

Aerial Pollutant Gases Concentrations in Tropical Pig Pen Environment in Nigeria

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ABSTRACT: Research on the concentrations of aerial pollutant gases in tropical livestock buildings is needed in order to establish baselines for exposure limits in context of animal and human welfare in the tropical environments. The concentrations of aerial ammonia, nitrous oxide, methane, carbon monoxide, hydrogen sulfide and sulfur dioxide in selected pigpens in the Owerri area of Imo State, Nigeria were measured during the month of August 2002. These were thereafter correlated with pig building measurements in order to determine the possible influence of building measurements on concentration of the gases. Overall mean aerial concentrations of carbon monoxide CO (2.7 ± 0.34 ppm) was the highest mean value recorded and was followed by the 1.4 ± 0.0 ppm and 0.07 ± 0.14 ppm recorded for flammable gas (methane) and hydrogen sulfide respectively while the 0.0 ± 0.0 ppm recorded for ammonia was lowest. The average length of the buildings was 64.20 ft., while 21.40 ft., 11.60 ft and 4.35 ft. were obtained for width, height and sidewalls respectively. In all pens, the simple linear regression was not significant ($P < 0.05$), with the coefficient of determination ranging from 0.001 (SO₂) to 0.364 (CO). For the different aerial pollutant gases, the best linear predictor was for CO using height of building followed by SO₂ using height and so on based on the R² values. Even though this study returned low levels of gases for the area during the month of August, there is the need to extend the study to other periods of the year especially the dry season months in order to further elucidate the effects of inclement weather on gas concentrations in pig pens. [Nature and Science. 2006;4(4):1-5].

Key words: Pig, pollutant gases, pigpen environment, tropical, Nigeria

INTRODUCTION

Livestock production in the tropics is essentially categorized into extensive, semi-intensive and intensive production systems. The intensive system usually involves commercial production of high performance exotic breeds of livestock. This system is resource driven and requires the operator to be in control of the housing, nutritional and health needs of the livestock (Williamson and Payne, 1978). The relative success of commercial pig and poultry production in the tropics (Delgado et al., 1998; FAO, 2000) has made these livestock business ventures very attractive in most developing countries.

In Nigeria, most livestock buildings used in intensive production are open sided affairs, roofed with corrugated iron sheets. While these open sided designs promote natural ventilation and are cheap to construct, non-insulated corrugated iron roofs may transmit considerable amount of incoming solar radiation into the livestock pen and may thus cause heat buildup. This constitutes a serious production problem especially in the warm humid tropical environment (Williamson and Payne, 1978;

Oluyemi and Roberts, 2000). Indeed, there is hardly any attempt at enforcing standards in livestock building design and construction in Nigeria either for the benefit of the health of the operators or for that of the welfare of the animals. For example in the warm tropical environment of southeastern Nigeria, humidity of air is high and air movement is usually slow (Harry, 1978). There is the need to consider these while designing and constructing of livestock pens.

One of the untoward effects of poor livestock housing design and construction is aerial pollutant gases buildup in livestock buildings. The concentrations of these pollutants in livestock houses and their emission rates have been studied extensively in developed economies and several comprehensive reviews have been published (Harry, 1978; O'Neil and Philips, 1992; Wathes et al., 1997). These studies have shown that the potential effects of air quality on livestock productivity involve complex interactions between physiological behavior and disease (Wathes, et al., 1983; Wathes, et al., 1998). There is also very strong evidence for occupational respiratory disease in those who work

with livestock (Donhann et al., 1995; Reynolds et al, 1996). This is believed to arise from chronic exposure over several years to complex mixtures of aerial pollutants in livestock pens. For example, the physiological and psychological effects of extended ammonia exposure on man may include nausea, headache, depression and dizziness (Donhann et al., 1995; Borgers et al., 1997).

