Nitrogen removal of a *Myriophyllum elatinoides* purification system for treating piggery wastewater in karst region

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Abstract. To investigate the feasibility of treatment of pigger wastewater by constructed wetland and to provide the operation parameters for a full scale constructed wetlands to improve the quality of effluent water, a pilot test was conducted with a plug flow constructed wetland to treat dairy farm wastewater in Huangjiang city, Guangxi province. The results show that, outflow concentration of TN and NH_4^+-N were greatly lower than inflow concentration. The biomass and water content of *M. aquaticum* also varied with the transplanting season and nitrogen concentration. The study indicates that nitrogen removal for piggery wastewater by constructed wetland is the combined actions of physical chemistry, plants and season.

Introduction

Piggery wastewater is characterized by high concentrations of nutrients, chemical oxygen demand (COD) and suspended particles, and have caused the degradation of water quality in many rivers and lakes [1]. To control pollution from animal wastewater, low-cost constructed wetlands (CWs) have been utilized in many sites all over the world [2]. In these studies, macrophytes growth assimilates nutrients to form organic compounds, are a key biological component and play an important role in removing nitrogen (N) in CWs. In addition, the N removal abilities of CWs depend on plant species, wastewater type, and N loading rates. The selected plant species should be tolerant of high ammonium concentrations and have high productivity to enable rapid nutrient uptake for animal wastewater treatment [3,4]. *Myriophyllum aquaticum* has been reported as a widespread submergent and emergent herb that can readily grows in tropical regions of the world [5]. Although it was also found that *M. aquaticum* roots can create oxidized areas and release organic compounds at the root-sediment interface to accumulate metal [6], there is limited available research regarding the use of *M. aquaticum* in improving environmental quality. Meanwhile, the potential of *M. aquaticum* for animal wastewater treatment in karst region have been unknown. Southwest China, as one of the largest karst regions in the world, is considered fragile because of its special geological background, small environmental carrying capacity, and low tolerance of interference [7]. During recent years, pig numbers has been increased and resulted as a fast-growing agricultural pollution [8]. In this region, piggery wastewater may has more ecological risk than that of non-karst region. Thus, this study mainly understand the potential of *M. aquaticum* for N removal from wastewater in karst region.

Material and methods

Study sites. Field experiments were conducted in 2015 at the Huangjiang county in the Hechi city, in northwest Guangxi Zhuang autonomous region, China (24°44′ – 25°33′N; 107°51′ – 108°43′E, altitude 220 m). Based on long-term (1971 – 2010) weather data from the site, the mean annual air temperature is 18.5 °C. Mean temperatures in January and July are 10.1°C and 28.0°C, respectively. There are 290 frost free days and 1451 sunshine hours per year. The region is water-sufficient, with a mean annual precipitation of 1389 mm and a mean annual pan evaporation of 1571mm [9].

Experimental designs. The eco-wetland was designed and constructed in the drain outlet of the piggery in December 2014 to treat the wastewater (Fig.1). The eco-wetland has five wetlands, which area were 600m^2, 400m^2, 200m^2, 100m^2 and 50m^2, respectively. The eco-wetland includes a series of weirs used as water control structures and various hydrophytes. Dominant vegetation at the eco-wetland was *M. aquaticum*. Water discharge was monitored at the outlet of eco-wetland using the observed flow velocity and the flow cross-section area method which described by our previous study. Site maintenance was undertaken when the eco-ditch began running.

Field sampling and measurements. During the 2015 study period (January–December), bimonthly water samples were collected at the inlet and outlet of the eco-wetland. Water samples were collected in glass 500 ml bottles to guarantee the volume requirements in laboratory analysis. All bottles were rinsed with sample water prior to collection of a depth-integrated sample. Samples were immediately stored at 4 °C after sampling and transported to the laboratory on the day of sampling. Samples were received by the laboratory, logged in and inspected for damage, and stored at 4 °C until filtering and analysis. All filtration and preservation of samples were completed within 24 h. TN and NH_4^+-N concentrations were measured using an automatic flow injection analyzer (Fia-star 5000, Foss Tecator, Sweden) according to the standard methods for Water and Wastewater Monitoring and Analysis (SEPA, 2002). TN concentrations were determined using the fully automated injection system after digestion with a $K_2S_2O_8$-NaOH solution.

