INFLUENCE OF QUANTITATIVE AND QUALITATIVE FACTORS ON CONCENTRATION OF AMMONIA IN SWINE HOUSES

INFLUENCIA DE FACTORES CUALITATIVOS Y CUANTITATIVOS EN LA CONCENTRACION DE AMONIACO EN COCHIQUERAS

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SUMMARY

Reiterative measurings showed us that concentration of ammonia in swine houses usually is from 5 up to 34 ppm, i.e. oftenly overdraws higienic passible limits (25 ppm). Influence of air exchange rate, temperature of premises, relative humidity, extraction of bad air throught manure channels, litter, and state of pens was investigated under conditions of natural production in order to improve the ways of reduction of concentration of ammonia.

We have made a polynomial regression equation connecting intensity of ammonia release with air exchange, temperature of premises, and relative humidity. According to this equation we get that if air exchange is increased from 1.6 up to 4.8 h^{-1}, i.e. three times, the intensity of ammonia release increases 2.9 times, while its concentration decreases only by 3 p. 100.

While extracting out 60 p. 100 of bad air throug manure channels the concentration of ammonia decreased from 25 to 22 ppm, in comparison with case when air is extracted out only through upper parts of premises. When the surface of the floor is uneven, i.e. it is always covered with a layer of manure (thickness of which is 0.5-1.0 cm) the concentration of ammonia overdraws higienic limits, even when air exchanging is intensive (relative humidity and temperature are normal). If the floor in the swine house with sows and litter is even and its surface is cleaned once in a day the concentration of ammonia is from 16 up to 18 ppm. If pens are scattered with peat which absorbs ammonia, the concentration of it will be 5 ppm even if the air exchange is not good enough (i.e. great relative humidity).

RESUMEN

Medidas reiteradas demuestran que la concentración de amoniaco en las cochiqueras, se encuentra habitualmente entre 5 y 34 ppm, por lo que con cierta frecuencia se superan los límites tolerables (25 ppm). Para tratar de mejorar las formas de reducir la concentración de amoniaco en condiciones normales de producción, se investigó la influencia de la tasa de cambio de aire, temperatura de llos locales, la humedad relativa, la extracción del aire viciado a través de los canales de estiércol, la cama y el estado de los corrales.

Se ha ajustado una ecuación polinomial de regresión para tratar de relacionar la intensidad de la producción de amoniaco con el intercambio de aire, la temperatura de llos locales y la humedad relativa del aire. De acuerdo con esta ecuación se estima que si el recambio de aire se eleva de 1,6 a 4,8 por hora, esto es tres veces, la intensidad de liberación de amoniaco se multiplica por 2,9, mientras que su concentración disminuye sólamente un 3 p. 100.

Cuando se extrae el 60 p. 100 del aire viciado a través de los canales de estiércol, en vez de hacerlo sólamente por la parte superior de los locales, la concentración de amoniaco desciende desde 25 a 22 ppm. Cuando la superficie del suelo no es uniforme, esto es, cuando está permanentemente cubierta con una capa de estiércol (espesor de 0,5 a 1,0 cm), la concentración de amoniaco supera los límites higiénicos, aun cuando se realice un recambio intensivo del aire (manteniéndose normales la humedad relativa y la temperatura). Si el suelo de la cochiquera con las cerdas y la camada, es uniforme, y su superficie se limpia una vez al día, la concentración de amoniaco es de 16 hasta 18 ppm. Si se esparce turba que absorbe el amoniaco, su concentración puede ser de 5 ppm, aun si el recambio de aire no es suficientemente bueno (p.e. gran humedad relativa).

