NEW MICRO-METEOROLOGICAL TECHNIQUES FOR MEASURING GAS EMISSION FROM STORED SOLID MANURE

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ABSTRACT

Composting stockpiled cattle manure is a source of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Methane and N_2O are greenhouse gases with a high warming potential and are considered a risk to the environment. However, accurate estimates of emission of these gases from stockpiled manure are sparse due to the lack of suitable measuring techniques. In this study, the backwards Lagrangian Stochastical (bLS) dispersion and the integrated horizontal flux (IHF) micrometeorological techniques were adapted to measure gas emissions (CH_4, N_2O and CO_2) from a manure pile. The measurements were carried out by manual sampling of gases with syringes and measuring CO_2, CH_4 and N_2O using gas chromatography (GC), and continuously by measuring CO_2 and CH_4 with an infra-red (IR) gas analyser. The study proved that one may get reliable estimates of the gas emisssion from measuring gas concentration and wind speed at one height downwind of a composting stockpile. If the source of gas is heterogeneous as it was for CH_4 in this study, then a large number of measurements are needed to get reliable emission estimates.

Keywords**:** *bLS micrometeorological technique, composting, methane, nitrous oxide.*

INTRODUCTION

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emission have increased significantly during the last century (IPCC, 2001). Relative to CO_2, the amounts of CH_4 and N_2O in the atmosphere are low, but their global warming potentials are 23 (CH_4) and 296 (N_2O) times higher than that of CO_2 (IPCC, 2001). In agriculture, manure storage is a source of CH_4 and N_2O. Stockpiling of solid manure after pen cleaning is a common practice if field conditions are not suitable for immediate land application. During storage, solid manure transformation of organic matter by microorganisms may enhance the production and emission of greenhouse gases (GHG: CH_4 and N_2O). Due to methodological restrictions, there are few measurements and hence limited knowledge of CH_4 and N_2O emission from undisturbed full-scale point sources, e.g., stored manure.

The static chamber technique has been used to measure emissions of N_2O, CH_4 and CO_2 during composting of stored solid manure (Sommer and Møller, 2000; Hao et al., 2001). A prerequisite of the technique is diffusion of gas from the source into the chamber positioned on the emitting surface (Hutchinson and Mosier, 1981). Therefore, the technique may be inappropriate for measuring gas emission from composting manure piles where heating creates an outflow of air from the surface (Hellebrand and Kalk, 2000).

Alternatives to the static chamber technique are micrometeorological techniques adapted to measure gas emission from stored manure. The objective of this study was to develop and test a micrometeorological backward Lagrangian Stochastical (bLS) dispersion technique for non intrusive measurement of gas emissions from manure piles (Flesch et al., 1995). The results are compared with the Integrated Horizontal Flux (IHF) technique, which is considered the standard technique when validating new methods for estimating NH_3 emission from field applied animal manure and fertilizers (Wilson et al., 1983; McInnes et al., 1985; Sherlock et al., 1989). Spatial distribution of the CO_2, CH_4 and N_2O emissions was measured with the Static Chamber (SC) technique.

MATERIAL AND METHODS

The study was conducted at Lethbridge Research Centre, Alberta in the fall of 2003. Manure from feedlot pens bedded with cereal straw was stacked in a circular stockpile, diameter 3.1 and height 1.1 m. The stockpile was cone shaped with a flat circular top (diameter 0.5 m). Since the manure was very dry, water was added using a sprinkler before removal from the pens to encourage composting of the stockpiled manure.

