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Spatial-temporal dynamics of organics and nitrogen removal in surface flow constructed wetlands for secondary effluent treatment under cold temperature

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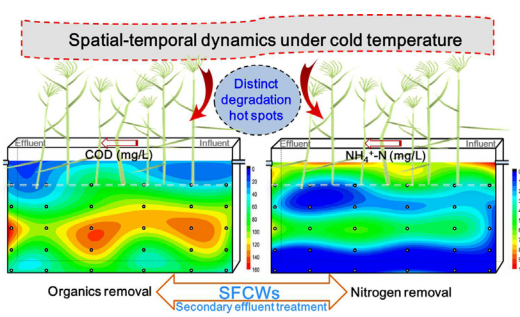
HIGHLIGHTS

- The degradation hot spots of organics and nitrogen in SFCWs were characterized.
- Obvious spatial–temporal dynamics was detected in SFCWs under cold temperature.
- Cold temperature had an important effect on TN removal from secondary effluent.
- Longer HRT with carbon addition would be necessary in low-temperature regions.

GRAPHICAL ABSTRACT



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ABSTRACT

Surface flow CWs (SFCWs) are widely applied as a potential alternative to treat secondary effluent in past several years, but its long-term application under cold temperature regimes is still a challenge because little quantitative information is available on the distribution of organics and nitrogen and their degradation modeling in the "black-box" CW in cold climates. A lab-scale SFCW was operated under a cold temperature (below 10 °C) in this study to investigate the spatial–temporal dynamics of organics and nitrogen removal from secondary effluent. The obtained results indicated that the distinct spatial–temporal variation of organics and nitrogen was observed in the experimental SFCW under the cold temperature. Organics degradation primarily occurred in the surface water and water–sediment-plant interface, while nitrogen removal was mainly accomplished in the water–-sediment-plant interface. Cold temperature had much more important effect on the TN removal. Based on the degradation model, organics and NH_4^+-N could be degraded significantly in a short time because of the appropriate oxygen level, but the TN removal might be hindered due to the limited carbon supply for denitrification in a longer time. The obtained findings would contribute to a better understanding of organics and nitrogen biodegradation processes in SFCWs treating low carbon wastewaters in low-temperatures regions.

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1. Introduction

Constructed wetlands (CWs), mainly including surface flow (SF) and subsurface flow (SSF) CWs, are considered to be the typical and most sustainable ecological wastewater technology for small, rural and remote communities especially in developing countries [1,2]. Due to its low costs and less operation and maintenance, CWs are widely used to treat various wastewaters (i.e. domestic sewage, industrial wastewater, etc.) and reduce organics, nutrients, heavy metals as well as micropollutants [3]. Secondary effluents from municipal wastewater treatment plants (WWTPs), which generally contain excessive nitrogen with relatively low contents of organics, may deteriorate the surface water environment quality and impact aquatic ecosystem health [4]. However, facing with the stringent discharge standards, the efficient removal of pollutants from secondary effluent in CWs is still a challenge for a long-term application [5].

In CW systems, transformation and removal of organics and nitrogen are mainly completed by a series of complex physical, chemical, and biological processes and interactions [6]. Specifically for organics removal, the aerobic and anaerobic heterotrophic degradation of organic compounds is the major route, while the traditional nitrification–denitrification carried out by nitrifying and heterotrophic denitrifying bacteria is the classical nitrogen removal pathway [7,8]. However, the above removal processes of organics and nitrogen removal in CW treatments could be generally influenced by various factors and parameters such as temperature, pH, dissolved oxygen (DO), plant and substrate types, hydraulic loading rates (HRL), hydraulic retention time (HRT) and feed mode [7,9]. Therefore, considering the efficient removal and successful operation, the design optimization and performance evaluation of CWs have been extensively studied in past several years in terms of overall performance, removal mechanisms and microbial populations. Various CW strategies and methodologies for enhancing the long-term treatment efficiency (particularly in colder temperatures) have been developed in previous studies [10–13]. A review study about the enhancement of treatment effectiveness in cold climates by Yan and Xu [14] showed that some engineering practices or measures including internal improvement of design and setup, optimization of operation, and external incorporation of other treatment technologies could raise the temperatures of CW systems in the winter and increase removal performances. A novel seasonal plant collocation system (*Potamogeton crispus and Phragmites australis*) was also investigated to enhance the performance of SFCWs at low temperature, and results showed that plant collocation achieved sustainable nutrients removal [4]. In addition, numerical modeling of flow and pollutant fate in CWs has been developed to describe the biochemical dynamics of organics and nitrogen removal taking place inside complex CW systems [15–18]. It has also been reported that cold temperatures always have a key impact on the microbial metabolism

