problems, and 60% of the lakes and reservoirs that were focused on were in Category IV or worse than Category V\cite{10}. According to statistics\cite{11}, during the 13th Five-Year Plan period, of the 111 important lakes (reservoirs) monitored for water quality, 7 lakes (reservoirs) with Class I water quality, accounting for 6.3%; 34 Class II, accounting for 30.6%; Class III 33 There are 29.7%; 19 are in category IV, accounting for 17.1%; 9 are in category V, accounting for 8.1%; 9 are inferior to category V, accounting for 8.1%. The main pollution indicators are total phosphorus, chemical oxygen demand and permanganate index.

The water quality survey data of major lakes across the country shows that 80% of urban lakes have reached a eutrophication state, and 30% of them have reached a super eutrophication state\cite{12}. The biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorus (TP), total nitrogen (TN) and non-ionic ammonia of more than 90% of urban lakes in my country have exceeded the national water environmental quality four types of standards\cite{13}.

3. Study on the regulation of urban lake water environment

3.1 Physical control

3.1.1 Water diversion replacement

Water diversion replacement is mainly a physical purification method. By introducing a body of water with better water quality into the lake to be repaired, it can be mixed. On the one hand, it improves the hydrodynamic conditions of the lake. On the other hand, it mainly dilutes the concentration of nutrients and pollutants to increase Water self-purification ability\cite{14}. For example, Green Lake, Moses Lake in the United States\cite{15}, Hangzhou West Lake in my country, and Xuanwu Lake in Nanjing all adopt clear water diversion measures, and alleviate the trend of water quality deterioration\cite{16-17}. The treatment advantages of this method: short cycle, quick effect, and can improve internal source pollution to a certain extent. Disadvantages: high requirements on the quantity and quality of the water source for diversion; the effect duration is short.

3.1.2 Sediment dredging

Sediment dredging is the most direct and effective way to reduce the internal source load\cite{18-20}. In the early 1970s, large-scale sediment dredging projects were carried out in lakes such as Teganuma and Kasumigaura Lake in Japan, and Lake Erie in the United States\cite{21}. Lake Trumen in Sweden and Zierikzee Bay in the Netherlands\cite{22} have also achieved better water quality improvement after sediment dredging projects. Among them, the average biomass in Lake Trumen was reduced by 87% after sediment dredging, and the phosphorus content was reduced by 90%\cite{23}. Most lakes and reservoirs in our country are facing a serious threat of endogenous sediment pollution\cite{24-25}. The domestic Wu Zhiying\cite{26} research on the dredging of Hangzhou West Lake’s sediment shows that the relevant indicators of West Lake eutrophication have improved to varying degrees after dredging. The content of nitrogen and phosphorus in the sediments of each layer has been reduced, and the algae biomass has been controlled. Through a one-year dredging simulation test, Zhong Cheng et al. found
that under the premise of effective control of exogenous phosphorus, sediment dredging is one of the effective technical means to reduce the load of endogenous phosphorus\cite{27}. However, there is still considerable controversy whether the method of sediment dredging is feasible for lake pollution remediation\cite{28,29}. For example, Ruley et al. believed that after the sediment was dredged, the phosphorus in the sediment was released to the water body to the previous level, which further deteriorated the water quality\cite{30}. Some scholars also believe that the dredging of lake sediments will lead to a series of ecological and environmental problems such as the release of toxic substances, resuspension of sediments and the destruction of the benthic community structure\cite{31,32}.

3.1.3 Underwater push
The aeration and reoxygenation technology is to artificially fill the water body with air, accelerate the reoxygenation process of the water body, ensure the aerobic environment of the water body, strengthen the activity of aerobic microorganisms, and play the role of degrading the pollution load\cite{33}.

In the 19th century, the United Kingdom used mobile aeration equipment to solve the problem of black and odor of the Thames water body and restore its original ecological function\cite{33}, thus opening a way for in-situ restoration of polluted water bodies in rivers and lakes. Since the 1950s and 1960s, developed countries such as Britain, Germany, and the United States have gradually applied oxygenation and aeration technology to control river and lake pollution\cite{34}. In 1965, Germany used floating oxygenation equipment to achieve better water purification effects on the Ruhr River. After the 1970s, the Emscher River, the Fulda River and the Berlin Teltow Canal in Germany used pure oxygen aeration facilities for river and lake pollution control\cite{35}. Among them, the German Emscher River put the aeration system on the river bed in the form of "aeration pads", and the oxygenation efficiency could reach about 70%. By 1988, the water pollution problem was basically solved. The fulda river is designed to automatically turn on when the dissolved oxygen content of the water body is lower than the limit to save operating costs. The Teltow Canal uses BIOX technology to increase the dissolved oxygen from 6.3mg/L to 7.8mg/L, and the oxygen utilization rate is 38%-44%\cite{36}. In 1987, the United States installed aeration equipment in the Mississippi River, which effectively reduced the black and odor of the river and controlled the growth of algae\cite{37}. The Port of Santa Cruz in the United States, the Swan River in Australia, and the Oeiras River in Portugal use different aeration equipment, all of which have achieved good water quality treatment effects\cite{38,39}.

According to the analysis of preliminary experimental data, As shown in Figure 1, the concentration of total nitrogen and total phosphorus fluctuates greatly at a distance of 10 meters from the thruster. The overall change trend of total nitrogen tends to be stable, and the concentration of total phosphorus is obviously lower than 50m near the thruster 3 meters.

