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# Application of artificial wetland technology in Miyun reservoir water management

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**Abstract.** In recent years, with the increasing attention to environmental pollution, water quality management has become an important part of protecting water resources and maintaining ecological balance. And as an important means of water pollution remediation, artificial wetlands have gradually received widespread attention. Miyun Reservoir, as an important drinking water source in Beijing, is particularly important for water quality management. As an ecological restoration technology, artificial wetland has significant water quality improvement effect by simulating and improving the function of natural wetland. Therefore, artificial wetland has important scientific research and practical significance in the water management of Miyun Reservoir. In this paper, we will discuss the application of artificial wetland in water management of Miyun Reservoir, and summarise the results and conclusions of the study, highlight the impact and significance of the study, and look forward to the future research direction. By exploring the application of artificial wetlands in reservoir water management, it is expected to provide scientific basis and technical support for water resource management departments and decision makers, and contribute to the improvement of water quality and ecological restoration of Miyun Reservoir.

**Keywords:** Sewage Treatment, Constructed Wetland, Rock Wool.

## 1. Introduction

Miyun Reservoir is one of the important water sources in Beijing, located in Miyun County, Beijing, with a total reservoir capacity of 523 million cubic metres. The construction and operation of the reservoir has provided Beijing with a large amount of drinking water and industrial water. However, with the acceleration of urbanisation and the increasing population, the water quality problems of Miyun Reservoir are becoming more and more prominent, bringing serious threats to the water source and ecological environment.

The water quality problems of Miyun Reservoir mainly include the exceeding of organic matter, nitrogen, phosphorus and other pollutants and eutrophication. These pollutants mainly come from three causes. Firstly, industrial wastewater discharge and agricultural surface pollution around Miyun Reservoir are one of the main causes of water quality problems. Industrial wastewater contains substances such as organic matter and heavy metals, while agricultural surface pollution mainly comes from the use of chemical fertilisers and pesticides, as well as breeding wastewater in farmland.

Secondly, the discharge of urban domestic sewage is also an important cause of water quality problems in Miyun Reservoir. With the growth of the urban population, a large amount of domestic

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sewage is discharged directly or indirectly into the Miyun Reservoir or its neighbouring water bodies after treatment in sewage treatment plants, leading to deterioration of water quality.

Finally, the chemical and physical properties of the reservoir itself also affect water quality. Minerals in the strata of the Miyun Reservoir and changes in the water level, as well as seasonal rainfall, may lead to changes in the concentration of dissolved substances in water body, thus affecting water quality[1].

Currently, the water quality problems of Miyun Reservoir are mainly managed by traditional methods. However, these methods have certain limitations. Firstly, traditional wastewater treatment plants usually treat domestic wastewater, and it is difficult to effectively treat industrial wastewater and pollution from agricultural sources. Secondly, the cost of chemical treatment methods is high, and the chemical substances produced during the treatment process may cause secondary pollution to the environment, which is not conducive to sustainable development. Finally, these methods can only be limited to local treatment, and cannot fundamentally solve the water quality problems of Miyun Reservoir [2].

Compared with the traditional treatment methods, the artificial wetland technology has the advantages of simple operation, economic applicability and environmental friendliness, which has potential application value in the water treatment of Miyun Reservoir. By simulating the ecological environment and biological process of natural wetland, artificial wetland can effectively purify the pollutants in the water body and improve the water quality.

Artificial wetland technology can be applied to the treatment of different pollution sources, including the treatment of industrial wastewater, the treatment of agricultural pollution and the treatment of urban domestic sewage. Through the construction of artificial wetland, it can reduce the concentration of organic matter, nitrogen, phosphorus and other pollutants in Miyun Reservoir, improve the water quality index, and reduce the pollution of the reservoir.

In addition, the artificial wetland has ecological functions, which can provide habitats and food sources for amphibious animals in the reservoir and promote the increase of biodiversity in the water body.

However, the application of artificial wetland technology in water management of Miyun Reservoir faces some challenges. How to reasonably design and arrange the artificial wetland and select suitable wetland plants and substrate materials need in-depth research and practice. In addition, the maintenance and management of artificial wetland also need to consume certain human and material resources[3].

## 2. Overview of Artificial Wetland Technology

Artificial wetland technology is a technology that makes use of the principles of natural ecosystems, such as plants and soils, to improve water quality and treat wastewater by constructing artificial wetlands to simulate the functions of natural wetlands. Artificial wetland can be defined as a special kind of ecosystem which removes pollutants from wastewater in a natural way and restores the water body to a better condition through the interaction of plants, microorganisms and soil[4].

