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ASSESSMENT OF KOREAN FARMER'S EXPOSURE LEVEL TO DUST IN PIG BUILDINGS

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Abstract: The purpose of the study was to assess Korean farmer's exposure level to dust in pig buildings and dust emissions by investigating airborne concentrations of total and respirable dust. Five main types of pig buildings operating currently in Korea were selected. For area air sampling, 30 sites per each building type were visited during spring (March – May) and autumn (September – November) seasons. For personal air sampling, concentrations of total and respirable dust were measured for 2–3 hours, during cleaning the pig building before the end of the daily shift, by attaching air sampling equipment near to the farmer's breathing zone. Measurement were taken for 8 hours, e.g. average daily work time (09:00–17:00), at 0.5 m above the floor at three locations on the central alley in the pig building. Emission rates of total and respirable dust were estimated by multiplying the mean concentration of total and respirable dust measured near the air outlet by the mean ventilation rate, and expressed either per area or per pig of live weight. The ranges of farmer's exposure level to total dust and respirable dust in the pig buildings were estimated as 0.6–6.7 mg m^{-3} and 0.3–3.5 mg m^{-3}, respectively. The pig buildings operated with a deep-litter bed system showed the highest dust level while the naturally ventilated pig buildings with slats represented the lowest dust level ($p<0.05$). Emission rates ranged from 35–400 mg $h^{-1}m^{-2}$ for total dust and from 4–40 mg $h^{-1}m^{-2}$ for respirable dust, respectively, indicating a similar pattern for the distribution of exposure level. Korean farmers' exposure level to dust in all the pig buildings investigated was below the exposure limit value equal in Korea equal to 10 mg m^{-3}, while it exceeded the threshold limit values (TLVs) established in other developed countries. In comparison with previous studies performed in other countries, mean exposure level in the pig buildings of Korea was generally lower for total dust and higher for respirable dust based on the area sampling method.

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INTRODUCTION

The current industry related to pig production in Korea has become larger and more intensified in terms of economics. Social concerns for environmental impact on air, water and soil pollution grew along with the accelerated growth of the industry. Needless to say, a massive amount of waste water and aerial contaminants emitted from pig production can cause serious environmental problems, which prompted the establishment of strict environmental regulations related to pig production [17, 39].

Of the aerial contaminants generated from pig building, particulate matters like dust play a role in not only deteriorating indoor air quality but also causing an adverse

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health effect on pigs and farm workers [3, 13, 25, 27, 31]. Generally, dust is recognized to adsorb and transport odorous compounds [7, 20] and biological agents [12, 24, 34]. Especially, biological factors associated with airborne dust are the most important hazards in pig buildings and include allergenic and/or toxic agents as well as infectious agents such as bacterial endotoxin, fungal mycotoxin and microbial cell components. If farmers inhale such microbial pathogens, allergic respiratory diseases like asthma, rhinitis and bronchitis are provoked in them [8, 10]. Therefore, if dust in pig buildings is exhausted into the outdoor, it would be responsible for accelerating environmental and hygienic problems such as odour complaint and spread of airborne infectious diseases.

Dust produced in pig buildings is a complex mixture of substances which include feed particles, pig protein (urine, dander, serum), faces, mould, pollen, grain mites, insect parts and mineral ash [15]. This was evidence to suggest that the most frequent and severe health problems were associated with workers tending pigs rather than poultry. Composition of dust from pig houses is as follows: dry matter, 87%; crude protein, 24%; fat, 4–5%; crude fibre, 3–5%; ash, 0–15% [2, 21].

Although several control methods such as ventilation, filtration and misting were applied to eliminate the sources or reduce their rate of dust production in pig building [31], their operational effects have not been satisfied until now. To efficiently control dust generation in pig buildings, plenty of scientific data related to dust quantification should be established in the first place. This fundamental study has already been conducted on a large scale in the EU [36] and fragmentary data were also reported by several researchers in the USA [22, 38, 41]. However, there is no data obtained through field survey in Korea.

Therefore, the principal purpose of this study was to assess the dust exposure level of Korean farmers by comparing values between personal and area sampling. Furthermore, it provides both pig producers and environmental regulators of Korea with information related to the concentrations and emissions of dust in the different types of pig buildings located in Korea by comparing them with previous foreign reports.

