INFLUENCE OF HOUSING TECHNOLOGY ON DUST LEVEL IN COWSHEDS

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Abstract. The aim of this paper is to present the results of microclimatic research focused on dust pollution in buildings of different housing technologies used for breeding of cattle. The constructions selected for this research include the old cowshed with stanchion housing and pipeline milking system inside the cowshed on the tying stalls with straw bedding, but also very modern building with loose housing technology without straw bedding, equipped with milking robots and mobile feeding technology. The results are compared with a reconstructed cowshed used for housing of fattening cattle and with dust pollution in the area near to the shed used for storage of straw. In the frame of this research the concentration of air dust was measured by exact instrument DustTRAK II Model 8530 aerosol monitor. Using the special impactors the PM_1, $PM_{2.5}$, PM_4, PM_{10} size fractions were also measured. The results indicate that the OEL value of 6,000 $\mu g \cdot m^{-3}$ was never exceeded. Total dust concentration 238.5 $\mu g \cdot m^{-3}$ was significantly higher in the shed for straw storage than in the other buildings. The limit value of PM_{10} (50 $\mu g \cdot m^{-3}$) applicable to the external environment has been exceeded in both buildings with straw bedding. The mean values of PM_{10} measured in the old cowshed (PM_{10} = 69.8 $\mu g \cdot m^{-3}$) and the building for fattening of beef cattle (PM_{10} = 74.0 $\mu g \cdot m^{-3}$) are significantly higher than PM_{10} values measured in the new cowshed without straw or in the hayloft for straw storage. Differences between the concentrations of fractions PM_4 and $PM_{2.5}$ in all tested buildings are statistically significant. The biggest concentration of these fractions was in the cattle houses with straw bedding. The limit value of $PM_{2.5}$ (25 $\mu g \cdot m^{-3}$) has been exceeded in all measured buildings. The mean values of PM_1 measured in both cattle houses with straw bedding are significantly higher than the PM_1 values in the cowshed without straw or in the hayloft for straw storage.

Keywords: cattle, dust fraction, measurement, straw bedding.

Introduction

Dust level is one of the factors that affect the global environment in which people, animals and plants spend entire life. The protection of people against high dust levels is solved mainly in terms of working conditions in mines, quarries, factories, workshops, transport systems and other workplaces, where technological dust is produced. The problems of dust pollution and protection against dust are the topic of important hygienic standards and regulations [1; 2].

The attention to dust is paid in many scientific articles and papers, e.g. [3-12]. The methodology and the results of measurements correspond to the research topic, especially to factors that are specific to studied space. There are studied, e.g., the impact of outdoor particulates transferred into the indoor space, the impact of processed and handled material, the influence of floor surface, particles released from special plastic materials used indoor, dust produced in animal farms etc.

In agriculture, there is among other environmental problems a large amount of organic dust during the grain harvest and by grain handling [13]. Dust pollution is a problem also in many animal houses, where except livestock the source of dust is the organic material used as a fodder, concentrate feed or bedding litter [14].

Problems of dust pollution in cowsheds are included in the paper [15]. The authors recognised that concentrations and particle count strongly depend on operation. Therefore, they measured in the cowsheds under different conditions and, e.g., concentration of PM_{10} reached the value of 2.2 $mg \cdot m^{-3}$ during the manual distribution of flour in the cowshed.

Dust particle PM_{10} concentration inside the cowshed was from 31 to 112 $\mu g \cdot m^{-3}$ during the experimental period according to the research published in [16]. The mean recorded concentrations of total dust concentration measured by the researcher in uninsulated loose housing cowsheds in Estonia and published in [17] were from 205 to 270 $\mu g \cdot m^{-3}$, PM_{10} from 65 to 121 $\mu g \cdot m^{-3}$ and $PM_{2.5}$ from 18 to 46 $\mu g \cdot m^{-3}$.

The aim of this paper is to present results of microclimatic research focused on dust pollution in buildings of different construction and different housing technologies used for breeding of cattle, mainly cows. The results are compared with a reconstructed cowshed used for housing of fattening cattle and with dust pollution in the area near to a large, partly opened building, used for storage of straw.

Materials and methods

This research work and measurements were carried out in an agricultural company situated in the south part of the Czech Republic. For research measurements buildings of different construction and different housing technologies used for breeding of cattle, mainly cows, were chosen. The constructions selected for this research include a very modern cowshed (A), which is not insulated, with natural ventilation, partly opened walls, with loose housing technology without straw bedding, equipped with milking robots and mobile feeding technology, but also an old cowshed (B) with stanchion housing and pipeline milking system on the tying stalls with straw bedding inside the cowshed. The construction is massive with brick walls and natural ventilation. The original forced ventilation is not functioning. The results are compared with a reconstructed cowshed (C), which was modernised and completely changed the technological equipment suitable for beef cattle fattening in group pens with littered lying areas and with dust pollution in the area near to the hayloft (D), where straw is stored in big bales. The building is partly made from concrete and steel construction with insulation panels. The ventilation is natural through the side wall openings and a ridge roof gap.

