Estimating ammonia losses during the composting of farmyard manure, using closed dynamic chambers

Estimation des émissions d’ammoniac lors du compostage de fumier bovin à l’aide de chambres dynamiques.

T. Morvan
Unité d’Agronomie, INRA,
65, rue de Saint-Brieuc,
F-35042 Rennes. France
E-mail : morvan@rennes.inra.fr
P. Cellier
Unité de Recherches en Bioclimatologie, INRA, F-78850 Thiverval-Grignon. France.

J. Dach
Instytut Mechanizacji Rolnictwa P-60-627 Poznan.

Abstract

Few studies have been made in to quantify ammonia volatilization occurring during the composting of cattle farmyard manure (FYM), although the mass balances show that nitrogen losses during such composting may represent 10 to 40 % of the total nitrogen. Ammonia emissions were measured for 25 days using three closed dynamic chambers arranged on top of the FYM windrow. The greatest fluxes were observed during the first few hours, rising to 0.9 to 1.3 g N m^{-2} h^{-1}. Ammonia emissions greatly decreased, and were insignificant two days after the beginning of the experiment Ammonia emissions resumed in two chambers on days 4, 5 and 8, and were greatly stimulated after turning the heap turning, on day 11.

Keywords *: volatilization, composting, farmyard manure, dynamic chambers*

Résumé

Peu d’études ont été menées pour quantifier la volatilisation de l’ammoniac se produisant au cours du compostage de fumier bovin, bien que les bilans azotés démontrent que ce processus représente 10 à 40% de l’azote total éliminé. Les émissions d’ammoniac ont été mesurées durant 25 jours à l’aide de trois chambres dynamiques fermées placées au dessus du tas en compostage (andain). Les flux maximum ont été mesurés au cours des premières heures, avec des valeurs de 0.9 à 1.3 g N m^{-2} h^{-1}. Les émissions d’ammoniac diminuent ensuite fortement et deviennent négligeables deux jours après le début de l’essai. Ces émissions se produisent ensuite lors de chaque retournement de tas.

Mots-clés : volatilisation, compostage, fumier, chambre dynamique.

1. Introduction

The many benefits of composting farmyard manure have been reviewed by Le Houerou (1993). Attention is currently being focused on the environmental effects of this practice. During composting, the N content of the manure decreases with total N losses ranging from 10 to 40 % of the total nitrogen (Kirchmann and Witter, 1989, Ballestero and Douglas, 1996). These N losses may occur via different pathways : i) the ammonia content of fresh farmyard manure may represent 5 to 20 % of the total nitrogen, part of which may be volatilized, due to high pH values and high temperatures inside the composting windrow, ii) nitrate is the end product of aerobic transformations, and may be lost through leaching, or as N_2O, through denitrification. De Bertoldi et al (1982) found that N losses were mainly due to ammonia volatilization, and were greater when turning than when aerating : similar results were obtained by Martins and Dewes (1992), who measured nitrogen losses during the composting of pig, cattle and poultry manure. These authors also pointed out that ammonia losses were mainly related to the original nitrogen concentration, temperature and heap rotation.

Most experimental set-ups consist of small farmyard heaps placed in tents or closed chambers (Inbar et al, 1990, Martins and Dewes, 1992). These designs might be criticized, because : i) ammonia losses, and other nitrogen transformations are strongly dependent on temperature and it is clear from the results of Martin and Dewes (1992) that such temperature increases are lower in small heaps, compared to those observed in a 1.5 m high windrow ; ii) gas diffusion in the upper part of the FYM heap is affected by outside air temperature and windspeed : it may therefore be supposed that the volatilization kinetics also differ depending on whether composting is carried out in a closed apparatus, or under natural conditions.

For these reasons we tested a simple apparatus which permitted measurements of ammonia volatilization during the composting of « real » cattle FYM windrows, in outside conditions, and study of the kinetics of ammonia loss.

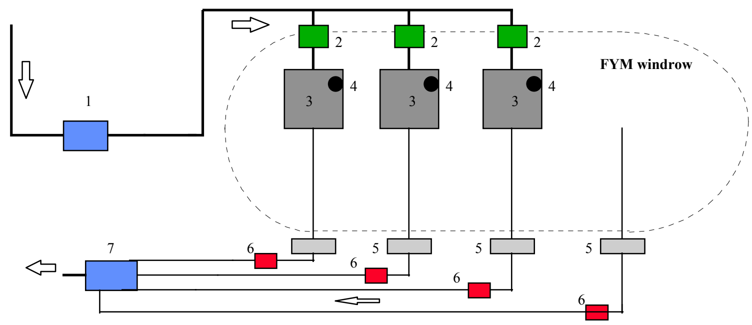

Figure 1

Diagram of the apparatus. 1 : pump ; 2 : inlet gasmeter ; 3 : chamber ; 4 : fan ; 5: acid trap ; 6 outlet gasmeter ; 7 : pump.

