Int. Agrophysics, 2007, 21, 323-328

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

CO_2, N_2O and NH_3 emissions from two different type of soils as affected by applications of dairy sewage sludge**

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Received October 29, 2007; accepted December 12, 2007

A b s t r a c t. A pot experiment with the dairy sewage sludge (DSS) was conducted under aerobic condition (60% WHC, water holding capacity) for a period of 240 days. The emissions of carbon dioxide (CO_2), nitrous oxide (N_2O) and ammonia (NH_3) were determined in grey-brown podzolic and brown soils. Both soils were amended by different doses of DSS (0, 30, 60, 80, 120, 200, 300 and 600 t ha^{-1}). In general, the amendment of DSS stimulated CO_2 and N_2O emissions from both soils. This effect increased after the incorporation of high doses of DSS. It was confirmed by significant positive correlations between the doses of DSS and CO_2 and N_2O fluxes. This study showed that DSS application had no sicnificant influence on the emission of NH_3. In both soils the NH_3 emission was noted only once during the incubation period and only in the treatments with the highest doses of DSS. The long-term addition of DSS on this parameters needs further examination.

K e y w o r d s: brown soil, carbon dioxide, dairy sewage sludge, grey-brown podzolic soil, nitrous oxide

INTRODUCTION

Soils are regarded as the important sources for the production of the carbon dioxide (CO_2) and nitrous oxide (N_2O). These two gases are important greenhouse gases in the atmosphere contributing about 50 and 5% to the global warming, respectively (Lou *et al.,* 2007). Microbial and chemical processes that occur in the soil affect the concentrations of greenhouse gases in the atmosphere (Mosier, 1998). Soil processes contribute about 1% of CO_2 (Chu *et al.,* 2007), 20% of NH_3 and 70% of N_2O (Mosier, 1998). Therefore, there is no doubt that agriculture plays an important role in the global budget of greenhouse gases (Chu *et al.,* 2007). Increasing concentrations of CO_2 in the atmosphere account for greater plant CO_2 assimilation and biomass production in many ecosystems (Mosier, 1998). There are two main groups of microorganisms in soil: heterotrophic and autotrophic organisms, that are involved in the CO_2 production in the soil. Most CO_2 produced by heterotrophic soil organisms is respired by microorganisms, such as bacteria, non-mycorrhizal and mycorrhizal fungi and actinomycetes (Kuzyakov, 2006). CO_2 in soils is produced also through various processes, such as biological oxidation of soil organic matter and decomposition of crop residues and wastes incorporated into the soil, such as sewage sludge (Kuzyakov, 2006; Mosier, 1998). Nitrification and denitrification, microbial processes which rely on mineral nitrogen (ammonia and nitrate) as their substrate, are responsible for most of the N_2O produced in soil (Azam *et al.,* 2002; Firestone and Davidson, 1989). The high antropogenic N_2O emission is also result of increased nitrogen input into agricultural soils (Chu *et al.*, 2004).

Land use of the dairy sewage sludge can also affect on the fluxes of nitrogen oxide (N_2O) and carbon dioxide (CO_2). Dairy sewage sludge, which contains high concentrations of plant nutrients, in particular N and P, and the large of organic matter content, is valuable for maintaining or improving soil biological characteristics (Jezierska-Tys and Frąc, 2005; 2006). It is well known that soil applications of organic and nitrogen materials stimulate surface emissions of CO_2 (Kuzyakov, 2006; Masunaga *et al.,* 2007) and N_2O productions (Ambus *et al.,* 2001). It is little known about the fluxes of CO_2, NH_3 and N_2O under the influence of the dairy sewage sludge (DSS). The aim of this study was to evaluate the emissions of these gases (CO_2, NH_3, N_2O) from two different type of soils in response to various doses of dairy sewage sludge applications in pot experiment.

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**This research was funded by the Ministry of Science and Informatization in Poland, Project No. 2 P06S 042 30.

