Gaseous emissions from dairy cattle collecting yards.

Emissions gazeuses issues des zones de stabulation des vaches laitières.

Misselbrook, T. H.; Pain, B. F.; Chadwick, D. R. and Headon, D. H.
Institute of Grassland and Environmental Research, North Wyke,
Okehampton, Devon, EX20 2SB, UK.
E-mail : tom.misselbrook@bbsrc.ac.uk

Abstract

Dairy cattle collecting yards may represent significant sources of emission of ammonia (NH_3), methane (CH_4) and nitrous oxide (N_2O). A system of small wind tunnels was used to measure NH_3 emission from a known quantity of urine and faeces applied to concrete and to assess the impact on emission of cleaning the concrete by hosing or scraping. NH_3 emission measurements were also made from the collecting yard of a commercial dairy farm using either a Lindvall hood or a system of dynamic chambers. Measurements of CH_4 and N_2O emission were made from the collecting yard using closed cover boxes. From the wind tunnel measurements, mean NH_3 emission from urine and faeces applied to concrete was estimated to be 50 % of the applied urea-N. Cleaning the concrete by hosing was more effective than scraping in reducing NH_3 emission. From Lindvall hood measurements, emission from the collecting yard was greater in summer than winter, with a mean emission over both periods of 4.5 g NH_3-N.m^{-2}.d^{-1} equating to 6.4 g NH_3-N.cow^{-1}.d^{-1}. Mean emission measured using the dynamic chambers (measured over a winter period) was estimated to be 6.5 g NH_3-N.cow^{-1}.d^{-1}. Emissions of CH_4 and N_2O were much lower, measured as 2 mg.m^{-2}.d^{-1} and 0.2 mg N.m^{-2}.d^{-1} respectively. Rates of emission were subject to large spatial and temporal variation.

Résumé

Les zones de stabulation des animaux peuvent représenter des sources significatives d'ammoniac (NH_3), de méthane (CH_4) et de protoxyde d'azote (N_2O). Un système de tunnels ventilés a été utilisé pour mesurer les émissions d'NH_3 à partir d'une quantité connue d'urine et de fèces épandues sur revêtement béton afin de vérifier l'impact sur ces émissions du nettoyage de la surface à l'eau ou du raclage.

Les émissions d'ammoniac ont été également mesurées sur une exploitation agricole à l'aide d'un système de boîte de Lindvall ou de chambre dynamique. Les mesures de CH_4 et N_2O ont été effectuées à l'aide de boîtes couvertes. A partir des mesures à l'aide des tunnels de ventilation, les émissions moyennes d'NH_3 issues des urines et fèces apportées sur béton ont été estimées à 50% de l'azote urée

apportée. Le nettoyage des dalles béton à l'eau s'est avéré plus efficace que le raclage dans la réduction des émissions d'ammoniac. A partir des mesures à l'aide des chambres de Lindvall, il apparaît que les émissions d'ammoniac étaient supérieures en été comparativement à la période hivernale, avec un taux moyen établi sur ces 2 périodes de 4,5 g N-NH_3 m^{-2};j^{-1} ce qui représente 6,4 g N-NH_3. $vache^{-i}$.j^{-1}. Les mesures à l'aide des chambres dynamiques conduisent à un taux moyen d'émission de 6,5 g N-NH_3. $vache^{-1}$. j^{-1}.

Les émissions de CH_4 et N_2O étaient bien inférieures, de l'ordre de 2 mg. m^{-2}. j^{-1} et 0,2 mg N m^{-2}. j^{-1} respectivement. Les taux d'émission étaient soumis à de larges variations spatiales et dans le temps.

Introduction

Many livestock, and dairy cattle in particular, spend time on uncovered yard areas, which will become contaminated with urine and faeces. These areas may represent sources of gaseous emission which, to date, have received little attention. Of particular concern are emissions of ammonia (NH_3), methane (CH_4) and nitrous oxide (N_2O).

NH_3 emissions from cattle excreta derive mainly from urine. Urea is the major N containing constituent of urine and, after excretion and contact with the ubiquitous enzyme urease, is hydrolysed to NH_3. Studies have shown that emission from urine returns by grazing cattle can account for between 4 and 35 % of the total urine N content (Ball *et al*., 1979; Vertregt and Rutgers, 1987; Lockyer and Whitehead, 1990) and exceptionally 66 % under hot, dry conditions (Ball and Ryden, 1984). Emissions from faeces alone are much lower, generally less than 5 % total N content (MacDiarmed and Watkin, 1972; Ryden *et al*., 1987). We might expect emissions from urine deposits on non-porous concrete yards to be greater than those from grassland, due to lack of infiltration and an increase in surface area from which volatilisation can occur as the urine spreads across the yard surface.

