AMMONIA VOLATILIZATION FOLLOWING WINTER AND SPRING DAIRY SLURRY APPLICATIONS ON A PASTURE OF A VOLCANIC SOIL IN SOUTHERN CHILE

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SUMMARY

Agriculture is considered the largest source of ammonia (NH_3) emission to the atmosphere, and application of slurry to pastures as fertilizer is one of the main emission sources. The aim of this study was to evaluate NH_3 volatilization following winter and spring dairy slurry applications to a pasture of a volcanic soil of southern Chile. Volatilization was measured in four field experiments (winters of 2009 and 2011 and early and late springs of 2011) using a micrometeorological mass balance method with passive samplers after the application of a target rate equivalent of 100 kg total N ha^{-1} as dairy slurry to a permanent pasture. The accumulated N loss was equivalent to 7, 8, 16 and 21% of the total N applied and 22, 34, 88 and 74% of Total Ammoniacal Nitrogen (TAN) applied for winters 2009 and 2011, and early and late spring 2011, respectively. Emission rates were high immediately after application and declined as time elapsed, so that up to 60% of the total N applied was lost within the first 6 h after application. Losses were highly influenced by environmental conditions, increasing with temperature and lack of rainfall. Dairy slurry application could be an important source of nutrients for pastures in southern Chile, however, its mismanagement could lead to important N losses to the environment.

Keywords: dairy slurry, ammonia emissions, volcanic soil, Chile

INTRODUCTION

Agriculture is recognized as a major source of atmospheric ammonia (NH_3), contributing with 50% of the global ammoniacal emissions (Sommer et al., 2004) and 23% are derived from fertilizers and field-applied livestock excreta (Bouwman et al., 2002). The N in the animal manure is easily hydrolyzed to NH_4^+, which is known as TAN and may be regarded as the source of almost all NH_3 emissions (Sommer et al., 2004). These emissions depends of many factors such as type and characteristic of the animal manure; food and feeding practices; time, quantity and application equipment; and local climatic and soil conditions (Martínez Lagos et al., 2010; Salazar et al., 2003). When slurry is applied to pasture several nutrients and organic matter are returned to the soil, contributing to improve the biological activity and the soil texture; however, the use of slurry also have been linked with negative impacts such as soil acidification, eutrophication, loss of biodiversity and acid rain (Alfaro y Salazar, 2005; Salazar et al., 2012). Dairy production systems of southern Chile are based on all year around grazing on permanent pastures, which results in the production of important volumes of dairy slurry. Besides, the intensification of the local production systems resulted in the frequent use of dairy slurry as organic fertilizer all year around, with the increasing risk of pollution when the slurry is applied in inappropriate time or rates through the year (Salazar et al., 2003). The objective of this study was to evaluate NH_3 volatilization following winter and spring dairy slurry applications to a pasture of a volcanic soil of southern Chile.

MATERIAL AND METHODS

The experiments were carried out on permanent pasture located at the National Institute for Agricultural Research (INIA Remehue) (40º 31'S, 73º 03'W, 65 m.a.s.l), with no recent history (3 years) of N fertilization or livestock grazing. The soil is an Andosol (IUSS,

2007) that belongs to the Osorno soil serie (Typic hapludands; CIREN, 2005) with an organic matter content of 18-25% and water pH of 5.3-5.7. The pasture was predominantly perennial ryegrass (*Lolium perenne* L.) and the climate corresponded to a typical Mediterranean cold weather with a 35 years mean annual temperature of 11.3 °C and mean annual precipitation of 1,267 mm. The experiments were conducted during winter and spring seasons (winter of 2009 and 2011 and early and late spring of 2011), evaluating volatilization for a period of seven days. Measurements were carried out on a singular circular plot of 15 m of radius in which dairy slurry was manually applied to a target rate equivalent to 100 kg total N ha^{-1}. The slurry was obtained directly from the slurry storage from the dairy unit located at INIA Remehue and samples were obtained before and at the application day and chemically characterized according to Sadzawka et al. (2007). Volatilization was measured using the micrometeorological mass balance method: integrated horizontal flux, as described by Denmead et al. (1977), with the use of passive flux samplers (Leuning et al., 1985) coated in a 3% solution of oxalic acid in acetone set at 5 different heights in the treatment area (2.80, 2.00, 1.20, 0.65 and 0.25 m above the soil surface) and 3 heights for the control area (2.80, 1.20 and 0.25 m) in agreement with Misselbrook et al. (2005). The passive flux samplers were set up immediately following the slurry application and remained exposed for periods of 2, 6, 24, 48, 96 and 168h. Following exposed periods, the passive flux samplers were eluted with deionized water and the extracts analyzed by automated colorimetry (SKALAR, SA 4000, Breda, The Netherlands). The cumulative emissions for the whole experimental periods were derived by summing the net emission in each sampling period. Main climate variables were registered in INIA meteorological station, distant 1.5 km of the experimental plot.

