The Research on In-situ Bioremediation Technology of Polluted Urban River

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Abstract

According to the water quality characteristics of the polluted river course in the city, slope wetland system (SWs) and submerged plant combination technology were used for in-situ restoration. It is found that moderately prolonging hydraulic retention time (HRT) is beneficial to the removal of pollutants. At the same time, the optimal combination of submerged plants and the slope wetland reactor are coupled. Coupling device at HRT = 5d, the best removal efficiency of COD, NH_3-N, TP and TN was 37.43%, 39.5%, 41.43% and 38.52%, respectively. It is found that the coupling of the two processes is conducive to the recovery of polluted river water quality, can enhance the removal effect of pollutants, and improve the stability of the reactor.

Keywords

Water quality; Pollution removal; Slope wetland.

1. Introduction

Urban river has a relatively stable river ecosystem (Huang et al., 2018). The existence of river plants provides habitat for wildlife, microorganisms, etc., maintains the integrity of the river ecosystem, and can adjust the nutrient balance of the river (Lai et al., 2011). It plays an important role in improving self-purification capacity of water body, improving water quality and reducing non-point source pollution of river. In addition to maintaining the above functions, urban watercourses also have many ecological and social functions for the urban ecological environment, such as alleviating the urban heat island effect, eliminating waves and waves, protecting biodiversity, maintaining underground water sources, purifying water quality and landscape construction (Wang et al., 2011).

As the key component of urban ecosystem, urban river has not only the functions of providing water, transportation shipping, flood protection and waterlogging drainage, but also has the important ecological value including adjusting the climate, cutting down pollution and the like (De Carvalho et al., 2018; Pereda et al., 2019). The water quality of urban river is affected by many factors, and human activities are the most important one. The water quality of the polluted river becomes worse, which affects the quality of life of the surrounding residents, damages the surrounding ecological landscape, and limits the economic development of the surrounding areas. Therefore, the treatment of river wastewater is imminent. The new in-situ repair technology uses artificial means to control and enhance the purification ability of the environment itself. At the same time, the technology can beautify the environment and enhance the aesthetic effect. In situ repair technology has been integrated into the environment, which has played a good role in environmental protection. Slope wetland system (SWs) and submerged plant combination restoration are two common ways of polluted river restoration. Slope wetland is a variant form of constructed wetland technology. In recent years, the combination of submerged plants is a new method of river restoration (Kałuża et al., 2018; Ecke et al.,2018). Both processes have the effect of maintaining polluted river water quality.

On the basis of this problem, we studied the removal effect of pollutants in the slope wetland under different hydraulic retention time, the water quality maintenance effect of different submerged plants combination and the operation effect of the two processes coupling. According to the change of polluted river water quality, we selected four indexes of chemical oxygen demand, total nitrogen, total phosphorus and ammonia nitrogen to carry out outdoor simulation experiment.

2. Material and methods

2.1 Experimental device

Two devices of the same size were set up in the experiment. Dimension is 2m wide, 6m long. The device was consisted by water inlet pipe, water inlet gate, water outlet, water outlet gate and sampling ports (Wang et al., 2018). SWs is set in the two units, and the wetland size is adder-like distribution. Each layer was 20cm high, the lower layer was 40cm wide, and the upper layer was 20cm wide. There are two kinds of wetland fillers in the devices, namely particle size 2-3cm gravel and particle size 2-3cm ceramicite and zeolite with 1:1. The bottom of the stepped SWs is planted with *ScirpusvalidusVahl*, the middle with *Typha orientalis Presl*, and the top with *Lythrum salicaria L.*. The density of all the three plants was 20 clump/m^2. They were all in good condition and stable growth. Two devices are placed horizontally on the test site, and the experimental water is replenished through the water tower. Submerged plant combination reactor is set beside the slope wetland reactor. The stainless steel pipe is set up on the upper part of the experimental water tank, and the submerged plants are planted in the flowerpot. The flowerpot is fixed on the stainless steel pipe by the wire rope and naturally sags, so as to keep different submerged plants suspended in the experimental water. 10 pots of plants are fixed in each steel pipe, 2-3 plants are planted in each pot, and the planting density is 30 plants/m^2. The unit size is 2.0m×1.0m×1.0m.

2.2 Influent quality

The experimental site is located at the confluence of Zhong-xiao River and Yu-wen River (116°67′W 39°93′N). Zhong-xiao River has a total length of 39km and a drainage area of 135km2. The total length of Yu-wen River is 47.5 km, and the drainage area is 4423 km^2. The sampling point is located near the intersection of the two rivers, which represents the water quality characteristics of the two rivers and the impact of the river on the downstream river. The sample is taken directly from the r through the water pump. The data are shown in Table 1. According to the calculated mean value, the pollutant content of the river water at the sampling point is Chemical oxygen demand (COD)=47mg/L, Ammonia nitrogen (NH_3-N)=1.46mg/L, Total phosphorus (TP)=1.21mg/L and Total nitrogen (TN)=10mg/L.

