Ammonia and Greenhouse Gases Concentration in Relation to Daily Routine Operations in Laying Hens Houses

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Abstract
In livestock houses, ammonia, greenhouse gases and particulate matter represent the main pollutants that can adversely affect the health status of animals and men working in animal husbandries. All these pollutants can reach high concentrations during the routine management operations performed by farmers, for example, following the litter removal. The aim of this work was to study ammonia, and CO_2, CH_4 and N_2O concentration during daily routine cleaning like litter removal in different housing systems for layers, a battery system with pit under cages and a scraper to remove manure (BSP) and an aviary system house (ASH). Data were collected for the 60 % of the cycles during a whole year. The same happened for methane concentration (4.33 mg m^{-3} in the BSP house vs 3.06 mg m^{-3} in the ASH house). Nevertheless, in the ASH, during and after litter removal, the methane concentration reached the value of 16.49 mg m^{-3}. The remarkable variation of these pollutants concentration that usually took place in the ASH during routine daily cleaning highlights how this layers house, even if endorsed by EU rules on animal welfare and that will be widespread in Europe in future, cannot guarantee a healthy working environment for operators, taking also into account the cumulative effects of noxious compounds like dust and ammonia.

Keywords: layers houses, ammonia, greenhouse gases, cleaning operations

Introduction
Workers and animals in hens units are exposed to a wide range of airborne contaminants that cause respiratory irritation and sensitization (Katila et al., 1981). The most important gases generated by animal facilities are ammonia (NH_3), greenhouse gases (GHG) as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Philippe et al., 2007). Gaseous NH_3 is the predominant pollutant gas in poultry production operations, it can also adversely affect bird performance and welfare and men's health (Andreasen et al., 2000, Donham, 1991). Ammonia is generated by the microbial decomposition of uric acid in bird faeces, its emission is of environmental concern because it contributes to soil acidification and increased nitrogen deposition in ecosystems. Carbon dioxide is considerably produced by respiration and manure fermentation. However agriculture is also a CO_2 consumer through plant photosynthesis, this gas contribution to the greenhouse effect is less important than that of CH_4 and N_2O, whose warming potentials are, respectively, 21 and 310 times that of CO_2 (Intergovernmental Panel on Climate Change, 2007). Methane is generated from anaerobic bacterial decomposition of organic compounds present in feed and excreta and it is emitted both as by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms in the animal digestive tract (mainly in ruminants), and from the decomposition of manure under anaerobic conditions, increasing with the Volatile Solids content of the excreta. N_2O is emitted from manure as an intermediate product of nitrification/denitrification

processes under condition of low oxygen availability which normally convert ammonia into inert dinitrogen gas, also it contributes to the ozone shield destruction. Dust, or particulate matter, represents another important aerial contaminant in animal houses, since it can combine with inorganic compounds, gases, bacteria and viable endotoxins, that fixed on dust particles surface, can become potentially hazardous agents (Hartung, 2002).
The aim of this study was to evaluate the concentration of ammonia, greenhouse gases and dust (PM_{10}) in two types of laying hens houses, with a particular interest to the variation in pollutant concentrations occurring during daily routine operation.

Materials and methods

Farms location

The measurements were taken in two commercial laying hen units located in Northern Italy in the same farm. The monitored techniques were:

1. Battery system with pit under cages and a scraper to remove manure (BSP)
2. Aviary system house (ASH)

<u>Battery system with pit under cages and a scraper to remove manure (BSP).</u>
The house, with 11.000 hens lodged, is 14m wide x 70 m long. The house is ventilated by 4 fans of 1.16 m of diameter, positioned on one of the two longitudinal walls, the maximum ventilation rate is 42000 m^3 h^{-1} for each fan.

