EFFICIENCY OF NITROGEN REMOVAL IN CONSTRUCTED WETLAND: A SIMULATION STUDY IN THE WEST JINLIN, CHINA

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ABSTRACT: Plenty of inorganic nitrogen in wastewater can cause the eutrophication in water bodies, so it is an important task to remove nitrogen. Purification role was realized by absorption, filtration, depositon, evaporation, nitrification and denitrification of microbes. Although the studies of *Phragmites austrilis* bed in the constructed wetland are popular, the purification performances of constructed wetland filled by saline-alkali soil substrate are less reported. In the paper, the purification efficiency of nitrogen with *Phragmites austrilis* bed in the constructed wetland filled by saline-alkali soil substrate was discussed through a simulation study. Results to date indicated that the first order plug flow model was adequate to describe the nitrogen removal. The experiment showed that the diminishing concentration of TN, NO_2-N, NO_3-N, NH_4-N were closely related to hydrological retention time (HRT), the correlation coefficient was $R^2 = 0.98499$, $R^2 = 0.9911$, $R^2 = 0.89407$ and $R^2 = 0.95459$, respectively. According to the data, the most suitable hydrological retention time (HRT) for this kind of constructed wetland should be determined to 4 days. In addition, the experiment showed the purification efficiency of nitrogen has very broad range and drastic vibration, TN (17% - 79%), NO_2-N (33% - 98%), NO_3-N (13% - 93%), NH_4-N (28% - 64%). The study will promote wetland's design and operation procedures in large saline-alkaline soil areas.

KEY WORDS: saline-alkali soil; constructed wetland; nitrogen; purification efficiency

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1 INTRODUCTION

Conventional wastewater treatment plants involve large capital investments and operating costs, and for that reason these systems are not a good solution at small villages (Solano, *et al.*, 2004). As a kind of cheap, effective, available technique of wastewater treatment, constructed wetland was applied to treat municipal wastewater (Gemma, *et al.*, 2003), industrial wastewater (Heaher, *et al.*, 2001), oil refinery wastewater (Ji, *et al.*, 2002, Anne, *et al.*, 1999) and non-point source pollution controlling (Braskerud, 2002). Nowadays this technique is prevalence in the field of wastewater treatment for small communities where are not developed in the economy.

Nitrogen plays a major role in causing eutrophication in rivers, streams, estuaries and coastal waters (Elser, *et al.*, 1990). This is particularly true in semi-arid regions like the west Jilin, China, and other parts of regions where have less annual precipitation and easily erodible soils. Plenty of inorganic nitrogen in the wastewater can cause water eutrophication, so it is an important task to removal

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nitrogen. Purification role of constructed was realized by absorption, filtration, deposition, plant uptake, volatilization, nitrification and denitrification of microbes (Zhang, *et al.*, 1999). Nitrification and denitrification of microbes are two main mechanisms of decreasing inorganic nitrogen from water (Poach, *et al.*, 2003). Denitrification removes inorganic nitrogen permanently from the system by transforming inorganic nitrogen into gaseous state (Groffman, 1994). In addition, inorganic nitrogen inputs are temporarily attenuated through plant uptake and immobilization in plant biomass. Since nitrogen could be re-released through the decomposition of senescent plant material at the end of the growing season (Kang, *et al.*, 1998), more permanent removal of nitrogen can be achieved by removing plant material through management practices that include harvesting or grazing (Sinkyu, *et al.*, 2002).

Phragmites austrilis is a kind of dominant plant species in the wetlnad of west Jilin province where they have extensive distribution with various species commonly found in many areas. Recent studies have showed that *Phragmites austrilis* is effective in removing nitrogen in wetland ecosystems (Romero, *et al.*, 1999). At the same time, saline-alkaline soils are widely distributed in the west plain of Jilin province regions. So in our study *Phragmites austrilis* were chosen as treatment plants and salt-alkaline soils was chosen as substrate to constructed wetland aimed to study the treatment performance of this kind of constructed wetland. The study provides baseline data for constructed wetland design and operation in these regions and data of the efficiency of nitrogen removal in constructed wetland.

