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Odour evaluation of a dairy farm with anaerobic digestion

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The present study focuses on the evaluation of odour impacts from a dairy farm with anaerobic digestion. This study pursues three main goals: 1.- To evaluate the effect of the anaerobic digestion process on the odour level; 2.- To compare field and laboratory odour measurement techniques, and 3.- To study the influence of the meteorological observation frequency on the predicted odour plume, using dispersion models. Three different measurement techniques were used to quantify the odours: dynamic and field olfactometry and sniffing team method. Odour emissions from all sources were measured by duplicated through dynamic olfactometry, under two different measurement conditions: in normal conditions (un-stirred manure) and after stirring the odour source. Two odour field measurement campaigns were also conduced in the surroundings of the farm, and meteorological conditions were recorded every 30 seconds by a weather station. Finally, field odour concentrations were recorded by using two field olfactometers. Dispersion modelling was used to compare odour measurement techniques in terms of odour plume and distance reached by odour. Emission rates measured with dynamic olfactometry under stirring conditions overestimated the reach of odour perceived in the field, whereas field olfactometry measurements provided valuable information about odour dispersion, and results were coherent with the plume measured by the sniffing team method. Odour emissions from digested manure were lower than non-treated manure. However, the presence of agricultural wastes increased global odour emission at farm level. Regarding the effect of the integration time for meteorological data in the dispersion model, 1-minute and 5-minute averages provided more accurate results. According to the results obtained here, field measurement techniques seemed to be more realistic than dynamic olfactometry.

1. Introduction

Odours emitted by intensive animal production constitute a major social concern of this activity. Objective measurements are required in order to determine if neighbours living

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near livestock houses could be affected by odour nuisances in terms of health or well-being. Actually, odour measurement in animal houses continues to be a challenge for researchers for different reasons: the nature of odour is very variable; odour composition and odour nuisance are difficult to relate and there are many parameters affecting odour emission and dispersion. Nowadays, dynamic olfactometry is the only normalized technique for odour emission measurement. The high uncertainty related to olfactometric measurements, the non-homogeneous distribution of odour emission rates along time and space and the sampling difficulty associated with intermittent activities are some of the weakness of this measurement method. In this sense, field measurements as sniffing team observations or nasal ranger concentrations reflect the real perceptibility of the odour in the environment and allow considering diffuse and surface sources (Nicolas *et al.*, 2006).

Among the treatment techniques mainly used in livestock facilities, anaerobic digestion is employed to produce heat or energy from biogas obtained through livestock wastes. In this biological process, some important odorants of slurry (such as volatile fatty acids) are degraded (Powers *et al.*, 1999), and some studies evidence that odour emission also decreases (Hansen *et al.*, 2006; Hjorth *et al.*, 2008).

2. Material and Methods

2.1 Site description

A dairy farm with an anaerobic digestion facility was studied in the present work. The facility is located in the Luxembourg province (Belgium) and has a specific area for storage of agricultural waste, which is needed for the energy production process. The yearly quantity of wastes digested by the facility are altogether 1825 t of slurry, 1925 t of manure, 270 t of corn silage, 300 t of grass and 6260 t of other agricultural substrates. The wastes are first digested in the anaerobic reactor and then they are mechanically separated into solid and liquid fraction. The liquid part is used as field fertilizer, whereas the solid fraction is devoted to a drying and pelletizing process, emitting gases through two stacks.

2.2 Measurement methodology

Three measurement approaches were conducted in the present work: dynamic and field olfactometry and the application of the sniffing team method. All measurements were conducted between June and September 2009.

Dynamic olfactometry (DO) was used to measure odour emissions from all sources in the farm. Measurements were done by duplicated in two different days in order to reflect the variability of the source in two different situations: wastes at rest (un-stirred) and after stirring the source. In the second case, the emission source was mixed during 5 minutes in order to simulate odour emission released by waste disposal or handling activities. Immediately afterwards, air samples were collected in Tedlar® bags with a 0.2 m^2 circular dynamic flux chamber. Odour concentration was determined in laboratory within the first 24h with an Odile olfactometer (Odotech, Canada). Odour concentration was determined by triplicate. Odour emission rate ($ou_E/m^2{\cdot}s$) was obtained by multiplying the airflow rate through the chamber (10 L/min) by the odour concentration.