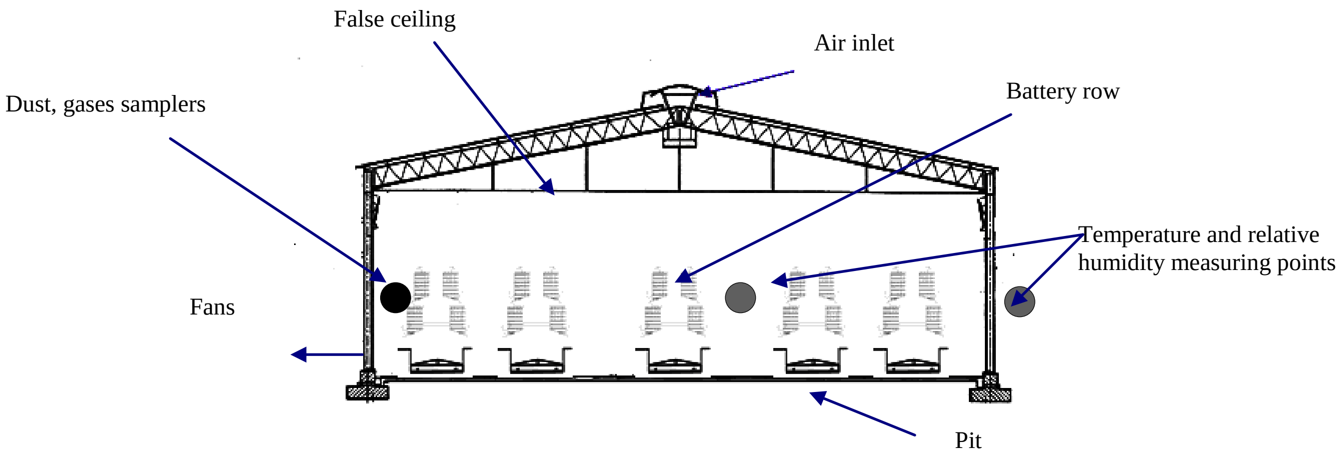

Figure 1. Cross section of the battery system house

The air is collected from the roof, insulated by polystyrene sheets, enters the house through a continuous longitudinal ridge chimney. The ventilation program is computer controlled and based on thermostatic regulation (the first group of fans are active for the minimum ventilation level, when temperature is higher than 15.4 °C, the second group switched on when temperature inside the barn was equal or greater than 22°C). Daily routine inspections and cleaning procedure were performed from 8.00 AM to 10.00 AM.
This conventional type of laying hens house in 2013 will be eliminated as a consequence of the application of European laws on Animal welfare.
<u>Aviary system house (ASH).</u>
The house, with 7500 hens lodged is 14m wide x 70 m long, is ventilated by 4 fans of 1.16 m of diameter, positioned on one of the two longitudinal walls, the maximum ventilation rate is 42000 m^3 h^{-3} for each fan.

As in the previous housing system, the air is collected from the roof, insulated by polystyrene sheets, enters the house through a continuous longitudinal ridge chimney.