2 STUDY SITE AND EXPERIMENTAL DESIGN

2.1 Study Site Description

The study site is located in Zhangjiadian pond, southeast far away from Taonan city, in the west Jilin province, where there are plenty of saline-alkaline soils. This study site can typically demonstrate the semi-arid climates and salt-alkaline soils characteristics of the west Jilin province where the annual average precipitation is 397.8 mm, while the evaporation is 1 891.7 mm. In addition, the climate of this region is characteristic of that the highest temperature is 38.6 ℃ in July and the lowest temperature is −34.6 ℃ in January annually. Due to the poor natural conditions, this region is underdeveloped, seeking for economic and feasible wastewater treatment technique as replacement of conventional treatment method is urgent. The constructed wetland is appealing for its potential advantages. In this study, the Zhangjiadian Pond, Taonan city in the west Jilin province was chosen as our study site and a pilot scale wetland ($L \times W = 100\ m \times 40\ m$) has been constructed in July, 2003. The schematic map of pilot scale constructed wetland is showed in Fig.1.

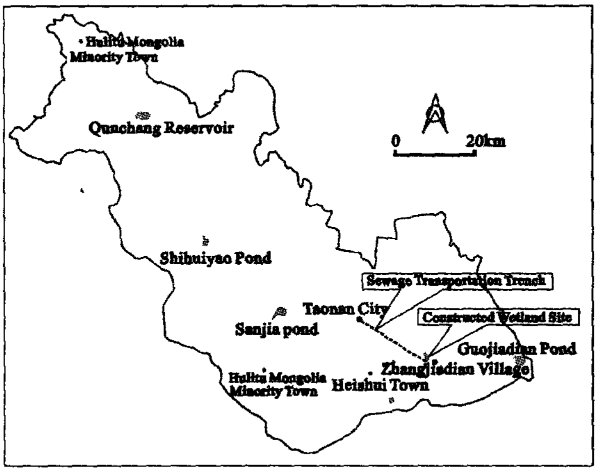

Fig.1 Schematic map of study site and pilot scale constructed wetland in the west Jilin Province

In order to control the experimental conditions and operations, the simulation experiment has been carried out in the lab. In the simulation, polyethylene glass box with the volume 40 cm × 40 cm × 80 cm was used and filled with saline-alkali soils according to the original soil layers sampled from Zhangjiadian pond. *Phragmites austrilis* roots were transplanted into the system. As soon as the *Phragmites austrilis* survived, constructed wetland is feed with municipal wastewater which delivered from Taonan city. The schematic of simulation treatment flow chart are depicted in Fig. 2.

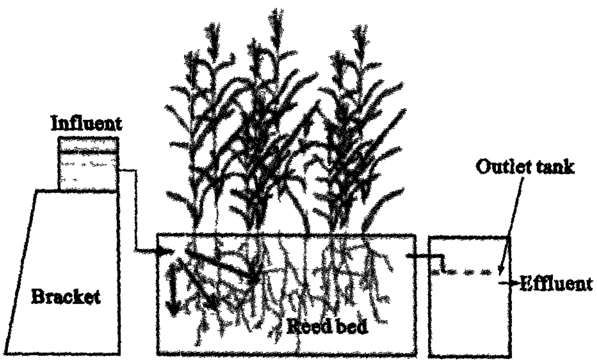

Fig.2 Flow schematic of constructed wetland treatment wastewater

2.2 Sampling and Analysis

The municipal wastewater come from total sewage pump station of Taonan city, Jilin province. From the first day loading wastewater into box on, 7 water samples were collected. The sampling and determination methods refer to the reference 14. Data were determined with SAN^{++} flow analysis apparatus made in Netherlands and were processed with software Origin 7. The influent nitrogen concentration of wastewater was listed in Table 1.

