Original Article
Journal of Biosystems Engineering

J. of Biosystems Eng. 39(2):76-86. (2014. 6)
http://dx.doi.org/10.5307/JBE.2014.39.2.076

eISSN : 2234-1862
pISSN : 1738-1266

Emissions of Odor, Ammonia, Hydrogen Sulfide, and Volatile Organic Compounds from Shallow-Pit Pig Nursery Rooms

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Received: February 27th 2014; Revised: April 22nd 2014; Accepted: May 22nd 2014

Abstract

Purpose: The objective of this study was to measure emissions of gases (ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2)), volatile organic compounds (VOC) and odor from two shallow pit pig nursery rooms. Gas and odor reduction practices for swine operations based on the literature were also discussed. **Methods:** This study was conducted for 60 days at a commercial swine nursery facility which consisted of four identical rooms with mechanical ventilations. Two rooms (room 1 (R1) and room 2 (R2)) with different pig numbers and ventilation rates were used in this study. The pig manure from both the R1 and R2 were characterized. Indoor/outdoor temperatures, ventilation rates/duration, NH_3, H_2S, CO_2, and VOC concentrations of the ventilation air were measured periodically (3-5 times/week). Odor concentrations of the ventilations were measured two times on two days. Three different types of gas and odor reduction practices (diet control, chemical method, and biological method) were discussed in this study. **Results:** The volatile solids to total solids ratio (VS/TS) and crude protein (CP) value of pig manure indicated the pig manure had high potential for gas and odor emissions. The NH_3, H_2S, CO_2 and VOC concentrations were measured in the ranges of 1.0-13.3, 0.1-5.7, 1600-3000 and 0.0-1.83 ppm, respectively. The NH_3 concentrations were found significantly higher than H2S concentrations for both rooms. The odor concentrations were measured in the range of 2853-4432 OU_E/m^3. There was significant difference in odor concentrations between the two rooms which was due to difference in pig numbers and ventilation duration. The literature studies showed that simultaneous use of dietary control and biofiltration practices will be more effective and environmentally friendly for gas and odor reductions from pig barns. **Conclusions:** The gas and odor concentrations measured in the ventilation air from the pig rooms indicate an acute need for using gas and odor mitigation technologies. Adopting diet control and biofiltration practices simultaneously could be the best option for mitigating gas and odor emissions from pig barns.

Keywords: Ammonia, Emission, Hydrogen sulfide, Pig, Odor, Volatile organic compounds (VOC)

Introduction

In recent decades, livestock production has shifted from small farms to industrialized operations with intensive confinement of animals and concentration of wastes. High-intensity livestock production satisfies the need to improve the efficiency of animal management. The concentration of livestock in stalls/barns or in open lots decreases labor requirements but increases the problem of waste disposal (Hays and Bianca, 1975). Concentrated animal feeding operations (CAFOs), including pig facilities, are sources of air pollutants, such as ammonia (NH_3), hydrogen sulfide (H_2S), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), volatile organic compounds (VOCs), particulate matter (PM), and odor that affect air quality. Sources of these emissions include barns, feedlot surfaces, composting structures, manure storage and treatment facilities, and land application areas. Emissions from animal agriculture are relevant to both local and global air pollution (Hood et al., 2011). Similarly, pig finishing operations near residential

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areas can create public nuisance concerns due to the annoyance potential of odor emitted from the pig operations (Schauberger et al., 2013). Besides the nuisance associated with odors, they have also been shown to have a negative impact on the public health of people living in close proximity of the pig farms, where several studies have suggested odors from intensive pig farms to be the cause for several ailments (Schiffman et al. 1995; Merchant and Ross 2002). Schiffman et al. (1995) reported that persons living near pig operations who experienced the odors had significantly more tension, more depression, more anger, more fatigue and more confusion than control subjects as measured by the Profile of Mood States. As a follow-up to this study, Thu et al. (1997) published the results of another project based on physical and psychological health data from 18 neighbors living within a two-mile radius of a 4,000-pig operation in Iowa, USA. Neighbors of the swine operation reported experiencing significantly higher rates of four clusters of symptoms known to represent toxic or inflammatory effects on respiratory tracts.

As livestock production has become more concentrated and the make-up of rural communities has changed, neighbor complaints about odors from livestock operations have increased in number and visibility to the point where odor concerns are a primary barrier at the local level to grow livestock operations. Associated with this increase is the air pollution problem (odors) which has become the center of public concern. This is reflected in the increased frequency of odor-related complaints in areas where swine production facilities are more intensified. Odor management is currently impacting many aspects of the swine industry and there appears a potential that the sustainability, productivity, and profitability of swine producers will be dependent upon whether they can reduce the emission of offensive odorants from operating swine production units to a level which surrounding communities could tolerate. Therefore, there exists an acute need for effective methods of odor control, for if the swine industries are to coexist with their neighbors, such control measures will have to be put into operation (Zhu, 2000). Concern about the potential for animal waste pollution has emerged as one of the most critical environmental issues confronting pig producers in the U.S.