### *2.1. Surface-flow wetland*

Also known as free-surface wetland, wastewater flows freely over the surface of the wetland. The wetland vegetation and microorganisms attached to the surface treat the wastewater through adsorption, biodegradation and sedimentation.

### *2.2. Horizontal Submerged Wetland*

Horizontal Submerged Wetland is a wastewater treatment system in which the wastewater percolates downward through a horizontal percolation layer in the root zone of the wetland plants. In a horizontal submerged wetland, wetland plants and microorganisms distributed in the percolation layer work together to convert pollutants such as organic matter, nitrogen and phosphorus in the wastewater into harmless substances.

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### *2.3. Vertical Submersible Wetland*

Vertical Submersible Wetland is a wastewater treatment system in which wastewater is injected from above into the soakaway layer, where it percolates downward and is eventually collected. Vertical submerged wetlands usually contain multiple layers, and wastewater flows between these layers and is treated by wetland vegetation and microorganisms.

### *2.4. Combined artificial wetland system*

This is a wastewater treatment system that combines different types of artificial wetlands, as shown in table 1. For example, surface flow wetlands are combined with horizontal submerged wetlands or vertical submerged wetlands to achieve more efficient wastewater treatment.

**Table 1.** Comparison of different wetlands.

| Property | Surface-flow wetlands | Horizontal submerged wetlands | Vertical submersible wetlands |
|---|---|---|---|
| Water flow | Surface diffusion | Horizontal flow under substrate | Surface to substrate bottom |
| Hydraulic load | Relatively low | High | High |
| Decontamination effect | General | Good removal of organic matter and heavy metals | Good removal of N and P |
| System control | Simple, highly influenced by the seasons | Relatively complex | Relatively complex |
| Environmental conditions | Foul odour in summer, breeding mosquitoes and flies | Favourable | Foul odour in summer, breeding mosquitoes and flies |

## 3. Miyun Reservoir Artificial Wetland Construction Programme

Miyun Reservoir is located in Miyun County, Beijing, as shown in figure 1. The terrain is mainly influenced by the Beishan Mountain Range and the peaks of Shifoshan and Daguanshan. The following is an analysis of the topography of Miyun Reservoir.

**Figure 1.** Figure with short caption (caption centred).

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### *3.1. Mountain features*

The terrain around Miyun Reservoir is very undulating and mainly consists of the Beishan Mountain and the surrounding peaks. The North Mountain is one of the main water sources of Miyun Reservoir. The mountain range is east-west oriented, with high elevation, steep topography and many ravines and valleys between the mountain ranges.

### *3.2. River features*

Miyun Reservoir is formed by the convergence of many rivers, such as the Bailong River, which form special geological landscapes such as canyons and gorges under the extrusion of the Beishan Mountain Range.

### *3.3. Plains*

Miyun Reservoir is surrounded not only by mountain ranges, but also by some relatively flat areas, including farmland and some grasslands. These plains are of great significance to the water quality protection of Miyun Reservoir.

### *3.4. Distribution of water bodies*

Due to the undulation of mountains and the influence of rivers, the distribution of water bodies in Miyun Reservoir presents complex topographic features, including lake bays, rivers and small islands.

### *3.5. Geological structure*

The area around Miyun Reservoir is mainly composed of gneiss, schist, gravel and other rocks, with complex geological structure and geological phenomena such as faults and caves. To sum up, Miyun Reservoir has a large undulation of topography, and the existence of mountain ranges and rivers has an important influence on its topographic features. Therefore, in the construction of artificial wetland, the following characteristic schemes can be adopted.

*3.5.1. Specific artificial wetland combination system.* Miyun Reservoir has several intakes, mainly including Xiaobei River intake, Bailong River intake and Slant River intake. Xiaobei River intake is located in the southeast of Miyun Reservoir. Xiaobei River is one of the main water intake channels of the reservoir, and its water source comes from the mountainous area in the north of Miyun County. The specific location of the intake is at the confluence of the Xiaobei River and the reservoir. The Bailong River intake is located in the southern part of Miyun Reservoir. The Bailong River is also one of the main water intake channels of the reservoir, and its water source mainly comes from the mountainous areas in the region of Miyun County. The intake is located at the confluence of the Bailong River and the reservoir. The inlet of the Slanted River is located in the northeastern part of the Miyun Reservoir. The Slanted River is a tributary of the Reservoir, and its water source mainly comes from the mountainous areas in the eastern part of Miyun County. The location of the intakes is at the confluence of the Slanted River and the reservoir. The schematic design of this artificial wetland is shown in figure 2.

