Emissions of NH_3, N_2O and CH_4 from a tying stall for milking cows, during storage of farmyard manure and after spreading

Emissions de NH_3, N_2O et CH_4 au cours du stockage de déjections solides (vaches laitières) et lors de l'épandage.

Amon B., Amon Th., Boxberger J.
Institut für Land, Unwelt-und Energietechnik,
Universität für Bodenkultur.
A-1190 Wien. Austria
E-mail : kiesslin@edv2.boku.ac.at

Pöllinger A.
Bundesanstalt für alpenländische Landwirtschaft,
A-8952 Irding. Austria.

Abstract

At the Institute of Agricultural and Environmental Engineering (ILUET) emission measurements are carried out with the aim to find factors influencing the amount of emissions and means to reduce emissions from different agricultural sources. Measurements are mainly performed on solid manure systems. All sectors of animal husbandry are investigated. This enables calculations of emissions for the whole management system including housing, storage and spreading of manure. Concentrations of NH_3, N_2O, CO_2 and CH_4 are analyzed by a high resolution FTIR spectroscope. To determine the emission rate the ILUET has developed a large open-dynamic-chamber which can be put over the emitting surfaces in the housing, on manure heaps and after spreading of manure.

In the housing system there was nearly no difference in CH_4 and NH_3 emissions between the liquid and the solid manure system. N_2O emissions were higher in the liquid manure system. NH_3 and N_2O emissions showed a clear dependency on the season, CH_4 emissions were mainly caused by ruminal fermentation. During storage and after spreading of the solid manure the compost emitted more NH_3 than the anaerobically stored solid manure. The anaerobically stored solid manure emitted much more N_2O and CH_4 than the compost.

Keywords : emission measurement, milking cows, ammonia, methane, N_2O.

Résumé

Des mesures d'émissions gazeuses sont réalisées à l'Institut d'Ingénierie pour l'Agriculture et l'Environnement (ILUET) afin de déterminer les facteurs influençant ces émissions et les moyens de les réduire à partir des différentes sources agricole. Les mesures sont effectuées principalement sur les déjections gérées sous forme solide. Toutes les étapes du système d'élevage sont étudiées, ce qui permet de calculer les émissions pour l'ensemble du système de gestion des déjections notamment le bâtiment, le stockage et l'épandage.

Les concentrations en NH_3, N_2O, CO_2 et CH_4 sont déterminées par spectroscopie FTIR. Afin d'obtenir les taux d'émissions, notre institut a développé une grande chambre dynamique ouverte qui peut ainsi être placée au dessus des surfaces d'émission dans le bâtiment, sur fumier en tas ou après épandage au champ.

Dans le bâtiment on n'observe pas de différence sur les émissions de CH_4 et NH_3 selon le mode fumier ou lisier. Les émissions de N_2O étaient plus importantes dans le système avec lisier. Les émissions de NH_3 et N_2O sont très dépendantes de la saison, alors que les émissions de CH_4 sont principalement issues des fermentations entériques par les ruminants.

Au cours du stockage et consécutivement à l'épandage de déjections solides compostées, les pertes par volatilisation de NH_3 sont supérieures à celles obtenues avec déjections solides gérées en conditions anaérobies. Par contre, les déjections gérées en conditions anaérobies émettent plus de N_2O et CH_4 que le compost.

Mots-clés : mesure émissions, vaches laitières, ammoniac, méthane, N_2O.

1. Introduction

At the Institute of Agricultural and Environmental Engineering (ILUET) emission measurements are carried out with the aim to find factors influencing the amount of emissions and means to reduce emissions from different agricultural sources. Measurements are mainly performed on solid manure systems. All sectors of animal husbandry are investigated. This enables calculations of emissions for the whole management system including housing, storage and spreading of manure.

In Austria most of the cows are housed in tying stalls with liquid or solid manure (KONRAD 1994). There is little knowledge on the amount of emissions from this housing system.