Exhaust ventilation air from livestock production buildings is a major source of pollution to the environment from agricultural operation. Indoor air quality in the building affects the well-being of both animals and workers. More detailed research identified the concentration levels of interior ambient airborne elements, including their interactive dynamics, which put exposed worker populations at risk. For example, recommended gas (7 ppm ammonia), dust (2.5 mg/m^3 total dust; 0.23 mg/m^3 respirable dust), and endotoxin (100 EU/m^3) levels have been developed for interior swine confinement operations based on dose–response research (Donham et al., 1995; Reynolds et al., 1996). Researchers have also noted that when these elements combine (e.g., ammonia attached to small dust particles), they may have an added negative health consequence. Many American agencies or organizations such as the United States Environmental Protection Agency, the Agency for Toxic Substances and Disease Registry have established threshold values for NH_3 and H_2S in ambient air. Based on these threshold values, on average, the NH_3 100 to 4,500 ppb; for the H_2S, 1.4 to 200 ppb, respectively (Lemay et al., 2007).

Since the state and federal governments may impose increasingly strict regulations on swine farms to reduce air and water pollution, the swine industry may have to respond by implementing new technologies and practices to reduce emissions.

Accurate estimation of air emissions from CAFOs is needed to predict their potential adverse impacts and to facilitate the selection of the most effective control measures. The US Environmental Protection Agency (EPA), the USDA Natural Resources Conservation Service (NRCS), as well as state and local governments, are seeking such information to assist them in making appropriate policy decisions to manage existing CAFOs, as well as plan for the construction, expansion or retrofits of CAFOs in their jurisdiction. In order to reduce NH_3, H_2S, VOC, and odor emissions from pig farms, it is firstly important to know the concentrations and emission rates associated with pig production systems. Thus, there is a need to know the amount of these pollutants being emitted from pig production buildings for simple regulatory purposes, but more importantly to determine how these airborne pollutants can be reduced to levels that will meet the regulatory limits, lower the impact of odors for neighbors, and minimize the risk to workers and pigs. The objectives for this research project were: (a) to measure the gas (NH_3, H_2S and CO_2) and VOC concentrations in the ventilated air; (b) to measure the odor concentration of the ventilated air; (c) to discuss the gas and odor mitigation practices.

Materials and Methods

Experimental site

This study was conducted at a commercial swine nursery facility, which consisted of four 4.3 m × 12.8 m, 120-head nursing rooms, in Kimberly, Idaho, USA. Two (room 1 (R1) and room 2 (R2) of the four rooms were used for this study. Each room had an independent tunnel ventilation system. During the test period, the R1 and R2 had 30 and 67 pigs, respectively. Air entered the rooms through an inlet located on the south wall of each room. There were two (primary and secondary) variable speed exhaust fans (Multifan, 4E40Q) in the north wall of each room (Figure 1). During this study, only primary fans were in operations. A shallow pit with depth of 0.6m was constructed below the slatted floor to collect manure and washing water. Around 60-70% of total volume in the shallow pit was drained to the lagoons every 5 days. Small Pigs were moved in at about 5-7 kg and were raised to approximate 64-68 kg at the nursery facility. After the pigs moved out, the room was completely flushed with well water before new small pigs were moved in.

Gas, VOC and odor measurements

The NH_3 and CO_2 concentrations in the ventilated air were measured with detection tubes and a gas sampler (Gastec Co. Ltd.) (Yasuda et al., 2009). The detection ranges of the NH_3 and CO_2 gas tubes were 0.5-35.0 ppm and 300-3500 ppm, respectively. The H_2S and VOC concentrations in the ventilated air were measured using a gas analyzer (Multi RAE Gas Analyser, RAE SYSTEMS, USA). The detection limit of the gas analyzer was 0.1ppm