Approximately 90 % of CH_4 emission from UK agriculture derive from enteric fermentation in cattle (Chadwick *et al*., 1998). However, freshly voided dung from grazing animals has the potential for CH_4 emission as it carries the appropriate organisms (Dar and Tandon, 1987). Jarvis et al. (1995), measuring emissions from cattle grazing returns, reported a mean cumulative emission from dung pats of 981 mg $CH_4.m^{-2}$, with a range in emission for dairy cows of 716 – 2040 mg $CH_4.m^{-2}$. There was no emission from urine patches. Interactions with the soil were thought to be minor, with the emission deriving directly from the dung. Therefore we might expect emissions from dung pats on concrete yards to be of a similar order to those from grazing returns.

N_2O emissions arise from denitrification and nitrification which are primarily soil-based microbial processes. Measurements from grazing returns show emissions to be greater from urine than dung patches (Oenema *et al*., 1997). Emissions from concrete yards may be lower than from grazing returns due to the microbial processes being primarily soil based.

The aim of the work presented in this paper was to quantify emissions of NH_3, CH_4 and N_2O from dairy cattle collecting yards and to examine some of the factors influencing emissions. A pilot study, measuring only NH_3 emissions was carried out during 1996. A more detailed study, measuring NH_3, CH_4 and N_2O commenced in November 1997. This study is part of a larger project being conducted jointly by IGER and ADAS in which emissions from different types of yard areas will be measured on a number of farms. Initial results from the dairy collecting yard of a farm being studied by IGER are presented here.

Materials and Methods

Ammonia

Two approaches were taken in the pilot study; a system of small wind tunnels (Lockyer, 1984) was used to measure NH_3 emission from known quantities of urine and faeces applied to concrete areas and to assess the effectiveness of cleaning the concrete by hosing or scraping, and a Lindvall hood (Lindvall *et al.*, 1974) was used to measure emissions from the collecting yard of a commercial dairy farm.

Using the system of small wind tunnels, NH_3 emission measurements were made from 1 l urine applied to 1 m^2 concrete. Air flow through the tunnels was controlled at 1 $m.s^{-1}$. Acid traps (bubblers) containing 0.02 M orthophosphoric acid were used to measure the NH_3 concentration of the air entering and leaving each tunnel. Emission was calculated as the product of the difference in NH_3 concentrations of outlet and inlet air and the volume of air flowing through each tunnel. Six experiments were conducted; experiments 1 - 4 on concrete areas which had previously been used by beef cattle and experiments 5 and 6 on clean, previously unused concrete areas. Experiment 1 examined the effect of the presence or absence of faeces on emission. In all the other experiments faeces was applied to the concrete prior to urine application. Experiment 2 assessed the effectiveness of hosing with water in cleaning the concrete and experiments 3 - 6 assessed the effectiveness of cleaning the yard using a hand scraper. Experiments 1 - 4 were conducted in September and 5 and 6 in November. Samples of urine were collected for urea-N analysis at the time of application.

Measurements of NH_3 emission were made from the dairy cow collecting yard of Oaklands Farm using a Lindvall hood. Management practices on the farm were common to those used by many UK dairy farmers, with 65 - 80 cows being milked twice each day, gathered in a concrete-surfaced collecting yard prior to milking, the yard being cleaned daily (after morning milking) using a hand-held scraper. The hood covered an area of 0.9 m^2 over which air was blown at a constant rate of approximately 1$m.s^{-1}$. NH_3 was scrubbed from the inlet air using a glass wool filter coated with oxalic acid. NH_3 concentration of inlet and outlet air was measured using bubblers and emission calculated as for the wind tunnels. The hood was left on the yard for a 24 h period, being temporarily removed while cows were in the yard for milking and when the yard was being scraped. Measurements were made from 5 different yard positions over a period of three weeks during both summer and winter.

