Agronomy Research Biosystem Engineering Special Issue 1, 211-218, 2012

Ammonia emission in cowsheds and pigsties during the summer period

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Abstract. As is known, cows in uninsulated cowsheds can tolerate lower temperatures much better than higher temperatures, so we can say that these buildings are well suited for animals, although there are problems with workers and the working environment in uninsulated cowsheds in extreme cases, during very low and high outside temperatures.

The goal of this study was to identify the outdoor climate impact on the indoor climate in cowsheds with 420, 500 and 500 cow places during winter and summertime. For that, indoor and outdoor temperature, relative humidity and indoor ammonia content were measured simultaneously. The processed results are well applicable when designing new cattle housing or improving the indoor climate of already existing uninsulated cowsheds.

Building of large pigsties with deep litter and without litter which use liquid manure removal systems has become a wide practice nowadays. Indoor climate parameters of the working environment have an impact on the human capacity for work and the productivity of animals. Enlargement of pigsties is accompanied with problems regarding the achievement of the required indoor climate for the working environment. For the purpose of studying the pigsties with different animal-keeping technologies and the simultaneous effect of temperature and relative humidity on the emission ammonia content in the air of a pigsty were measured in summer above a pig-pen at the height of 1.5 meters from the floor and were measured daily. Data logger equipment, relevant sensors and content of ammonia in the air was measured for the study by using Gas Monitor Pac III equipment. Measurement results were statistically processed by using the computer programmes AMR Win Control, Pac III Software3.nn, SAS and MS Excel.

Keywords: uninsulated cowshed, pigsty, deep-litter, liquid manure, system, pens, tending passages, working environment, air temperature, relative humidity, ammonium hydrate, ammonia contend correlation, tending activities, data logger.

Introduction

The indoor climate of un-insulated cattle-sheds is largely influenced by the outer temperature and relative humidity as well as the work executed inside.

The aim of this paper was to research the influence of the outer climate on the indoor climate in un-insulated cattle-sheds with cubicles in summer. The air temperature, relative humidity and the content of ammonia were measured round-the-clock. At the same time the temperature and relative humidity of outdoor air were also measured.

A pig farm represents a biotechnical system 'man-machine-animal', which together with the indoor climate of buildings or premises constitutes a work environment for producing animal products. Indoor climate parameters of a working environment have an impact on the human capacity for work (ASHRAE, 2006; Liiske et al., 2002; Sada & Reppo; Liiske, 2002) and the productivity of animals (ASHRAE, 2006; Mothes, 1973; Liiske, 2002). Humidity and ammonia have a more harmful effect on premises, whereas the indoor climate depends on various factors such as applicable tending technology, number of animals, systems for providing animals with forage and water, removal of manure, use of litter, and season or outdoor climate (MWPS-33, 1989; Mothes, 1973; Kender et al., 1998; Sada & Reppo, 2006). The indoor air temperature and relative humidity of a pigsty have been researched more thoroughly (Liiske, 2002; Mothes, 1973; MWPS-33, 1989). The working environment air gas composition, its variations on a daily basis and its dependence on applicable technologies and animal keeping methods have been studied to a lesser extent.

The aim of the present research was to find out the impact of different methods for animal keeping and tending works on an indoor working environment during summertime. The daily developments of air velocity and the contents of oxygen, carbon dioxide and ammonia were measured at a height of 1.5 m above the floor of the pigsty in the central part. Study results provide further information concerning the indoor climate in pigsties and also allow selecting the method for the keeping of animals with the least harmful tending environment.

Materials and methods

The air temperature, relative humidity and the content of ammonia in uninsulated cowsheds were measured round-the-clock in summer, in the un-insulated cattle-sheds with 420, 500 and 500 cow places at the height of 1.5 m (Table 1) (https://www.riigiteataja.ee... 25048; Karhunen, 1992). At the same time the temperature and relative humidity of outdoor air were also measured.

Table 1. Data of the observed farms

Farm	Farm nr. 1	Farm nr. 2	Farm nr. 3
Cow places	420	500	500
Feedings per day	2	2	2
Fodder (mixture)	Silage with grain mixture and mineral additives	Silage with grain mixture and mineral additives	Silage with grain mixture and mineral additives
Herdsmen (tractor driver)	2	1	2
Loader	Manitou	MTZ-82 (Belarus)	Claas
Fodder mixer	DeLaval + Valmet	Eurocomp + MTZ-952 tractor	Optimix + Valmet tractor
Parlour size	DeLaval 2x20	Strangko 2x20	DeLaval 2x14
Parlour type	parallel	parallel	parallel
Milking devices	40	40	28
Manure disposal	scraper + pump continuously	scraper + pump 5 times a day	Tractor + pump 3 times a day
Ventilation	natural	natural	natural

