

Exposure levels of farmers and veterinarians to particulate matter and gases during operational tasks in pig-fattening houses

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Abstract

The main objective of the study was to assess particulate matter (PM) exposure levels for both the farmer and the veterinarian during different operational tasks in pig-fattening houses, and to estimate their exposure levels on a daily working basis (time-weighted average (TWA)). The measured PM fractions were: inhalable and respirable PM, PM₁₀, PM_{2.5} and PM₁. The effects of pig age, pen floor type (conventional or low emission surface) and cleaning of the pens on the personal PM exposure were also investigated. Indoor concentrations of NH₃, CH₄ and CO₂ were additionally measured during some operational tasks. The results showed that personal exposure levels can become extremely high during some operational tasks performed by the farmer or veterinarian. The highest concentration levels were observed during feed shovelling and blood sampling, the lowest during the weighing of the pigs. For the farmer, the estimated TWA exposure levels of inhalable and respirable PM were 6.0 and 0.29 mg m⁻³, respectively. These exposure levels for the veterinarian were, respectively, 10.6 and 0.74 mg m⁻³. The PM concentration levels were mainly determined by the performed operational tasks. There was no significant effect of pig age, pen floor type, nor cleaning of the pens on the personal exposure levels.

Key words

particulate matter, occupational exposure, pig, ammonia and greenhouse gases

INTRODUCTION

During recent years, an increased interest has shown in the impact of particulate matter (PM) on human health. The upscaling and specialisation of swine farms has caused an increase in working hours inside the confinement buildings, increasing exposure to PM. The European regulation for dust concentrations in workplace environment [1] has defined different particle sizes that need to be considered when evaluating occupational health. These particle sizes are defined on the basis of their behaviour and penetration depth in the human respiratory tract. According to these conventions, the human health-related sizes are: inhalable (particles which can be inhaled through the nose and mouth), thoracic (particles inhaled which can penetrate into the larynx), and respirable (particles which can go beyond the larynx and penetrate into the unciliated respiratory system). Many authors also mention total dust or total suspended particles (TSP) as an evaluation parameter. TSP is the total amount of solid or liquid particles in the aerosol [2]. In ambient air, PM₁₀, PM_{2.5} and PM₁ are commonly used terms, and can be defined as particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at respectively 10, 2.5 or 1 µm aerodynamic diameter [3].

Today, no occupational exposure limits are assessed at the European level. In Belgium, the workplace air quality is regulated according to the Royal Decree of 11 March 2002. This regulation provides concentration limits of 3 and 10 mg m⁻³, respectively, for inhalable and respirable PM over a reference period of 8 hours (a time weighted average or TWA). The PM of interest is collected by personal sampling with well-defined instruments [1].

Previous work by Donham et al. [4] and Reynolds et al. [5], suggested exposure limits for swine confinement workers of 2.40 mg m⁻³ for total dust and 0.23 mg m⁻³ for respirable PM. Measurements of PM in mechanically ventilated pig fattening houses showed concentrations of 0.40–4.56 mg m⁻³ for inhalable dust, while the respirable PM fraction varied from 0.04–0.85 mg m⁻³ [6,7,8,9]. However, most of these PM measurements were obtained by stationary sampling in the pig house and over a whole day (24 hours). In contrast, PM measurements for exposure assessments must take place during the daytime, when indoor PM concentration levels can be up to 50% higher compared to the night time [10].

A study of Radon et al. [11] showed that pig farmers, compared to other agricultural employees, have the highest prevalence of occupational airway diseases regarding work-related respiratory symptoms and asthma-like syndrome. PM emissions can also influence the air quality in the vicinity of livestock buildings, causing health problems for nearby inhabitants [12]. According to Harry [13], PM has an impact on human health due to its irritating effect on

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the respiratory tract, but also due to its role as a carrier of potential pathogenic micro-organisms. PM in pig-fattening houses is a carrier of different micro-organisms, such as bacteria, fungi and endotoxins [14,15]. An 'endotoxin' is a toxin which is part of the outer membrane of the gram negative bacteria, and is known to play an important role in occupational lung diseases [14]. The inhalation of organic dust and endotoxins can cause different symptoms and diseases and is the most important provoker of the inflammatory process in the lungs [16]. Bacteria recovered from air in livestock houses are mostly gram positive bacteria, e.g. *Bacillus* spp. and *Staphylococcus* spp. [17,15]. According to Lee et al. [18], the most prevalent airborne fungal spores in agriculture environments are: *Aspergillus*, *Penicillium*, *Basisidiospores*, and *Cladosporium*.

