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Monitoring of emission of Ammonia, Hydrogen sulfide, nitrogen oxide and carbon dioxide from pig house

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Abstract: The aim of this study was to determine the concentration level of ammonia (NH_3), nitrous oxide (N_2O), hydrogen sulfide (H_2S), and carbon dioxide (CO_2) in two different fattening pig houses operated with slatted floor and straw flow system. The field study was performed for three day. One large-scale pig house with capacity of 230 pigs operate with deep litter manure system under the fully slatted floor and one small-scale pig feeding operation with capacity of 200 pigs operated by scraper and straw flow system, located at the Iksan city, South Korea, were investigated in this study. Average emissions of gases on the slatted floor pig house measured were 59.8-70.5 ppm NH_3, 0.048-0.78 ppm H_2S, 453.1-650.8 ppm CO_2 and 0.21-0.68 ppm N_2O while the concentrations of these gases at straw flow pig house were determined as 28.17-42.53 ppm NH_3, 0.11-0.43 ppm N_2O, 0.018-0.043 ppm H_2S, 400.2-498.3 ppm CO_2. In general, result of H_2S, CO_2, N_2O and NH_3 emissions from the straw flow system were lower than values for fully slatted floor systems.

Keywords: Gas Emission, Pig House, Slatted Floor System, Straw Flow System

1. Introduction

Livestock activities are by far one of the largest sources of odor emission. Ammonia, hydrogen sulfide, carbon dioxide and nitrous oxide emissions coming from livestock urine and manure are considered as emissions which increase the greenhouse effects and acid rain [1]. Much of the research on gaseous emissions from pig farms has been conducted in parallel with important differences between the ways in which pigs are fed, housed and management their manure.

The gaseous odor caused by the operation of pig production facilities constitutes a serious social issue [2]. Ammonia is the most common poison in the pig's environment. The source of ammonia from poultry excreta is uric acid which under moist conditions is quickly broken down to urea and then to ammonium-N from which ammonia is released. Ammonia is very soluble in water and readily reacts with other substances in the atmosphere to form ammonium (NH_4^+) compounds such as ammonium sulphate which can have profound effects on natural ecosystems. Generally, ammonia levels are less than 5 ppm in well managed pig houses. The human respiratory tract can detect levels at around 10 ppm, at levels of 50 ppm and above the clearance of bacteria from the lungs is also impaired and therefore the animal is more prone to respiratory diseases [3]. High concentration of ammonia is generally obtained from pig-feeding operation processes compared to other odorous compounds but the contribution of this gas to odor intensity is actually insignificant because its odor threshold limit value is higher than that for other odorous compounds [4].

Sulfuric odorous compounds such as hydrogen sulfides (H_2S) are generated in lower abundance than NH_3 but they contribute substantially to the total odor because their odor threshold limits are very low [5]. This gas is produced by decomposition of organic matter by anaerobic bacteria, particularly that found in faeces and slurry. The greatest source of H_2S and indeed the greatest potential for disasters comes from slurry that is held in pits beneath slatted houses. Some American states have implemented ambient hydrogen sulphide limits. For example, the Minnesota Pollution Control Agency (MPCA) has implemented a monitoring program for ambient H_2S concentrations in Minnesota, USA. At the property boundaries around livestock facilities, H_2S should not exceed 42 $\mu g/m^3$ for 0.5

h more than twice a week or 70 μg/m^3 for 0.5 h more than twice a year [6].

The greenhouse gas emissions involved in livestock production are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) [7]. High concentrations of these gases can seriously affect animal health and production. As an example, CO_2 or methane is considered as a cause of suffocation or asphyxiation which can displace oxygen [8].

Table 1 shows previously studies on the emissions rate of ammonia, hydrogen sulfide and carbon dioxide in pig buildings in various countries. This study was aimed at quantifying the concentration and emission levels of NH_3, N_2O, H_2S and CO_2 emitted from deep litter manure system under the fully slatted-floor and straw floor system from pig feeding operations, South Korea.

