Study on the Effect of Porous Subsurface Flow Constructed Wetland on Sewage Purification

Xinyue Zhou, Yancheng Han*, Yuelei Wang, Pingping Chu, Mengyuan Liang

Department of hydraulic engineering, School of Water Conservancy and Environment, Univ. of Jinan, Jinan 250022, China

*Corresponding author’s e-mail: stu_hanyc@ujn.edu.cn

Abstract. In this paper, a new porous subsurface flow constructed wetland was developed to remove BOD, TN and TP from sewage. A water inlet is arranged at the front of the wetland 0.25m and 0.45m from the ground. The design has the characteristics of simple structure and uniform water distribution, which makes the wetland easy to construct and improve the removal effect of pollutants. The results showed that the average removal rates of BOD, TN and TP in the wetland system were 85.63%, 80.29% and 89.07%, respectively, when the average temperature was 26℃ and the hydraulic retention time was 1.3d. The removal effect is good, which can play a certain ecological and social benefits.

1. Introduction

Water is an indispensable natural resource for the development of human society. However, with the expansion of cities and population growth, water pollution has gradually become an important factor affecting the sustainable development of society, especially in the north of China, where water resources are scarce, the problem of water pollution needs to be solved. In this case, as a new sewage treatment technology with low investment, low energy consumption, simple maintenance and high pollutant removal efficiency, constructed wetland has been paid more and more attention and developed rapidly [1]. It is widely used in the fields of industrial wastewater treatment[2], domestic sewage treatment[3] and lake ecological restoration[4].

Wetland is called "the kidney of the earth", which has the functions of purifying water quality, adjusting climate, storing flood and preventing drought, protecting biodiversity and so on. Constructed wetland is an engineering wetland system which uses soil, substrate, plant and microorganism to purify sewage in accordance with the construction of natural wetland[9]. The common constructed wetland includes subsurface flow constructed wetland and surface flow constructed wetland, but the traditional subsurface flow constructed wetland has the problem of uneven water distribution, which affects the effect of sewage treatment. Therefore, this paper introduces a new type of porous subsurface flow constructed wetland with more uniform water distribution. Based on the study of the removal effect of pollutants by the constructed wetland, the advantages of the system compared with other wetland systems are analyzed, so as to provide a reference for the practical application of the porous subsurface flow constructed wetland in wastewater treatment.

2. Test device and method

2.1. Test device
The constructed wetland adopts horizontal subsurface flow structure, and the test device is made of stainless steel. The structure is shown in Figure 1, with length × width × height of 1m × 0.8m × 0.6m respectively. Two inlets are arranged at the front of the wetland, with a height of 0.25m and 0.45m from the ground respectively. Wetland filler is divided into three layers, the lower layer is 25cm thick gravel with a diameter of 25-35mm; the middle layer is 20cm thick vermiculite with a diameter of 15-25mm; the top layer is 10cm thick soil.

The selection of aquatic plants should follow the principles of strong pollution resistance, good decontamination effect, suitable for local environment, developed root system, strong resistance to diseases and pests, beautiful appearance and economic value[8]. Based on the comprehensive consideration, calamus with developed root system, good decontamination ability and easy management was selected, and the planting density was 25 plants / m².

![Figure 1. Structure of proposed wetland.](image)

### 2.2. System operation

Synthetic water is used to simulate the quality of sewage in the test. See Table 1 for the influent quality.

| Property                | BOD     | TN      | TP      |
|-------------------------|---------|---------|---------|
| Concentration (mg/L)    | 172.52~186.46 | 42.31~51.63 | 2.16~2.98 |
| Average concentration (mg/L) | 179.49 | 46.97   | 2.57    |

The test adopts the continuous water inlet mode, the hydraulic retention time is 1.3d, and the average temperature during the test is 26℃. After the wetland plant growth and operation are stable, water samples will be taken at the wetland outlet every three days for determination and determination items include BOD, TN and TP.

### 3. Results and analysis

#### 3.1. Analysis of BOD removal effect

Organic matter in constructed wetlands comes from organic matter in sewage, plant root secretions and humus, which mainly exists in volatile, dissolved and solid state [10]. Plant absorption has a certain contribution to the removal of organic matter, but most of the organic matter in sewage is still removed through the metabolic process of microorganisms [5].