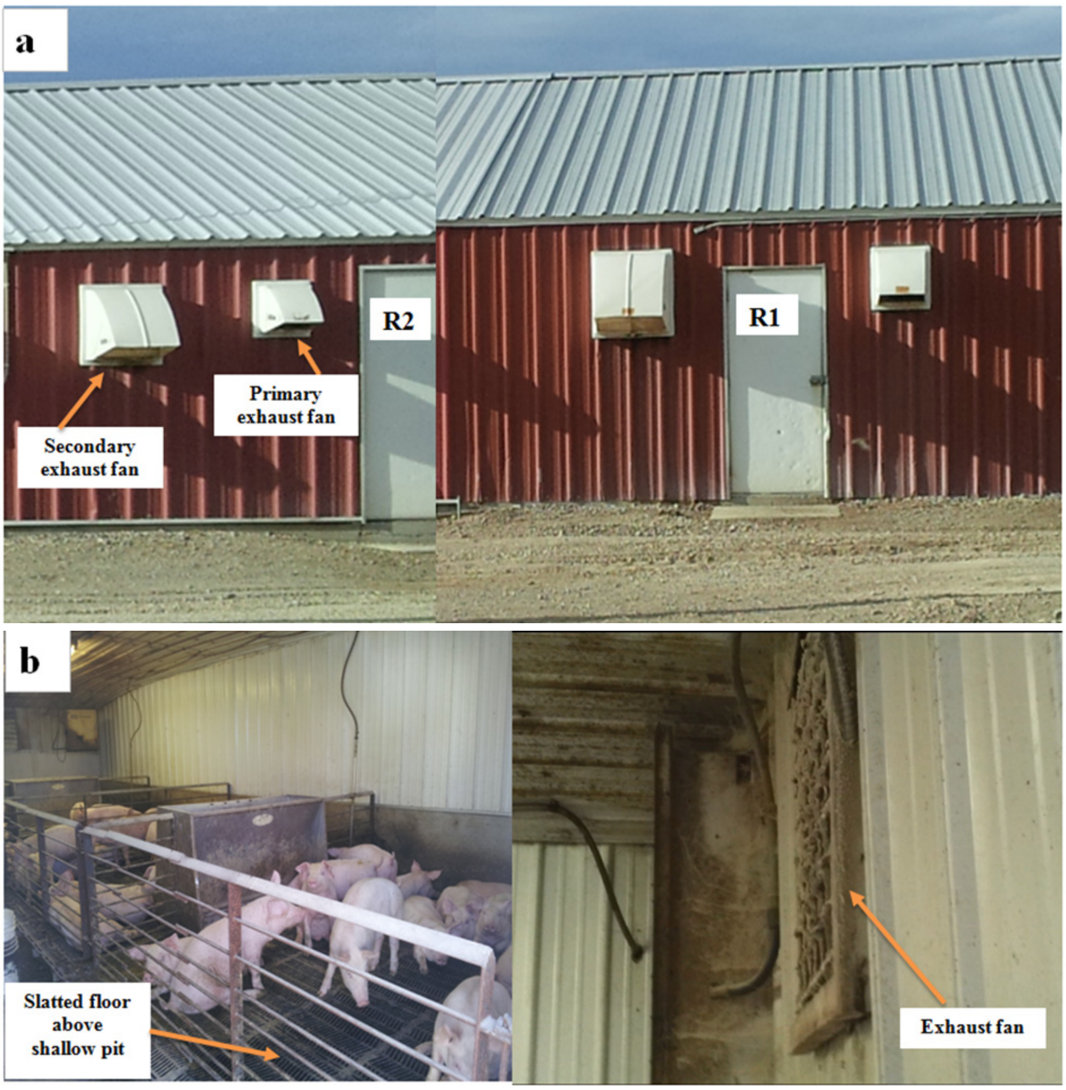

Figure 1. Pig nursery facility (a) outside view from north showing exhaust fans; (b) inside view.

for both H_2S and VOC concentrations.

Odor samples were collected using 10 L Tedlar® bags (SKC Inc., Eight Four, PA). Two vacuum pumps (224-PCXR3, SKC Inc., Eight Four, PA) and vacuum boxes (Vac-U-Chamber, SKC Inc., Eight Four, PA) were used to fill the bags. All odor samples were analyzed within 24 h of collection using a dynamic forced-choice olfactometer (AC'SCENT International Olfactometer; St. Croix Sensory, Inc. Stillwater, Minn.) based on ASTM E679-04 (ASTM, 2004). Eight panelists were used for each evaluation. Each panelist was screened based on their ability to detect n-butanol in the 20 to 80 ppb range as defined by EN13725 (Committee for European Normalization, 2003). Each panelist was given a series of presentations at decreasing dilution ratios. At each dilution ratio, the panelist was given one presentation which contains the odor and two blank presentations (triangular testing). The panelist must select the presentation which is different from the other two and declare to the test administrator whether the selection is a "Guess," "Detection," or "Recognition," as defined by ASTM E679-04.

Ventilation rate and temperature measurements

Ventilation rate, indoor and ambient air temperatures were measured using a TSI VelociCalc® Air velocity meter (model: 9565 series, TSI Incorporated, Shoreview, MN, USA). A plywood duct was connected to the exhaust fan and a hole was provided on the duct for measuring the ventilation rate. Measurements were taken three to five times per week.

Analytical methods for pig manure compositions

TS and VS of pig manure were determined in the well-mixed samples in triplicate according to standard methods (APHA, 1998). pH value was determined using a pH meter (YK-2001 PH, Taiwan) (Kafle and Kim, 2012a; Kafle and Kim, 2012b).The analysis of crude fiber (CF), CP, and Ether extract (EE) were done according to the methods described in AOAC (1990). The total volatile fatty acids (TVFA), total alkalinity (TA) were determined using the Nordmann-titration method (Kafle and Kim, 2011; Kafle et al., 2012; Kim and Kafle, 2010).

Statistical analysis

The significance of differences in odor , gas, and VOC concentrations were determined by single factor ANOVA (Analysis of Variance) with a threshold p-value of 0.05 and 0.01 in Excel software 2007 (Lim et al., 2012). Fisher's least significant difference (Fisher's LSD) was calculated to judge whether two or more averages were significantly different (Bhattarai et al., 2012; Kafle et al., 2014; Kafle et al., 2013).

