DUST POLLUTION IN BUILDINGS FOR CHICKEN FATTENING

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Abstract
The aim of this paper is to present the results of dust measurement in two poultry houses. Total dust concentrations measured by Dust-Track aerosol monitor were 1,425.4 ± 270.8 and 1,476.4 ± 219.4 μg·m^{-3}. Using impactors PM_1, $PM_{2.5}$, PM_4, PM_{10} size fractions were measured. The majority of dust particles inside poultry houses created the particles bigger than 4 μm (83 % hall A, 82 % hall B). The biggest percentage (50 % hall A, 43 % hall B) of dust were the particles bigger than 10 μm. The parallel arrangement of halls and cross ventilation increased by 31 % dust pollution of air inlet of second hall B than in air supplied into the first hall A. Removal efficiency of total dust by ventilation was 0.13 in hall A and 0.19 in hall B, in the case of smaller particles PM_1, $PM_{2.5}$, PM_4 was from 0.44 to 0.76.

Key words: air, dust fractions, efficiency of dust removal, measurement.

INTRODUCTION

Poultry housing technology, external climatic conditions and weather influence the indoor microclimate during different periods of the year. Creation of internal environment in the halls for poultry housing is complicated mainly because of the high biological load of indoor environment, resulting from the large number of chickens per 1 m^2 of the floor area. Problems occur particularly towards the end of fattening. Chickens have a large mass; they produce large quantities of pollutants (AARNINK ET AL., 2009; KIC ET AL., 2012). Usually this problem is solved by intensive ventilation (KIC ET AL., 2007A; ŠOTTNÍK, 2007; ZAJÍČEK AND KIC, 2013A), but it has a rather negative influence also on the technical equipment (KIC ET AL., 2007B).

Dust particles which are smaller than 10 μm occur in the air in small amounts, but they have a great biological importance. They are inhaled, but for the most part they are already captured in the upper respiratory airways. Here, they are deposited a film of mucus, which is moved by cilia toward the nasopharynx. Smaller particles with an aerodynamic diameter of about 0.003 to 5 μm are deposited in the tracheobronchial and alveolar regions. Particle size of about 1 μm permeate bronchioles until the alveoli, where they are captured sometimes more than 90 %. These particles are therefore in the terms of retention of aerosol in the lungs the most dangerous. One of the best known diseases caused by organic dust is so called Farmer's lung (SETHI ET AL., 2013; VIEGAS ET AL., 2013).

To improve internal conditions inside the buildings can help different methods for reduction of noxious gases concentration or bad odor pollution (LIŠKA AND KIC, 2010; LIŠKA AND KIC, 2011), but the dust pollution can be by these methods hardly reduced. The source of dust is the poultry feather, particles of feed and bedding on the floor. Dust pollution can be reduced either by reduced production of dust at the source, which is in this case rather difficult, or by intensive ventilation. Some of publications present the methods of calculation of main parameters of ventilation system (GŰRDIL ET AL., 2001) and simulation of indoors conditions (MISTRIOTIS ET AL., 1997; MUTAI ET AL., 2011; ZAJÍČEK AND KIC, 2012; ZAJÍČEK AND KIC, 2013B; ZAJÍČEK AND KIC, 2013C).

The aim of this paper is to characterize particulate matter (PM) contamination and to show the measurement results of dust pollution in poultry houses and to study the influences of the indoor dust pollution by the hall construction and the farm design, particularly the possibility of influencing the dust pollution inside by surroundings and appropriate solution of the ventilation system.

MATERIALS AND METHODS

This research work and measurements were carried out in two buildings for fattening of meat chickens. Both poultry houses are located parallel to each other in one farm, and they are situated on the small slope, the 1st building is on the top, the 2nd hall is in the down part of the farm. Both halls have the same dimensions:

length 76 m, width 11.5 m, height 2.7 m, and inside each hall is housing of 16,800 chickens on the floor. The measurements were carried out on the 24th day of fattening when the chickens have average weight about 1.1 kg. The floor in the halls is covered by the bedding material Absorfyt made from chopped wheat straw.

The cross ventilation of halls is transverse, with under-pressure created by the axial fans in the side wall in outlets, with a total maximum air flow of 93,250 $m^3 \cdot h^{-1}$. The fresh air is sucked in the 1st hall from its opposite wall into the inlets from the open area. Into the 2nd hall the air is sucked from the space between these halls. The distance between the halls is about 16 m. Because of this arrangement of buildings the attention in this research is paid to the relations between the outlet from the hall and the suction into the inlet of the next hall.

