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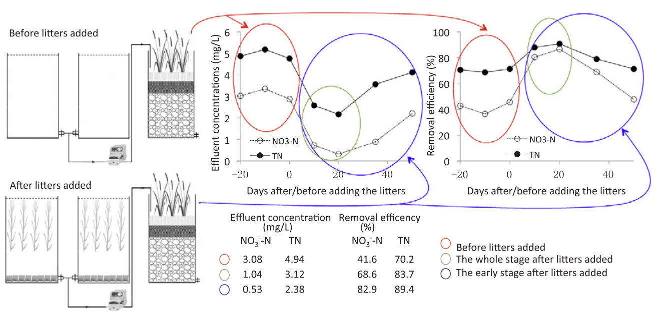
Can cold-season macrophytes at the senescence stage improve nitrogen removal in integrated constructed wetland systems treating low carbon/nitrogen effluent?

Dehua Zhao[a,*], Miao Zhang[a], Zhe Liu[a], Jing Sheng[b], Shuqing An[a]

[a] Department of Biological Science and Technology, Nanjing University, Nanjing 210093, China
[b] Circular Agriculture Research Center, Jiangsu Academy of Agricultural Sciences, Nanjing 210014, China

GRAPHICAL ABSTRACT



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ABSTRACT

Cold-season macrophytes were configured in a system of stabilization ponds (SPs) and batch operation constructed wetlands (BCWs) to supply a carbon source for low carbon/nitrogen (C/N) effluent in spring and summer without generating secondary pollution during the decomposition process. For eutrophic water, the macrophyte configuration increased the average removal efficiency (RE) from 41.6% to 68.6% and from 70.2% to 83.7% for NO_3^--N and TN in the final BCW effluent, respectively, with the concentrations decreasing from 3.08 mg/L to 1.04 mg/L and from 4.94 mg/L to 3.12 mg/L, respectively. In the early decomposition stages, the RE and concentrations were 82.9% and 0.53 mg/L and 89.4% and 2.38 mg/L for NO_3^--N and TN, respectively. Thus, cold-season macrophytes can improve N removal in SP-BCW systems at the senescence stage, especially at the early decomposition stage.

1. Introduction

For influent with a low ratio of carbon and nitrogen (C/N), adding an exogenous carbon source as electron donors during denitrification is widely used in constructed wetlands (CWs) for the removal of nitrogen (Hang et al., 2016). Numerous CWs have been built in recent years in China for the treatment of secondary effluent from wastewater treatment plants (WWTPs), which are generally characterized by low C/N due to the use of A/O processes (He et al., 2018; Wu et al., 2014). Therefore, exogenous carbon sources have specific significance for CWs fed with secondary wastewater. Exogenous carbon sources include methanol, polyethylene, starch, and high organic matter soil/water (Shen et al., 2015; Yang et al., 2018). Plant residues, such as wheat/rice straw, cattail litter flower straw, and rice husk (Fu et al., 2017; Hang

* Corresponding author.
E-mail address: dhzhao@nju.edu.cn (D. Zhao).

