AMMONIA, METHANE, NITROUS OXIDE AND PARTICULATE MATTER EMISSIONS IN TWO DIFFERENT BUILDINGS FOR LAYING HENS

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ABSTRACT

Ammonia, methane, nitrous oxide and dust concentration as Particulate Matter ($PM_{2.5}$ and PM_{10}), were monitored in two different buildings for laying hens in Italy, both breeding approximately 60000 hens each. The first unit has an in-house prolonged droppings storage (deep-pit), the ground floor is for manure storage, the hens are housed on the first floor. The second unit has a manure removal system with a lower environmental impact, in which the droppings are dried on ventilated belts. The data were collected continuously in six periods of approximately 1 week each, over one whole year, using a photoacustic detector (Bruel&Kjaer) to measure NH_3, CH_4 and N_2O and an on-line instrument to measure PM. The ventilation rate was also continuously recorded so that emissions could be assessed. The ammonia emission factors resulted 0.162 kg y^{-1} hen $place^{-1}$ for the deep-pit system and 0.063 kg y^{-1}hen $place^{-1}$ for the ventilated belt. The emission factor for the deep-pit house is fully compatible with the value assessed by Italy within the IPPC-TWG (0.154 kg y^{-1} hen^{-1}), but much lower than the Dutch value (0.386 kg y^{-1} hen^{-1}) for the same technique. This result confirms that this technique can achieve lower ammonia emissions in countries with warmer climates, where higher temperatures and higher ventilation rates lead to faster and higher drying of the manure in the pit. The ammonia emission reduction factor of the ventilated belt technique, compared to the deep-pit technique, was 62%.

Keywords: *emissions, ammonia, greenhouse gases, BAT, laying hens*

INTRODUCTION

The EU 96/61/EC Directive, also known as IPPC (Integrated Prevention Pollution Control) which Italy has adopted (Decree n. 372 of 04/09/99) for existing installations, including intensive animal housings, aims at regulating all forms of emission into the atmosphere, water and soil, and obliges producers to declare the final destination of any waste.

The directive is based on the concept of Best Available Technique (BAT), according to which farmers have to choose and adopt those technologies available on the market, that can prevent or limit the emissions, and that are sustainable, which means economically affordable for farmers.

Emissions of ammonia from layer droppings is enhanced by their moisture content (ILF-BREF, 2002) so techniques to reduce emissions from laying hen houses combine frequent removal with fast drying of manure to inhibit the chemical reactions which give rise to emissions. The quicker the manure is dried the less ammonia emitted.

To assess the effectiveness of two of the candidate BATs for laying hen houses, which have fairly good success among poultry farmers in Italy, a long-term monitoring program was conducted within a project of the Italian Agency for New Technology, Energy and Environment (ENEA), funded by the Italian Ministry of the Environment.

MATERIALS AND METHODS

Description of the monitored buildings

The measurements were taken in two houses with approximately 60000 layers each. The monitored techniques were:

- battery system with aerated open manure storage (**deep-pit**). The ground floor is for manure storage, the hens are housed on the first floor;
- vertical tiered cages with manure belts with forced air drying (**ventilated belt**).

The deep-pit (DP) house has 5 rows of 6-tier cages. The droppings are collected on baffles (plates) under the cages and scraped every day (around 5 p.m.) to the underfloor storage, where they remain in heaps for the complete breeding cycle. The house is ventilated by 14 fans placed on the longitudinal walls on the ground floor. The air is collected from the upper floor, enters the house through a longitudinal ridge chimney and is delivered into the hen space through continuous openings in the false ceiling over every row of batteries. The opening of the windows is manostat controlled to a negative pressure of 2 mm H_2O.

The ventilated belt (VB) house has 6 rows of 8-tier cages. The manure is collected on the manure-belts under each tier and an air jet dries the droppings. The manure ventilation system is designed to have maximum air velocity at bird level no higher than 2.0-2.5 m/s, so that the birds are not disturbed in the winter months. The ventilation air is recirculated from the inside in order to pre-heat it. The ventilation program runs from midnight to 7 a.m.. The manure is discharged every 3-4 days to sheltered external storage. The house has a longitudinal, thermostatically controlled ventilation system.

Environmental parameters

The ventilation rate was continuously monitored by measuring the rotation speed and number of active fans and correlating these values with the air flow rate by on-site anemometric measurements. The temperature and relative humidity were monitored constantly both inside and outside the two buildings.

Ammonia, greenhouse gases and particulate matter

The gases and particulate matter concentration were measured continuously in six periods of approximately 1 week, over one year, using an Infrared Photoacustic Detector (Bruel & Kjaer, Multi-gas Monitor Type 1302) to measure NH_3, CH_4, N_2O and CO_2, and an innovative instrument, the “Haz-Dust EPAM-5000”, to measure $PM_{2.5}$ and PM_{10}.

The ammonia and greenhouse gas emission factors, determined at the end of each monitoring period, were obtained by multiplying the ventilation rate of the housing by the difference in concentration between the point of emission and the immediate outside environment.

RESULTS AND DISCUSSION

Environmental parameters

The outside ambient parameters were essentially similar in both the monitored houses, with slightly higher temperatures in the VB house (23.8°C for VB *vs.* 23.1°C for DP). The air flow rate during the monitored periods was higher in the DP system (8.4 $m^3\ h^{-1}$ bird place^{-1} for DP *vs.* 6.2 $m^3\ h^{-1}$ bird place^{-1} for VB, or, referring the ventilation rate to a unit live weight, 5575 $m^3\ h^{-1}\ t_{lw}^{-1}$ for DP *vs.* 2865 $m^3\ h^{-1}\ t_{lw}^{-1}$ for VB). This was probably due to the different type of ventilation system, longitudinal and more effective in the case of the VB house. The minimum and maximum ventilation rates ranged from 3.3 to 12.2 $m^3\ h^{-1}$ bird place^{-1} for the DP and from 3.0 to 17 $m^3\ h^{-1}$ bird place^{-1} for the VB house.

