Abstract. This paper describes a pilot study aimed to use constructed wetland (CW) technology for urban lake water treatment to maintain water quality. A SFS (Surface Flow Wetland) and/or a FWS (Subsurface Flow Wetland) CW was continuously operated in autumn and winter. The results were then compared and the factors to affect the results were examined. The results showed that, regarding the overall level of the system stability and the pollutants removal efficiency, SFS constructed wetland is better than the FWS wetland. The average removal efficiency of SFS wetland is 84.2% for COD, 53.8% for NH3-N, 47.9% for TN, 73.3% for TP and 86.6% for SS. It is noted that the NH3-N, TN removal rate is not high in single-stage wetlands. Therefore, some novel actions and other ecological processing technologies such as multi-stage wetland system, effluent recirculation etc should be introduced.

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Keywords: constructed wetland; urban lakes; water pollution; water quality

1. Introduction.

The rapid urbanization, industrialization, and highly accelerated economic development in China have resulted in excessive water consumption and degradation of water resources. Serious water pollution reduces the use of water features, increasing pollution-induced water shortage city, further aggravated the water shortage[1]. Some urban lakes (like Taihu lake, Chaohu lake, Dianchi lake) and landscape lake water ecosystem are impaired due to point and non-point sources which originate from a wide variety of human activities[2]. The pollution caused the process of eutrophication is more aggravated, the water environment function is degraded, the carrying capacity of water environment is reduced, the amount of water for ecosystem need is hardly assurance. Rely on the conventional centralized energy- and cost-
intensive technology (physical—chemical-- biological treatment) has proved to be rather limited and not entirely feasible. It is practically urgent to consider new, cheap and environmentally friendly approaches to solving these serious problems[3].

Constructed wetlands (CWs) offer a cheaper and low-cost alternative technology for wastewater treatment[4]. At the same time, it could contribute in creature variety protection, environmental education and feature tourism. It can also help the cities a good service as all important portion in the system of ecological landscape. The system, undoubtedly, promotes sustainable use of local resources, which is a more environment friendly biological wastewater treatment system and landscape water quality maintain system[5,6].

The objective of this study was to examine the performance and effectiveness of CWs for an urban lake, namely Xing-qing Lake in central Xi’an city, Shaanxi province, China, water quality control and water quality maintenance. Results from the experiment of SFS and FWS constructed wetland in autumn and winter with a continuous operation was presented.

2. Methods And Materials

2.1. The design of CWs

The experimental time from October 3, 2007 to November 24, 2007, under the conditions of hydraulic loading 0.5m3/(m^2•d), the water depth 0.7m. The CWs was set up using a three-side PVC and one-side Pyrex plate with dimensional size of 1.8m×0.6m×1.0m, the bottom slope is 1%. The CWs treatment system consists of an influent tank, a water distribution area, a surface flow wetland and a subsurface horizontal flow CWs, a catchment area (Fig. 2-1). By the side near the wetlands pool, the uniform installed porous tube make the water distribution and catchment. Catchment area includes the free surface flow above and the subsurface flow below, with a snorkel between the two areas, to ensure that subsurface catchment areas and the level of the external air pressure balance. The end of the catchment area has free surface water and a subsurface flow outlet, respectively. The depth of wetland substrate is 0.7m .From the bottom up, respectively, 0.4m sized gravel, 0.15m coarse sand and 0.15m local soil. Phragmites australis collected from a river bank outside Xi’an city were planted on the top of the CW (see Fig. 2-1).
2.2. Analysis of experimental raw water quality

Xing-qing Lake, located in the Imperial palace park of Xi’an city, Shaanxi province. The lake was planned and built in 1956, the average water depth is 1.6 m with maximum depth of 2.0 m. The water volume of 170,000 m³ for normal season and 270,000 m³ for flooding season, respectively. As the Lord King of the park, Xingqing lake with the function of sightseeing, tourism, flood control, disaster mitigation, conservation of groundwater resources, beautify the urban environment. In recent years, a large number of residential areas around the lake and sewage runoff into the lake led to serious pollution. After comprehensive treatment in 2003 for Xingqing lake, the water quality has greatly improved. The majority of the urban landscape water quality indicators have been consistent with the water quality standards for Class C, however, solely relying on dilution of dredging and water diversion projects and other measures cannot fully maintain the landscape water quality. The water quality (see Table 2-1) of the lake is still not optimistic, moreover, the trend has continued to deteriorate.

