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Wastewater Treatment Appliances for Urban Constructed WQT Wetland Landscaping

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Abstract. Shortage of water resources has become one of vital problems world widely, so improvement for making more sufficient use of urban tailwater is one of significant issues for environmental engineering as well as landscaping. With different technologies and various of its types, constructed wetlands can be applied to purify lightly polluted water. Urban water quality treatment (WQT) wetland is an economical and efficient infrastructure for tertiary wastewater treatment, which would be potential once its purification capabilities could be developed. Three principles, including ecological, service, and aesthetic principles, have been concluded in this research. In addition, relationships among practical landscape design strategies of constructed WQT wetlands and other factors, including its water treatment performance, simulation analysis and landscape aesthetics, should be applied in practical landscape design, which will enable them to play a key role as one of nature-based solutions (NBS) in future.

Keywords. WQT wetland, wetlands landscaping, wastewater treatment, urban constructed wetlands

1. Introduction

Shortage of water resources has become one of vital problems world-widely with increasing water consumptions. Meanwhile, light-polluted tailwater from urban sewage treatment plants should be treated based on specific processes, for diverse types of tailwater holds distinctive chemical constituents. Thus, improving means for making more sufficient use of urban tailwater will be one of significant issues for environmental engineering, urban planning, as well as landscape architecture.

For there has been increasingly vital acquirements of in-depth urban wastewater treatments, more attentions should be paid to tailwater purification by local and low-impact methods. For instance, "the circular economy of water treatment", which has raising in recent decade, can be explained as a new practical method based on 5R principles [1]. The ecological tailwater treatment technology has clear distinctions from the traditional ones, with its extremely comprehensive and interdisciplinary characteristics, which involves all aspects of majors related to urban environmental

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design and construction, i.e., civil engineering, water conservancy engineering as well as landscape architecture.

2. Wastewater Treatment and Constructed WQT Wetland

2.1. Wastewater Treatment Abilities of Constructed WQT Wetlands

The concentration of certain pollutants in the wastewater discharged after secondary treatment is still obviously remarkable, for tailwater has limited self-purification abilities. At present, the water quality indicators (WQI) of urban sewage treatment plants focus on BOD_5, COD_{Cr}, SS, TN, TP and other conventional indicators, which cannot meet the needs of ecological environment protection and human health and safety [2], and water qualities fail to meet WQI standards.

Urban constructed water quality treatment (WQT) wetland is one of most effective methods to purify domestic and industrial wastewater while also be suitable for deep purification of urban tailwaters. Since 1950s, Germany has been the first country to evaluate the pollutant removal capabilities of the urban constructed WQT wetland treatment system. When the pollutant concentration or load is within the wetland purification threshold range of 80% - 99%, the pollutant removal capabilities of the urban constructed WQT wetland is better than other solutions [3].

2.2. Wastewater Treatment Technologies of Constructed WQT Wetlands

Toxic and harmful chemicals in wastewater and sewage cannot be completely removed by adapting traditional wastewater treatment processes, while higher energy consumption and costs would need in the artificial treating processes. However, urban tailwater which meets the WQI standards may still hold considerable concentrations of pollutants, and the sensory indicators of water quality such as odor and clarity are also unsatisfactorily controlled [4]. It has been shown that high concentrations of organic matter, i.e., nitrogen (N) and phosphorus (P), often occur in both domestic sewage and industrial tailwater. N in domestic sewage and industrial tailwater are nitrate nitrogen and ammonia nitrogen. Both dissolved and granular nitrogen can migrate through surface runoffs or between waterbodies and groundwater through unsaturated zones [5]. P is often adsorbed on sediment particles and organic matter and accomplish migrations, from terrestrial ecosystem to aquatic ecosystem in particulates and dissolved states with runoffs.

Existed research has shown that the growth of aquatic plants in freshwater systems is more limited by phosphorus much more than nitrogen [6]. While the advanced treatment methods of urban tail water in my country are limited to the traditional chemical oxidation method and/or activated carbon adsorption method, thus, both N and P in the first-level A effluent standard of the sewage plant often reach a prominent level. Otherwise, the use of chemical oxidation, activated carbon adsorption and other treatment methods has the disadvantages of high construction costs and technological difficulties. By integrating the physical, chemical, and biological technologies in the constructed wetlands, an ideal water environment that comprehensively absorbs, transforms, and degrades pollutants can be created (Table 1).

