Evaluation of aerial pollutant gases concentrations in poultry pen environments during early dry season in the humid tropical zone of Nigeria

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Abstract: A study was conducted at Port Harcourt, in the humid tropical rainforest zone of Nigeria, to determine the concentrations of pollutant gasses in livestock buildings in order to establish baselines for exposure limits in the context of animal and human welfare in tropical environments. The concentrations of aerial ammonia, nitrous oxide, methane, carbon monoxide, hydrogen sulphide and sulphur dioxide in selected intensively managed poultry pens in Port Harcourt area of Rivers State, Nigeria were measured during the month of November, 2007. Studies reveal that overall mean aerial concentrations of carbon monoxide CO (19.1±1.35 ppm) was the highest mean value recorded and was followed by the 1.06 ± 0.16 ppm and 0.89±0.14 ppm recorded for flammable gas (methane) and ammonia respectively, while the 0.12±0.07 ppm recorded for nitrous oxide was lowest. The study showed that these figures are lower than limits recommended for animals in Europe.
[Chidi Nwagwu, Promise N. Ede, Ifeanyi C. Okoli, Okwunna K. Chukwuka and Grace C. Okoli. Evaluation of aerial pollutant gases concentrations in poultry pen environments during early dry season in the humid tropical zone of Nigeria. Nature and Science 2011;9(2):37-42]. (ISSN: 1545-0740). http://www.sciencepub.net.

Keywords: Pollutant gases, poultry pen, aerial environment, humid tropics, Nigeria

1. Introduction

The poultry production system 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 poultry production in the tropics (Delgado ***et al***., 1998; FAO, 2000) has made these livestock business ventures very attractive in most developing countries. The intensification of modern poultry production systems in the tropics is however increasingly regarded as a source of air pollutants, which could be both aggravating and environmentally harmful. Aerial pollutants in livestock buildings include organic and inorganic dusts, pathogens and other microorganism as well as gases (Whyte, 1993; Carpenter, 1996; Wathes ***et al***., 1997).

Most gaseous pollutants found in such environment originate from the breakdown of fecal matter, thus, their concentrations will at least in part, depend on the ventilation efficiency and rate, as well as the stocking density and movements of the animals (Wathes ***et al***., 1983; MAFF, 1987). Over 100 gaseous compounds are found in the air of livestock building in the temperate zone (Hartung, 1988), and include aerial ammonia, carbon monoxide, sulphur oxide, hydrogen sulphide, nitrous oxide and flammable gas (methane), among others. Most are simple odorants, which may give rise to complaints among neighbors, while some are green house gases. In this zone, concentrations of most of the gases are usually in the range of parts per million (ppm) or lower with the exception of carbon dioxide which may record concentration levels 5 to 10 times higher than the ambient (Wathes, 2001).

Aerial pollutants have economic and public health importance in livestock production (Okoli ***et al***., 2006). Their concentration levels and emission rates in livestock buildings when high eventually result in health problems among housed animals. Their public health importance is predicated on the diseases they may cause in livestock workers, when their levels become high in the livestock pens (Okoli ***et al***., 2004). Most studies of noxious gases in livestock pens have focused upon ammonia probably because of its' toxicity and role in acid rain formation. However, intensive livestock production contributes to global emission of other important aerial pollutants such as volatile (VOC) and reactive organic compounds (ROC) that impact adversely upon the countryside and has contributed many defects on the ozone layer (Nahm, 2000). Human and animal respiratory health may be compromised indoors by pollutants such as gases, dust, microorganisms and endotoxins, also addressed as bioaerosols (Hamilton *et al.,* 1993; Hartung, 1994; Hartung *et al.*, 2002).

Specifically, particulate emissions such as dust and microorganisms from buildings play a role in respiratory affections in people living in the vicinity of animal enterprises (Müller and Wieser, 1987; Seedorf, 2004). Interest in air quality in livestock buildings has grown substantially among agricultural, environmental and animal scientists, engineers and veterinarians over the past decade (Okoli *et al*., 2006). 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 poultry pens in the Port Harcourt area of Rivers State, in the humid tropical zone of Nigeria, during the month of November 2007.

