INVESTIGATION OF WATER EVAPORATION FROM CATTLE MANURE

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Abstract. One of the important factors that influence the physiological state and productivity of cows is humidity in the livestock area. It is known that 10-15 % of water vapor with respect to the total amount of vapor emissions is released from cattle manure. The aim of this study was to identify the dependence of the amount of moisture released from the stored manure on its humidity, storage time and temperature. It was found that under natural manure moisture of 85-86 % and air temperature of 26-28 ºC, the most intense release of water vapor from manure occurs in the first 5-6 hours, then the emission process stabilizes. The absolute humidity in the laboratory installation increases from 16.5 to 32.8 g·m^{-3}.

Keywords: barn inside climate, cattle manure, water vapor, emissions.

Introduction

Optimum microclimate in livestock buildings contributes to more complete realization of the genetic potential of animals, disease prevention, increased natural resistance, as well as longer life of buildings and installed equipment [1]. Ensuring optimal indoor climate is achieved by compliance with evidence-based values forming its environmental factors (temperature, humidity, air velocity, etc.), which are summarized and set for each type of animals in the relevant engineering standards of livestock enterprises.

Microclimate is formed by mixing the outdoor (clean) air with the release of animal waste products. Study of microclimate dynamics on a dairy farm remains a problematic and urgent task, but it has become particularly acute owing to the growth of productivity of animals that require a special approach to the housing conditions. The main difficulty in studying the dynamics of micro-climatic conditions is the imperfection of the measurement methods and means of animal habitats parameters.

The inside air of animal houses has more water vapor than in the outside atmosphere. Apart from outside air moisture (about 10-15 %), the water vapors in the indoor air coming from the floor, feeding trough, drinking-bowl, etc. In large amounts (up to 75 %), it is released from the animal skin, with the mucous membranes of the respiratory tract and oral cavity, as well as with exhaled air. Thus, under optimal indoor air temperatures a cow weighing 400 kg releases to 8.7-13.4 kg of water vapors per day. Approximately 10-15% the total amount of water vapors from animals is released from the cattle manure [2].

Saturated air, under both low and high temperatures, is equally harmful to animals. Long-term keeping of animals in wet premises with high relative humidity is accompanied by lower appetite, nutrient uptake, weight gain, increased morbidity and reduction of juvenile mortality. The optimum humidity for cattle is considered to be 75...85 %. Under such conditions, good animal performance and high productivity is provided.

Materials and methods

The purpose of this study was to monitor the dynamics of water vapor of release from animal manure during its storage and removal from the barn, an experiment was carried out using the static methods of experimental design. When planning a three-factor experiment, the three most significant and linearly independent factors are air temperature, air velocity, humidity of manure. They are controllable factors. Their limit values are found in the analysis source of literature. In order to construct a plan-matrix the experiment conducted encoding factors for translation of natural factors in dimensionless quantities. The optimization criterion was adopted by the concentration of airborne water vapor and harmful gases. Each experiment was performed in triplicate. [3]

To investigate the emission of gases and water vapor, which are released from cattle manure, IEEP developed a laboratory setup (Figure 1), which is an airproof chamber 1 where a metal frame 2 is placed. On the frame temperature, humidity and air velocity 3 the data are fixed from which via the electronic recorder 9 recorded on the computer. Under the chamber a tray for the heating and cooling element is placed. Thermoelectric flexible cable with the capacity of 0.08 kW is used as a heating element. The cooling element is based on a thermoelectric module. The test material 7 (manure) is loaded into the pan 6, which is installed in the chamber. The air velocity is regulated by a fan 8.