INTRODUCTION

Higienic limits concentration of ammonia in Lithuanian swine houses is 25 ppm. Reiterative measurings showed that concentration of NH_3 is from 5 up to 34 ppm. We have established that intensification of air exchange, preventing air leakage into stables through manure channels usually does not reduce concentration of ammonia to higienic limits. State of pens floor has greater influence on concentration of NH_3. This can be illustrated by examples:

- a swine house is ventilated with the heated air, temperature of premises is 20º C, relative humidity is 50 p. 100, concentration of NH_3 is 34 ppm, because swine lie on the floor which is made from boards;
- no ventilation system, temperature is 19º C, relative humidity is 90 p. 100, concentration of ammonia is 5 ppm, because pens are scattered with peat;
- swine house is ventilated with the heated air, temperature is 16º C, relative humidity is 70 p. 100, concentration of NH_3 is 18 ppm; when ventilators are switched off after 90 minutes temperature increased up to 17º C, relative humidity up to 89 p. 100, and the concentration of NH_3 up to 23 ppm. The floor is concrete and is not scattered.

In latter years several works on concentration and release of ammonia were anounced. Influence of various factors (air leakage into the stable through manure channels, the manuring system, the density of animals, the air flow rate, design and location of air inlets and outlets) on concentration of NH_3 in swine houses was investigated (Gustafsson, 1993). It was established (Hartung, *et al.*,1994) that with regard to waste air directing, the results were that with a liquid manure level of around more than 50 cm below the slatted floor, the ammonia emissions are generally not more unfavourable with downward ventilation than with upward one. A computer model for predicting ammonia release rates from swine manure pits was construted (Zhang, *et al.*,1994). Results of our investigations will help to undestand what influence state of pens, air exchange in swine houses with sows and litter, and air extaction through

manure channels in swine houses with fatlings have on concentration and release of ammonia in swine houses.

The aim of our work is to establish the influence of quantitative (air exchange rate, temperature, relative humidity) and qualitative (state of pens floor, kind of litter, air extraction through manure channels) factors on the concentration and release of ammonia in swine houses.

EXPERIMENTAL SWINE HOUSES AND METHODS OF INVESTIGATION

In order to determine the influence of quantitative (air exchange rate, air temperature in premises, and relative humidity) factors on the intensity of release of ammonia investigations were carried out in swine houses with sows and litter. Sows with litter were kept in individual pens (area of each pen was 9 m^2). Animals were foddered with liquid mixtures offorage. Two cases were investigated. In first case pens were not scattered, and in second they were scattered with straw which was changed daily (approximately 1 kg of straw for one sow daily). In both cases the surface of the floor was uneven and was covered with layer of manure (thickness of which 0.5-1.0 cm). Manure is removed with the transporter, which is arranged in covered channel. There was an electrocalorific system of heating and ventilation. Fresh and heated air was pumped in through duct and bad air was extracted out through shafts which were in upper part of premises. Litter was heated additionally by infrared lamps. Figure show a scheme of the experimental swine house.

Air temperature, relative humidity, the amount of air inlets and outlets, concentration of NH_3 (in premises, in air which is pumped in and in one which is extracted out) were measured.

The amount of pumped in and extracted out air was determined by measuring air speed in a duct and shaft. Air temperature and relative humidity were measured with Asman psychrometer, air speed in duct with micromanometer and air speed in shaft with anemometer, concentration of ammonia with universal gas analyzer.

Measurements were carried out not earlier than 60 minutes after the door was closed and the system of air exchange was tuned. 60 experiments were carried out.

With the help of the obtained data the rate of release of ammonia (ΣZ, mg/s) was calculated:

$$\Sigma Z = V_o \cdot \mu_o - V_i \cdot \mu_i \qquad (1)$$

where,

V_i, V_o - amounts of air which was pumped in and which was extracted out, m^3/s;

μ_i, μ_o - concentration of ammonia in the air which is pumped in and out respectively, mg/m^3 (mg/m^3 = ppm/1.2 = 0.8 ppm).

Obtained data were analyzed in statistic way.

In order to establish the concentration of ammonia when bad air is extracted out through manure channels, experiments were carried out in swine houses with fatlings. These swine houses

were not scattered. The manure is removed through the channel which has 1 meter width and is covered with grille. The concentration in the height of 0.3 meter in pens, in manure channels, also the amounts of air which was removed through manure channels and upper parts of premises were measured.

In order to establish the influence of state of floor, and influence of litter on concentration of NH_3 measurements were carried out in 20 different swine houses all over Lithuania.

