Ammonia Emission Assessment After Buffalo Manure And Digestate Application

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Abstract

Quite recently, considerable attention has been paid to the effect of anaerobic digestion on ammonia emissions from digestate spreading in the field, due to the growing interest in NH_3 emission monitoring. Unfortunately, there are still some different studies finding about the effect of anaerobic digestion on ammonia emissions. Thus, more research into this topic is still necessary before obtaining a definitive answer to the increment or not in emission. For this purpose, this paper proposes comparison study between ammonia emissions from buffalo raw (Farmyard) manure and digestate on bare soil under Mediterranean climate, using the wind tunnel equipped with acid traps, to assess the ammonia emission fluxes. The sampling campaign, in three replicates, lasted each time, for 6 days to ensure that most of the ammonia has been emitted before the end of each campaign. The results obtained indicate that a diurnal correlation between emission and external temperature occurs, especially during the first days. Specifically, for both fertilizers, ammonia volatilization increased with air temperature raising. Overall, the total digestate cumulative NH_3 emission is 54% higher than raw manure emission. This is certainly due to the Total NH_4^+-N rate, which was 55,8kg ha^{-1} for the raw manure and 107 kg ha^{-1} for the digestate, around 1.9 times higher for the digestate TAN content. Finding suggests the need for adjusting digestate application rate based on TAN content, in order to reduce the impact on the environment.

Keywords: Ammonia volatilization, Farmyard manure, organic fertilizers comparison, anaerobic digestion, open field monitoring, wind tunnel.

1. Introduction

The intensive livestock breeding leads to the production of high quantities of manure which contribute to ammonia emission especially following manure application to the land, in regions where livestock production increased (Sommer et al., 2013). Ammonia emissions decrease the nutrient availability of organic fertilizers and they are responsible for human and environmental problems (Pedersen et al., 2018).

In the last years, according to the incoming Directive NEC (National Emission Ceiling), there has been a growing interest in NH_3 emissions monitoring and reduction. A considerable attention has been paid to field manure application, because of its major contribution to NH_3 volatilisation from livestock activities (Carozzi et al., 2013). The intensity of the process is mainly related to the field conditions and manure characteristics, such as pH, dry matter (DM) and total ammoniacal nitrogen (TAN). Specifically, manure characteristics can vary depending on manure pre-treatment (Evans et al., 2018). Therefore, current studies have been focused on some manure pre-treatments such as anaerobic digestion and soil-liquid separation. In this sense, anaerobic digestion (AD), is the only with the advantage of reducing odour and methane emissions along with production of biogas fuel (Neerackal et al., 2015). On the other hand, AD may potentially increase the NH_3 emissions following the digestate field application, due to the increase in pH and TAN concentration (Sun et al., 2014) because of the mineralization of organic nitrogen to ammonia. The assessment in the field of these possible side-effects is necessary to guarantee the environmental suitability of digestage land application in terms of gaseous N losses (Chantigny et al., 2009).

Unfortunately, there are still some different finding in literature on the effect of anaerobic digestion on ammonia emissions, that underline the importance of planning new experiments about this topic (Holly et al., 2017; Möller, 2015)

Based on the background presented, the purpose of this study was to assess the effect of AD on NH_3 volatilization on bare soil under Mediterranean climate, comparing ammonia emissions of buffalo digested manure and buffalo farmyard manure (FYM). For this purpose, three field trials were carried out using wind tunnel technique, that is a favoured tool in comparison studies for ammonia emissions evaluation (Sommer and Misselbrook, 2016).

2. Materials and Methods

Trials were carried out in the experimental field of University of Naples Federico II, Portici (Campania region, Southern Italy, 40°48'49.9"N 14°20'48.3"E). The site is located in a typical Mediterranean environment, characterized by a temperate Mediterranean climate, according to Emberger's index (Leone, A., 2011). A weather station (PCE-FWS

20) has been placed next to the field to measure wind velocity and direction, temperature, rainfall, humidity and relative pressure for all the duration of trials and recorded by a data logger with a resolution of 10 minutes.

Three field trials were carried out in consecutive weeks during the month of June 2017, to keep similar weather conditions, using fertilizers from buffalo species, reared mainly in Southern Italy (Pindozzi et al., 2013). Buffalo raw manure and buffalo digested manure were applied by hand at a rate of 200 kg N ha^{-1}, spreading the same total nitrogen content (TKN), in order to assess NH_3volatilization within a period six consecutive days.