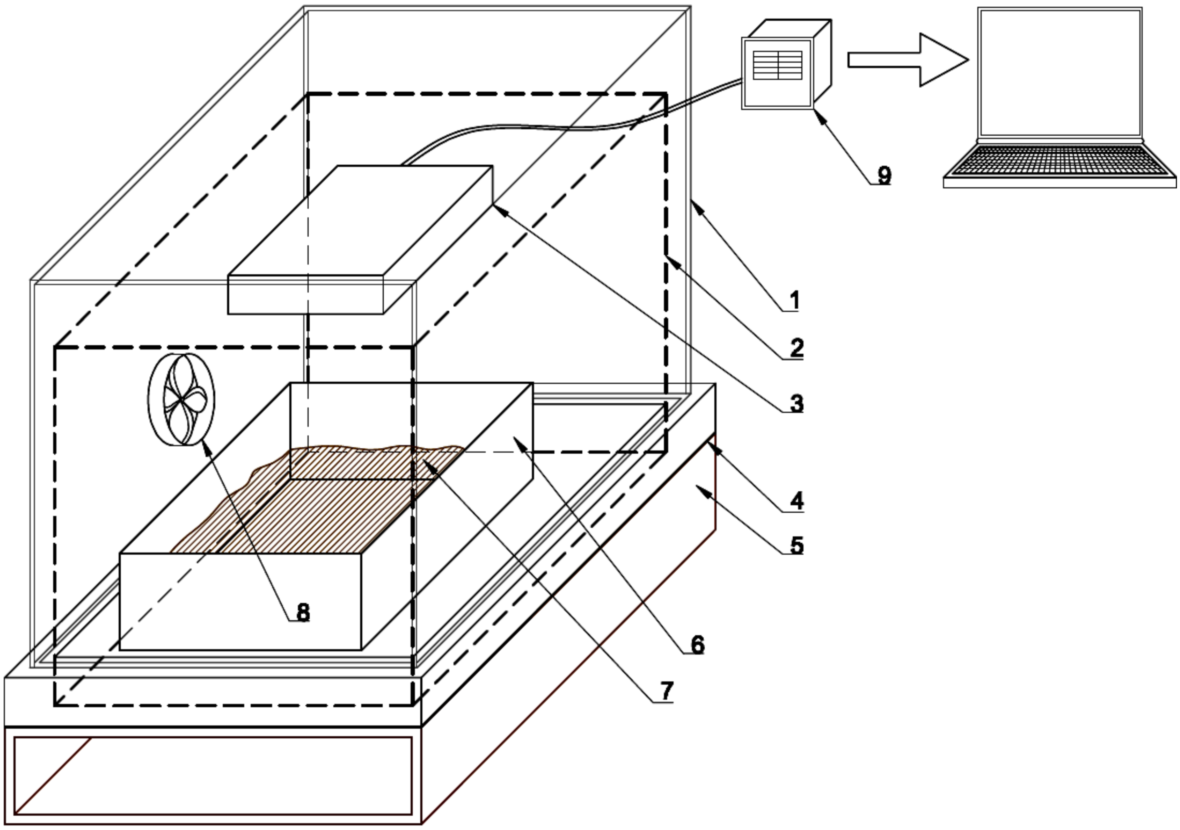

Fig. 1. **Scheme of laboratory setup for studying the dynamics of selection harmful substances from cattle manure:** 1 – airproof chamber; 2 – frame for mounting sensors; 3 – sensors; 4 –foundation installation; 5 – tray for heating (cooling) element; 6 – tank for the test material; 7 – test material; 8 – fan with variable speed; 9 – electronic recorder of signals from sensors

Intensity dynamics of moisture and gas release from the manure under different conditions was determined in the laboratory in real time. The initial parameters were set according to the experience of the plan-matrix. To obtain accurate mathematical models in the experiments a randomized matrix is used that is generated using STATGRAPHICS Centurion XV. Results of monitoring are carried out by known methods of mathematical statistics to determine the mean value, the standard deviation of the test values for the specified time periods. The sensors used for the study: temperature and humidity sensor "ДТВ-02" with a sensitivity of ±1.0 ºC; air velocity transducer "E-75" with a sensitivity of ± 0.05 $m \cdot s^{-1}$; carbon dioxide sensor "EE-85" with a sensitivity of ±50 ppm; ammonia concentration sensor "ADT-23-3408" with a sensitivity of ±1%; hydrogen sulfide sensor "ADT-53-1197" with a sensitivity of ±2 $mg \cdot m^{-3}$. The average duration of the experiments was T = 15...20 hours, natural manure relative humidity W = 84...86 %; mass of manure – one kg.

Results and discussion

As a result of the studies, it was found that the process of separation of water vapor from manure occurs in the first 5-6 hours, then it keeps at the same level (Fig. 2). Then this water vapor concentration reaches its peak value at about 7 hours, and then decreases slightly. Relative humidity is described by the regression equation of the third order:

$$W = 0.0163T^3 - 0.5491T^2 + 5.7353T + 81.726$$

$$R^2 = 0.9762.$$

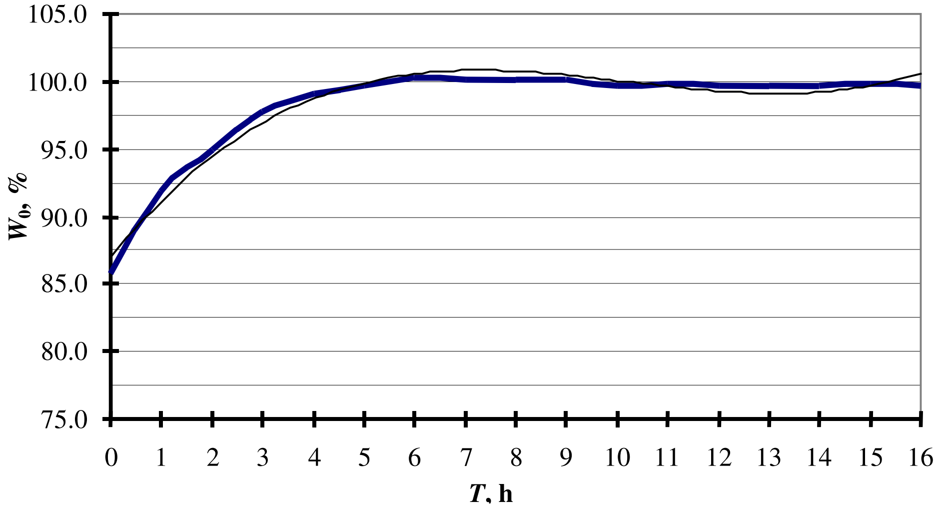

Fig. 2. **Emission rate of water vapor**

Absolute humidity gradually increased throughout the experiment and reached within 9 hours – 32.8 g·m^{-3} (Fig. 3). The air temperature in the laboratory installation ranged from 26 to 28 ºC. The amount of moisture release during the test did not exceed 1.3 g (Fig. 4).

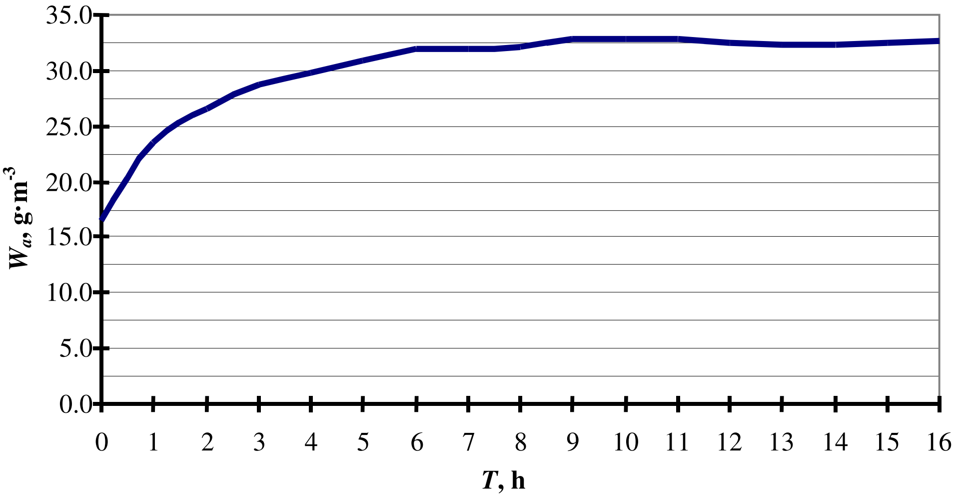

Fig. 3. **Dependence of absolute humidity on the time of water evaporation from cattle manure**

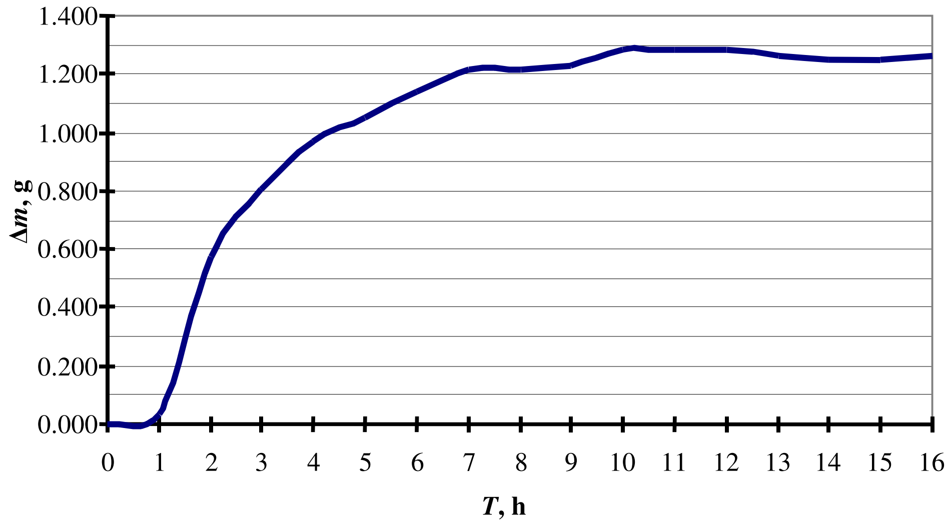

Fig. 4. **Dependence of moisture evaporation from cattle manure on time**

Conclusions

1. The experimental studies show that the relative humidity in the chamber of the laboratory installation reaches its maximum value (100 %) within 6 hours, air temperature of 26 ºC.
2. The absolute humidity during the experiment reached the maximum value (32.8 $g \cdot m^{-3}$) within 9 hours under the temperature growth up to 28 ºC.
3. The amount of moisture, which was released from one kg of manure during the experiment, was about 1300 mg.
4. Further studies will clarify the process of water vapor emissions from cattle manure that will improve the animal welfare and increase their productivity.

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