Farmyard manure can either be anaerobically stored or aerobically composted. Most of the investigations that have been carried out so far concentrated on ammonia emissions from composted farmyard manure (DEWES 1996, RÖMER ET AL. 1994). Recently also N_2O and CH_4 emissions have been included in the measurements on the laboratory scale (e.g. HÜTHER ET AL. 1997 , OSADA ET AL. 1997). Emission measurements should be carried out under field conditions and should include all ecologically harmful gases. As the way of storing farmyard manure influences the change of manure composition (esp. NH_4 content) and as the composition of the farmyard manure influences the amount of ammonia emissions after spreading, the emissions during storage and after spreading of the manure should be included in the investigations.

2. Experimental

If the emission rate is to be determined, gas concentration and air flow have to be known. Concentrations of NH_3, N_2O and CH_4 are analysed by a high resolution

FTIR spectroscope. In closed stables with a central exhaust fan, the ventilation rate is measured with a measuring fan that covers the whole cross-section of the central exhaust fan. For the determination of the air flow over manure storages and during and after spreading of manure the ILUET has developed a large open dynamic chamber (fig. 1, AMON ET AL. 1997).

The mobile chamber covers an area of 27 m^2 and can be built upon emitting surfaces in the animal housing, on manure storages and over manure spread areas. Fresh air enters the chamber at the front. In the chamber the fresh air accumulates the emissions and leaves the chamber on the other side. Gas concentrations are measured alternating in the incoming and in the outgoing air. The difference between incoming and outgoing air can be traced on emissions from the substrate inside the chamber. The exhaust fan at the end of the chamber can vary the air flow between 1.000 and 11.000 m^3/h. The air flow is recorded continuously by a measuring fan. At the front of the chamber a closed meshed net serves as a wind shield. A flow rectifier is installed at the end of the chamber. A funnel diminishes the cross-section of the chamber to that of the exhaust fan. The large open-dynamic-chamber has little influence on the natural conditions inside the chamber. The continuous air flow prevents heating up inside the chamber.

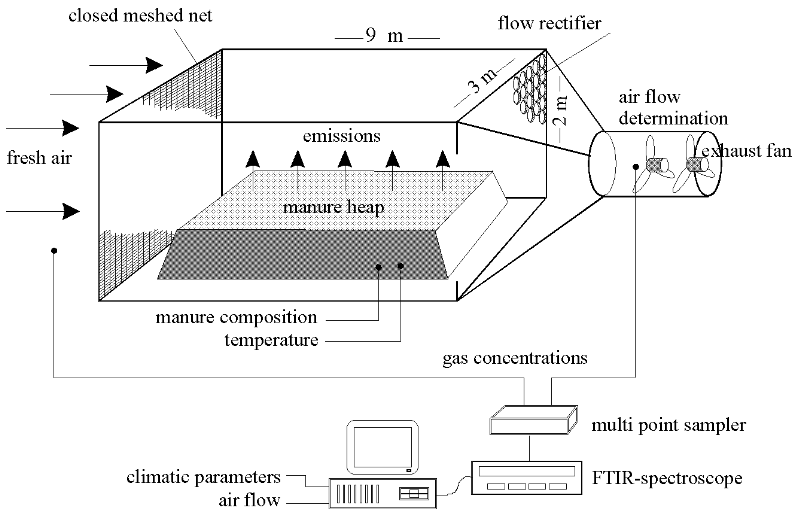

Figure 1.
Large open dynamic chamber developed by the ILUET

2.1. Emissions from a tying stall for milking cows

Emissions of NH_3, N_2O and CH_4 were measured from a tying stall with dung grid (slurry based system) for 12 milking cows. The housing was ventilated by a central exhaust fan in which ventilation rate and gas concentrations could be measured. Feed intake, feed composition, weight, milk yield, and temperature and humidity in the housing were registered. The slurry based system was changed into a straw based system for two weeks during each measurement campaign. Wooden boards were placed upon the dung grid and 2 kg of straw per LU were littered down. The solid manure was removed by hand twice a day. The measurement campaigns were repeated in every season of the year to get an overview over the course of emissions during the year.

