Ammonia emission from a flexible bag storage system

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Abstract

Intensive farm systems handle large volume of livestock wastes, resulting in large ammonia (NH_3) emissions which could lead to adverse environmental effects. In this study, an on-farm experiment was performed in order to estimate NH_3 emission from a flexible bag storage system for cattle slurry. Ammonia emission was estimated using the micrometeorological mass-balance integrated horizontal flux (IHF) method, with two vertical masts located in the storage and a background mast at 150 m, supporting five passive flux samplers mounted at different heights. Manure management operations, such as loading and emptying, resulted in an NH_3 peak of 1.0 mg N m^{-2} h^{-1} and 5.1 mg N m^{-2} h^{-1}, respectively, accounting for 82% of total NH_3 volatilized during the experimental period. In conclusion, flexible bag can be effectively used to control NH_3 emissions from slurry storage, with manure management (loading and emptying operations) as the main factor that can increase NH_3 volatilization.

Introduction

Handling large volume of livestock wastes in intensive farm systems has become a difficult task that could lead to adverse environmental effects. According to the European Environmental Agency [1], the agricultural sector remains the major source of ammonia (NH_3) emissions (94% of total 2009 emissions), which derive mainly from the decomposition of urea in animal wastes. The simplest control method to mitigate NH_3 emissions from slurry storage open to the atmosphere is to use a physical cover to contain the emissions, being impermeable covers generally more effective (up to 100%) than permeable covers [2]. Among these covers, flexible bags are used as a manure management alternative to handle large volume of slurry [3]. However, few on-farm studies have been carried out to support the likely benefits of flexible bags on NH_3 mitigation. In this study, an on-farm experiment was performed in order to estimate NH_3 emission from a flexible bag storage system for cattle slurry.

Material and methods

Experimental set-up

The experiment was conducted between the 27th August and 12th September 2012 in a cattle slurry storage system in Araba, North of Spain (42º 55’ N, 2º 39’ W). Wind speed and direction were registered by means of four anemometers (3R KYWS) at heights of 0.3, 0.48, 1.0 and 2.7 m, respectively, and a wind vane (S-WDA) at 2.7 m placed with a datalogger (HOBO U30, Onset HOBO© Data Loggers) in a meteorological station. Daily air temperature was recorded by a datalogger (HOBO U12-013, Onset HOBO© Data Loggers). There were no wind-disturbing elements within 700 m of the experimental plot. Slurry (vol. 2000 m^3) was collected from seven dairy cattle farms during the 16th July to 31st August and stored in an impermeable plastic bag (polyester with double PVC layer) with 3500 m^3 capacity (20 m width, 80 m length, 2.2 m deep). Produced biogas is discharged to the atmosphere through 6 chimneys located at the centre of the lagoon. Slurry was mixed and removed from the storage at 9:00 on day 12th September in order to be applied to 70 ha land.

Measurement of ammonia emission

Ammonia emission was estimated using the micrometeorological mass-balance integrated horizontal flux (IHF) method. This method equates the vertical flux of NH_3 from a treated area of limited upwind extent with the net integrated horizontal flux at a known downwind distance [4]. Two vertical masts were placed in each side of the storage (M1 and M2, respectively), being considered as upwind or downwind, depending on main wind direction recorded during the exposure session. A background mast (M_{BG}) was located 150 m upwind from the storage area. M1 and M2 masts supported five passive flux samplers coated with oxalic acid and mounted logarithmically at heights of 0.3, 0.48, 1.0, 2.05 and 3.05 m above the soil surface. M_{BG} was composted by four samplers placed at 0.48, 1.0, 2.05 and 3.05 m height. Samplers were replaced every 24 h during 12 days and immediately transported to the laboratory to be leached with 60 ml of deionised water and analyzed for NH_4^+-N by spectrophotometry.

Slurry characterization
Six replicates of slurry were taken from the collecting tank for chemical characterization during emptying. Dry matter (DM) and organic matter (OM) were measured according to AFNOR (1976) organic products' procedures. Total nitrogen (TN), ammonium-N (NH_4^+-N), organic nitrogen (N_{org}) and organic carbon (C_{org}) were estimated based on official methodologies for soil and water analysis described by the Spanish Ministry of Agriculture (1974). Slurry pH was recorded *in situ* by a HQ40D phmeter (Hach Lange, Germany).