MATERIAL AND METHODS

The experiment was carried out on two different type of soil: grey-brown podzolic soil and brown soil. The grey-brown podzolic soil used in this study was collected from Piaseczno while brown soil was collected from Krasnystaw, both located at south-east of Poland. The grey-brown podzolic soil had the following granulometric composition: sand fraction 65%, silt fraction 19% and fine slit and clay fraction 16%. The brown soil was formed from silt-loam with 8% sand fraction, 47% slit fraction and 45% clay and slit fraction. Other characteristics of both soils are given in the Table 1. The dairy sewage sludge (DSS) used in the experiment came from the Regional Dairy Cooperative in Krasnystaw. Some chemical properties of this sludge are presented in Table 1.

Table 1. Characteristics of soils and dairy sewage sludge used in the experiment

Parameters	Brown soil	Grey-brown podzolic soil	Dairy sewage sludge (DSS)
pH_{KCl}	6.4	4.8	8.5
C (g kg^{-1})	13.5	4.5	400.0
N (g kg^{-1})	1.6	0.4	33.2
C/N	8.3	12.5	12.0
	Macronutrients (total g kg^{-1})		
P	18.3	5.3	11.5
K	26.8	8.7	2.5
	Heavy metals (mg kg^{-1})		
Zn	28.7	11.7	95.0
Cd	0.16	< 0.16	2.6
Cu	7.16	2.21	19.8
Pb	10.3	7.08	9.0
Ni	10.1	2.98	12.6
Cr	18.4	8.10	36.8
Hg	0.09	0.03	0.22

The soils were collected up to a 20 cm depht from a few different locations to obtain representative samples. Air-dried and sieved (<2 mm) soil (4 kg) was placed in pots and mixed up with different doses of dairy sewage sludge. There were 16 of treatments (8 in the grey-brown podzolic soil and 8 in the brown soil). There were incorporated the same doses of DSS into each soil. Each treatment consisted at three replicates. The dairy sewage sludge were applicated into soils at the following doses: control – no sludge (DSS-0); 30 (DSS-30); 60 (DSS-60); 80 (DSS-80); 120 (DSS-120); 200 (DSS-200); 300 (DSS-300) and 600 t ha^{-1} (DSS-600). The soil samples were incubated at the 20ºC through 240 days. Each treatment was watered up to 60% of the total water capacity. The analysis were measured after 14, 30, 60, 90, 120 and 240 days after the incorporation of DSS. 5 g of soil was put into the jar (60 cm^3). The soil was watered (5 ml) and closed by stopper. The gas samples were evacuated through a septum in the jar lid.

The following methods were used to determine the CO_2 and N_2O emission: according to Włodarczyk (2000) and Horn *et al.* (1994), respectively. The gas samples were analysed for CO_2 and N_2O by a gas chromatograph (Shimadzu GC-14) equipped with TCD and ECD, respectively. These analyses were done in Institute of Agrophysics PAS in Lublin. The emission of NH_3 from soils was measured by the spectrophotometric method of Kim (1973).

Statistical analysis were performed using Statistica 7.1 software. An ANOVA at a probability level of 5% was used to test the significance of the treatment effects. The correlation test was used to estimate the relationships between the examined characteristics.

RESULTS

In comparision with the control, the amendment of DSS obviously stimulated CO_2 emission from the both soils. Generally, CO_2 fluxes from the grey-brown soil were higher than from the brown soil. CO_2 fluxes were affected by the DSS amended to the soils, especially at the early stage of the incubation (Fig. 1). From grey brown podzolic soil the highest CO_2 emission was observed since the beginning of the incubation till 60 days after the incorporation of DSS and then decreasde until the end of this study. The little increase was noted only since the last terms of analysis. In brown soil the highest stimulation of CO_2 emission was observed also at the beginning of the incubation till 30 days of the experiment. The stimulating effect showed up better in gas samples from grey-brown podzolic soil than brown soil. The highest increase CO_2 emission from both soils was measured in the treatments with the highest doses of DSS, that is 200, 300 and 600 t ha^{-1} (Fig. 2). Statistical analyses further indicated that CO_2 fluxes were significantly positively correlated with doses of the DSS incorporated to the soils and N_2O emission from soils. The significantly negative correlation was noted between CO_2 emission and the soils time of incubation (Table 2).