Besides PM, indoor gas concentrations in agricultural houses can also cause health problems. Ammonia (NH₃) threshold values of 20 ppm for an 8-hour reference period (TWA) are recommended by the European Council [19]. The short-term exposure limit (STEL) over a period of 15 minutes is 50 ppm. For CO₂, a TWA of 5,000 ppm is recommended; no STEL value is available at the moment [20].

Donham et al. (1991) carried out measurements of ammonia (NH₃) and carbon dioxide (CO₂) in pig-fattening houses to assess exposure limits for workers. They concluded that a TWA limit of 7 ppm for NH₃ and 1,540 ppm for CO₂ was to be recommended. Other research has shown that NH₃ concentrations between 24–50 ppm can cause nose and throat irritation after more than 10 minutes exposure [21]. Short duration (30 seconds) exposure to 100 ppm ammonia leads to nasal irritation and increases nasal airway resistance [22].

Objectives. To evaluate the following:

- PM (inhalable, respirable, PM₁₀, PM_{2.5} and PM₁) exposure levels of different operational tasks in the fattening house, both for the farmer and the veterinarian;
- To estimate the time-weighted average (TWA) PM exposure for both the farmer and the veterinarian, based on the exposure measurements for their respective operational tasks;
- the effects of pig age, pen floor type and cleaning of the pens on the personal PM exposure;
- personal vs. static PM sampling in the pig house;
- the exposure to indoor gases (NH₃, CH₄, and CO₂) in the fattening house during operational tasks.

METHOD

All measurements were performed at 2 mechanically-ventilated pig-fattening houses during 6 different days in April and May 2012.

Measurements at farm 1. Farm 1 is situated in Melle, Belgium, and is a part of the ILVO research facilities. This was a conventional pig house with a fully-slatted floor. During the experiments, the pig house was occupied with fatteners ranging from 30–100 kg. Feeding was carried out manually with pelleted feed.

Measurements at farm 2. Farm 2 is situated in Diksmuide, Belgium, and consisted of 8 compartments, 4 of which were conventional compartments with fully-slatted floors;

the other 4 had a reduced emission surface in the pit and partially-slatted floors. During the first series of experiments at Farm 2, 2 groups of pigs with an age difference of 4 weeks were evenly divided between the compartments. The younger group occupied 4 compartments, with an average weight of 109 kg; the older group occupied the other 4 compartments and had an average weight of 114 kg. A second series of experiments was conducted in the same 8 compartments, after 4 compartments were cleaned and refilled with small piglets (approximately 23 kg). The other 4 compartments were not cleaned before the measurements and contained older fatteners.

At Farm 2, the feed was not pelleted and delivered automatically to the troughs by a feeding chain, which was manually started when entering the compartment of the pig house.

All PM concentration measurements were performed with a Grimm spectrometer 1.109 (Grimm Aerosol Technik GmbH & Co. KG, Ainring, Germany). This instrument measures continuously, with an average concentration output every 6 seconds. This instrument also measures simultaneously both workplace related PM fractions (inhalable, respirable according to EN 481) and PM₁₀, PM_{2.5} and PM₁. This direct-reading portable PM monitor works on the principle of scattered light beams to count the number of particles for 32 different size fractions. The counts are converted into PM mass density, according to general algorithms provided by the manufacturer. A correction factor specific for the PM under investigation was not applied.

PM concentrations were obtained both by personal and static sampling. For the personal sampling, the spectrometer was carried by the person of interest (farmer or veterinarian) at chest height. The indoor static PM measurements were obtained in the central pen of the compartment and at animal height (0.8m). At this same location, indoor static gas measurements (NH₃, CH₄, and CO₂) were performed with an infrared photo acoustic detector (1314 multigas monitor, Innova Air Tech Instruments, Santa Clara, USA), which was connected to a multi-sampler (CBISS, a1-envirosciences ltd., Wirral, UK). Gases were measured once per hour.