Furthermore, there is evidence that poor air quality influence the incidence and severity of common endemic respiratory diseases of pigs (Muirhead and Alexander, 1997; Wathes, 2001). Such information are however lacking for most tropical farming environments. Research on the concentrations and emission rates of aerial pollutant gases in tropical livestock buildings is therefore needed in order to establish baselines for exposure limits in context of animal and human welfare in the tropical environments.

This study reports recent field measurements of the concentrations of aerial ammonia, nitrous oxide, methane, carbon monoxide, hydrogen sulfide and sulfur dioxide in selected pig pens in the Owerri area of Imo State during the month of August 2002 and their correlation with livestock building measurements.

MATERIALS AND METHODS

Study area: Imo state is situated in the southern rain forest vegetational belt of Nigeria. It lies between latitude 5° and 6° 3'N and longitude 6° 15' and 7° 34' E. The area is dominated by plains 200m above sea level except for elevations associated with the Okigwe uplands (Ofomata, 1975). It has an annual rainfall of about 1700 mm to 2500 mm, which is concentrated almost entirely between March and October. Average relative humidity is about 80% with up to 90% occurring during the rainy season. The mean daily maximum air temperature range from 28°C to 35°C while the mean daily minimum range from 19°C to 24°C.

In this rainforest zone, smallholder livestock production predominate with over 80% of rural families keeping west African Dwarf (WAD) ruminants and mixed breeds of local and exotic chicken (Molokwu, 1982; Ejiogu, 1990) primarily as source of investment, manure and meat at home or during festivals. In most parts of the state livestock are allowed to roam throughout the seasons, with little supplementation from kitchen wastes (Okoli et al., 2003). Prophylactic management of common infectious diseases is rarely practiced.

Pollutant gases and pig house measurements: Measurements of the concentrations of aerial ammonia NH₄, nitrous oxide (NO₂), Flammable gas

(methane, CH₄), carbon monoxide (CO), hydrogen sulfide (H₂S) and sulfur dioxide (SO₂) were made in five intensive pig farms located in the Owerri area of Imo state during the month of August 2002. Average number of pig per pig house was 58 pigs. The measurements were taken between 10th and 20th August 2002 and during morning (9-11am.) and afternoon (1-3pm) hours. Each house was monitored once over a period of 12 hours. The procedure described by Wathes et al. (1997), which involves taking representative readings at different locations in a pen, was adopted. The factors considered included proximity to the open sided wall or middle of the pen as well as the sampling height. Such representative readings from each pen were later pooled to obtain the mean for each pen.

Concentrations of gases were measured in parts per million (ppm) as well as lower emissible limit (LEL) in the case of flammable gas (Methane) using the Gasman hand held personal gas detector (Crowcon, Instruments Ltd. England) that employs a catalytic bead sensor for flammable gas and electrochemical sensors for other gas measurements. During the gas measurements, these hand held equipment were held at about 2.5 feet above the litter level and the readings were recorded within 10 seconds. All analyses were calibrated for zero and span before and after reading.

In each farm, both inside and outside air temperature of the pens and relative humidity were also recorded. The length, width and height (floor to ridge) as well as the height of the sidewalls of the pens were measured in feet. The husbandry system practiced in these farms and the type of pig breeds kept were equally recorded.

Data analysis: Data generated were subjected to statistical analysis such as simple averages and analysis of variance (ANOVA). Where significant differences were observed, means were separated using the Duncan's multiple range test method, (Steel and Torrie, 1980). Furthermore, simple linear regression statistics was used to determine the possible influence of building measurements on concentration of the gases.

RESULTS

General observation: All the five farms studied were involved in commercial pock production with replacement stock being also being produced. The major breeds reared were large white, landrace and landrace x large white crosses (Table 1). Mean daily air temperature during the period of study was 26.35°C while mean relative humidity was 88%. Daily removal of dung was practiced in all the farms. Roofing materials

utilized were mainly corrugated iron and asbestos sheets.