RESULTS AND DISCUSSION

The accumulated N loss was equivalent to 7, 8, 16 and 21% of the total N applied. Loses of TAN were equivalent to 22, 34, 88 and 74% for winters of 2009 and 2011, and early and late spring 2011, respectively. Total N lost due NH_3 volatilization per season reached a maximum in winter 2011 and late spring 2011 applications with 8% (34% of the TAN) and 21% (74% of the TAN), respectively. Nitrogen losses are within the data reported elsewhere with N total losses on field conditions up to 49% of the total N applied (van der Weerden and Jarvis, 1997). The highest emission rate during the experiments (4.3 kg NH_3-N ha^{-1} h^{-1}) was observed following the late spring application, while the lowest was observed following the winter application of 2011 (0.7 kg NH_3-N ha^{-1} h^{-1}; Figure 1), both within the first 6 h after slurry application. These results are according with published data which describes that NH_3 emissions after slurry application are higher immediately after the slurry application and then decline rapidly within 12-24 hours, followed by low rates of N loss for another 5-10 days (Eckard et al., 2003). After 24 h of the slurry application, 50, 69, 61 and 73% of the total applied N had been lost for winter 2009 and 2011, early and late spring 2011 experiments respectively, which is in agreement with Lewis et al. (2003). This pattern is strongly dependent on the urea hydrolysis, which is influenced by soil and climate variables (Sommer et al., 2004).

The cumulative N loss due NH_3 volatilization from both spring applications were greater than winter applications, most likely due to soil properties and climate influence (Figure 1). In three of the four experiments, there were rain events within the first 6 h following application. This water moistened the soil surface but not allowed the slurry to leach into the soil matrix, enhancing the NH_3 emission by increasing the rate of hydrolysis in accordance with Black et al. (1987). Mean temperatures were higher in spring season (at c. 9.7-13.9 °C) than winter (at c. 8.7-9.4 °C), and the mean wind velocity was similar for the 2011 experiments (at c. 1.4 m s^{-1}). The results obtained during the experiments showed that NH_3 volatilization could be an important pathway of N loss to the wider environment. Reducing losses is key management practice to improve N use efficiency in Chilean pastures. At the present, there is no regulation for the rate, time and slurry application method; however, several optional management practices has been implemented elsewhere to reduce NH_3 volatilization emission during slurry application, these include the reduction of the slurry DM content (e.g. mechanical separation), the physical incorporation or direct injection of the slurry into the soil, and the use of additives to slow down the hydrolysis (Martínez-Lagos et al., 2010; Sommer and Hutchings, 1995).

CONCLUSIONS

Nitrogen losses due to NH_3 volatilization were high in spring (21 and 16% of total N) compared to winter slurry applications (8 and 7% of total N). As a percentage of the TAN applied losses were higher, being equivalent to 22 to 88%. Most of the NH_3 emissions occur within 6 h of the slurry application, representing up to 60% of the total N loss. Dairy slurry can be an important nutrient source in agricultural pastures, however NH_3 emissions in volcanic soils of southern Chile can be high when slurry is used as N source. The inefficient management of the slurry could lead to losses to the wider environment, where N fluxes can affect the pristine ecosystems. The incorporation of best management practices may reduce the NH_3 volatilization, increasing the pasture productivity due to more efficient use of available N.

ACKNOWLEDGMENT

This research was funded by the Milk Technology Consortium (CIF-CS-C-2004-1-P-001) and the Scientific and Technological Research Council (FONDECYT), project 1080368. The authors also acknowledge Rothamsted Research, North Wyke for its technological support.

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Figure 1. Ammonia emission (kg N-NH_3 ha^{-1} h^{-1}) with mean climate variables in a) 2009 winter; b) 2011 winter; c) 2011 early spring; d) 2011 late spring experiments.