MEASURING OF DUST AT PIG FARM

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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. The above-mentioned fractions were measured using the gravimetric method and on-line measurement in 24-hour cycles. Standard and other micro- and macroclimate elements were being recorded at the same time. The mean concentration inside the stable was 502.8 for fraction PM_{10} and 121.8 $\mu g.m^{-3}$, around the stable (= immission) it was 410 and 75.1 $\mu g.m^{-3}$. The indicated values, especially the immission values, were subject to a rather significant fluctuation of 19.2 – 58.4%. The concentration consisted of PM_{10} immissions of 81.5% and 61.7% respectively.

Key Words: Pigs, dust fractions, PM_{10}, $PM_{2.5}$, measurement, microclimate

Animals or their products, such as scruff, released skin particles from older animals, hair, fur, saliva and other body wastes contain strong allergens that can cause respiratory and dermatological problems in animal keepers, veterinarians, veterinary technicians, lab staff, researchers and other persons who spend a long time in animal confinement buildings together with animals or their discharge or secretions. 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.

The work in animal confinement buildings where poultry and pigs are kept involves a significant exposure to organic dust and endotoxines, as stated by Iversen et al. (2000). This fact corresponds with the increased occurrence of respiratory symptoms in workers at pig farms. There is a correlation between these symptoms and the number of exposure hours. Long-term studies prove the exacerbation of respiratory functions in pig keepers causing their serious illness. Since a large number of persons work in this profession for long hours, a serious problem of respiratory function loss has appeared especially in pig keepers who do not smoke cigarettes. The authors believe that the proposed concentration limit for endotoxines in dust (< 100 $ng.m^{-3}$) is safe. 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. Dust is closely connected with odour. Razota et al. (2002) indicate that airborne dust analyses (aerodynamic diameter < 10 µm) carried out in pig stables identified large quantities of carboxylic acids, aldehydes, alcohols, ketones, hydrocarbones, phenols, indoles, phtalates and esters. According to Bottcher et al. (2004) the results of odour measurement are influenced by the presence of dust particles which increase the persistence of odour above the level of gaseous odorous substances.

The objective of this paper is to present the results of measuring dust concentrations in fractions PM_{10} and $PM_{2.5}$ during the year 2008 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

Dust concentration measurement

The method is based on technology standards which are also European standards: Both standards indicated below concern the thoracic fractions (aerosol), i. e. particles that reach beyond the larynx by respiration

ČSN EN 12 341: Air quality – defining PM_{10} fraction of aerosol particles – reference method and procedure for field tests verifying the required closeness of compliance between the results of evaluated and reference methods.

ČSN EN 14 907: Air quality – standardised gravimetric method of defining $PM_{2.5}$ fraction of aerosol particles.

The dust concentration definition is based on the gravimetric method supported by on-line monitoring systems.

Technology

An Apex Pro pump (made in the UK) was used to determine the dust concentration using the gravimetric method. This equipment can be programmed for various air-flow levels. To define the concentration of fraction with aerodynamic diameter up to 10 µm – PM_{10} and up to 2.5 µm – $PM_{2.5}$ the recommended air-flow of 3.5 $l.minute^{-1}$ (=0,21 $m^{-3}.h^{-1}$) was set. The pump is connected with the sampling head with a PE hose (internal diameter 8mm). Two filters are situated in the sampling head:

• Separation paper filter (diameters 25 and 37mm). During exposure it separates the required size of dust particles.

• Defining polyurethane filter (diameters 37 and 10mm). It leaks particles of the required aerodynamic size. Filters are available for PM_{10}, $PM_{2.5.}$

The following formula determines the weight concentrations of fractions:

$$k = \frac{m_E - m_0}{Q}$$

where: k = fraction concentration (µg.m^{-3}, mg.m^{-3})

m_E = weight of exposed filter (µg, mg)

m_0 = weight of unexposed filter (µg, mg)

Q = air-flow during exposure time (L, m^3)

Airborne particulate concentrations measurement with Microdust Pro and Dusttrak systems

Both systems are used in default setting calibrated to 'Arizona Fine' calibration dust (ISO Fine 12103-1A2). The identified average value during the exposure has to be adjusted according to the gravimetric setting. For this purpose it is necessary to create a conversion factor - f.

The factor is used for further processing of data in Excel (Microsoft). Both work with the near forward angle light scattering technique. Microdust uses infrared light, Dusttrak uses laser beam.

The Microdust Pro monitor is compatible with Apex Pro air pumps (both products are manufactured by Cassella UK). In gravimetric measurement the Apex Pro pumps can operate independently or in-line with Microdust Pro monitors. The Apex Pro pump can be connected to a Microdust monitor via an adaptor. In such case it is guaranteed that the volume of dust fraction passing through and measured in Microdust Pro is identical with the fraction deposited on the filter.

