Ammonia losses from the land application of raw pig slurry and solid and liquid fractions generated from its mechanical separation

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Two trials were carried out to examine the influence of manure application rate, air temperature, air velocitiy and slurry mechanical separation on ammonia volatilisation from pig slurry surface-applied to grassland.

Three fractions (pig raw slurry, liquid fraction and solid fraction) were applied on alfalfa over two seasons (summer and autumn) with two application rates (40 and 70kgN/ha) and with two air velocities (0-0.6 m/s) at the soil surface. Trial results pointed out that the raw slurry was the most emitting substrate, followed by the liquid and solid fractions. Up to 23% of the applied total Kjeldahl nitrogen (TKN) was lost as ammonia from the raw slurry over five days of trials in autumn and windy conditions (0.6 m/s). A similar value was determined in summer conditions with the same air velocity over the soil surface. A significant effect of the air velocity on ammonia emissions was observed while no effect of the application rate was observed. Ammonia emissions after the spreading of the raw slurry were up to 48% higher compared to those generated after application of the two resulting fractions (solid + liquid).

Introduction

Nitrates Directive (91/676/EEC) is encouraging farmers and the Public administration to find alternative animal waste management strategies to solve the problem of Nitrogen (N) surplus of vulnerable areas. The mechanical separation of raw liquid manures is considered as reliable method to concentrate nutrients in the solid fraction and to obtain a more diluted liquid fraction (Møller *et al*., 2000). The latter can be used for fertirrigation of the fields close to the farm centre whereas the solid one can be more conveniently transported in areas with lower animal density. For such a reason, this technology is nowadays meeting the Italian farmers interest and is rapidly spreading all over the territory. To promote a new technology, anyway, it is necessary to consider all environmental aspects not only the ones concerning the soil but also the potential air pollution.

It is well known that a substantial portion of N applied to soil as manure can be lost via ammonia (NH_3) volatilisation. Emission of NH_3 may cause eutrophication of natural ecosystems (Fangmeier et al., 1994) and it is implicated in airborne $PM_{2.5}$ and PM_{10} particulates formation that can be a health hazard (McCubbin et al., 2002). Nevertheless, few national data are nowadays available on the environmental sustainability of animal slurry mechanical separation technique. In this context, the present study focuses on measuring NH_3 emissions from the land application of raw pig slurry and of the solid and liquid fractions generated from its mechanical separation.

Materials and methods

Raw pig slurry from a commercial farm was collected from a storage pit and separated by a screw press mechanical separator (Chior Meccanica, model 300). Samples of the raw slurry and of the two fractions were collected to determine their main chemical characteristics (Table 1).

Immediately after mechanical separation, the two fractions (liquid and solid) and the raw slurry were manually applied to plots (2.0 x 3.0 m) of two years old alfalfa over two seasons (summer – second cut and autumn - third cut) at two application rates (40 and 70kgN/ha). The soil was loamy sand with pH of 8.5, 3.1% loam, 10.6% silt, 86.3% sand, 0.11% total N and a cation exchange capacity (CEC) of 0.09 Cmol/kg.

Table 1. Main chemical characteristics of the manures used in the trials

Manure	Total solids(%)	TKN(kg/t)	TAN(kg/t)	TAN/TKN	pH
	Summer trial				
Raw pig slurry	3.5	4.3	3.0	0.70	7.8
Solid fraction	23.2	7.2	3.3	0.45	8.4
Liquid fraction	2.4	4.0	3.0	0.75	8.0
	Autumn trial				
Raw pig slurry	3.5	3.6	2.0	0.56	7.8
Solid fraction	28.9	6.8	2.5	0.37	8.2
Liquid fraction	2.1	3.2	2.1	0.66	7.8

The emission of ammonia were measured by means of two sets of devices: the Wind tunnel by Schmidt and Bicudo (2002), adjusting the air velocity at 0.6m/s (surface covered by the wind tunnel: 0.32m^2), and by the Funnel system (Balsari et al., 1994) which allows to perform the measurement with an air speed close to 0 m/s. The last system consists of a funnel of 0.138 m^2 surface, a trap containing a 1% boric acid solution, a vacuum pump, a volume meter and a flow meter. The NH_3 concentration in the incoming air is measured by means of a second set of pump, volume meter and acid trap. The funnel systems are arranged to collect the air from the captor with a flow rate of approximately 9 l/min. Ammonia present in the air is fixed in the boric acid trap by being transferred into ammonium borate and its concentration is determined by titration. Each trial lasted 5 days with daily sampling of the gaseous emissions and were performed in three replicates. Results are given in percentage of nitrogen lost as ammonia as regards to the amount of total Kjeldahl nitrogen (TKN) spread with the raw slurry and the two fractions. Results were processed by ANOVA.