RESULTS AND DISCUSSION

1. THE INFLUENCE OF INTENSITY OF VENTILATION, AIR TEMPERATURE AND RELATIVE HUMIDITY ON THE RATE OF RELEASE OF NH_3

It was established that in non scattered swine houses with sows and litter and in ones which are scattered with straw (1 kg of straw for each sow daily) when the floor is constantly covered with layer of manure (thickness 0.5-1.0 cm) the intensity of release of ammonia (which is computed for some area of floor, z, $mg/m^2/s$) can be expressed in form of this polynomial equation:

$$z = 0.052+0.028K+0.001t-0.001\varphi \quad (2)$$

where
K - air exchange, h^{-1} ;
t - temperature of air, °C ;
φ - relative humidity, p. 100.

The meanings of coefficients were: $(1.6 \leq K \leq 5.2)$ h^{-1} or 85-280 m^3/h for one sow with litter; $(10 \leq t \leq 26)$ °C; $(42 \leq \varphi \leq 80)$ p. 100. Coefficient of polynomial correlation $R_{1.234}=0.88$. Coeficients of partial correlation: between z and K $r_{12.34}=0.74$; between z and t $r_{13.24}=0.21$ and between z and φ $r_{14.23}=-0.45$. Standard error of equation $S_{1.234}=0.015$.

According to statistic data we can conclude that air exchange rate has the greatest influence on rate of release of NH_3 whiles other conditions are the same. E.g. if air exchange is increased from 1.6 up to 4.8 h^{-1}, i.e. 3 times, rate of release of ammonia increases 2.9 times, and its concentration decreases only by 3p. 100. This can be explained due to the fact that when ventilation is more intensive, greater amount of water evaporates. And it's known that 52 g of ammonia are dissolved in 100 g of water. After water evaporates ammonia spreads in the air. In winter time when air

Table I. Concentration of ammonia in swine houses with fatlings in accordance with extracted air. (Number of experiments carried out 9, $p<0.05$). (Concentración de amoniaco en las cochiqueras de cebo segun el aire extraido. Número de experimentos realizados, 9; $p < 0,05$).

Amount of air which is extracted through manure channels, p. 100	Concentration of NH_3, ppm in manure channel	in height of 0.3 m
60	27.4 ± 0.8	21.8 ± 0.7
0	25.2 ± 0.6	25.2 ± 1.0