Following the pilot study, a more detailed study commenced in November 1997 measuring emissions from the same collecting yard at Oaklands Farm as in the pilot study. NH_3 emission was measured using a system of dynamic chambers. Full details of the method are given in Svensson (1994). Briefly, the method relies on theory derived from the meteorological law of resistance :

$$\phi_{NH3} = (C_{eq} - C_{a,z})K_{z,a}$$

where ϕ_{NH3} is the NH_3 emission per unit area and time, C_{eq} is the NH_3 equilibrium concentration in the air at the soil surface, $C_{a,z}$ is the ambient NH_3 concentration at height z and $K_{z,a}$ is the mass transfer coefficient in the air above the soil. Using a system of dynamic chambers together with ambient samplers, the parameters C_{eq}, $C_{a,z}$ and $K_{z,a}$ can be determined. Six chambers and four ambient samplers were used, allocated randomly across the yard. Emission rates were measure throughout the day, typically at 8 am (just after yard scraping), 11.30 am, 3 pm, 7 pm (after evening milking) and 10 pm. On one occasion further measurements were made throughout the night to give the full pattern of emission over 24 h. Emission rates for periods between measurements were estimated as the mean of that for the period before and after. Measurements were made at approximately three week intervals.

Methane and Nitrous Oxide

CH_4 and N_2O emission measurements also commenced in November 1997 and were made on the same collecting yard using closed chambers. Each chamber was fitted with a silicon rubber septum to allow samples of air to be taken by syringe. The chamber was weighted with a brick and a neoprene rubber seal was glued to the lower flange to provide a good seal with the yard surface. Samples of air were taken from the chambers 0, 20 and 40 minutes after placing them on the yard surface to determine the increase in CH_4 and N_2O with time. Gas samples were stored in evacuated vials before analysis by gas chromatography. As for NH_3 measurements, the chambers were positioned randomly across the yard. Notes were made of the nature of the yard beneath each chamber, *i.e.* the presence or absence of a dung pat, a dirtied area or a clean area.

Results and Discussion

Ammonia

Results of the six wind tunnel experiments are given in Table 1. When urine was applied to clean concrete, rather than concrete dirtied with faeces, emission was minimal. This is more likely to have been due to rapid evaporation, which occurred within 2 h, than to an absence of urease. Areas where faeces had also been applied remained wet for much longer, allowing volatilisation to continue for longer.

Expt.	Duration	Mean temp.	Urea-N input	Emission of NH_3-N (g/m^2)		
	h	^oC	g/m^2	not cleaned	cleaned 2h	cleaned 6h
1	76	14.9	7.7 (0.38)	0.1 (0.03)†	-	-
			-	4.3 (0.82)‡	-	-
2	29	12.3	6.6 (0.56)	2.0 (0.77)	0.3 (0.15)	1.1 (0.05)
3	29	13.5	4.6 (0.69)	1.5 (0.80)	0.5 (0.11)	0.9 (0.17)
4	22	13.9	6.6 (0.28)	1.6 (0.58)	1.0 (0.04)	1.5 (0.42)
5	75	11.3	5.5 (0.49)	2.2 (0.06)	1.3 (0.07)	1.2 (0.31)
6	78	8.3	6.4 (0.29)	2.4 (0.07)	1.3 (0.23)	2.0 (0.62)

( ) standard error † urine only applied ‡ urine and faeces applied

Table 1.
NH_3 emission from 1 l urine applied to 1 m^2 concrete - wind tunnel measurements.

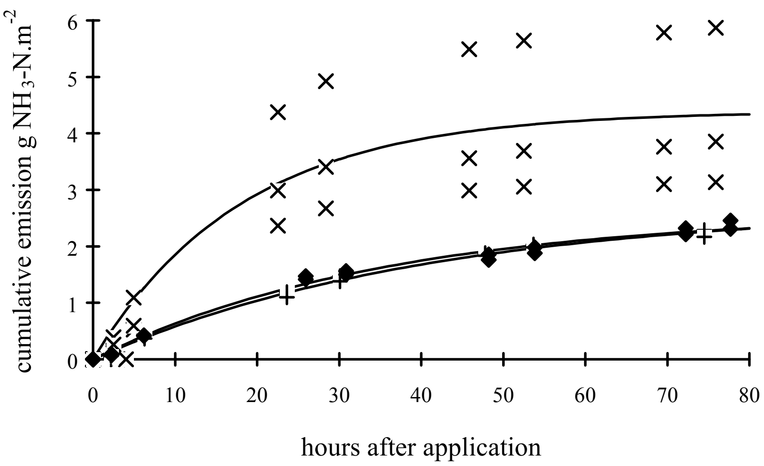

Figure 1
Cumulative NH_3 emission from 1 l urine applied to 1 m^2 concrete.
Data from experiments 1 (x), 5 (+) and 6 (◆) together with fitted lines.

