METHANE, NITROUS OXIDE AND AMMONIA EMISSIONS DURING STORAGE AND AFTER APPLICATION OF DAIRY CATTLE AND PIG SLURRY AND INFLUENCE OF SLURRY TREATMENT

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ABSTRACT

Ammonia, methane and nitrous oxide emissions from the manure management continuum “storage” and “field application” were quantified under field conditions. Experiments included dairy cattle and pig slurry. Emissions were followed from untreated, separated, anaerobically digested, straw covered and aerated slurry. About 10 m^3 slurry were stored in concrete tanks. Emission rates were determined with a large open-dynamic chamber and with high resolution FTIR spectrometry. Sampling frequency was high. No potential for ammonia abatement was found within the investigated slurry treatment options. Ammonia emissions mainly occurred after field application. Promising mitigation options are low trajectory application techniques and proper timing of application. Anaerobic digestion is an effective means to reduce greenhouse gas emissions. Straw cover and slurry aeration showed negative environmental effects.

Keywords: biogas, slurry separation, nitrous oxide, methane, manure management

INTROCUCTION

Manure management is a source for methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3) emissions. CH_4 and N_2O emissions are estimated according to the “Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories” (IPCC 1997). It is assumed that manure has a maximum methane production potential (B_0). B_0 values for animal manures have been measured under lab conditions. The IPCC guidelines give methane conversion factors (MCF) that estimate how much of the maximum methane production potential is realised when manure is stored on commercial farms. N_2O emissions during storage and after application of animal manures are estimated with emission factors that give N_2O losses as percentage of nitrogen excreted by the animal. Manure treatment options are not differentiated in the emission factors. B_0 values, MCF, and emission factors for N_2O are associated with considerable uncertainty. Mitigation options can only be proposed, if knowledge on emissions from manure management is improved. The influence of contrasting manure treatment options must be investigated.

The research project aimed at finding slurry treatment options that reduce ammonia and greenhouse gas emissions during slurry storage and after field application. Emissions during storage and after application were followed as it is important to reduce net total emissions and avoid the swapping of emissions from one stage of the manure management continuum to the next.

APPROACH

NH_3, CH_4 and N_2O during slurry storage were quantified in 10 m^3 pilot scale slurry tanks. The tanks were made from concrete and buried in the ground, with 5 cm of the wall above the soil surface (Fig. 1). Emissions of NH_3, N_2O and CH_4 were quantified by moving a large open dynamic chamber on a slurry tank and collecting the emissions. Emissions of each variant were measured at least twice a week for several hours.