To research the parameters of indoor climate the device ALMEMO Data Logger 8990-8 was used together with the computer programme AMR WinControl. To measure the temperature and relative humidity the sensor FH646-1 of the company AMR was used with the corresponding measuring ranges –20…+80 °C (measuring precision 0.01 °C) and 5…98% (measuring precision 0.1%). The content of ammonia was measured using the sensor ZA 3601-FS2 (Bacarach EIT Co) with the measuring range 0…100 ppm and the measuring precision 0.01 ppm. To measure the temperature and relative humidity of outdoor air the device HygroLog was used with the sensor HygroClip S (measuring range –40…+85°C and 0…100%, measuring precision correspondingly ±0.3°C and ±1.5%). The numerical values of the climate parameters were measured with an interval of 60 seconds. Measuring results were analysed using the computer programme AMR WinControl, HW3 and MS Excel (Kiviste, 1999; SAS 2007).

Indoor climate was studied in pigsties for 1,600 fattening pigs, and 800 young pigs, which are hereinafter referred to as Pigsty A, and B (Table 2). Pigsties were made of silicate bricks and reinforced concrete. Fattening pigs and young pigs were fed with dry fodder delivered by an automatic conveyor from automatic feeders. Automatic conveyor Big Dutchman was used in Pigsty A and Roxcell device was used in Pigsty B. In Pigsty A fattening pigs were kept on straw litter (60 pigs per pen), the manure was removed with the shovel-loader after replacing the fattening pigs in the pigsty. In Pigsty B the liquid manure system was used, where manure was drained from the pen with 30 young pigs into a channel below the grated floor, leading to a pump-room, where it was pumped to manure storage. Nipple drinkers were used as a drinking device in all pigsties. Ventilation was regulated by automatic forced ventilation with controlled temperature.

Table 2. Data on pigsties

Item	Pigsty A	Pigsty B
Number of pigs	1,600 fatlings (25–100 kg)	800 young pigs (15–50 kg)
Way of keeping	Deep-litter	Liquid manure system
Ventilation	Compulsion ventilation	Compulsion ventilation
Air flow control	Automatic	Automatic
Additional heating	Missing	Water-heated floor
Fodder delivery	Automatic system Big Dutchman	Automatic system Roxcell
Manure disposal	With tractor	Liquid manure, with flow to the pumping-station
Drinking device	Nipple drinker	Nipple drinke
Litter used	Straw	Missing

The methods of the study were based on the Health Protection Act of the Republic of Estonia (https://www.riigiteataja.ee...25048) and Finnish standards (Karhunen, 1992), American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHARAE, 2006) according to which the numerical values of indoor climate parameters of work environment can be defined for animals at the height of 1.0 m and for the human workplace at the height of 1.5 m. In order to study the daily changes in the indoor climate of pigsties depending on outdoor climate, methods for animal keeping, performing technological processes, activities of the tender and animal behaviour, the indoor air temperature, relative humidity and ammonia were measured on a daily basis at an interval of 60 seconds in the central part of pigsties and at a height of 1.5 m above the floor of the pigsty in summer. The same devices (ALMEMO Data Logger 8990-8 equipment with relevant sensors) as for cowsheds were used for studying the indoor climate.

Measurement results were analysed using similar computer programmes as for cowsheds (AMR WinControl, Pac III Software 3.nn and statistically processed by using the programs MS Excel and SAS (Kiviste, 1999; SAS 2007).

Results and discussion

It was identified that in summer, when the outdoor temperature was 8.38…23.19°C, the indoor temperature of the cattle-sheds was within the range of 9.81…22.07°C, the average being correspondingly 16.33 and 17.12°C (Table 3).

Table.3. Indoor and outdoor climate parameters in summer

Parame-ters	Uninsulated cowshed					Pigsty A					Pigsty B				
	Indoor			outdoor		indoor			outdoor		indoor			outdoor	
	NH_3, ppm	t,°C	W,%	t,°C	W,%	NH_3, ppm	t,°C	W,%	t,°C	W,%	NH_3, ppm	t,°C	W,%	t,°C	W,%
min	0.58	9.81	60.2	8.38	41.8	5.0	11.40	63.3	12.2	44.5	2.2	14.93	73.90	1.19	43.4
average	4.12	17.12	86.38	16.33	80.66	20.92	17.04	68.11	18.15	71.88	8.76	17.59	78.59	8.75	84.19
max	10.34	22.07	100.0	23.19	96.4	38.0	21.40	88.7	21.45	97.7	25.0	25.71	96.73	21.19	100.0
σ_x	3.14	2.70	9.32	3.20	11.51	8.01	2.34	3.02	4.31	18.55	4.291	1.88	2.98	4.42	15.43
S_x	0.12	0.04	0.14	0.05	0.17	0.10	0.03	0.04	0.12	0.53	0.050	0.02	0.03	0.11	0.39

The numerical values of summer outdoor and indoor relative humidity were correspondingly in the range of 51.8…96.4% and 86.4…100.0% (respective average values 80.66 and 86.38%, (Table 3).