Dusttrak system (TSI Inc., USA). The required fractions (PM_{10} and $PM_{2.5}$) are defined with relevant nozzles.

Specification of monitoring results obtained in and around the animal confinement building

Animal confinement technology description

The monitoring took place in one of two identical pig fattening halls. The entire floor is gridded. It is divided into 6 pens (3 + 3). Among the pens there is a service passage. The nominal hall capacity is 90 pigs. At the time of monitoring the occupancy was 85 – 90%. Liquid manure in pits under the grids is pumped into a service pit in regular weekly intervals from where it is regularly taken out to the fields and worked in the soil. The stable area is 77 m^2. Pigs are fed several times a day with a wet feed mixture. Low-pressure ventilation is used in the hall. The air is sucked in through vents in the windows or doors with two axial ventilators.

Location of monitors and input data

The monitors, their openings for sucking in air from the hall, were positioned 1m above the floor grid level in order to cover the living space of animal keepers as well as that of the animals. The outdoor data were monitored at a point situated 10m from the hall and protected against the weather.

The following data were monitored:

- date of measurement
- dust particle concentration:
- basic - aerodynamic size PM_{10} and $PM_{2.5}$ – concentration in the hall
- immission - PM_{10} and $PM_{2.5}$ concentration outdoors

The data specified above are processed for 24-hour cycles.

- conditions during 24-hour monitoring: temperature, relative humidity, air-flow speed, air pressure, cloud cover and precipitation for 24 hours. The data concerned outdoor values.

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 data specified above are supported by simple statistics. Since the monitoring took place during 2008, data was spread over individual months. 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 µg.m^{-3})

The resulting indicator shows the portion of dust that was generated directly in the hall and together with the portion of dust in the inlet air mass creates the gross concentration of the relevant fraction. It is the portion of dust particles that originated in the hall as a result of the hall operation technology. This indicator pertains especially to the pig fattening technology.

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

It is the share of immissions (fraction concentrations in the outdoor air) in the gross concentration measured inside the hall. It is indicated in %.

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

It compares the share of dust generated in the stable in the gross concentration in %.

It puts the previous category in relation.

Dust structure (%)

The proportion of respirable fraction ($PM_{2.5}$) in the overall thoracic fraction (PM_{10}). It is a relative expression of $PM_{2.5}$ share in PM_{10}. The higher this number is, the finer is the dust. It was applied on the dust inside the hall as well as on the outdoor dust – immission.

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). In terms of extreme temperatures, the measurement taken in January was not made at low temperature. In general, the measurements took place at temperatures between 5.3 and 16.3°C, at relative humidity between 58.3 and 86.6 %, at air-flow speed 2.7 – 8.0 m.s^{-1}.

Dust fraction concentration in and around the animal confinement building (= immission)

In the concurrently measured concentrations of fractions PM_{10} and $PM_{2.5}$ inside and outside the animal confinement building the average values inside were 502.8 (PM_{10}) and 121.8 µg.m^{-3} ($PM_{2.5}$). Corresponding values obtained outside the building were 410.0 and 75.1 µg.m^{-3}.

Table 1 shows a great variation in values: 47.8 in fraction PM_{10} and 19.2 % in fraction $PM_{2.5}$ when measured inside the building and the immission outdoors was even higher: 58.4, resp. 32.3 %.

An important information resulting from the measurements described above is the difference in the concentration values obtained inside and outside the animal confinement building in both fractions. In fraction PM_{10} the average difference was 92.8 and in fraction $PM_{2.5}$ it was 48.7 µg.m^{-3}. In practice this means an increase in particles contained in the ventilated air, i. e. dust particles originating from the stable. The variability of these values was significantly lower than that in the average concentration inside and outside the building; it was 6.4 % in fraction PM_{10} and 10.2 % in fraction $PM_{2.5}$.

The clearly highest concentration of fractions was recorded in May: the average inside the building was 789 (PM_{10}) and 146 µg.m^{-3} ($PM_{2.5}$) and 695 and 91 µg.m^{-3} outside the building. On the contrary, the lowest concentrations were recorded in September: in fraction PM_{10} inside the building (286) as well as outside (191 µg.m^{-3}) but in fraction $PM_{2.5}$ 105, resp. 48 µg.m^{-3}. The values obtained in individual months are shown in Table 2.