Table 1. Water purification technologies of urban constructed WQT wetland and target pollutants.

Technologies of wastewater purification	Main types of pollutants to be treated
Microbial action	N, P, pathogen, metal
Sedimentation	P, carbide
Deposition	S, metal
Flocculation	Dissolved organic carbon, pathogen
Plant absorption	N, P
Volatilization	Toxic organic compounds

2.3. Comparations among Diverse Types of Constructed WQT Wetlands

In the ecological practices conducted in the recent decade, the types of urban constructed wetlands can be divided into the following types: surface flow wetland (SF), subsurface flow wetland (SSF), floating wetland island system (FWI) and complex pre-treatments (CP). Ammonia, nitrogen, phosphorus, suspended matters, and metals are pollutants that are ubiquitous in domestic sewages and tailwater produced by urban sewage treatment plants. For WQT effects of polluted water bodies, factors such as types of wetlands, scales and layouts of wetlands, types of aquatic vegetation and their density, have strong impacts on constructed wetlands, respectively. In a general way, the types of wetlands have a greater impact in purification effects than other factors (Table 2).

Table 2. Water purification technologies of urban constructed WQT wetland and target pollutants.

Types	Methods to remove Pollutants	Advantages	Disadvantages
Surface flow wetland (SF)	Pollutants can be removed by the microbial film on the stems of plants growing underneath water	Low cost, easy for operation and management	Runoffs in the watershed must be stable; lacks positive impacts on biodiversity, limited nitrification abilities
Subsurface flow wetland (SSF)	Use fillers for interception, vegetation root absorption and surface biofilm for degradation and digestion.	High pollutant removal rate, less affected by temperature, better moisturizing effect and good sanitary conditions	Hard for Management, higher costs
Floating wetland island (FWI)	Utilize the attached organisms to absorb N, P and other pollutants	Good inhibitory effect	Occasions for engineering practices are more restricted
Complex pre-treatments (CP)	Adsorption and removal of pollutants such as P and heavy metals with gravel, iron and Aluminum mud	Preliminary interception and purification of pollutants before migrating to main sections of wetlands	Only suitable for preliminary pollution control of non-point source polluted sewage

Surface flow wetland (SF) system has integrated characteristics, including wastewater treatment, waterfront wildlife protection, waterfront recreation area construction, and good runoff stability, which has potential for being integrated with landscape design.

Subsurface flow wetland (SSF) system uses aquatic plants as the surface layer, owns high use rate in practical treatments, and is more convenient for managing compared with SSF. However, the form of its integration with landscape construction is slightly simpler, and its ability to remove ammonia in sewage is lower [7].

Floating wetland island (FWI) system has the advantages of less secondary pollution risks, low cost, no need to occupy land, and creating good habitats for organisms. FWI can produce good landscaping effects when arranging plants with different florescence [8].

Complex pre-treatments (CP) system, which can be constructed based on natural ponds, creeks, rivers according to local conditions, shall integrates technical measures including surface runoff collection, interception, and settlement.

3. Wastewater Treatment and Constructed WQT Wetland

Certain types of basic principles can be adopted in constructed WQT wetland landscaping, includes ecological, service, and aesthetic principles, which are of major help for landscape architects to put up design strategies with proper guideline of ecological wastewater treatments. Principles and strategies of WQT wetland landscaping can be concluded as follow:

3.1. Ecological principles

It can be concluded that several ecological principles should be followed in landscape design of constructed WQT wetlands. Firstly, WQT wetlands can make full use of the self-organised WQT ability of natural-form waterbodies and physiological purification capacity of plants. The insoluble organic matter in polluted waterbodies, usually includes domestic sewage and tailwater from sewage plants can be absorbed by plants' roots or biodegraded through the precipitation and filtration of plant communities [9].