Ammonia is originated in the decomposition process with the presence of excrements and urine. Ammonia is extremely toxic for organisms, causing liver troubles and constant nervousness, irritating respiratory organs, inflicting chemical burns. Capacity of ammonia diffusing through cell walls increases ammonia riskiness for mammals. The utmost permissible concentration of ammonia in the work zone air is 25 ppm (for a 5 minute workday).

The dependence of the content of ammonia in the air was within the permitted limits, measured within the range of 0.58…10.34 ppm. The dependence of the content of ammonia P_{NH_3} (ppm) on the summer indoor temperature t_{is} (°C) can be expressed by the function (R^2=0.17; n=4,320) (Fig. 1).

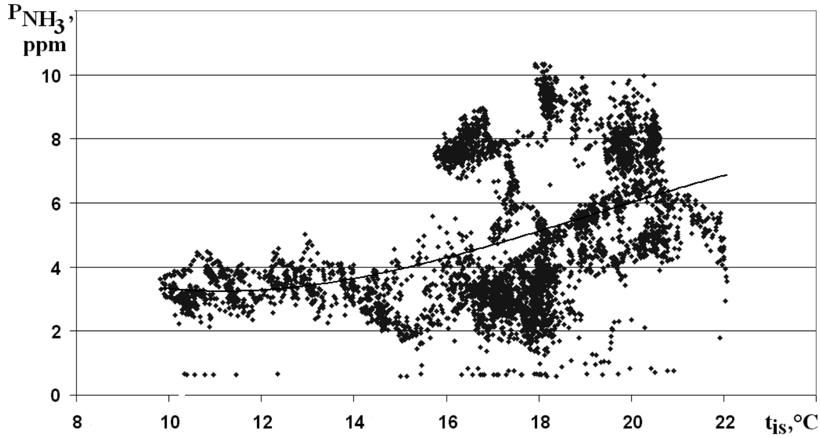

Fig. 1. Dependence of the content of ammonia on indoor temperature in a cattle-shed.

Indoor air temperature, relative humidity and ammonia concentration are the main indoor climate parameters of the pigsty (Maatalouden…, 1990; Tuunanen and Karhunen, 1984). The recommendatory temperatures for pigs depending on their age and live weight are considered as follows: the lowest admissible temperature 5°C, the highest 32–34°C and optimum 16–21°C (ASHRAE, 2006; CIGR, 1984; Rosti, 1988; Maatalouden…, 1990; Tuunanen and Karhunen, 1984). Relative humidity of the indoor air is recommended to be 60–75%, not over 85%, because the other microclimatic parameters then also deteriorate (Mothes, 1976; Veinla, 1987; Rosti, 1988). Surplus humidity causes drippings, mould and mildew on the building border area and reduces heat resistance of the building and pigs as well. Insufficient air humidity of less than 55% can cause mucous membrane desiccation because of dust in the room (Mothes, 1976; Veinla, 1987).

The study results revealed that with deep litter pigsty A, and also liquid manure pigsty B, the indoor air temperature was (accordingly 11.4–21.4°C and 14.93–25.7°C) practically within the limits.

The measured relative humidity was Pigsty A 63.3–88.7% and Pigsty B 73.9–96.7%, exceeding the limits (Table 3).

Indoor climate investigation showed that time ammonia concentration in the Pigsty A air was 5–38 ppm and pigsty B was 2–25 ppm.

The information also varies in case of the highest concentration of ammonia in the air. The allowed concentration of ammonia in the air is up to 20 ppm in the European Union (CIGR, 1984). Estonian standards (http://riigiteataja.ee...73153, 2002) and authors (Tuunanen and Karhunen, 1984) refer to 20 and 25 ppm as the allowed average standard limit in the air inhaled in a human working zone. Ammonia content 6–12 cm^3 $(m^3)^{-1}$ was measured in the piggery for 220 fattening pigs (Karhunen, 1994).

According to relevant literature (Kauppinen, 2000; Pals, 2003; Reppo, 2002) elevated air temperature and moist litter in the animal-keeping premises increase the air emission of ammonia. The data provided by several authors (Mothes, 1976; Einberg, 2001; Pals, 2002; Reppo and Pals, 2003) reveal that the air emission of ammonia in the premises used for animal keeping depends on the handling of manure, air temperature and relative humidity. It is also noted that the amounts of ammonia emitted from the manure are higher in the case of higher air temperature and higher relative humidity.