2.2. Emissions during composting and anaerobically storage of farmyard manure

From June to September 1996 a comparison between emissions from anaerobically stored and aerobically composted farmyard manure from a tying stall for milking cows was carried out. Two heaps of farmyard manure (each about 3.5 t) were stored on concrete slabs with a drainage system. Seepage water emissions during storage were collected and analysed for their N content. Table 1 shows the composition of the composted and the anaerobically stored farmyard manure and the mean temperature inside the manure heaps. The large open-dynamic-chamber was moved from one heap to the other three times a week to measure the emissions.

	DM [%]	N_t [kg/t]	NH_4-N [kg/t]	C/N	pH	temp. [°C]
composted FYM	28.3	6.60	1.10	14	7.55	45.0
anaerobically stored FYM	20.4	6.39	1.17	14	7.43	35.3

Table 1.
Composition of the FYM and mean temperature inside the manure heaps

One heap was composted aerobically, which means it was turned seven times during the storage period. The turning was performed by hand. The large open-dynamic-chamber was built up over the compost and collected the emissions during and after the turning. The other heap was stored anaerobically. No manipulations were performed during the storage period.

2.3. Emissions after spreading of farmyard manure

After the storage period the large open-dynamic-chamber was built up on grassland and the composted and the anaerobically stored farmyard manure were spread in the chamber. The amount of spreaded manure was equivalent to 20 t/ha. Emissions during and after spreading were also measured so that the sum of emissions (storing, turning, loading and spreading) could be determined.

3. Results

3.1. Emissions from a tying stall for milking cows

Table 2 shows the emissions measured in the tying stall for milking cows with slurry and straw based system. The mean emissions of all three gases in course of the year showed no statistical difference between both housing systems (t-Test, a ≤

0.05). However there was a clear variation in the emissions in course of the year. NH_3 and N_2O emissions were dependent on the season: the higher the temperature the higher these emissions. CH_4 emissions also changed throughout the year but those changes did not show a correlation with the season. They were caused by the different milk yield and feed intake of the cows.

	NH_3 [g/LU*d]			N_2O [mg/LU*d]			CH_4 [g/LU*d]		
	min	max	mean	min	max	mean	Min	max	mean
slurry based system (n ≈ 860)	4.0	6.1	5.7	141.6	1188.0	609.6	170.4	218.4	194.4
straw based system (n ≈ 860)	3.9	7.4	5.8	300.0	1135.2	619.2	184.8	232.2	194.4

Table 2.
Emissions of NH_3, N_2O and CH_4 from a tying stall for milking cows

Calculations of the amount of CH_4 emissions that were caused by ruminal fermentation (KIRCHGESSNER ET AL. 1991) showed, that in both housing systems about 80% of the emissions came from ruminal fermentation. The housing system did not influence the CH_4 emissions. Ruminal fermentation is a major source of methane emissions (KINSMAN ET AL. 1995, HEYER 1994).

Ammonia emissions were comparatively low (tab. 2). ISERMANN (1994) gives mean ammonia emissions for housing systems for milking cows of 16.56 g NH_3/LU*d. This value was mainly derived from emissions of loose housing systems. GROENESTEIN & MONTSMA (1991) found ammonia emissions of 9.0-14.0 g NH_3/LU*d. Their measurements were carried out in tying stalls for milking cows in the Netherlands.

Due to the lack of data the N_2O emissions can not be compared with values given in the literature. Their share of the total N emissions was about 5-10%. However N_2O emissions play an important role in the greenhouse effect and have to be reduced.

3.2. Emissions during storage and after spreading of farmyard manure

Table 3 shows the ammonia emissions during storage and after spreading of composted and anaerobically stored farmyard manure. The compost emitted more NH_3 than the anaerobically stored farmyard manure. The periods of turning contributed with 4% to the total emissions. Most of the ammonia was lost during the first two weeks of storage. After spreading of the compost no ammonia emissions were measured due to the fact, that there was no NH_4 in the compost. Whereas about 35% of the ammonia losses from the anaerobically stored farmyard manure were measured after spreading. The higher NH_4 content after the storage period resulted in higher ammonia emissions after spreading.