All measurements were performed during specific tasks of the farmer or veterinarian. For each task, the average PM or gas concentration is calculated for the respective task duration. The following indoor operational tasks were monitored:

- 1) sampling of pig blood by the veterinarian;
- 2) pig vaccination by the farmer;
- 3) control walk with the start of the automated feeding by the farmer;
- 4) control walk by the farmer with the manual feeding (Fig. 1);
- 5) moving pigs out of the pens for weighing by the farmer and the veterinarian;
- 6) weighing of the pigs by the veterinarian;
- 7) shovelling by the farmer of pelleted feed from bags into buckets for distribution of the feed;
- 8) control walk of the farmer in the central alley.

An overview of the performed measurements for each operational task of the farmer or veterinarian is given in Table 1. A measurement repetition is counted if the operational task is interrupted by another operational task during measurements, or if the operational task was performed and measured in different compartments. Blood sampling and weighing of the pigs at Farm 2 were executed

Table 1. Overview of the performed measurements for each operational task with sampling location (1=farm 1, 2=farm 2), performer of the operational task, average operational task time and number of repetitions.

Operational task	Farm	Performer	Average operational task time (min)	Repetitions
(1)	2	veterinarian	23	5
(2)	1	farmer	4	1
(3)	2	farmer	1	14
(4)	1	farmer	8	6
(5)	1	farmer	59	2
(5)	2	veterinarian	27	19
(6)	2	veterinarian	13	23
(7)	1	farmer	7	7
(8)	1	farmer	6	3
(8)	2	farmer	5	6

- (1) sampling of pig blood by the veterinarian;
 (2) pig vaccination by the farmer;
 (3) control walk with the start of the automated feeding by the farmer;
 (4) control walk by the farmer with the manual feeding (Fig. 1);
 (5) moving pigs out of the pens for weighing by the farmer and the veterinarian;
 (6) weighing of the pigs by the veterinarian;
 (7) shovelling by the farmer of pelleted feed from bags into buckets for distribution of the feed;
 (8) control walk of the farmer in the central alley.

within the framework of an extended research on the effect of PM on animal health.

All statistical analysis were performed using SPSS 19.0 (SPSS Inc., Chicago, IL, USA). A multivariate ANOVA test was performed at 0.05 significance level to evaluate PM results from different operational tasks, and to evaluate the effect of age, pen floor type and cleaning of the pens, on the PM concentrations measured by personal sampling.

RESULTS

Farmer and veterinarian exposure levels to PM (personal sampling). Table 2 shows the mean concentrations, standard errors (S.E.) and maximum concentrations for the different PM fractions obtained by personal sampling during each operational task. Figure 2 shows the mean inhalable and respirable PM concentrations per task and per pig house. Single peak concentrations were considered as artefacts and were removed from the dataset. Maximum concentrations as shown in table 2, occurred several times.

For each PM fraction, all measured concentrations were significantly different ($p < 0.0001$). The highest inhalable concentrations were measured during feed shovelling, with



Figure 1. PM concentration measurements by personal sampling of the farmer during manual feeding. Sampling inlet is indicated with an arrow.

Table 2. Mean inhalable PM, respirable PM, PM10, PM2.5 and PM1 concentrations per operational task, with respective standard error (S.E.) and maximum values (mg m^{-3}).

Operational task	Inhalable PM			Respirable PM			PM10			PM2.5			PM1		
	Mean	S.E.	Max	Mean	S.E.	Max	Mean	S.E.	Max	Mean	S.E.	Max	Mean	S.E.	Max
(1)	20.0	32.2	368	1.33	0.85	7.1	4.9	3.2	17	0.53	0.38	3.5	0.077	0.034	0.24
(2)	6.0	3.7	16	0.36	0.20	0.7	1.6	0.8	3	0.13	0.08	0.4	0.025	0.008	0.05
(3)	3.9	2.3	11	0.44	0.23	1.2	1.6	0.9	4	0.18	0.10	0.5	0.032	0.012	0.06
(4)	28.2	38.1	259	0.48	0.57	5.8	2.7	2.5	15	0.19	0.43	5.0	0.024	0.023	0.27
(5)	15.2	19.4	456	0.80	0.57	10.2	3.9	2.5	31	0.29	0.29	9.0	0.047	0.027	0.40
(6)	3.9	9.8	261	0.22	0.34	11.4	0.9	1.3	29	0.10	0.22	9.8	0.033	0.014	0.32
(7)	46.4	67.6	730	0.76	0.66	4.1	4.8	4.1	23	0.24	0.33	2.9	0.034	0.025	0.21
(8)	5.13	11.8	89	0.15	0.15	0.9	0.6	0.7	5	0.07	0.07	0.5	0.021	0.012	0.05