Experimental trials and fertilization information are summarized in Table 1.

Table 1. Experimental plan design

Trial	Starting date	Ending date	N rate (N ha^{-1})	Manure (kg)	Digestate (l)
1	06/06/2017	12/06/2017	200	1.2	1.9
2	13/06/2017	19/06/2017			
3	20/06/2017	26/06/2017			

Before spreading the organic fertilizers, representative samples were collected, to analyse dry matter (DM) content, ammonium-N (TAN) and total-N (TKN). Table 2 gives the main characteristics of fertilisers.

Table 2. Chemical characteristics of fertilizers used in the field trials

Fertilizers	pH	TAN (mg l^{-1})	DM (%)	TKN (mg l^{-1})
Digestate	7.73	1804.5	7.892	3374
Manure	8.13	1710	18.131	6119

After fertilization, ammonia emission rate was measured using two wind tunnels (Scotto di Perta et al., 2016), consisting of an open chamber placed on a rectangular area (0.32 m^2), which simulate the wind action on a fertilized surface by means of a fan (Figure 1).

Figure 1. Wind tunnels measuring ammonia emission from bare soil

Wind tunnel was characterized by two air sampling points, at the inlet and the outlet. NH_3 in sampled air was trapped using acid traps system made up of: a bottle contained 1% sulphuric acid solution, a flow meter stabilizing the rate to 4 l min^{-1} and a suction pump. The sampling lasts for 6 days to ensure that most of the ammonia has been emitted before the end of each campaign. Acid solutions were replaced every 3 hours during the daytime. The concentration of ammonia trapped in acid solutions was measured in lab spectrometrically using a continuous flow analyzer (FIAstar 5000, Foss, Denmark). The NH_3 flux can be computed by following equation (1):

$$\boldsymbol{J} = \frac{\boldsymbol{Q}\,(\boldsymbol{C_{out}} - \boldsymbol{C_{in}})}{\boldsymbol{A}} \tag{1}$$

where C_{out} and C_{in} (μg m^{-3}) are the NH_3 concentration in the outlet and inlet air, respectively, while Q (m^3 s^{-1}) is the inlet flow rate and A (m^2) is the fertilized area.

3. Results and Discussion

Figure 2 shows selected NH_3 emission measured along with air temperature variations. As shown, a diurnal correlation between NH_3 emission and air temperature occurred, especially during the first days. Specifically, for both fertilizers, ammonia volatilization increased with air temperature raising. Furthermore, the highest emission rates occurred for both fertilizers during the first hours, because of the high TAN concentration at the application time (Sommer and Misselbrook, 2016).

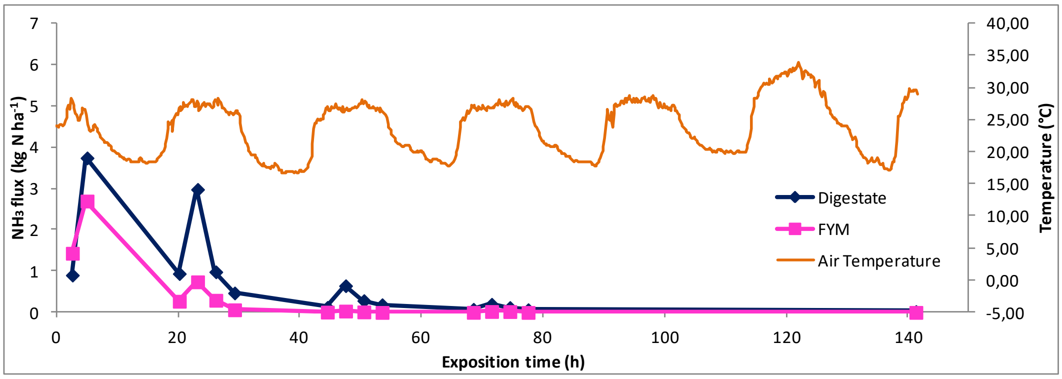

Figure 2. NH_3 emissions rate and air temperature variations during trial 1.