2. Materials and methods

2.1 Study area: The study area, Port Harcourt, is the capital of Rivers State Nigeria. It is located in the South-south humid geopolitical zone of Nigeria; bounded by latitude 4^o 44` to $4^o$ 52` North of the equator and longitudes 6^o 56` to $7^o$ 07` East of the Greenwich meridian. The climate falls within the sub-equatorial climate belt. It has a mean yearly temperature 30^oC and relative humidity of 80% to 100% and a mean yearly rainfall of about 2327mm (Port Harcourt Master Plan, 1975).

A survey of various farms engaged in commercial layer and/or broiler production was carried out in Port Harcourt. Four farms were selected based on the following criteria, the age of the farm, age of birds, breed type, size of the flock, length of exposure in the industry, proximate to residential areas etc. The husbandry system practiced in farm 1, 2, and 3 were deep litter system except in farm 4 were battery cage and deep litter system with other livestock such as pig, fish, and goat were reared. The age of the litter in the deep litter system ranged from 2 to 20 weeks, while the flock size ranged from 300 to 8000 birds. A random sampling of poultry litter was made in each of the poultry pens and the moisture content analysed within 24 hours of collection according to AOAC (1990) method.

2.2 Husbandry methods employed in the various poultry farms: Table 1 shows the husbandry methods employed in the various poultry farms in early dry season. Flock age in different farms studied ranged from 5 to 8 weeks in broiler farm, 23 to 58 weeks in layer farm and 9 to 20 weeks in pullet farm respectively. Age of litter also ranged from 4 to 6 weeks in broiler farm, 3 to 7 weeks in layer farm and 3 to 12 weeks in pullet farm, flock size ranged from 650 – 1450 in broiler farm, 500 – 3000 in layer farm and 350 – 8000 in pullet farm as shown below.

Table 1: Husbandry methods employed in poultry pens during early dry (November)

Farms	Pens	Litter	Age of litter	Type of birds	Age of bird	Flock size	Roofing method
	FA1	D.L	4WKS	B	5WKS	650	I.R
	FA2	D.L	6WKS	B	7WKS	1450	I.R
Broiler	FA3	D.L	5WKS	B	8WKS	1000	I.R
	FA4	D.L	5WKS	B	7WKS	1000	I.R
	FA5	D.L	5WKS	B	7WKS	1000	I.R
	FB1	D.L	5WKS	L.H	42WKS	500	I.R
Layer	FB2	B.C	7WKS	L.H	58WKS	3000	I.R
	FB3	B.C	7WKS	L.H	58WKS	3000	I.R
	FB4	B.C	3WK	L.H	23WKS	3000	I.R
	FC1	D.L	5WKS	P	9WKS	350	I.R
Pullet	FC2	D.L	14WKS	P	20WKS	7800	I.R
	FC3	D.L	14WKS	P	20WKS	8000	I.R

FA in the above row means poultry pens, D.L = Deep litter, B.C = Battery cage, L.H = Laying hens, P = Pullets, B = Broilers, WKS = Weeks, I.R = Corrugated iron sheets.

2.3 Structural measurements of poultry farms for aerial pollutant gases: Table 2 shows the building measurements of poultry houses used for the study. The mean value obtained were 21.95m, 3.88m, 10.23m and 0.65m for the length of the wall, height of the roof, width of the wall and sidewall, respectively. The highest value recorded in length of wall was 49.98m obtained from FC2 and FC3 respectively while the lowest value 5.79m was obtained from FA1 and FB1 respectively.

2.4 Measurement of environmental factors of poultry farms: The temperature readings were taken in the morning (9 – 11am) and afternoon (1 – 3pm) in each poultry pen. Both inside and outside temperature were determined with a hygrometer (Praziosonshtgro Multithern model). The measurement was carried out every 6 minutes at a height of 2m upward of the poultry house. The wind speed of the area was measured hourly using the Beaufort wind scale.

