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RANGE OF NITROUS OXIDE EMISSION AFTER APPLICATION OF PIG SLURRY

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ABSTRACT

Nitrous oxide emissions of agricultural soils is known to contribute significantly to global climatic changes and to depend on the soil, the climate, and the fertiliser. We evaluated the range of nitrous oxide emissions after slurry application by reproducing conditions where both nitrification and denitrification were possible. Both the observed emission and the ^{15}N deficit went beyond 20% of total applied nitrogen (35.6% of applied ammonium). It shows that models of nitrous oxide emissions can be improved with a better knowledge of the frequency of favourable pedoclimatic conditions.

INTRODUCTION

A large part of the global warming potential of agriculture is attributed to the net nitrous oxide emissions that follow organic and mineral nitrogen inputs to cultivated soils. Kelly (1996) stress the role of the soil microflora in controlling the sources and sinks of nitrous oxide through both nitrification and denitrification. Damgaard and Revsbech (1996) show the high nitrous oxide gradients that can occur in soils. IPCC (1996) recommends the bulk value of 1.25% of total nitrogen applied per year to account for all spatial and temporal variations that may occur in the soils at the global scale. It follows the review of Bouwman (1996), who showed the wide range of observed emissions and the lack of relevant models to explain them. Mariotti (1982) reviewed the isotopic methods to estimate nitrogen fluxes.

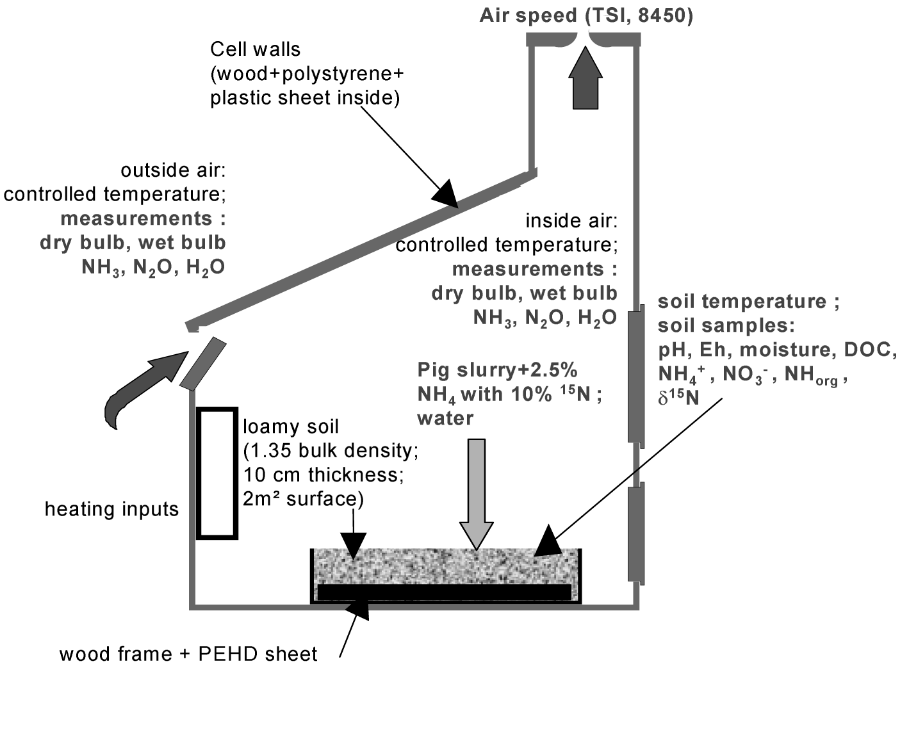
Recent works suggest that higher nitrous oxide emissions may follow slurry application. In the case of emissions after slurry spreading, most work was done on ammonia emissions allowing decision-making models (Morvan, 1999) and few on nitrous oxide. Bouwman (1996) recognised that emissions are higher with organic fertilisers but gave a value close to the IPCC recommendation (1.5%). More recently, Yu et al (2001) showed that high emissions due to denitrification can occur when the redox potential is in the range +120mV to +250mV. However, they relate their flux to "kg soil" that is difficult to extrapolate to "hectares" because of the sensitivity to the considered soil depth and bulk density. Prieme and Christensen (2001) worked with intact soil cores of 10 cm diameter and 19 cm height and show the high impact on nitrous oxide emission of freezing-thawing and drying-wetting cycles. Finally, Jaffrezic et al (1998) showed the redox potential variations that follow slurry applications or rainfall events. Therefore, nitrous oxide emissions may be increased after slurry application. Nitrous oxide is produced from two sources (Davidson, 1991). The first one is the nitrification of the ammonia contained in the slurry or produced by mineralisation of organic nitrogen. The second source is the denitrification when favourable conditions appear after the nitrification has produced nitrates.

