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Nitrous oxide (N2O) emission patterns from baffled subsurface constructed wetlands

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ABSTRACT

In this study, nitrous oxide (N_2O) emission was analyzed in a newly developed baffled subsurface constructed wetland. N_2O was collected using a closed chamber. The effect of different loads and seasons was investigated and N_2O emission rate within 24 h was obtained. In addition, variation of N_2O flux along the flow direction was tested. The results indicated significant seasonal and diurnal variation. The peak of N_2O emission occurred in September, which is 393.21μg/m^2•d; the lowest value was in January, which was 84.291 μg/m^2•d. The maximum emission within a day was most likely occurred in the morning, whereas the minimum value was in the midnight. The nitrous oxide emission also varied obviously along the flow direction. The highest emission was observed at the inlet of the wetlands while lowest value was at outlet of the wetlands.

KEYWORDS

Constructed wetland;
Greenhouse gas;
Nitrous oxide;
Baffled subsurface constructed wetland.

INTRODUCTION

Constructed wetland (CW) is widely utilized in small towns and rural area for its hygienic and environment reasons, including low-maintenance-cost, easy-to-manage,efficient and stable performance[4,6]. Pollutant removal in constructed wetland is related to biological pathways and no additional energy is demanded. Constructed wetland is able to treat various types of wastewater and tolerate wastewater with high nutrients[11,12]. Besides, constructed wetlands can enhance the environment by planting ornamental plants[21]. Two basic types of constructed wetland used for wastewater treatment are surface-flow constructed wetlands and subsurface-flow constructed wetlands. According to the water flow, subsurface-flow constructed wetland could be further classified into vertical flow constructed wetlands (VFCW) and horizontal flow constructed wetlands (HFCW). VFCW is efficient at oxygen transportation and it has a greater capacity of denitrification[18]. However, neither VFCW nor HFCW could achieve high removal efficiency independently due to their deficiency in creating aerobic and anaerobic environment at the same time[17,18].

Compared to natural wetlands which are known as important carbon and nitrogen sinks[2,8], constructed wetlands receive higher nutrient and organic matter therefore they release higher amount of greenhouse gas. Numerous studies have proven that constructed wetlands make a substantial contribution to the greenhouse gas emission[10,14,16,20]. Nitrousoxide (N_2O), mainly produced during denitrification, has a global warming potential of 296 relative to CO_2[7] and contributes of global warming[13]. Methane (CH_4), generated in anaerobic condition, has a global warming potential of 23 relative to CO_2[7] and is responsible for 25 % of global warming[7].

This study adopted a novel design for subsurface constructed wetland, which constructedvertical baffles along length of the wetland thus achieving better flow pattern[15]. Conventional constructed wetlands usually use graded gravel as the growing medium, while this novel designed constructed wetland was filled enzymatic material thus increase the microbial attachment by improving its strength, stability and specific surface area.

This study monitored the emission of N_2O in this baffled subsurface constructed wetland. This paper reports about N_2O emission data from this constructed wetland, and its emission pattern was established thus fundamentalinformation for evaluating N_2O emission in China could be provided.

MATERIALS AND MATHODS

Wastewater quality

The experimental wastewater used domestic wastewater in Chongqing University, Chongqing, China. The influent quality varied significantly according to the students' daily activity. The extra rain water was added proportionally to stabilize the wastewater quality when high concentration of pollutants was contained in the domestic wastewater. The wastewater quality was listed in TABLE 1.

TABLE 1 : The experimental wastewater quality

COD	BOD_5	TN	NH_3-N	TP
90-150	44-60	17-32	17-25	0.8-2

The experimental constructed wetlands

Paralleled walls were constructed inside the baffled constructed wetlands and divided each baffled unit into 400 mm in width. The slope of the bottom was 1 % along the length of the constructed wetlands. The diagram of the baffled constructed wetlands was showed in Figure 1.

Three levels of constructed wetlands were designed to adjust the experimental operation. For each level, the effective area was 2.5 m^2 and height was 1 m thus the effective volume for each level was 2.5 m^3. A trough for reaeration was set between two levels to increase the dissolved oxygen in the wastewater. The trough was 2.2 m at length and 0.4 m at width. Different combination of different levels could be chosen based on the designed load.