The total concentration of air dust was measured by special exact instrument Dust-Track™ II Aerosol Monitor 8530 produced by TSI in USA, 500 Cardigan Road Shoreview, MN 55126, with operating range 0.001 to 150 $mg \cdot m^{-3}$ with resolution ± 0.1 % of reading of 0.001 $mg \cdot m^{-3}$, whichever is greater. Total dust concentration and after the installation of different impactors PM_{10}, PM_4, $PM_{2.5}$, PM_1 size segregated mass fractions of dust were also measured.

According to the type of material, dust has specific characteristics to which respond the properties. According to the Act Government Regulation No. 361/2007 Coll., this type of dust has irritating effects (poultry feather, particles of feed, straw and sawdust from the wood). For this type of dust the prescribed Occupational Exposure Limits (OEL) are permissible exposure limits of total concentration. There are Exposure Limits of some noxious gases in the animal houses from the animals' point of view, but there are not the limit values for the dust concentrations. Occupational Exposure Limits are listed in Tab. 1.

Tab. 1. – Types of dust and occupational exposure limits (OEL)

Dust	**OEL ($\mu g \cdot m^{-3}$)**
Feather	4,000
Feed	6,000
Straw	6,000
Sawdust	5,000

Measured dust inside this type of buildings is not aggressive, therefore, as a criterion for comparative evaluation of the measured values can be also used the limit level of outdoor dust. According to the Air Protection Act No. 201/2012 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 $PM_{2.5}$ is 25 $\mu g \cdot m^{-3}$.

Measuring devices and equipment technology environment continues to improve and provide a larger volume and more accurate results. New studies are constantly providing fresh information, but there are still many uncertainties. Maybe, new and more precise ideas about the influence on the human health or on the animals can be discovered.

Very helpful and also important is to know the details about the composition and size of dust particles from the point of view of technical equipment and technology of indoor environment. This is important among other things for the selection of appropriate filters, scheduling maintenance and cleaning, and overall management options how to reduce the dust inside the buildings.

One of the possibilities how to use the measurement results of dust concentrations is an assessment of the effectiveness of ventilation. Air moves inside a ventilated hall due to the pressure gradient between the air inlets and outlets. Location of air inlets and outlets together with the other factors inside the ventilated space affects the final effect of ventilation and manifests purity of the air. The final effect can be assessed as a dust removal efficiency, calculated according to equation (1). The maximum of dust removal efficiency could be theoretically $e_v = 1$, if the concentration of dust in the outgoing air is the same like the concentration inside the building. The same evaluation principle can be used not only for the total dust, but also for the calculation of a removal efficiency of dust particles, probably influenced also by air velocity, properties of particles and other factors. These results could be useful for improvement of ventilation system designs.

$$e_V = \frac{(k_o - k_e)}{(k_i - k_e)} \quad (1)$$

Where: e_V – dust removal efficiency of ventilation, -;
k_o – concentration of dust in the outgoing air, $\mu g \cdot m^{-3}$;

k_e – concentration of dust in the incoming air, μg·m^{-3};
k_i – concentration of dust inside the poultry house, μg·m^{-3}.

Therefore the dust measurements have been provided not only according to the prescribed normal national or international standards (e.g. PM_{10} and $PM_{2.5}$), but it was also measured the total dust concentration and particulate matter by all available impactors PM. Larger amounts of information allow to obtain more detailed information on the composition and percentage of size fractions of dust.

The 90 data of dust concentration for total dust as well as of each fraction size in air inlets, inside the hall and in the outlet from the halls were collected. The obtained results of dust measurements were processed by Excel software and verified by statistical software STATISTICA 12 (*ANOVA and TUKEY HSD Test*).

Different superscript letters (a, b) mean values in common are significantly different from each other in the rows of the tables (*ANOVA; Tukey HSD Test;* $P \le 0.05$), e.g. if there are the same superscript letters in all the rows it means the differences between the values are not statistically significant at the significance level of 0.05.

RESULTS AND DISCUSSION

Principal results of dust measurement in the halls A and B are summarized and presented in Tables 2-5 and Figures 1-3.

Tab. 2. – Dust concentrations total and fractions in air inlets, data in the table are means ± SD. Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test;* $P \le 0.05$)

Hall	**A**	**B**
Dust	**(μg·m^{-3})**	**(μg·m^{-3})**
Total	127.3 ± 3.2^a	166.2 ± 2.9^b
PM_{10}	108.0 ± 1.1^a	164.7 ± 1.4^b
PM_4	116.9 ± 0.7^a	147.7 ± 1.9^b
$PM_{2.5}$	13.1 ± 1.7^a	14.5 ± 1.3^b
PM_1	9.2 ± 2.7^a	13.1 ± 1.3^b

The comparison of dust concentrations in the inlets of both halls (Tab. 2) shows that fresh air sucked into the inlet of hall A is less polluted than the air in inlet of the hall B. The concentration of dust in the air inlet of the hall B is higher by approximately 31 %, than the concentration of dust in the air supplied to the hall A.