Table 2: Structural measurements of poultry houses for aerial pollutant gas measurements

Farm	*Pens*	*Length (m)*	*Height (m)*	*Width (m)*	*Sidewall (m)*
	FA1	5.76	1.67	4.26	0.30
	FA2	20.00	4.57	10.00	0.76
Broiler	FA3	20.00	4.57	10.00	0.76
	FA4	20.00	4.57	10.00	0.76
	FA5	20.00	4.57	10.00	0.76
	FB1	5.76	1.67	4.25	0.30
Layer	FB2	20.00	4.57	10.00	0.76
	FB3	65.62	4.57	10.00	0.76
	FB4	20.00	4.57	10.00	0.76
	FC1	11.94	2.13	4.26	0.30
Pullet	FC2	49.98	4.57	20.00	0.76
	FC3	49.98	4.57	20.00	0.76
	MEAN	21.95	3.88	10.23	0.65

2.5 Measurement of concentration of aerial pollutants in the poultry pen: Measurement of the concentration of aerial ammonia, nitrous oxide, methane, carbon monoxide, hydrogen sulphide and sulphur dioxide were made in four poultry farms, equally divided between broilers reared on deep litter, pullets reared on deep litter and layers reared on both deep litter and battery cage. The buildings were chosen to be representative of their type. Each house was monitored once at 6 hours in the early dry season.

The procedure described by Wathes *et al.* (1997), which involves taking representative reading at different locations in a pen, was adopted. Six of the sampling locations were within the birds or human's breathing zone 0.5m and 1.5m above the floor respectively. The factors considered included proximity to the open side wall, middle of the pen as well as sampling height. Such representative readings from each were later pooled to obtain the mean of each pen.

Concentration of gasses were measured in part per million (ppm) as well as lower emission limit (LEL) in the case of flammable gas methane using the Gasman hand held personal gas detector (Crowcon, Instruments Ltd, England). During the gas measurements, these hand held equipment were held at about 0.3m above the litter and the readings were recorded within 10 seconds. Gas detector was calibrated for zero and span before and after reading.

2.6 Data analysis: Both the descriptive and inferential methods were adopted in the analysis of data. The descriptive statistics include the use of mean, standard deviation and coefficient of variation (ANOVA). Where significant differences were observed, mean were separated using Least Square Difference method (Steel and Torrie, 1980). Computer software used was statistical package for social science (SPSS, 2003).

3. Results

3.1 Environmental factors measurements: Table 3 showed the measurements of environmental factors in the study. The mean air temperature within the pen during the period of the study ranged from 32.2 to 32.3^{O}C, while mean relative humidity was in the range of 83 to 83.8%. The mean moisture contents of the litter in the various poultry pens were 18.04, 38.07 and 25.78% for broilers, layers and pullets, respectively. The mean wind speed during the period of the study was 4.22m/s, 4.35m/s and 3.33m/s for broilers, layers and pullet pens, respectively.

Concentration of gases measured in different pen in early dry season: Table 4 showed the concentrations of aerial pollutant gases in the different pens in early dry season (November). In the broiler pen, CO recorded the highest mean concentration (18.8 ± 1.36ppm) followed by CH_4 (1.06 ± 0.16 LEL) and NH_3 (0.89 ± 0.14ppm), while the 0.57 ± 0.10, 0.16 ± 0.06 and 0.06 ± 0.03ppm recorded for SO_2, H_2O and N_2O respectively were lowest. The range of 0.66 ± 0.51 to 1.00 ± 0.00ppm of SO_2 obtained in FA1, FA3 and FA4 were significantly higher (Pp< 0.05) than those of other pens.

