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Emission of Nitrous oxide, Nitrogen and Methane from Palm Oil Sludge-amended Soil

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ABSTRACT. *Improper incorporation of organic matter in arable lands pollutes the atmosphere and reduces soil fertility, mainly the nitrogen value of agricultural lands, due to emission of gases through the process of denitrification and methanogenesis. Nitrous oxide and CH_4 are specially responsible for the atmospheric warming and destruction of the ozone layer. Present practices to minimize the emission of these gases are scanty.*

Hence, a study was conducted to find out the effect of pore size distribution under different organic matter amendments on the emission rates of N_2O, N_2, and CH_4; because such information will be useful in the identification of contributing measures. Palm oil sludge (POS) was used as the source of organic matter. This was mixed with sandy loam soil at different ratios to make different POS-soil mixtures. The amount of N_2O, N_2 and CH_4 emitted from each POS-soil mixture was quantitatively estimated daily, using "Porpoak Q" column containing flame-ionization-detector. The pore size arrangement of POS-soil mixtures was studied by scanning electron microscopy (SEM). The results revealed that lower and higher rates of POS amendments enhanced the emission rate of N_2O, N_2 and CH_4. Significant reduction ($P > 0.001$) in the emission rate of the above gases was observed at the rate of 15% amendment, compared to the higher and lower rates. Estimated reduction in emission rates of N_2O, N_2 and CH_4 were 73.6, 391.7 and 231.3 μg/g/day at the 15% POS mixtures, compared to the highest emission rates of 366.6, 780 and 756 μg/g/day, respectively. Scanning electron microscopic study revealed that there was considerable blocking of macro pores of sandy loam soil by POS particles, which may have resulted in varying emission rates of gases from different POS-soil mixtures.

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INTRODUCTION

More careful and efficient use of inorganic and organic fertilizers are needed to raise agricultural efficiency and to optimize crop production (Newbould, 1989). Improper addition of organic matter to arable lands pollutes the atmosphere and reduces soil fertility; mainly the nitrogen and carbon values of agricultural lands, due to the emission of gases through the process of denitrification (Sprent, 1990) and methanogenesis (Dixon, 1991). Most of these gases adversely affect the composition of the atmosphere, climate and functioning of terrestrial eco-systems (Harold *et. al.*, 1987). Nitrous oxide and methane are specially responsible for the atmospheric warming and destruction of the ozone layer; and a quantitative estimation of these global gases under different agro-climatic regions is well documented (Ramanathan, 1988; Lindau and De Laune 1991; Marie Kralova *et al.*, 1992). At present, knowledge on the practices of organic matter application to minimize these adverse effects is scanty. Proper incorporation of organic matter, with soil as a soil conditioner, could help to minimize environmental pollution due to gas emission. The gas emission rate/unit weight or area of soil could depend on soil structure and aeration capacity of soil, particularly on proportion of macro and micropores volumes. Incorporation of higher doses of palm oil sludge with sandy loam soil, deteriorates soil structure by blockage of soil pores; which caused reduced oxygen penetration, creating anaerobic conditions (Vidhana Arachchi and Nor, 1994). Emission of gases from wet lands depends on the soil and atmospheric temperature, soil moisture, the amount and composition of organic substrate and vegetation (Harold *et al.*, 1987).

Palm oil sludge (POS) is a waste product that can be successfully utilized as an important source of organic matter and as a soil conditioner (Teoh *et al.*, 1986). Hence, the effect of different application rates of POS to soil on pore size distribution and their effect on emission rates of N_2, N_2O and CH_4 are discussed in this paper.