Table 1 change of river water quality

Date	Name			
	NH3-N (mg/L)	COD(mg/L)	TP (mg/L)	TN (mg/L)
2019.7.11	1.21	42	1.12	10.7
2019.7.13	1.23	53	1.17	9.8
2019.7.17	1.36	46	1.05	10.3
2019.7.29	1.21	51	1.12	10.7
2019.8.1	1.23	53	1.27	9.8
2019.8.3	1.36	49	1.15	10.3
2019.8.27	1.32	45	1.35	9.2
2019.8.29	1.84	47	1.42	10.1
2019.9.1	1.42	51	1.23	9.1

2.3 Experiment methods

Through outdoor experiments to simulate the change of polluted river water quality, the pollutant removal rate of slope wetland under different hydraulic retention and the pollutant removal effect of different combination of submerged plants were studied. At the same time, considering the operation effect of the two processes, the optimal operation conditions of the coupling reactor are determined.

3. Result and discussion

3.1 Removal of pollutants in SWs with different HRT

The experiments were carried out in outdoor natural condition. Due to the fluctuation of river water quality during the experiment, the data was calculated by means of multiple measurements to ensure the stability of the data.

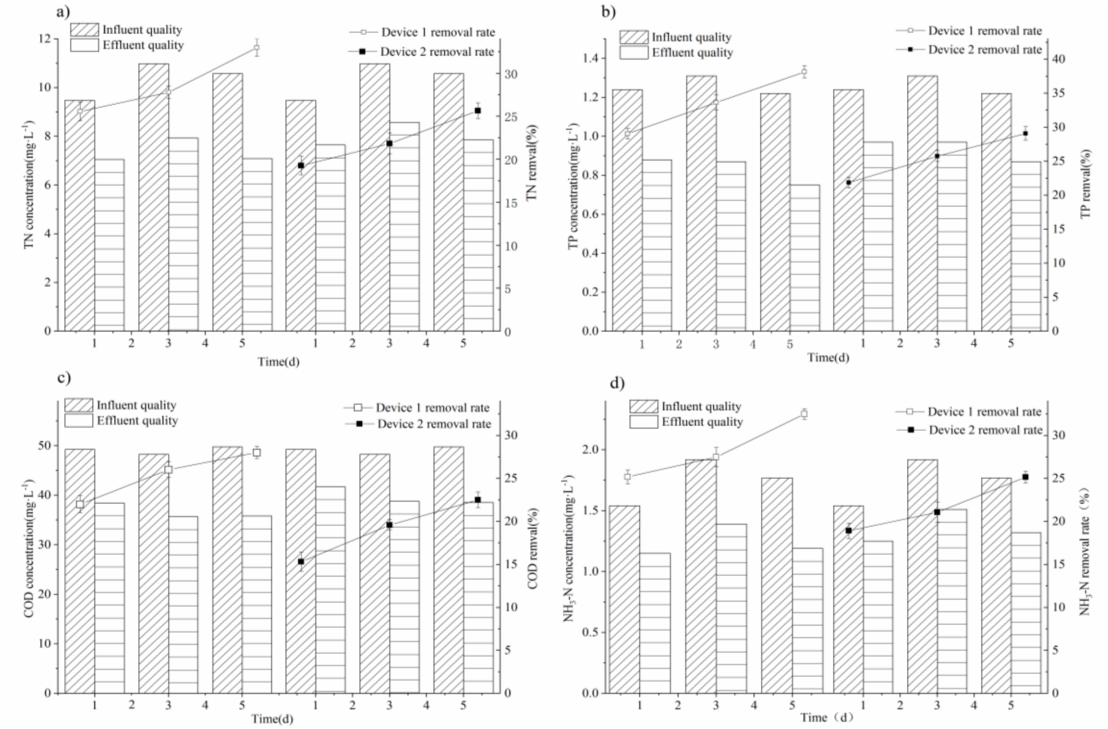

Fig.1 Removal of pollutants under different HRT (a.TN b.TP c.COD d.NH_3-N)

As shown in the Fig.1, under different residence time, the removal rate of each index was inconsistent, but on the whole, moderate extension the residence time, the suitable the removal of pollutants. Observing the above figure, it could be found that the effect of device 1 was significantly better than that of gravel reactor, and the treatment efficiency of each index is increased by more than 5%. This phenomenon is related to the adsorption performance of the filler (Lu et al. 2016).

