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Results of Research on the Influence of Winter Weather Conditions on Ammonia Concentration in Barn

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Abstract: During the winter period of research on the cattle farm in the barn with 200 dairy cows of tethered housing with a natural ventilation system, the average values of ammonia concentration were 5-8 mg/m3, which does not exceed MAC 10 mg/m3; while the natural background concentration of ammonia in the area of the farm was 0.57-0.60 mg/m3. Also, significant changes in ammonia concentration in the barn were observed during the day with a difference between day and night up to 2 times. Studies in a barn with 200 tethered dairy cows showed that external weather conditions influenced the redistribution of ammonia emitted over the volume of the room, creating zones of increased and decreased concentration. As a rule, on the windward side of the barn ammonia concentration was 20-50% lower than on the leeward side of the barn; wind intensification contributed to lower ammonia concentration in the barn.

Key words: barn; microclimate; microclimate; ammonia; weather conditions

Introduction

The realization of milk productivity of animals depends to a great extent on the creation of a favorable air environment in the barn. One of the harmful gas components of the atmosphere of the livestock room is ammonia NH3, a colorless gas with an acrid odour. It is found in atmospheric air in small concentrations. Ammonia, dissolving on the mucous membranes of the upper respiratory tract, and eyes, irritates them, in addition, it reflexively reduces the depth of breathing, therefore, and lung ventilation.

In livestock buildings, ammonia is formed by the decomposition of urine, manure, and bedding. Ammonia is released from the surface layers of manure and with evaporating moisture, with increasing air exchange over the surface of manure, the amount of released ammonia increases. It accumulates especially actively in buildings with poor ventilation and inefficient manure management system. The maximum permissible concentration of this gas is 20 mg/m3 [1, 7,9,13].

Increase of ammonia concentration by 1 mg/m3 and by 2% of moisture in the air of barns above the accepted standards is accompanied by a 1.7% decrease in milk productivity of cows with a 3.7% increase in feed costs per each unit of production [2,8,10,11], which confirms the need for constant monitoring of ammonia concentration and timely, in the necessary volume of ventilation of livestock buildings.

Materials and methods

The basis of the research is an instrumental express method with computer registration and data processing, allowing to determination of the values of controlled parameters in a given interval of real time. The analogue signal from the ammonia concentration sensor is recorded by an electronic recorder with a time interval of 5 min at the stationary unit and 10 s at the portable unit.

The results of monitoring were processed by known methods of mathematical statistics with determination of average values of the studied values for the set time periods using Excel package [3,12,].

Content of work

The research was conducted in January-February 2016-2023 on two cowsheds of different farms of the Bukhara region with tied housing of dairy complexes. In a 72 m long and 21 m wide barn with 200 dairy cows, ammonia concentration measurements were conducted at nine points according to the scheme shown in Fig. 1 using a portable unit at a height of 1.4 m above the floor during daytime. In another barn with a length of 72m and width of 18m with 150 dairy cows, the research was conducted by a stationary unit at one point in the middle of the barn (point 5 of Fig. 1) with recording of microclimate parameters in the round-the-clock mode. Manure removal in both barns is performed 2 times a day, manure removal systems do not contain manure storage tanks, it is accumulated directly in manure chutes of transporter type TSN and unloaded directly into a special tractor trailer. The ventilation system is natural through shafts in the roof ridge. During the daytime, if weather conditions allow, the gate is opened, which ensures normal conditions of animal housing.

External weather conditions such as temperature, humidity and wind speed were obtained from meteorological stations located at a distance of 13 and 26 km from the barns. It should be noted that the studied cowsheds are part of a complex of buildings, so the formation of their microclimate parameters is influenced by the mutual location of buildings, as between the buildings are formed their air flows, which in each case requires special research.

For measurements, we used an electronic device (Fig. 2) consisting of an ammonia sensor Astra-D with measurement limits 0 - 64 mg/m3, temperature and relative humidity sensor DVT-03 with current outputs 4-20 mA, archiver MSD-200. Power supply is carried out by direct current voltage of 24 V. Signals from the sensors at a given interval are fed to the MFM-200 archiver, which is an electronic device with analogue inputs and a memory card for 32 GB, which allows for a sufficiently large period of time to collect and archive information, transfer to a computer for further processing and analysis [4, 5, 6].