Considering that the relative humidity of piggeries also depends on air temperature (Reppo and Pals, 2002), this study also included determining the effect of air temperature t (°C) and relative humidity W (%) on the emission of ammonia $P(NH_3)_{tW}$ (ppm), which was expressed by formulas (R^2_1=0.918, n=7,200; R^2_2=0.949, n=1,440) with regard to Piggery A (Fig. 2) and Piggery B (Fig. 3), 1 and 2 respectively:

$$P(NH_3)_{tW} = -51.02+3.227 \cdot t+0.239 \cdot W \quad (1)$$

$$P(NH_3)_{tW} = -32.24+1.424 \cdot t+0.184 \cdot W. \quad (2)$$

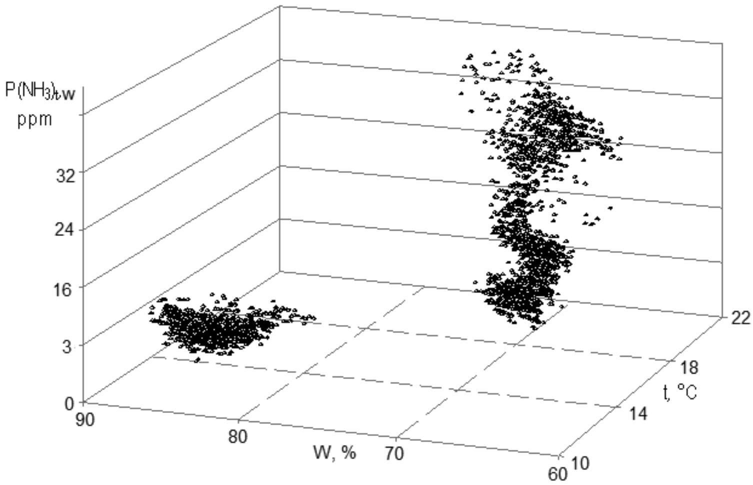

Fig. 2. Ammonia content correlation in air temperature and relative humidity in the Pigsties A.

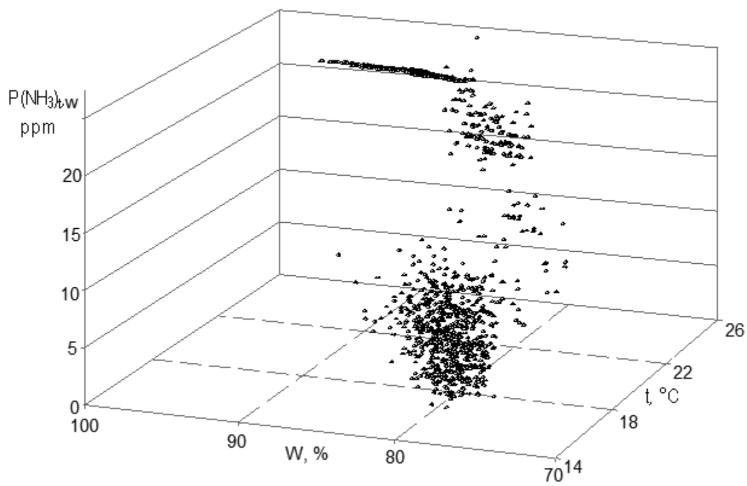

Fig. 3. Ammonia content correlation in air temperature and relative humidity in the Pigsties B.

Conclusions

1. In summer the cattle-shed temperature was on average 0.79°C higher than the outdoor temperature. The content of ammonia was relatively low, measured values were observed – 0.58…10.34. Regardless of this all the measured parameters remained within the recommended limits (Riigiteataja.ee…25048).
2. During the research in summer, in piggeries with a system of deep litter and liquid manure the air temperature, relative humidity and ammonia content were measured during the night time if the animals rest time is 18:00–4:00, and above the pig pen the height is 1.5 meters.
3. Data Logger with appropriate sensors and programmes AMR WinControl, Pac III Software 3.nn, were used for the research, and the measurement data were statistically processed.
4. As a result of this study the graphical and empirical relationships were determined between the concentration of ammonia and combined effect of the temperature and relative humidity of indoor air in summer and winter (Fig. 2 and 3; formulas 1 and 2).
5. In a pigsty with deep litter values, air temperatures of 11.4–21.4°C and liquid manure 14.9–25,7°C within the limits and relative humidity respectably of 63.3–88.7% and 73.9–96.7% in the pigsties were not in the limits.
6. The ammonia concentration was respectably 5–38 ppm and 2–25 ppm and exceeded limits.
7. Ammonia emission affected by temperature and relative humidity.

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