The measurements were carried out during the summer period with average external temperature 24.8 ± 6.7 ºC and relative humidity 51.3 ± 19.2 %. In the frame of this research the concentration of air dust was measured by exact instrument DustTRAK II Model 8530 aerosol monitor. Using the special impactors the PM_1, $PM_{2.5}$, PM_4, PM_{10} size fractions were also measured.

According to the type of material, dust has specific characteristics, to which the properties respond. According to [1] the type of dust (grain and straw) produced by cereals has irritating effects. For this type of dust the prescribed Occupational Exposure Limits (OEL) are permissible exposure limits of total dust concentration 6,000 $\mu g \cdot m^{-3}$. Measured dust is not aggressive, therefore, as a criterion for comparative evaluation of the measured values also the limit level of outdoor dust can be used. According to [2] PM_{10} limit value in 24 hours is 50 $\mu g \cdot m^{-3}$, 1 year limit value is 40 $\mu g \cdot m^{-3}$ and 1 year limit value of $PM_{2.5}$ is 25 $\mu g \cdot m^{-3}$. The 90 data of total dust concentration as well as of each fraction size in each measured place were collected. The obtained results of measurements were processed by Excel software and verified by statistical software Statistica 12 (*ANOVA and TUKEY HSD Test*). Different superscript letters (a, b, c, d) mean that the values in common are significantly different from each other in the row (*ANOVA*; *Tukey HSD Test*; $P \leq 0.05$), e.g., if there are the same superscript letters in all columns, it means the differences between the values are not statistically significant at the significance level of 0.05.

Results and discussion

The mean values and standard deviations (SD) calculated from the results of measurements of the total dust concentration and concentrations of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 measured in the new cowshed (A) with loose housing technology and without straw, old cowshed (B) with stanchion housing on tying stalls with straw bedding, reconstructed fattening house (C) for beef cattle in group pens with littered lying areas and hayloft (D) for straw storage in big bales are summarized in Table 1, where different letters (a, b, c, d) in the superscript are the sign of high significant difference between the values (columns) in one row (*ANOVA*; *Tukey HSD Test*; $P \leq 0.05$).

Table 1

Total dust concentration and fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in the farm buildings

Dust fraction	A	B	C	D
Total, $\mu g \cdot m^{-3}$ ± SD	58.2 ± 10.9^{a}	108.1 ± 27.0^{a}	76.2 ± 13.0^{a}	238.5 ± 213.3^{b}
PM_{10}, $\mu g \cdot m^{-3}$ ± SD	46.5 ± 3.6^{a}	69.8 ± 38.3^{b}	74.0 ± 9.4^{b}	42.3 ± 8.0^{a}
PM_4, $\mu g \cdot m^{-3}$ ± SD	44.3 ± 6.9^{a}	68.2 ± 15.0^{b}	52.4 ± 2.5^{c}	33.8 ± 1.1^{d}
$PM_{2.5}$, $\mu g \cdot m^{-3}$ ± SD	40.3 ± 1.4^{a}	53.3 ± 10.2^{b}	44.6 ± 1.7^{c}	33.0 ± 1.8^{d}
PM_1, $\mu g \cdot m^{-3}$ ± SD	33.2 ± 1.1^{a}	38.5 ± 5.0^{b}	36.9 ± 0.1^{b}	32.5 ± 2.7^{a}

The results indicate that the OEL value of 6,000 $\mu g \cdot m^{-3}$ was never exceeded. Total dust concentration 238.5 $\mu g \cdot m^{-3}$ was significantly higher in the shed D for straw storage than in the other buildings. Rather high is also the total dust concentration in the cowshed B. The dust pollution is high because of the frequent use and manipulation with straw inside the buildings. It corresponds with the

result presented in [15]. The solution for dust reduction is sufficient ventilation. The modern cowsheds are usually equipped with the technological equipment, which needs lower quantity of straw bedding. The most important parameters of dust pollution are PM_{10}, $PM_{2.5}$ and PM_1. The mean values of PM_{10} and $PM_{2.5}$ exceeded the limits applicable to the external environment.

The limit value of PM_{10} (50 $\mu g \cdot m^{-3}$) has been exceeded in the cowshed with straw bedding B and in the building C for fattening of beef cattle. The mean values of PM_{10} measured in both buildings with straw bedding B (PM_{10} = 69.8 $\mu g \cdot m^{-3}$) and C (PM_{10} = 74.0 $\mu g \cdot m^{-3}$) are significantly higher than PM_{10} values measured in the cowshed A without straw or in the hayloft D for straw storage. The results are similar to the results and conclusions in [16; 17]. Differences between the concentrations of fractions PM_4 and $PM_{2.5}$ in all tested buildings are statistically significant. The biggest concentration of these fractions was in the cattle houses B and C with straw bedding. The limit value of $PM_{2.5}$ (25 $\mu g \cdot m^{-3}$) has been exceeded in all measured buildings.

The mean values of PM_1 measured in both cowsheds with straw bedding B (PM_1 = 38.5 $\mu g \cdot m^{-3}$) and C (PM_1 = 36.9 $\mu g \cdot m^{-3}$) are significantly higher than PM_1 values measured in the cowshed A without straw (PM_1 = 33.2 $\mu g \cdot m^{-3}$) or in the hayloft D for straw storage (PM_1 = 32.5 $\mu g \cdot m^{-3}$).