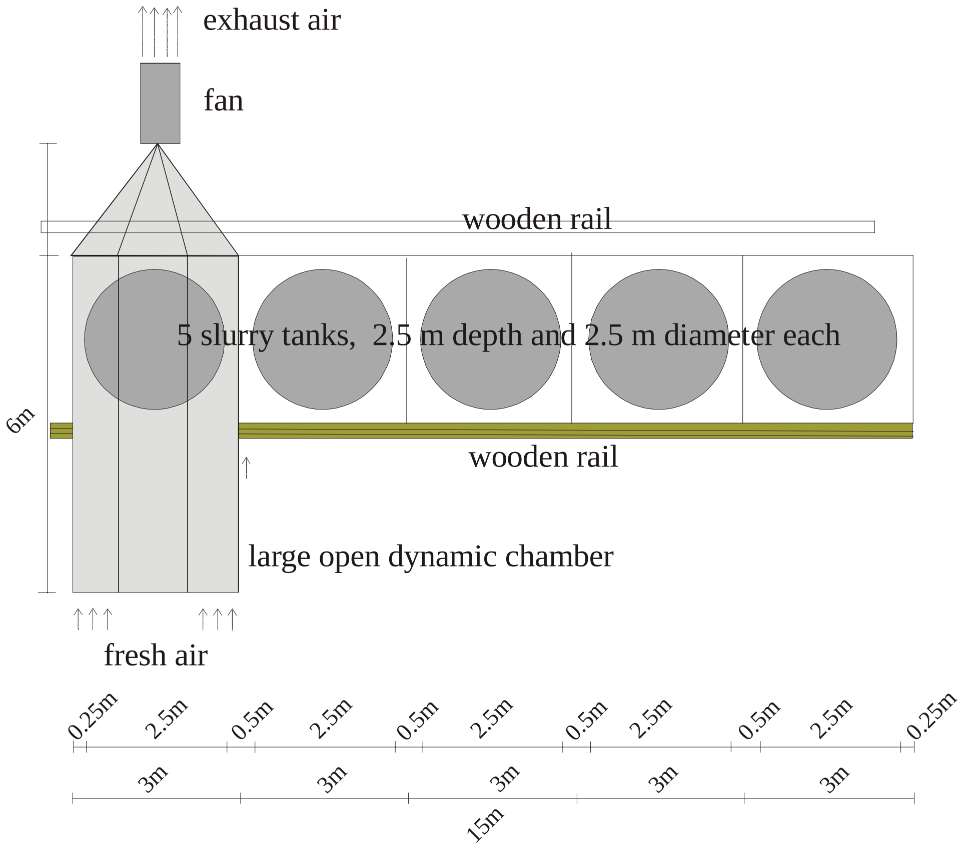

Fig. 1. Design of the experimental facility for quantifying emissions from slurry stores (Amon et al. 2002)

The large open dynamic chamber determines the air flow over stored manure. It covers an area of 27 m^2 and can be built over emitting surfaces in the animal housing, on manure stores and over spread manure. Fresh air enters the chamber at the front. In the chamber the fresh air accumulates the emissions and leaves the chamber on the far side. Gas concentrations are measured alternately in the incoming and in the outgoing air. The air flow is recorded continuously by a fan-based flow meter (Amon et al. 1996).

NH_3, N_2O, and CH_4 concentrations were quantified by FTIR spectroscopy, which is a reliable possibility for continuous online detection of gaseous emissions in the field. The applied FTIR spectroscope has a spectral resolution of 0.25 cm^{-1}. It is operated with a white cell with 8 m light path. The detection limit is 0.5 ppm for ammonia and ambient air level for carbon dioxide, methane, and nitrous oxide. Slurry temperature was continuously measured at two heights in each slurry tank. Samples for the analysis of slurry composition were taken at weekly intervals in the first few weeks of storage and every second week during the rest of the storage. Slurry samples were analysed for dry matter, ash, pH, NH_4-N, total nitrogen, and total carbon.

The effect of the following treatment options was investigated: untreated slurry, mechanically separated slurry (emissions from the slurry and from composting of the separated solids), anaerobically digested slurry, slurry covered with a layer of chopped straw, and slurry aeration. Measurements were carried out with dairy cattle, and with pig slurry.

After storage, manures were field applied to permanent grassland with the low emission band spreading technique. The weather was warm and dry with a mean air temperature of 18.6 °C. NH_3 emissions were continuously followed for two days with the large open dynamic chamber. N_2O and CH_4 emissions were quantified with closed chambers on days 1, 2, 4, 8, 13, and 20. N_2O and CH_4 concentrations were analysed by gas chromatography (EC and FI detector).

Statistical data analysis was carried out with the software package SPSS, version 10.0. Regression curves were fitted to cumulative emissions. Differences in regression equations were tested with a pair wise comparison of regression parameters by the t-test. Level of significance was set to at least 0.05.

RESULTS

Figure 2 gives net total ammonia emissions during storage and after field application of *dairy cattle slurry*. Field application contributed to the greatest extent to net total ammonia emissions (exception: slurry separation). With slurry aeration *c.* 50 % of NH_3 was lost after field application. The band spreading took place during rather warm weather. Field application under cool weather conditions - e.g. in the morning or in the evening - can further reduce ammonia emissions.

