

Methane emission in constructed wetland with/without emerged plant

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Abstract. To investigate the effect of plant presence/absence and plant species on the methane emission, we established three treatments by using two different plant species in microcosms of constructed wetlands. Results showed that methane emission and carbon removal efficiency were significantly difference among the 3 treatments ($P < 0.001$). The methane emission ($P < 0.001$) and microbial biomass ($P < 0.01$) in the planted microcosms were higher than in those unplanted treatment, but total organic carbon ($P < 0.001$) concentrations in effluents were lower. The methane emission and total organic carbon had no significant difference between those microcosms planted with *Phragmites australis* and *Typha orientalis* ($P > 0.05$). Although the aboveground and belowground biomass in the microcosms planted with *Phragmites australis* ($P < 0.05$) was lower than that in the microcosms planted with *Typha orientalis*, the shoot height of *Phragmites australis* was higher than *Typha orientalis* ($P < 0.001$). Hence, our study highlights the importance of plant presence/absence and plant species in mediating methane emission intensity in CWs.

1. Introduction

Constructed wetlands are engineered systems designed to use soils, plants and the microorganisms in plant root zones, to remove pollutants from various contaminated wastewaters ^[1]. Early studies have focused on measuring important within-CWs processes, which include carbon, nitrogen removal and the role of plants in these cleaning processes ^[2]. More recent work indicated that plants are important as “ecological engineers” in enhancing the purification ability of CWs ^[1].

Despite of many advantages such as the inexpensive cost and high removal performances of pollutants, constructed wetlands emit considerable amount of Methane (CH₄) due to their higher pollutant loadings ^[3]. CH₄ is an important greenhouse gas in controlling the atmospheric warming and is currently increasing at an annual rate of 0.8 to 1.0% per year ^[4]. CH₄ emission is controlled by the combined effect of plants and microorganisms, and often influenced by important factors such as total organic carbon (TOC) and dissolved oxygen (DO) ^[5]. Among the factors mentioned above, plants are the main driver of these factors ^[6].



Some researchers have conducted CH₄ emission studies in CW systems, but the effects of plant species on the CH₄ emission in CWs have been in debates. Some researchers claim that planted CWs emit higher levels of CH₄ than unplanted systems^[7], while others have found that vegetated CWs emit lower CH₄ levels than unvegetated systems^[5]. These conflicting results may be caused by the use of different plant species in CWs. In this study, we established 9 constructed wetlands which assembled 3 community treatments (unplanted, *Phragmites australis*, *Typha orientalis*) to investigate: (1) whether plant presence have an impact on CH₄ emission; (2) if plant presence does affect CH₄ emissions, whether the CH₄ emissions are different between *Phragmites australis* systems and *Typha orientalis* systems.

2. Materials and methods

2.1. Microcosm design

The study was conducted in 9 simulated CWs microcosms on Agriculture and Forestry University campus, in Fuzhou City, Fujian Province of China. The microcosms were constructed using plastic boxes and filled with fine sand to a depth of 30 cm. Two common local plant species, *Phragmites australis* and *Typha orientalis* were selected for the experiment. In March of 2017, the seedlings were transplanted into microcosms with a density of 12 individuals per microcosm.

The simulated wastewater used in this study was the 100% Hoagland's nutrient solution^[8] with a minor modification. The inorganic N concentration is 112 mg L⁻¹ (percentage of NH₄⁺-N, NO₃⁻-N ratios of 1:1). The ratio of carbon to nitrogen reached 1:1 by adding glucose. The wastewater was introduced into the microcosms, remained in each microcosm for 10 days, and then each microcosm was drained.

2.2. Parameter analysis

The static chamber – gas chromatography technique was used to estimate CH₄ fluxes in situ. The static chambers (diameter = 44 cm, height = 120 cm) were made of commercially available high-density polyvinyl chloride materials according to the size of the microcosm and heights of matured plants. We collected gas samples at 0 and 30 min on 26th August in 2017. The CH₄ concentrations were determined using a gas chromatograph (Agilent 7890B, USA). The CH₄ flux was calculated using the formula as described by Zhang et al. (2012)^[9].