Table 1 The influent concentration of wastewater

TN (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	NH_4-N (mg/L)
2.5326	0.3258	0.6234	1.8654

3 RESULTS AND DISCUSSIONS

3.1 Relationship between the Nitrogen Concentration and HRT

Nitrogen removal was mainly realized by plant uptake, denitrofication and nitrification. Nitrogen concentration was decreased along with hydrologic retention time (HRT). Fig. 3 showed the relationships between TN, NO_2-N, NO_3-N, NH_4-N and HRT.

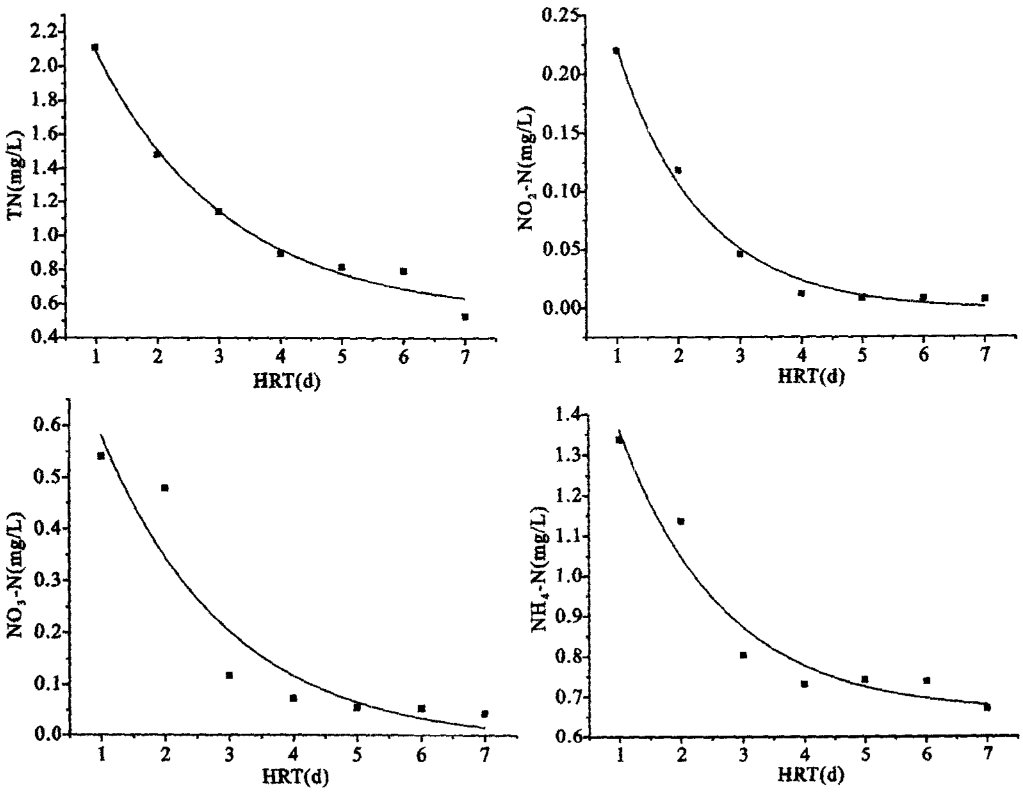

Fig.3 The relationship between TN, NO_2-N, NO_3-N and NH_4-N concetration and HRT

The results from our study showed that *Phragmites austrilis* bed in constructed wetland occupy higher capacity to treat nitrogen. Additionally, the purification performances of constructed wetland were higher. However, in this study, manipulations like preliminary denitrification suggested by some researcher didn't be implemented (Laber, Perfler, Haberl, 1997).

Experiments only demonstrated the static purification performance of constructed wetland, while natural wetlands usually keep a dynamic flow state. Definitely, water flow status must be an important factor affecting treatment efficiency of system. Unfortunately, confined to the simulation conditions, this aspect weren't simulated. But this study provided profile for static status of wastewater's purification.