MATERIALS AND METHODS

Subjects. As shown in Table 1, the pig buildings investigated in this research were selected in terms of three criteria; manure removal system, ventilation mode and growth stage of pig. The representative types of manure removal system applied in pig buildings in Korea were classified as the manure removal system by scraper, the deep-litter bed system and the deep-pit manure system. The manure removal system by scraper, called the Haglando system [18], consists of a shallow manure pit with scrapers under a fully slatted floor. The floor of the pit is finished very smoothly and covered with an epoxy coating. In this way the manure can be removed from the pig building completely several times a day. The deep-litter bed system is a housing system in which pigs are kept on an about 30 cm-thick layer of a mixture of manure and litter – sawdust, straw or woodshavings. The manure mixed with the litter, mainly sawdust, will be fermented in the bed and dried-up during growing period. The deep-pit manure system, lately expanded in Korea, is composed of a deep manure pit under a fully or partially slatted floor. The manure stored in the pit for relatively long period is removed, by pulling the pit plug, into the manure storage located outside the pig building.

The ventilation modes of the pig buildings adopted in Korea were mechanical ventilation by wall exhaust fans and natural ventilation by operation of a winch-curtain. Generally, the pig confinement style buildings were mechanically ventilated and the open style pig buildings were naturally ventilated. Most of pig buildings with the deep-litter bed system in Korea were the naturally ventilated open houses.

In this study, approximately 1–4 farmers were employed per pig building. They were responsible not for feeding but for cleaning indoor pig buildings or caring for the pigs, because the automated feeding system was installed in all the pig buildings investigated. The pig buildings housing only growing/finishing pigs weighing approximately 50–100 kg were selected in order to objectively compare the measurement values of concentration and emissions between pig housing types.

Table 1. Characteristics of the investigated pig buildings.

Housing type		Pig type	No.*	No.†		Total area (m²)	
Manure collection system	Ventilation mode			Mean	Range	Mean	Range
Deep-pit manure system with slats	natural ventilation	Growing/ Finishing	30	2,200	980–4,350	5,230	2,254–10,440
	mechanical ventilation			2,900	1,120–4,760	4,860	2,688–9,996
Manure removal system by scraper	natural ventilation			1,800	760–3,310	3,840	1,763–7,512
	mechanical ventilation			2,300	860–3,820	5,030	2,003–8,862
Deep-litter bed system	natural ventilation			1,400	570–2,830	3,660	1,277–6,594

*Numbers of investigated pig buildings; †Numbers of pigs per building.

Measurements. This field study was conducted from March to May (spring) and from September to November (autumn) in 2004-2005. Total and respirable dust in pig buildings were measured in 5 pig housing types and the visited farms were 30 sites per each housing type. Thus, the numbers of total measurements were 300 because 150 pig buildings were investigated once each year. Investigated pig buildings were randomly selected and situated in the central districts in Korea: provinces of Kyung-gi, Chung-buk and Chung-nam.

For personal air sampling, concentrations of total and respirable dust were measured for 2–3 hours, during cleaning the pig buildings before the end of the daily shift, by attaching air sampling equipment near to the farmer's breathing zone. For area air sampling, were measured for 8 hours, e.g. average daily work time (09:00–17:00), at 0.5 m above the floor at three locations on the central alley in the pig building.

Emission rates of total and respirable dust were estimated by multiplying the mean concentration (mg m^{-3}) of total and respirable dust measured near the air outlet by the mean ventilation rate (m^3 h^{-1}), and expressed either per pig of live weight 75 kg (mg h^{-1} pig^{-1}) or per area (mg h^{-1} m^{-2}). Total weight of pigs in the pig building was determined by multiplying the directly counted pig numbers by averaged weight of one pig as estimated by the stockman. Total area of the pig building was measured with tapeline or, in case of the pig building measurements not being allowed, estimated by the stockman. Ventilation rate of the pig building was estimated with different techniques depending on ventilation mode. Ventilation rates of the mechanically ventilated pig buildings were estimated by multiplying the area of side wall exhaust fans by averaged value of air velocity measured every 2 h for 8 h sampling time, using a hot-wire anemometer (Model 444, Kurz, Inc., Calif., USA), in the crossed five points near exhaust fans. For the naturally ventilated pig building, the CO_2 balance method described by Albright [1] was simultaneously used for estimation of the ventilation rate.