- (1) sampling of pig blood by veterinarian;
 (2) pig vaccination by the farmer;
 (3) control walk with the start of automated feeding by the farmer;
 (4) control walk by farmer with manual feeding (Fig. 1);
 (5) moving pigs out of pens for weighing by the farmer and veterinarian;
 (6) weighing of pigs by veterinarian;
 (7) shovelling by farmer of pelleted feed from bags into buckets for distribution of the feed;
 (8) control walk of farmer in the central alley.

maximum concentration of 730 mg m^{-3} . The highest respirable PM, PM₁₀, PM_{2.5} and PM₁ concentrations were measured during blood sampling. The measured PM concentrations were significantly higher during manual feeding compared to automated feeding, especially for the larger fractions inhalable PM and PM₁₀.

The task of moving the pigs out of the pens for weighing was performed on both farms. The measured concentrations were significantly different for PM₁₀, PM_{2.5} and PM₁ ($p < 0.0001$) and inhalable PM ($p = 0.046$), but not so for the respirable PM fraction ($p = 0.107$). Still, the mean concentrations of inhalable and respirable PM were in the same range for both farms (Fig. 2). Furthermore, it can be observed in Figure 2 that the ratio between the inhalable and the respirable PM fractions, differs according to the performed operational task. Automated feeding showed a relatively high concentration of respirable PM compared to inhalable PM, while for manual feeding and feed shovelling, the opposite was observed. Probably the effect of feed type (pelleted vs. non-pelleted) played an important role in the PM fraction ratio.

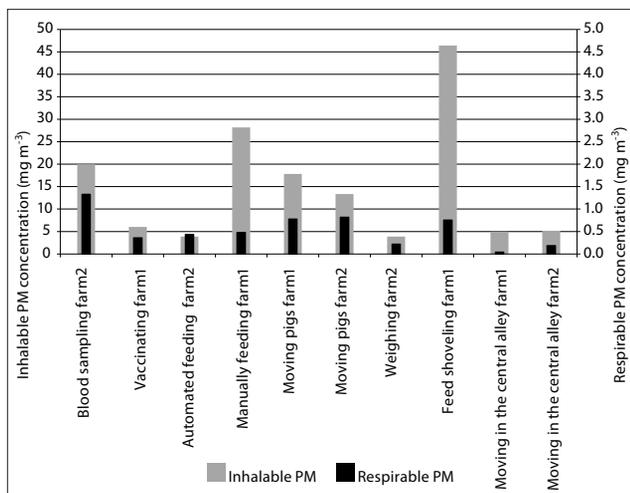


Figure 2. Mean inhalable and respirable PM concentrations per operational task and per farm.

Typical PM concentration patterns during personal sampling. An advantage of using the spectrometers is the semi-continuous output (every 6 seconds), which allows a detailed investigation of the PM exposure. As an example, 2 operational tasks were selected to illustrate the exposure evolution during the operational task.

Figure 3 shows the inhalable and respirable PM concentration patterns, measured at Farm 1 by personal sampling during 3 repetitions of manually-shovelling pelleted feed from bags into buckets for distribution in the pig house. As the PM concentrations were measured every 6 seconds, different peak concentrations could be observed and attributed to specific partial operational tasks, like shovelling the feed out of the bag (Fig. 3, arrow 1), and filling the bucket with feed (Fig. 3, arrow 2). These peaks were noticed for both the inhalable and respirable fraction. Occasionally, high peak concentrations occurred due to PM clouds created when filling the buckets. Peak concentrations of the inhalable and respirable fractions were not always observed at the same moment. This was probably due to the different behaviour of these fractions: inhalable PM consists of larger particles compared to respirable PM, which behaves more like a gas [8].

