ANALYSIS OF DUST FRACTIONES AT PIGGERY

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Abstract

During 2008 the concentrations of volatile dust particles in the form of fractions sized up to 10 µm (PM_{10}) and up to 2.5 µm ($PM_{2.5}$) were measured in the pig farm building with the nominal capacity of 180 pigs placed in stalls with grids. It followed from the multilinear model analysis that $PM_{2.5}$ fraction was the most impacted with the conditions under survey both inside and outside the building (determination coefficient $r^2 = 0.98$), the PM_{10} fraction ($r^2=0.55$) was less affected. The highest correlation achieved inside the building was that between the concentration of the PM_{10} fraction and the precipitation (r = +0.533), between the $PM_{2.5}$ fraction and the air pressure (r = -0.470). In terms of immissions, it was between the PM_{10} fraction and the precipitation (r = +0,538) and the $PM_{2.5}$ fraction and the relative air humidity (r = +0.456).

Key Words: Pigs, dust fractions, PM_{10}, $PM_{2.5}$, macroclimate, multilinear model, correlation

Working operations of keepers involving the handling of animal products or materials such as litter and feeds are risky. Millions of keepers are permanently exposed to animals or their products. The majority of them have allergic symptoms, others experience symptoms of asthma. The asthma and allergies caused by animals are exaggerated immune system reactions to animal proteins known as allergens.

According to Von Essen and Romberger (2003) describe confinement buildings for keeping pigs as such where multiple factors are present that can cause systemic inflammatory symptoms in the respiratory tract caused by dust, endotoxines and ammonia. The research concludes that the pig keepers‘ adaptation and tolerance to endotoxines and other substances was induced by repeated exposure. Various subjects were tested in regular pig keeping conditions to prove this. O´Shaughnessy et al. (2002) monitored the daily variance in the concentration of airborne dust in the stable. They found out that it was inversely dependant on the ambient temperature and air exchange in the stable. As expected, the concentration was higher during cold months but the difference from other months was not statistically important. The dependencies were especially remarkable on days when there were great variations in the outside air temperature, as stated by Achutan et al. (2001). Even in the winter the dust concentration was very low, the annual average was around 0.1 $mg.m^{-3}$.

The objective of this paper is to present the results of measuring dust concentrations in fractions PM_{10} and $PM_{2.5}$ and to analyse the correlation between net concentrations of individual fractions and immissions and to capture the dependence of dust concentration on the outdoor meteorological conditions.

Material and Methods

Data Analysis

Reference data for further information processing are the net concentration of fractions PM_{10} and $PM_{2.5}$ inside the hall and data from the area around the monitored hall in the same fraction size. This information has the character of immission, i. e. one of the components of net dust concentration. The concentration of a particular fraction in the hall itself is a hygienic and zoohygienic indicator.

The analysis of obtained data concentrated on the following categories:

-Difference in individual dust fraction concentrations indoors and outdoors (Δ $\mu g.m^{-3}$)

-Share of immissions in gross concentration of dust fractions (%)

- Share of concentration difference in the gross concentration of dust fraction (%)
- Dust structure (%)

Multilinear regression model

The multilinear regression model is the basis:

$$\mathbf{y = b_0 + ax_1 + ax_2 + ax_2 + ax_3 + ax_4 + ax_5 + ax_6}$$

where: x_1 = air temperature (°C),
x_2 = relative air humidity (%),
x_3 = air pressure (hPa),
x_4 = air-flow speed ($m.s^{-1}$),
x_5 = cloud cover (N – in eights of sky surface) and
x_6 = 24-hour precipitation (mm).

Dependent variables (y) are individual dust fractions PM_{10} and $PM_{2.5}$ in the measurement in the hall (= gross concentration) and in the measurement outdoors (= immission). Independent variables are x_1 to x_6.

A change in the independent variables by one unit will initiate a change in relevant dependent variables by a value stated in $\mu g.m^{-3}$. The determination coefficient (r^2) defines the level of prediction of value y on the basis of the independent variable values. The values of linear coefficients were subject to t-test and F-statistics.

Correlation between dependent variables and ambient elements

This is a correlation between dependent variables (gross particles concentration and immission concentration) and ambient elements (see the multilinear model).