Total and respirable dust were measured by the gravimetric method. Glass fibre filters (37 mm diameter, 0.8 µm pore size, Nuclepore Corp., CA, USA) were dried in a desiccator for 24 h and weighed, under controlled atmosphere to avoid rehydration, before and after collecting dust with a microbalance (Ohaus model AP250D, Switzerland). The flow rate for collecting dust was precalibrated to 2.0 l min^{-1} for total dust and 1.7 l min^{-1} for respirable dust, respectively. Air sampling was carried out with a low volume sampling pump (Model 71G9, Gillian Corp., NJ, USA). Total particles were collected in close-faced plastic cassette (Nuclepore Corp., Calif., USA) and respirable fractions were collected through 10 mm cyclone preselectors (Gillian Corp., NJ, USA). Control filters were brought to the sampling site and exposed, but not subjected to sampling, and weighed according to the same procedure.

Statistical analysis. Analysis of variance utilizing SAS package programme [35] was performed for the experimental data to determine the significant difference of total and respirable dust between variables of selection criteria. Duncan's multiple range tests were also performed to indicate significant differences among group means in ANOVA.

RESULTS

Total dust. Table 2 presents the concentration of total dust, measured by personal and area sampling, in different pig buildings in Korea. The average and range of total dust concentrations in the pig buildings were 3.02 (0.64–6.67) mg m^{-3} for personal sampling and 1.88 (0.53–4.37) for area sampling, respectively, which varied considerably among pig housing types. The value of total dust concentration measured in a farmer's breathing zone, personal sampling, was generally higher than those measured by area sampling. For both personal and area sampling, the pig buildings with the deep-litter bed system and the mechanically ventilated pig buildings with scraper had higher levels of

Table 2. Concentrations of total dust according to pig housing types in Korea.

Housing		Concentrations of total dust (mg/m^3)			
		Personal value		Area value	
Manure collection system	Ventilation mode	Mean	Range	Mean	Range
Deep-pit manure system with slats	natural ventilation	1.64^a	0.64–2.86	0.83^a	0.53–1.13
	mechanical ventilation	2.78^b	1.23–4.85	1.52^b	0.78–2.12
Manure removal system by scraper	natural ventilation	3.05^b	1.36–4.64	1.67^b	0.82–2.58
	mechanical ventilation	3.48^{b,c}	1.88–5.03	2.42^c	1.26–3.25
Deep-litter bed system	natural ventilation	4.15^c	2.02–6.67	2.94^c	1.88–4.37
Mean		3.02	0.64–6.67	1.88	0.53–4.37

$^{a, b, c}$ – averaged values within the row by the same letter are not significantly different.

Table 3. Concentrations of respirable dust according to pig housing types in Korea.

Housing		Concentrations of respirable dust (mg/m^3)			
Manure collection system	Ventilation mode	Personal value		Area value	
		Mean	Range	Mean	Range
Deep-pit manure system with slats	natural ventilation	0.82^a	0.43–1.08	0.24^a	0.18–0.52
	mechanical ventilation.	0.93^a	0.48–1.43	0.51^b	0.24–0.88
Manure removal system by scraper	natural ventilation.	1.01^a	0.67–1.72	0.48^b	0.31–0.74
	mechanical ventilation.	1.72^b	1.04–2.67	0.83^c	0.23–1.32
Deep-litter bed system	natural ventilation	2.23^c	1.23–3.45	1.14^d	0.52–1.68
Mean		1.34	0.43–3.45	0.64	0.18–1.68

[a, b, c, d] – averaged values within the row by the same letter are not significantly different.

Table 4. Emissions of total dust according to pig housing types in Korea.

Housing		Emissions of total dust			
Manure collection system	Ventilation mode	Personal value (mg/h/pig)[*]		Area value ($mg/h/m^2$)[†]	
		Mean	Range	Mean	Range
Deep-pit manure system with slats	natural ventilation	78.28^a	24.55–110.26	105.22^a	37.14–192.38
	mechanical ventilation	82.35^a	47.64–151.43	110.69^a	63.25–235.18
Manure removal system by scraper	natural ventilation	80.09^a	51.08–184.76	107.65^a	63.16–208.34
	mechanical ventilation	93.18^a	38.16–210.19	125.24^a	53.28–264.29
Deep-litter bed system	natural ventilation	152.74^b	84.16–305.24	205.30^b	93.18–386.46
Mean		97.33	24.55–305.24	130.82	37.14–386.46

[a, b] – averaged values within the row by the same letter are not significantly different; [*] Based on growing/finishing pig (75 kg); [†] Assuming 0.75 m^2 of floor area per pig

total dust concentrations than those of the other pig buildings ($p<0.05$), and the lowest values of total dust concentrations were observed in the naturally ventilated pig buildings with slats ($p<0.05$).

