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MEASUREMENT ISSUES OF DUST EMISSIONS ON AGRICULTURAL FARMS

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Abstrakt: Measurement of emissions and dust pollution originating from farming activities has become important in relation to health of attending staff, animals and people living nearby. Methods of measurement of dust particles PM10, PM2.5,together with evaluation of net and gross dust production are discussed in the presented article and method of their formulation is proposed.

Key words: Dust emission; dust pollution; gross and net dust production; dust emission determination; particular matter

INTRODUCTION

Attention paid to environment pollution has been initiated by growing industrial development, bringing foreign matters into natural ecosystems. It has been proved that air pollution effects health condition of the population. It could be demonstrated in many different ways such as subjective health troubles, increase of respiratory problems and increase of death of persons weakened by chronic diseases of respiratory and cardio-vascular organs. The effect of dust particles from environment is related to particles composition, shape and size. Particles larger than 10 μm do not penetrate into breathing system or they are captured in air passages. Smaller particles (under 10 μm) penetrate into lower air passages and make the lung self cleaning mechanism more difficult.

According to contemporary research, there is no safe threshold limit value of aerosol concentration, under which there are no effects on human health. WHO (World Health Organization) states, that dust aerosol is a matter of no limit effect. In spite of the fact, that effects on health have been proved for aerosol of particle size of nm (Hůnová, Šantroch 2000), practice of gathering samples of dust aerosol (TSP - Total Suspended Particulate) without particle size differentiation continues in the most of European states. Dependence of health effects on concentration of dust fraction up to 10 μm (PM10) instead of on TSP has been proved in epidemiology studies (Kryzanovský et al.1998). The European Standard 12341 – Environment Quality – Determination of the PM10 fraction of aerosol particles deals with the emission of aerosol particles PM10 in exterior atmosphere.

Emission of dust particles from stables effects stables vicinity. It often brings conflicts between farmers and their neighborhood. Fodders (particularly fine particles of treated cereal and dry plants), animals skin particles, crystals of urine and excrements particles are the main source of dust in stables. Concentration of particles is not uniform (Chardon 1999) it varies in course of year and season. The highest concentration is reached in spring, the lowest insummer and winter. There is a monthly range of concentration of 65 – 96%. Production ofaerosol fraction PM10 has been monitored in current stables conditions (Dolejš et al. 2004). The following net emission of dust particles has been found for dust particles: in dairy cow breeding (69.9), dairy bull breeding (30.5), breeding swine (37.4), and in broiler breeding (34.2), values measured in g per head per year. Health state of cattlemen and other persons working in stables is effected by particles of animal products such as scurf, skin particles, hairs, saliva and other body debris. They contain strong allergens that could cause respiratory and skin problems. Also when handling with animal products, fodders and litter are hazardous. The most usual contamination by allergens comes through inhalation. During the time period, often lasting for several months or years, sufficient volume of allergens could reach limits leading to sensitivity inception. Symptoms after repeated exposure are developedand sensitivity to very small amount of allergens can follow (Chan-Yeung, Malo 1994).Symptoms of asthma and allergy often lead to job changing (Bardana1992). Asthma andrhinitis are occupational illness, characteristics for cattleman and persons working withpoultry, sheep and gouts.

Exposure of air containing animal allergens to persons shows itself first by excitation of nose, throat and by rush (Ohman 1978). For about 50% of such exposed persons, symptoms are further developing into repeated cough characterized by wheeze, asthma and difficultbreathing (Bardana 1992).

Harmful substances originating in stables could be divided into the following groups:

Emissions originated directly in stables

Emissions originating directly in stables are as follows: ammonia (NH3), hydrogen sulphide (H2S), methane (CH4), monoxide nitrogen (N2O) and odour. Above mentioned noxious agents are originating in stables due to animal metabolism and microbial activities of bedding. The agent volume is related to number of animals, their weight, level of nutrition and technique of feeding and attendance. There is no pollution indicated.

Harmful substances as stable pollution

Harmful substances are created by tropospheric ozone (O3) and sulphure dioxide (SO2). Level of its concentration is created primarily by power supply and transportation, secondarily bymeteorological conditions.