The variations of N_2O emission from soils are presented in Fig. 3. The N_2O emission was varied according to the type of soils. In grey-brown podzolic soil, compared with the control, N_2O emission was rapidly increased from 0 to 30 days after the amendment of DSS and then gradually reduced to the lower values near to the control. In brown soil the stimulation of N_2O fluxes were observed only after 30 days of incubation. In other terms of analysis the N_2O emission was at the same level in all the treatments. Statistical analysis confirmed that only the highest doses of DSS significantly increased the N_2O emission from soils

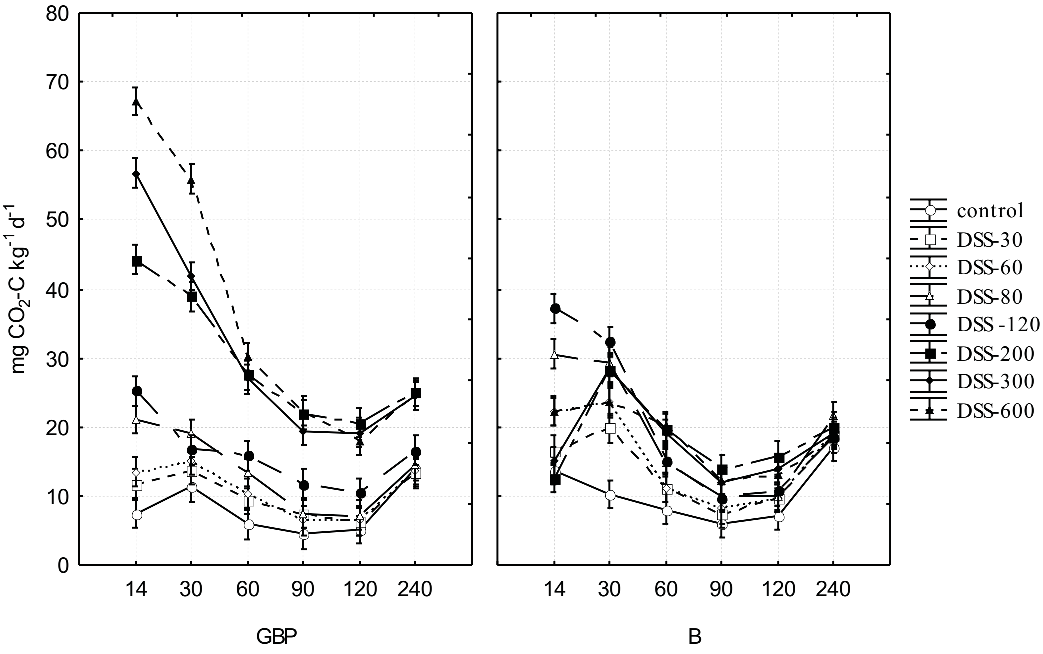

Fig. 1. Changes of CO_2 fluxes from a grey-brown podzolic (GBP) and brown (B) soils amended with dairy sewage sludge under aerobic incubation. Values are the mean of triplicates. Vertical bars indicate the standard error of the averages. ANOVA for dose of DSS – $LSD_{0.05}$=3.13.

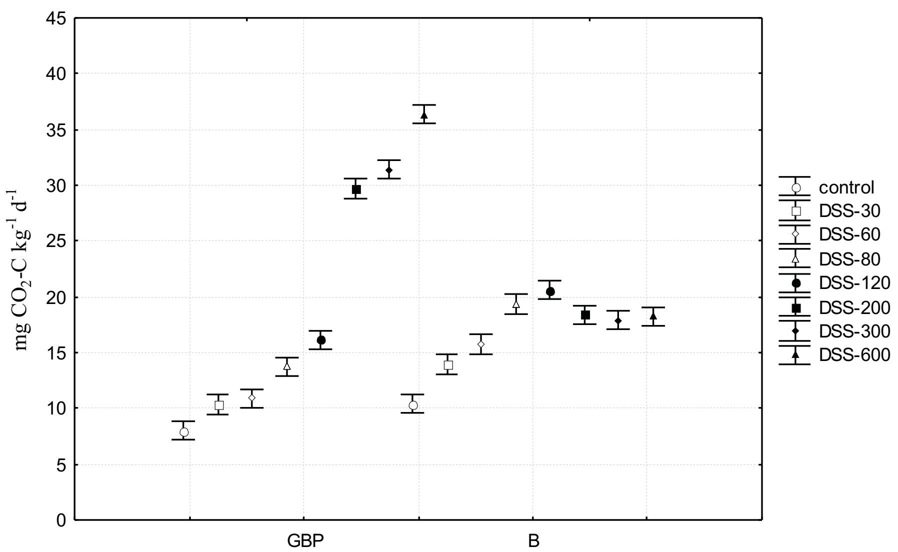

Fig. 2. The mean values of CO_2 fluxes during incubation period.