Results and Discussion

Pig manure characterization

The fresh pig manure produced everyday remained in the shallow pit until it is flushed (for around five days). Manure undergoes anaerobic decomposition naturally during a storage period. The odor, gas, and VOC emissions in the pig barn are due to decomposition of manure and due to pig activity in the barn (Schauberger, et al., 2013). The factors affecting the concentrations of odor and gas in the ventilated air are indoor temperature/outdoor temperature, ventilation rate, animal activity, season, relative humidity, manure depth, pig density, air cleanliness, barn cleanliness, fan size, fan location, pig health and pit type (Schauberger, et al., 2013). Similarly, the chemical composition of the pig manure is another main factor governing the concentrations of odor and gas in the ventilated air (Leek et al., 2007). Leek et al. (2007) expressed NH_3 emission as a function of total Kjehldahl nitrogen (TKN) and TVFA concentrations (R^2 = 0.70) of the manure. The chemical compositions of pig manure collected from the two rooms are shown in Table 1. The VS/TS ratio of pig manure was found to be 0.87, which

Table 1. Characteristics of pig manure

Parameter	units	Range	Mean	SD
Total solids (TS)	%	31.4-30.6	31.0	0.6
Volatile solids (VS)	%	26.8-27.3	27.1	0.4
VS/TS		0.87-0.88	0.87	0.0
pH		5.84-5.90	5.59	0.0
Total nitrogen (TN)	% TS	4.2-4.4	4.30	0.1
Crude Protein (CP)	% TS	26.3-27.5	26.88	0.9
Crude Fiber (CF)	% TS	20.2-20.6	20.40	0.3
Ether extract (EE)	% TS	9.3-9.5	9.4	0.1
Total volatile fatty acids (TVFA)	mg/L	2320-2464	2392	102
Total alkalinity (TA)	mg/L	1500-1606	1553	75

SD: Standard deviations

indicates the manure still contains more digestible organic matter. The CP contents in the pig manure were calculated to be 26.9% (TS basis). The manure pH (5.59) was lower than the neutral pH, which was due to the higher TVFA concentration than TA in the manure. The fresh pig manure is stored in a shallow pit so during the storage period the pH of the manure is expected to increase due to degradation of CP by micro-organisms. The degradation of CP will increase the ammonical nitrogen concentrations (Herrmann et al., 2011), resulting in an increase in the alkalinity and pH of the manure.

Indoor/outdoor temperature and ventilation rate/duration

The tests for the R1 and R2 were performed during Sep-28 to Nov-21(55 days) and Sep-19 to Nov-17(60 days), respectively. The daily average indoor and outdoor temperature for R1 and R2 are shown in Figure 2(b) and Figure 3(b), respectively. The outdoor temperatures was in the range of 2.3-19.9°C (Table 2). The indoor temperature for R1 and R2 were in the range of 15.1-22.6°C and 18.3-23.9°C, respectively. Results of ANOVA analysis and least significant difference (LSD) analysis are shown in Table 3. Statistically, indoor temperatures for both the R1

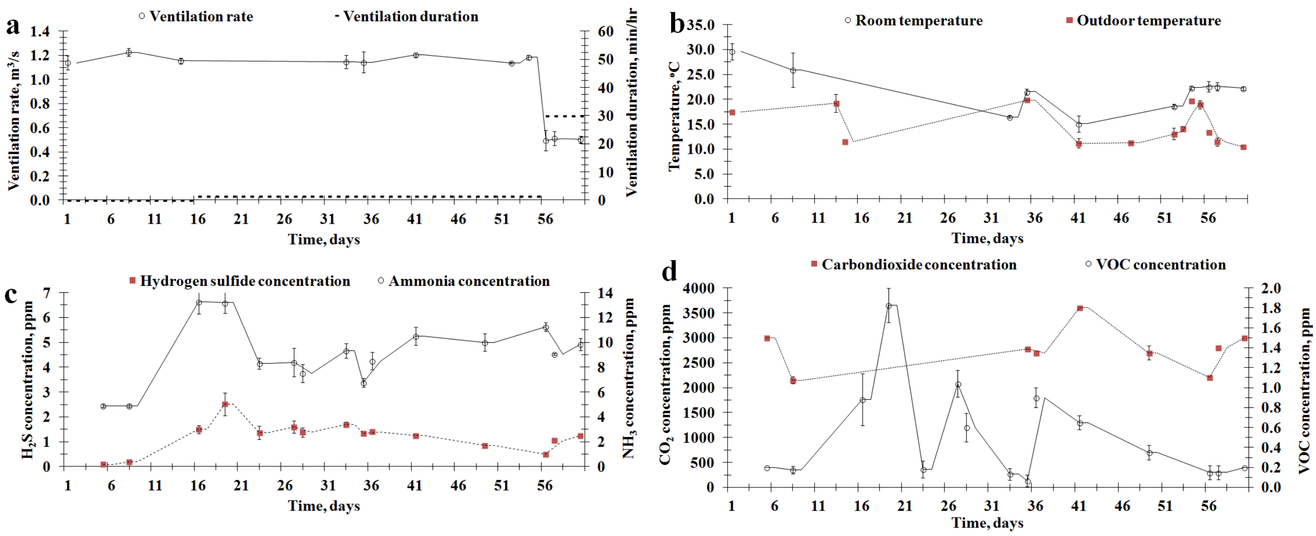

Figure 2. Patterns of gas and volatile organic compounds (VOC) concentrations in ventilated air from room 1(R1) with total number of 30 pigs.