Slurry separation resulted in an increase in net total ammonia emissions to 402.8 g NH_3 per m^3 slurry. This was mainly due to ammonia emissions during composting of the solids which contributed *c.* 70 % to net total ammonia emissions. NH_3 emissions during composting of the solids may be reduced by adding more straw to the solids. This must be checked in further experiments. NH_3 emissions after field application of the liquid phase of separated slurry were much lower than after field application of untreated slurry. From anaerobically digested slurry nearly the same amount of NH_3 was emitted as from untreated slurry (229.9 g NH_3 per m^3 slurry). During storage, NH_3 emissions were lower than from untreated slurry. After field application, an increase of *c.* 18 % in NH_3 emissions compared to untreated slurry was observed. This was probably due to the higher NH_4-N and pH of digested slurry. Covering the slurry store with a layer of chopped straw increased NH_3 emissions during storage and after field application compared to slurry that was covered with a wooden lid. The highest net total NH_3 emissions were measured from aerated slurry. Dry matter content of aerated slurry was a little lower than of untreated slurry. Nevertheless, NH_3 emissions after field application were not reduced. This may be due to the higher NH_4-N-content.

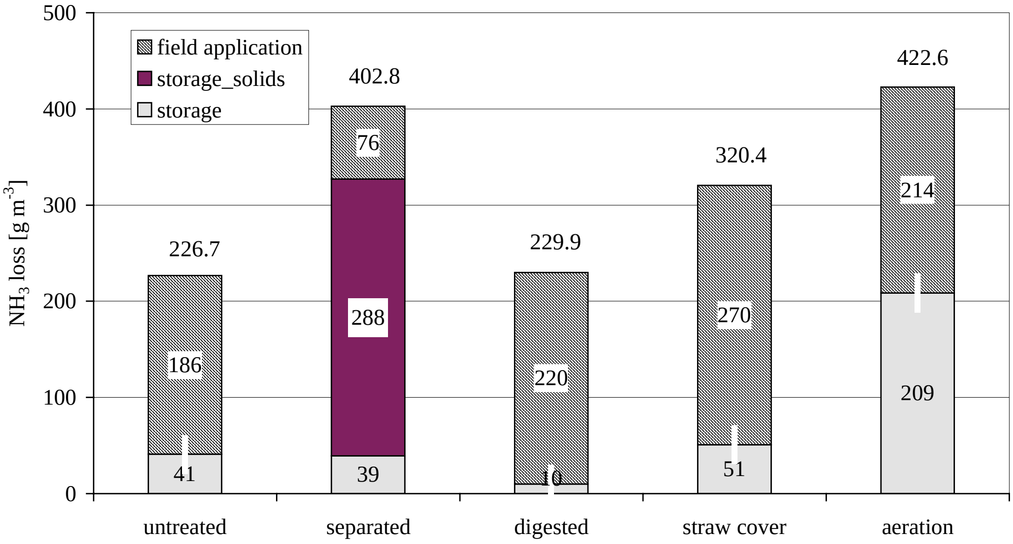

Fig. 2. NH_3 emissions during storage and after field application of dairy cattle slurry.

Net total emissions of greenhouse gases expressed as kg CO_2 equivalents per m^3 slurry are shown in Figure 3. They have been estimated from CH_4 and N_2O losses. The global warming potential of CH_4 is 21 times higher than that of CO_2. N_2O has a 310 times higher GWP than CO_2 (Houghton et al. 1996).