(Fig. 4). The statistical analyses showed significant positive correlations between the N_2O emission and the dose of DSS and CO_2 fluxes. The negative correlation was observed between N_2O emission and soils incubation time (Table 2).

The content of NH_3 emission from both soils was at the level of zero during incubation time in most of the treatments. In grey-brown podzolic soil, the significant increase of NH_3 emission was observed only 30 days after the incorporation of DSS in the treatment with the highest dose of sludge (600 t ha^{-1}). In brown soil, the increase of NH_3 emission was observed also 30 days after the application of DSS in treatments with 300 and 600 t ha^{-1} (Fig. 5). These values had the influence on the level of means values of NH_3 emission, that are presented on the Fig. 6. Amounts of NH_3 emitted were significantly positively correlated with the dose of DSS and negatively with incubation time (Table 2).

T a b l e 2. Statistical characteristic (correlation coefficients)

Parameters	DSS dose	Incubation time	CO_2	N_2O	NH_3
DSS dose	–	–	0.54 ***	0.33 ***	0.22 ***
Incubation time		–	-0.36 ***	-0.33 ***	-0.20 ***
CO_2			–	0.72 ***	0.14 *
N_2O				–	n.s.
NH_3					–

DSS – dose of dairy sewage sludge. Indicate significance at the: *5, **1, ***0.1% level, n.s. – no significant.

emission from soil amended with sludge suggests that soil microbial activity is affected by this waste application in a prolonged period. Similar results were obtained in the presented study, but the dairy sewage sludge was used in this experiment.

Nitrous oxide fluxes are often stimulated by mineral fertiliser applications, particularly on wet soil (Clayton *et al.,* 1994), and also by organic amendment (Ball *et al.,* 2002). In our research DSS applications increased the emission of N_2O. However, the incorporation of DSS had little effect on the N_2O emission, because the single application resulted in increase only at the beginning of the experiment. The results of the present study do not indicate that losses of N_2O are high during single application of DSS, but N_2O emission increases with the dose of this waste application.