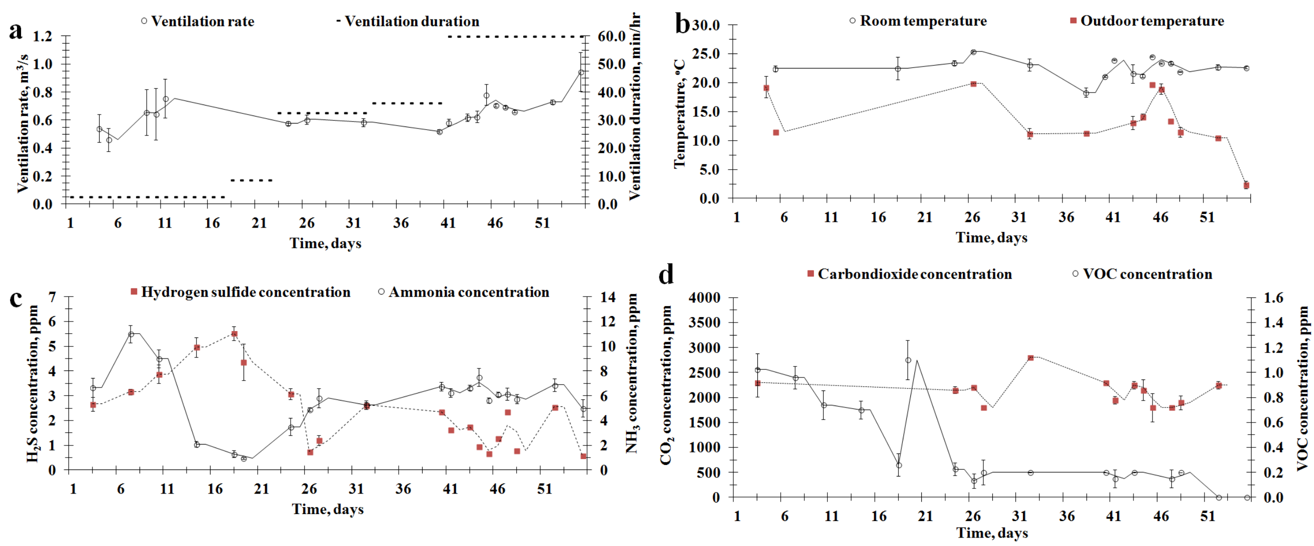

Figure 3. Patterns of gas and volatile organic compounds (VOC) concentrations in ventilated air from room 2 (R2) with total number of 67 pigs.

Table 2. Test conditions and odor, volatile organic compounds (VOC) and gas concentrations for ventilated air from Room 1(R1) and Room 2 (R2)

	Units	R1		R 2	
		Min/Max	Mean(SD)	Min/Max	Mean(SD)
Ventilation rate	m^3/s	1.225(0.496)	0.985(0.311)	0.521(0.944)	0.649(0.111)
Ventilation duration	min/hr	0/30	3.4(8.1)	2.7/60.0	29.2(23.1)
Indoor temperature	oC	15.1/22.6	21.7(4.30)	18.3/23.9	22.6(1.6)
Outdoor temperature	oC	2.3/19.9	14.7(3.7)	2.3/19.9	14.7(3.7)
NH_3 concentration	ppm	4.9/13.3	9.0(2.5)	1.0/11.0	5.7(2.4)
H_2S concentration	ppm	0.1/2.5	1.2(0.6)	0.6/5.7	2.4(1.5)
CO_2 concentration	ppm	2150/3000	2769(435)	1600/2500	2127(282)
VOC concentration	ppm	0.15/1.83	0.50(0.49)	0.0/1.2	0.38(0.37)
Odor concentration	OU_E/m^3	2854/4650	3843(821)	2647/3770	3066(426)

SD: Standard deviations
OU_E/m^3: European odor unit

Table 3. Results of ANOVA analysis and least significant difference (LSD) analysis

Parameter	Room	Units	LSD α=0.05	LSD α=0.01	p-value
Odor concentration	R1 & R2	OU_E/m^3	585	826	0.001837306
NH_3 concentration	R1&R2	ppm	1.1	1.4	1.0553E-21
H_2S concentration	R1&R2	ppm	1.80	2.37	7.86973E-24
NH_3 and H_2S concentration	R1 & R2	ppm	0.80	1.06	6.62205E-56
VOC concentration	R1&R2	ppm	0.13	0.18	3.80916E-22
CO_2 concentration	R1&R2	ppm	224	299	1.75421E-12

R1: Room 1
R2: Room 2
VOC: Volatile organic compounds

and R2 were significantly higher than outdoor temperatures (Table 3).