Harmful substances existing as emissions as well as pollution

Carbon dioxide (CO2) as emission originates in animals metabolism and partially in microorganism in stable bedding. At the same time, it exists as pollution and it is a part of current air composition. Its concentration is steady, of the value of 380 ppm. Dust particles ofaerodynamic diameter of 1μm: dust emission originates directly in stables, quantity of emission relates on animal type and its category, number of animals and their weight, on technology of stabling and working operations technique. Extent of dust particles pollution is dependent on local and meteorological conditions and on amount of permanent dust deposit in surrounding area. Due to above mentioned facts; concentration of dust pollution varies a lot.

Dust Dynamic Deposit System (DDSP)

Deposit of dust particles of all sizes, such as rough dust (> 10 μm), dust (1 – 10 μm) and particles up to 1 μm, originating in cattle houses is created around the buildings. In case strong ventilation exists, majority of dust is transported further from the buildings, in still air, due to cyclonic effect, dust deposits mainly on building surface. In addition, there are often muddy track nearby. It is impossible to quantify dust particles. Amount of fixed and free dust particles is changing in relation to weather condition as well as specific local conditions (e.g. effect of transport). Higher temperature, decrease of humidity, high airflow and lower air pressure are factors, effecting release of dust particles into the air. On the contrary, increase of humidity, lower air flow, higher air pressure and sufficient amount of air ions have a positive effect on dust settlement.

MATERIALS AND METHODS

Methodology of dustiness measurement

Dustiness is sometime expressed as an air aerosol. It is suspension of firm and liquid particles in the air. The size of particles ranges from 1 nm to 100 μm. Methods of weight determination or numerical concentration are used for setting up particles weight. In this article, only method of numerical concentration is used.

Methodology follows the Czech technical norms that are also European norms, both following norms refer to thoracic dust fractions (aerosol), e.g. fractions that penetrate into air ways up to larynx.

ČSN EN 12 341: Quality of environment – Determination of PM10 fraction of aerosol particles – Referential method and procedure of field test of approval of required closeness of harmony between tested results and referential method.

ČSN EN 14 907: Quality of environment – Standardized gravimetric method of aerosol particles fraction PM2.5 determination method. Determination of dustiness follows gravimetric method complemented with systems for on line monitoring.

Technical means for dustiness determination

Used gravimetric methods

For dustiness determination by gravimetric method, Apex Pro air pump is used. The pump can be programmed for various air flow. To determine concentration of fraction of aerodynamic diameter up to 10 μm – PM10 and diameter up to 2.5 μm – PM2.5, recommended flow of 0.21m3/h has been used. Display of the measuring instrument reads adjusted air flow, running period and resulting air volume, transported by the pump during measurement. The pump is connected by polyethylene pipe (of the inside diameter of 8 mm) with sampling head. In the sampling head, there are the following filters used:

1. Intercepting paper filter. During measurement, filter captures dust particles of required size and deposits them.
2. Terminative filter – it transmits particles of required aerodynamic size.

Filters are placed into case, conditioned at 20°C and humidity of 50%, for time period of 24 to 48 hours. The case, containing conditioned filters is weighted and transported to place of measurement in an airtight polyethylene bag. The case is placed into sampling head. Sampling head is connected with the Apex Pro air pump. After the filter exposition, minimally for 24 hours, the case is placed into polyethylene bag and conditioned for minimally 48 hours at the 20°C and 50 % humidity. Exposed filter is finally taken out and weighted.

For exact weighting of unexposed and exposed filters, analytical balance, with weighting precision to 10 μg is used. Weight of concentration of the fraction is determined according to the following formula:

$$k = \frac{mE - m0}{Q}$$

where:
k - fraction concentration (μg/m3, mg/m3)
mE – weight of exposed filter (μg, mg)
m0 – weight of unexposed filter (μg, mg)
Q – air flow during exposition time (l, m3)

On – line measurement

Dustiness determination is done by the Microdust Pro and Dusttrak systems. Both systems are in basic mode, calibrated for Arizona road dust (ISO Fine 12103-1A2). Figures of measured average values must be adjusted according to gravimetric set up.

The Microdust Pro System is compatible with air pumps Apex Pro. During gravimetric measurement, the Apex pro pumps can work individually or can be directly connected to the Microdust Pro. In case of direct connection with the Microdust Pro, it is guaranteed that volume of dust fraction, measured by the Microdust Pro is identical with fraction, deposited on the filter. Principle of operation is based on rebound of infrared beam from particles passing through specific chamber. The apparatus can provide measurement in intervals,ranging from 1 second to 1 hour. Measurement record contains date, time and measured valuein mg/m3. Dust of different aerodynamic size can be measured by the apparatus, such as current PM10 and PM2.5, and also not frequently used TSP sizes (total dust, respiratory and inhalational dust) can be detected. The size of measured particles is limited by appropriate filters. Appropriate software is used to process data in Excel format.