Results and Discussion

Measurement conditions

The dust concentration measurement was performed in conditions of relatively average temperatures. No measurement took place in the summer (July – August). The summary is provided in Table 1.

Multilinear model of dust fraction concentration dependence on ambient conditions

The elaboration of multilinear models of dependence of individual dust fraction concentrations inside and outside the animal confinement building (dependent variables) on measurement conditions (independent variables) indicated a very strong dependence of fraction $PM_{2.5}$ on measurement conditions with the determination coefficient – $r^2 = 0.98$ in the concentration inside and outside the building. The link between the PM_{10} concentration and ambient conditions appeared to be somewhat weak ($r^2 = 0.55$ indoors, 0.54 outdoors). These correlations are described in Table 2. The ambient condition elements had a varying effect on the concentration of monitored fractions:

Air temperature: it was established that the air temperature had a varying effect on the monitored fractions. The increasing temperature resulted in reduced PM_{10} concentration but it had an opposite effect on the finer fraction $PM_{2.5}$ in which the concentration increased. In fraction PM_{10} at 1°C the indoor concentration was reduced by 19.4 or 18,4 $\mu g.m^{-3}$. On the other hand, the indoor concentration of $PM_{2.5}$ increased by 3.9, or 4.9 $\mu g.m^{-3}$ outdoors (both values $p \leq 0.01$). The varying effect of air temperature can by explained by the fact that in relatively large particles (PM_{10}) their further aggregation is prevented. On the other side, the temperature has an effect on the releasing of fine particles from the transitory layer of settled dust.

Relative air humidity: it has a positive effect, i. e. the dust concentration increased alongside with the temperature. An increase in the temperature by 1°C provoked an increase in fraction PM_{10} concentration by 9.9 indoors or 9,7 $\mu g.m^{-3}$, in fraction $PM_{2.5}$ it was by 3.6 indoors or 3,9 $\mu g.m^{-3}$ outdoors. The statistical importance of both linear coefficients was great ($p \leq 0.001$).

This dependence can be explained by the positive effect of relative air humidity on the aggregation of dust fractions and aerosoles.

Air pressure: it has a negative effect, i.e. with the growing air pressure the concentration of both fractions indoors and outdoors dropped. An increase in the air pressure by 1 hPa resulted in a decrease in fraction PM_{10} concentration by 28.9 or 26.8 $\mu g.m^{-3}$, in fraction $PM_{2.5}$ by 3.8 ($p \leq 0.001$) or 3.2 $\mu g.m^{-3}$ ($p \leq 0.01$). The mechanism of this factor is probably affected by the settlement of particles on the substrate which reduces the concentration of particles in the air layer above. This assumption is supported by the fact that it was mainly the PM_{10} concentration that was reduced.

Air-flow speed: it has a thoroughly negative effect on the concentration of monitored fractions. Increased air-flow speed by $m.s^{-1}$ reduced the fraction PM_{10} concentration by 33.2 or 30.6 $\mu g.m^{-3}$, in fraction $PM_{2.5}$ it was by 9.3 ($p \leq 0.001$) or by 7.2 $\mu g.m^{-3}$ ($p \leq 0.01$). The horizontal ventilation reduces the content of particles in the measured layer of air above the ground.

Cloud cover: in this factor a negative effect on the dust fraction concentration was established. Increasing the cloud cover by 1/8 of the sky surface reduced the concentration by 15.6 or 15.4 $\mu g.m^{-3}$ in fraction PM_{10} and in fraction $PM_{2.5}$ by 6.3 ($p \leq 0.001$) or 6.1 $\mu g.m^{-3}$ ($p \leq 0.01$). It is presumed that the effect mechanism lies in the existence of convective current which weakens with the growing cloud cover. The convective current takes away part of the dust load from the lower layers and thus reduces its concentration in the measured air layer.