Two field measurement campaigns were completed using field olfactometry and sniffing team method. Two Nasal Ranger ® field olfactometers were used in one of the two campaigns in order to determine inmission odour concentrations around the farm. The Nasal Ranger olfactometer is a nasal olfactometric instrument portable device that dynamically dilutes the ambient air with carbon-filtered air in different dilution ratios known as 'dilution-to-threshold' dilutions factors (Pan *et al.*, 2005). Measurements were taken in the axis of odour plume from the furthest downwind points from the facility to the nearest ones, in order to avoid the assessors getting used to the odour. Each measurement was done simultaneously by two trained assessors and each point was determinate by triplicate.

The sniffing team measurement technique is described in detail in a previous paper (Nicolas *et al.*, 2006) and it is inspired by a method developed by University of Gent (Van Langenhove and Van Broeck, 2001). Two expert field assessors determined odours in the field. Prior to field measurements, the assessors' sense of smell was checked using the *n*-butanol odour standard. They were also familiarised with odour sources and were trained in the use of the methodology. The method consists in detecting and recognizing odours in different points around the axis of the plume by a zig-zag movement. Observers determined the points where odour was clearly smelled and points where odour was not detected, recording them in a GPS system. They also defined the maximum perception distance and the odour area. During field measurements, a portable weather station determined and recorded wind direction, wind speed, solar radiation, temperature and humidity every 30 seconds. Later on, meteorological data were averaged each one, five and fifteen minutes, in order to study the influence of integration time on the shape and distance of the odour plume. For all cases, the stability class was instantaneously deduced from Pasquill (1974).

2.3 Dispersion modelling

Odour data was processed using an atmospheric bi-Gaussian dispersion model superposed with the meandering model of Gifford, which includes a suitable correction of odour dispersion. For each field odour campaign, odour emission rates were estimated by inverse modelling using the Tropos Impact software (Odotech, Canada) using instantaneous meteorological data registered in the field. The methodology consisted in adjusting the emission rate by trial and error to approximate the isopleth 1 ou/m^3 obtained from field measurements using the sniffing team method procedure.

We calculated the area affected by odours using the measured emissions and the dispersion model previously described. We considered three different situations: odour emission rates at rest conditions, after stirring and the average between the two previous situations. We obtained therefore three areas potentially impacted by odour. Furthermore, each simulation was done considering different integration times for meteorological data: 30 seconds, 1 minute, 5 minutes and 15 minutes.

3. Results and discussion

3.1 Dynamic olfactometry

Odour emissions obtained in the two studied scenarios (at rest and mixing the source) differed considerably, as is it shown in Table 1. Agricultural liquid wastes had a very offensive odour, so it was only analyzed one time because the measured odour concentration exceeded the measurement range of the olfactometer.

Among all measured odour sources, the higher odour emission rates corresponded to the agricultural liquid and solid wastes used in the digestion process. Therefore, it seems that the presence of these substrates may increase the global odour emission of the farm. Other sources of odour (dairy stall, digested wastes and corn silage) were low in comparison with the mentioned substrates. However, odour emission from digested manure was on average 85% lower than undigested manure. Hansen *et al.* (2006) studied the anaerobic digestion and separation treatments in the potential decrease of odour concentrations, and they obtained an odour reduction of 50%. Consequently, odour emission during land application of digested substrates could be significantly lower than those emitted from manure or slurry application. In the study of Pain *et al* (1990), a reduction on odour emission of 70-80% during the first 6h of land application following anaerobic digestion was observed. Odour emissions from the two stacks of the drying facility were more homogeneous than area sources. Average emission values were 5157 and 4258 ou_E/s for stack 1 and 2, respectively.

Table 1.Odour emission rate ($ou_E/m^2 \cdot s$) measured by dynamic olfactometry and confidence interval (in parenthesis) in normal conditions (minimum odour rate) and after stirring the odour source (maximum odour rate)

Source	Maximum odour rate	Geometric Average odour rate	Minimum odour rate
Agricultural liquid wastes	-	515.0 (325.9 - 813.8)	-
Agricultural solid wastes	68.66 (43.45 - 108.51)	19.50	5.54 (3.50 - 8.75)
Dairy stall	43.57 (27.6 - 68.8)	5.54	0.71 (0.44 - 1.11)
Storage digested wastes	1.86 (1.18 - 2.95)	0.85	0.39 (0.24 - 0.62)
Corn silage	0.74 (0.47 – 1.17)	0.17	0.039 (0.025 – 0.062)

3.2 Dispersion modelling

The effect of the integration time for meteorological data was studied for the same odour emission rate, which was obtained from dynamic olfactometry average values (Table 1). Different dispersion plume shapes were found, as shown in Figure 1. In all cases, the reach of odour using the 15-minute integration time was about two times the reach of odour corresponding to 30 seconds. When using the 15-minute integration time, the shape is narrow and longer, whereas for the 30-second basis the shape is wider and shorter. Intermediate shapes were found for integration times of 1 and 5 minutes. This situation was observed when using minimum, average and maximum measured emission rates.