Data analysis. Statistical analyses were performed using SPSS 13.0 for windows (SPSS Inc., Chicago. IL).

Results and Discussion

Water quality characterization of the eco-wetland is presented in Fig. 2. As can be seen from this figure, inflow concentration of TN and NH_4^+-N were typically greater than outflow concentration. Total N and NH_4^+-N entering the eco-wetland were 1405 mg/l and 1109 mg/l, respectively. After the treatment of five eco-wetlands, the outflow concentrations of TN and NH_4^+-N were 10.4 mg/l and 9.5 mg/l, respectively. The *M. aquaticum* biomass in same wetland increased sharply as the transplanting season progressed (Fig. 3). However, the biomass also decreased from the first wetland to the fifth wetland. This may due to low concentration of TN and NH_4^+-N. In addition, the water content of *M. aquaticum* varied with the transplanting season and nitrogen concentration.

Figure 1 The eco-wetland in this study

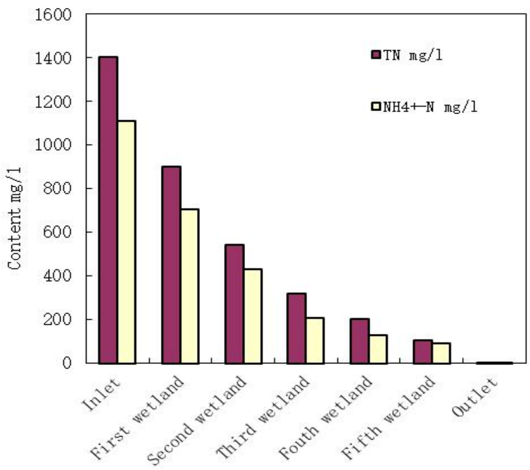

Figure 2 Nitrogen content in the eco-wetland

In this study, macrophytes in wetlands play important roles in N removal and eco-wetland investigated was observed high N removal efficiency, which suggest that proper species selection is important for the design and planning of wetland management [4,10]. The present study focused on the potential of *M. aquaticum* for N removal from NH_4^+-N-dominated wastewater in experimental mesocosms. The changes in NH_4^+-N and TN concentrations indicated that wastewater strengths affected the N removal efficiency in *M. aquaticum* mesocosms. This phenomenon was consistent with the changes in N concentrations in three strengths of dairy wastewater treated by ecological treatment systems [11].