Experiments 1, 5 and 6 were of sufficient duration for a model of cumulative NH_3 emission versus time to be fitted (Fig 1) in the form $E_t = N_\infty (1-e^{-\beta t})$, where E_t is the cumulative emission at time t, N_∞ is the theoretical cumulative emission after infinite time and β is a constant. Estimated final cumulative emissions were 57, 49 and 41 % of the applied urea-N for experiments 1, 5 and 6 respectively, giving a mean cumulative emission of 49 % applied urea-N. Differences in final cumulative emission may have been due to differences in ambient temperature. The differences in pattern of emission with time, with proportionately more of the emission in experiment 1 occurring soon after application, may have been due to differences in urease activity on the concrete areas used, that used for experiments

5 and 6 being new, clean concrete on which urease activity may have been much lower.

Cleaning the concrete by hosing was more effective than scraping, with respective reductions in emission from cleaning after 2 h of 85 and 50 % and from cleaning after 6 h of 45 and 25 % compared to emission from an uncleaned control. In practice, a tractor-mounted scraper may be less effective at removing the faeces and urine than the hand-held scraper used in these experiments. Scraping passages in cubicle housing has been reported to have little effect on emission (Kroodsma *et al*., 1993; Braam *et al*., 1997) although flushing with water reduced emission by 70 % (Kroodsma *et al*., 1993).

NH_3 emissions from the dairy cow collecting yard at Oaklands Farm measured using the Lindvall hood are given in Table 2. Taking into account the area of the yard (87 m^2) and the number of cows being milked on each occasion, the mean emission over both summer and winter measurement periods was 6.4 g $N.cow^{-1}.d^{-1}$.

	Summer		Winter	
Measurement	Mean air temp °C	Emission g $N.m^{-2}.d^{-1}$	Mean air temp. °C	Emission g $N.m^{-2}.d^{-1}$
1	16.3	1.80	1.5	0.23
2	15.4	2.79	4.4	0.90
3	15.6	13.96	8.9	1.12
4	16.1	6.95	0.0	2.01
5	19.1	18.65	-	-
	Mean Summer	8.83	Mean Winter	1.07

Table 2.
NH_3 emission from Oaklands Farm collecting yard;
summer and winter measurements using Lindvall hood.

Emissions were much lower in the winter than in the summer. This was probably due to a combination of lower temperatures and a lower urea-N content of the urine (3.1 $g.l^{-1}$ in winter compared to 11.1 $g.l^{-1}$ in summer) resulting from dietary differences between the two periods.

Disadvantages of the hood method of NH_3 emission measurement are that emission is not measured under ambient conditions (with wind speed controlled at 1 $m.s^{-1}$ and rainfall excluded) and measurements can only be made from one small area of yard at any one time, thereby taking no account of spatial variability. It was for these reasons that the system of dynamic chambers were used to measure NH_3 emission in the more detailed study, as measurements can be made from several positions simultaneously and under ambient conditions.

Date	Duration h	Mean air temp. °C	Cumulative emission g $N.m^{-2}$	Cumulative emission g N.cow-1.d-1
6 November	20	10.8	2.77	3.61

26 November	14	10.8	5.88	10.96
22 December	15	7.1	7.47	13.00
14 January	15	5.3	1.12	1.95
12 February	25	9.8	3.28	3.42
5 March	14	7.7	3.38	6.30
			Mean	**6.54**

Table 3.
NH_3 emission from Oaklands Farm collecting yard measured using dynamic chambers.