In order to compare the emission of ammonia generated from the spreading of the same amount of nitrogen by raw slurry only or by the spreading of the two resulting fractions (solid and liquid), the emissions were expressed as index values. These latter were calculated by considering as 100 the emission of ammonia generated from a known amount of raw slurry and then comparing this latter value to the emission of ammonia after the land application of the two fractions derived from the mechanical separation of the same amount of raw slurry (Balsari et al., 2008). Environmental temperature and humidity were recorded during the two trials by a thermo hygrometer (Salmoiraghi 1750-2/Q).

Results and discussion

During the summer trial, an average temperature of 18.4°C (range 11.3-27.8°C) and a relative humidity of 67.5% were recorded while during the autumn trial an average temperature of 11.4°C (range 9.1-17.0°C) and a relative humidity of 89.0% were measured.

According to trials results (Figs 1 and 2), in most cases the raw slurry was the most emitting substrate, followed by the liquid and solid fractions.

Up to 23% of the applied total Kjeldahl nitrogen (TKN) was lost as ammonia from the raw slurry over the five days of trials in autumn and windy conditions (0.6 m/s). Lower emissions were found from the liquid fraction (11.5% of the spread TKN) and the solid one (17.6% of the spread TKN). Similar values were determined in summer conditions and with the same air velocity over the soil surface. Generally, lower ammonia emissions were measured with the highest application rate (70 kgN/ha) as regards to the 40 kgN/ha application rate. Other studies have shown that NH_3 volatilization rates per unit volume of applied slurry decrease with increase in application rate (e.g. Frost, 1994). With an air velocity of ~0 m/s (funnel system) NH_3 losses were always higher in Summer than Autumn conditions (Fig. 1), but no relationship was found between total ammonia losses and temperature with an air velocity of 0.6 m/s (Fig. 2). In the latter case the high air velocity may have caused higher water evaporation and induced rapid crust formation on the surface layer of applied manure in summer conditions. This reduced NH_3 volatilization (Sommer et al., 1991).

Fig. 1. Total ammonia emissions expressed as nitrogen losses (% on the applied TKN) with an air velocity of ~0 m/s. (A) Summer conditions; (B) Autumn conditions

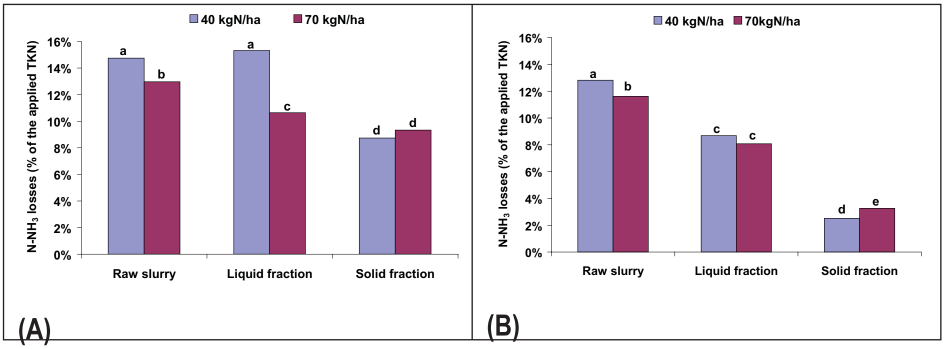
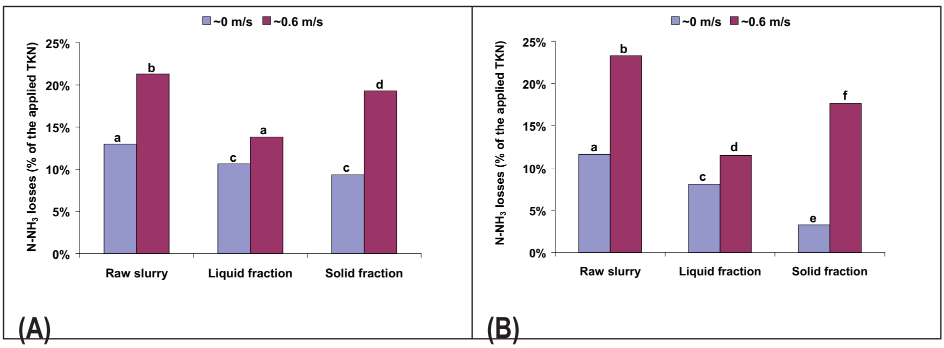


Fig. 2. Total ammonia emissions expressed as nitrogen losses (% on the applied TKN) (A) Summer conditions; (B) Autumn conditions



A significant effect of the air velocity on ammonia emissions was observed: in all cases the air current over the spread slurry determined an increase of ammonia losses as regards to the ~0 m/s air velocity treatments. In all tests, the spreading of the raw slurry determined higher ammonia emissions to air than the application to land of the same total nitrogen rate by the two resulting fractions (solid + liquid) (Figs 3 and 4). In Autumn conditions (Fig. 4) with an application rate of 70 KgN/ha and 0.6 m/s air velocity, emissions of ammonia from the raw slurry were up to 48% higher than those generated from the two fractions.