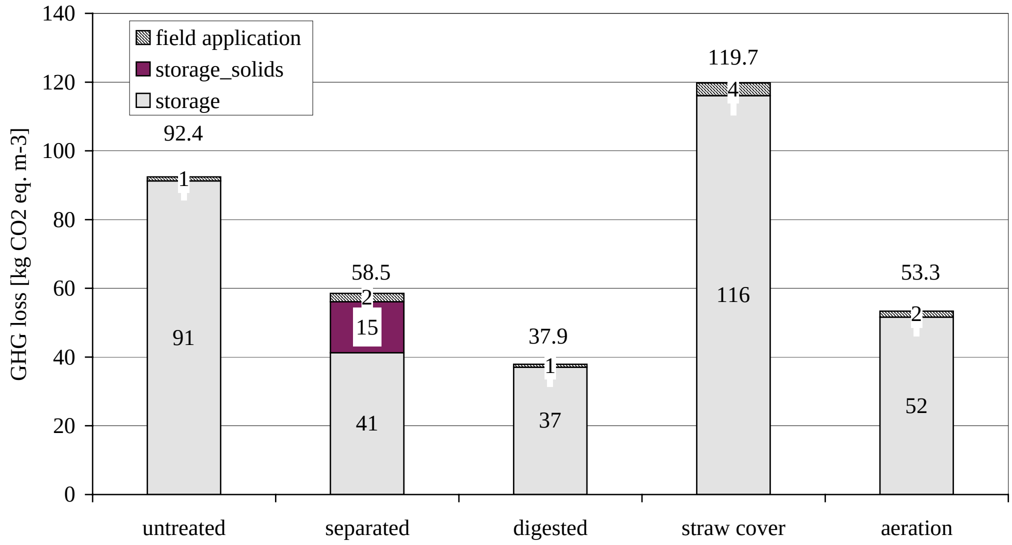

Fig. 3. Greenhouse gas emissions during storage and after field application of dairy cattle slurry.

More than 90 % of net total greenhouse gas emissions from untreated slurry originated from methane emissions during slurry storage. This means that greenhouse gas abatement measures are most effective if they reduce methane emissions during slurry storage. Slurry separation and anaerobic digestion could effectively reduce greenhouse gas emissions. Covering the slurry store with a layer of chopped straw increased greenhouse gas emissions mainly by increasing CH_4 and N_2O emissions during slurry storage. Even if N_2O emissions during storage of aerated slurry were greater than during storage of untreated slurry, net total greenhouse gas emissions were still reduced compared to untreated slurry. This was due to the reduction of methane emissions during storage of aerated slurry.

Table 1 summarises NH_3, CH_4, N_2O, and greenhouse gas emissions that were measured during a 100-day storage period and after field application of untreated, separated, anaerobically digested, straw covered and aerated dairy cattle slurry.

Table 1. NH_3, CH_4, N_2O, and greenhouse gas emissions during storage and after field application of dairy cattle slurry

treatment	NH_3 [g m^{-3}]	%	CH_4 [g m^{-3}]	%	N_2O [g m^{-3}]	%	GHG[b] [kg CO_2 eq. m^{-3}]	%
untreated	226.7	100.0	4046.9	100.0	23.9	100.0	92.40	100.0
separated[a]	402.8	177.7	2363.3	58.4	28.6	119.7	58.51	63.3
anaerob. digested	229.9	101.4	1344.5	33.2	31.2	130.3	37.90	41.0
straw cover	320.4	141.3	4926.2	121.7	52.5	219.7	119.73	129.6
slurry aeration	422.6	186.4	1739.3	43.0	54.2	226.8	53.32	57.7

[a] liquid and solid phase [b] GHG = greenhouse gases

From Figure 4 net total ammonia emissions during storage and after field application of *pig slurry* can be taken. As with dairy cattle slurry, field application contributed to the greatest extent to net total ammonia emissions. With slurry aeration *c.* 57 % of ammonia was lost during storage and *c.* 43 % after field application.