This pollution of inlet air of hall B can be caused by discharged air from the outlet of the hall A. The side distance between the halls is probably not sufficient. The distribution of dust size fractions in air inlets into the poultry houses is presented in Fig. 1. The biggest percentage (73 % hall A, 79 % hall B) of dust are the particles smaller than 1 μm.

Comparison of dust concentration inside both halls is in Tab. 3. Total dust concentrations are not significantly different in both halls; also the difference of PM_4 is not statistically significant. OEL limits are not over crossed, but the concentrations of all dust particles are very high, which is obvious in comparison with the limit level of outdoor dust (PM_{10} limit value in 24 hours is 50 μg·m^{-3}, 1 year limit value is 40 μg·m^{-3} and 1 year limit value $PM_{2.5}$ is 25 μg·m^{-3}). These limit values are over crossed in all cases.

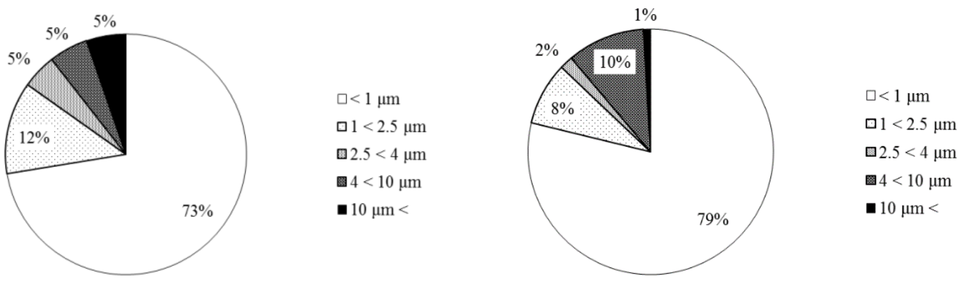
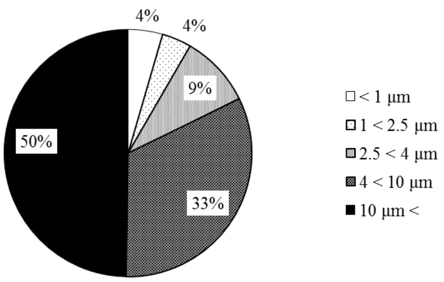


Fig. 1. – The distribution of dust size fractions in air inlet of the halls A (left) and B (right)

Tab. 3. – Dust concentration total and dust fractions inside, data in the table are means ± SD. Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test; P ≤ 0.05*)

Hall	**A**	**B**
Dust	**(μg·m^{-3})**	**(μg·m^{-3})**
Total	1,425.4 ± 270.8^{a}	1,476.4 ± 219.4^{a}
PM_{10}	716.4 ± 97.5^{a}	839.5 ± 113.5^{b}
PM_4	252.9 ± 45.6^{a}	256.7 ± 19.8^{a}
$PM_{2.5}$	118.8 ± 16.5^{a}	172.3 ± 17.0^{b}
PM_1	63.9 ± 17.6^{a}	75.8 ± 15.8^{b}

The distribution of dust size fractions inside the poultry houses is presented in Fig. 2. The biggest percentage (50 % hall A, 43 % hall B) of dust are the particles bigger than 10 μm. Rather big portion of dust (33 % hall A, 39 % hall B) create the dust particles smaller than 10 μm and bigger than 4 μm, which means that the majority of dust inside these poultry houses create the particles bigger than 4 μm (83 % hall A, 82 % hall B).