Considering COD, when HRT was extended from 1 day to 3 days, COD removal rate increased by 4.02%, and when HRT was extended from 3 days to 5 days, COD removal rate increased by 2%. This situation is related to the change of oxygen content in the water, and the residence time is extended appropriately, which is conducive to the adsorption of dissolved organic matter by plants and matrix (Wang et al. 2012). However, the excessive extension of residence time will lead to the decrease of oxygen content in the system. In the anaerobic state, the degradation rate of organics is significantly lower than that in the aerobic state. The situation of NH_3-N is similar to that of COD. Prolonging HRT properly is beneficial to the removal of NH_3-N. Too long residence time will lead to the decrease of oxygen content in water and the reduction of removal efficiency of NH_3-N. Phosphorus in the SWs is mainly removed through the absorption of microorganisms and plants and the physical and chemical effects of fillers. Overlong HRT is easy to cause anaerobic environment in the SWs. The excessive phosphorus absorbed by microorganisms in the aerobic environment is released again, resulting in the decrease of TP removal rate (Wan et al. 2012). The removal rate of TN is poor in the end, which is mainly due to the fact that the nitrification process only takes place. In the aerobic environment, the content of dissolved oxygen in the SWs is poor, which does not have good conditions for nitrification. Only through the atmospheric diffusion to the soil and the oxygen release of plant roots, the aerobic microenvironment is provided.

3.2 Removal of pollutants in submerged plant combination

The selection of raw materials should take into account many aspects, including adaptability, purification effect and economic benefit. In the experiment, the submerged plant combinations combination *Hydrilla verticillata* + *Ceratophyllum demersum*(HJ), *Myriophyllum spicatum* + *Elodea canadensis Michx*(HY), *Potamogeton wrightii Morong* + *Potamogeton pectinatus, Cabomba caroliniana A.Gray* (MB) +*Vallisneria natans (Lour.) Hara*(SK), were selected. Before the experiment, the submerged plants were domesticated for 7 days by running water to ensure the physiological stability of submerged plants.

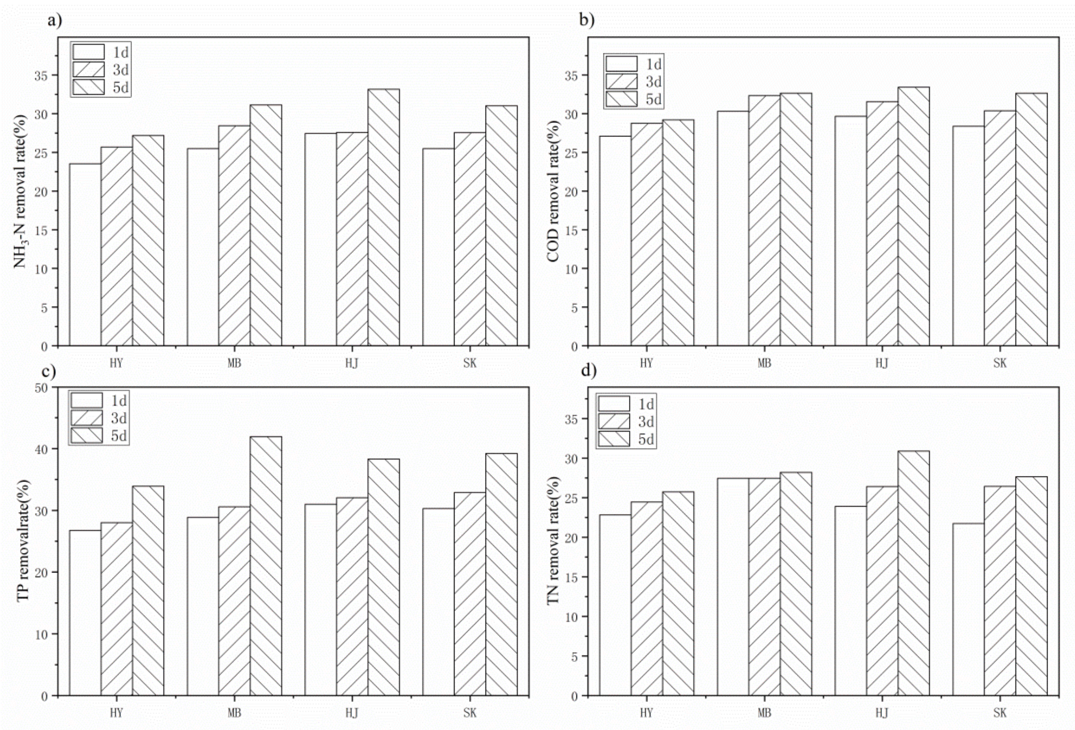

Fig.2 Pollutants remove effect in submerged plant combination (a. NH_3-N b.COD c.TP d. TN)