Results of the dynamic chamber measurements, for the first six sampling dates (covering the winter period), are given in Table 3. The emission rates varied throughout the day, but typically decreased from an initially high value immediately after scraping in the morning to very low rates throughout the day (even becoming negative, indicating deposition from surrounding ammonia sources such as slurry lagoons and animal buildings), then increasing again after evening milking (Fig 2). Scraping the yard after morning milking obviously removes the majority of the faeces and urine from the yard surface. However, a thin layer remains from which emission occurs, but which soon becomes depleted. During evening milking, fresh deposits of urine and faeces are made to the yard and are not scraped away, so emission increases to a maximum rate after a few hours and then decreases again until morning milking. Actual emission rate will depend on the amount of ammoniacal-N present on the yard surface and the resistance to volatilisation. Conditions which promote fast drying of the yard will result in high emission rates which rapidly decline. Re-wetting of the yard (*e.g.* due to rainfall) may promote further emission. Heavy rain may wash urine and faeces off the yard and may also increase the efficiency of yard scraping, thereby decreasing emissions.

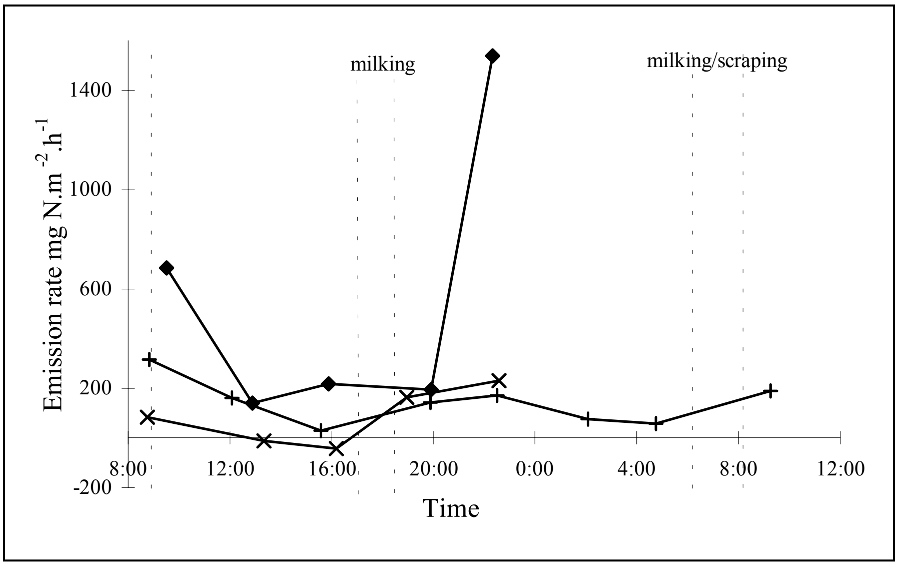

Figure 2.
Diurnal pattern of NH_3 emission from dairy cattle collecting yard

Emissions measured using the dynamic chambers were greater than those using the Lindvall hood in the winter period. However, this may have been due to the relatively high ambient temperatures during the dynamic chamber measurements compared to those of the previous winter when the Lindvall hood was used. Taking a mean emission value of 6.5 g $N.cow^{-1}.d^{-1}$, annual emission per dairy cow would be 2.4 kg N, representing over 10 % of the NH_3-N emission from a dairy cow as estimated recently by Pain *et al*. (1998), showing yard areas to be a significant source of NH_3 emissions.

Methane and Nitrous Oxide

Emission rates of CH_4 from the collecting yard were variable. Emission rates from the clean yard following scraping were low (<100 $\mu g.m^{-2}.h^{-1}$) and sometimes negative indicating deposition of CH_4. However, following evening milking emission rates increased as CH_4 was emitted from dung pats and dirtied areas, with mean emission rates from the yard of up to 1000 $\mu g.m^{-2}.h^{-1}$ being recorded. The pattern of emission from the six chambers over a 24 h period is shown in Figure 3. Again, rates were very low from the clean yard, but were much greater following evening milking, when the greatest emission rates were recorded from dung pats, followed by dirtied areas with lowest emissions from clean looking areas of the yard. The emission rates from the dung pats were similar to those reported by Yamulki *et al*. (1998). From the 24 h measurement, mean emission rate was estimated as 1.9 $mg.m^{-2}.d^{-1}$, or 2.1 $mg.cow^{-1}.d^{-1}$. Emission from yards would be fairly insignificant compared with total emission per dairy cow, where enteric fermentation accounts for 90 % of emission (Chadwick *et al*., 1998).

