Effects of emerged plant on soil methane emission and nitrogen content in constructed wetland

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Abstract. To find the effects of emerged plant on soil methane (CH₄) emission and nitrogen content in constructed wetland, we constructed the constructed wetland microcosms with 3 treatments through 2 emerged plants (Typha orientalis and Phragmites australis). Results showed that soil CH₄ flux have no different (2.0, 2.4, 2.5 mg m⁻² d⁻¹, P > 0.05), but soil nitrogen contents and microbial biomass nitrogen were significantly different (P < 0.01) among the 3 treatments. The soil ammonium nitrogen (P < 0.001) and nitrate nitrogen (P < 0.01) contents in the planted constructed wetland were lower than in those unplanted constructed wetland, but microbial biomass nitrogen (MBN) were higher (P < 0.01). The soil CH₄ flux, microbial biomass, organic matter and nitrogen content had no different between those constructed wetlands planted with Typha orientalis and Phragmites australis (P > 0.05).

Hence, emerged plant regulate soil nitrogen removal but not affect soil CH₄ emission in these systems.

1. Introduction

Constructed wetlands (CWs) have been constructed for purifying various pollutants, for example nitrogen, from wastewater using microorganisms, plants and soils [1]. Although there are so many advantages (low costs and high treatment efficiency etc.), CWs also emit a great deal of CH₄ due to the high carbon (C) loading in wastewater [1]. CH₄ is the second largest greenhouse gas (GHG) in contributing the global warming and produced by microorganisms (methanogens) or even plant itself in CWs [2]. CH₄ emission is highly volatile and adjusted by a number of factors, involving emerged plant, organic carbon and dissolved oxygen [3]. Emerged plant is the main regulator of above factors [4]. Substantial labile carbon of low molecular weight containing organic acids, amino acids and sugars are continuously secreted into the soil from plant roots, where the quality and quantity of these carbon sources depends on plant species [5]. Besides, oxygen released from root systems effects soil microbial activities [5].
Many investigators have studied CH$_4$ flux in constructed wetlands, however, there is no consistent conclusion about the effect of emergent plant on CH$_4$ flux in constructed wetland. Some investigators find that planted constructed wetlands release lower CH$_4$ flux than unplanted constructed wetlands \cite{6}, while others claim that planted constructed wetlands release higher CH$_4$ flux than unplanted constructed wetlands \cite{3}. These contradictory results may be due to the use of different emergent plant in CWs, since the quantity and quality of emergent plant root exudates and the oxygen (O$_2$) released through emergent plant roots might different among species. In this research, we constructed the constructed wetland microcosms with 3 treatments through 2 emergent plants (\textit{Typha orientalis} and \textit{Phragmites australis}) to study: (1) whether emergent plant presence effect soil CH$_4$ flux and nitrogen removal; (2) if emergent plant presence affect soil CH$_4$ flux, whether the soil CH$_4$ flux and nitrogen removal are different between \textit{Typha orientalis} microcosms and \textit{Phragmites australis} microcosms.

2. Materials and methods

2.1. Constructed wetlands design
This research was carried out in vertical flow constructed wetlands microcosms in Fuzhou City of China from April to October, 2016. We selected \textit{Typha orientalis} and \textit{Phragmites australis} for this study. The simulated wastewater contained nitrogen 112 mg L$^{-1}$. The simulated wastewater was injected into the constructed wetlands every 10 days.

2.2. Index analysis
Soil CH$_4$ fluxes was quantified by static chamber. We sampled soil CH$_4$ gas at 0, 15 and 30 min on the 21th of September in 2016. The soil CH$_4$ fluxes were calculated by the calculation methods by Sun et al. (2013) \cite{7}.

After collecting the soil CH$_4$ gas samples, we collected plant samples from each microcosm and then we dried plant samples at 80 $^\circ$C for 36 r to constant weight. Later, we collected six soil samples from each microcosm and mixed into one composite sample. The moist soil were immediately collected in Ziplock bags and stored in the refrigerator at -20 $^\circ$C. Soil NH$_4^+$-N content and NO$_3^-$-N content were measured using automated discrete analyzers (Smart Chem 200, Italy).