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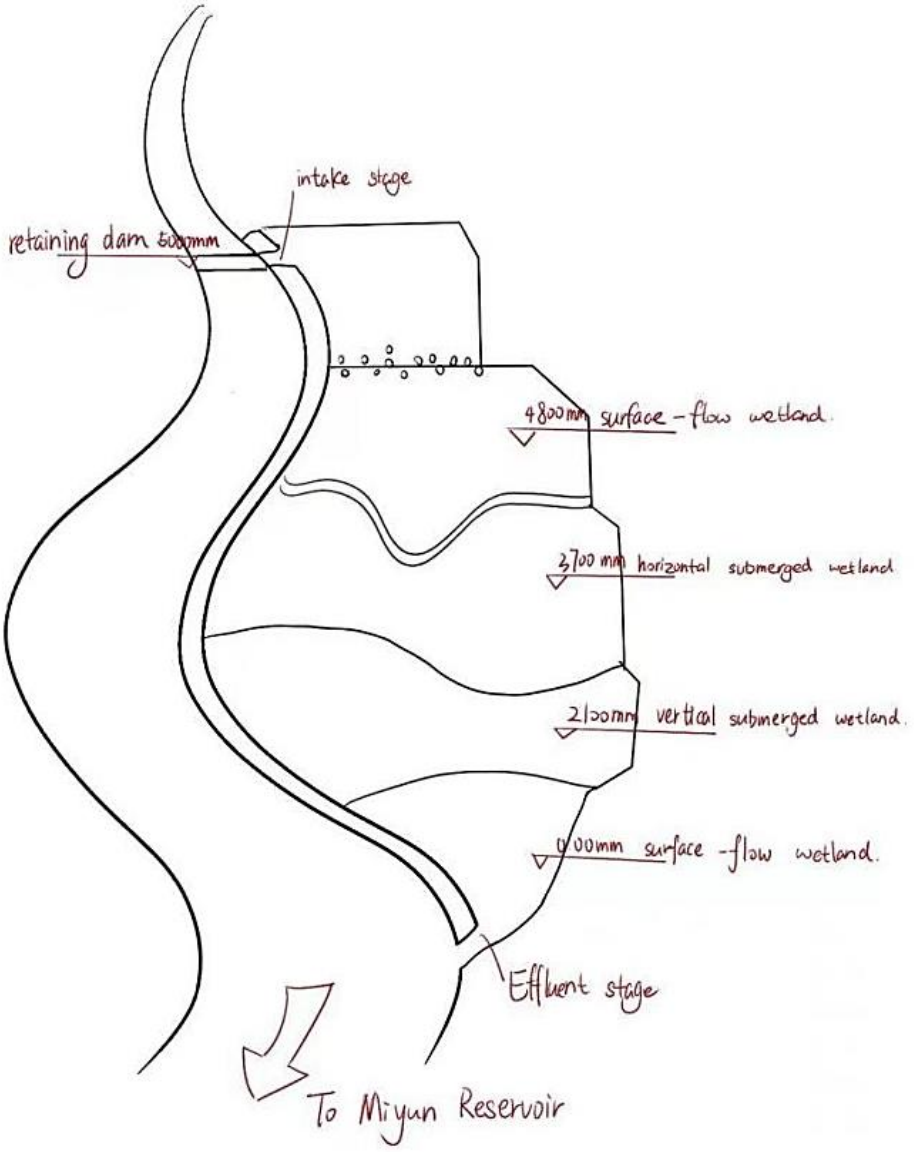


**Figure 2.** Schematic design of this artificial wetland.

*3.5.2. Barrage.* The design concept of barrage is mainly inspired by the Dujiangyan Water Conservancy Project of Li Bing, a famous water conservancy engineering expert in China during the Warring States Period (475 B.C.-221 B.C.)[5]. The barrage was built at several suitable locations upstream of the Miyun Reservoir inlet, aiming to regulate the amount of water entering the artificial wetland, so that any river water entering the wetland can be effectively purified. The height of the barrage and the shape of the inlet are determined according to the area and treatment capacity of the artificial wetland. In order to save cost, the construction materials used for the barrage can be mainly considered to apply the large stones dug out during the levelling of the artificial wetland, supplemented by reinforced concrete. The exterior design of the barrage should meet the aesthetic requirements. Through the roles of intercepting flow in the dry season and overflowing flow in the abundant season of the check dam, the amount of water entering the artificial wetland in the dry season is guaranteed, and the damage of water impacting the artificial wetland during flood is avoided .