The ventilation rate of the exhaust fans of each room was different. Thus the ventilation duration was different for the two rooms (Figure 2 and Figure 3). The ventilation system was automatically controlled depending on the indoor room temperature and humidity. The ventilation duration for the R1 and R2 was in the range of 0-30 min/hr and 2.7-60 min/hr, respectively. The ventilation duration (min/hr) for the R2 increased with an increase in the size of the pig until the end of the test (Figure 3). But the ventilation duration for the R1was almost constant until day 55 and thereafter rapidly increased from 1.33 min/hr to 30 min/hr till the end of the test (Figure 2). The low ventilation duration for the R1 was due to fewer pigs.

Gas and VOC concentrations of the ventilated air

Figure 2(c and d) and Figure 3(c and d) shows the patterns of gas (NH_3, H_2S and CO_2) and VOC concentrations in the ventilated air from the R1 and R2, respectively. Table 2 summarizes the min/max and the average gas and VOC concentrations for the R1 and R2 during the test period. Table 3 shows the results of ANOVA and LSD analyses for odor, gas and VOC concentrations. There was significant difference between NH_3, H_2S, CO_2 and VOC concentrations for both the R1 and R2 (Table 3). The NH_3, H_2S, CO_2 and VOC concentrations for the R1 were measured to be in the range of 4.9-13.3, 0.1-2.5, 2150-3000, 0.15-1.83ppm, respectively. The NH_3, H_2S, CO_2 and VOC concentrations for the R2 were measured to be in the range of 1.0-11.0, 0.6-5.7, 1600-2500, 0.0-1.2 ppm, respectively. The NH_3 concentrations for both the R1 and R2 were significantly higher than H_2S concentrations (Table 2 and Table 3). The average NH_3 concentration in the R1 was significantly higher than that in the R2; however, no significant difference was found in the average H_2S concentration between the R1 and R2. No significant difference was found in the average VOC concentrations between the R1 and R2, however, average CO_2 concentration for the R1 was significantly higher than that for the R2. The difference in ventilation duration and number of pigs could be reasons for differences between the gas concentrations in the R1 and R2.

Odor concentrations of ventilated air

Odor is a mixture of various compounds, of which four groups may be the major contributors: sulfurous compounds, indolic and phenolic compounds, volatile fatty acids, and ammonia and volatile amines. Odor mainly originates from microbial conversion of crude protein (CP) and fermentable carbohydrates (FC) in the large intestine of pigs and by microbial conversion of urinary and fecal compounds in the manure (Aarnink, et al., 2007). In animal houses, odor may come from animal bodies, floors, and manure in the pit (Aarnink, et al., 2007).

Figure 4 shows the odor concentrations of the ventilated air from the R1 and R2. Odor concentrations of the ventilation air were measured on two days during the test period. The odor concentrations for the R1 and R2 were in the range of 2958-4432 OU_E/m^3 and 2853-3770 OU_E/m^3, respectively. The odor concentrations were higher for the R1 than R2 in spite of a lower number of pigs in the R1. The reason for the higher odor concentrations in the R1 may be due to its lower ventilation (1836 m^3/hr) compared to that in the R2 (9986 m^3/hr) (Table 2). For the R1, there was found a significant decrease in odor concentrations when ventilation duration was increased from 1.33 min/hr to 30 min/hr (Figure 1(a)). The results of the R2 showed no significant difference in odor