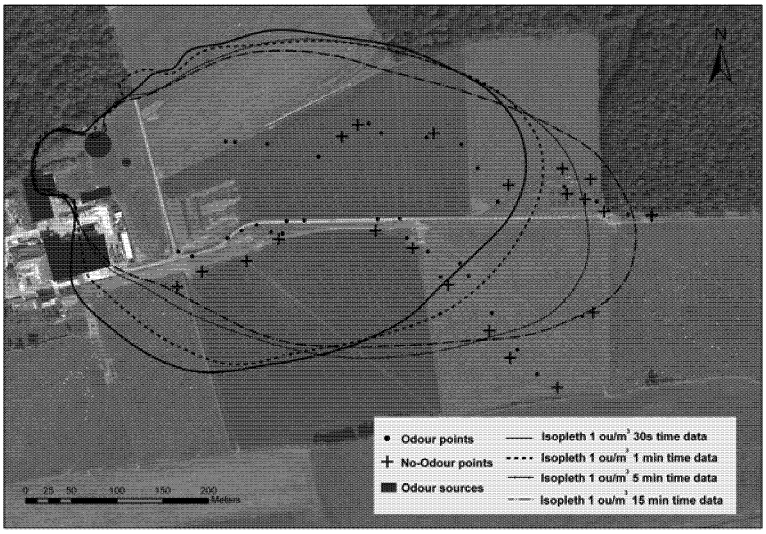

Figure 1. Odour plumes corresponding to the studied integration times for the first field odour working day comparing modelled emission with field measurements.

3.3 Methodology comparison

Odour emissions from DO and field measurements have been confronted (Table 2). For the first measurement day, olfactometric values which provide better results corresponded to average values between stirring and non-stirring sources. This is coherent with the observations of the farm conditions in the studied day, because at the moment of field measurements, wastes were being handled. The integration time that fits better with odour measurements (Figure 1) were those of 5 and 15 minutes.

Table 2.Odour emissions (ou/s) obtained by dynamic olfactometry and estimated using inverse modelling from field measurements

Measurement technique	Odour emission (ou/s)	Day 1	Day 2
Dynamic olfactometry	Maximum odour emission	149,507	
	Average odour emission	69,938	
	Minimum odour emission	53,669	
Inverse modeling from field measurements	Integration time 30s	111,991	39,255
	Integration time 1 min	100,792	35,329
	Integration time 5 min	78,394	23,553
	Integration time 15 min	67,195	23,553

Regarding to the second measurement day, any of the measured odour emissions were similar to those estimated from field measurements. In this case, even the minimum odour emission value measured with DO overestimates the reach of odour with respect to field measurements. In this case, wastes were not being handled during the measurements, and therefore minimum odour emission values might theoretically be suitable. On the other hand, odour concentrations measured by Nasal Ranger olfactometer indicate that minimum odour emission values seem to be appropriate. This observation suggests that the combination of two field measurement techniques is recommended in order to estimate odour emission rates with inverse dispersion modelling. In addition, odour field measurement techniques provide more realistic and reliable data than dynamic olfactometry, which could overestimate the impact of odour if few measurements are done. Moreover, field measurements are cheaper than olfactometric analysis, and allow obtaining odour emission data through the application of atmospheric dispersion models.

4. Conclusions

In the present work a dairy farm has been odour evaluated by three odour measurement techniques: dynamic and field olfactometry and the application of the sniffing team method. Olfactometric analysis showed the efficiency of anaerobic digestion on the reduction on the odour from digested wastes. Nevertheless, global odour level of the facility is higher due to the presence of other agricultural liquid and solid wastes in the farm. Comparing dynamic olfactometry and odour field measurements, we concluded that dynamic olfactometry does not account for intermittent changes of odour emission rates, and can over- or underestimate the actual odour emission rate. Field measurements techniques appeared to be more realistic and easy to perform. The combination of two field measurement techniques could also provide more accurate results. Regarding the evaluation of integration times, it affected the shape of the odour plume. This could also affect the estimated odour emission rate use inverse modelling.

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