Overall mean concentration of CO (19.1 ± 1.35ppm) was highest followed by the 2.12 ± 0.72ppm, 1.87 ± 0.54 LEL and 1.10 ± 0.44ppm recorded for NH_3, CH_4 and SO_2 respectively while 0.38 ± 0.12ppm and 0.12 ± 0.07ppm recorded H_2S and N_2O respectively were lowest in the layer pen as shown Table 5. The range of 3.16 ± 0.75 to 2.83 ± 1.60ppm of NH_3

obtained in FB3 and FB4 were significantly higher ($p < 0.05$) than those of other pens. Again, the 1.60 ± 0.54 to 0.91 ± 0.20ppm of SO_2 obtained in FB3, FB4 and FB1 were significantly higher ($P < 0.05$) than those of other pens. Similarly, 0.63 ± 0.20 to 0.53 ± 0.15ppm and 2.6 ± 0.63 to 2.16 ± 0.75ppm of H_2S and N_2O obtained in FB3, FB4 respectively were significantly higher (Pp< 0.05) than those other pens.

Table 3: Measurement of environmental factors in various poultry pen during early dry season (November)

Farm	Pens	Moisture of litter (%)	Relative humidity %	Temperature (^oC)	Wind speed m/s
	FA1	27.67	83.00	32.00	1.60
	FA2	25.31	83.00	32.00	3.30
Broiler	FA3	34.14	85.00	33.00	5.40
	FA4	21.74	85.00	32.00	5.40
	FA5	27.74	83.00	32.50	5.50
	Mean	18.04	83.80	32.20	4.22
	FB1	43.21	83.00	32.00	3.30
Layer	FB2	48.21	83.00	32.00	3.30
	FB3	48.17	85.00	33.00	5.40
	FB4	42.87	83.00	33.00	5.40
	Mean	38.07	83.50	32.20	4.35
	FC1	27.48	83.00	32.00	3.30
Pullet	FC2	28.24	83.00	32.00	3.30
	FC3	21.64	83.00	33.00	3.40
	Mean	25.78	83.00	32.30	3.33

Table 4: Concentration of aerial gases in different broiler pins in early dery season (November)

Pens	NH_3 (ppm)	H_2S (ppm)	SO_2 (ppm)	CO (ppm)	N_2O (ppm)	CH_4 (LEL)
FA1	0.91±0.20	0.21±0.07	1.00^a±0.05	19.80±1.32	0.08^a±0.04	1.16±0.40
FA2	1.00±0.00	0.16±0.08	0.66^a±0.51	20.5±1.22	0.01^b±0.04	1.00±0.00
FA3	1.00±0.00	0.11±0.04	0.10^b±0.00	19.8±1.47	0.06^a±0.05	1.16±0.40
FA4	0.83±0.25	0.13±0.05	0.10^b±0.51	20.0±1.78	0.10^a±0.00	1.00±0.00
FA5	0.75±0.27	0.20±0.06	1.00^a±0.00	14.3±1.03	0.03^b±0.05	1.00±0.00
MEAN	0.89±0.14	0.16±0.06	0.57±0.10	18.8±1.36	0.06±0.03	1.06±0.16
SEM	0.04	0.01	0.20	1.15	0.01	0.03

a,b: Means in the same column with different superscript are significantly different ($p<0.05$).

In the pullet pen (Table 6), overall mean concentration of CO (19.8 ± 1.16ppm) was highest followed by the 0.77 ± 0.35 and 0.55 ± 0.47ppm of CH_4, NH3 and SO_2 respectively, while the 0.17 ± 0.35 and 0.15 ± 0.08ppm for H_2S and N_2O were lowest. The range of 20.8 ± 1.16 to 20.3 ± 1.03ppm of CO obtained in FC3 and FC2 were significantly higher ($P < 0.05$) than those of other pens. Similarly, 1.00 ± 0.00ppm and 1.00 ± 0 .00 LEL of NH_3 and CH_4 obtained in FC3 were significantly higher ($p<0.05$).