![Figure 1. Figure with the changing trend of nutrient salt concentration in water body under the action of underwater thrust](image-url)

my country's research on push-flow aeration technology started relatively late. In the early 1980s, my country independently developed domestic aeration equipment, but there were disadvantages such as low aeration efficiency, high energy consumption and high cost\cite{41}. In 1990, my country applied the aeration and oxygenation technology to the treatment of Beijing Qinghe earlier. After 47 days of operation, the black and odor of the river was basically eliminated. Later in 1996, based on the
analysis and summary of the causes of Suzhou Creek pollution, the push-flow aeration technology BIOX process was applied to the downstream water bodies of Xinjing Port, a tributary of the Suzhou Creek. The COD removal rate reached 19.5%-55.6%, and the black odor was weakened and recovered. The ecological function of Suzhou Creek

3.2 Chemical control
Chemical control is a method of removing pollutants in water by adding chemicals to the water. Such as adding algaeicides, hydrogen peroxide, potassium hydrogen persulfate, quicklime and other agents to the water body to improve the water quality of rivers and lakes. Main advantages: quick results and simple operation. Disadvantages: There is a certain risk, and it is easy to cause secondary pollution.

3.3 Biological-ecological regulation
Bio-ecological restoration technology is a pollution control technology that developed rapidly in the 1990s. In 1938, German scholar Seifert put forward the concept of "near natural river management", marking the beginning of river ecological restoration. In 1965, Emst Bittmann used reeds and willow branches to protect the banks of the Rhine, which was regarded as the earliest practice of ecological restoration. Bio-ecological restoration technology mainly uses plants, microorganisms or protozoa to realize the process of material and energy exchange, absorption, conversion, and degradation during the growth and reproduction process to achieve the purpose of purifying the water body and restoring the ecological functions of the water. Bio-ecological restoration technology considers the principle of being close to natural restoration, relying on natural self-balancing ability or supplemented by artificial measures, and evolving in the direction of a virtuous circle. There are two common biological-ecological restoration methods:

3.3.1 Aquatic plant restoration
Aquatic phytoremediation mainly relies on the growth of higher aquatic plants and the metabolism of microorganisms attached to their rhizosphere to reduce pollutants in water bodies. The main performance aspects: absorption of nitrogen and phosphorus nutrients, enrichment of certain metal ions and organic matter, synergistic degradation with microorganisms, gas transmission and release, and the biochemical effects on algae.

Since 1820, foreign botanists have begun to use aquatic plants to repair water bodies. For example, it has been applied to Lake Biwa in Japan, Lake Constance in Germany and Moon Lake in Austria, and has achieved very good governance effects. In 1967, the Netherlands established a large number of surface undercurrent wetlands dominated by aquatic plants. In the late 1990s, European countries such as Denmark, Germany, and the United Kingdom began to build a large number of subsurface wetlands.

Domestic research on aquatic plant restoration technology started relatively late. Since the 21st century, a lot of research has been conducted on aquatic plant restoration technology in water ecological restoration. Liu Aibao applied the integrated ecological restoration technology to a landscape water body in Nanjing. After restoration, the transparency of the water body reached more than 80cm, and the coverage rate of submerged plants reached more than 60%. Lu et al. conducted experiments on the removal of pollutants by constructing five submerged wetlands and found that the purification effect on COD was the most significant, with a removal rate of 53.44%-62.08%. Meng et al. found that the submerged plant Potamogeton crispus has a significant purification effect on organic matter pyrene in water. Zhang Meng et al. used aquatic phytoremediation technology in Wuhan East Lake and Fruit Lake, and the transparency of the repaired water body was significantly improved, and the water quality was greatly improved.

For submerged plants to purify landscape water bodies, scholars have conducted a lot of research. According to the analysis of preliminary experimental data, as shown in Figure 2, the removal effect of total phosphorus in water bodies is obvious at a distance of 10-20 meters from the planting area. The effective radius is 20 meters. The removal effect of total nitrogen is not obvious. The
concentrations of total nitrogen and total phosphorus reached their lowest values at a distance of 20 meters from the submerged plant planting area. Regarding the long-term removal effect, further observations and experimental studies are needed.

Figure 2. Figure with the trend of Nutrient Salt in Water Body under the Action of Submerged Plant

3.3.2 Restoration of aquatic animals

The use of aquatic animals for water purification has always been a research hotspot at home and abroad. By using water bodies such as mussels, snails, herbivorous zooplankton and fish to regulate phytoplankton, reduce suspended solids in water bodies and achieve the purpose of water purification[60].

The biological chain regulation technology was first proposed by Shapiro et al. on the basis of the enlightening preliminary work done by Brooks and Dodson. By constructing a biological chain of bacteria-algae-plankton-fish, fish production is used to reduce nutrient salt concentration and algae biomass[65]. For example, Liu Jiankang[62] et al. used silver carp and bighead carp to directly control the water bloom of Microcystis in East Lake. Wang Xiaofei[63] et al. found that the removal rates of total nitrogen, total phosphorus and chlorophyll a reached 69.9%, 59.2% and 92.2% when the filter-feeding fish silver carp and the aquatic plant Myriophyllum sp. were used in combination. Fei Zhiliang et al. [64] found that the elimination rate of suspended solids and chlorophyll a by Hyriopsis mussel reached 76% and 94%, respectively, and the water transparency increased nearly twice.

4. Conclusion

Urban lakes are an important part of the urban landscape. The domestic research on urban lake water environment control has made certain research progress. There are many domestic urban lake water environment control methods, and there have been many successful application cases, but these control studies mostly focus on applications. Less than considering its impact on ecological and environmental benefits.

The regulation of urban lake water environment mainly includes physical regulation, chemical regulation and biological-ecological regulation. Among them, the underwater push flow in the physical control measures can improve the hydrodynamic conditions of the lake, improve the concentration of dissolved oxygen in the lake, and the operating cost is low. Biological-ecological regulation follows close to nature and relies on the self-balancing ability of the ecosystem to naturally restore water bodies. These two methods can be used as key research methods for subsequent urban lake restoration.

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