Respirable dust. Table 3 gives the concentration of respirable dust for different pig housing types in Korea. In personal sampling, the mean respirable dust concentration was 1.34 mg m^{-3} and the range of respirable dust concentrations was from 0.43–3.45 mg m^{-3}. On the other hand, the average and range of respirable dust concentration measured by area sampling were 0.64 mg m^{-3} and 0.18–1.68 mg m^{-3}, respectively. Just as for total dust, the mean value of respirable dust was higher in personal sampling than area sampling. Of the investigated pig housing types, also, the pig buildings with deep-litter bed system showed the highest dust levels ($p<0.05$) whereas the lowest values were found in the naturally ventilated pig buildings with slats ($p<0.05$).

Dust emission. Table 4 presents the emissions of total dust from different types of pig buildings in Korea. Mean total dust emissions from the pig buildings were 37.83 mg h^{-1} per pig (75 kg in terms of live weight) and 50.85 mg h^{-1} per area (m^2). The total dust emissions per pig and area ranged from 24.55–305.24 mg h^{-1} and from 37.14–386.46 mg h^{-1}, respectively, which demonstrated that there were considerable variations of total dust emissions among the investigated pig housing types. The lowest and highest values of total dust emissions were generally found in the naturally ventilated pig buildings with slats and the pig buildings with deep-litter bed system, respectively ($p<0.05$).

As indicated in Table 5, The mean respirable dust emissions per pig (75 kg in terms of liveweight) and area (m^2) from pig buildings were 9.55 mg h^{-1} pig^{-1} and 12.83 mg h^{-1} m^{-2}, respectively. Considerable variations of respirable dust emissions by pig housing types were observed, ranging from 2.82–28.08 mg h^{-1} based on pig and from 4.14–38.64 mg h^{-1} based on area. The highest levels of respirable dust emissions were generally found in pig buildings with the deep-litter bed system ($p<0.05$). However, the respirable dust emissions from the other pig buildings were not significantly different ($p>0.05$).

Table 5. Emissions of respirable dust according to pig housing types in Korea.

Housing		Emissions of respirable dust			
Manure collection system	Ventilation mode	Personal value (mg/h/pig)*		Area value (mg/h/m²)†	
		Mean	Range	Mean	Range
Deep-pit manure system with slats	natural ventilation	7.05ᵃ	3.14–10.27	9.48ᵇ	4.26–15.28
	mechanical ventilation	6.18ᵃ	4.25–9.16	8.31ᵃᵇ	5.33–11.26
Manure removal system by scraper	natural ventilation	8.24ᵃ	2.82–15.18	11.08ᵇ	4.14–25.27
	mechanical ventilation	9.12ᵃ	5.22–19.26	12.26ᵇ	7.64–30.18
Deep-litter bed system	natural ventilation	17.14ᵇ	10.54–28.08	23.04ᶜ	14.32–38.64
Mean		9.55	2.82–28.08	12.83	4.14–38.64

a, b, c – averaged values within the row by the same letter are not significantly different; * Based on growing/finishing pig (75 kg); † Assuming 0.75 m² of floor area per pig.

DISCUSSION

The reason that the dust concentration measured in a farmer's breathing zone is higher than for area sampling would be due to farmer's activity in the pig building. A cleaning floor or frame of the pen by broom causes solid particles, derived from feedstuff and dried manure, to suspend in the air, which would increase the potential of farmer's exposure to airborne dust. The range of dust concentrations by personal sampling method in this study were below the exposure limit value, 10 mg m^{-3}, recommended in Korea. However, considering the fact that it exceeded the threshold limit values (TLVs) of dust established in other developed countries, e.g., 0.5 mg m^{-3} in the USA (ACGIH), 3 mg m^{-3} in Canada and 4 mg m^{-3} in the Czech Republic, a preventive strategy by the government should be provided in order to reduce Korean farmers' exposure to dust in pig buildings.