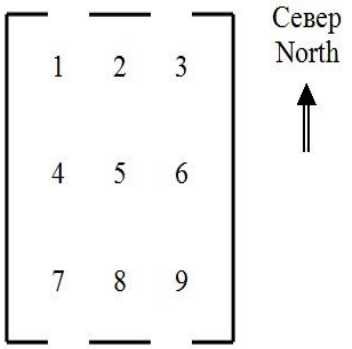


Figure 1. Scheme of ammonia concentration measurements in barns: 1-9 - measurement points by portable installation

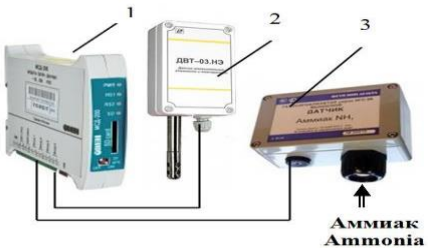


Fig. 2. Schematic diagram of the device for measuring ammonia concentration: 1 - archiver MFM-200;

2- sensor of temperature and relative humidity of air DVT-03; 3 - sensor of ammonia concentration Astra-D

ammonia concentration sensor Astra-D

The microclimate of the livestock room is a complex mixture of gases with water vapour, dust and other components, including biological ones, which are in constant motion under changing temperature conditions. Ammonia is a chemical compound included in the air gas composition, high concentration of which negatively affects the personnel and animals on the farm.

The conducted studies have shown that ammonia concentration in the barn is not constant, both during the day and in the area of the room and depends on the technology of animal housing and maintenance, ventilation system, external weather conditions.

Fig. 3 shows the graph of ammonia concentration change for 5 days in the barn with 150 tethered dairy cows. It is noted that at night time ammonia concentration is 2-3 mg/m3 higher than during the day. This is due to several conditions.

1. Inefficient operation of natural ventilation system. In winter period to ensure temperature regime excluding freezing of watering and manure removal systems, the farm staff closes ventilation ducts in order not to allow cold air to enter, which leads to increase in concentration of harmful gases and air humidity up to exceeding permissible standards.

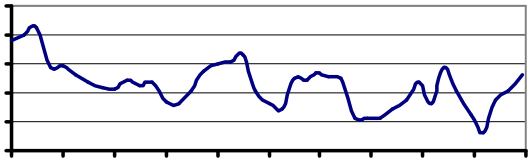
2. Decrease in ammonia concentration during the daytime is favoured by the fact that in connection with the performance of a number of technological operations the gate is opened, which provides an additional inflow of outdoor air that has a natural background concentration of ammonia in the area of the farm at the level of 0.57 - 0.60 mg/m3.

3 Ammonia is highly soluble in water, and the lower the temperature of the liquid the higher the solubility. So at a temperature of +5°C in 1 kg of water can dissolve up to 800 g of ammonia, at a temperature of +20°C only about 500 g [7]. Presence of water vapours and surfaces covered with water at temperature decrease create conditions for ammonia concentration decrease in the barn. In this regard, the temperature and humidity regime of the barn has a certain influence on the concentration of ammonia in the room.

Fig. 4 shows the graphs of change in temperature of external (1) and internal (2) air for 5 days, and Fig. 5 the change of relative humidity in the barn for the same period. The graphs show that there is a complex interdependence of ammonia concentration, temperature and relative humidity in the barn with the daily technological cycle and external weather conditions.

The ammonia content in the air is affected by the moisture content of the air by its absolute humidity. Fig. 6 shows the minimum and maximum average daily values of absolute humidity of outdoor and indoor air. So according to the results of research in 1 m3 of outdoor air contains from 2.8 to 5.0 g H_2O, and in the air of barn 5 - 10.8 g/m3. Consequently, with 1 m3 of air from the room at temperature 5 ÷ 15°C can be removed through ventilation in the form of aqueous solution up to 8 g of ammonia. This process can be controlled by changing humidity and temperature of the barn air.

Ammonia concentration, mg/m.cu.