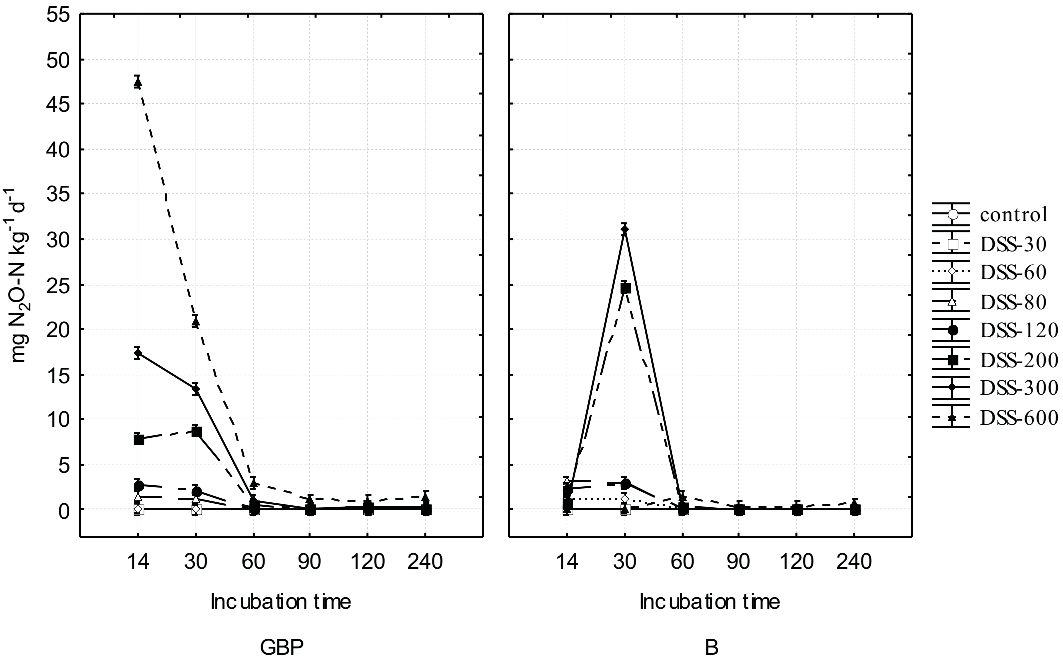

Fig. 3. Changes of N_2O fluxes from a grey-brown podzolic (GBP) and brown (B) soils amended with dairy sewage sludge under aerobic incubation. ANOVA for dose of DSS – $LSD_{0.05}$=9.93.

DISCUSSION

Under non-planted conditions, soil CO_2 emission is mainly caused by microbial respiration, and it is important parameter for evaluating microbial activity in soils (Lou *et al*., 2007). In our study CO_2 emission was significantly higher in the dairy sewage sludge amended soils than in the control (Fig. 1). Soil CO_2 flux was rapidly increased at the beginning of the experiment. This indicated that the microbial activities were stimulated by probably the increased C supply and the substrates after DSS incorporation. Significantly positive correlation was obtained between CO_2 flux and dose of DSS, with the correlation coefficient 0.54***. According to Ambus *et al.* (2001) the high content of CO_2

According to Ambus *et al.* (2001) the utilisation of sewage sludge in agriculture may have a relatively limited impact on the N_2O gas balance. Nitrous oxide emissions measured in the soil with different doses of DSS indicated that organic matter and nitrogen incorporated into soil with thie sludge stimulated microbial activity, especially in the treatments with high doses of the DSS. A significant positive correlations between N_2O and CO_2 emissions observed in the present study and these reported by others (Azam *et al.,* 2002) support the contention that enhanced microbial activity is responsible, at least partially, for the observed N_2O emissions that followed nitrogen matter addition.

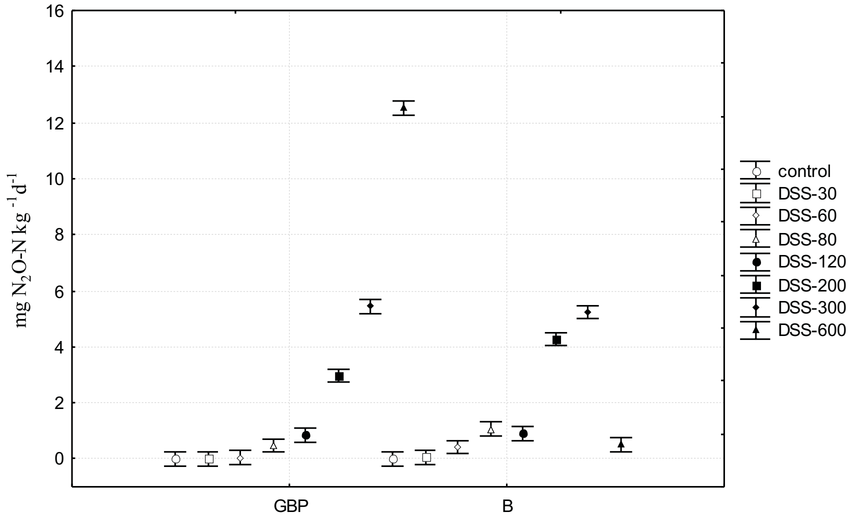

Fig. 4. The mean values of N_2O fluxes during incubation period.