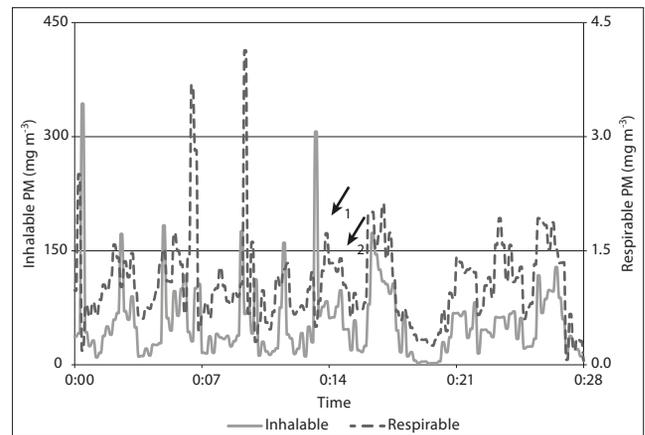


Figure 3. Inhalable and respirable PM concentration patterns during feed shovelling in the pig house at Farm 1. (1) Peak concentration caused by shovelling feed out of the bags. (2) Peak concentration caused by filling the bucket with feed.

Figure 4 shows the inhalable and respirable PM concentration patterns, measured at Farm 2 by personal sampling, during the control walk with automated feeding in the different compartments. Entering the compartment, the concentrations of both PM fractions increased by a factor of 10. Much lower concentrations were observed when the farmer was moving from one compartment to another via the central alley. In total, 7 compartments were checked by the farmer. The fourth peak in the graph was caused by briefly re-entering the previous compartment. The data from the measurements at the eighth compartment were removed as there was a problem with the feed chain.

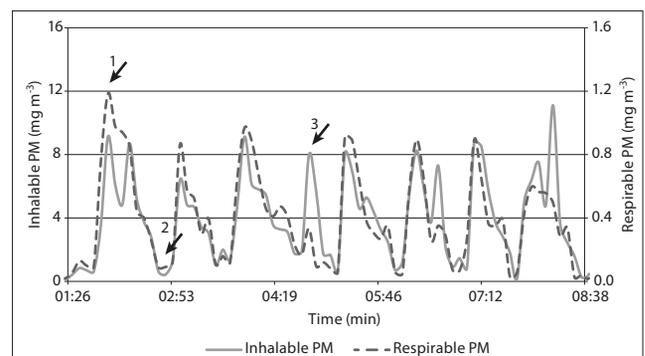


Figure 4. Inhalable and respirable PM concentration patterns for the control walk with automated feeding. The arrows indicate the levels at the time of entering (1) and leaving (2) compartment 1, and the re-entering of compartment 3 (3).

Effect of pig age, pen floor type and cleaning on the PM exposure levels (personal sampling). At Farm 2, the effect of pig age, pen floor type and cleaning could be observed on the personal PM exposure levels for the farmer during a control walk with automated feeding (operational task 3). These measurements were performed twice with a 4-week interval. After the first measurement period, 4 compartments were cleaned and refilled with young piglets. The other 4 compartments were not cleaned and contained older fatteners.

During the first measurement period and over all the measured compartments, no significant differences in PM concentration were found during this specific operational task, except for the respirable PM fraction ($p = 0.011$) and PM₁ ($p = 0.018$) between 2 compartments with the same floor type

and different pig age. Overall, these results suggest that pig age nor floor type, had a significant effect on the personal exposure levels.

During the second measurement period, significantly different concentrations of inhalable PM, PM₁₀, PM_{2.5} and PM₁ were found between 2 compartments with the same floor type, different pig age and different cleaning, and also between 2 compartments with different floor type, same pig age and same cleaning. As for the first measurement period, all measured PM concentrations in the other compartments did not differ significantly. Thus, also from this second measurement period it could be concluded that floor type, pig age and cleaning of the pens had no significant influence on the personal measured PM concentration.

Furthermore, comparing the results of both measurement periods, significantly lower PM concentrations were measured for all fractions and for all compartments during the second measurement series (e.g. 39–83% lower values over all compartments for inhalable PM). According to the statistical test however, these lower PM concentrations could not be attributed to cleaning nor to pig age (no significant interaction between cleaning treatment/pig age and day of measurement). Overall, this led to the conclusion that pig age (4 weeks age difference), pen floor type (fully- or partially-slatted) nor cleaning had a significant effect on the personally sampled PM concentrations. Most probably, the operational task performed in the pig house is the main influencing factor on the PM concentration exposure levels.