2.3. Water sampling analysis

The experimental treatment target was raw water in urban lakes, CODcr, TN, TP, NH3-N and SS was measured. The CW in and out water were collected and analysed periodically for COD, NH3-N, NO2-N, NO3-N, TN, TP, pH and SS. COD was measured using a Hach DR/4000 spectrophotometer. The TP analysis was based on TP was determined by spectrophotometry Mo-Sb. NH3-N, NO2-N, NO3-N, TN, pH and SS All the parameters mentioned above were determined according to the method as described in the Standard Method for Examination of Water and Wastewater[7].

Table 2-1 Water quality of Xing-qing Lake

| Parameter | Range (mg/l) | Mean (mg/l) | Parameter | Range (mg/l) | Mean (mg/l) |
|-----------|--------------|-------------|-----------|--------------|-------------|
| SS        | 65—331       | 198         | TP        | 0.34—1.43    | 0.885       |
| pH        | 7.21—8.75    | 7.98        | TN        | 0.43—1.86    | 1.15        |
| CODcr     | 59.5—135.0   | 97.22       | NO3-N     | 0.15—0.44    | 0.295       |
| NH3-N     | 1.41—5.65    | 3.53        | NO2-N     | 0.13—0.79    | 0.46        |
3. Results And Analysis

3.1. Overall treatment efficiency

After the sewage was introduced into the wetland through sedimentation, filtration, adsorption, microbial decomposition and plant uptake the concentration of pollutants was decreased significantly. It can be seen from Fig. 3-1, two wetland COD, TP, SS removal were satisfactory, with SFS wetland for removal of type 84.2%, 73.3%, 86.6%, FWS wetlands removal rate was 80.4%, 74.9%, 85.6%. The SFS constructed wetland demonstrate good CODcr removal capacity than the FWS constructed wetlands, but the removal rate of NH3-N is not high, TN, TP, SS removal efficiency of similar levels. Both subsurface flow and free surface flow have a high SS removal rate.

The two wetlands, however, the purification efficiency for TN and NH3-N are poor. In the SFS and FWS, the average TN removal rates were 47.88%, 49.28%, on average NH3-N removal 53.77% and 59.54%. This was mainly due to a direct effect of temperature and seasonal variation of nitrogen ammonification, nitrification and denitrification process, thus affecting the wetland nitrogen removal. Substrate at low temperature microbial enzyme activity will be inhibited, resulting in the enzymatic reaction is slow, thereby affecting the degradation of nitrification and nitrogen-containing organic compounds[8]. Conversely, at higher temperatures leaves and roots of plants has been enhanced metabolic activity, local microbial metabolic activity also enhanced, so the increase of NH3-N and TN removal rate [9].

Fig. 3-1 Overall performance of the SFS and FWS construct wetland system

3.2. Effects of hydraulic retention time on treatment performance

It can be seen from Fig. 3-2, 3-3, HRT in the 0~48h, the two constructed wetland contaminant removal efficiency increased with longer HRT gradually increased, the best HRT is 48h. The SFS and FWS's best hydraulic residence time is 48h, the maximum COD removal rates reached 82.48% and 76.9% in 48h, SS removal rate reached the maximum 85.63% and 83.97% for the. The TP and TN removal efficiencies, whereas, in the 0~72h HRT as has been slow to improve, but the overall effect is not very good. Horizontal subsurface flow constructed wetlands in the removal of NH3-N reached the maximum 40.25% at 48h, free surface flow in the maximum removal rate of 57.66% at 72h. Then the level of NH3-N
removal rate reduced with the HRT prolong, because the residence time is too long, the system is hypoxia, inhibited nitrification, resulting in the removal rate decreased[10]. Overall, at the same level of HRT under the conditions of SFS wetland contaminant removal efficiency is better than the FWS wetland.