Table 1. *Previously studies on ammonia, hydrogen sulfide and carbon dioxide production in pig buildings in various countries.*

Country	Housing type	Conc. range (ppm)	Reference
		NH_3	
England	Straw flow	5.1–14.3	[9]
Germany	Straw flow	12.5–27.3	[9]
	Slatted	0.2–19.0	[10]
U.S.	Slatted	0.3– 32.1	[11]
	Slatted	1.5– 13.2	[12]
Canada	Slatted	6.5– 64.9	[13]
	Slatted	1.9 –25.9	[14]
Korea	Slatted	6.6– 12	[15]
		H_2S	
U.S.	Slatted	120.0–2,174	[16]
U.S.	Slatted	154.0– 378.0	[17]
Taiwan	Slatted	1.9 – 4.2	[18]
Korea	Straw flow	17.4– 20.5	[19]
		CO_2	
Korea	Slatted	603– 849	[15]
Korea	Straw flow	690– 1615	[19]

2. Materials and Methods

The pig houses investigated in this study were selected based on manure removal system. The types of manure removal system installed at selected houses were scraper removal system and deep litter bed manure system. The manure removal system by scraper consists of shallow manure pit with scrapers under the straw flow [20]. The floor of the pit has a smooth finish which is covered with an epoxy coating, allowing the complete removal of the manure from pig houses several times a day. The deep litter bed system is a layer of mixture manure and litter compose with sawdust or straw. The manure mixed with litter is fermented in bed and dried during the pigs growing periods and is cleaned out once a week. The deep pit manner system which has become more popular in Korea in recent years is a combination of deep manner pit under a fully or partially slatted floor [21]. Manure stored in pit for long period is removed by pooling the pit plug allowing the manure drain into a storage compartment located outside the pig house area. Pig houses arranged with straw flow scraper remove system and fully slatted floor designs are illustrated in Figure 1.

2.1. Measurement Methods

The concentrations of H_2S, NH_3, CO_2, N_2O and two environmental parameter relatively humidity and temperate ure were measured and recorded.

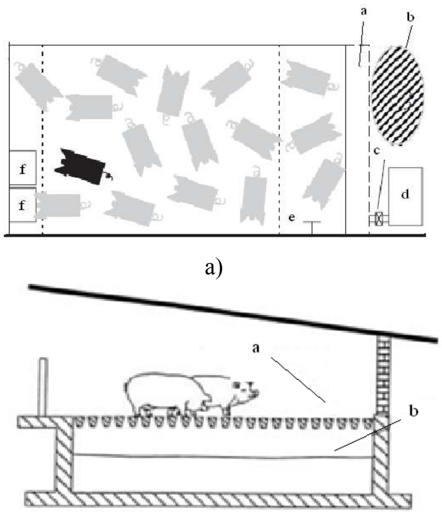

Figure 1. *A) House arranged with the straw flow system (a = scraped passage, b = manure storage, c = pump, d = slurry tank, e = drinker, f = feeder) B) fully slatted housing system (a = concrete slats, b = deep pit).*

An ammonia trap system consisted of acid bottle to trap the emitted ammonia, variable area flow meter to regulate flow rate of the sweep-air and a vacuum pump to pull air through the system (Fig. 2). This method involves capturing ammonia in a boric acid solution. Experiment will be continued to determine the concentration of collected ammonia in liquid phase according to indophenols method. The sample was buffered at a pH of 9.5 with borate buffer in order to decrease hydrolysis of cyanates and organic nitrogen compounds and was distilled into a solution of boric acid. Alkaline phenol and hypochlorite react with ammonia to form indophenol blue that is proportional to the ammonia concentration. The blue color formed was intensified with sodium nitroprusside and measured by the OPTIZEN 1412V spectrophotometer at the wavelengh of 640 nm [22]. In this study we used 25 ml boric acid (0.5%) which was placed in adsorption bottle. Air sample collected by using vacum pump with flow rate of 5.0 L/min for 10 min. Collected samples were transferred to laboratory for analysis.

The range of hydrogen sulfide, carbon dioxide and nitrous oxide concentration inside the pig houses were estimated by collecting the air sample in 10 liter Tedler air bag by using vacuum pump.

A schematic view of the air sample collection process is shown in Figure 3. Tedlar bag was fitted with a valve with unique push-pull operation and valve consistently achieves a positive open or closed setting.

The analysis of hydrogen sulfide concentration in the collected samples was carried out by SHIMADZU GC-2010 gas chromatography (GC) flame photometric detector (FPD). The details of the method can be found at [23, 24].

NO_2 analyzer model KN-210 purchased from KNETCH company, South Korea has been used to determine the concentration of NO_2 based on Chemiluminescence method (chemical reaction that produces light).

When an nitric oxide (NO) molecule reacts with ozone, it is oxidized to NO_2 which in excited state. Small fraction of the molecules in this excited state with decay by emitting a photon in the near infrared portion of the spectrum. Thus, by measuring the amount of light emitted, the concentration of NOx in the mixes a gas sample with ozone may be determined.