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*3.5.3. Surface flow wetland layer.* According to the actual situation of the selected site, the specific design of the surface flow wetland layer is as follows: firstly, it is determined that the wetland is located at the entrance of the wetland, covering an area of about 1,000 square metres in order to ensure the reception and treatment of the inflowing water. Secondly, plants adapted to the local climate and soil conditions are selected, such as prosperous wisps and fragrant bushes, which can effectively purify the water quality. Then, the structure of the wetland is designed with inlets and outlets, and water flow is controlled using channels and overflow valves. In addition, according to the depth and flow rate of the reservoir, set the appropriate water depth and water flow rate to maximise the removal of pollutants. Finally, water quality monitoring equipment is equipped to continuously monitor the water quality indicators of the wetland and take timely measures to ensure the normal operation of the wetland and the effective removal of pollutants.

*3.5.4. Horizontal submerged layer.* According to the actual situation of the selected site, the specific design of the surface flow wetland layer is as follows: firstly, it is determined that the wetland is located at the back of the surface flow wetland, covering an area of about 1,000 square metres to ensure the reception and treatment of inflowing water. Secondly, plants adapted to the local climate and soil conditions, such as traditional witch hazel and cattail, are selected to be able to purify the water effectively. Then, the structure of the wetland is designed with inlets and outlets, and water flow is controlled using channels and overflow valves. In addition, according to the depth and flow rate of the reservoir, set the appropriate water depth and water flow rate to maximise the removal of pollutants. Finally, water quality monitoring equipment is equipped to continuously monitor the water quality indicators of the wetland and take timely measures to ensure the normal operation of the wetland and the effective removal of pollutants.

*3.5.5. Vertical submerged flow layer.* According to the actual situation of the selected site, a vertical submerged flow wetland layer is designed. The site is selected in the low-lying area, which is the downstream of the horizontal submerged layer, with an area of about 1000 square metres. Grids are installed at the inlet to remove large impurities. The interior of the wetland is designed with multiple layers of gravel and sand for filtering and dispersing the water flow. Plant vegetation is used for biodegradation treatment, such as wetland plants like reeds, udon, and fragrant bushes. An aquifer is provided at the bottom to collect and temporarily store the purified water. Permeable soil covers the surface to help water infiltration and plant growth. A monitoring system is equipped to monitor water quality indicators to ensure that the wetland layer operates properly, effectively removes pollutants, and improves the water quality of the reservoir.

Because there is a height difference of about 5m in this type of site selection, water pumps will not be needed. This design not only reduces energy consumption, but also protects the ecological environment to a certain extent.

*3.5.6. Artistic surface flow wetland.* According to the actual situation of Miyun Reservoir, in order to enhance the ecological function of the reservoir, several large surface flow wetlands are designed. These wetlands are set up at suitable locations around the reservoir with unlimited area. The wetlands are separated from the water body in the reservoir by cofferdams, so that the water will be full in during the abundant water period, while the wetland layer can retain some water during the dry water period, forming a small ecosystem.

To ensure the effectiveness of the wetland, designing an inlet grate can effectively remove large impurities from the water. This prevents impurities from adversely affecting the plants and organisms inside the wetland. Inside the wetland, shallow water and shallow areas suitable for aquatic plants are designed, for example, plants such as lotus root and goldfish grass are chosen. These plants not only beautify the landscape of the wetland, but also provide habitats and breeding places. At the same time, the bottom of the wetland is also equipped with sprinklers and spraying devices to create a water-mist

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climate environment suitable for birds' activities, attracting more wild birds to come here for feeding and roosting [6].

In order to strengthen the boundary and barrier function of the wetland, it is designed to plant perennial plants, such as reeds and cattails, at the edge of the wetland. These plants can beautify the environment and effectively block the flow of water, forming the boundary and barrier of the wetland. During the dry season, the wetland will retain some of the water, forming a small ecosystem. This ecosystem can support a number of organisms such as birds, insects and small fish, providing a place for them to breed and feed.

In order to facilitate visitors' viewing and resting, walkways and viewing platforms at the edge of the wetland are designed. Visitors can stroll through them to enjoy the beauty of the wetland and at the same time observe the birds and other organisms in the lake. At the same time, a water quality monitoring system is set up to monitor the water quality inside the wetland. This allows for timely monitoring of the changes in the water body, safeguarding the ecological environment of the wetland and the stability of the water quality.