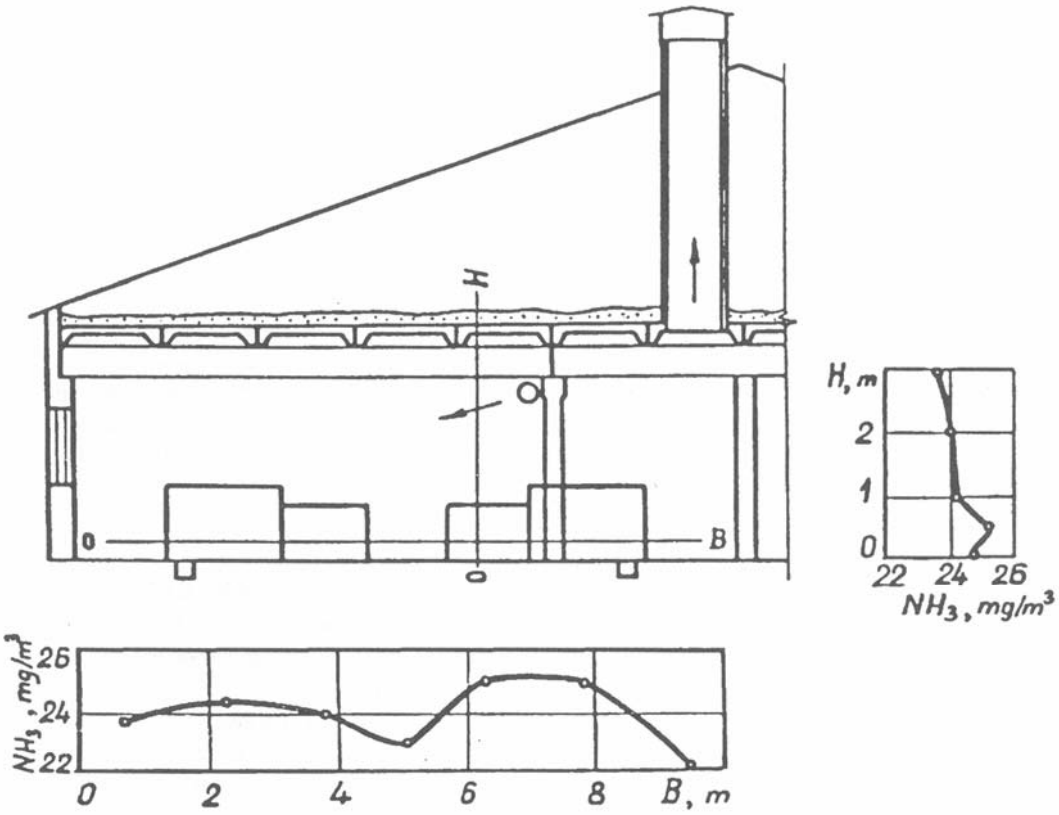

Figure 1. *Spreading of ammonia in swine house with sows and litter according to width B (in heigt of 0.5 m) and according to height H. Fresh air is pumped in from duct and bad air is extracted out through upper parts of premises. Air exchange is 3.6 h^{-1}, temperature is 17°C, relative humidity is 52 p. 100. Floor is uneven, i.e. it's covered with layer of manure (thickness 0.5-1.0 cm). (After year when the floor was evened, and conditions were the same, the layer of manure has thickness 0.0-0.5 cm and average concentration of ammonia decreased to 18 ppm).* (Distribución del amoniaco en las cochiqueras con cerdas y camadas según la anchura B (en una altura de 0,5 m) y de acuerdo con la altura H. El aire fresco es bombeado dentro desde los conductos y el aire viciado es extraído desde la parte alta de los locales. El recambio de aire es de 3,6 h^{-1}, la temperatura es de 17 °C y la humedad relativa del 52 p. 100. El suelo no es uniforme, está cubierto con una capa de estiércol de 0,5 a 1 cm. Después de un año, cuando el suelo fue uniformizado, y con las mismas condiciones, la capa de estiércol tenía un grosor de 0,0 a 0,5 cm y la concentración media de amoniaco descendió a 18 ppm).

Table II *Concentration of NH_3 in swine houses with sow and litter.* (Concentración de NH_3 en las cochiqueras con cerdas y camadas).

Variant	Airexchange and heating	Concentration of NH_3 (ppm) in height of 0.3 m	Indoor temperature °C	Relative humidity p. 100	Outdoor temperature °C
1	Ventilation with heated air	34	20	50	-5
2	Ventilation with heated air	28	21	48	-2
3	No heating. Natural ventilation	26	8	86	0
4	Ventilation with heated air	18	22	48	-2
5	Natural ventilation	16	8	87	-5
6	Ventilation with heated air	5	11	80	-2
7	Ventilator recirculates with calorifer Orifices of leakage are closed	5	19	90	-2

State of floor: 1, Made from boards. 2, Concrete uneven floor, scattered with straw (1 kg for each sow daily). Surface covered with layer of manure (thickness 0.5-1.0 cm). 3, The same. 4, Concrete even floor, scattered with straw (1 kg for each sow daily). Surface covered with layer of manure (thickness 0.0-0.5 cm). 5, The same. 6, Concrete floor scattered with peat (layer of peat is 5 cm). 7, The same.

exchange rate is increased 3 times, the intensity of heating should be increased 2.2 times, in order be keep constant temperature. This demands big amount of energy. When temperature increases and relative humidity decreases, the release of H_2O and NH_3 becomes more intensive as well.

According to investigations when relative humidity is normal and concentration of ammonia overdraws hygienic limits it should be decreased in other ways but not by increasing the rate of air exchange. It's also seen **(figure 1)** that ammonia in premises is spread evenly. The difference of concentration of ammonia in different places of premises does n't overdraws 5 p. 100. That's why the concentration of NH_3 can't be decreased by modifying of mode of air exchange (either changing air flow rate).