Fig. 3-2 Effects of HRT on the performance of the SFS construct wetland system

Fig. 3-3 Effects of HRT on the performance of the FWS construct wetland system

Fig. 3-3 Effects of HRT on the performance of the FWS construct wetland system
3.3. Effects of season (temperature) on treatment performance

When experiment in autumn, the outdoor temperature is 4~23°C, average 13.5°C; water temperature is 11.6~19.3°C, average 15.5°C. In winter, outdoor temperature is -5~17°C, the average 6°C; water temperature is 1.8~12.6°C, average 7.2°C. Fig. 3-4 shows the SFS and FWS constructed wetland in winter COD, SS removal rate slightly higher than in autumn, indicating that the COD, SS is not dependent on temperature. It may be due to the removal of organic matter and SS is mostly a result of the microbial activity of aerobic and anaerobic bacteria. Even at low temperature case, because the porous matrix and the role of plant roots in a common insulation, making the internal temperature of wetlands higher than the outside world, so the activity of bacteria can be maintained [11,12]. The TP removal efficiency in FWS constructed wetlands in the winter increase larger, from 55.7% to 73.7%, in addition to phosphorus adsorption matrix, the more important is the plant harvested in winter makes the phosphorus from the wastewater and wetlands been removed [13]. SFS are subject to lower of the temperature and TP, NH3-N, TN removal efficiency showed a decline. For the temperature changes consistent with the seasonal changes, throughout the experiment the FWS wetland removal less stable.

Fig. 3-4 Effects of season on the overall performance of the two construct wetlands system

4. Discussion

As an ecological landscape water, the ecological system's main features of urban lake are: eco-systems are imperfect, self-repair capacity is weak; water environment capacity is small, the water carrying capacity is low; frequent human disturbance, anti-pollution is poor. In many Chinese urban landscape water environment, CW technology as a low-cost technology to maintain water quality has been widely used. The SFS and FWS wetland were carried out in pilot experiments in Xingqing lake, Shaanxi Province, and achieved certain results, the results are consistent with the literature. However, results processing efficiency from the above, we can see that the use of single-stage constructed wetland treatment process to purify the water quality is difficult to achieve the desired result. Which is required in the implementation of the project fully grasp the actual situation in order to optimize the combination, can satisfactory treatment results. Constructed wetland treatment technology coupled with other ecological
processing, recycling of constructed wetlands and wetland complex multi-level may be a direction of concern.

Constructed wetlands and the ecological floating bed coupling can cash crops, while in the effective management of eutrophication harvest agricultural products, while in the process of governance can beautify the water landscape, can also play a positive role in promoting the diversity of aquatic development. In China, Zhan et al. [14] study use ecological floating bed-easy wetland complex system on the eutrophication of water purification effect, the results show that the combined system of purification significantly higher than single ecological floating bed or simple wetland system. Zhu[15], Li[16] have other similar studies. Many experimental results show that the longer the wetland HRT, the better pollutant removal capacity. Studies have shown that recycling of sewage effluent treatment can improve the removal of pollutants, especially compared with TN removal good. Kantawanichkul[17] and other studies have shown that a combination of artificial wetlands, wastewater recycling treatment can improve the removal of pollutants, especially compared with TN removal good. Stefanakis and Tsihrintzis [18] and Zhao et al. [18] reported the similar results. The system can not only loop wetland effluent treatment can also pay for cleaning the lake, help promote nitrification, enhancing the role of dissolved oxygen.

In addition, the multi-stage constructed wetlands can be set blocks of wetland according to the lake terrain, wetlands between the pipe connected to form a series constructed wetland system, and set the installation of artificial fountain or waterfall between several wetlands, so that oxygen in the air can enter the water body in the formation of dynamic 'living water' landscape, both to strengthen the removal of pollutants, and to strengthen ornamental value and social benefits [20,21]. It has practical application prospect.

Conclusion

Constructed wetland can be as a landscape water maintenance technique. The application not only considers its technical feasibility, but also focuses on its economic rationality, aesthetic characteristics and other factors. In this study, Xi'an Xingqing Lake, for example, the SFS and FWS constructed wetlands operating results were compared. The results showed that the overall level of SFS wetland removal and stability is better than the FWS wetland. SFS wetlands COD, NH3-N, TN, TP, SS, the average removal efficiency was 84.2%, 53.8%, 47.9%, 73.3%, 86.6%; FWS wetland COD, NH3-N, TN, TP, SS, the average removal efficiency was 80.4%, 59.5%, 49.3%, 74.9%, 85.6%, single-stage constructed wetland for NH3-N and TN removal capacity greatly reduced in winter. Therefore, the article mentioned in the constructed wetland treatment technology coupled with other ecological processing, recycling of constructed wetlands and multi-level complex constructed wetlands as a new direction remains to be elucidated.

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