0 12 24 36 48 60 72 84 96 108 120

1 Observation period, h

Fig. 3. Change of ammonia concentration in the barn per day

Figure 4. Change of air temperature outside

1, inside 2 of the barn over a day

Relative air humidity in the barn, %

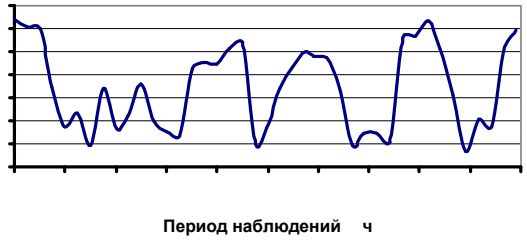


Fig. 5. Change of relative humidity in the barn over a day

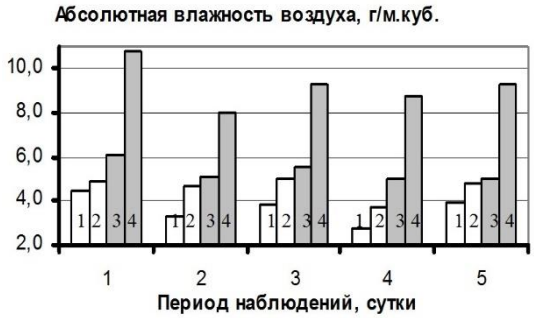


Fig. 6. Minimum and maximum values of absolute air humidity inside and

outside the barn for a day, where column 1, 2-

outside the barn; column 3,4 - inside the barn

External weather conditions also influence the distribution of ammonia in the barn. Due to the fact that livestock buildings have very large dimensions tens of metres in length and width, more than 4 metres in height, the concentration of harmful substances, including ammonia has an uneven distribution. As studies show, the difference between separate zones of the barn on ammonia can be up to 2 times.

Factors influencing the distribution of ammonia in the room are volume-planning solutions, technology of keeping and servicing of animals, feeding, climatic conditions.

Livestock buildings have a significant infiltrating capacity, creating additional to ventilation systems, significant air exchange through the non-density of structural elements of buildings. Therefore, the direction and strength of the wind blowing the barn, contribute to the redistribution of ammonia in the volume of the room, creating zones of increased and decreased concentration.

Fig.7, 8, 9, 10 show the distribution of ammonia concentration (according to the scheme of Fig.1), in a barn with 200 tethered dairy cows at different wind directions. In Fig. 7, the wind direction is southeast, speed is 5 m/s, the average value (for three points) of ammonia concentration in the barn on the windward side is 2.4 mg/m3, and on the leeward side is 3.8 mg/m3. The outside air temperature is about -3.0°C and the average air temperature in the barn is +3.5°C.

Figure 8 shows the distribution of ammonia under south-west wind with a speed of 2 m/s. Here it can be seen that the concentration of ammonia is higher on average than in Fig.7, because the wind speed is 2.5 less and the infiltration of the room and the efficiency of the natural ventilation system is lower. At the same time, the trend of lower ammonia concentration on the windward side is maintained. The windward side of the barn has an average ammonia concentration of 4.6 mg/m3, the leeward side 5.9 mg/m3. The highest ammonia concentration of 8.46 mg/m3 is observed in the central part of the barn. Outside air temperature is about -5°C, average air temperature in the barn is +11.5°C.

Ammonia concentration, mg/m.cube

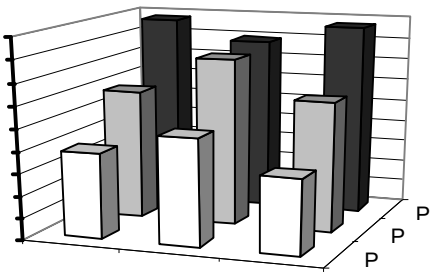


Figure 7. Ammonia concentration in the barn at

S-W wind 5 m/s

Ammonia concentration, mg/m. cubic metre.