2. INFLUENCE OF AIR EXTRACTION THROUGH MANURE CHANNELS ON CONCENTRATION OF AMMONIA IN ANIMAL-ZONE

From **table I** it's seen how much the concentration of NH_3 in animal-zone decreases when bad air is extracted through manure channels.

In swine houses fatlings are kept on concrete floor. Manure is removed through the channels which have 1 meter width and are covered with grille. Two cases were investigated:

- in the first one 40 p. 100 of air were pumped out through the upper part of premise with the help of ventilators which were arranged in ceiling, and 60 p. 100 of air through manure channels;
- in the second case all the air is pumped out through the upper part of premises (with the help of ventilators).

In the first case the concentration of

ammonia in animal zone (in height of 0.3 meter) was decreased from 25.2 to 21.8 ppm, i.e. by 13 p. 100. When the air is extracted through manure channels it increases the rate of release of NH_3, that's why concentration of ammonia in channel increases from 25.2 up to 27.4 ppm.

In both cases avarage rate of air exchange was 42 m^3/h for one animal, temperature was 19°C, relative humidity 58 p. 100.

3. INFLUENCE OF STATE OF PENS ON CONCENTRATION OF AMMONIA IN SWINE HOUSE

In swine houses where sows with litter were kept, state of pens and litter had the greatest influence on concentration of NH_3. Several typical cases are given in the **table II**.

When floor of pens is made from boards there is urine under them. That's why concentration of ammonia overdraws hygienic limits even if premises are intensively ventilated and heated (variant nº 1). Great intensity of air exchange is shown by low relative humidity (50p. 100).

When the surface of floor is uneven and it's impossible to remowe all manure from it the concentration of NH_3 also overdraws hygienic limits (variants nº 2 and nº 3 shown in the **table II**).

When the floor is concrete and it's cleaned daily, concentration of NH_3 does not overdraw hygienic limits. It is 18, 16 ppm (variants nº 4 and nº 5). It's also seen that in premises with intensive air exchange and heating the concentration of NH_3 isn't lower than in premises with lower temperature and heiger relative humidity. In case of intensive air exchange and heating, the manure usually grows dry quicker and it absorbs more of urine. While urine evaporates, NH_3 is released. When heating and air exchange are less intensive greater amount of urine flows to manure channels.

Litter has the greatest influence on concentration of ammonia. Peat is especially good in absorbing ammonia. When pens were scattered with peat, concentration of ammonia was only 5 ppm in spite of air exchange wasn't intensive (variant nº 7) and was intensive (variant nº 6).

In all cases manure daily had been removed to manure channels. Sows were foddered with liquid mixtures of forage. Litter was additionally foddered with combined concentrates.

CONCLUSIONS

We have investigated the influence of air exchange rate, temperature, relative humidity, extraction of bad air through manure channels, state of pen floor, kind of litter on concentration and release of ammonia in swine houses. Experiments were carried out under conditions of natural production. Investigations are characterized by conclusions and results.

1. When floor of pens is made from boards (i.e. it's uneven) and is covered with layer of manure (thickness 0.5-1.0 cm), the concentration of NH_3 was overdrawing hygienic limits (25 ppm) even when air exchange was intensive (relative humidity and temperature were normal).

2. We have made a polynomial regression equation, connecting rate of

release of NH_3 with intensity of air exchange, temperature and relative humidity. When air exchange was increased from 1.6 to 4.8 h-1, i.e. 3 times rate of release of ammonia increases 2.9 times, while its concentration decreases only by 3 p. 100. When temperature and relative humidity are normal, it is not economic to increase air exchange in order to decrease concentration of NH_3.

3. When 60 p. 100 of bad air are extracted out through manure channels and 40 p. 100 through upper of premises, concentration of ammonia (in height of 0.3 m) decreased from 25 to 22 ppm in comparence with case when air was extracted out only through upper parts of premises.

4. When the floor in swine house with sow and litter was even and cleaned daily, concentration of ammonia was 16-18 ppm.

5. When pens were scattered with peat which absorbs ammonia, the concentration of it was 5 ppm even when air exchange was not sufficient.

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