Analyzed with software Origin 7, the rules of degradation of TN, NO_2-N, NO_3-N, NH_4-N along with HRT were shown in the formula(1), (2), (3) and (4), respectively.

$$Y = 2.48764 \times \exp(-\frac{X}{2.1239}) + 0.5416 \quad R^2 = 0.98499 \tag{1}$$

$$Y = 0.46469 \times \exp(-\frac{X}{1.37628}) - 0.00187 \quad R^2 = 0.9911 \tag{2}$$

$$Y = 0.9877 \times \exp(-\frac{X}{1.97235}) - 0.01257 \quad R^2 = 0.89407 \tag{3}$$

$$Y = 1.2766 \times \exp(-\frac{X}{167158} - 0.66091 \quad R^2 = 0.95459 \tag{4}$$

As the HRT increasing, the trends of concentration change of TN, NO_2-N, NO_3-N, NH_4-N become slower. So it means the HRT = 4d was appropriate and feasible for the constructed wetland system.

3.2 Relationship between Nitrogen Removal Efficiency and HRT

The relationship between nitrogen removal efficiency and HRT were showed in Fig.4 and Table 2. From table 2, it can be known that when HRT = 4d, the removal efficiency of TN, NO_2-N, NO_3-N,. NH_4-N was 65%, 96%, 88%, 61%, respectively.

Possible factors controlling the nitrogen removalrates include pH, water temperature, dissolved oxygen, hydraulic retention time, organic substrate, and attachment media. In our study, only temperature (25 - 30℃) and hydraulic retention time were not controlled, other aspects were kept original wastewater conditions. During the experiment, wastewater was exposed in the air all day and night in order to guarantee the oxygen demand.

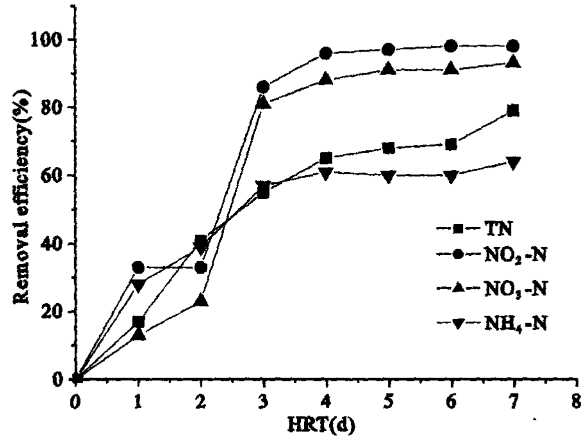

Fig.4 Relationship between nitrogen removal efficiency wetland

Table 2 Removal efficiency of nitrogen in constructed wetland

Removal efficiency	TN (%)	NO_2-N (%)	NO_3-N (%)	NH_4-N (%)
HRT(1d)	17	33	13	28
HRT(2d)	41	33	23	39
HRT(3d)	55	86	81	57
HRT(4d)	65	96	88	61
HRT(5d)	68	97	91	60
HRT(6d)	69	98	91	60
HRT(7d)	79	98	93	64
Mean Value	56	77	69	53

3.3 System Improvement

To reach high N removal some experiences needed to be considered:

(1) Load *Phragmites austrilis* beds intermittently (Kern, Idler, 1999);

(2) Guarantee long flowing distances in constructed wetland;

(3) Combine with VFWs and HFWs can achieve good results.

(4) Use naturally aerated ponds for preliminary denitrification (Laber, Perfler, Haberl, 1997).

4 CONCLUSIONS

Constructed wetlands have advantages of easy operation, low cost, stable efficiency. Such semi-centralized solutions were, therefore, very sustainable in rural areas and also in smaller towns. Experiments showed it was feasible to treat urban wastewater with saline-alkaline soil substrate in constructed wetland. And nitrogen treatment efficiency as high as TN (17% - 79%), NO_2-N (33% - 98%), NO_3-N (13% - 93%), NH_4-N (28% - 64%) were observed. During the experiment, the simulation experiment demonstrated that HRT = 4d was an optimal for nitrogen removal. In addition, some experiences needed to be improved in our future studies, such as some combined system and enlargement of flow distances.

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