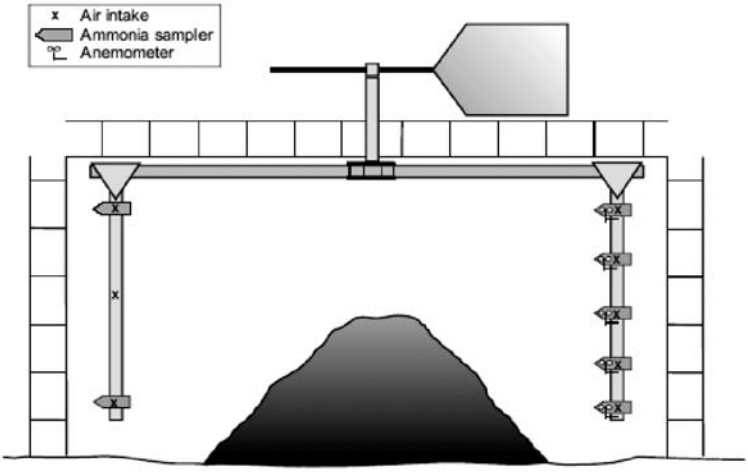

Figure 1. *Schematic draft of measurement system for net horizontal gas fluxes from a manure stockpile. Two poles with instruments and air-intake are mounted on a turning boom that is attached to a bearing fixed to a horizontal bar carried by two towers. A wind vane is ensuring an up- down wind position of the two poles with instruments.*

To facilitate gas sampling upwind and downwind of the stockpile, gas intake and anemometers were mounted on each of two poles (height 2.9 m), which could rotate 360^o around the stockpile (Fig. 1). The two poles were fastened to opposite ends of a rotating bar (4.6 m), which was attached at the middle to a bearing supported by a fixed horizontal bar (Fig. 1). A large wind vane positioned 1 m above the rotating bar controlled the orientation of the poles with air intakes and samplers relative to the stockpile and ensured that the upwind pole was always upwind and the downwind pole was always downwind, for all wind directions. Anemometers and gas intakes (0.45 mm filters) were mounted on the downwind pole at 0.44, 0.88, 1.39, 1.90 and 2.4 m and on the upwind pole at 0.44, 1.39 and 2.4 m above the soil surface. The gas samples were analysed on-line with an IR-analyser. Ten times during the initial 7 experimental days gas samples (triplicate) were taken manually with syringes. The concentration of N_2O, CH_4 and CO_2 was determined on a GC.

Static chamber technique

Spatial emissions of CH_4, N_2O and CO_2 were determined with 12 static chambers placed on the heap surface. The chambers were homogeneously distributed over the surface to give a picture of the spatial distribution of gas emissions. During each sampling period the chambers were mounted on the stockpile and air was collected from the chamber headspace at 0, 5, 10, 20 and 30 min using disposable syringes. The air samples were analyzed within 24 h on a GC. Gas emission was calculated by fitting the concentration of the gas versus time for each chamber with a second-order polynomial equation ($y=a+bx+cx^2$) and multiplying the second derivative b (µg N or C m^{-3} s^{-1}) by V/A (m).

Backward Lagrangian Stochastic (bLS) dispersion technique

The bLS technique is an inverse-dispersion method for calculating tracer emissions from a surface area source. The bLS dispersion model simulates the transport of tracer from a source to a measurement location, and predicts the ratio of the average tracer concentration to the emission rate, $(C/F)_{sim}$. The emission rate is inferred as:

$$F_{bLS} = \frac{\overline{\chi_{obs}}}{(C/F)_{sim}}$$

where χ_{obs} is the observed concentration (above background) at the measuring location. In this study the increase in concentration of CO_2 and CH_4 estimated with the IR gas analyser was used as input to the commercial software, which we used to calculate F_{bLS} (*WindTrax*, Thunder Beach Scientific, Halifax, Canada). In addition to gas concentrations, wind speed and estimates of atmospheric stability and surface roughness were used in the calculations.

Integrated Horzontal Flux (IHF) technique

The IHF technique calculates the average surface flux density of gases from the stockpile, F_{IHF} (µg m^{-2} s^{-1}), by the difference in the horizontal fluxes of gas across down- and upwind boundaries:

$$F_{IHF} = \frac{1}{X}\int_{z_0}^{z_p} netF_{hor}\,dz$$

where X (m) is the distance traveled by the wind across the stockpile, $netF_{hor}$ the net horizontal flux of gas (µg m^{-2} s^{-1}) and z (m) the height above the soil surface. The integration limit z_p is the height at which the gas concentration is at background level.