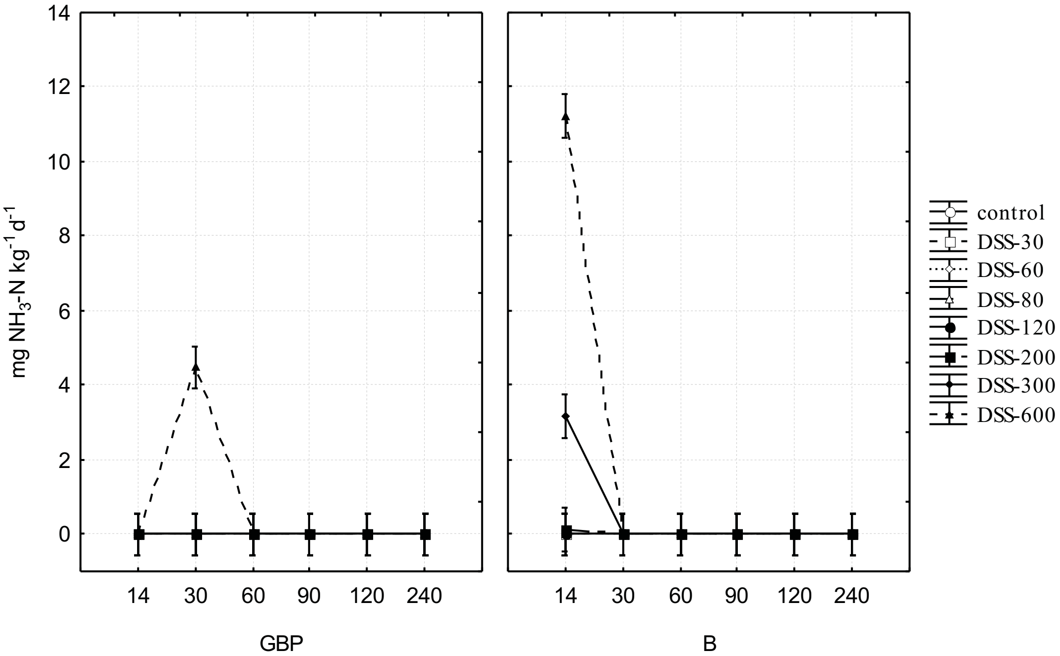

Fig. 5. Changes of NH_3 emission from a grey-brown podzolic (GBP) and brown (B) soils amended with dairy sewage sludge under aerobic incubation. ANOVA for dose of DSS – $LSD_{0.05}$=0.85.

In our experiment only one type of organic wastes (DSS) was tested, further research is needed to investigate the contribution of different wastes to the emissions of CO_2 and N_2O, and to assess the controling factors to predict CO_2 and N_2O emissions from different type of soils. It is important to assess how the long-term addition of DSS will influecne on the CO_2 and N_2O emissions, because in this study only single application was researched. This needs further examination.

CONCLUSIONS

1. The present study showed that DSS application, in general, had no significant effect on the emission of NH_3 from soils. In both soils the NH_3 emission was noted only once during the incubation period in the treatments with the highest doses of DSS (300 and 600 t ha^{-1}).

2. The results of our research indicated that the dairy sewage sludge is one kind of the organic wastes that increased emission of greenhous gases (CO_2, N_2O) from soils.

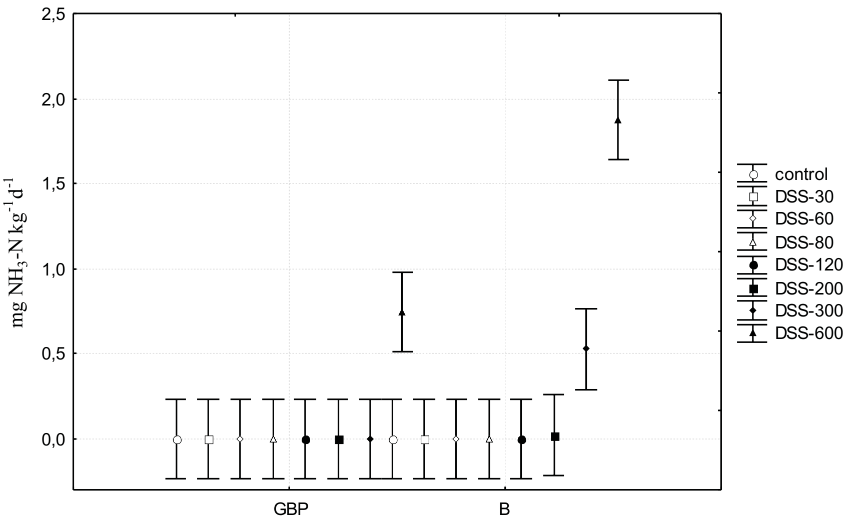

Fig. 6. The mean values of NH_3 emission during incubation period.

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