Overall, the specific design of the surface flow wetland inside the Miyun Reservoir has fully considered the environmental and ecological characteristics of the reservoir. It not only enhances the ecological function of the reservoir and improves biodiversity, but also provides a viewing and resting place for visitors. Through reasonable design and management, this wetland layer can become an important part of the reservoir ecosystem.

In practice, if the water level of the wetland cannot be guaranteed during the dry season, pumps can be added to draw water from the reservoir, and the water level in the wetland will infiltrate and return to the reservoir, which also locally realises the function of vertical submerged wetland.

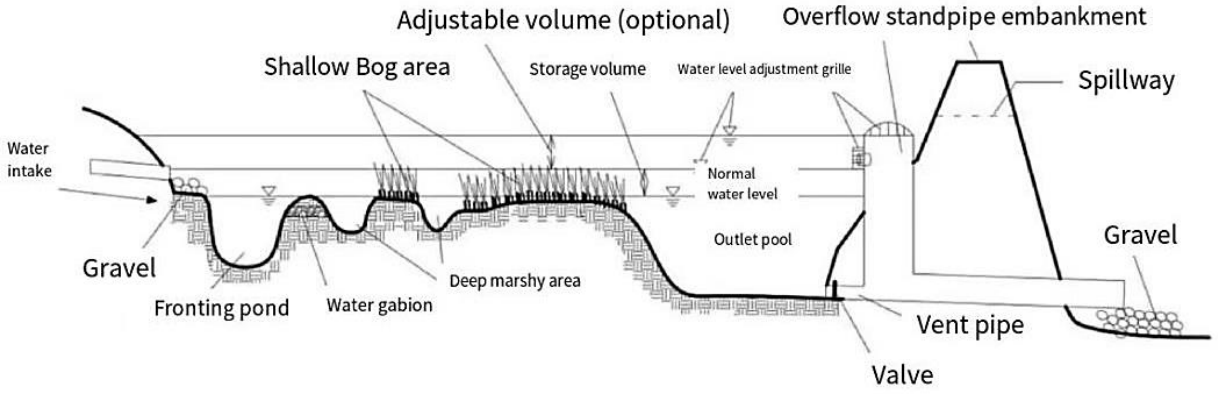


**Figure 3.** Schematic design of cross-section structure [6].

*3.5.7. Selection of plants.* The selection of plants can be seen in table 2. In the table, long-term flooding tolerance refers to the ability of plants to live in a flooded environment (>0.5m) for a long period of time. Short-term flooding tolerance: refers to the ability of plants to live in a cyclically fluctuating flooded environment (<0.5m). Drought tolerance: refers to the ability of plants to live in a water-deprived environment [7]. Solid circle refers to strong plant capacity. Circle refers to average plant capacity. Triangle refers to poor plant capacity.

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**Table 2.** Selection of plants.

| | Latin name | LID Facility use | Long-term flooding tolerance | Short-term flooding tolerance |
|---|---|---|---|---|
| 1 | *Cortaderia selloana* | Low marsh, high marsh | ● | ● |
| 2 | *Cortaderia selloana Pumila* | Low marsh, high marsh | ● | ● |
| 3 | *Colocasia antiquorum* | Alternate wet and dry zone | ○ | ● |
| 4 | *Colocasia tonoimo* | Alternate wet and dry zone | ○ | ● |
| 5 | *Colocasia gigantea* | Alternate wet and dry zone | ○ | ● |
| 6 | *Canna glauca L* | Alternate wet and dry zone | ○ | ● |
| 7 | *Canna generalis* | Alternate wet and dry zone | ○ | ● |
| 8 | *Zingber officinalis* | High marsh | ○ | ● |
| 9 | *Cperus alternifolius* | Alternate wet and dry zone | ○ | ● |
| 10 | *Saccharum arundinaceum* | Alternate wet and dry zone | ○ | ● |
| 11 | *Mariscus cyperinus* | Low marsh, high marsh | ○ | ● |
| 12 | *Lythrum salicaria* | Alternate wet and dry zone | ○ | ● |
| 13 | *Iris Louisiana hybrids* | Low marsh, high marsh, alternate wet and dry zone | ○ | ● |
| 14 | *Iris pseudacorus* | Low marsh, high marsh | ○ | ● |
| 15 | *Iris ensata* | Low marsh, high marsh | ○ | ● |
| 16 | *Pontederia cordata* | Low marsh, high marsh | ○ | ● |
| 17 | *Thalia dealbata* | Low marsh, high marsh | ○ | ● |
| 18 | *Scirpus tabernaemontanni* | Low marsh, high marsh Alternate wet and dry zone | ○ | ● |
| 19 | *Scirpus validus Zebrinus* | Low marsh, high marsh Alternate wet and dry zone | ○ | ● |
| 20 | *Ayundo donax* | Bioretention facilities, infiltration ponds, wetlands, dry ponds | ○ | ● |
| 21 | *Ayundo donax var.versicolor* | Bioretention facilities, infiltration ponds, wetlands, dry ponds | ○ | ● |
| 22 | *Phragmite saustralis* | Low marsh, high marsh Alternate wet and dry zone | ● | ● |