The cumulative ammonia emission curves, obtained in the three trials, are illustrated in Figure 3. As can be seen, NH_3 emission decreased after the first 24h for both treatments. The cumulative ammonia emissions after 141 h after fertilization were 31.77 kg N ha^{-1} from the buffalo digested manure and 14.77 kg N ha^{-1} from the buffalo raw manure, respectively. Thus, it has been found that the digestate emitted around 54% of total NH_3 amount more than raw manure. The higher ammonia emission may be due to the TAN content digestate is twice that of manure, indeed generally the anaerobic process increases the TAN content because of organic nitrogen mineralization (Holly et al., 2017).

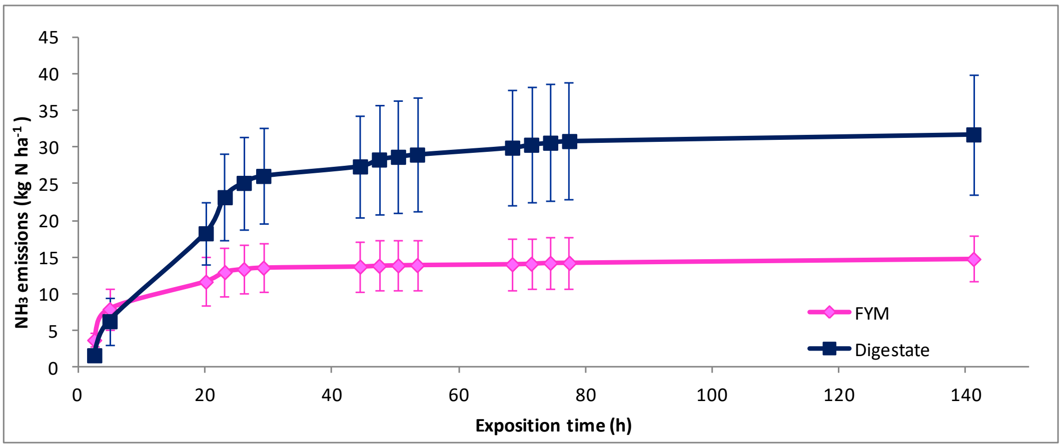

Figure 3. cumulative NH_3 emissions. Vertical bars represent standard error of means (n=3).

FYM emission decreased substantially after the first 26 hours, probably due to water evaporation and the crust formation, as reported also by Neerackal et al. (2015) in a previous study, contrary to the digestate that emitted for a longer period.

Normalized emissions by TAN and N applied for the first 24 h and for the last day have been considered (Table 3), to improve treatments comparison.

Table 3. Comparison of cumulative NH_3 emission normalized by applied N and TAN

Fertilizers	kg N ha^{-1}		% of TAN applied		% of N applied	
	24h	Last day	24h	Last day	24h	Last day
Digestate	24.56	31.77	22.95	29.69	12.28	15.89
FYM	13.25	14.77	23.75	26.46	6.63	7.38
% difference	46.05	53.51	-3.48	10.88	46.01	53.56

As may be seen from the comparison, when cumulative NH_3 emission is normalized by applied TAN, the difference between fertilizers decreases substantially. This could confirm the hypothesis that the difference of 46 and 53% between the cumulative NH_3 emission of digested manure and FYM is mainly due to the greater TAN content of digestate compared to FYM (Evans et al., 2018).

Studies on digestate effect on NH_3 emissions after field digestate spreading are still lacking, moreover, sometimes results are different to each other. The most likely explanation is that experiments are carried out in different climate conditions, sometimes introducing also other manure treatments, such as soil/liquid separation or storage, reducing the opportunity of a clear conclusion (Möller et al. 2015). According to relevant literature reports in this field, NH_3 losses are greater in case of digestate spreading than manure when the application rate is based on equivalent Total N or volume (Amon et al., 2006; Möller and Stinner, 2009; Rubæk et al., 1996), due to the application of a higher total NH_4^+-N concentration, as in the case of this study. As a matter of fact, when the application rate is based on equivalent total NH_4^+-N, literature results showed that anaerobic digestion could reduce NH_3 emissions from field-applied digestate (Neerackal et al., 2015; Rubæk et al., 1996).

4. Conclusions

The cumulative ammonia emissions of the digestate is 2.15 times higher than the total manure ammonia emission, most likely because of Total NH_4^+-N rate, which was 55.8kg ha^{-1} for the manure and 107 kg ha^{-1} for the digestate, around 1.9 times higher for the digestate. Results confirm the need for adjusting digestate application rate based on TAN content, in order to reduce the impact of the spreading activities.

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