Because emissions of dust reported from the previous studies are expressed with various units, as indicated in Tables 4 and 5, they were converted to unit of "per area" and "per pig" to make an objective comparison among countries and housing types. Pig, addressed herein, is indicated as growing/finishing pig weighing 75 kg and 0.75 m^2, which is generally regarded as a pertinent living space for one finishing pig [17], was applied to convert emissions of dust into a basis of area.

Based on results, in terms of the area sampling method, reported by some researchers (Tab. 6), values of the average, minimum and maximum for total dust concentration in the pig buildings were 4.03 mg m^{-3}, 0.03 mg m^{-3} and 21.04 mg m^{-3}, respectively. The mean emissions of total dust were 100.34 mg h^{-1} per pig and 134.86 mg h^{-1} per area (m^2). Concentration of respirable dust in the pig building obtained by the some researchers was on average 0.31 mg m^{-3} and ranged from 0.03 mg m^{-3}–3.10 mg m^{-3}. Respirable dust emissions, based on pig and area (m^2), from the pig buildings reported from some studies were on average 10.28 mg h^{-1} pig^{-1} and 13.81 mg h^{-1} m^{-2} (Tab. 7).

Table 6. Concentrations and emissions of total dust in pig buildings as reported in the literature.

Concentration				
Country	Housing type	Mean (mg/m³)	Range (mg/m³)	References
U.S.	Slats	8.00	6.4–9.6	Curtis *et al.* [11]
	Slats	15.30	–	Donham *et al.* [14]
	Slats	2.00	1.3–2.7	Meyer and Manbeck [28]
	Slats	7.85	6.9–8.8	Heber and Stroik [22]
	Slats	2.41	–	Zhang *et al.* [41]
	Slats	2.75	–	Wang *et al.* [38]
E.U.	Slats	2.82	0.47–9.55	Attwood *et al.* [4]
	Slats	–	1.66–21.04	Crook *et al.* [10]
	Slats	3.19	0.4–47.00	Pederson [32]
	Slats	2.40	1.00–5.00	Hinz and Linke [23]
	Slats	2.42	–	Takai *et al.* [36]
	Litter	1.30	–	
Canada	Slats	2.20	1.60–2.74	Barber *et al.* [5]
	Slats	3.54	2.15–5.60	Duchaine *et al.* [16]
Taiwan	Slats	0.25	0.03–1.11	Chang *et al.* [8]
Mean	4.03	0.0–21.04		

Emission				
Country	Housing type	Mean		References
		mg/h/pig*	mg/h/m²†	
E.U.	Slats	91.84	123.44	Takai *et al.* [36]
	Litter	108.83	146.28	
Mean		100.34	134.86	

* Based on growing/finishing pig (75 kg); † Assuming 0.75 m² of floor area per pig

Table 7. Concentrations and emissions of respirable dust in pig buildings as reported in the literature.

Concentration				
Country	Housing type	Mean (mg/m^3)	Range (mg/m^3)	References
EU	Slats	0.22	–	Takai *et al.* [36]
	Litter	0.13	–	
Canada	Slats	0.69	0.31–3.10	Duchaine *et al.* [16]
Taiwan	Slats	0.20	0.03–1.45	Chang *et al.* [8]
Mean	0.31	0.03–3.10		
Emission				
Country	Housing type	Mean		References
		mg/h/pig*	$mg/h/m^2$†	
EU	Slats	9.90	13.31	Takai *et al.* [36]
	Litter	10.65	14.31	
Mean		10.28	13.81	

* Based on growing/finishing pig (75 kg); † Assuming 0.75 m^2 of floor area per pig.

According to previous reports, only the EU has surveyed dust emissions from pig buildings whereas the dust concentration was performed well in all the investigated countries. Considerable differences in concentration and emission of dust were found between countries and the pig housing types. Variations in the concentration and emission of dust between the previous reports would be due to differences in external climatic conditions and degree of cleanliness in the pig buildings when taking samples.

Emissions of dust are generally estimated by multiplying the dust concentrations near the air outlet by the ventilation rate. Concentrations of dust in the pig buildings can be measured simply, while it is very difficult to accurately estimate the ventilation rate of the pig building. According to Gay *et al.* [17], the use of static pressure readings and fan curve data for mechanically ventilated pig buildings and tracer gas, heat balance, or carbon dioxide measurements for naturally ventilated pig buildings provide, at best, rough estimates of ventilation rate. In addition, numerous factors that affect airflow, including diurnal pig activity, dust accumulation on fan shutters and blades, loose fan belts, and changes of static pressure in the pig building, are not accounted for by the existing methods of ventilation rate estimation [6]. Therefore, this point will be considered in evaluating and comparing emissions of dust from the pig buildings reported in this article.