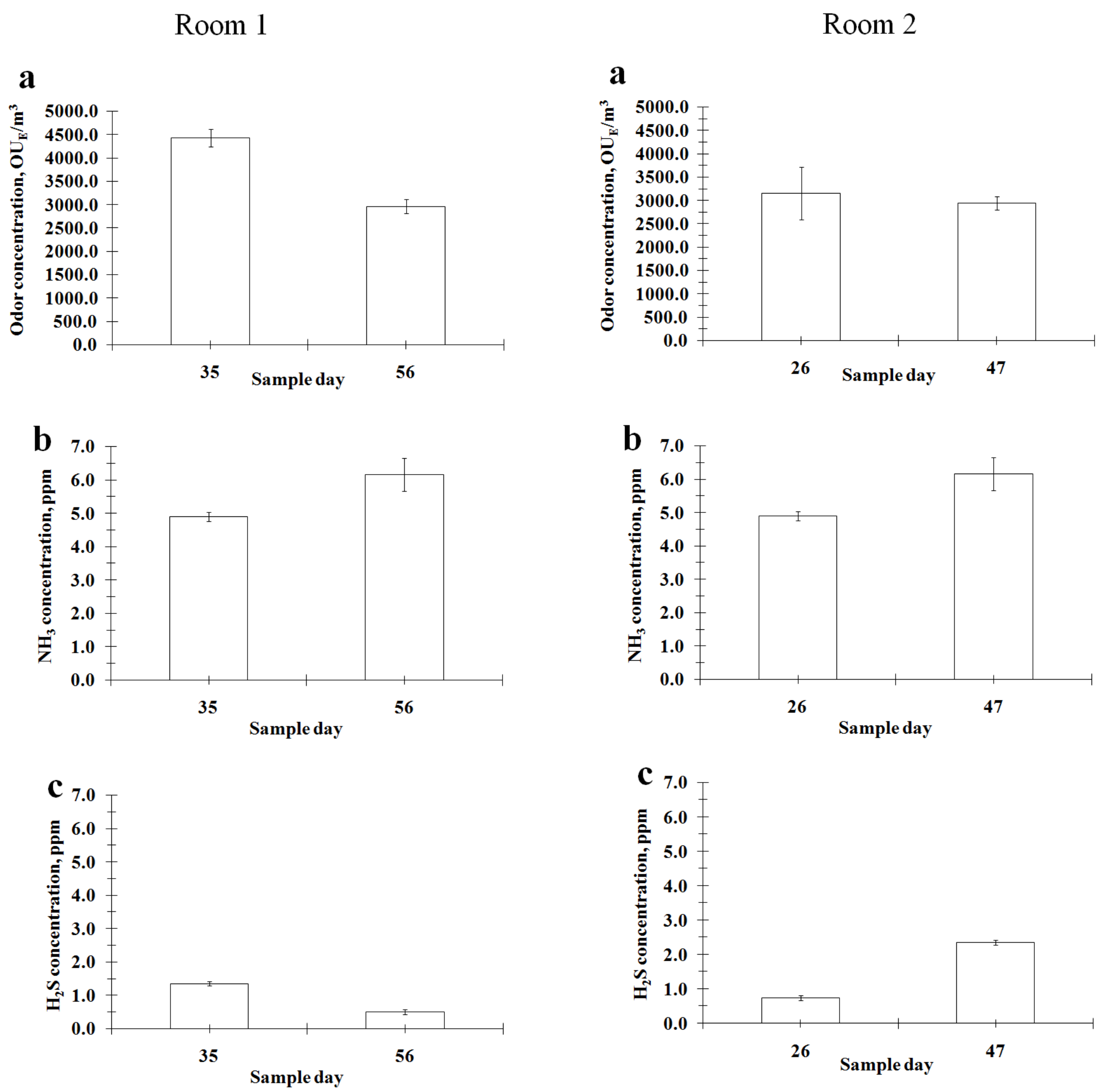

Figure 4. Odor concentrations for room 1(R1) and room 2 (R2).

concentrations between the two different days when the ventilation rate and duration were almost constant (Figure 2(a)). The reason for difference in odor concentrations for the R1 may be due to the significant difference in the ventilation duration (Figure 1 and Figure 2). The average of the two days' odor concentrations for the R1 was significantly higher than that for the R2 (Table 2 and Table 3). Sheridan et al. (2002) measured odor concentrations in the range of 476-2149 OU_E/m^3 on a swine farm which is lower than in our study. In contrast, Lau and Cheng (2007) reported a higher range of odor concentrations (8553-12171 OU_E/m^3) on a duck farm compared to this study.

The NH_3 and H_2S concentrations in the ventilation air for the different odor concentrations are shown in Figures 4(b) and (c). Both NH_3 and H_2S concentrations in this study did not show any relation with the odor concentrations of both the R1 and R2. Aarnink et al. (2007) also did not found any correlation between their NH_3, H_2S concentrations with odor concentrations. Aarnink et al. (2007) reported that the correlation between ammonia and odor emission depends on environmental factors that may result in both positive and negative correlations. NH_3 and H_2S are odorous gases and they are typically found in the headspace of the manure and wastewater storage pits at relatively high concentrations. However, there are over 300 odorous compounds, of which some compounds such as 4-methyl phenol (*p*-cresol), indole, and 3-methyl-1H-indole (scatole) have lower detection thresholds and might be dominant odorous compounds even at low concentrations (Jacobson et al., 2010).

Gas and odor mitigations practices

Airborne pollutants generated in pig-confinement buildings exert adverse health effects on pig farmers, pigs and neighbors. Thus, many farmers are interested in finding ways of controlling airborne pollutants and odor on their farms. Reducing odor associated with pig farming will be instrumental to the success of pig industry. Dietary control, acidification, oxidizing agents, activated carbon adsorption, wet scrubbing, masking agents, biofiltration and biological additives are some of the practices studied in the literature and these practices are discussed in this section.

Minimization of nitrogen (N) excretion is the most obvious method to curb NH_3 emissions. By reducing the amount of nitrogen excreted, less NH_3 will be formed and volatilized (Leek et al., 2007). Different studies showed possibility for the odor reductions from swine farms by controlling the diet in the pig feed (Aarnink et al., 2007; Canh et al., 1998; Kay and Lee, 1997). Different diet ingredients have different patterns of digestion and absorption and thus differ in pathways of odor precursor excretion. Aarnink et al. (2007) reported low odor production from pig manure when pigs were fed diets with a low CP and a low FC diet or a high CP combined with a high FC diet. Similarly, Canh et al. (1998) concluded that lowering dietary CP and supplementing essential amino acids while maintaining normal growth rate reduces urinary nitrogen and ammonia emission (10-12.5% reduction in NH_3 emission with each percentage of decrease in dietry CP) from the slurry of growing-finishing pigs. The excess CP causes production of odor precursors excreted via urine and feces and these are thus present in the manure (Aarnink et al., 2007). The precursors are responsible for the production of sulfurous, indolic and phenolic compounds, volatile fatty acids (VFA), ammonia and volatile amines in the manure. Therefore, one of the dietary approaches to reducing odor from pig manure is to decrease dietary CP level. Peirson and Nicholson (1995) reported a 40% reduction in odor emission rate with a control and low nitrogen diets. Although dietary control of pigs showed reduction in gas and odor emissions, it will be not possible to totally stop the gas and odor emissions from pig barns. Thus, along with diet control strategies other technologies should be simultaneously used to improve reductions of gas and odor emissions from ventilated air.