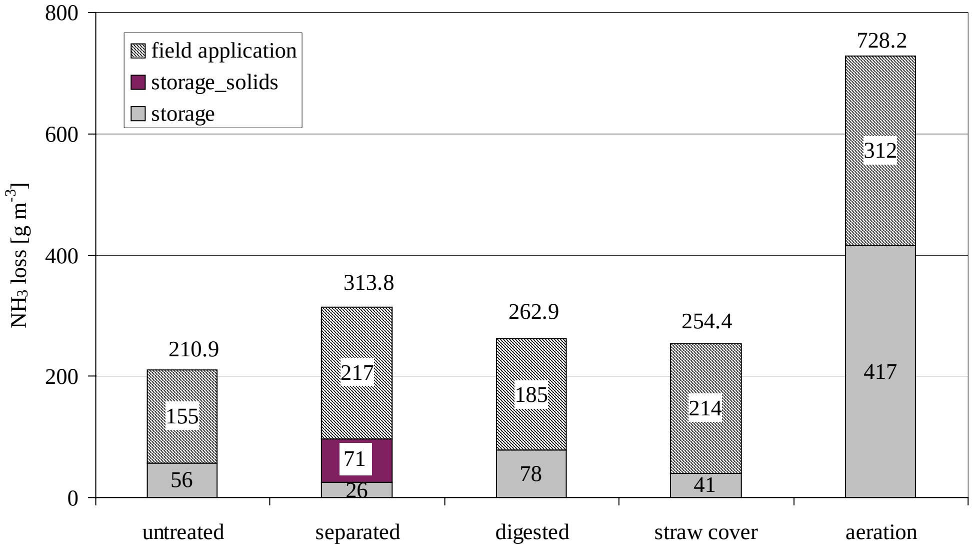

Fig. 4. NH_3 emissions during storage and after field application of pig slurry.

Untreated pig slurry emitted 210.9 g NH_3 per m^3 slurry. Slurry separation resulted in an increase in net total ammonia emissions to 313.8 g NH_3 per m^3 slurry. This was mainly due to ammonia emissions during composting of the solids. Ammonia emissions during storage of the liquid phase of separated slurry were lower than during storage of untreated slurry. From anaerobically digested slurry *c.* 25 % more NH_3 was emitted than from untreated slurry. Ammonia emissions amounted to 262.9 g NH_3 per m^3 slurry and were higher during storage and after field application. This was probably due to the higher NH_4-N and pH of digested slurry. Digested slurry should always be applied with low trajectory techniques and not during very warm weather.

Covering the slurry store with a layer of chopped straw increased NH_3 emissions after field application. They amounted to a net total of 254.4 g NH_3 per m^3 slurry. The highest net total ammonia emissions were measured from slurry aeration (728.8 g NH_3 per m^3 slurry). Aeration increased ammonia emissions during slurry storage. Dry matter content of aerated slurry was a little lower than of untreated slurry. Nevertheless, ammonia emissions after field application were not reduced. This may be due to the higher NH_4-N-content.

Net total greenhouse gas emissions from untreated pig slurry amounted to 35.6 kg CO_2 eq. per m^3 (Fig. 5). About 50 % of net total emissions originated from methane emissions during storage of untreated pig slurry. Slurry separation reduced net total emissions of greenhouse gases to 18.0 kg CO_2 eq. per m^3 slurry. With separated slurry, no big difference was observed in the contribution of the different sources to total emissions. Anaerobically digested slurry emitted 28.5 kg CO_2 eq. per m^3 slurry. Methane emissions during storage contributed *c.* 16 % to total greenhouse gas emissions. The share of nitrous oxide emissions after slurry application was *c.* 60 %.

Straw cover and slurry aeration both increased greenhouse gas emissions. Nitrous oxide emissions after field application held the biggest share in net total greenhouse gas emissions with both treatments. From the straw covered slurry, net total greenhouse gas emissions of 71.0 kg CO_2 eq. per m^3 slurry were lost. Greenhouse gas emissions from aerated slurry amounted to 201.1 kg CO_2 eq. per m^3 slurry. Nitrous oxide emissions after field application held a considerable share in total GHG emissions.