MATERIALS AND METHODS

Soil and palm oil sludge (POS)

Palm oil sludge was used as a soil conditioner in this study, and a sandy loam top soil was collected from the premises of the University Sains, Malaysia. The soil was air dried and passed through a 2 mm sieve before carrying out the experiment. Fresh solid POS was obtained from Malpom Industries Bhd in Seberang perai, Penang. The top oil layer of POS was removed by adding a sufficient amount of water and drying at 60°C for 3 days. The dried POS was ground to pass through a 1 mm sieve. Ground sludge (23% moisture content on dry basis) was mixed with soil to obtain various sludge:soil mixtures, such as, 3%, 5%, 10%, 15%, 20%, 35%, 50%, 75%, and 100%. Soil without mixing POS was taken as the control. Selected properties of POS and soil are shown in Table 1.

Table 1. Selected properties of Palm Oil Sludge and soil.

	Dried POS	Air dried soil
Total N %	2.6 ± 0.2	0.1 ± 0.01
Organic C %	29.9 ± 1.5	0.9 ± 0.19
Ash %	23.2 ± 4.9	-
Loss on Ignition %	76.4 ± 4.1	4.6 ± 0.4
C:N	11.0 ± 1.0	10.0 ± 2.7
pH (in H_2O at 1:2)	5.6 ± 0.5	5.4 ± 0.2
Bulk density (g/cm^3)	0.4 ± 0.01	1.4 ± 0.01
Moisture content %	22.6 ± 0.28	0.5 ± 0.03
Silt %	-	32.5 ± 1.4
Clay %	-	4.1 ± 0.24
Sand %	-	63.4 ± 3.60

+ SD

Incubation study

Various POS soil mixtures were moistened with a fine spray of distilled water and thoroughly mixed to adjust their moisture content at field capacity (26% w/w). Fifteen grams of moistened soil mixture samples were placed in 200 ml (10 cm height x 5 cm internal diameter) glass bottles. Atmospheric gases in bottles were flushed with helium and sealed with parafilm. Gas samples (300 μl) of the head space of the soil was extracted and analyzed using Shimadzu gas chromatograph (GC-14A), equipped with a flame-ionization detector (FID) and 1.8 m x 0.3 cm in OD glass "Poropak Q" column; 50-80 mesh. Helium was used as carrier gas. Standard gases of methane, nitrous oxide and nitrogen were used to draw the calibration graph. The following specification and operating conditions were used to identify the retention time of CH_4 , N_2O and N_2:

Carrier gas:	Helium; flow rate, 60 ml min^{-1}
Temperature:	Detector, 300°C; Column, 150°C; Injector, 150°C
Sensitivity range:	10° ; Attenuation 3
Flow rate V_s Pressure:	H_2 = 0.6; Air = 0.6
Pressure for Primary (P):	3 kg/m^2

Bottles were incubated at 32°C and emission of N_2O, N_2 and CH_4 were quantitatively estimated daily for each set of bottles. Four replicates were used for each treatment. Scanning Electron Microscopy (Cambridge Stereoscan S4-10)-SEM was used to study the pore size arrangement of POS-soil mixtures. These mixtures were allowed to decompose for two months, and their small aggregates were vacuum coated with gold (20 nm) to observe their pore size distribution. "COOL" sputter coater (polaron) was used for the vacuum coating (Davey, 1978).

RESULTS AND DISCUSSION

Emission of CH_4 , N_2O and N_2

Experimental results revealed that FID with porpak Q column can be used to separate peaks of N_2O and N_2 , as well as CH_4 , employing the operating conditions mentioned above. The identified retention times of CH_4 , N_2O and N_2 were 37.2, 72.0 and 32.4 s, respectively. FID is generally used for response on Hydrocarbon analysis (Holzapfel-Pschorn *et. al.*, 1985; Holzapfel-Pschorn *et. al.*, 1986), while electron-capture detector is mostly used for analysis of inorganic gases, such as, CO_2 , N_2O , O_2 , N_2 , NO *etc.* Separated the peaks of N_2O from that of CH_4 , using flame ionization detector, and reported the retention time of N_2O as 110 s for 0.5 ml sample under different operating conditions.