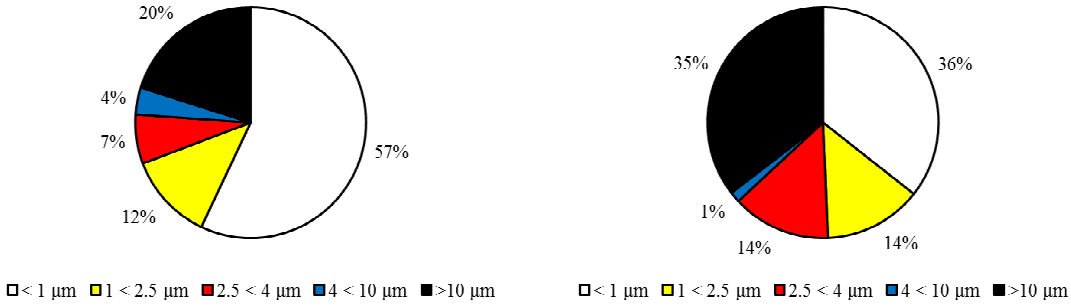

Fig. 1. **Percentage of dust fractions in new cowshed A (left) and B (right)**

The left part of Fig. 1 presents the graph of the size distribution of dust particles in the new modern cowshed A without straw bedding. The main parts of dust are the particles smaller than 1 µm (PM_1 = 57 %) and 20 % of total dust are the large particles bigger than 10 µm. The air contains also quite big percentage (12 %) of dust particles bigger than 1 µm and smaller than 2.5 µm. Particles between 2.5 µm and 10 µm create the rest of dust pollution. The right part of Fig. 1 presents the graph of the size distribution of dust particles in outside air in the old cowshed B with straw bedding. Dust fractions are rather uniformly distributed between the smallest particles (PM_1 = 36 %), the biggest particles (35 % particles bigger than 10 µm) and the rest (29 %) are particles bigger than 1 µm and smaller than 10 µm. The left part of Fig. 2 presents the graph of the size distribution of dust particles inside the shed C used for fattening of beef cattle. Dust contains main part (49 %) of dust the particles smaller than 1 µm (size fraction PM_1) and 28 % are the particles bigger than 4 µm and smaller than 10 µm. There are 10 % of particles bigger than 1 µm and smaller than 2.5 µm and 10 % of particles bigger than 2.5 µm and smaller than 4 µm. There are only 3 % particles bigger than 10 µm.

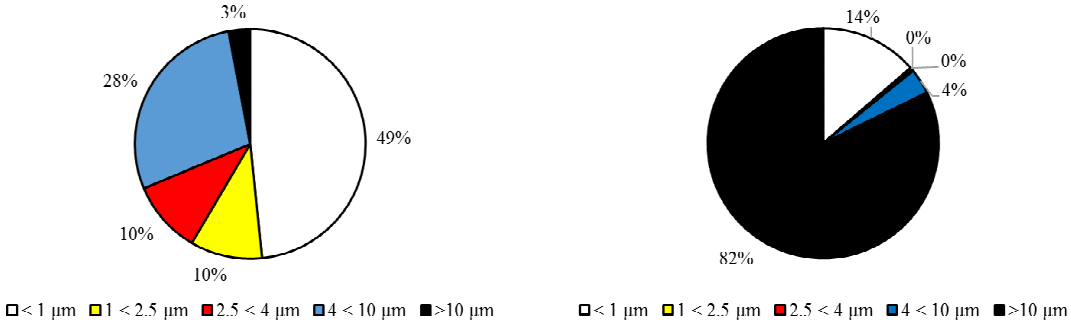

Fig. 2. **Percentage of dust fractions in fattening house C of beef cattle (left) and dust fractions near straw storage D (right)**

Completely different is the distribution of the size of dust particles near to the shed D for storage of straw on right part of Figure 2. There are 82 % of the biggest dust particles (bigger than PM_{10}), 14 % the smallest PM_1 and only 4 % particles bigger than 4 µm and smaller than 10 µm.

Conclusions

1. The housing technology with straw bedding causes significantly higher total dust pollution (from 63 to 135 $\mu g \cdot m^{-3}$) than the housing systems without straw (from 47 to 69 $\mu g \cdot m^{-3}$).
2. The mean values of PM_{10} measured in the buildings with straw bedding (from 70 to 74 $\mu g \cdot m^{-3}$) are significantly higher than mean PM_{10} values measured in the cowshed without straw (46.5 $\mu g \cdot m^{-3}$).
3. Very high average total dust pollution (238.5 $\mu g \cdot m^{-3}$) is inside the sheds used for straw, nevertheless, the concentration of PM_{10} from 34 to 50 $\mu g \cdot m^{-3}$ is in the level similar to the other farm buildings.
4. People working in farm buildings during the manipulation with straw should control sufficient ventilation and use individual respiratory protective equipment (protective masks, filters etc.).

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