Results and discussion
Environmental data
The temperature ranged from 5.5 to 38.6ºC during the experimental period, with daily mean temperature of 18.7ºC. The prevailing wind direction during the study was W-N (i.e. 61-100% of the sampling time), which was in accordance with historical data of the area.

Slurry characterization
Table 1 shows the characterization of slurry collected from the flexible bag after being mixed. These values are in the range of dairy cattle slurry found in our region (data not shown), which were obtained from an on-site sampling survey on 76 dairy cattle farms [5].

Table 1. Slurry characterization after being stored in a flexible bag system. Analysis is reported on a dry weight basis; Mean (standard deviation).

DM (%)	8.5 (0.2)
OM (%)	69.9 (1.5)
TN (g l^{-1})	3.2 (0.2)
NH_4^+-N (g l^{-1})	1.7 (0.1)
C_{org} /N_{org}	8.4 (0.3)
pH	7.5 (0.0)

Ammonia flux on days without slurry management operation averaged 0.2 mg N m^{-2} h^{-1}, being lower than results reported by Vanderzaag et al. [6], who estimated an NH_3 emission of 0.7 ± 0.5 mg m^{-2} h^{-1} from a dairy manure tank (8.6 m^3) with permeable cover in Nova Scotia, Canada (temperature 10ºC-20ºC). Slurry loading operation, performed 18 h after the beginning of the experiment, resulted in an NH_3 peak of 1.0 mg N m^{-2} h^{-1}, while the highest peak was obtained on the last day, with 5.1 mg N m^{-2} h^{-1}, as a result of slurry mixing and emptying operations (Figure 1). These emissions accounted for 82% of total NH_3 volatilized during the experimental period. Cumulative NH_3 emission before slurry removal was 55.3 mg N m^{-2}, while cumulative NH_3 during 12 measuring days, including removal, was 197.6 mg N m^{-2}.

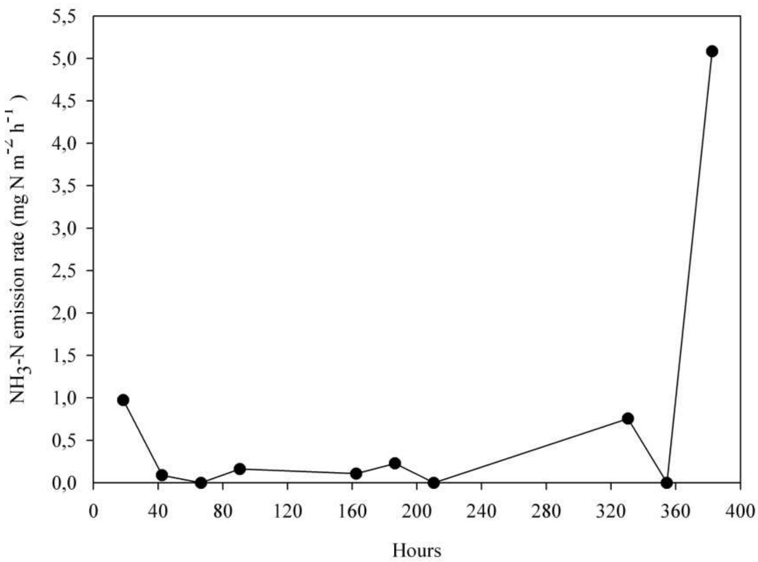

Figure 1. Ammonia emission rate (mg N m^{-2} h^{-1}) from flexible bag storage system.

Conclusions and perspectives

The results of this study have demonstrated that flexible bag can be effectively used to control NH_3 emissions from slurry outdoor storage, with loading and emptying operations as the main factors increasing NH_3 volatilization, representing 82% of total NH_3 volatilized. Data will be analyzed by an inverse dispersion technique (backward Lagrangian stochastic model) in order to compare with those from the IHF technique.

References

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