Table 1. Input data (indoor and outdoor measurement)

Date	Indoors (µg.m^{-3})		Outdoors (µg.m^{-3})		Difference Δ(µg.m^{3})	
	PM_{10}	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
21.-22.1.	469	111	377	68	92	43
28.-29.1.	459	95	377	53	82	42
13.-14.5.	590	112	506	68	84	44
19.-20.5.	890	153	791	111	99	42
21.-22.5.	887	152	789	102	98	50
23.-24.9.	337	97	241	49	96	48
29.-30.9.	322	102	227	47	95	55
15.-16.10.	295	144	200	100	95	44
20.-21.10.	276	130	182	78	94	52
average	**502.8**	**121.8**	**410.0**	**75.1**	**92.8**	**46.7**
SD selection	240.5	23.4	239.3	24.2	5.9	4.8
variance (%)	47.8	19.2	58.4	32.3	6.4	10.2

Table 2. Integration of values into months of measurement

Months	n	Indoors (µg.m^{-3})		Outdoors (µg.m^{-3})	
		PM_{10}	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
January	2	464	93	377	61
May	3	789	146	695	91
September	2	330	105	234	48
October	2	286	142	191	91

Data Analysis

Share of immissions in dust concentration inside the animal confinement building

The concentration of dust particles inside the building consisted of two components, as mentioned previously in Table 2. It was especially the portion of dust in both fractions contained in the ventilation air and the portion generated directly in the building. Part of the dust contained in outdoor air ventilating the measured building had the character of an immission. This portion in fraction PM_{10} made up 81.5 % and in fraction $PM_{2.5}$ it made up 61.7 %. The highest share of immissions was recorded in fraction PM_{10} in May: 85 to 89 %, the lowest was recorded in October: ca. 70 %. In fraction $PM_{2.5}$ the minimum share was achieved in September, the maximum is spread over other months of measurement (Table 3).

Share of dust particles originating directly in the stable

This share originates directly from the animals (pigs) kept in the confinement building, they are released skin particles, hair, excrements or crystalline urine. Most particles come from the leftover feed and litter. Besides this the building contains small acari and other fauna producing more solids through their activities. The share of this part in the concentration value inside the building was 22.0 % in fraction PM_{10} and 38.3 % in fraction $PM_{2.5}$, as shown in Table 3. This means that a larger portion of fine fraction $PM_{2.5}$ is produced in the pig confinement building. The greatest portion of these particles in fraction PM_{10} was detected in October (around 30 %), the lowest in May (around 11 %). Fraction $PM_{2.5}$ showed its highest share in September (over 50 %). In this respect there is a visibly small share of variability in the values of dust concentration shown in Table 1. In fraction PM_{10} it was only 6.4 %, in fraction $PM_{2.5}$ it was 10.2 %. Compared to the variability of values of dust concentration in the buildings as well as in the immission it is comparatively lower. For this reason the portion of dust produced in the stable could be used for evaluating the animal keeping technology.

Dust structure

This survey looks at the aerodynamic size of prevailing airborne dust in the building. The share of fraction $PM_{2.5}$ as a subset of fraction PM_{10} was 28.2 % on average in the measured building, in the immission the proportion was 22.9 %. Its highest concentration in the building was recorded in October (47 – 49 %), on the other hand the lowest concentration was obtained in May (17 – 19 %). The proportion was similar in the outdoor dust concentration. The highest concentration was recorded in October (43 – 50 %), the lowest in May and January (13 – 18 %). This evaluation is offered in Table 3.

Table 3. Share of immission and pig keeping technology in the dust concentration and dust particle structure

Date	**Share of hall in (%) of indoor concentration**		**Share of immission in (%) of indoor concentration**		**Dust structure $PM_{2.5}/PM_{10}$ (%)**	
	PM_{10}	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**	**indoors**	**outdoors**
21.-22.1.	19.6	38.7	80.4	61.3	23.7	18.0
28.-29.1.	17.9	44.2	82.1	55.8	20.7	14.1
13.-14.5.	14.2	39.3	85.8	60.7	19.0	13.4
19.-20.5.	11.1	27.5	88.9	72.5	17.2	14.0
21.-22.5.	11.0	32.9	89.0	67.1	17.1	12.9
23.-24.9.	28.5	49.5	71.5	50.5	28.8	20.3
29.-30.9.	29.5	53.9	70.5	46.1	31.7	20.7
15.-16.10.	32.2	30.6	67.8	69.4	48.8	50.0
20.-21.10.	34.1	40.0	65.9	60.0	47.1	42.9
average	**22.0**	**38.3**	**81.5**	**61.7**	**28.2**	**22.9**

Conclusion

The monitoring of dust concentration in the pig confinement building proved that the concentration of monitored fractions PM_{10} and $PM_{2.5}$ was heavily dependent on the concentration of dust immission which shows a significant variability throughout the year. A remarkably lower variability was recorded in the portion of monitored fractions that originated directly in the hall. A greater proportion of fine dust $PM_{2.5}$ was generated directly at the pig farm.

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