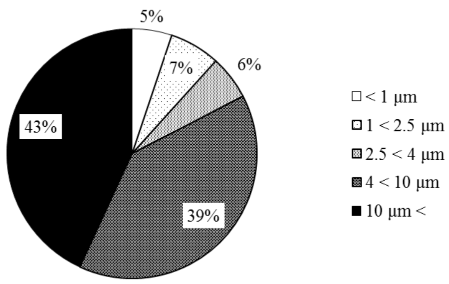


Fig. 2. – The distribution of dust size fractions in air inside the halls A (left) and B (right)

Tab. 4 – Dust concentration total and fractions in the air outlet, data in the table are means ± SD. Different letters (a, b) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test; P ≤ 0.05*)

Hall	**A**	**B**
Dust	**(μg·m^{-3})**	**(μg·m^{-3})**
Total	198.8 ± 56.6^{a}	295.6 ± 97.1^{b}
PM_{10}	176.3 ± 44.4^{a}	254.3 ± 44.9^{b}
PM_4	140.7 ± 42.5^{a}	197.5 ± 29.4^{b}
$PM_{2.5}$	76.6 ± 21.4^{a}	96.9 ± 16.4^{b}
PM_1	46.4 ± 11.1^{a}	40.6 ± 14.3^{b}

The comparison of dust concentrations in the outlets from both halls (Tab. 4) shows that air discharged from the outlet of hall A is less polluted than the air in outlet from the hall B. The total concentration of dust in the air outlet from the hall B is higher by approximately 49 %, than the concentration of dust in the air discharged from the hall A. This pollution of outlet air from hall B can be caused by higher concentration of dust inside the hall A.

The distribution of dust size fractions in air outlets from the poultry houses is presented in Fig. 3. The majority of dust inside these poultry houses is created by the particles smaller than 4 μm (70 % hall A, 67 % hall B). The biggest percentage (32 % hall A, 34 % hall B) of dust create particles bigger than 2.5 μm and smaller than 4 μm. Rather big portion (23 % hall A, 14 % hall B) of dust are the particles smaller than 1 μm.

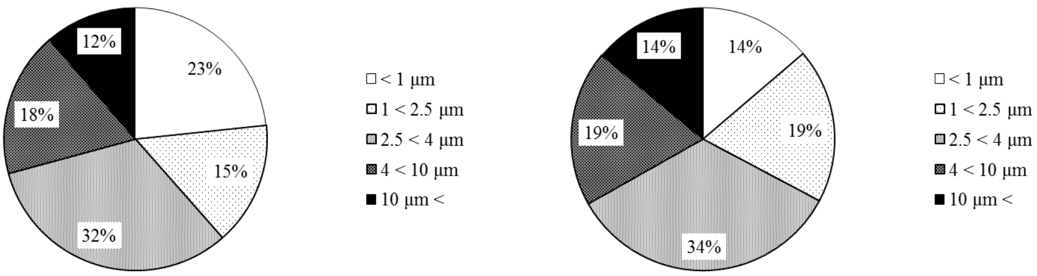


Fig. 3. – The distribution of dust size fractions in air outlet of the halls A (left) and B (right)

The measured values of dust concentrations of air in the inlet, inside the halls and in the outlet enable to calculate the dust removal efficiency of ventilation according to the equation (1).

Tab. 5. – Dust removal efficiency of ventilation in the halls A and B

	e_v (-)	
Hall	**A**	**B**
Total	0.13	0.19
PM_{10}	0.23	0.29
PM_4	0.54	0.76
$PM_{2.5}$	0.61	0.52
PM_1	0.68	0.44

The results of these measurements and calculations presented in Tab. 5 show that the dust removal efficiency of ventilation is rather dependent on the size of dust particles. If it is calculated for the case of total dust removal, the efficiency e_v is 0.13 in the hall A; e_v is 0.19 in the hall B. More efficient is dust removal of smaller particles PM_1, $PM_{2.5}$ and PM_4.

CONCLUSIONS

Total dust concentrations in poultry houses were 1,425.4 ± 270.8 and 1,476.4 ± 219.4 µg·m^{-3}. The biggest percentage (50 % hall A, 43 % hall B) of dust are the particles bigger than 10 µm.

The comparison of dust concentrations in the inlets of both halls (Tab. 2) shows that the concentration of dust in the air inlet of the hall B is by approximately 31 % higher than the concentration of dust in the air supplied to the hall A. This pollution of inlet air of hall B can be caused by discharged air from the outlet of the hall A. The parallel arrangement of both buildings and cross transverse ventilation would need bigger side distance between the halls or another positioning and construction of inlets and outlets of air. The suitable location of air outlets should prevent undesired recirculation of exhaust air back inside the hall or pollution of air sucked into another building. The poultry houses are characterized by huge ventilation rates, therefore it is necessary to strictly separate the areas of air inlets (suction of fresh air) and outlets (discharge of polluted air). More suitable dissipation zone of polluted air seems to be outlets in the same area between two halls or above the buildings.

The dust removal efficiency by ventilation calculated according to the equation (1) show that it is more efficient in the case of smaller particles. It can be the reason why the majority of dust particles inside these poultry houses create the particles bigger than 4 µm (83 % hall A, 82 % hall B).

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