2. Material and methods

Cattle farmyard manure (FYM), the composition of which is given in table 1, was composted in a 1.5 m high windrow ; the ammonia content of the cattle FYM was relatively high (19% of total nitrogen) and was typical of a fresh manure.Three closed dynamic chambers immediately arranged on top of this windrow. These chambers consisted in a ventilated stainless steel cover equipped with a fan for mixing the air inside. The exposed surface area of manure was 0.25 m² (0.5m x 0.5 m). The inlet air flow was 114 l mn^{-1} and was measured with a gas meter (± 1 l) .The ammonia concentration of the air leaving the chamber was measured by sampling at a rate of 2.8 l mn^{-1} and driving it through absorption flasks filled with an H_2SO_4 solution (0.072 N) and positioned near to the chambers. The flasks were sampled at intervals varying from 1 to 24 hours ; ammonia emissions were continuously measured during the first 15 days, and on days 20 and 25. Ammonia concentration was also measured in the free air just above the surface of the heap.

pH	8.5
dry matter (%)	27.5
$N\text{-}NH_4$ (g kg^{-1})	0.97
N_{tot} (g kg^{-1})	4.99

Table 1
Composition of the cattle farmyard manure (FYM) at the start of the experiment.

Temperature was monitored in the windrow, using 6 thermoelements set up at 0.2, 0.5 and 0.8 m depth ; data was measured at hourly intervals and recorded on a datalogger. pH was also measured at hourly intervals during the first seven days.

3. Results

The temperature rose rapidly to 65-70°C during the first three days at depths of 0.50 and 0.80 m depth inside the heap, and remained constant, whereas the temperature near to the surface of the heap , measured at 0.20 m depth, was subject to variations ranging from 40-52 °C, from the second to 25 th day. pH rapidly rose from 8.5 to 9, during the first day, and then remained constant.

Temperature and pH were therefore highly favourable to volatilization.

The plots of ammonia fluxes are presented in figure 2.

- Ammonia emission was considerable during the first few hours, decreasing from 0.9-1.3 g N m² h^{-1} to insignificant values, 30 hours after the beginning of the experiment ; these observations differ from the results of Martin and Dewes (1992), who showed that volatilization in a closed composter occurred progressively during the first few days. The pattern of volatilization that we describe may be explained by the rapid increase of temperature which was favourable to the « production » of gaseous NH_3. The cumulative fluxes over the first four days were similar in all three chambers (8.3 ± 0.8 g N m^{-2}).

- Ammonia emissions resumed on days 4, 5 and 8 in two chambers only, and in the free air measurement. These « pulses » were lower than those observed during the first few hours, and were associated with increasing temperature in the upper part of the FYM heap, which were consistent with increasing air temperature.

- Ammonia emission was strongly stimulated in chambers 1 and 2 by turning the heap, whereas low rates of volatilization were observed in chamber 3. The ammonia fluxes occurring after heap rotation were lower than those observed just after the beginning of the experiment : this was probably due to the 2.5 fold lower ammonia content of the cattle FYM, on day 11, compared to the original ammonia content.

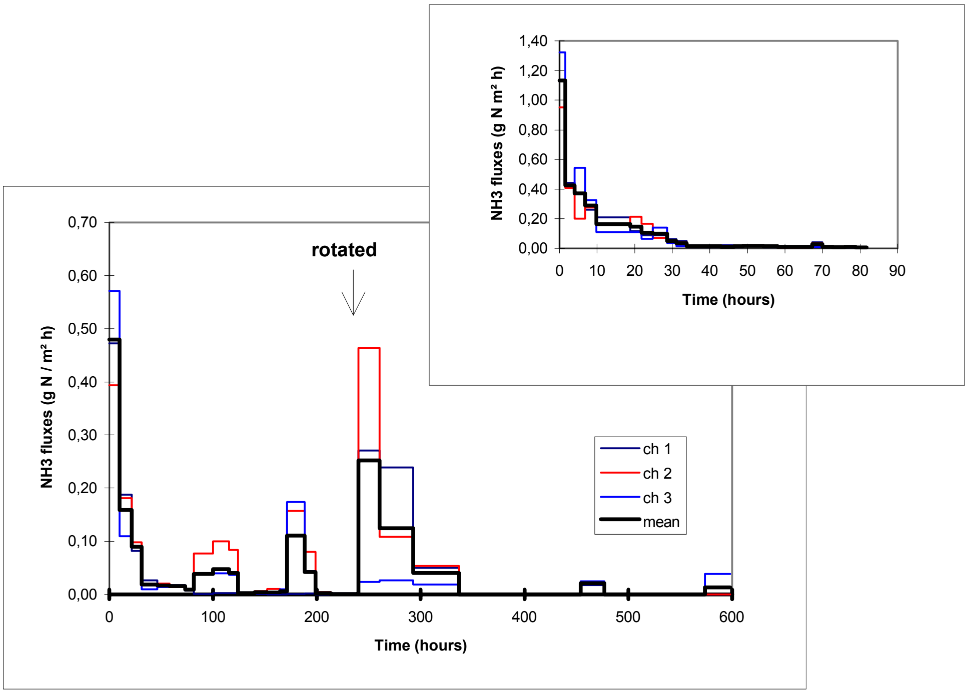

Figure 2
Changes in NH_3 content in the three chambers over a 25 day period (ammonia emissions were continuously measured during the first 15 days, and measured on days 20 and 25 over the 15-25 days period)

4. Conclusion

Ammonia losses during composting of FYM were related to the temperature and heap turning ; the simple set up that we used was able to show that the kinetics of ammonia volatilization during composting of « real » FYM windrows seemed to be different to those observed in small heaps placed in closed chambers. This apparatus is cost-effective and easy to maintain. Great variability was however observed between the three measuring repetitions and will require further investigation.

5. References

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