CARBON DIOXIDE EMISSION FROM CATTLE MANURE REMOVED BY SCRAPERS

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Abstract. Prolonged exposure of human and animal organisms to carbon dioxide can cause chronic poisoning, various diseases, and reduction in productivity. The normative permitted content of carbon dioxide in the indoor air of cattle premises is 0.25 %. Carbon dioxide emission from cattle manure when removed by a scraper-chain conveyor was studied in a typical barn for 200 head with the tied housing system, natural ventilation and 11 $t \cdot d^{-1}$ manure output. The study included continuous measurements of carbon dioxide concentration before, during and after manure removal. In the experiment, CO_2 concentration was measured just above the manure canal and in the opposite ends of the barn – near the milk collecting unit and manure accumulation tank with the unloading conveyor. For study purposes IEEP designed a mobile unit for microclimate monitoring. The study revealed that during manure removal, which lasted for 15-17 minutes, the CO_2 concentration increased 1.3 to 1.5 times in different parts of the barn. When manure removal was completed, the concentration of carbon dioxide decreased and after 6 to 10 minutes, returned to initial values. This short-term increase in CO_2 concentration, even in case the permissible values were slightly exceeded, was not dangerous for the animal care personnel and had no adverse effect on animals and their productivity. The study revealed the dependences of CO_2 emissions; relevant mathematical models were created.

Keywords: barn, microclimate, carbon dioxide, manure removal.

Introduction

According to FAO, the livestock industry accounts for 18 % of greenhouse gas emissions. An equivalent gas, which causes the greenhouse effect, is carbon dioxide. A farm with 100 dairy cows releases into the atmosphere 0.279 m^3 of carbon dioxide per hour. High concentration of carbon dioxide pollutes the environment and is harmful to both animals and livestock handling personnel. Long-term exposure of animals to the air containing above 1 % of carbon dioxide may cause chronic intoxication, lower productivity and disease resistance [1; 2]. According to the legislation of the Russian Federation the normative permitted content of carbon dioxide in the indoor air of cattle premises is 0.25 %, or 2500 ppm. Manure accumulated on the farm for several hours is a significant source of harmful emissions, carbon dioxide included. The intensity of CO_2 emissions in the atmosphere of the barn is greatly increased when the manure is removed [3]. Therefore, reduction of carbon dioxide emissions from manure in the barn is very important and interrelated with the animal housing and caring practices.

Materials and methods

The study was conducted in August 2016 in the Leningrad Region, in a four-row cow barn for 200 head and tied housing system (Fig. 1). The barn had 21 m x 72 m dimensions and natural ventilation, with the air flow coming through the side windows and the gateway at the end of the building and exhausting through the shaft in the roof. Manure was removed by two ТСН-2Б conveyors three times a day, immediately loaded in a special vehicle (Fig. 2) and delivered to the manure storage. The chain-and-scraper conveyor ТСН-2Б with a capacity up to 4.5 $t \cdot h^{-1}$ is designed to remove manure from the livestock buildings with up to 100-110 cows. The animals in the barn were housed on the saw dust bedding. The average daily output of manure was up to 11 t, with the relative humidity being 85-86 %. The cows were milked three times a day with a linear milking plant – "milk delivery line", with the milk collecting unit being located directly at the end of the barn. Outdoor climatic conditions of the barn were as follows: temperature of 16-18 ºC, relative humidity of 78-82 %, East wind of 1-2 $m \cdot s^{-1}$, the content of carbon dioxide (the background concentration) at 470-490 ppm.

To measure the inside climate parameters a mobile unit was designed (Fig. 3), which included a sensor of carbon dioxide concentration level EE-85 with an accuracy ± 50 ppm +3 %. The analog signal of 4-20 mA was supplied to the logger with an interval of 10 s, where it was archived on the memory card and then processed on a computer for further analysis. The output parameters were displayed in the form of EXCEL tables [4; 5].

Fig. 1. **General view of the barn**

Fig. 2. **Loading of manure into the vehicle**

The study procedure of carbon dioxide emissions consisted of continuous measurements of carbon dioxide concentration before the manure removal (the conveyor was not working), during the conveyor operation and after the manure removal process was completed, in other words during the stabilisation period of CO_2 concentration to the initial level. Concentrations were measured directly over the manure removal conveyor (Fig. 4) in different points of the barn.

Fig. 3. **General view of mobile unit for microclimate parameters measuring**

Fig. 4. **Measurement of CO_2 concentration in the process of manure removal**

Results and discussion

The in-barn climate formation is a complex process dependent on many factors, both external and internal, including the methods of accumulation and removal of animal waste [6].