Depending on the pH, nitrogen can exist in different forms. Reducing the pH maintains more nitrogen in the form of ammonium, which is not released as a gas. Therefore, strategies that acidify manure (reducing the pH) can be used to trap ammonium and prevent its release as ammonia. A disadvantage of acidification is that although it traps ammonia, the reduced pH is conducive to volatilization of H_2S, another odorous compound produced from the anaerobic decomposition of manure. Costs associated with this practice include the acid and the equipment to apply and mix the acid with the stored manure. The chemical methods using many different oxidizing agents are also effective in reducing malodors in pig building, but these have relatively short periods of effectiveness and can be potentially toxic to farmers and pigs if applied excessively (Kim et al., 2008).

Any technology used to reduce emissions must be able to treat a broad spectrum of airborne compounds. Various air pollution control technologies have been invented and applied, such as activated carbon adsorption, wet scrubbing, and masking agents (Ottengraf and Van Den Oever, 1983; Chung et al., 2007). These methods, however, often transfer odor causing materials from the gas phase to scrubbing liquids or solid adsorbents, and their derivatives have resulted in wastewater and solid waste concerns (Lin et al., 2001; Chung et al., 2007). However, biofiltration is a green technology that uses no chemicals, thereby creating no issues of potentially hazardous media disposal. This technology has become, in the past few decades, the most feasible, cost-effective and widely accepted technology for treating air streams containing odorous compounds (Prado et al., 2009). Biofiltration is a promising control technology for processes that emit large off-gas volumes with relatively low concentrations of contaminants. Biofiltration has the advantage that the pollutants are not transferred to another phase and, therefore, new environmental problems are not created or are only minimal. Moreover, the process is said to be cheap and reliable and does not usually require complex process facilities (Ottengraf, 1987). The technology has been successfully applied to a wide range of industrial and public sector sources for the abatement of odors, VOCs and air toxics, with an elimination efficiency of more than 90%. Owing to its economic advantage over the conventional air pollution control methods coupled with environmental benefits like low energy requirements and the avoidance of cross-media transfer of pollutants, biofiltration is becoming more popular and practical in meeting the statutory emission regulations (Wani et al., 1997). Different literatures have reported biofilter performance for odor and ammonia reductions in the range of 67.0-95% (Chen et al., 2009; Chen and Hoff, 2012; Lau and Chang, 2007; Sheridan et al., 2002)) and 54-95% (Chen et al., 2009; Chen and Hoff, 2012; Nicolai and Janni, 2001; Sheridan et al., 2002), respectively.

In the last two decades, various biological additives (essential oils, soybean oils, and microbial additives) have been utilized in controlling odors in pig buildings. Kim et al. (2008) evaluated the performance of various additives (tap water, salt water, digested manure, microbial additive, soybean oil, artificial spice and essential oil) and reported that salt water, artificial spice and essential oil showed positive effect on reducing odor generation. All additives cost extra money and need application equipment. In addition, their effectiveness for odor abatement is weaker than the biofiltration method and chemical method addressed above (McCrory and Hobbs, 2001).

Above discussions on different gas and odor mitigation practices showed that some are environmentally friendly and effective while others are not. Based on the above discussions, adopting dietary control and biofiltration simultaneously could be the most effective and environmentally friendly practices for mitigating odor emissions from the pig barns.

Conclusions

The shallow pit pig nursery barns were found to be potential sources of air pollutions and there is an urgent need for adopting the gas and odor reduction practices. The NH_3, H_2S, CO_2 and VOC concentrations were measured in the range of 1.0-13.3, 0.1-5.7, 1600-3000 and 0.0-1.83 ppm, respectively. NH_3 concentrations were found to be significantly higher than the H_2S concentrations in the pig barns. The odor concentrations were measured in the range of 2853-4432 OU_E/m^3 and the odor concentration was decreased with an increase in the ventilation duration. Simultaneous adoption of dietary control and biofiltration practices are suggested to pig farmers for reducing the gas and odor emissions from their operations. The data obtained in this study can be helpful in preparing strategies to reduce the gas, VOC and odor in pig nursery houses.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgements

This project was partially funded by the USDA Natural Resources Conservation Service through a Conservation Innovation Grant. The authors gratefully thank Mr. Dave Roper for his cooperative efforts during this research.

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