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Evaluation of nutrient removal efficiency and microbial enzyme activity in a baffled subsurface-flow constructed wetland system

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HIGHLIGHTS

- Baffled subsurface-flow constructed wetland (CW) is a new type CW.
- Very significant correlation exists between the activity of urease and the rate of N removal in this CW.
- Activity of urease in the CW is an important indicator for N removal from wastewaters.

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ABSTRACT

In this study, the enzyme activities and their relationships to domestic wastewater purification are investigated in four different types of subsurface-flow constructed wetlands (CWs), namely the traditional horizontal subsurface-flow, horizontal baffled subsurface-flow, vertical baffled subsurface-flow, and composite baffled subsurface-flow CWs. Results showed that the urease activity in the composite baffled subsurface-flow CW was significantly higher than in the other three CWs, while the phosphatase activity in the vertical baffled subsurface-flow CW were higher than in the other three CWs. There were significant and very significant correlations between the activities of urease and the removal rates of TN and NH_4^+—N for the horizontal baffled flow, horizontal subsurface flow, and composite baffled subsurface flow CWs. This study suggests that the activity of urease in the root zones of those three CWs is an important indicator for N purification from wastewaters.

1. Introduction

Constructed wetland (CW) is a promising technique for removing pollutants from wastewaters due to their low energy consumption and cost-effective operation (Kadlec and Knight, 1996). The major mechanism of CWs for purifying wastewater is the interactions among substrates, plants, and microorganisms through a series of physical, chemical and biological processes (Martin and Moshiri, 1994). Although the pollutant removal efficiency varies with different CW systems, the effects of microorganisms cannot be ignored (Gersberg et al., 1986; Wu et al., 2001). Microorganisms play a primary role in pollutant adsorption and degradation (Hoppe et al., 1988; Savin and Amador, 1998;). Degradation of organics, nitrification and denitrification, and transformation of nitrogen and phosphorus in CWs were mainly resulted from the activities of microorganisms in the root zone (Corbitt and Bowen, 1994; Bachand and Home, 2000; Stottmeister et al., 2003). The biochemical reaction processes such as synthesis and degradation of organic compounds, hydrolysis and transformation of plants and microbial residues, and oxydoreduction reaction are controlled by microbial enzyme activities.

Microbial enzymes include intracellular and extracellular enzymes. A variety of enzyme accumulations are due to activities of microorganisms, animal and plants (Zhou et al., 2005). Phosphatase include acidic, alkaline and neutral (three types) enzymes. They could promote the hydrolysis of the phosphonolipid and organophosphorous compounds to release phosphate at different pH conditions. The urease as a kind of soil enzyme is a hydrolase of linear amide C–N bond (not peptide). The urease could make organic N pollutants hydrolysis to improve wetland nitrogen removal and plays important roles in CW system. In the last decade, scientists have paid close attentions to the distribution and effect of microbial enzymes in CWs. Shackle and Freeman (2000) studied the regulation of carbon quantity and quality and improved the activity of extracellular enzyme in CW to achieve the best wastewater purification. Similar studies on enzyme activities in CW system can be found elsewhere (Koottatep and Polprascrt, 1997; Liu