RESULTS AND DISCUSSION

A recent unpublished study using thermovision to measure temperature profiles in composting manure piles has shown that the temperature is very high throughout the interior but declined within 5-10 cm from the surface of a pile that has been stockpiled recently (Sommer Sven G.). In the present study, the compost temperature was measured spatially at 10 cm depth and these measurements confirmed that temperature is high to within a few centimetres of the surface (Fig. 2). Although the stockpile was small, after 48 h, the temperature at 10 cm depth reached 11-49ºC, and from 72 to 144 h, the temperature reached 50-70ºC (typical of conditions associated with thermophilic composting) and was evenly distributed spatially.

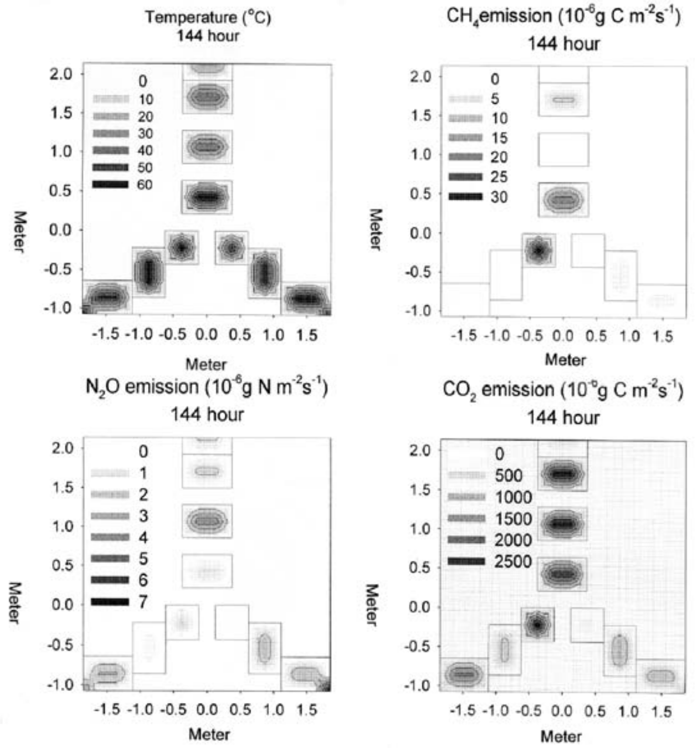

Figure 2. Spatial distribution of GHG emission measured with static chambers and of temperature at 10 cm depth below the surface of the manure pile. Temperature and gas emission was measured 144 h after establishing the stockpile. The curved surface of the stockpile has been projected planar.

We often assume that air enters mostly through the lower section of the stockpile and leaves the pile at the top ('chimney effect'), due to an upward airflow generated by high temperatures in the stockpile. However, in our study the gases were emitted from 'hot spots' of high production or areas where they were leaked to the atmosphere, and not through a chimney at the top of the pile (Fig. 2). During periods with high wind speed most of the emission was measured with chambers placed on the leeward side of the stockpile, indicating that the spatial distribution of emission may also be affected by wind. There were hot spots with both high CO_2 and CH_4 emission and other hot spots with only elevated CO_2 emissions. This may be explained by the nature of gas production, i.e., CO_2 is produced during both oxic and anoxic transformation of biomass and CH_4 is produced only in an anoxic environment. It is known that N_2O is produced near the surface of compost in loci of low temperature and high in inorganic N, where nitrification and denitrification is enhanced (Petersen et al., 1998), this has probably contributed to a homogeneous spatial distribution of N_2O emission.

The emission calculated with the bLS technique depends on the estimated or assumed atmospheric stability, when stability is not measured then it is recommended that neutral atmospheric stability is used in the calculations (Sommer et al. 2004). Further, it has been shown that at measuring heights near the so called ZINST height (Wilson et al. 1982, 1983), where stability effects on calculated flux density is low, the precision of computed emissions using the bLS technique is precise within 10-20% of the emission measured with the IHF technique (Sommer et al., 2004). At the lowest measurement height of 0.50 m we found the greatest accuracy in F_{bLS} (average F_{bLS}/F_{IHF} = 0.8, SD=0.19, Fig. 3). At heigher elevation the technique was not precise, probably due to declining accuracy of the concentration measurements at increasing heights. Increasing the size of the pile and moving the measuring devices and gas intake to greater distances may greatly improve the measurements, because the emission of gases will be higher and air movement will be less affected by the heap.