Personal versus static PM sampling. During some measurements at Farm 2, simultaneous personal and static indoor sampling was performed. In total, 7 such comparison tests were made, spread over different compartments. On average, the concentrations obtained by personal sampling, were 7–25% higher than those by static sampling. The highest concentration differences were measured for PM₁. For this PM fraction, a still high correlation ($R^2=0.79$) was found between concentrations obtained by personal and static sampling. Similar, relatively high correlations were found for inhalable PM and PM₁₀ ($R^2=0.54$ and $R^2=0.53$, respectively). For the respirable PM and PM_{2.5}, the R^2 values were lower, at 0.36 and 0.07, respectively.

Farmer and veterinarian exposure levels of gases (static sampling). Indoor concentrations of NH₃, CH₄, and CO₂ were measured statically during 3 operational tasks on Farm 2 (Table 3). In general, all respective gas concentrations remained fairly constant during the different operational tasks. The NH₃ concentrations varied from 18.3–19.6 ppm, for CH₄ from 47.0–57.2 ppm, and for CO₂ from 1,222–1,330 ppm.

It should be noted that these concentrations were relatively low compared to those measured during wintertime in the

same pig house (unpublished results). During the winter period of 2012, indoor concentrations increased with a factor of 5, compared to the concentrations measured during this research period.

DISCUSSION

As farm operational tasks can vary in time and also differ per farmer or veterinarian, it is important to have specific exposure concentration levels per operational task performed in the pig house. In this way, it is possible to make reliable estimations of the 8-hour daily exposure levels (TWA). To date, few authors have reported such data. O'Shaughnessy et al. [23] measured a mean exposure concentration of 1.93 mg m⁻³ during feeding (both manual and automated) for inhalable dust, which was up to 15 times lower than the concentrations measured in the presented research. Furthermore, O'Shaughnessy et al. [23] reported a maximum inhalable PM concentration of about 55 mg m⁻³ during the operational task of moving the pigs. This value was also significantly below the maximum concentrations measured in the presented research. Winkel and Aarnink [24] reported an exposure level for PM₁₀ between 1.1–1.6 mg m⁻³ during the weighing of fattening pigs, which was somewhat higher than the mean concentration measured in the presented research (0.9 mg m⁻³). It must be noted that the PM concentrations during manual feeding could have been higher, since the use of pelleted feed can cause a significant decrease in PM concentrations of up to 20% [25].

As most farms not only have fattening pigs, and since farmers and veterinarians perform a variety of tasks which extend beyond those investigated in the presented research, it is always difficult to make a consistent estimation of the respective 8-hour exposure levels. However, these measurements can be used to make useful estimations, since the monitored tasks represent an important part of the indoor operational tasks for both farmer and veterinarian.

Considering, for example, an 8-hour shift of the farmer at Farm 2, spending half-an-hour feeding the pigs, 1 hour moving pigs, 1 hour weighing them, and spending the rest of the time in the central alley of the pig house, the total exposure to inhalable and respirable PM during an 8-hour shift (TWA) would be 6.0 +/- 8.8 and 0.29 +/- 0.14 mg m⁻³, respectively (based on values from Table 2). If the automated feeding would be replaced by manual feeding during 1 hour and an additional 1 h hour of shovelling feed, the TWA values become 9.9 +/- 7.1 and 0.23 +/- 0.08 mg m⁻³ for inhalable and respirable PM, respectively.

A similar example can be given for a veterinarian. Suppose a veterinarian performed 8 farm visits during a working day, spending on average 10 minutes to inspect the pig houses (comparable to automated feeding and control by the farmer) and 30 minutes blood sampling. The PM exposure in between farm visits can be neglected. Based on the exposure levels from Table 2, the TWA exposure of the veterinarian would be 10.6 +/- 16.1 and 0.74 +/- 0.43 mg m⁻³ for the inhalable and respirable PM fraction, respectively.

These calculated TWA exposure levels of inhalable PM for both farmer and veterinarian are close or even higher than the exposure limit of 10 mg m⁻³ as recommended by the Belgian legislation [26], especially considering the standard errors. Furthermore, both inhalable and respirable PM

Table 3. Indoor gas concentrations (ppm) during different operational tasks in the pig house of farm 2.