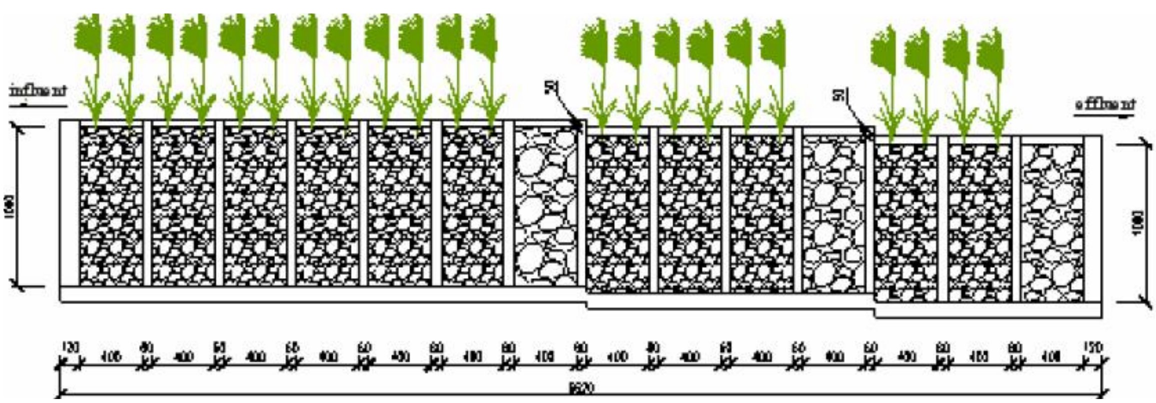

Figure 1 : The diagram of experimental constructed wetland

According to the preliminary experiment (Li, 2013), enzymatic material was filled to support the plants and microbe. The diameter of the enzymatic material was decreased along the length thus prevented the system from blocking. Smaller material was used at the end of the constructed wetland to enhance the microbe attachment.

The *Cyperusalternifolius* L. and *Eichhornia-crassipes* (water-hyacinth) were planted. The density of *C. alternifolius* L. and water-hyacinth was 20 rhizomes/m^2 and 10 rhizomes/m^2, respectively. Nitrousoxide (N_2O) was analyzed using Portable HA80- N_2O.

Treatment studies

The experiment was conducted in august, winter and spring. During each season, three hydraulic loads were designed to monitor the N_2O emission from the baffled constructed wetland, including high (0.35 m/d), medium (0.25 m/d) and low (0.15 m/d) hydraulic load. And the system was operated for 25-30 days until it reached stability in different seasons. Rainy days were avoided in this experiment to guarantee the accuracy. The hydraulic retention time was 12-24 h and organic load was2-6 kgBOD_5/m^3•d.

Nitrous oxide (N_2O) was collected using a closed chamber. The chamber was place along the center axle of the constructed wetland to eliminate the difference along the width. The sampling was conducted from August 2012 to April 2013, twice or three times a week. Gas samples were collected at 10:00 -11:00 and analyzed at 0, 5, 10, 15, 20, 25, 30, 40, 50 and 60 after enclosure. In order to obtain N_2O emission rate within 24 h, the gas samples were measured every 2 h; whole-day monitoring was conducted once a week.

For water samples, BOD_5 and pH were measured by HACH BODTrak and HACH sensor2, respectively. The concentration of TN, NH_4^+, NO_3^-, NO_2^- and COD were tested according to Standard Methods for the Examination of Water and Wastewater[1].

RESULTS AND DISCUSSIONS

Seasonal variation of N_2O emission

The gas was collected from August, 2012 to April, 2013. Monthly average data were calculated to obtain the N_2O flux in each month. The results under the maximum load were illustrated in Figure 2.

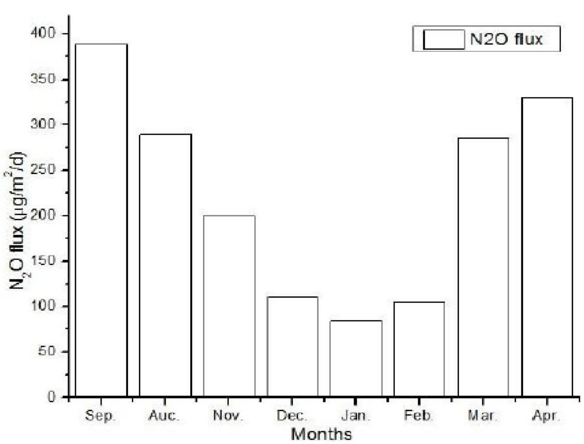

Figure 2 : Seasonal variation of N_2O flux in the constructed wetland

From Figure 2, it was obvious that N_2O flux in autumn was much higher in spring and winter. The value