This study shows that the concentrations and emissions of dust were highest in the naturally ventilated pig buildings with the deep-litter bed system. The principal reason for this could be the effect of the bedding material on dust generation. The sawdust generally used as the bedding material in Korea would contribute to an increased dust level, in addition to the feed. In particular, this trend can be intensified, along with a dry floor and increased pig activity, because of appreciable resuspension of deposited dust bound on the floor after pig's activity. This observation was demonstrated by many researchers [19, 30, 33, 40]. Although Takai *et al.* [36] reported that the pig buildings with litter were wetter than other housing types, which was reflected in the high relative humidity causing low dust concentrations, such a phenomenon was not observed in this field survey. Another possible reason for variable results could be the difference between the manure collection systems. Barber *et al.* [5] and van't Klooster *et al.* [37] reported that the pig buildings with the deep-pit manure system with slats showed lower dust concentration than other housing types due to relative reduction of surface area of floor where dust can settle and be emitted. Generally, this data indicated that pig buildings with the mechanical ventilation system showed a higher concentration of total dust than those with the natural ventilation system. This was opposite to the finding reported by Chiba *et al.* [9] and would indicate that the current pig buildings with the mechanical ventilation system in Korea are operated at a lower ventilation rate than optimal ventilation rate recommended by MWPS [29].

Table 8. Data comparison between previous reports and present study for total and respirable dust.

Dust	Unit		Reported data		Data in Korea	
			Mean	Range	Mean	Range
Total Dust	Concentration	mg/m^3	4.03	0.03–21.04	1.88	0.53–4.37
	Emission	mg/h/pig*	100.34	–	97.33	24.55–305.24
		$mg/h/m^2$	134.86	–	130.82	37.14–386.46
Respirable Dust	Concentration	mg/m^3	0.31	0.03–3.10	0.64	0.18–1.68
	Emission	mg/h/pig*	10.28	–	9.55	2.82–28.08
		$mg/h/m^2$	13.81	–	12.83	4.14–38.64

* Based on growing/finishing pig (75 kg).

In this study, a large variation of dust emissions according to the pig housing types was observed, similar to data reported by the previous foreign studies [8, 16, 36, 38, 41]. One reason for this could be the variation in ambient air temperature and relative humidity which affect the level of dust generation in pig buildings [22, 26]. The other reason could be the different and imprecise methods applied for estimating the ventilation rate. These methods provide only rough estimates of house airflow and are likely to have contributed to the appreciable variation in the dust emissions data [6]. Additionally, different housing management and animal diet adopted by the investigated farms probably also affect the variation in dust emission data.

Concentrations and emissions in the pig buildings were generally lower for total dust and higher for respirable dust in Korea compared to data reported from other countries (Tab. 8). This could be explained by three reasons. Firstly, there was no seasonal effect on data obtained in this research. This field survey was performed, under a relatively moderate climatic condition, in spring and autumn. Therefore, available data to reflect extreme season, such as summer and winter in Korea, were not included in this research. It would be impossible to objectively compare this data with the previously published foreign data which inherently considered the seasonal variation. Therefore, supplementary studies conducted in the extreme seasons are needed to further quantify the amount of total and respirable dust in pig buildings. Secondly, the experimental procedure for measuring dust was different from other studies. Differences between sampling sites and period, weather condition during sampling, and analysis techniques adopted in each study, would be somewhat influential on variation in concentrations and emissions of dust in the pig buildings. Third, the types of mechanical ventilation applied to the pig buildings were different between the countries. For example, pit ventilation, chimney ventilation and wall ventilation were predominantly used in US, EU and Korea, respectively. Thus, this difference in type of mechanical ventilation would probably contribute to variations in dust levels in the pig buildings.

The limit of this study is that detailed factors in on-site investigation were not thoroughly considered. They are included in pig stocking density, pig building's nutrition system, intermittent measurements and lack of macroclimatic conditions information which definitely affect concentration and emission of dust in pig building, To obtain more accurate survey data, therefore, these contents would be reflected in future further study.

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