MEASUREMENT OF GREENHOUSE GAS EMISSIONS FROM CONSTRUCTED WETLTANDS FOR SLUDGE TREATMENT

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Abstract

Constructed wetlands have been successfully employed as wastewater treatment for pollutant and nutrient removal during the last years. More recently those systems have been adapted to sewage sludge treatment as a drying and stabilization technique. In constructed wetlands, nutrients and organic matter are converted to organic compounds through microbiological processes during which greenhouse gases as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are released. The aim of this work is to establish a sampling and analyzing method to determine greenhouse gases emissions from constructed wetlands for sludge treatment. Furthermore, methane and nitrous oxide fluxes are evaluated in a full-scale system located in Spain. In order to fulfill the objective, sampling and analyses techniques used to determine greenhouse gases emissions from croplands and natural wetlands have been employed in a sampling campaign carried out in July. CH_4 emissions from the studied systems vary between 30 $mg/m^2 \cdot d$ before feeding and 5000 $mg/m^2 \cdot d$ after sludge spreading, when methanogenic activities are enhanced due to the anaerobic conditions. Those values are consistent with previous studied carried out on wastewater constructed wetlands. Concerning N_2O emissions, values between 20 and 2500 $mg/m^2 \cdot d$ have been detected, similar to those found previously in crop fields. Generally the increasing of one of the gases correspond to the decreasing of the other, probably due to the high correlation between gas emission and oxygen content. In fact, anaerobic conditions enhance methane production while aerobic conditions promote nitrous oxide fluxes.

Keywords

Drying reed beds; Global Warming Potential; Methane; Nitrous Oxide; Sludge Management

Introduction

Constructed wetlands (CWs) are widely recognised as an alternative to conventional wastewater treatments able to reduce pollutant and nutrients input to water bodies and thus to prevent eutrophycation. More recently, CWs have been adapted to sewage sludge management as a low cost and low energy demand treatment able to enhance sludge dewatering and stabilisation in order to obtain a final product suitable for agricultural uses (Uggetti et al., 2010).

In wetlands, the elevated amount of nutrients and organic matter is removed as a result of physical, chemical, biological and microbial processes. As a result of those processes gaseous compounds like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are released to the atmosphere contributing to the global warming (Kadlec and Wallace, 2009).

The aim of this study is to establish a sampling and analyzing method to determine greenhouse gases emissions from constructed wetlands for sludge treatment. Furthermore, methane and nitrous oxide fluxes are evaluated in a full-scale system located in Spain.

Methods

La Guixa is a small wastewater treatment plant (1000 PE) located in the province of Barcelona (Spain) treating 100 m^3/d of wastewater in an extended aeration system. Here 5 beds with a total surface of 210 m^2 were established in 2005 to treat the sludge from the biological treatment. To allow gas sampling, during the experiment period (3 weeks), the sludge corresponding to the week loading was spread at once at the beginning of each week. Thus, the bed was weekly fed with 4 m^3 of sludge, corresponding to 0.08 kg TS.

One bed (5m x 7m) was sampled in 9 points daily during 3 cycles of loading (day 1, 6 and 11), resulting in 15 sampling. Gas samples were collected using static chamber technique adapted for emergent macrophytes (Crill et al, 1991). Each cylindrical PVC chamber (diameter of 40 cm and height of 60 cm) with a removable lid was equipped with a thermometer and two computer fans to ensure thorough gas mixing and to prevent excessive warming within the sampler.

During the first sampling day the chambers were pressed into the sludge about 10 cm deep to ensure air tightness. Afterwards, to prevent further sludge and vegetation disturbance, the frames were left in the sludge during the whole sampling period while the fans where running. Consequently the chambers volume used ranged from 125.5 and 134 dm^3 depending on the sludge thickening. The measurement starts after fitting the lid, blending accurately the highest plants inside the chamber. Gas samples (30 ml) were taken by means polypropylene syringes 0, 5, 10, 20 and 40 minutes after the installation.

Samples, stored in glass evacuated vials, were analysed using gas chromatograph (Shimadzu GC-14B or Hewlett-Packard 5890) equipped with flame ionisation (FI) and electron capture (EC) detectors. The calibration was made with three standards containing respectively 1.98 and 15 µl/l of CH_4 and 0.389, 3 and 50 µl/l of N_2O. The linear change in gas concentrations in the headspace of the chamber allows the calculation of the gas fluxes. The rate of gases increasing in the chamber was calculated from the linear regression of concentration measurement versus time. Subsequently, the emission rate was calculated in unit of $mg/m^2 \cdot d$ correlating the rate of gas increasing and the surface area and volume of the chamber.

Results and discussion

The average emission form different sampling points and standard deviation are resumed in Figure 1, where CH_4 and N_2O emissions are showed for each sampling day. CH_4 values before the sludge feeding vary between 30 $mg/m^2 \cdot d$ in the first measurement (day 1 in the graph), 600 $mg/m^2 \cdot d$ in the second (day 6) and 2000 $mg/m^2 \cdot d$ in the third feeding (day 11). It is important to highlight that the variability between emissions is confirmed by differences in moisture content (45, 65 and 80% in the three campaigns respectively). In fact, due to the short period between feedings (only 5 days), the bed is getting more wet after each feeding and CH4 emissions are increasing.