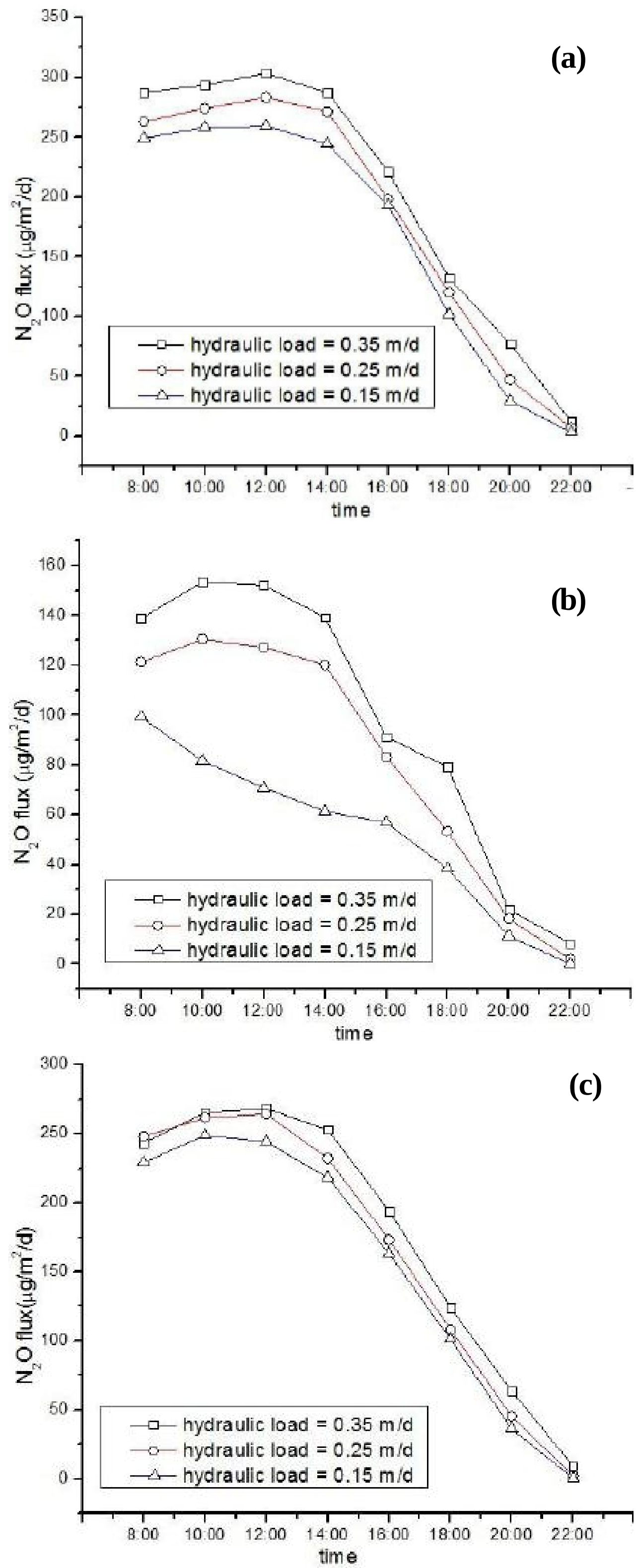

Figure 3 : Diurnal variation of N_2O flux under different hydraulic load in autumn (a), winter (b) and spring (c)

dropped to its bottom in winter, and in some monitoring dates, the data indicated that N_2O was absorbed into the wetlands. The plants grew vigorously in autumn, and temperature was relatively higher in that time, thus the treatment capacity was stronger in autumn. In winter, the microbes were low in quantity and activity due to the cold environment, the withered plants also lead to low purification ability; in spring, plants and microbes started to revive, and the risen temperature also contributed to improvement of treatment capacity. In addition, vigorous growth of *C. alternifolius* L in autumn consumed large amount of dissolved oxygen, and under low oxygen environment, N_2O is a common intermediate in denitrification[3,9].

Figure 2 also indicated significant difference of N_2O flux in different months. During the monitoring period, N_2O flux reached its peak (389.25 μg/m²•d) in September which the temperature was the highest; the lowest flux (84.29μg/m²•d) occurred in January, 2013, which was the coldest month.

Day variation of N_2O flux of constructed wetland

Day variations of N_2O flux were analyzed under different loads and seasons. The results (Figure 3 a, b and c) indicated the flux varied significantly within a day.

From Figure 3, the N_2O flux varied in a wide range. The constructed wetlands release more N_2O when the hydraulic load was high; under the same load condition, the N_2O flux reached its maximum from 10:00 to 14:00. In this period of time, both temperature and photosynthesis rate reached maximum within a day. Plant stopped photosynthesis at night while respiration became much stronger due to lower temperature, thus N_2O emission was low even negative (i.e. sink) at night.

Variation of N_2O flux along the length

Gas was sampled along the length of the constructed wetlands. Results were showed in TABLE 2, which indicated that N_2O declined along flow direction. Organic content was highest at the inlet of the wetlands, adequate carbon and nitrogen source generated the highest N_2O flux. Organic content as well as carbon and nitrogen source consumed during purification process, thus N_2O emission reduced.

CONCLUSION

The N_2O fluxes in experimental wetlands indicated significant seasonal and diurnal variation. The peak of N_2O emission occurred in September, which is 393.21μg/m²•d; the lowest value was in January, which was 84.291 μg/m²•d. The maximum emission within a day was most likely occurred in the morning, whereas the minimum value was in the midnight. The nitrous oxide emission also varied obviously along the flow direction. The highest emission was observed at the inlet of the wetlands while lowest value was at outlet of the wetlands. Adequate carbon and nitrogen source promoted nitrification and denitrification, thus the N_2O flux increased.

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