	NH_3-losses [g NH_3/t FM[a]]			
	Storage	turning	spreading	*Sum*
composted FYM	643.3	27.2	-	*670.5*
anaerobically stored FYM	162.7	-	85.3	*248.0*

[a] FM = fresh matter

Table 3.
Ammonia losses during storage and after spreading of composted and anaerobically stored farmyard manure

Table 4 shows the total N losses of composted and anaerobically stored farmyard manure. The N losses of the compost amounted to 10.84% of the nitrogen content of the farmyard manure at the beginning of the storage period. From the anaerobically stored farmyard manure 7.79% of the total N were lost via NH_3, N_2O and N in the seepage water NO_3,NH_4. The shares of NH_3-N and N in the seepage water were nearly equal. 77% of the N losses from the compost were emitted as NH_3. The compost emitted less N_2O and less N in the seepage water than the anaerobically stored farmyard manure.

	N losses [g N/t FM[a]]				
	NH_3-N	N_2O-N	N in seepage water	*Sum*	% of total N
composted FYM	552.2	23.9	141.5	*717.6*	10.84
anaerobically stored FYM	205.7	36.5	260.1	*502.3*	7.79

[a] FM = fresh matter

Table 4.
N losses during storage and after spreading of composted and anaerobically stored farmyard manure

In table 5, the sum of greenhouse gas emissions from composted and anaerobically stored solid manure is shown. To compare the global warming potential of the two treatments, N_2O and CH_4 emissions are given in CO_2 equivalents, that means relative to the global warming potential of CO_2 (EK 1995).

	Greenhouse gas emissions [kg CO_2 equiv./t FM[a]]		
	N_2O emissions	CH_4 emissions	*Sum*
composted FYM	8.87	4.96	*13.83*
anaerobically stored FYM	13.65	47.85	*61.50*

[a] FM = fresh matter

Table 5.
Greenhouse gas emissions of composted and anaerobically stored farmyard manure

Greenhouse gas emissions from the anaerobically stored farmyard manure were about 4.5 times higher than from the composted farmyard manure. Methane emissions contributed about 78% to the total emissions. Methane is formed under anaerobic, warm conditions, when degradable C is available. Conditions in the anaerobically stored farmyard manure favoured methane production. Methane emissions were observed during the whole storage period and had not come to their end by the end of storage. They were strongly dependent on the temperature inside the manure heap. N_2O emissions also occurred during the whole storage period.

4. Conclusions

The measurements carried out by the ILUET have shown, that NH_3 and N_2O emissions from tying stalls for milking cows in Austria are low. Methane emissions from the animal housing were mainly caused by ruminal fermentation.

During storage and after spreading of farmyard manure substantial differences concerning NH_3, N_2O and CH_4 emissions were observed with composted and anaerobically stored FYM. The compost emitted more NH_3 than the anaerobically stored FYM. About one third of the NH_3 emissions from the anaerobically stored FYM occurred after spreading. It is very important to include the spreading in the calculations of the emissions. Total N losses were on a low level with both storage systems. Greenhouse gas emissions (N_2O and CH_4) were much higher from the anaerobically stored farmyard manure than from the compost. As they are also ecologically harmful gases they have to be considered when judging the manure treatments and have to be reduced.

It is important to take into consideration all sectors of animal husbandry if mitigation options for ecologically harmful gases are to be found. The distribution of the emissions to the emitting sources differs in dependency on the treatment. E.g. in the investigations presented in this paper 80.6% of the ammonia emissions from the composting system occurred during the storage period and 19.4% came from the animal housing. With the anaerobic storage of the farmyard manure the distribution of ammonia emissions was quite different: 46.1% of the emissions came from the animal housing, 35.4% from the storage and 18.5% emitted after spreading of the farmyard manure. If the spreading had not been included in the calculations, the NH_3 emissions would have been underestimated.

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