Cumulative values of CH_4, N_2O and N_2 emission after one week in POS amended soils are shown in Figure 1. Results show that cumulative values of CH_4, N_2O and N_2 emission significantly ($P > 0.001$) increased at lower (<5%) and higher (>20%) rates of POS-amended soil compared to the control and the 15% POS amended soil. Holzapfel-Pschorn *et. al.* (1986) reported that methane is produced by methanogenic bacteria which are strictly anaerobic and use only a very limited range of substrates. Alexander (1977) reported that N_2O and N_2 originated from nitrification and denitrification processes in soils. Hence, lower and higher rates of POS amended soil could have favourable anaerobic conditions for growth of microbes, which are responsible for the emission of CH_4 and N_2. Fine *et. al.* (1984) found that a high rate of decomposition of organic matter tends to increase pH in the media; and Vidhana Arachchi and Nor (1994) reported that 15% POS-soil mixture produces a good soil structure within a two month period due to its higher decomposition rate. Moreover, results show that the initial pH value of 15% POS mixture (6.2 ± 0.2, H_2O; 1:1) was higher than the 100% POS (5.6 ± 0.5) and control (5.4 ± 0.2). Alexander, (1977) also stated that the increase of pH through rapid decomposition of organic matter was not favourable for growth of methanogenic and denitrifying microorganisms. Hence, these characteristics of the 15% POS mixture could help to retard the emission of CH_4, N_2O and N_2.

Effect of pore size distribution and moisture on CH_4, N_2 and N_2O emission

Scanning electron microscopic (SEM) photographs of soil amended with POS at different rates (Figure 2) showed that a high rate of sludge incorporation (>35%) with soil resulted in blockage of soil pores, which could cause reduced oxygen penetration. This condition promotes anaerobic situation, which could result in enhanced emission of CH_4, N_2O and N_2 (Figure 1). Moreover, moisture absorption by sludge particles at the lower rates of POS additions would be lower. Therefore, the amount of freely available water could be greater at the lower rates of POS that would block soil micropores creating an anaerobic condition. This would be one of the reasons for a higher emission rate of N_2, N_2O and CH_4 in the lower rates of POS mixtures. Micrographs also showed that low rates of sludge addition produced more macropores (black spaces in Figure 2a and 2b) compared to higher POS-Soil-rates (Figure 2c and 2d). This could cause increased oxygen penetration that would result in rapid carbon and nitrogen mineralization. This could also be the reason for the higher rates of