Water samples were taken after collecting the gas samples. The total organic carbon (TOC) concentration in effluents was measured by total organic carbon analyzer (TOC-L, Japan). After the effluent sample collections were completed, plant samples from each microcosm were immediately collected. Aboveground plant tissue (stems and leaves) was clipped at the stem base above the substrate surface to analyze the total aboveground biomass, and the belowground plant tissues (roots) were collected to analyze the total belowground biomass. Plant samples were dried at 65 °C for 72 hr and weighed. After plant tissues harvesting, the substrate of each microcosm was well homogenized and sampled. Microbial biomass carbon (MBC) was determined by the chlorform fumigation-extraction technique (Zhang et al., 2011)^[10].

2.3. Data analysis

The significant differences of all parameters among plant species were analyzed using a one-way ANOVA followed by Tukey tests (at P = 0.05). All analyses were performed using SPSS for Windows, version 16.0 (SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Effects of plant presence on CH₄ emissions

The CH₄ emissions measured in this study fell within the scope of the previous studies in CWs and at a low level. The methane emissions in the planted microcosms were higher than in those unplanted treatment (Fig. 1a, P < 0.001), showing a positive effect of plant presence on the CH₄ emission in the microcosms. The increased CH₄ emission with plant presence can be explained by the plant biomass.

Increased plant biomass fixes more carbon and allocates more available carbon to the systems [2, 11], which could further increase microbial biomass and CH₄ emission [12]. Thus, the positive effect of plant presence on CH₄ emissions results, at least in part, from the positive response of plant biomass (Fig. 2, $P < 0.05$) and microbial biomass (Fig. 3, $P < 0.05$) to plant presence.

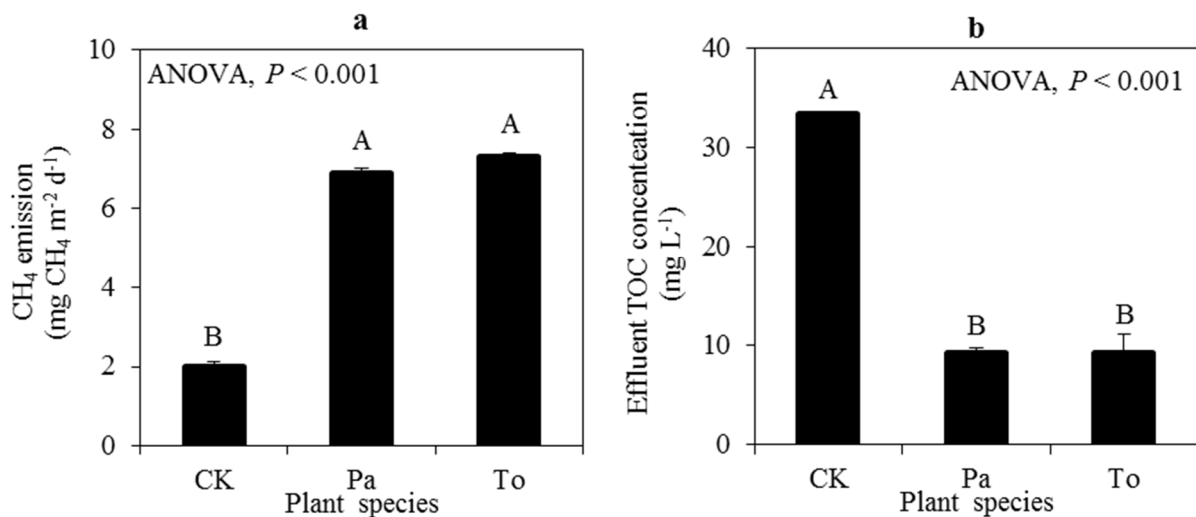


Fig. 1 Effects of plant species on a (CH₄ emission) and b (Effluent TOC concentration). Species abbreviations are: Pa, *Phragmites australis*; To, *Typha orientalis*