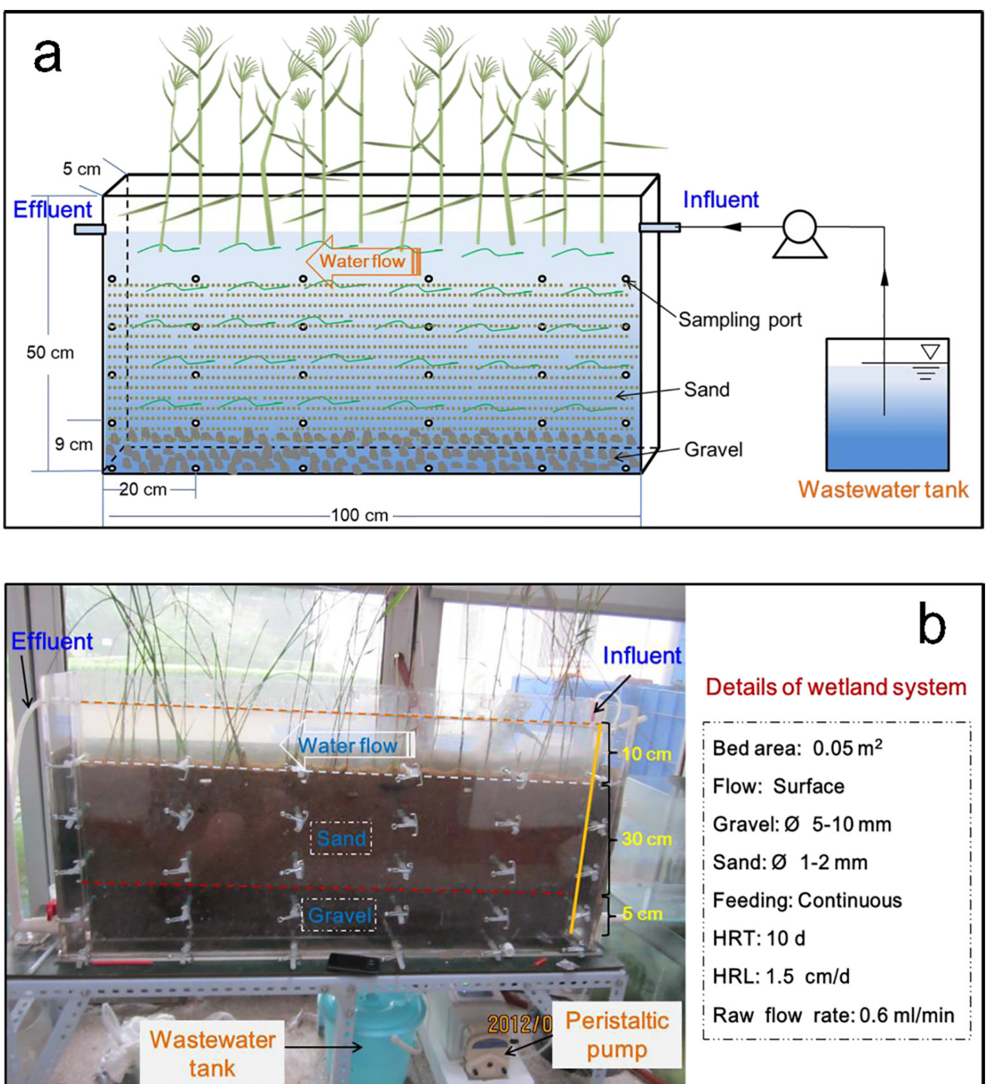

Fig. 1. Schematic diagram of the surface flow constructed wetland (a) and photograph of experimental constructed wetlands system (b).