System Dusttrak works on similar principle of laser beam rebounding. Values of dustconcentration are recorded in intervals ranging from 1 second to 1 hour, in the mg/m3 format. The measurement is provided for PM10, PM2.5 and PM1 particle sizes. Differentiation of sizes is provided by nozzles for each size. Gained data are recorded in memory and downloaded for further processing.

An apparatuses placing during the measurement

Placing of apparatuses depends on measurement purpose. Currently, particles of sizes of PM10 and PM2.5 are measured. Other particles sizes measurement requires specific process.

Hygienic conditions

Sampling head is placed into animal zones. To determine conditions for dairymen, apparatuses are placed 1.7 m above floor.

Dust emissions set up

To measure dust concentration, sampling head must be placed into ventilation outflow of building. Jacketing buildings have outflow vents. Measurement in cattle houses requires smoke test in order to find suitable places for test probes location. In such case, air flowthrough building must be measured.

RESULTS AND DISSCUSION

Dust concentration analyse

Sufficient database for data processing has been gathered during measurement. In the following table 1, data on dust concentration in stables and their surrounding are presented, for two measured fractions, during 24hours course.

Table 1: Review of dust fraction concentration measured in stables and in their surroundings (μg/m3)

Data variability

Great variability of particles concentration has been found. PM10 – The highest variability has been detected inside building for broiler fattening. Variation coefficient reached 90.8% insidebuilding and 70.0% outside. Similar variability has been gained for fattening pigs stables (inside 86.3%, outside 96.1%). The lowest ratio has been found for dairy cattle stables (inside 23.7 %, outside 38.5 %). PM2.5 – The highest figures have been found out for broiler fattening (stable: 89.0 %, stable surrounding: 81.8 %). The highest data variation has been also found in calf stables (97.7 %) but in stable surrounding the figure has reached only 49.2 %. The lowestvariation has been found in dairy cow stable (inside 23.7 %, outside 38.5 %).

Inside dust concentration is significantly influenced by outside dust concentration (immission). PM10 – The highest proportion of outside pollution on inside particles concentration has been found for fattening pigs processes (80.3 %), calf and dairy cows (58.1% and 52.5% respectively). The lowest proportion has been detected for broiler fattening processes. PM2.5 – Same as the above mentioned fraction, the highest figures have been detected in fattening pigs stables, in calf stables (52.4%) and dairy cows stables 50.3%). The lowest coefficient has been detected in broiler stables (30.1%).

Increasing of dust inside of building is expressed as an excessive valuation of particle concentration due to pollution. PM10 - data, gained inside stables have been over valued (due to pollution) by 40 – 50%, except for data from pig stables (only 24.6% over valuation). PM2.5 - over valuation of this fraction has varied in range of 42.7% (pig stables) to 56.5% (broiler stables).

Analysis of individual dust fractions production

Gross – production: Production evaluation is provided on base of measured dust concentration of relevant fraction inside the treated facility (stable). Another important measured factor is air flow of the facility. Measured values of air flow at individual ductsin jacketed buildings (pigs fattening, poultry) are recalculated for total air flow (m3/h). For the dairy cattle facilities with natural air flow, measured values are assessed by balance method. Emission flow from facility is calculated by multiplication of dust fractionconcentration and air flow (μg/m3). To take into account the measurement time, the gained value is multiplied by 24. The final figure is related to number of animals (total value is divided by number of animals).

Net – production: Input value is represented by difference of value of gross concentrationand pollution value of relevant fraction. Calculation as above follows.

The review of determined values of gross and net production of PM10 and PM2.5 fractions is presented in the tab. 2 Table 2: Review of gross and net production of PM10 and PM2.5 in g per head per day

Data variability

Similarly as at measured concentration of both dust fractions, the production data have beeneffected by considerable variability. Dust production for the whole range of animal weight (from start of fattening to slaughter) is taken into account during the measurement. For the net dust production, pollution variability arising from dust deposit in stable surrounding has animportant impact. Dust particles are being released from surrounding deposit in relation to external factors (temperature, humidity, wind velocity, air pressure, rainfall, and running of the stables). Share of net and gross production is following. PM10 - The highest net production has been measured in dairy cows facilities and in broiler production facilities (49.2%). For the calf production and pig fattening processes, only value of 21.2 % of fraction net production has been measured. PM2.5 - The highest share net-production for fine dust has been found in broiler fattening (64.7 %), the lower figure has been found for dairy cow production and the lowest figure has been assessed for calf rearing (26.5 %). When comparing the share of net production for both dust fractions we have found that the highest share had occurred in dairy cow and broiler production processes. The lowest share has been detected in calf rearing processes.