## 4. Use of new materials

Nowadays, various kinds of materials beneficial to water treatment keep appearing, which can be used in the design scheme of artificial wetland in Miyun reservoir, such as rock wool and other new materials. Rock wool is a kind of rock ore melting, fibre made, its main raw material is basalt and other rock ore, through the high temperature melting and adding the appropriate amount of binding agent, and then through the high-speed rotary method or jetting method will magma sprayed into the air, so that it quickly becomes a fine fibre. These fibres are collected and pressed into rock wool products in the form of sheets, felts, tubes and other forms [8].

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The special structure of rockwool can also be used to increase the growth and diversity of aquatic plants in reservoirs. Different types of plants, such as shallow water plants and wetland plants, can be grown on rockwool. In addition, the pore structure of rockwool can provide microbial populations to provide habitats and reproduction, strengthening the water purification ability of microorganisms and helping to improve the water quality of the reservoir [9].

Rockwool materials can be used to construct artificial islands or floating islands to increase the ecological function and landscape effect of the reservoir. Artificial islands can be planted with plants suited to the watershed environment, create wetland and lakeshore zone ecosystems, provide habitats for birds and other animals, and increase the landscape appeal of the reservoir [10].

The use of rockwool in the Miyun Reservoir also improves the efficiency of water use in the reservoir. Through its ability to absorb and retain water, rockwool can reduce evaporation of water from the reservoir and loss of water storage, increasing the water use efficiency of the reservoir. In addition, rainwater collection facilities can be installed on the surface of rockwool for collecting and storing rainfall water sources, further improving the water utilisation efficiency of reservoirs.

In summary, the application of rock wool and other new material materials in the Miyun Reservoir can not only improve the ecological environment and water quality of the reservoir, but also improve the stability of water quality, biodiversity and water use efficiency of the reservoir.

## 5. Conclusion

By thinking about the application of artificial wetland in water management of Miyun Reservoir, it is found that the artificial wetland has significant effect in improving the water quality and ecological environment of the reservoir. According to existing studies, artificial wetlands can remove pollutants such as organic matter, nutrients and heavy metals from the reservoir through mechanisms such as the absorption of plants and the degradation of microorganisms, which can effectively improve water quality. In addition, artificial wetlands can provide suitable habitats and food resources to promote the reproduction and growth of aquatic organisms. The application of artificial wetland in water management of Miyun Reservoir is of great significance. Firstly, it can effectively improve the water quality of the reservoir, reduce the input of pollutants and improve the quality of the water environment of the reservoir. Secondly, the artificial wetland can also increase the ecological function and landscape effect of the reservoir, and improve the biodiversity of the waters and landscape attractiveness. In addition, artificial wetlands can be used for storing and utilising rainwater to improve the efficiency of water resources utilisation. Therefore, it is of great social, economic and ecological significance to study and apply artificial wetlands in the water management of Miyun Reservoir. Although some progress has been made in the current research on the technical solutions for the application of artificial wetlands in Miyun Reservoir, there are still some problems and challenges. Future research can further explore the construction and management methods of artificial wetlands, optimise plant selection and configuration, and improve water purification efficiency. In addition, the combined application of artificial wetlands and other water management technologies can be studied to explore more integrated and efficient water management solutions. In addition, the long-term maintenance and management of artificial wetlands also need to be studied in depth to ensure their lasting and stable water quality improvement effect. Finally, research on the relationship between artificial wetlands and socio-economic development can also be carried out to explore the contribution of artificial wetland construction to the sustainable development of local economy and society. Through these studies, the application of artificial wetlands in water management of Miyun Reservoir can be further expanded and provide experience and reference for water management of other reservoirs.

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