The process of carbon dioxide emission from the cattle manure in the barn during its removal may be divided into three periods shown in Fig. 5. The chart shows the average values of CO_2 concentration changes within one minute. The variation in this time period did not exceed ± 5 ppm.

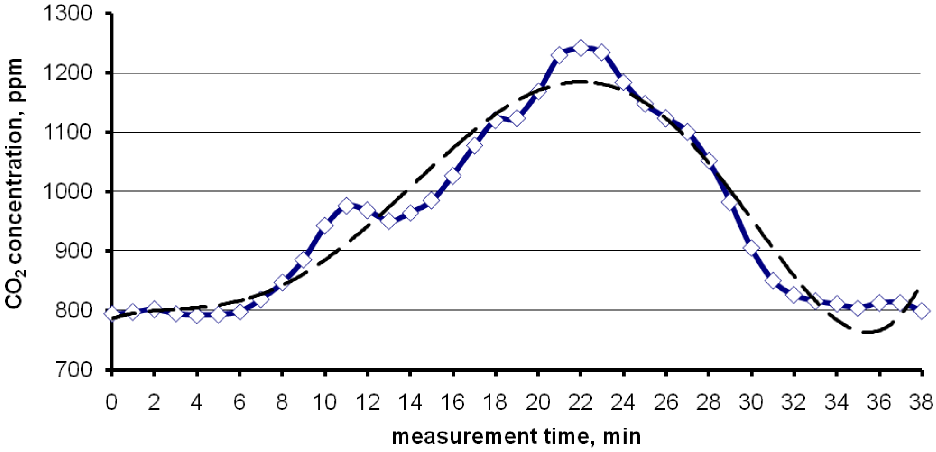

Fig. 5. **Dependence of CO_2 concentration in the barn from the stage of manure removal:**
______ experimental data; --------- approximated data

The first period is before switching on the conveyor. In Fig. 5 this time is from 0-6 minutes on the horizontal scale. During this period the concentration of carbon dioxide is stable and meets the current technological conditions; the level is of about 800 ppm with small deviations.

The second period starts on the 7th minute, when the conveyor begins to work. The process of manure removal lasts for up to 24 minutes (Fig. 5), and CO_2 concentration increases from 800 to 1230 ppm, or by 53 %. It should be noted that the concentration of carbon dioxide begins to go down even before the conveyor stops owing to smaller amount of transported manure.

The third is a period of CO_2 concentration lowering and stabilisation on the initial level of about 800 ppm. The third period lasts for 8 to 10 minutes. It should be noted that the studies were conducted in summer with maximum ventilation (open windows and doors of the barn). So in winter, under significant reduction of air exchange, the dependences will be somewhat different. In addition, the wind direction and strength also affect the amount of air exchange; therefore the time to stabilise the level of carbon dioxide concentration may vary significantly [7].

Based on the study results a mathematical model (1) was created describing the dependence of CO_2 concentration in the barn from the time of manure removal:

$$CO_2 = -0.0028T^4 + 0.0545T^3 + 1.0324T^2 - 0.6602T + 770.12,\ R^2 = 0.9633 \quad (1)$$

where CO_2 – concentration of carbon dioxide in the air, ppm;
T – measurement time, min;
R^2 – multiple correlation coefficient.

Fig. 6 and 7 show the graphs of the CO_2 concentration in the second and third periods of manure removal near the milk collecting unit and the manure accumulation tank. Their specific feature is that near the milk collecting unit (Fig. 6) the initial level of CO_2 concentration is significantly lower than that near the manure accumulation tank (Fig. 7); this is associated with a different amount of manure in these parts of the barn.

In Fig. 6 the work of manure removal conveyor in the final stage is presented by the time period of 0 to 2 minutes; then begins the third period – stabilisation of carbon dioxide concentration near the milk collecting unit that lasts for 6-7 minutes. These processes are described by model (2):

$$CO_2 = 0.7739T^3 - 11.439T^2 + 23.29T + 793,\ R^2 = 0.989 \quad (2)$$

where CO_2 – concentration of carbon dioxide in the air, ppm;
T – measurement time, min;
R^2 – multiple correlation coefficient.

In Fig. 7 the work of manure removal conveyor in the final stage is presented by the time period of 0 to 3 minutes; then begins the third period – stabilisation of carbon dioxide concentration near the manure accumulation tank that lasts for about 7 minutes. These processes are described by model (3):

$$CO_2 = 1.0918T^3 - 19.587T^2 + 53.41T + 1015,\ R^2 = 0.982 \quad (3)$$

where CO_2 – concentration of carbon dioxide in the air, ppm;
T – measurement time, min;
R^2 – multiple correlation coefficient.