Ammonia and greenhouse gas emissions

Table 1 provides a summary of the yearly average emission factors for NH_3, CH_4, N_2O and CO_2 (expressed both per hen place and per unit live weight).

Table 1. *Laying hen houses: average emission factors of gases*

	Emission factors			
Gases	**NH_3**	**CH_4**	**N_2O**	**CO_2**
Deep-pit				
kg y^{-1} hen place^{-1}	0.16 ± 0.10	0.02 ± 0.03	n.d.	51.37 ± 7.35
kg y^{-1} LU^{-1} (*)	52.5 ± 30.1	7.6 ± 9.2	n.d.	17107 ± 1612
Ventilated belt				
kg y^{-1} hen place^{-1}	0.06 ± 0.02	0.08 ± 0.10	n.d.	77.49 ± 14.06
kg y^{-1} LU^{-1} (*)	14.6 ± 4.3	18.2 ± 24.5	n.d.	18020 ± 3270

(*) LU = Livestock Unit = 500 kg live weight

Figure 1 and Figure 2 show the annual "average day" pattern for ammonia and methane emission of the two techniques.

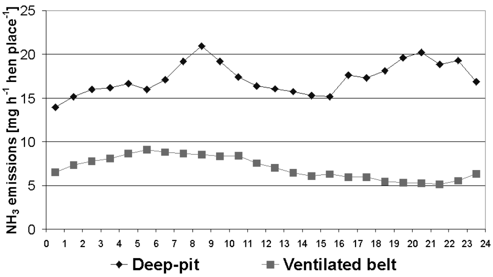

Figure 1. *Laying hens houses: "average day" for ammonia emissions*

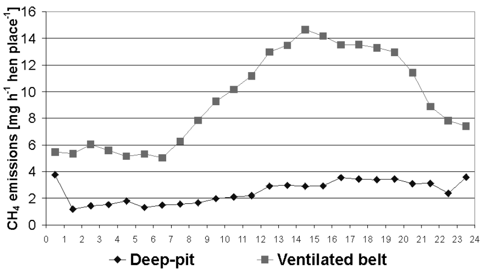

Figure 2. *Laying hens houses: "average day" for methane emissions*

It can be seen that the 24h ammonia emission pattern is different, with emissions from deep-pit technique peaking two times (8:00 a.m. and 20:00 p.m.), while the emissions from the ventilated belt technique are fairly constant, showing a lightly sinusoidal pattern peaking in the early morning.

The ammonia emission factors resulted 0.162 kg y^{-1} hen place^{-1} for the deep-pit technique and 0.063 kg y^{-1} hen place^{-1} for the ventilated belt technique.

Our results for the deep-pit system are significantly lower than the Dutch data included in the IPPC-TWG BREF for the corresponding technique, equal to 0.386 kg y^{-1} hen place^{-1}. This result can be explained by taking into account the higher Italian temperatures which require a higher ventilation rate of the house leading to faster drying of the droppings.

The results for the ventilated belt system are higher than the corresponding technique of the ILF-BREF (0.035 kg y^{-1} hen place^{-1}). This less satisfactory result can be attributed to the restricted ventilation time of the droppings on the belt practised by the farmer (7 hours a day, during the night). The ammonia reduction efficiency of the VB technique, compared to the DP, was 61%, close to the reduction level assessed by the IPPC-TWG between the VB and the reference.

The methane emission factors resulted 0.02 kg y^{-1} hen $place^{-1}$ for the deep-pit technique and 0.08 kg y^{-1} hen $place^{-1}$ for the ventilated belt technique, which correspond to a 75% lower emission. This result may be attributed to the fact that in the deep-pit system the droppings are scraped every day to the underneath storage, while in the ventilated belt system the manure is removed twice a week.

The emission factors measured in our work lie within the range of some literature results for layer facilities, reviewed by Jungbluth *et al.* (2001), which range from 0.076 to 0.383 kg y^{-1} bird $place^{-1}$, and close to the Dutch data for laying hens (Monteny *et al*., 2001), assessed at 0.06 kg y^{-1} bird $place^{-1}$ that is 15 kg y^{-1} LU^{-1} .

No significant emissions were registered for nitrous oxide, consistently close to zero for both the techniques.

Particulate matter

The results reported in Table 2 show the average dust concentration, both as PM_{10} and $PM_{2.5}$ measured during the six 1-week periods of observation. The emissions were considerably higher in the case of the deep-pit system.

Table 2. *Laying hen houses: average concentration of PM10 and $PM_{2.5}$*

Particulate Matter	***PM_{10}***		***$PM_{2.5}$***	
	mean	***(min-max)***	***mean***	***(min-max)***
Deep-pit system				
mg h^{-1} hen $place^{-1}$	2.01	(0.23-17.27)	0.59	(0.03-4.83)
Ventilated belt				
mg h^{-1} hen $place^{-1}$	0.78	(0.08-4.88)	0.26	(0.01-2.22)

CONCLUSIONS

The emission factor for the deep-pit house is fully compatible with the value assessed by Italy within the IPPC-TWG (0.154 kg y^{-1} hen^{-1}), but much lower than the Dutch value (0.386 kg y^{-1} hen^{-1}) for the same technique. This result confirms that this technique can achieve lower ammonia emissions in countries with warmer climates, where higher temperatures and higher ventilation rates lead to faster and higher drying of the manure.

The ammonia emission reduction factor of the ventilated belt technique, compared to the deep-pit technique, was 62%.

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