Operational task	NH ₃	CH ₄	CO ₂
(1)	18.3	47.0	1 222
(3)	19.6	57.2	1 275
(5)	19.4	51.7	1 330

(1) sampling of pig blood by the veterinarian;

(3) control walk with start of automated feeding by the farmer;

(5) moving pigs out of pens for weighing by the farmer and veterinarian.

exposure levels exceed the limits which were suggested by Donham et al. [4] and Reynolds et al. [5]. It must be noted that these latter exposure limits are significantly lower than the regulated ones. This is probably related to the specific aerosol composition in fattening houses where also high amounts of micro-organism are encountered.

In evaluating the indoor gas concentrations, a distinction should be made between NH_3 and CO_2 , on the one hand, and CH_4 on the other. For the first 2 gases, neither the TWA nor the STEL limits were exceeded during the measurements. However, the STEL value for NH_3 was exceeded during previous measurements performed during the winter period. Furthermore, the measured NH_3 concentrations were all higher than 7 ppm, which is the exposure limit suggested by Donham et al. [4].

For CH_4 , no exposure limitations are suggested. The exposure to CH_4 in agricultural houses has been judged to have a low health impact [14]. CH_4 is a non-toxic gas beneath the concentration of 50,000 ppm [27], which is high compared to the measured concentrations in the presented research.

When comparing personal sampling vs. static sampling, PM concentrations obtained by the first were significantly higher than obtained by the latter. Similar findings were reported by Cherrie et al. [28], comparing different aerosol concentrations as measured by personal and static sampling at different industrial sites. According to Vincent (2007), this is due to the fact that workers tend to be located closer to the PM emitting sources than the static samplers. Furthermore, workers can create 'personal dust clouds' due to their own specific operational tasks. Therefore, this concentration difference could probably be even bigger when the static sampling in the pig house is conducted further away from the personal sampling. In the presented research, the static sampling was performed in the middle of the pen at animal height. This is relatively close to the 'personal dust clouds' of the animals which can occur during a higher animal activity caused by the farmer or veterinarian entering the pig house. It can also be noted that the personally sampled inhalable PM concentrations of this research, were generally higher than the statically measured concentrations found in literature.

Based on the maximum measured concentrations during these experiments, it can be concluded that the personal exposure to PM can instantly become extremely high during some operational tasks in the pig-fattening house. Appropriate personal protective equipment, such as dust masks, are therefore advised.

Furthermore, measurements have not been performed in the most unfavourable conditions, that is during the winter period. During this period, an increase in the personal exposure levels can be expected, because indoor concentrations of PM10, PM2.5 and PM1 and gases (NH_3 , N_2O , CH_4 and CO_2) can increase more than 50% compared to the summer period as shown by Van Ransbeeck et al. [29].

CONCLUSIONS

During some working operational tasks in the pig-fattening house, both farmer and veterinarian were exposed to relatively high concentration levels of PM. The highest inhalable concentrations were measured during feed shovelling, with maximum concentrations of 730 mg m^{-3} . The highest

respirable PM, PM10, PM2.5 and PM1 concentrations were measured during blood sampling.

Based on the individual exposure levels per task, the TWA exposure levels of inhalable and respirable PM can be estimated for the farmer and veterinarian. These levels were respectively 6.0 and 0.29 mg m^{-3} for the farmer, and 10.6 and 0.74 mg m^{-3} for the veterinarian. These calculated TWA exposure levels of inhalable PM for both farmer and veterinarian are close or even higher than the exposure limit of 10 mg m^{-3} as recommended by the Belgian legislation [26], especially considering the standard errors. Furthermore, different authors suggest even lower exposure limits, as those mentioned in the legislation, which were exceeded for both the inhalable and respirable PM fraction.

Based on the presented research, there was no clear effect of pig age, pen floor type or cleaning of the pig house on the personal exposure levels. It was concluded that these levels were mainly determined by the operational task performed by the farmer or veterinarian.

Significantly higher PM concentrations levels were obtained by personal sampling compared to static PM sampling. This difference ranged from 7–25%, depending on the measured PM fraction.

During these experiments, the measured indoor gas concentrations did not exceed the TWA exposure limits. However, measurements at the same fattening facility during the winter period showed much higher gas concentrations, which exceeded the suggested STEL limit for NH_3 .

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