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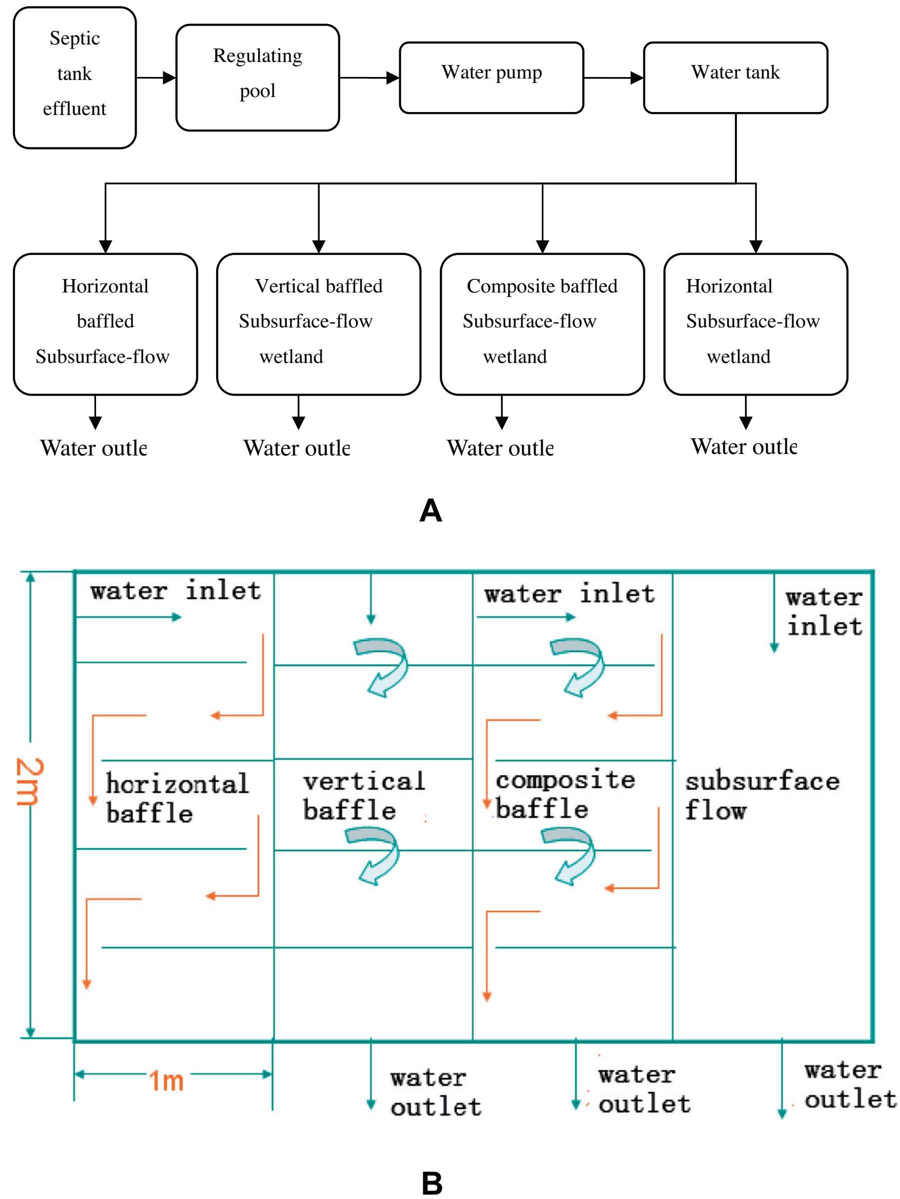

Fig. 1. Schematic diagram of four different types of constructed wetlands (A) and their plain views (B).

and Cao, 2001; Ebersberger et al., 2003). By measuring the wetland root zone phosphatase and urease activities, Wu et al., 2001 found the relationship of urease activity to total nitrogen (TN) removal was apparent and visible, while the relationship of phosphatase activity to total phosphorus (TP) removal was not significant. A similar result also was obtained by Cui et al., (2011). The removal of phosphorus in CWs is through the matrix adsorption and precipitation, plant and microorganism uptake, while the removal of nitrogen is mainly due to plant uptake, ammonization, nitrification, denitrification, and volatilization of ammonia (Fan et al., 2013). Under normal circumstances, organic nitrogen was decomposed by microorganisms and transformation. Urease is used urea as a substrate for the hydrolysis of urea to form ammonia and carbon dioxide. So urease can be used as an important indicator of wetland treatment. Currently, no literature reports are found on investigating enzyme activity in the baffle-type CWs.

Baffle subsurface-flow CW is based on the traditional horizontal subsurface-flow CW with increasing baffle through the horizontal and vertical directions to make wastewater repeatedly flow through the CWs. Thus, the pollutants removal efficiency is improved (Tee et al., 2012). The aims of this study were to: (1) examine the microbial enzyme activities in four types of CWs (i.e., traditional horizontal subsurface-flow, horizontal baffled subsurface-flow, vertical baffled subsurface-flow, and composite baffled subsurface-flow), and (2) obtain the relationship between enzyme activity and water purification. This study could provide a theoret-

Table 1
The contents of water quality constituents in original wastewater (mg/L).

Index	Variation range	Average
TN	52.46–234.12	145.20 (6.27)[a]
TP	3.31–50.05	12.72 (1.12)
BOD_5	11.12–214.32	84.78 (7.05)
COD	65.89–793.70	233.59 (18.78)
NH_4^+–N	34.65–240.66	137.93 (6.73)
pH	6.64–8.20	7.68 (0.071)

[a] Values in the parentheses were standard errors (S.E.).