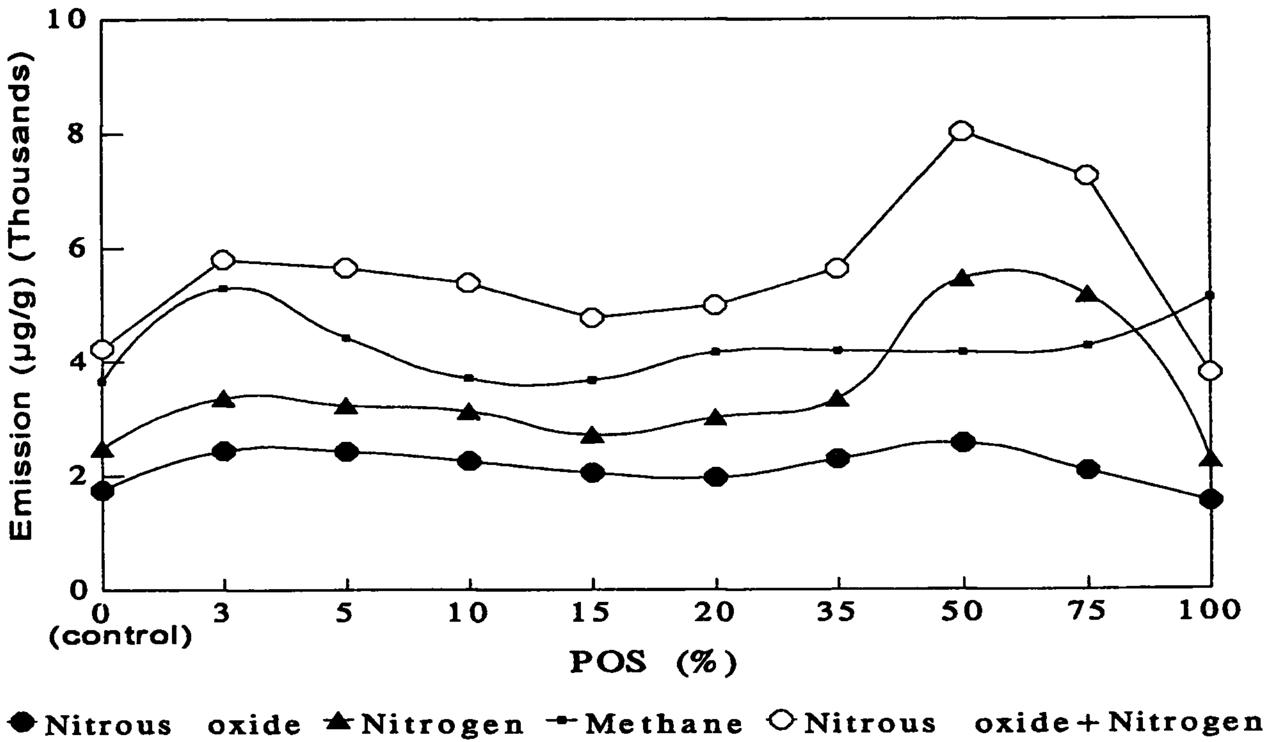
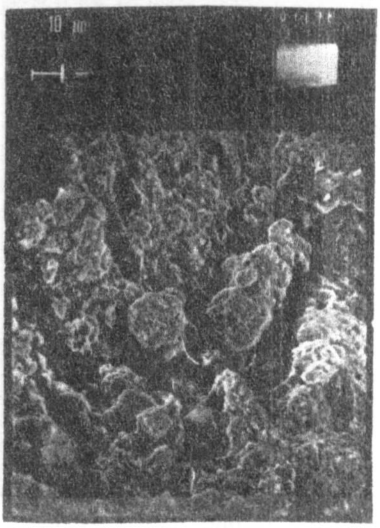


Figure 1. Nitrous oxide, Nitrogen and Methane emission in POS Amended soil.

(a) Soil only 350 x

(b) 5% POS 350 x



(c) 15 % POS 700 x

(d) 35 % POS 700 x

Figure 2. Scanning - electron micrographs on POS amended soil.

emission of gases at lower rates of POS amendments. Kreithinger *et. al.* (1985) and Hornby *et. al.* (1986), also found that a high rate of mineralized nitrogen could result in loss of N_2O and N_2 due to denitrification in sewage sludge treated soil. Management of these higher emission rates through proper POS incorporation is useful; and results revealed that 15% POS-soil mixture had a good potential to reduce the emission rates of CH_4, N_2O and N_2, compared to the lower and higher rates of sludge addition. Estimated values of these reduction rates for CH_4, N_2O and N_2 are 231.3, 73.57 and 391.71 μg/g/day, compared to the highest emission rates of 366.6, 780 and 756 μg/g/day respectively. However, emission rates of CH_4, N_2O and N_2 of the 15% POS-soil mixture are some what higher than that of the control.

Due to specific characters of the 15% POS amended soil in its pore size distribution; it could restrict the growth of methanogenesis and denitrifying bacteria, and reduce the emission rates of CH_4, N_2O and N_2. However, only 15 g of soils were used for the present incubation study, and it provides a basis for deciding the soil:POS ratio that is to be tested under field conditions. Field trials should be carried out to test the gas emission rate at desirable rates of soil:POS mixtures including 15% rate. This study shows that a proper amount of POS addition would be desirable to reduce denitrification and methanogenesis, which may in turn help minimize environmental pollution through the emission of gases.

CONCLUSIONS

This study revealed that the 15% POS amended soil reduced the emission of CH_4, N_2O and N_2; compared to the lower and higher rates of POS amended soil due to its specific pore size distribution.

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