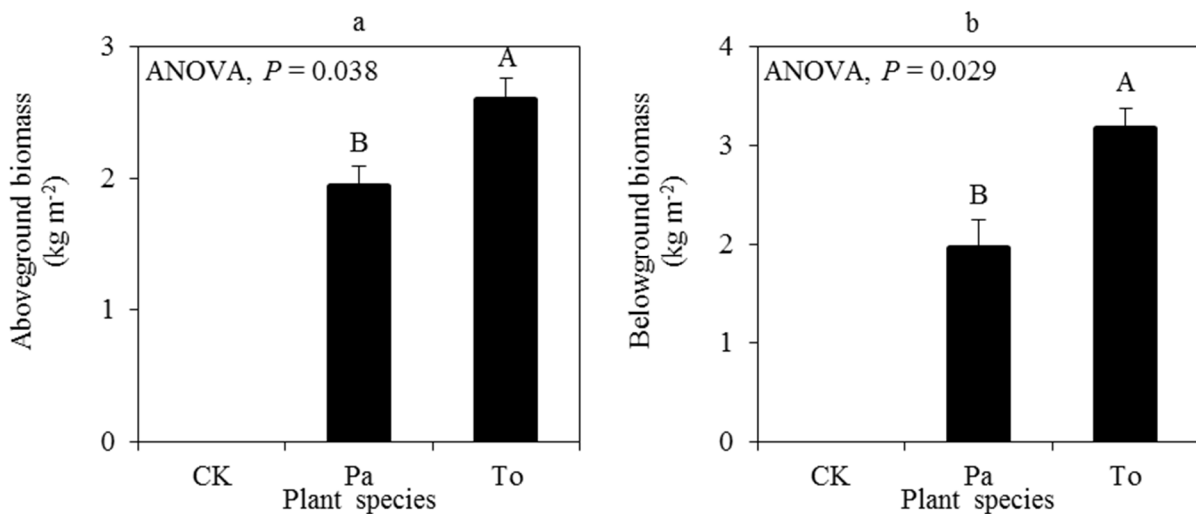


Fig. 2 Effects of plant species on a (aboveground biomass) and b (belowground biomass)

3.2. Effects of plant species on CH₄ emissions

In the current study, the CH₄ emissions in microcosms planted with *Phragmites australis* and *Typha orientalis* had no significant differences (Fig. 1a, $P > 0.05$). A possible reason was that the microorganisms related to CH₄ processes had no significant differences, because microbial biomass had no differences between *Phragmites australis* and *Typha orientalis* systems (Fig. 3a, $P < 0.001$). In addition, the aboveground and belowground biomass in the microcosms planted with *Phragmites australis* were lower than that in the microcosms planted with *Typha orientalis* (Fig. 2, $P < 0.05$), but the effluent TOC concentration had no differences in the two systems (Fig. 1b, $P > 0.05$). It is possible that the CH₄ production does not only depend on plant biomass but also available carbon quantity.

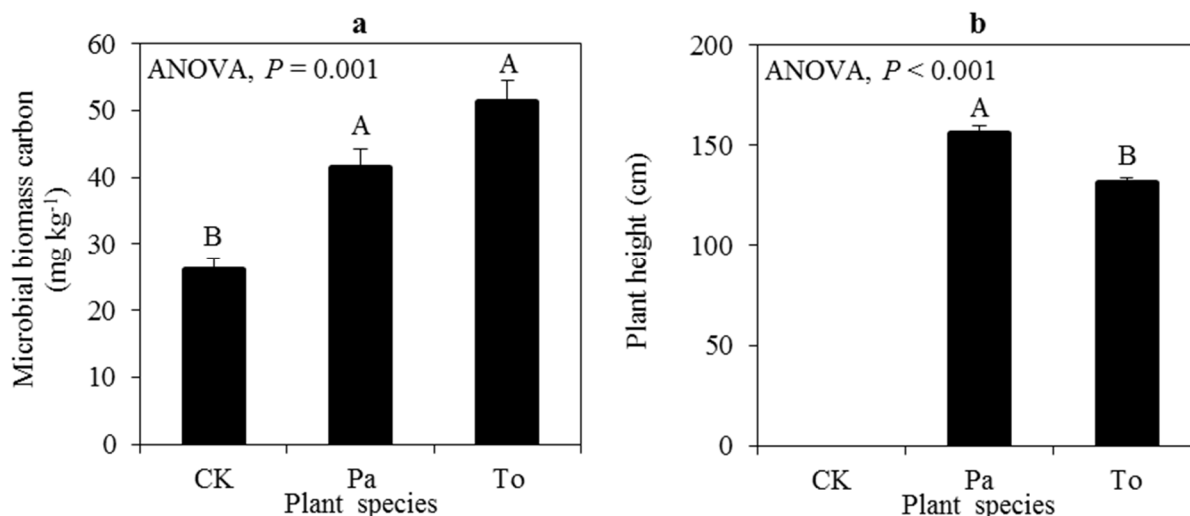


Fig. 3 Effects of plant species on a (Microbial biomass carbon) and b (plant height)