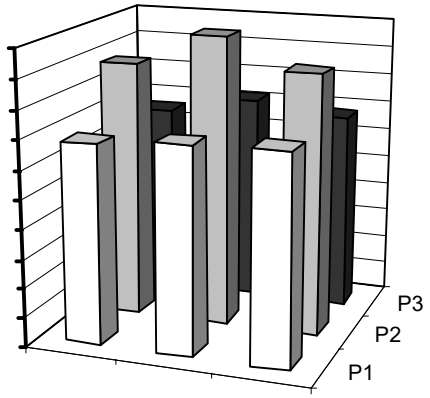


Figure 8. Ammonia concentrations in the barn under a

South-West wind of 2 m/s.

Figure 9 shows the ammonia concentration under north-east wind with a speed of about 2 m/s. From the graph, it can be seen that on the windward side, the average ammonia concentration is 1.4 mg/m3 lower than that on the leeward side with 9.92 mg/m3 at the midpoint. The outside air temperature is about -10.0°C and the average air temperature in the barn is +7.8°C.

At north-west wind with a speed of 1-2 m/s (Fig.10) the average values from both windward and leeward sides are approximately equal to 6.7 mg/m3 with 5.94 mg/m3 in the middle part of the barn, which is probably explained by the influence of other buildings of the livestock complex on the formation of air flow. The outside air temperature is about 8.0°C, the average air temperature in the barn is +6.9°C.

Concentration of ammonia, mg/m. cubic metre.

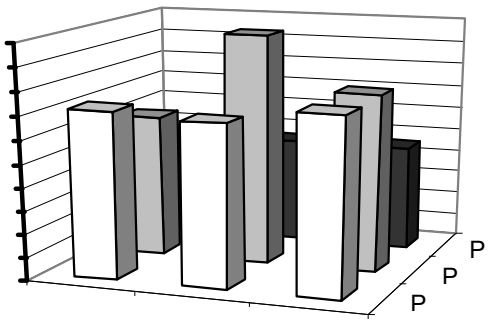


Figure 9. Ammonia concentration in the barn at 2 m/s C-W winds

Ammonia concentration, mg/m.cu.

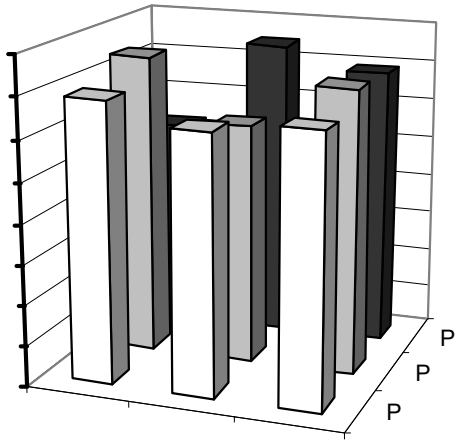


Figure 10. Ammonia concentrations in the barn in the following conditions

NW wind 1-2 m/s

Conclusions

1. During the winter period of research at the cattle farm in the barn with 150 dairy cows of tethered housing, with natural ventilation system, the average values of ammonia concentration were 5-8 mg/m3, which does not exceed the maximum permissible norm of about 10 mg/m3. The natural, background concentration of ammonia in the area of the farm is 0.57 - 0.60 mg/m3.

2 Ammonia is highly soluble in water depending on temperature, and the lower the temperature of the liquid, the higher the solubility. The presence of water vapour and condensate with decreasing temperature create conditions for decreasing ammonia concentration in the barn. With one cubic metre of air from the room at temperature 5 ÷ 15°C can be removed through one metre of ammonia.

15°C can be removed through ventilation in the form of aqueous solution up to 8 g of ammonia.

3. Significant changes of ammonia concentration in the barn are observed during the day. The difference in concentration level between day and night can reach up to 2 times depending on the technology of animal housing and maintenance, ventilation system, external weather conditions.

4. At large volumes and peculiarities of volume-planning and technological solutions in barns create conditions for uneven distribution of ammonia, including due to the impact of external weather conditions. The direction and strength of the wind blowing the barn with a population of 200 dairy cows tied housing, as well as the temperature of the outside air contribute to the redistribution of the released ammonia in the volume of the room, creating zones of increased and decreased concentration. As a rule, on the windward side of the barn ammonia concentration is 20-50% lower than on the leeward side. Increase of wind favours reduction of ammonia concentration in the barn.

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