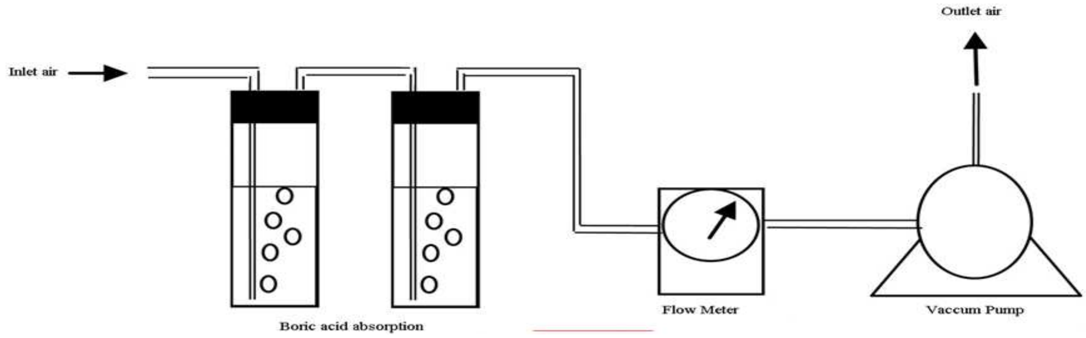

Figure 2. *Schematic of ammonia absorption in boric acid.*

Non Dispersed Infrared Analyzer (NDIR) method used to measure the CO_2 emission in collected air sample. Each constituent of gas in a sample absorbs some infrared radiation at a particular frequency. An infrared beam is passed through a sample cell (containing CO or CO_2) and the amount of infrared absorbed by the sample at the necessary wavelength is measured by a NDIR detector.

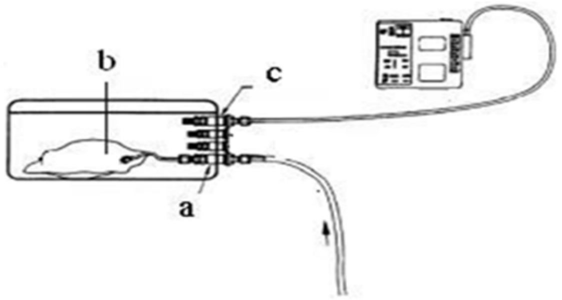

Figure 3. *Schematic view of the air sample collection process. a) Sampling port, b) Tedler bag, c) vacuum port.*

3. Result and Discussion

Range of temperature and humidity observed during the study period (17th to 19th of April, 2011) are shown in Table 2. The mean indoor temperature in both the building was between 22.1-25.2°C. The mean outdoor temperature ranged between 14.2-16.3°C.

It was observed that huge amount of the heat lost occurred through the walls in both studied pig houses. Heat lost through the walls of the room with the slatted-floor system (large scale) was at a lower level compared to room with the straw flow system (small scale). The temperature range covered did not substantially influence the level of gases emission.

The characteristics of the pig farms are presented in Table 3. Pig house with slatted floor was equipped with automatic concentrate-dispensing systems where fattening pigs were kept in collective facilities. Depending upon the type of farming, two indices of stocking density have been used: live weight per unit building area and air volume available per unit. Increase in stocking density involved an increase in variability of gas emission exposure. Table 4 presents gas emission observed during the study period**.**

NH_3 emissions were nearly two times more in a house with pigs on the slatted floor than on the straw flow. This means more N gaseous emission occurred with the slatted floor system. These emission may occur in form of NO, N_2O, NH_3 and N_2. In this study, the difference between the NH_3 higher emissions of the two systems,70.5ppm in slatted floor and 42.53ppm in straw flow can explain around 45% of the difference in the manure N-content. NH_3 emissions come principally from the microbial degradation of urea by enzyme urease, which is abundant in faeces [25]

In a straw flow system, the pigs excrete only in the rear of the pen which keep the lying area dry and clean. This reduces NH_3 emissions since less emitting surface is used. On the other hand, it was expected that separation of liquid manure associated with storage in a hermetic tank as part of straw flow system [26] would have decreased the release of NH_3. Hence, the increase in manure surface and amount of manure explains the main part of the higher estimated increase in mean daily NH_3 emission from slatted floor system.

N_2O emissions are mainly during gentrification, in presence of oxygen and / or low availability of degradable carbohydrates [27]. Therefore, its formation needs both aerobic and anaerobic conditions, these heterogeneous conditions can be found in slatted floor system.