Aerial pollutant gases concentrations:

Overall mean aerial concentrations of carbon monoxide CO (2.7 ± 0.34 ppm) was the highest mean value recorded and was followed by the 1.4 ± 0.0 ppm and 0.07 ± 0.14 ppm recorded for flammable gas (methane) and hydrogen sulfide respectively while the 0.0 ± 0.0 ppm recorded for ammonia was lowest (Table 2).

The range of 3.5 ± 1.7 ppm to 4.0 ± 0.0 ppm of CO obtained in PA, PC and PE were significantly higher ($P < 0.05$) than those of the other pens. The 2.0 ± 0.0 ppm of FM was obtained in PC and PD and was significantly higher ($P < 0.05$) than those of the other pens. Similarly, the 0.15 ± 0.3 ppm H₂S obtained in PC was significantly higher than those of other pens (Table 2).

The building measurements: The average length of the buildings was 64.20ft., while 21.40ft., 11.60ft and 4.35ft were obtained for width, height and sidewalls respectively. The highest length value was the 114 ft. obtained in PB and PC while 8ft was recorded as the lowest measurement and was obtained in PE. The highest width value recorded was 32 ft. (PB) while the lowest was the 7ft obtained in PE (Table 3).

Correlation of aerial pollutants and pig house measurements:

In all pens, the regression was not significant ($P < 0.05$), coefficient of determination ranging from 0.001 (SO₂) to 0.364 (CO). For the different aerial pollutant gases, the best linear predictor was for CO using height of building followed by SO₂ using height and so on based on the R² value of the regression (Table 4).

Table 1. Husbandry methods employed in the various pig farms.

Pens	Floor type	Breed of pig	Dung Mgt.	Flock size	Roofing method	Ambient Temp (°C)	Relative humidity (%)
PA	CF	LW	DRD	85	Asbestos Sheets	26.7	87.0
PB	CF	L x LW	DRD	123	Iron Sheets	26.5	88.0
PC	CF	LW	DRD	114	Iron sheets	26.2	88.5
PD	CF	L x LW	DRD	45	Iron Sheets	26.5	85.8
PE	CF	LW	DRD	8	Iron sheets	26.5	87.0

P = Pigpen, CF = Concrete floor, LW = Large white, L = Landrace, DRD = Daily removal of dung.

Table 2. Concentration of aerial pollutant gases in selected pigpens.

Pens	FM (LEL)	NH ₃ (ppm)	CO (ppm)	SO ₂ (ppm)	H ₂ S (ppm)	NO ₂ (ppm)
PA	1.0±0.0	0.0±0.0	3.5±1.7 ^a	0.05±0.3	0.2±0.4	0.1±0.0
PB	1.0±0.0	0.0±1.0	2.0±1.0 ^b	0.1±0.0	0.0±0.0	0.2±0.0
PC	2.0±0.0 ^a	0.0±0.0	4.0±1.0 ^a	0.1±0.0	0.15±0.3	0.15±0.3
PD	2.0±0.0 ^a	0.0±0.0	1.0±1.0	0.0±0.0	0.0±0.0	0.1±0.0
PE	1.0±1.0	0.0±0.0	3.0±0.0 ^a	0.1±0.0	0.0±0.0	0.15±0.3
Total	7.0	0.0	13.5	0.35	0.35	0.5
Mean	1.4±0.0	0.0±0.0	2.7±0.34	0.07±0.14	0.07±0.14	0.1±0.08

ab, means in the same column with different superscript are significantly different ($P < 0.05$).

Table 3. Structural measurements of pig houses used for aerial pollutant gases measurements.

Pens	Length (Ft)	Height (Ft)	Width (Ft)	Sidewall (Ft)
PA	38.00	11.00	23.00	3.25
PB	114.00	15.00	32.00	5.00
PC	114.00	11.00	25.00	4.00
PD	47.00	14.00	20.00	5.00
PE	8.00	7.00	7.00	4.50
Total	321	58	107	21.75
Mean	64.20	11.60	21.40	4.35

Table 4. Prediction equations for concentrations of aerial pollutants gases using pig house measurements.