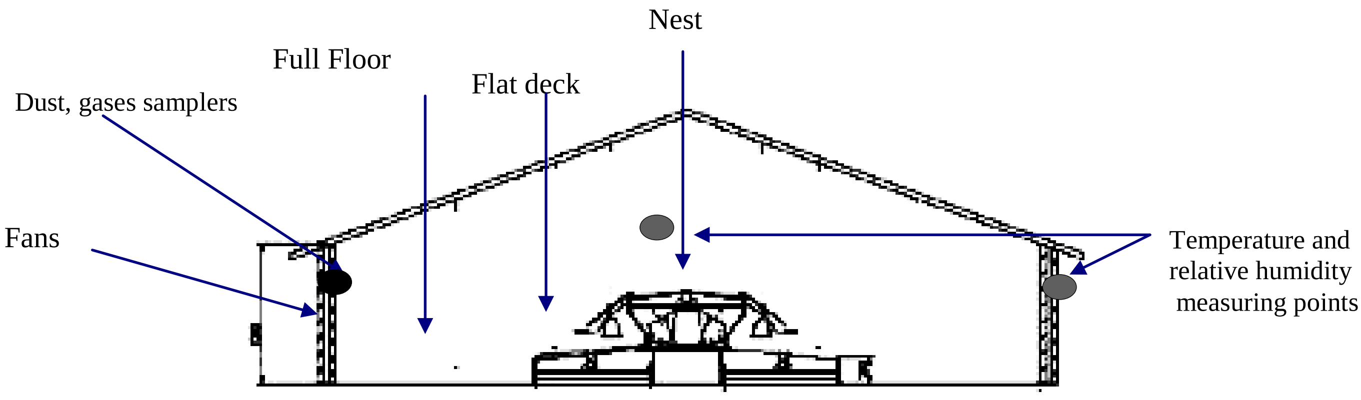

Figure 2. Cross section of the aviary system house

The ventilation strategy is computer controlled and based on thermostatic regulation (the first group of fans are active for the minimum ventilation level, when temperature is higher than 15.4 °C, the following groups are switched on when temperature inside the barn reaches 22°C). In this house hens are reared on the litter and flat decks at different levels. The nest for eggs deposition is located in the middle of the room. Daily routine inspections and cleaning procedure were performed from 10.00 AM to 12.00 AM.
This housing type is endorsed by EU rules on animal welfare.

Gases and dust concentration measuring equipment
NH_3, CO_2, CH_4 and N_2O concentrations were continuously measured in the exhaust ducts using an infrared photoacustic detector IPD (Brüel & Kjaer, Multi-gas Monitor Type 1302, Multipoint Sampler and Doser Type 1303) collecting data every 15 minutes.
In each of these facilities, the PM_{10} concentration was continuously monitored, with an acquisition interval time of one minute, using calibrated scatter light photometers (accuracy: ± 3 μg m^{-3}; EPAM 5000, HAZ-Dust; Environmental Devices Corporation, Plaistow, NH). Measurement were performed continuously, at least, for the 60 % of the period of the cycle, to include all the seasons of the year (Arogo et al., 2003). From the year of measurements, only data recorded in presence of no other activity than the usual daily routine, was kept for the study.

Ventilation rate and environmental parameters
The ventilation rate was monitored by recording the number of active fans, the air flow rate was measured for each fan in 9 different positions of its surface using a hot wire anemometer (BSV 105, LSI, Settala, Milano). Measurements were taken for each monitoring cycle (six times per year) for each ventilation step. The mean air flow rate was compared to the nominal ventilation rate to calculate the effective ventilation rate for each fan and the measurement error. The use of the hot wire anemometer allows an accuracy ranging from to 0.5 to 25 % in

checking the effective ventilation rate (Scholtens and Van 't Ooster 1994), in our study the measurement accuracy was calculated to be 5 %. The temperature and relative humidity were monitored constantly both inside and outside the houses, with dataloggers (Babuc M, LSI, Settala, Milano).

Results

Environmental parameters

In table 1, the results of the yearly monitoring in the three laying hens houses are shown, subdivided in the periods between November 2006 and May 2007 (I period), and June and November 2007 (II Period).

Table 1. Structural characteristics, environmental parameters and dust emission factors in the two laying hens houses

Building type		**BSP**		**ASH**	
	Monitoring period	**Period I**	**Period II**	**Period I**	**Period II**
Structural characteristics	Ventilation system	4 Exhaust fans in one of the two the longitudinal walls		4 Exhaust fans in one of the two the longitudinal walls	
	Number of animals	11.000		7500	
	Dropping removal system	Dip pit with a scraper to remove droppings		Litter, a belt in front of the nest removes droppings	
Inside Microclimate	Temperature °C;(min; max)	18.68 (11.24; 25.60)	19.31 (13.24; 27.32)	14.88 (9.72; 26.21)	21.42 (17.47; 26.53)
	Relative Humidity %, (min; max)	55 (24; 88)	56 (27; 86)	62 (28; 97)	46 (32; 58)
Outside Microclimate	Mean Temperature °C, (min; max)	12.41 (-1; 29)	19.34 (6.2; 32.3)	12.41 (-1; 29)	19.34 (6.2; 32.3)
	Relative Humidity %, (min;max)	66 (25; 99)	55 (25; 93)	66 (25; 99)	55 (25; 93)
Ventilation rate	Mean of the period $m^3 h^{-1}$	59481	65498	18892	72752