Our objective was to evaluate a range of nitrous oxide emissions after slurry application in the conditions of western Europe agricultural systems linked to intensive pig farming.

MATERIAL AND METHODS

Nitrous oxide emissions were measured during 17 days after spreading of pig slurry in controlled conditions (fig. 1). The nitrogenous losses were controlled with the mass budget of labelled $^{15}NH_4$ added to the slurry. A 10 cm thick and 2 m² layer of a loamy soil was installed in four cells with controlled inside and outside temperature. The initial bulk density and moisture were respectively 1.35 and 19%. We applied either pig slurry or water at a rate of 3 l/m² on two of the four cells. On day 9 (and 11) after slurry application, we applied a 21 mm rainfall (3 mm on day 11) on two cells (one with pig slurry, the other with water) while the other two cells were just maintained at the soil water holding capacity. This treatment aimed at achieving either anoxic or aerobic conditions at the soil surface. The ammonium, pH, redox potential, dissolved organic carbone and moisture of the soil surface (0-1 cm) were measured on soil samples taken ten times between days 1 and 17, with three repetitions of 110 g soil each time. Organic nitrogen, nitrate and ammonium were measured as well as there ^{15}N enrichment on days 10 and 17. The cells allowed continuous measurement of N_2O, NH_3 and H_2O emissions with infrared spectroacoustic gas analyser and hot-wire anemometer. The nitrous oxide emissions were calculated as the difference between the " slurry treatment " and the " water treatment ". All details are given in Florentin (2001).

Figure 1: experimental design



RESULTS AND DISCUSSION

High nitrous oxide emissions were observed on the " anoxic slurry treatment " while it was negligible on the " aerobic slurry treatment ". The emission happened between day 9 and 17 (fig. 2). The observed emission and the ^{15}N deficit went beyond 20% of total applied nitrogen (over 30% of applied ammonium, fig. 3). We explain the high emission with optimal redox potential (between 120 - 250 mV ; Yu et al, 2001), high nitrate content, dissolved organic carbon, and high soil moisture (fig. 4 to 7). The pH reduced regularly from 8 on day 8 to 5.8 on day 17 for both slurry treatments. The total observed emission was only slightly higher than the ^{15}N deficit between days 10 and 17 (respectively 26% and 22% for direct and ^{15}N measurements) : it suggests that most of the nitrous oxide emission comes from the transformations of the ammonium contained in the slurry. Therefore, it was not possible to estimate the respective contributions of nitrification and denitrification to the total emission. As already emphasised by Prieme & Christensen (2001), these results show the importance of short-term climatic events on the total emission of nitrous oxide.