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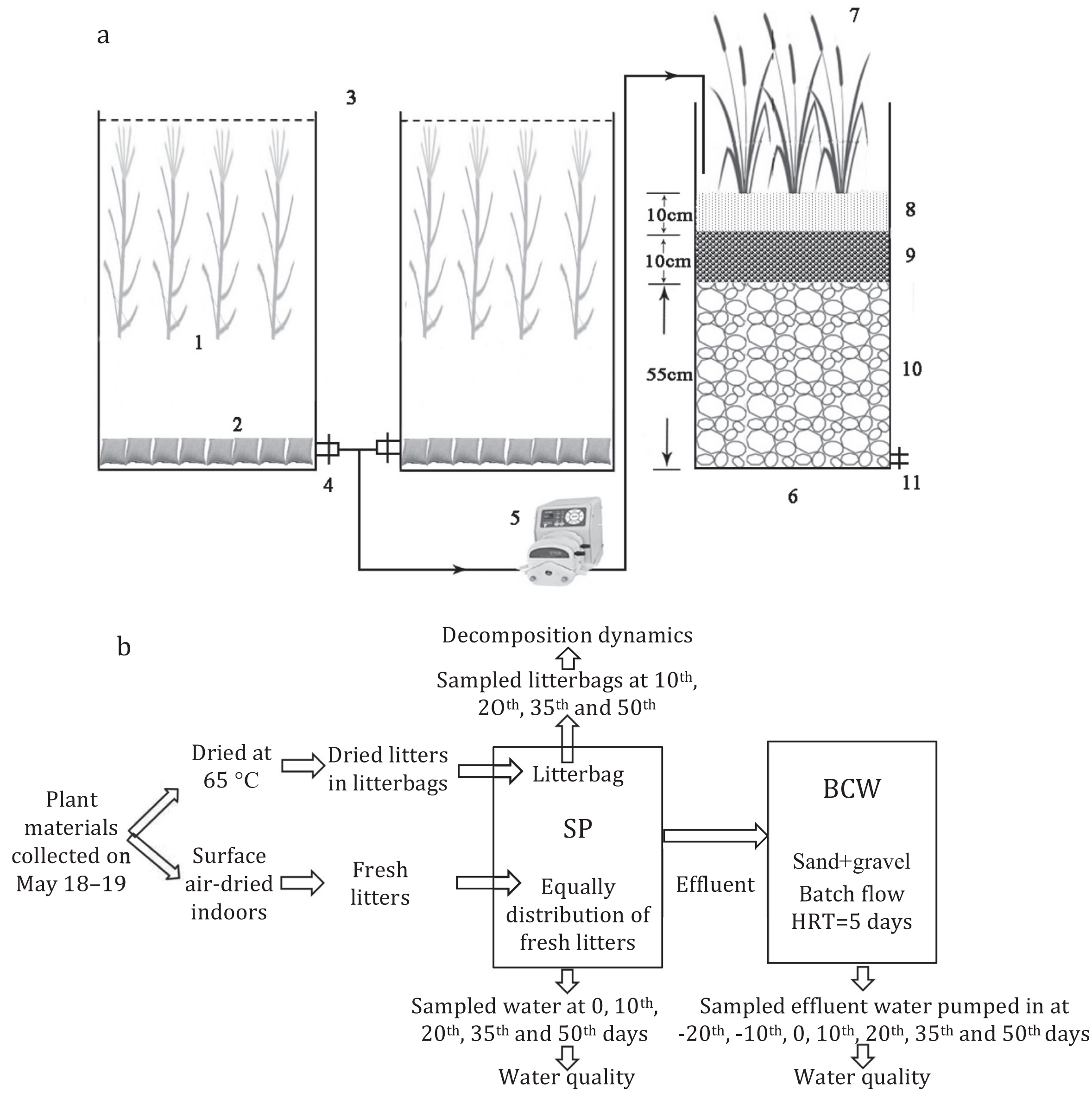

Fig. 1. Experimental system and flowchart. (a) Schematic diagram of the integrated sequential system of stabilization ponds (SPs) and batch operation constructed wetlands (BCWs). (1) Equally distributed fresh litters; (2) litterbags containing fried litters; (3) Two incubators of the SP; (4) Outlet from the SP; (5) Peristaltic pump; (6) BCW; (7) Litters of *Iris pseudacorus* L.; (8) 1–2 mm of sand; (9) 1–2 cm of gravel; (10) 3–5 cm of gravel; (11) Outlet from the BCW. (b) Experimental flowchart for investigating the decomposition dynamics of macrophyte residue and its effect on effluent water quality from SPs and BCWs.

et al., 2016; Tee et al., 2012), present great potential for use as carbon sources due to their low cost and ease of acquisition.

However, the application of plant carbon sources also presents a series of challenges. First, adding the plant carbon source likely increases the risk of clogging CWs, which can be mitigated by the pretreatment, such as cutting/milling, acid/alkaline hydrolysis, and fermentation in isolated containers, of the plant residue before their use in the CWs (Chen et al., 2014; Zhang et al., 2016). The complex pretreatment of plant residue increases operational costs of CWs and thus reduces the practicality of using this carbon source. Second, plant carbon sources have a relatively low denitrification efficiency and may lead to color problems in the effluent (Yang et al., 2018). Adding plant residue to the middle layers of the CWs instead of the surface can improve the denitrification efficiency by decreasing the aerobic decomposition (Chen et al., 2014), which likely improves the risk of clogging. Third, due to the slow and complex decomposition process of the plant residue, adding the proper amount of the plant carbon source is difficult to control in practice. Without the proper amount of carbon source, a significant worsening of the water quality or a continued lack of a carbon source may be observed (Lai et al., 2016).

As an alternative strategy, the configuration of cold-season macrophytes in integrated CW systems has great potential to avoid the negative effects of using an exogenous plant carbon source. For example, macrophytes can be planted in the front links of vertical or subsurface-flow CWs, such as stabilization ponds (SPs), in integrated CW systems. In the growth stage of cold-season macrophytes, these plants can improve the purification efficiency by promoting direct absorption and radial oxygen loss, supplying a surface area for biofilm attachment and promoting suspended matter flocculation (Zou et al., 2016), and they also supply organic matter to CWs by root exudates and litter decomposition (Zhai et al., 2013; Zhao et al., 2018). At the senescence stages in spring and summer, the lack of a carbon source is very serious due to