Table 5: Concentration of aerial pollutant gases in different layer pens in early dry season (November)

Pens	NH_3 (ppm)	H_2S (ppm)	SO_2 (ppm)	CO (ppm)	N_2O (ppm)	CH_4 (LEL)
FB1	1.00^b±0.00	0.21^b±0.07	0.91^a±0.20	18.6±1.36	0.06^b±0.05	1.00±0.00
FB2	1.50^b±0.54	0.18^b±0.07	0.33^b±0.51	19.6±1.36	0.03^b±0.05	1.66±0.81
FB3	3.16^a±0.75	0.63^a±0.20	1.50^a±0.54	18.1±0.75	0.21^a±0.07	2.66±0.63
FB4	2.83^a±1.60	0.53^a±0.15	1.60^a±0.54	20.3±1.96	0.23^a±0.12	2.16±0.75
MEAN	2.12±0.72	0.38±0.12	1.10±0.44	19.1±1.35	0.12±0.07	1.87±0.54
SEM	0.51	0.11	0.28	0.49	0.05	0.25

a,b: Means in the same column with different superscript are significantly different ($p<0.05$)

Table 6: Concentration of aerial pollutant gases in different pullet pens in late rainy season (October)

Pens	NH_3 (ppm)	H_2S (ppm)	SO_2 (ppm)	CO (ppm)	N_2O (ppm)	CH_4 (LEL)
FC1	0.66±0.51	0.20±0.08	0.33^b±0.51	18.50±1.04	0.21±0.16	0.50^b±0.54
FC2	0.50±0.54	0.20±0.08	0.33^b±0.51	20.30±1.03	0.13±0.05	0.33^b±0.51
FC3	1.00±0.00	0.15±0.05	0.83^a±0.25	20.80±1.16	0.11±0.04	1.00^a±0.00
MEAN	0.72±0.35	0.17±0.07	0.55±0.42	19.80±1.16	0.15±0.08	0.77±0.35
SEM	0.14	0.01	0.16	0.69	0.03	0.20

^{a,b}: Means in the same column with different superscript are significantly different ($P<0.05$).

The 0.83 ± 0.40, 0.21 ± 0.16 and 0.20 ± 0.08ppm of SO_2, N_2O and H_2S obtained in FC3, FC1 and FC2 respectively were significantly higher ($p< 0.05$) than those other pens.

4. Discussion and Conclusion

The mean environmental factors readings such as temperature and humidity in the pens during the period of study were 32^o and 83.5% respectively and were much higher than the optimal levels for efficient poultry production (Ferguson, 1986). The present results revealed that the concentrations of the various aerial pollutant gases in the poultry pens were relatively low during the month of November. For example, the mean concentration of ammonia in this study ranges from 0.72 to 2.12ppm, while that of CO was 18.8 to 19.8ppm. 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 months (Wathes *et al.*, 1997; CIGR, 1992). The relatively low concentration of aerial pollutant gases in this study confirms the findings of Okoli *et al*. (2004) in the month of August in nearby Imo State. Similar values were also reported by Vucemilo *et al.* (2005) in an earlier study of intensive poultry breeding facilities.

The present study showed variations in the gas concentration across the farms, which could be attributed to the breed effect of the birds, age and type of litter management, type of feed, type of housing design and individual farm attributes. It would be seen from the study that environmental factors associated with high temperature, relative humidity and wind speed during the period of study may have helped in moving gases generated inside the poultry pens to the outside. Taken together, these measurements demonstrate relatively high standard of air quality in the poultry pens.

However, there is hardly any attempt at enforcing standards in livestock building design and construction in Nigeria either for benefit of the health of the operators or for the welfare of the animals. There is need for further studies on the actual impact of polluted environment on human and animal health. Further studies of gas concentration during other months of the year and other livestock species and facilities will be needed to generate detailed data for policy formulation on the management of pollutant gases in livestock production.

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5. References

AOAC (1990). Official methods of analysis, 13th ed. Association of official Analytical Chemists. Washington DC.

Carpenter, G. A., Smith, W. K., Maclaren, A. P. C. and Spackman, D. (1996). Effect of internal air filteration on the performance of broilers and the aerial concentration of dust bacteria. British Poultry Science, 27: 471 – 480.