Aerial pollutants	Prediction equation	R ²	Standard Error	Significance
CO	CO = 22.983 – 5.860W	0.006	10.571	NS
	CO = 15.836 – 1.569H	0.364	2.882	NS
SO ₂	SO ₂ = 20.875 + 7.500W	0.001	10.595	NS
	SO ₂ = 13.438 + 26.250H	0.141	3.351	NS
H ₂ S	H ₂ S = 19.816 + 22.632W	0.058	10.291	NS
	H ₂ S = 11.987 – 5.526H	0.032	3.561	NS
NO ₂	NO ₂ = 11.000 + 74.286W	0.115	9.976	NS
	NO ₂ = 10.000 + 11.427H	0.023	3.572	NS

NS = Not significant; W = Width pen; H = Height of roof

DISCUSSION

Temperatures in the pens during the period of measurements were within the optimal range of 26 - 27°C, while the mean humidity of 88.0% was much higher than the desirable 60-70% (Ferguson, 1986). This very high relative humidity is attributed to the period of the year (August), which is usually a heavy rainfall period. High temperature and humidity causes wet litter, which enhances the growth and multiplication of fungal, protozoa and bacterial pathogens in the tropics (Oluyemi and Roberts, 2000).

The present results revealed that the concentrations of the various aerial pollutant gases in the pigpens were relatively low during the month of August. For example, the mean concentration of ammonia in this study was 0.0ppm, while that of CO was 2.7 ppm. These figures are much lower than the current exposure limits recommended for animal welfare in Europe or the averages of 12.3 ppm and 24.2 ppm obtained in poultry houses in the UK during winter and summer month (Wathes et al., 1997; CIGR, 1992). It would seem from this study that the relatively clement weather conditions associated with mild temperatures and increased air movement during this period of the year may have helped in moving gases generated inside the pig pens to the outside. These measurements probably demonstrate relatively high standard of air quality in the pens. It would seem from the present result that the tropical open sided pens being used in the study area are well suited for pig production during the month of August. Because of the low levels of gases obtained during the period of study, there is the need to extend the study to other periods of the year especially the dry season months in order to further elucidate the effects of inclement whether on gas concentrations.

The study revealed that there is lack of standardization in the construction of pigpens in the

study area. Some of the houses were either very wide or very low. The optimal width of pigpens in the humid tropics has been shown to be 10m wide, with 1.2m internal passages (Williamson and Payne, 1978). These help for more effective ventilation and reduction of heat irradiation from the roof especially during the hot periods of the year.

The study equally revealed the relative contribution of pig house dimension to the concentration of aerial pollutants and tried to explain the rate of increases of these pollutants due to changes in house measurements. The relative magnitude of the regression coefficient obtained was highest and positive for NO₂ (74.286) and lowest and negative for CO (1.569). These indicate the average rate of increase or decrease of aerial pollutant gases concentrations with respect to the building dimensions

CONCLUSIONS

Even though this study returned low levels of gases for the area during the month of August, there is the need to extend the study to other periods of the year especially the dry season months in order to further elucidate the effects of inclement whether on gas concentrations in pig pens.