The emission pick around 5000 mg/m^2·d has been recorded immediately after feeding (day 1), when the humidity was higher (near 80%). CH_4 fluxes are then decreasing up to 1400 mg/m^2·d 24h after feeding (days 2 and 7), followed by a light increase after 48 hours (around 3000 mg/m^2·d in days 3 and 8). This patter indicates that methanogenic activity is lower when the sludge is dryer (47% of moisture) and increase significantly during sludge loading (77% of moisture), afterword emissions decrease and oscillate around intermediate values according to sludge dryness. This outline is confirmed by the third feeding, when the humidity is higher (around 80%) during the four days and the gas flux increases approximately from 4000 to 6000 mg/m^2·d. Correlations between soil moisture and gas emission were found in peats (Martikainen et al, 1993, Regina et al, 1996).

Concerning N_2O emissions, the variations are generally lower than CH_4. The values vary between 950 and 500 mg/m^2·d in the first feeding period (days 1-5) and between 2500 and 300 mg/m^2·d in the second (days 6-10). After the third feeding (day 11) values are always lower than 60 mg/m^2·d. Contrary to the methane, the N_2O fluxes are reduced immediately after feeding (from 950 to 600 mg/m^2·d, from 2000 to 500 mg/m^2·d and from 130 to 30 mg/m^2·d after the three feedings respectively), values are roughly constant and significantly lower after the third feeding (day 11), corresponding to the higher CH_4 emissions (up to 5000 mg/m^2·d).

Even if N_2O fluxes are significantly lower than CH_4, an inverse trend is highlighted, the increasing of one of the gases correspond to the decreasing of the other. This is probably due to the variations in oxygen content within the bed, in fact in saturated and anaerobic conditions (after feeding) methane is produced while during sludge drying the moisture reduction leads to a higher oxygen content which enhance nitrification and denitrificaiton with the consequent N_2O emissions. Indeed methane is generally produced in anoxic soils and sediments, while nitrous oxide is formed as intermediate in denitrification or as a byproduct in nitrification (Knowles, 1982).

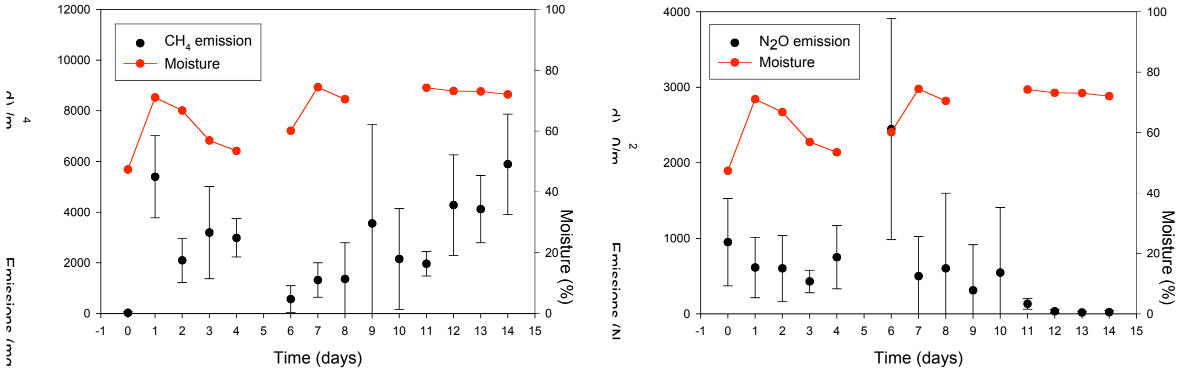

Figure 1. Average of CH_4 and N_2O emissions recorded within the bed and moisture data.

According to Sovik et al. (2006), in wastewater constructed wetlands CH_4 emissions vary between 30 and 980 mg/m^2·d, similar values have been found in this study when the sludge is more dry (mainly before feeding). On the other hand, N_2O emissions from sludge are significantly higher than wastewater emissions (0.1-15 mg/m^2·d) probably due to the nitrification-denitrification processes and to the high nitrogen content within the feeding sludge. However, emissions from barely crop and potato fields can reach N_2O emissions of 2400 $mg/m^2 \cdot d$ (Maljanen et al, 2007). If we consider the surface area of a crop field compared with a constructed wetlands, N_2O emissions found in this study are negligible in the global warming potential.

Conclusions

From the study carried out the following conclusions can be drawn:

The static chamber technique used to determine greenhouse gases emissions from croplands and natural wetlands can be successfully used in constructed wetlands for sludge treatment.

The emissions of CH_4 vary between 30 and 5000 $mg/m^2 \cdot d$ before and after sludge feeding, while N_2O variations are lower (17-700 $mg/m^2 \cdot d$). In average, CH_4 fluxes are consistent with emissions from wastewater constructed wetlands, while N_2O emissions are comparable to crop fields ones.

Generally the increasing of one of the gases correspond to the decreasing of the other, probably due to the high correlation between gas emission and oxygen content. In fact, anaerobic conditions enhance methane production while aerobic conditions promote nitrous oxide fluxes.

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