2.3. Data analysis
The difference in soil CH$_4$ emission, MBN, total plant biomass and soil N content was tested by One-way analysis of variance. SPSS, version 15.0 (USA) were used to data analysis.

3. Results and discussion

3.1. Effects of emergent plant presence on soil CH$_4$ fluxes
The soil CH$_4$ fluxes in the planted constructed wetlands (2.5 mg m$^{-2}$ d$^{-1}$) were not lower than in those unplanted constructed wetlands (2.0 mg m$^{-2}$ d$^{-1}$) (Fig. 1a, $P > 0.05$), showing no significant effect of emergent plant presence on the soil CH$_4$ flux in the constructed wetlands. The soil CH$_4$ flux with emergent plant presence may be interpreted by the microbial processes. Emergent plant fixes carbon through photosynthesis and then allocates available carbon by root exudation to the soil \cite{10}, which might subsequently increase the microbial quantity \cite{11}. In the current study, we found that the MBN (Fig. 2b, $P < 0.01$) and total plant biomass (Fig. 1b, $P < 0.05$) in the unplanted constructed wetlands were lower than in those emergent systems, but organic matter content in soil were not differences (Fig. 2b, $P > 0.05$) between planted and unplanted treatment. Thus, microbial carbon conversion processes in planted treatment were stronger than that in unplanted treatment. However, soil carbon may be released more in the form of carbon dioxide rather than CH$_4$, because of the oxygen transport by plant roots.
3.2. Effects of emergent plant species on soil CH$_4$ fluxes

The emergent plant species have vital role on ecosystem function\textsuperscript{[10]}. In this study, the soil CH$_4$ fluxes in constructed wetlands planted with \textit{Typha orientalis} and \textit{Phragmites australis} had no differences (2.4 mg m$^{-2}$ d$^{-1}$ and 2.5 mg m$^{-2}$ d$^{-1}$) (Fig. 1, $P > 0.05$). On the one hand, the MBN had no significant differences between \textit{Typha orientalis} and \textit{Phragmites australis} constructed wetlands (6.9 mg kg$^{-1}$ and 6.5 mg kg$^{-1}$) (Fig. 3a, $P < 0.001$), the microbes relevant to CH$_4$ processes might no differences. On the other hand, the total plant biomass in the constructed wetlands planted with \textit{Typha orientalis} were higher than in the constructed wetlands planted with \textit{Phragmites australis} (Fig. 1b, $P < 0.01$), but the organic matter content in soil had no significant differences in the two constructed wetlands (Fig. 2a, $P > 0.05$). It is possible that the soil CH$_4$ flux does not only depend on available carbon but also plant biomass.

3.3. Effects of emergent plant on soil N content

Contrary to soil CH$_4$ fluxes, the soil NH$_4^+$ content and NO$_3^-$ content in the planted constructed wetlands were lower than in those unplanted constructed wetlands (Fig. 3a, 3b, $P < 0.01$), showing the positive effect of emergent plant on the N removal efficiency in our study. A possible cause was that the N in different forms (NH$_4^+$, NO$_2^-$ or NO$_3^-$) is assimilated by emergent plants. We found the MBN (Fig. 2b, $P < 0.001$) were lower except for plant biomass in unplanted constructed wetlands than that in planted constructed wetlands.

Similar with soil CH$_4$ fluxes and MBN, the soil NH$_4^+$ content and NO$_3^-$ content in constructed wetlands planted with \textit{Typha orientalis} and \textit{Phragmites australis} had no differences (Fig. 3a, 3b, $P >$...
0.05). However, the total plant biomass in constructed wetlands planted with Typha orientalis and Phragmites australis had differences. Plant uptake and microbial transformation are two major N removal ways in microcosms [11]. So, we think microbial transformation had lower rate of removal contribution than plant uptake in our study.

4. Conclusion
This study demonstrated that emergent plant had no significant effect on soil CH₄ flux, but emergent plant presence increased N removal, indicating that emergent plant presence is vital factors in regulating nitrogen removal but not affect soil CH₄ flux in constructed wetlands.

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