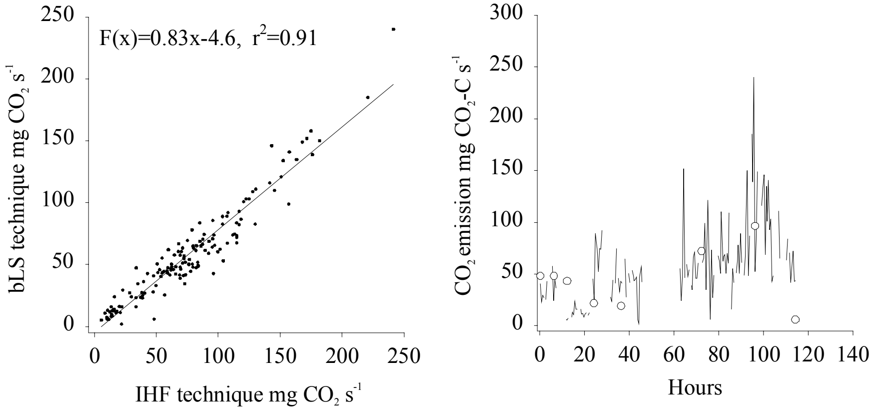

***Figure 3**. GHG emission from a composting stockpile of manure estimated with bLS technique using continuous measurements of CO_2 and wind speed at 0.5 m height assuming a neutral atmosphere (Left) versus IHF reference estimates (1:1 line included) and (right) continuous measurements depicted with a line and periodic measurements with symbol versus time after stockpiling the manure.*

The bLS-periodic technique analysing the gas concentration with GC was used to estimate the CO_2, CH_4 and N_2O emissions. The emission of CO_2 and N_2O estimated with the bLS technique using 0.5 m measurements of wind speed and gas concentration was within 20% of results obtained using the IHF technique, whereas the CH_4 measurements with the bLS was very different from those using the IHF. Cumulated CO_2 emission measured periodic with the GC analy-

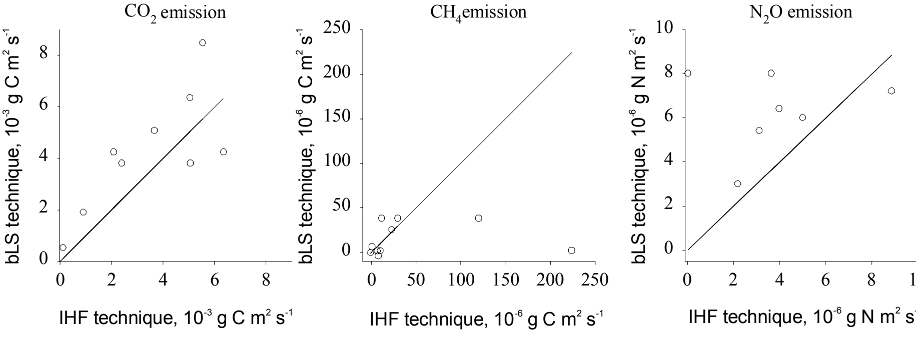

***Figure 4**. GHG emission from a composting stockpile of manure estimated with bLS technique using measurements of CO_2, CH_4 and N_2O and wind speed at 0.5 m height assuming a neutral atmosphere versus IHF reference estimates (1:1 line included).*

tical technique was within 20% of the cumulated emission measured with the continuous IR technique, no continuous measurements of N_2O emission were carried out. A 20% precision could not be achieved for the periodic CH_4 measurements, the low precision was probably an effect of the heterogeneous source strength of this gas. These results indicate that gas emission should be measured more frequent than carried out in this study when sampling gas for the GC analysis. Further one may improve gas sampling by simultaneously filling up air bags over 15 min period at each height, thereby providing an 15-min average of the gas concentration.

CONCLUSION

This study showed that gas emission from a composting stockpile of manure is not homogeneous in terms of spatial distribution, and that the distribution pattern depends on the gas in question (CO_2, N_2O or CH_4). Our results show that gas emission from stockpiled manure can be computed using the Backwards Lagrangian Stochastic technique using measurements of gas concentration and wind speed at one height. Using this technique require the emisison be measured numerous time during the experiments, due to the great variation in emission and the short integration time of each measurement.

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