Moreover, by the absorption effects of gravels, pebbles, and soils in the bottom side of purification ponds and waterfronts, in which the species composition and structures of the riparian plant buffer zones can also affect the purification effects of constructed wetlands as "filter" and "barrier" [10]. It should be highlighted that some of these stages can be integrated with landscape design and engineering, which could effectively increase the ecological value in landscaping design projects.

3.2. Service Principles

There are various approaches to introduce water-purifying constructed wetland landscaping into cities. By organically connecting urban rivers with existing ponds, depressions, wetlands, and other ecological patches, designing urban constructed wetlands, integrating wetlands and natural low-lying areas in the urban space into the urban green space system [11]. Furthermore, WQT wetlands can be developed in coordination with the urban drainage networks and urban rainstorm system to relieve the serious situations of flooding in the rainy season, keep the water level in dry seasons. Its water purification effect is better than conventional sewage treatment facilities with the same construction costs and can promote the formation of waterfront vegetation belts and biological habitats in landscaping zones.

3.3. Aesthetic Principles

For the aesthetic value of the landscape, different forms of waterbodies, such as concave banks, meanders, islands, shoals, pools, can be arranged in landscaping, due to the various changes in layouts of waterbodies [12]. By adapting ecological water purification measures with specific node designs, i.e., buffers, green infrastructures, should be designed based on spatial visual guidance to create natural views with a certain aesthetic value. It can also significantly offer recreational facilities for the public, creating more areas for sightseeing by integrating with landscape design, especially for waterfront landscape recreational belts.

4. Relationships among Design Strategies and Related Factors

4.1. Relationships between WQT Performance and Landscaping

For the composition of different ecological treatment processes is different from each other, types of pollutants being targeted are also different. Also, the efficiency of purification technologies is also limited by the climate and topographic conditions of the site [13], for which their applicability would be obviously distinctive.

In practical wetland design, especially integrated ones which combines landscape design and wastewater treatment engineering, landscape architects often adapting design by their own experience, which lacks quantitative guidance. Consequently, strategies for ecological treatment process of sufficient WQT effects for diverse sites are vital in landscaping engineering, which is also the focus to optimise operation and management of wetland systems with practical landscape design.

4.2. Relationship between Simulation Analysis and Landscaping

Once the correlation analysis between WQT wetland landscaping and its water purification effectiveness be conducted, more specific analysis can be conducted to study the water quality characteristics of mild sewage discharged from different urban sewage plants in various regions, distinctive types of urban constructed wetlands which would be selected for water purification effect comparison. Specific design practices should be adapted based on water quality simulation (i.e., ECOLAB software) and hydrodynamic simulation (i.e., MIKE11 software). Relying on related parameters [14], landscape design of constructed WQT wetlands can be perfected, and the detailed application of wetlands in tailwater treatment can be conducted to guild practical design.

4.3. Relationships between Landscape Aesthetics and Landscaping

In addition to the value of ecological optimization, urban constructed wetland also has its service function as one part of urban green infrastructures (GI) [15]. Although WQT landscaping projects have potentials in being combined with water engineering projects, most of current wetland landscape designs have ignored these advantages but based on subjective judgements and insignificant amounts of experience, while relevant supporting strategies which could guide design practices should be summarized by scientific methods. Further, landscape aesthetics can commonly be evaluated by quantifying the scenic beauty index (SBI) in scenic beauty estimation (SBE) process.

5. Conclusion

As a typical representative used of WQT engineering, urban constructed WQT wetland ecosystems should be designed to ease pollution problems that would not be harmful to urban ecosystems, as wetland ecosystems are managed as copies to purify pollutants for the benefits of urban built environments by its self-organisation characteristics [16]. Abilities of water purification by urban constructed wetlands play a key role as one nature-based solutions (NBS).

For adapting urban constructed wetland landscaping in practical WQT engineering, the functional requirements of water quality improvement and other aspects, must be considered simultaneously, including its design principles, design strategies and its relationships among other factors, i.e., WQT performance, simulation analysis, landscape aesthetics, etc. Related domains, such as the refined and specialised managements of urban water resources, better use of the tailwater purification function of wetlands, as well as landscape design integrated with its unique values on landscape aesthetics, should be studied thoroughly by landscape design practices in future.

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