As is shown in the Fig.2, we found that the COD content of polluted river water changes obviously after being treated by submerged plants. In general, each combination mode has certain effect on COD purification of reclaimed water. In the experiment, the effecton COD purification was HJ>MB>SK>HY. The removal rate of COD is 33.27% for MB combination under 5day residence time. MB is the best for total phosphorus removal. When HRT=5day, the removal of ammonia nitrogen was HJ>MB>SK>HY. The effect of HJ combination treatment was the best, and the maximum removal rate of ammonia nitrogen was 33.42%. TN removal rate was successively HJ>MB>SK>HY. The TN removal rate of HJ can reach 30.9% in 5 days. Compared with the removal rate of pollutants, we think MB combination is the best. In general, with the increase of HRT, the removal efficiency of pollutants has increased. The reason for this phenomenon may be that the appropriate extension of HRT increases the oxygen content of water body on the one hand, and on the other hand, it prolongs the contact time between plants and water body(Herrera et al., 2016; Hu at el., 2019).

3.3 Removal of pollutants in Coupling process

The reactor size of SWs remains unchanged, zeolite and ceramsite are evenly mixed as filling materials for it. *Potamogeton wrightii Morong* + *Potamogeton pectinatus, Cabomba caroliniana A.Gray* is selected as submerged plant, with planting density of 30plants/m^2. In order to ensure the operation effect of the reactor, the device was put into trial operation for 7 days. After the experiment, the purification effect of each pollutant was observed as shown in the fig.3.

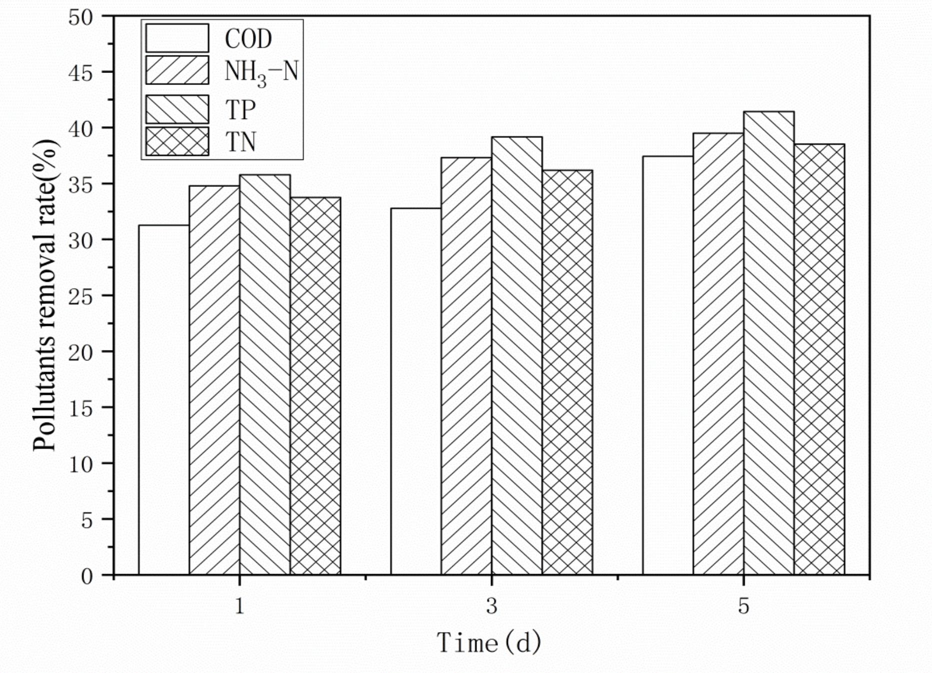

Fig.3 Pollutants remove effect in coupling process

As is shown in the Fig.3, when the combined reactor was used to treat the polluted river water in situ, we found that the removal rate of each pollutant was improved. It shows that the coupling of the two processes can promote the purification of polluted river water. On the one hand, the presence of submerged macrophytes reduces the flow velocity of polluted river water to a certain extent, and increases the attachment point of microorganisms in water body. On the other hand, the metabolism of submerged macrophytes can utilize part of the pollution, so as to maintain the water quality.

4. Conclusion

SWs has good purification effect of polluted river water, and its treatment effect is affected by the composition of fillers. The removal efficiency of pollutants in the mixed reactor of ceramsite and zeolite is better than that in the crushed stone reactor, and the removal efficiency of each pollutant index is increased by about 5%. The combination of submerged plants also has good water quality maintenance effect. The effect of *Potamogeton wrightii Morong* + *Potamogeton pectinatus, Cabomba caroliniana A.Gray* is better than the other three combinations. Better removal of pollutants. The device formed by coupling the two technologies has better pollutant effect than single technology. For the maintenance of polluted river water, the operation effect of coupling process is good. At the same time, the coupling process enhances the aesthetic value and energy utilization rate of the device.

Acknowledgements

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