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REFERENCES

1. Borgers, P., Huothuijs, D., Remijn, B., Brouner B. and Bliersker, K. (1997). Lung function and respiratory symptoms in pig farmers. *Br. J. Industrial Med.*, 44: 819-823.
2. CIGR (1992). *Climatization of animal houses: Second report*. State University of Ghent, Belgium, Center for Climatization of Animal Houses – Advisory Services. Commission Internationale Du Genie Rural, Pp: 147.
3. Delgado, C. L., Courbois, C. B. and Rosegrant, M. W. (1998). Global food demand and contribution of livestock as we enter the new millennium. In: M. Gill et al., (Eds.), *Land food and livelihoods – setting research agendas for animal science*. *BSAS Occasional Publication*, 21: 27-42.
4. Donhann, K., Reynolds, S., Whitten, P., Merchant, J. Burmeister, L. and Pependort, W. (1995). Respiratory dysfunction in swine production facility workers, dose-response Relationships of environmental exposures and pulmonary function. *Am. J. Industrial Med.*, 27: 405-418.
5. Ejiogu, G. E., 1990. Seasonal effects on the productivity of indigenous chickens and improved cockerels under extensive systems of management. B. Agric. Tech. Project Report. Federal University of Technology Owerri, Nigeria.
6. FAO (2000). *Food and Agricultural Organization of the United Nations*, Rome. *Quarterly Bull. Stat.*, Vol. 1.
7. Ferguson, W. (1986). Poultry housing in the tropics—Applying the principles of thermal exchange. *Trop. Anim. Hlth and Prod.*, 2: 44-58.
8. Harry, E. G. (1978). Air pollution in farm buildings and methods of control: a review. *Avian Pathol.*, 7: 441-454.
9. Molokwu, E. C. I. (1982). Goat production in Nigeria – Prospects and problems. Paper presented at National workshop on small ruminant diseases and productions in Nigeria. University of Nigeria, Nsukka, Nigeria.
10. Muirhead, M. R. and Alexander, T. J. (1997). *Managing pig health and treatment of disease*. 5M Enterprise, Sheffield, UK.
11. O’Neil, D. H. and Philips, V. R. (1992). A review of control of odor nuisance from livestock buildings: Parts 3, Properties of the odorous substances, which have been identified in livestock, waste on in the air around them. *J. Agric. Eng. Res.*, 58: 23-50.
12. Ofomata, G. E. (1975). *Nigeria in maps – eastern, Nigeria*. Ethiopia Publishing House, Benin City, Nigeria. Pp: 8 – 9.
13. Okoli, I. C., Ebere, C. S., Uchegbu, M. C., Udah, C. A., Ibeawuchi, I. I. (2003). Survey of the diversity of plants utilized for ruminant feeding in southeastern Nigeria. *Agric. Ecosys. Environ.*, 96: 147-154.
14. Oluyemi J. A., and Roberts, R. A. (2000). *Poultry production in wet climates 3rd Ed*. Macmillan Press, London.
15. Reynolds, S., Donham, K. Whitten, P., Merchant, J. Murmeister, L. and Pependorf, W. (1996). Longitudinal evaluation of Doze-response relationships for environmental exposures and pulmonary function in swine production workers. *Am. J. Indus. Med.*, 29:33-40.
16. Steel, G. D., Torrie, J. H. (1980). *Principles and procedures of statistics*. 2nd Ed. McGraw Hill Book Co. Inc. New York.
17. Wathes, C. M. (2001). Aerial pollutants from weaner productions. In: Varley M. A., and J. Wiseman (Eds.), *The weaner pig nutrition and management*. CAB International, Wallingford, UK, Pp: 259-271.
18. Wathes, C. M., Holden, M. R. Sneath, R. W. White, R. P. and Philips, V. R. (1997). Concentrations and emission rates of aerial ammonia, nitrous oxide, methane, carbon dioxide, dust and endotoxin in UK broiler and layer house. *Br. Poult. Sci.*, 38: 14-28.
19. Wathes, C. M., Holden, M. R., Sneath, R. W. White, R. P. (1998). Aerial emissions from poultry production. *World’s Poult. Sci. J.*, 54: 1 – 11.
20. Wathes, C. M., Jones, C. D. R. and Webster, A. J. F. (1983). Ventilation, air hygiene and animal health. *Vet. Rec.*, 113: 554-559.
21. Williamson, G. and Payne, W. J. A. (1978). *An introduction to animal husbandry in the tropics*, Longman, England.