Figure 2 shows the removal effect of BOD. It can be seen from the figure that the purification effect of the whole system on BOD is relatively stable and good during the test. The BOD
concentration of effluent is between 23.11mg/L and 28.23mg/L, and the average removal rate is 85.63%.

![Figure 2. BOD removal effect.](image)

3.2. Analysis of TN removal effect

Nitrogen will lead to eutrophication of water body. Eutrophication of water body will not only lead to the growth of algae in the water, but also make the oxygen content in the water drop sharply, which will affect the survival of aquatic organisms such as fish. The removal ways of nitrogen include ammoniation, nitrification and denitrification, volatilization and adsorption [6].

Figure 3 shows the TN removal effect. It can be seen from the figure that the TN removal effect of this system is relatively stable. The TN effluent concentration is between 8.56mg/L and 10.68mg/L, the average removal rate is 80.29%, and the removal effect is good.

![Figure 3. TN removal effect.](image)
3.3. Analysis of TP removal effect

Phosphorus is also the key substance of eutrophication. In the process of sewage treatment, the form of phosphorus is mainly phosphate in organic compounds and inorganic compounds. The removal methods include sedimentation and adsorption, plant absorption, microbial absorption, etc.[7].

Figure 4 shows the removal effect of TP. It can be seen from the figure that the wetland system has a significant removal effect on TP. The effluent concentration of TP is between 0.23mg/L and 0.33mg/L, with an average removal rate of 89.07%.

![Figure 4. TP removal effect.](image)

4. Conclusion

In this paper, a new type of porous subsurface flow constructed wetland is proposed. The constructed wetland itself has certain ornamental value. Compared with other wetland systems, this constructed wetland system is more uniform in water distribution, which can improve the efficiency of sewage purification, and has simple structure and is easy to construct.

The test results of wetland system show that the removal rate of three pollutants is relatively stable. The average removal rate of BOD is 85.63%; TN is 80.29%; TP is 89.07%. The removal effect is good and has certain ecological and social benefits.

References
[1] Niu, Y.F., Ma, X.Y., Lv, L.Y., Yu, M. (2009) The Wetland Used in Tannery Effluent Treatment. J. Leather Science and Engineering, 6: 35-38.
[2] Lai, C.M., Meng, Q.J. (2018) Review on the Progress of Industrial Wastewater Treatment by Constructed Wetland. J. Environmental Science Survey, 5: 75-83.
[3] Liang, K., Wang, Q.S., Wang, H.F., Liang, W. (2014) Research Progresses in Domestic Wastewater Treatment by Constructed Wetlands. J. Journal of Agro-Environment Science, 3: 422-428.
[4] Weng, B.S., Yan, D.H., Zhao, Z.X., Zhang, C., Wang, G. (2010) Roles of constructed wetland system in lake ecological restoration. J. Chinese Journal of Ecology, 12: 2514-2520.
[5] Ye, J.F. (2007) Research on Removal Mechanism for Pollutant in Vertical-Flow Constructed Wetland. D. Shanghai: Tongji University.
[6] Wang, B., Qi, P.S., Liu, Y.Z., Li, Y.L. (2017) Nitrogen removal mechanisms and influence factors in subsurface flow constructed wetlands. J. Applied Chemical Industry, 2: 350-355.
[7] Li, Y. (2016) Purified Efficiency and Transformation of Phosphorus through Integrated Vertical Flow Constructed Wetlands. D. Chongqing: Chongqing University.

[8] Wu, J.Q., Ding, L. (2006) Study on treatment of polluted river water using pilot-scale surface flow constructed wetlands system. J. Environmental Pollution & Control, 6: 432-434.

[9] Zhao, H.S. (2019) The development and application prospect of constructed wetland. J. Modern Agricultural Science and Technology, 7: 167+174.

[10] Yang, Y. (2013) Treatment of the organic matters of the polluted river water in constructed wetland. D. Xi’an: Xi’an University of Architecture and Technology.