Figure 2: observed nitrous oxide emissions

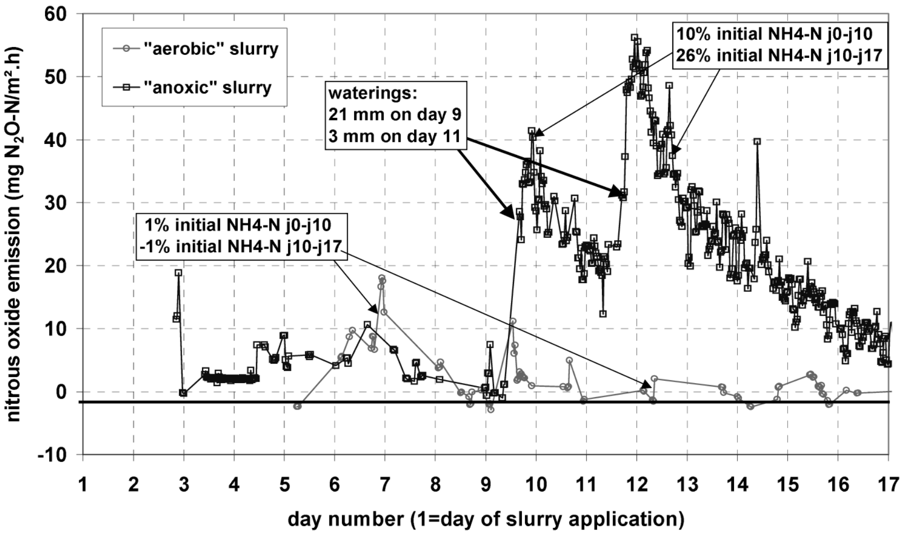


Figure 3: observed ^{15}N balance in "anoxic" slurry

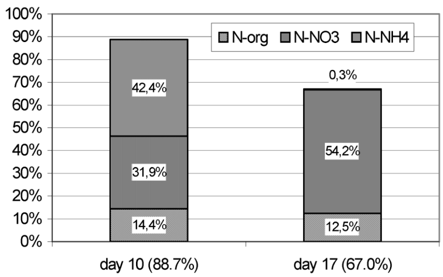


Figure 4: dissolved organic carbon

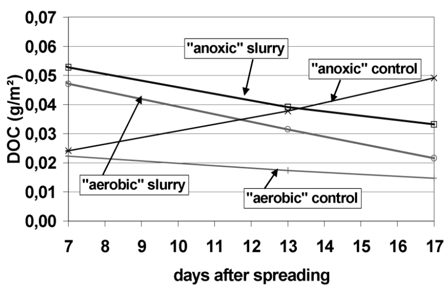


Figure 5: observed soil mineral nitrogen at days 10 and 17

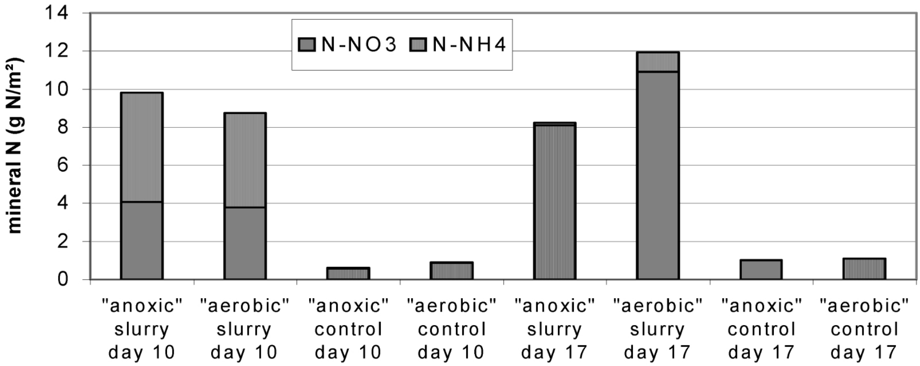


Figure 6: redox potential

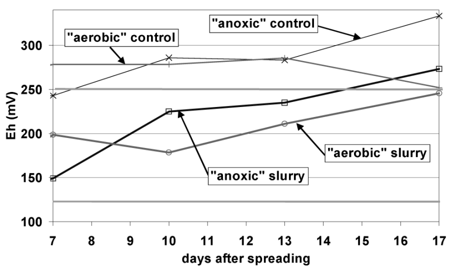
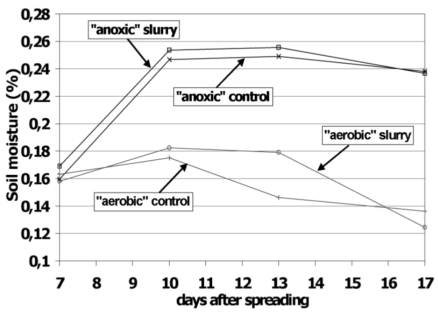


Figure 7: soil moisture



CONCLUSION

We conclude that a high proportion of nitrogen can be lost as nitrous oxide after pig slurry application. This study shows the importance to improve the models of nitrous oxide emissions after fertilisation. We observed a range of variation between 0 and 20% of the total nitrogen content of the slurry. The uncertainty around the emission factor of 1.25% of applied nitrogen may be reduced with a frequency analysis of the pedoclimatic conditions favourable to nitrous oxide emission during the weeks after slurry spreading.

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