3.3. Effects of plant presence and plant species on nutrient removal efficiency

Contrary to CH₄ emissions, the effluent TOC concentration in the unplanted microcosms were higher than in those planted treatment (Fig. 1b, $P < 0.01$), showing a positive effect of plant presence on the C removal in the microcosms. A possible reason was that the nitrogen in different forms is absorbed by plants to build organic compounds. Our studies found that, the microbial biomass (Fig. 3a, $P < 0.001$) higher except for plant biomass production (Fig. 2, $P < 0.05$) in planted microcosms than that in unplanted systems. Carbon in the systems are degraded and transformed by a series of biochemical reactions by microbes.

Similar with CH₄ emissions, the effluent TOC concentration in microcosms planted with *Phragmites australis* and *Typha orientalis* had no significant differences (Fig. 1b, $P > 0.05$). However, the plant biomass and height in microcosms planted with *Phragmites australis* and *Typha orientalis* had significant differences. Microbial consumption and plant uptake are two major removal processes of carbon in CWs [13]. So, we think plant uptake had higher rate of removal contribution than microbial transition in this study.

In conclusion, our study demonstrated that plant presence enhanced CH₄ emissions, but plant species had no effect on CH₄ emission, indicating that plant presence and plant species are important factors in regulating CH₄ emission in CW systems.

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References

- [1] J. Vymazal, "Constructed wetlands for waste water treatment: five decades of experience" *Environmental Science Technology* 45: 61–69, 2011
- [2] A. Joabsson, T.R. Christensen, "Methane emissions from wetlands and their relationship with vascular plants: an Arctic example" *Global Change Biology* 7: 919–932, 2001
- [3] N.W. Zhu, B. Krishnakumar, L. Zhao, L.W. Sun, M. Mizuochoic, Y.H. Inamori, "Effect of plant harvest on methane emission from two constructed wetlands designed for the treatment of wastewater" *Journal of Environmental Management* 85: 936–943, 2007
- [4] L. Ström, A. Lamppa, T.R. Christensen, "Greenhouse gas emissions from a constructed wetland

- in southern Sweden" *Wetlands Ecol. Manag.* 15: 43–50, 2007
- [5] G. Maltais-Landry, R. Maranger, J. Brisson, "Effect of artificial aeration and macrophyte species on nitrogen cycling and gas flux in constructed wetlands" *Ecological Engineering* 35: 221–229, 2009
- [6] K.R. Edwards, H. Čížková, K. Zemanová, H. Šantrůčková, "Plant growth and microbial processes in a constructed wetland planted with *Phalaris arundinacea*" *Ecological Engineering* 27: 153–165, 2006
- [7] L. Ström, A. Lamppa, T.R. Christensen, "Greenhouse gas emissions from a constructed wetland in southern Sweden" *Wetlands Ecology Manage* 15 43–50, 2007
- [8] D.R. Hoagland, D.I. Arnon, "The water culture method for growing plants without soil", *California Agricultural Experiment Station* 347: 1–32, 1950
- [9] C.B. Zhang, H.Y. Sun, Y. Ge, B.J. Gu, H. Wang, J. Chang, "Plant species richness enhanced the methane emission in experimental microcosms" *Atmospheric Environment* 62:180–183, 2012
- [10] C.B. Zhang, W.L. Liu, J. Wang, Y. Ge, Y. Ge, S.X. Chang, J. Chang, "Effects of monocot and dicot types and species richness in mesocosm constructed wetlands on removal of pollutants from wastewater" *Bioresource Technology* 102: 10260-10265, 2011
- [11] A. Liikanen, J.T. Hurrunen, S.M. Karjalainen, K. Heikkinen, T.S. Väisänen, H. Nykänen, P.J. Martikaninen, "Temporal and seasonal changes in greenhouse gas emissions from a constructed wetland purifying peat mining runoff waters" *Ecological Engineering* 26: 241–251, 2006
- [12] A.K. Søvik, Kløve B. "Emission of N₂O and CH₄ from a constructed wetland in southeastern Norway" *Science of the Total Environment* 380: 28–37, 2007
- [13] J. Vymazal, "Removal of nutrients in various types of constructed wetlands" *Science of the Total Environment* 380: 48 – 65, 2007