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.

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.

FAO (2000). Food and Agricultural Organization of the United Nations, Rome. Quarterly Bull. Stat., Vol. 1.

Ferguson, W. (1986). Poultry housing in the tropics—applying the principles of thermal exchange. Trop. Anim. Hlth and Prod., 2: 44-58.

Hamilton, T.D.C., Roe, J.M., Taylor, F.G.R., Pearson, G., Webster, A.J.F. (1993): Aerial Pollution: An exacerbating factor in atrophic rhinitis of pigs. Proceedings of 4th International Livestock

Environment Symposium, Warwick, American Society of Agricultural Engineers, pp. 895-903.

Hartung, J. (1994). The effect of airborne particulates on livestock health and production.In: I. AP DEWI (ed.): Pollution in Livestock Production Systems. CAB International, Wallingford, UK, 55-69.

Hartung, J. (1988). Tentative calculations of gaseous emission from pigs houses by way of the exhaust air. In Nielsen, V. C., Voorburg, J.H and Le Hermite, P. (eds), Volatile emissions from livestock farming and sewage operations. Applied Science, Pp: 54 – 58.

Hartung, J., Pedersen, S., Garz, S., Blainey, D., Rabe, U., Nowak, D. (2002). Prevalence and risk factors for airway diseases in farmers – summary of results of the European farmers´ project. Ann Agric Environ Med, 9: 207-213.

MAFF (1987). Code of recommendation for the welfare of livestock: Domestic fowl. MAFF Publication London.

Müller, W. and Wieser, P. (1987). Dust and microbial emissions from animal production. In: Strauch, D. (ed.), Animal Production and Environmental Health. Elsevier, Amsterdam, Oxford, New York, Tokyo, pp. 47-89.

Nahm, K. H. (2000). A stategy to solve environmental concerns caused by poultry production. World's Poultry Science Journal, 56: 379 – 388.

Okoli, .I C., Alaehie, D. A., Akano, E. C., Okoli, C. G., Opara, M. N., Uchegdu, M. C. Ogundu, U. E. and Iheukwumere, F.C. (2004). Concentration of aerial pollutant gases in selected poultry pen in Imo State, Nigeria. International Journal of Poultry Science, 3(6): 427 – 431.

Okoli, .I C., Alaehie, D. A., Okoli, C. G., Akano, E. C., Ogundu, U. E., Akujobi, C. T., Onyicha, I. D., Chinweze, C. E. (2006). Aerial pollutant gases concentrations in tropical pig pen environment in Nigeria. Nature and Science, 4(4):1 – 5.

Port Harcourt Master Plan (1975). Final report. Rivers State Government, Port Harcourt, Nigeria.

Seedorf, J. (2004). An emission inventory of livestock-related bioaerosols for Lower Saxony, Germany. Atmospheric Environment, 38: 6565 – 6581.

Steel, G. D., Torrie, J. H. (1980). Principles and procedures of statistics. 2nd Ed. McGraw Hill Book Co. Inc. New York.

SPSS (Statistical Package for Social Sciences), (2003). Spss pc+11.0, Chicago USA.

Vucemilo, M., Vinkovic, B., Tofant, A., Šimpraga, B., Pavicic, Ž. and Matkovic K. (2005). Microbiological air contamination in intensive poultry breeding. In: Proc. 12th Int. Congress ISAH, September 4–8, Warsaw, Poland, 1, 127–129.

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.

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.

Wathes, C. M., Jones, C. D. R. and Webster, A. J. F. (1983). Ventilation, air hygiene and animal health. Vet. Rec., 113: 554-559.

Williamson, G. and Payne, W .J. A. (1978). An introduction to animal husbandry in the tropics, Longman, England

Whyte; R. T. (1993). Aerial pollutants and health of poultry farmers. World's Poultry Science Journal, 49: 139-156.

12/15/2010