Legend:
Period I: November 2006 - May 2007, Period II: June 2007 - November 2007

Table 2. Pollutants concentrations in the two laying hens houses

	BSP						**ASH**				
Variable	**NH_3**	**N_20**	**CO2**	**CH_4**	**PM_{10}**	Variable	**NH_3**	**N_20**	**CO2**	**CH_4**	**PM_{10}**
Mean	3.88	1.53	2001	4.34	0.094	Mean	3.18	1.45	1920	3.07	0.215
Std.Dev	2.26	0.37	576	2.51	0.059	Std.Dev	1.49	0.53	885	32.22	0.262
Minimum	1.07	0.60	717	0.68	0.001	Minimum	0.47	0.00	678	0.65	0.001
Maximum	30.00	2.54	3160	34.70	0.844	Maximum	13.60	3.12	5360	34.00	11.837

Gases Concentration

As shown in Figure 3, in the two houses, ammonia concentration showed a similar trend during the day, with a minimum in both concentration at 3.00 PM, as expected, also for the increase in ventilation rate in the warmest part of the day.

During the morning, gaseous ammonia concentration raised in correspondence with increased animal activity and routine cleaning procedure. In the ASH house, mean value of ammonia concentration was lower in comparison with the BSP house, (3.88 mg m^{-3} vs 3.18 mg m^{-3}), in agreement with literature (Fabbri et al., 2007), also the maximum values registered during workers inspections from 10.00 AM to 12 AM was lower (30 mg m^{-3}vs 13.6 mg m^{-3}).

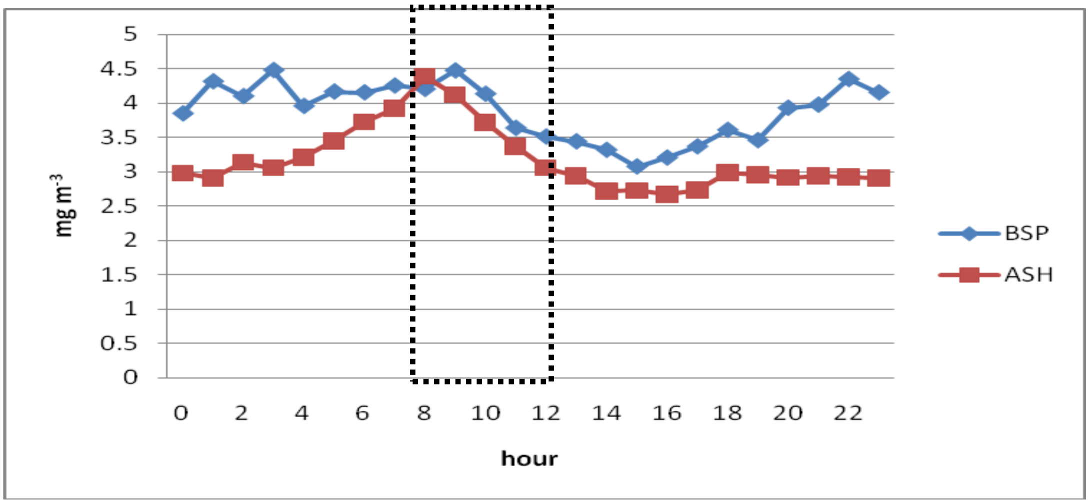

Figure 3. Daily ammonia concentration in the two hens houses

Yearly mean methane concentration, was 4.33 mg m^{-3} in the BSP house vs 3.06 mg m^{-3} recorded in the ASH house.
In the ASH house, from 10.00 to 12.00 AM, corresponding to workers inspection time, methane concentration reached a mean value of 16 mg m$^{-3.}$.