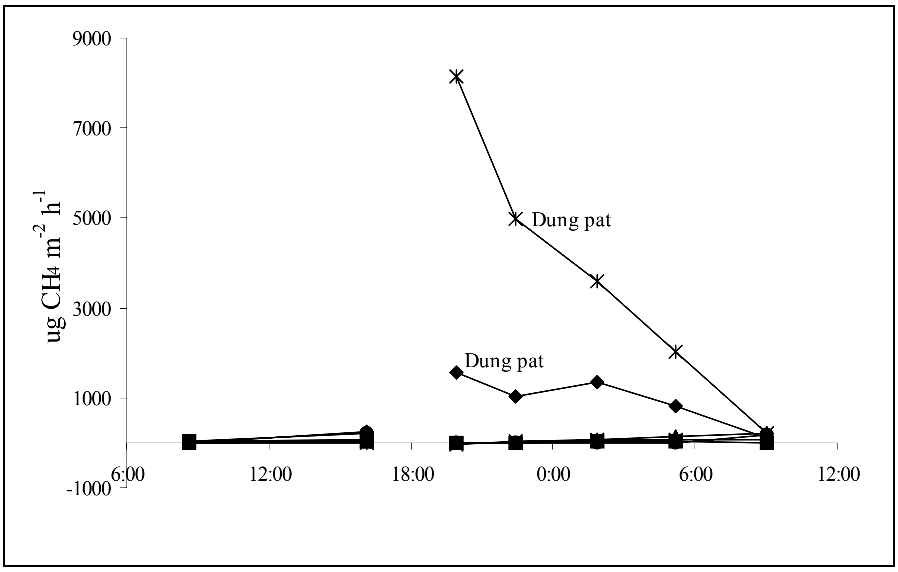

Figure 3.
Diurnal pattern of CH_4 emission from dairy cattle collecting yard

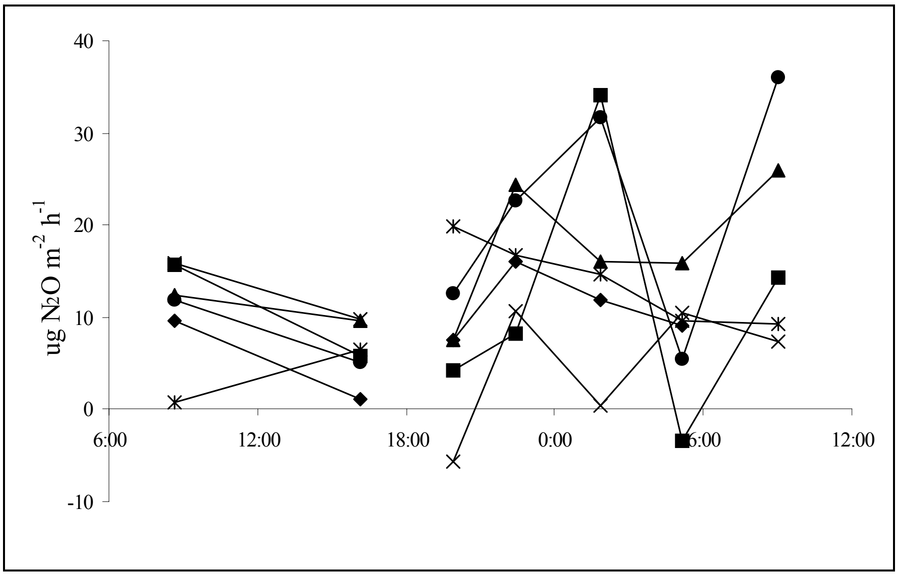

Figure 4.
Diurnal pattern of N_2O emission from dairy cattle collecting yard.

Emission rates of N_2O were low and very variable. Figure 4 shows emission rates from the six chambers over a 24 h period. Emission rates were not related to the presence or absence of dung pats but, as for ammonia emission, would be more related to the presence of urine, being the major source of inorganic N. From the 24 h measurement, mean emission rate from the collecting yard was estimated as 0.2 mg $N.m^{-2}.d^{-1}$. N_2O emission from yards would form a very small proportion of total N_2O emission from agriculture (Chadwick *et al*., 1998).

Future work

Measurement of gaseous emissions will continue throughout the year on the dairy collecting yard at Oaklands Farm to assess seasonal changes. Measurements are also being made on other dairy farms. Measurements will also be made on other yard areas, such as feeding areas or walkways, so that an attempt can be made to estimate total emission from yard areas. Factors such as surface type and condition and management practice will be investigated.

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