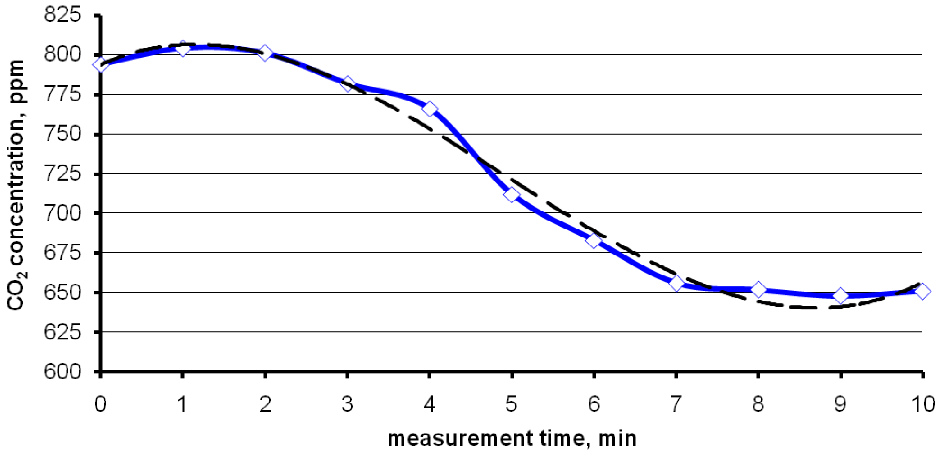

Fig. 6. **CO_2 concentration in the process of manure removal near the milk-collecting unit:**
_______ experimental data; --------- approximated data

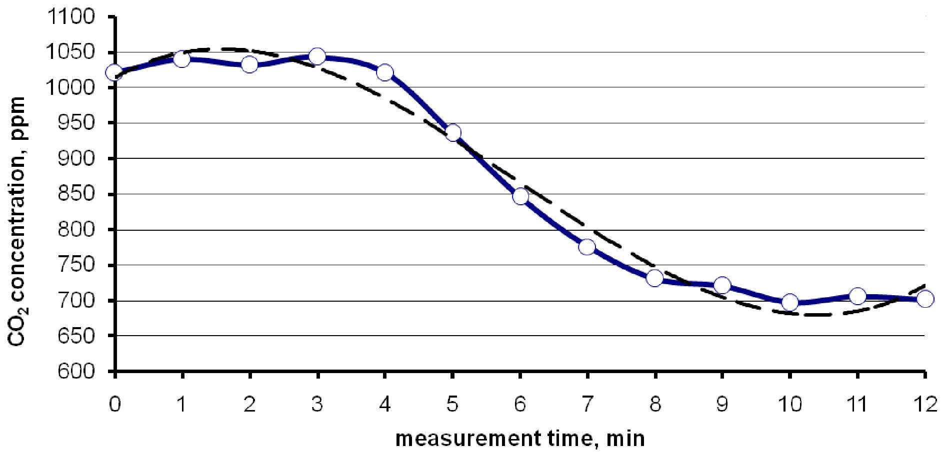

Fig. 7. **CO_2 concentration in the process of manure removal near the manure accumulation tank:**
_______ experimental data; --------- approximated data

Conclusions

Removal of manure by the chain-and-scraper conveyor of TCH-2Б type is the most common technology on cattle farms in Russia. With this technology manure is accumulated directly in the canal, where the chain with scrapers is located, and with the frequency of three times per day it is collected in the accumulation tank or discharged directly into a vehicle and transported to the place of disposal.

In the process of manure accumulation in the manure canals there is a constant emission of carbon dioxide and a particular microclimate is formed dependent on the number of animals in the barn, the design features of the ventilation systems or the outdoor climatic conditions. When the manure removal conveyors start to move and mix the manure, the carbon dioxide emissions intensify and their concentration in the animal house increases.

During the manure removal, which lasts for 15-17 minutes, the CO_2 concentration increases 1.3 to 1.5 times in different parts of the barn. When manure removal is completed, the concentration of carbon dioxide decreases; and after 6 to 10 minutes returns to initial values. Such a short-term increase in the CO_2 concentration, even in case the permissible values are slightly exceeded, is not dangerous for the animal care personnel and has no adverse effect on animals and their productivity.

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