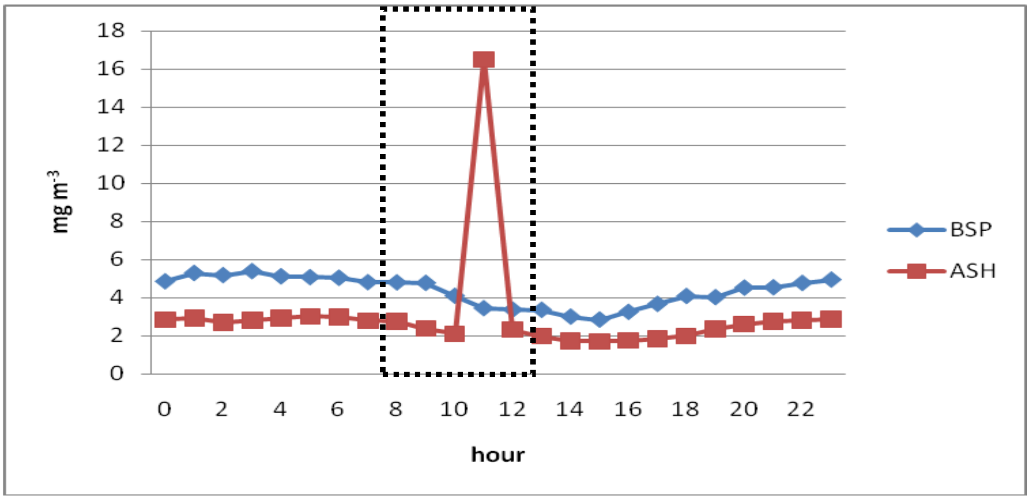

Figure 4. Daily methane concentration in the two hens houses

Yearly mean nitrous oxide concentration was lower than 1.53 mg m^{-3} in both hens houses, it reached a mean hourly value of 1.73 mg m^{-3} in both houses at around 8.00 AM and declined during the afternoon in a remarkable way in the ASH.

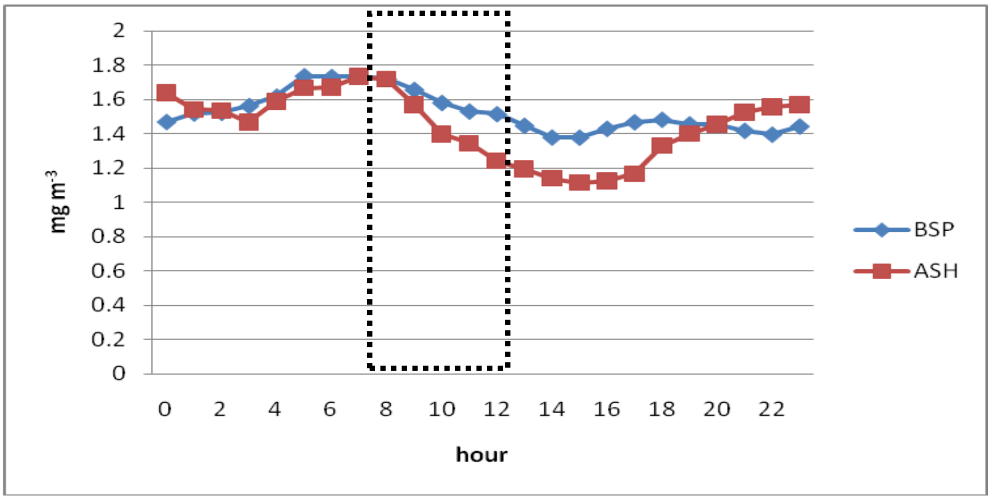

Figure 6. Daily nitrous oxide concentration in the two hens houses

Carbon dioxide showed a similar trend, with higher concentrations (around 2200 mg m^{-3}) in both houses during the first hours of the day, characterized by the beginning of animal activity and low ventilation rate.