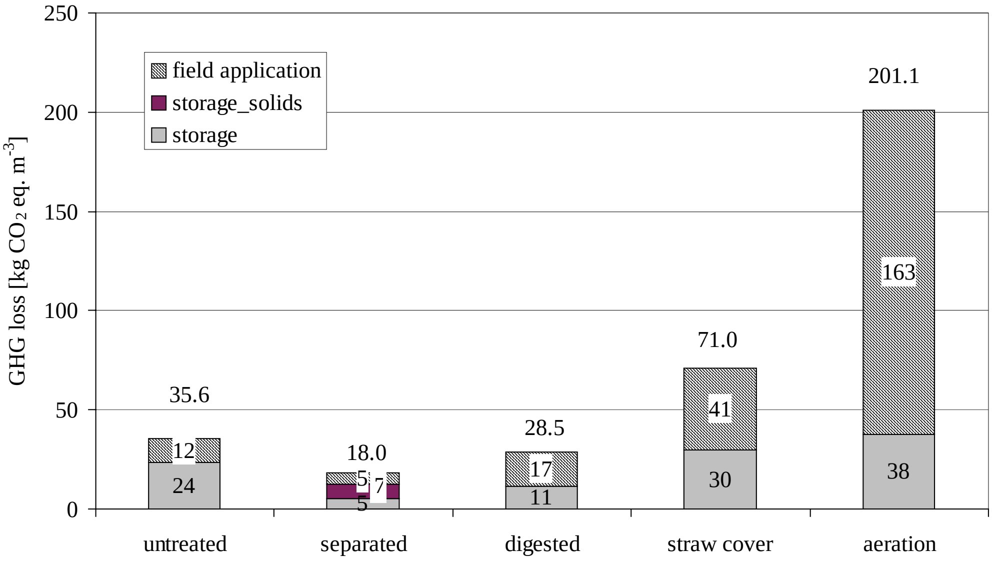

Fig. 5. Greenhouse gas emissions during storage and after field application of pig slurry.

Table 2 summarises results from experiments with pig slurry. As with dairy cattle slurry, non of the investigated slurry treatment options was able to reduce NH_3 emissions. NH_3

emissons from slurry separation mainly occured during composting of the solid fraction. Slurry aeration led to a massive increase in NH_3 emissions by 345.3 %.

Slurry separation and anaerobic digestion reduced net total greenhouse gas emissions compared to untreated slurry. Slurry aeration and covering the store with a layer of chopped straw markedly increased GHG emissions. A big increase in N_2O emissions With pig slurry, CH_4 emissions were not reduced through aeration. This might be due to the higher slurry temperature that favoured CH_4 formation during the intermittent aeration.

Table 2. NH_3, CH_4, N_2O, and greenhouse gas emissions during storage and after field application of pig slurry

treatment	NH_3		CH_4		N_2O		GHG[b]	
	[g m^{-3}]	%	[g m^{-3}]	%	[g m^{-3}]	%	[kg CO_2 eq. m^{-3}]	%
untreated	210.9	100.0	865.8	100.0	56.2	100.0	35.6	100.0
separated[a]	313.8	148.8	248.6	28.7	41.3	73.5	18.0	50.6
anaerob. digested	262.9	124.7	217.2	25.1	77.2	137.5	28.5	80.1
straw cover	254.4	120.6	906.4	104.7	167.5	298.2	71.0	199.4
slurry aeration	728.2	345.3	1328.2	153.4	558.6	994.5	201.1	564.8

[a] liquid and solid phase [b] GHG = greenhouse gases

CONCLUSIONS

No potential for ammonia abatement was found within the investigated slurry treatment options. Ammonia emissions mainly occurred after field application. Promising mitigation options are low trajectory application techniques and proper timing of application. Anaerobic digestion is an effective means to reduce greenhouse gas emission. Straw cover and slurry aeration showed negative environmental effects.

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