Utilization of found results

Outputs of measurements are applicable in the following fields:

Work hygiene of dairy men and animals hygiene

The useful data for this sphere have been gained directly by measurement of particles PM10 and PM2.5 concentration inside stables. Referential values, used for comparisonwith measured values are currently published in hygienic standards.

Facilities with animals as a source of dust emissions

Data for emission assessment are gained by aggregation of measured data with other values such as air flow, number of animals in stable, eventually with animal weight. Data are assessed for fractions of aerodynamic diameter up to 10 µm (PM10) and up to 2.5 µm(PM2.5). There is planed to add fraction up to 1 µm PM1 in the future. Emission isexpressed by emission flow, e.g. value of dust weight contained in certain fraction during certain time period. Time period can be one hour, one day or one year.

Proposal for dust emission expression

Units expressing emission factor of dust emission should be expressed by lower order position unit then gas emission, e.g. in g. per head per year rather than in kg per head per year.

CONCLUSION

System of dustiness measurement, related to hygienic condition of workers and hygienic condition of animals is adequate to current needs. Systematic measurements of dustiness in stables and stable surroundings brought about a new system of assessment of dust emission,especially the PM10 and PM2.5 fractions. In an effort of harmonization with system ofmeasurement of gases emission (ammonia and greenhouse gases), certain specificity in existence of variable pollution of dust particles and an order lower concentration of dustparticles have occurred. Such specificity is necessary to take into account. That was the reason, why category of net-production of relevant dust fractions has been implemented. Such category eliminates the influence of variable concentration of dust pollution. In addition, a change of format of expression of emission flow of relevant fractions (emission factor) is presented, in comparison with emission flow of gases. Presented change takes into account an order lower concentration of the PM10 and PM2.5 fractions in the air.

Table 1

Animal sort and category	n=	PM_{10}				$PM_{2.5}$			
		gross weight	immission	% immission	Percentage overestimation	gross weight	immission	% immission	Percentage overestimation
Livestock/calf	8								
Average		259,9	150,8	58,1	40,7	99,6	52,2	52,4	56,3
Standard deviation		112,9	77,2			97,3	25,7		
Variability (%)		43,4	51,2			97,7	49,2		
Livestock/dairy cattle	3								
Average		292,6	153,7	52,5	47,1	172,7	90,3	50,3	49,1
Standard deviation		17,9	24,0			41,0	34,8		
Variability (%)		6,1	15,6			23,7	38,5		
Fattening pigs	7								
Average		367,7	295,1	80,3	24,6,	150,1	90,3	60,2	42,7
Standard deviation		317,4	283,6			80,3	55,2		
Variability (%)		83,3	96,1			53,5	61,1		
Poultry/ broiler	5								
Average		554,0	206,0	37,1	49,1	271,6	81,8	30,1	56,5
Standard deviation		503,3	144,1			241,7	66,9		
Variability (%)		90,8	70,0			89,0	81,8		

Table 2

Animal sort and category	n=	PM_{10}			$PM_{2.5}$		
		gross production	Net production	% Net production	gross weight	Net production	% Net production
Livestock/calf	8						
Average		0,099	0,021	21,2	0,034	0,009	26,5
Standard deviation		0,117	0,019		0,036	0,008	
Variability (%)		118,2	90,5		105,9	88,8	
Livestock/dairy cattle	3						
Average		4,214	2,074	49,2	2,572	1,189	46,2
Standard deviation		1,460	1,005		1,233	0,420	
Variability (%)		34,6	48,5		47,9	35,3	
Fattening pigs	7						
Average		0,427	0,084	19,7	0,166	0,065	39,2
Standard deviation		0,404	0,048		0,081	0,027	
Variability (%)		94,6	57,1		48,8	41,5	
Poultry/ broiler	5						
Average		0,0179	0,0088	49,2	0,0068	0,0044	64,7
Standard deviation		0,0175	0,0081		0,0060	0,0044	
Variability (%)		97,7	92,0		88,2	100,0	

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