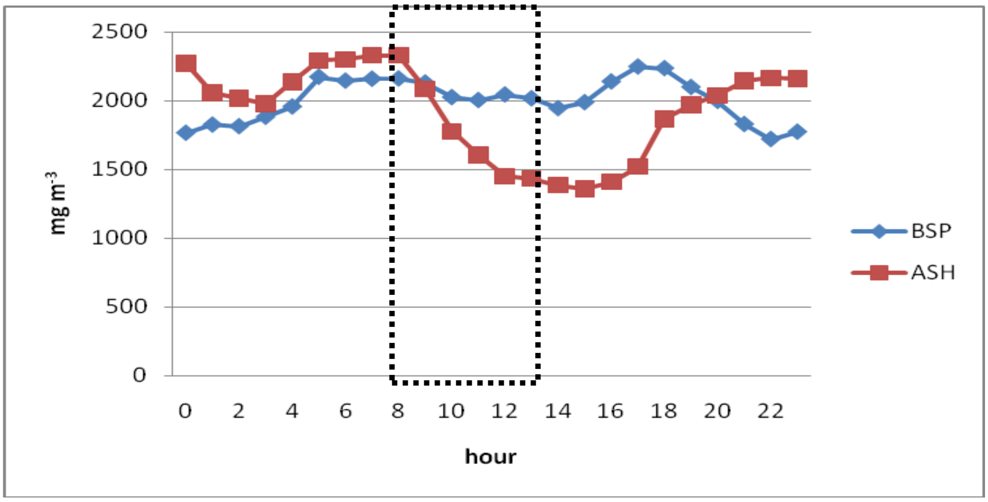

Figure 6. Daily carbon dioxide concentration in the two hens houses

Mean yearly PM_{10} concentration was remarkably higher in the ASH with 0.215 mg m^{-3} vs 0.094 mg m^{-3} for the traditional battery cages house, with appreciable peaks of dust concentration during the morning, together with the increased animal activity (Costa et al., 2009) and daily farmer operations.
Table 2, that reports mean, standard deviations, maximum and minimum values of pollutants, shows the high variability occurring during the 24 hours in both layers houses, an example of the trend of gases concentration in the ASH is reported in Figure 7.

This study evaluated the variation occurring in ammonia, GHG gases and dust concentration in a conventional housing system (BSP) that, in 2013 will be eliminated as a consequence of

the application of European laws on Animal welfare, and in a layers house (ASH) endorsed by EU rules on animal welfare and that will be widely spread in Europe in future.
Methane and dust concentrations, even if lower as mean values in the ASH house, reached very high concentrations during the working time of men, and so dust, as shown in a previous work (Costa et al., 2009).
In both houses, in the presence of farmers during routine daily operations a high concentration of pollutants occurs: epidemiological studies conducted in United States, Denmark and Canada demonstrated a greater prevalence of respiratory symptoms such as shortness of breath, chronic bronchitis, wheezing, and cough among workers and animals than in unexposed controls (Porterjoie et al., 2002; Katila et al., 1981).
ACGIH recommends a threshold limit value (TLV) of 25 mg m^{-3} a short-term exposure limit (STEL) and 17 mg m^{-3} on a timeweighted average (TWA) to avoid irritation of the eyes, nose and throat.
Ammonia, mainly generated by the enzymatic decomposition of urea from urine, at high concentration, can affect animal health and performance and is an important cofactor in the genesis of atrophic rhinitis and enzootic bronchopneumonia (Hamilton et al., 1996).
CIGR (1984) recommended a maximum ammonia concentration of 14 mg m^{-3} while Urbain et al. (1994) and Portejoie et al., (2002) indicated the ammonia threshold of 10 mg m^{-3} for irritations to the respiratory tract, while Gerber et al., (1991) indicated a human-related limit value of 5 mg m^{-3}.
Mean yearly methane concentration, although lower in the BSP house (3.06 mg m^{-3} vs 4.33 mg m^{-3}), in the ASH reached the mean value of 16.49 mg m^{-3} during routine cleaning operations and 34 mg m^{-3} during litter removal.