Our result showed the released N_2O emission from pig houses with slatted floor as well as straw flows are negligible. Highest level of N_2O emission from slatted floor obtained were 0.68 ppm while 0.43 ppm measured from straw flow system. These results further confirm that N-content emissions from the slatted-floor system are higher than emission from the straw-flow system.

The majority of the CO_2 in the air of pig houses comes from animal respiration. It has to be noted that CO_2 emission estimated in this study did not take into account heating energy, ventilation energy or energy involved in removing manure. The result revealed that ammonia emissions and CO_2 emissions had same pattern during the study period. The CO_2 emission varied with range value of 453.1-650.8 ppm in slatted floor system and 400.2-498.3 ppm in straw flow system pig house. It is reported that when the pigs are very active during the daytime, the CO_2 exhalation rate is about 200% higher than at tranquil condition [28].

H_2S concentration was in range of 0.018 to 0.074 ppm for small pig house with straw flow system while the concentration range was 0.048 to 0.78 ppm in large scale pig house equipped by deep litter and slatted floor. H_2S formation is closely related to amount of the production of manure which depends on animal number. This is expected with the more number of pigs at large scale pig house and higher amount of manure. However, unlike NH_3 the response of H_2S emission to amount of animal manure production is not immediate since more H_2S is generated from stored manure as compared to fresh manure.

Table 2. *Mean temperatures and humidity observed in the experimental houses slatted floor and straw flow*

	17th (10 am)		**18th (2 pm)**		**19th (8pm)**	
Temperature (°C)	Mean	SD	Mean	SD	Mean	SD
Slatted floor (L)	23.4	1.3	25.2	0.42	25.1	0.38
Straw flow (S)	22.1	0.54	23.5	1.2	23.9	1.12
Outside	14.2	6.3	15.5	5.3	16.3	7.5
Humidity (%)						
Slatted floor	23	0.7	21.2	1.03	20.5	0.6
Straw flow	24.6	1.5	22.7	1.04	23.8	0.42

SD = standard deviation

Table 3. *Characteristics of the pig farms studied*

Farm identification	**Management system**	**Type of housing System**	**Cleaning system**	**Built-up area (m^2)**	**Total air volume (m^3)**	**Stocking density (kg/m2)**
Large Scale	Intensive	Freestall	Slats	350	1,720.00	92.55
Small Scale	Intensive	Freestall	Scraper	230	1,010.40	74.00

Table 4. *Mean concentrations of NH_3, H_2S, N_2O and CO_2 measured from two swine farms and surrounding area*

		Mean conc. ppm			
	Gas	**Slatted floor (L)**	**Surrounding area**	**Straw flow (S)**	**Surrounding area**
Day 1(17th)	NH_3	70.5	2.4	42.53	1.83
Reading time(10am)	H_2S	0.78	0.45	0.043	0.074
	CO_2	650.8	378.6	498.3	420.5
	N_2O	0.68	0.022	0.43	0.056
Day 2(18th)	NH_3	63.09	1.38	35.86	1.17
Reading time(2pm)	H_2S	0.055	0.016	0.028	0.014
	CO_2	494.6	360.7	450	410.8
	N_2O	0.47	0.018	0.21	0.02
Day 3(19th)	NH_3	59.8	1.2	28.17	0.84
Reading time(8pm)	H_2S	0.048	0.025	0.018	0.02
	CO_2	453.1	355.4	400.2	380.8
	N_2O	0.21	0.014	0.11	0.011

Pig houses operation time start at approximately 7:30–8:00 AM The readings of gas detector were taken at 2hr (first day), 6hr (second day) and 8 hr (third day) after operation time.Surrounding area included farm perimeters.

4. Conclusion

Concentration level of nitrous oxide (N_2O), hydrogen sulfide (H_2S), ammonia (NH_3) and carbon dioxide (CO_2) were determined in two different fattening pig houses operated by with slatted floor and straw flow system.

Concentration level of NH_3 in pig house operated by slatted floor ranged from 59.8 to 70.5 while the concentration level of this gas obtained in a range of 28.17

to 42.53 in the pig house operated by straw flow system. The results showed the higher value in both pig houses compared to previously studies.

Based on the concentration level of different gaseous in two different pig houses (Table 4), the environmental assessment of the raising of fattening pigs on the welfare-friendly straw-flow system seems to have a lower manure N content and lower greenhouse gas emissions in comparison with the slatted-floor system.

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