Precipitation: the analysis identified a varying effect on the monitored fractions. While in fraction PM_{10} the precipitation caused an increased concentration, in fraction $PM_{2.5}$ the concentration dropped. An increase in the fraction PM_{10} concentration to 1mm of precipitation in 24h was 76.7 or 78.3 $\mu g.m^{-3}$, in fraction $PM_{2.5}$ there was a decrease by 4.0 ($p \leq 0.01$) or by 1.1 $\mu g.m^{-3}$. This can be explained by the fact that a portion of small drops with diameter around 10μm became part of the dust – aerosole. On the other hand, the fine dust $PM_{2.5}$ was absorbed by precipitation.

Tab. 1: Summary of conditions during measurement

Date	Temp.	Rel.humidity	Air pressure	Air-flow	Cloud cover	Precipitation
	°C	%	hPa	$m.s^{-1}$	x/8	mm
21.-22.1.	8.9	83.9	978.4	8.0	8	0
28.-29.1.	5.3	89	994.3	2.8	1	2.0
13.-14.5.	16.3	58.3	981.3	3.8	1	2.4
19.-20.5.	9.7	86.6	977.8	3.2	8	4.0
21.-22.5.	9.3	83.4	980.3	3.0	8	0.7
23.-24.9.	10.7	67.5	981.8	2.7	6	1.9
29.-30.9.	12.2	66.1	979.3	4.2	6	0
15.-16.10.	13.7	79.8	980.1	4.0	7	1.1
20.-21.10.	10.2	71.5	983.5	4.0	1	0

Tab. 2: Multilinear model of dependence between gross indoor concentration and outdoor immission (linear coefficients of independent variables - x_n)

Parameter	x_n	Unit	Indoors		Outdoors	
			PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Determination coefficient	r^2		0.554	0.986	0.542	0.983
air temperature	x_1	°C	-19.4	+3.9**	-18.4	+4.9**
relative air humidity	x_2	%	+9.9	+3.6***	+9.7	+3.9***
air pressure	x_3	hPa	-28.9	-3.8***	-26.8	-3.2**
air-flow speed	x_4	$m.s^{-1}$	-33.2	-9.3***	-30.6	-7.2**
cloud cover	x_5	x/8	-15.6	-6.3***	-15.4	-6.1**
24-hour precipitation	x_6	mm/24 h	+76.7	-4.0**	+78.3	-1.1

$^{**}p \leq 0.01$, $^{***}p \leq 0.001$

Linear dependence between dust concentration and individual ambient parameters

The analysis of partial correlations between the concentrations of both monitored fractions and the monitored ambient conditions elements is shown in Table 3.

In fraction PM_{10} (indoors as well as outdoors) a significant closeness of the correlation between precipitation (correlation coefficient r = +0.53) was recorded. The relative air humidity and cloud cover showed only a mild correlation with the concentration of the fraction (indoors and outdoors) r = +0.38 and +0.33 respectively. In other parameters only a small correlation was identified.

In fraction $PM_{2.5}$ the air pressure r = -0.47 (indoors) and r = -0.41 (outdoors) showed only a mild correlation. A mild correlation was recorded also with the relative air humidity r = +0.37 (indoors) and r = +0.45 (outdoors). Other elements had only a weak correlation to the concentration of this fraction.

The weakest linear dependence on the dust concentration was found in the air-flow speed and namely in the air temperature.

Tab. 3: Correlation between dust concentration inside the hall and immission outside the hall with monitored ambient elements

Parameter	x_n	Unit	Indoors		Outdoors	
			PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
air temperature	x_1	°C	-0.153	+0.117	-0.155	+0.082
relative air humidity	x_2	%	+0.387	+0.374	+0.386	+0.456
air pressure	x_3	hPa	-0.228	-0.470	-0.211	-0.414
air-flow speed	x_4	$m.s^{-1}$	-0.198	-0.119	-0.198	-0.089
cloud cover	x_5	x/8	+0.337	+0.144	+0.332	+0.202
24-hour precipitation	x_6	mm/24 h	+0.533	+0.182	+0.538	+0.299

Conclusion

The regression linear analysis of ambient conditions effect established that these conditions influenced mainly the concentration of the fine fraction $PM_{2.5}$ which proved to be highly statistically dependent on temperature, relative humidity and air-flow speed, air pressure, precipitation and cloud cover. On the other hand, only a small effect of the ambient conditions was identified in fraction PM_{10} concentration.

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