Fig. 3. Summer trial – Cumulative losses of ammonia of the investigated samples in relation to those of the raw slurry (raw slurry: 100) (A) 40 kgN/ha, ~0 m/s; (B) 70 kgN/ha, ~0m/s, (C) 70 kgN/ha, ~0.6 m/

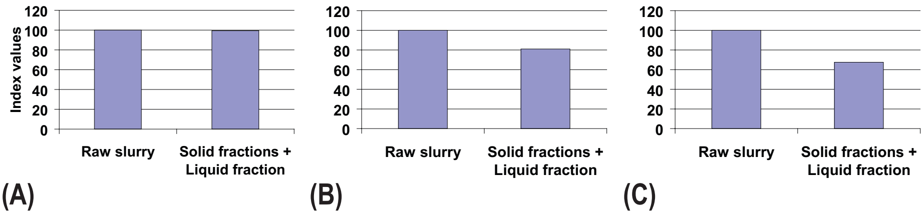
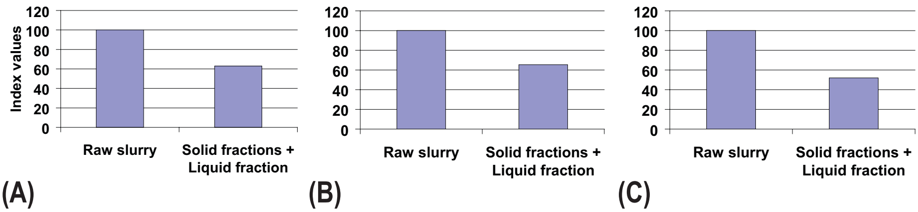


Fig. 4. Autumn trial - Cumulative losses of ammonia of the investigated samples in relation to those of the raw slurry (raw slurry: 100) (A) 40 kgN/ha, ~0 m/s; (B) 70 kgN/ha, ~0 m/s, (C) 70 kgN/ha, ~0.6 m/s



Conclusions

According to trials results, the mechanical separation of pig slurry seems to have positive environmental effects by reducing ammonia emissions after the application of the two resulting fractions (solid + liquid). Nevertheless, to assess the sustainability of the mechanical separation as regards to the traditional slurry management a whole system approach is required. Thus, as it is necessary to consider also the other steps of the slurry management chain (starting from the storage phase), trials are nowadays running nearby the DEIAFA – Torino University.

References

Balsari, P., Magrini, G., Pons, R., 1994. Ammonia losses from pig slurry storage: first results of field test. Proceedings of the seventh technical consultation on the ESCORENA Network on animal waste management, Bad Zwischenahn, Germany, 31-35.

Balsari, P., Dinuccio, E., Santoro, E., Gioelli, F., 2008. Ammonia emissions from rough cattle slurry and from derived solid and liquid fractions applied to alfalfa pasture. Australian Journal of Experimental Agriculture 48, 198–201.

Directive of the Council of December 12, 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC), European Commission, Brussels pp. 1–8.

Fangmeier, A., Hadwiger-Fangmeier, A., Van der Eerden, L., Jager, H.J., 1994. Effects of atmospheric ammonia on vegetation: a review. Environ. Pollut. 86, 43–82.

Frost, J.P., 1994. Effects of spreading method, application rate and dilution on ammonia volatilization from slurry. Grass and Forage Science 49, 391-400.

McCubbin, D.R., Apelberg, B.J., Roe, S., Divita, F., 2002. Livestock ammonia management and particulate-related health benefits. Environ. Sci. Technol. 36 (6), 1141–1146.

Møller, H.B., Lund, I., Sommer, S.G., 2000. Solid-liquid separation of livestock slurry: efficiency and cost. Bioresource Technology 74, 223-229.

Schmidt DR, Bicudo JR. (2002) Using a wind tunnel to determine odor and gas fluxes from manure surfaces. Paper No. 024083 presented at XXXII ASAE-CIGR Meeeting, Chicago, USA.

Sommer, S.G., Olesen, J.E., Christensen, B.T., 1991. Effects of temperature, wind speed and air humidity on ammonia volatilization from surface applied cattle slurry. Journal of Agricultural Science 117, 91-100.