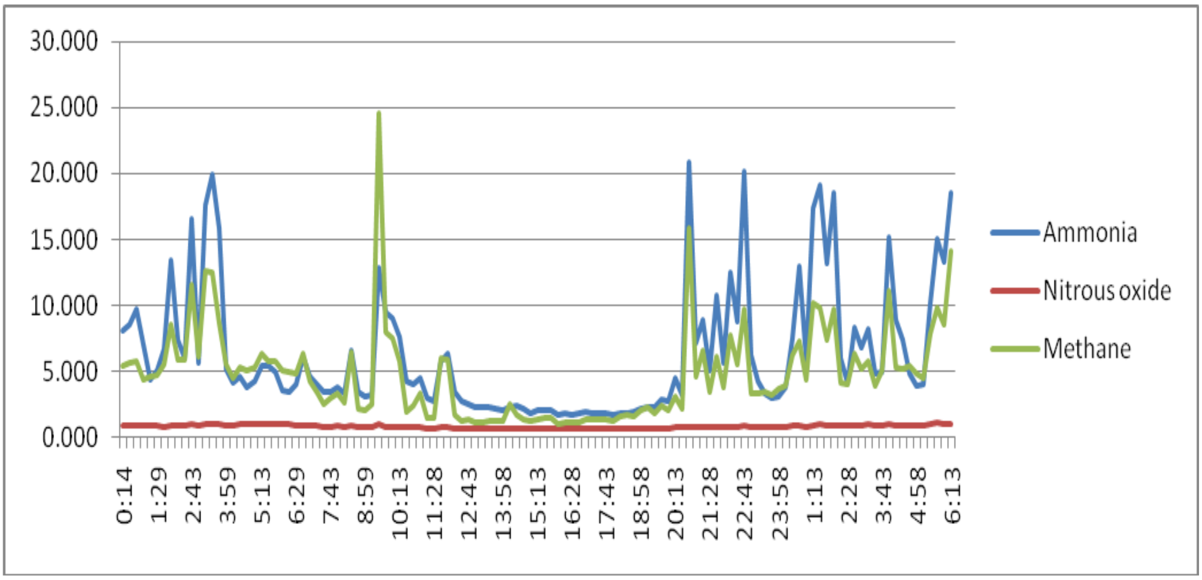

Figure 7. Example of gases concentration in the ASH during one day in July

In fact, for laying hens the CH_4 enteric fermentation emissions are expected to be negligible and the emission from manure management are connected with lack of oxygen in the stored manure.
Generally, methane could be taken as an indicator of good management practices adopted by the farmer, hence it is evident how the droppings removal procedure in this animal house

represent a risk for health and is not suitable for air quality inside and outside the animal building.

Conclusions

The remarkable variation of pollutants concentration that usually took place in the ASH during routine daily cleaning highlights how this layers house, even if endorsed by EU rules on animal welfare and that will be widespread in Europe in future, cannot guarantee a healthy working environment for operators, taking also into account the cumulative effects of noxious compounds like dust and ammonia.

Acknowledgements

The authors would like to express appreciation for the cooperation of the farmers in collecting the data used in this study. Funding was provided by ISPRA (ex APAT, Italian Agency for Environmental Protection; Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici, Roma) for a research initiative into agricultural air quality and emission into atmosphere (2nd year, Survey on Poultry Housing).

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