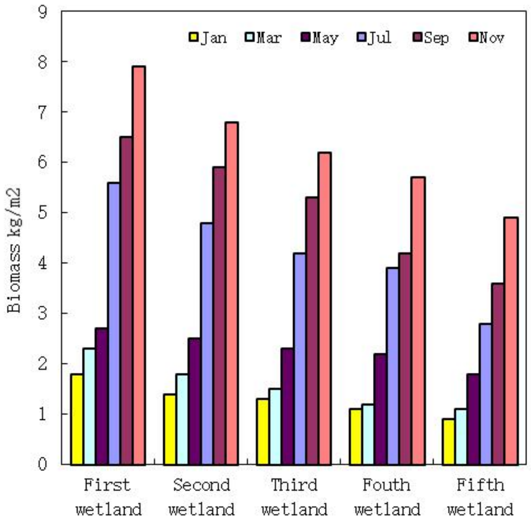

Figure 3 The biomass of *M. aquaticum*

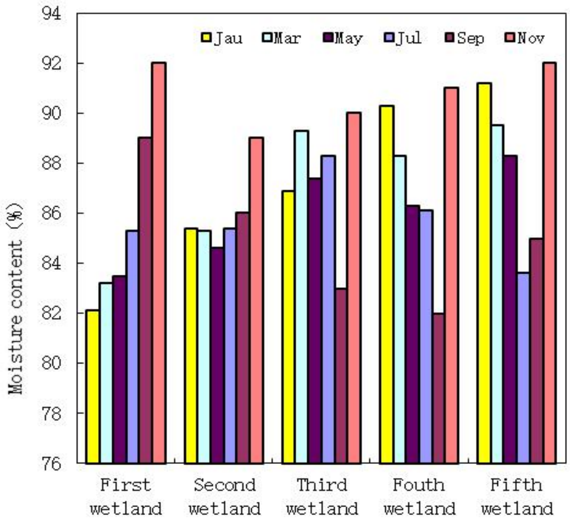

Figure 4 The water content of *M. aquaticum*

The removal mechanisms of contaminants may including sedimentation, volatilization, plant uptake, and microbial processes in the CWs [9,12,13]. Plant growth has proven to be a great purification method for wastewater in CWs. In previous studies, not only are these plants able to uptake the N from the wastewater, but the microbial processes in the sediments of these plant purification systems remove primarily N [14]. The removal of N from aquatic environments by denitrification has been reported to be particularly important for coastal sediments [11,15,16]. Finally, based on the results of this study, potential benefits of the integration of eco-wetland into agricultural wastewater to reduce N concentrations are apparent. The eco-wetland in the current study is managed similarly to a free water surface wetland, to maximize N removal rates.

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References

[1] Cronk, J.K., 1996. Constructed wetlands to treat wastewater from dairy and swine operations: a review. Agric. Ecosyst. Environ. 58, 97-114.

[2] Brix, H., 1997. Do macrophytes play a role in constructed treatment wetlands? Water Sci. Technol. 35, 11-17.

[3] Kouki, S., M'hiri, F., Saidi, N., Belaid, S., Hassen, A., 2009. Performances of a constructed wetland treating domestic wastewaters during a macrophytes life cycle. Desalination 246, 452-467.

[4] Li, L., Yang, Y., Tam, N.F.Y., Yang, L., Mei, X.Q., Yang, F.J., 2013. Growth characteristics of six wetland plants and their influences on domestic wastewater treatment efficiency. Ecol. Eng. 60, 382-392.

[5] Liu, F., Xiao, R.L., Wang, Y., Li, Y., Zhang, S.L., Luo, Q., Wu, J.S., 2013. Effect of a novel constructed drainage ditch on the phosphorus sorption capacity of ditch soils in an agricultural headwater catchment in subtropical central China. Ecol. Eng. 58, 69-76.

[6] Li, Y.Y., Men, C., Gao, R., Yang, W., Jiao, J.X., Li, Y., Wang, Y., Wu, J.S., 2014. Study on phosphorus loadings in ten natural and agricultural watersheds in subtropical region of China. Environ. Monit. Assess. 186, 2717-2727.

[7] H.Du, K.L.Wang, W.X.Peng, F.P.Zeng, T.Q. Song, H. Zhang, S.Y.Lu, Spatial heterogeneity of soil mineral oxide components in depression between karst hills, Southwest China, Chin. Geo. Sci. 24(2014) 163-179.

[8] H.Du, W.X.Peng, T.Q.Song, F.P.Zeng, K.L.Wang, M.Song, H.Zhang, Spatial pattern of woody plants and their environmental interpretation in the karst forest of southwest China. Plant Biosys. 149(2015)121-130.

[9] Nie, Y.P., Chen, H.S., Wang, K.L., Tan, W., Deng, P.Y., Yang, J., 2011. Seasonal water use patterns of woody species growing on the continuous dolostone outcrops and nearby thin soils in subtropical China. Plant Soil 341, 399–412.

[10] Saeed, T., Sun, G., 2012. A review on nitrogen and organics removal mechanisms in subsurface flow constructed wetlands: dependency on environmental parameters, operating conditions and supporting media. J. Environ. Manag. 112, 429-448.

[11] Morgan, J.A., Martin, J.R., 2008. Performance of an ecological treatment system at three strengths of dairy wastewater loading. Ecol. Eng. 33, 195e209.

[12] Braskerud BC (2002) Factors affecting nitrogen retention in small constructed wetlands treating agricultural non-point source pollution. Ecol Eng 18:351 – 370

[13] Pant HK, Reddy KH (2003) Potential internal loading of phosphorus in a wetland constructed in agricultural land. Water Res 37:965 – 972

[14] Fleming-SingerMS, Horne AJ (2002) Enhanced nitrate removal efficiency in wetland microcosms using an episediment layer for denitrification. Environ Sci Technol 36(6):1231 – 1237

[15] Voss M, Liskow I, Pastuszak M et al (2005) Riverine discharge into a coastal bay: a stable isotope study in the Gulf of Gdansk, Baltic Sea. J Mar Syst 57:127 – 145

[16] Zhang D, Gersberg RM, Kate TAS (2009) Constructed wetlands in China. Ecol Eng 35:1367 – 1378