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Effect of Environmental Factors and Structural Dimensions on Aerial Pollutant Gas Concentrations in Tropical Poultry Pen in Nigeria

C. Nwagwu[1], P. N. Ede[1], I. C. Okoli[2], O. K. Chukwuka[2], G. C. Okoli[3] and J. C. Moreki[4]

[1]Institute of Geosciences and Space Technology, Rivers State University of Science and Technology, PMB 5080 Port Harcourt, Nigeria; [2]Tropical Animal Health and Production Research Lab, Department of Animal Science and Technology, Federal University of Technology PMB 1526, Owerri, Nigeria; [3]Department of Environmental Technology, Federal University of Technology PMB 1526, Owerri, Nigeria; [4]Department of Animal Science and Production, Botswana College of Agriculture, Private Bag 0027 Gaborone, Botswana

ABSTRACT

A study was conducted to determine the relationship between environmental factors (temperature, relative humidity, moisture content of the litter and wind speed), poultry house structural dimensions and concentrations of aerial gases in selected intensively managed poultry farms at Port Harcourt, Rivers State, Nigeria during the month of November, 2007. Inferential statistics, which included the use of multiple regression models and stepwise multiple regression analysis was employed to determine the relationship between environmental factors, structural dimensions and concentration of gases in poultry pens in the study area in order to identify the factors that are critical to concentration of gases. The regression coefficient obtained in pullet farmed showed that SO_2, CO, N_2O and CH_4 were highly related with house measurement (92.4, 89.1, 79.2 and 76.5%), while H_2S and NH_3 were moderately correlated with the same house measurement (49.2 and 46.4%. Similarly, in the layer farm, CH_4 was highly related with house measurement (66.8%), while N_2O, H_2S, CO, NH_3 and SO_2 recorded poor correlation results. In the broiler farm, H_2S, SO_2, N_2O, CO and CH_4 were highly related with house measurement. From the standard coefficient of regression equation, moisture content of the litter had the highest standard coefficient and also the highest t – value. The study concluded that because of differences in livestock buildings structural measurements, natural ventilation and other interacting factors in the tropical farming environment variations are bound to occur in terms of concentrations and emission rates of aerial pollutants.

Keywords: Poultry farm, pollutant gases, tropical environment, ventilation

Corresponding author: J. C. Moreki, Department of Animal Science and Production, Botswana College of Agriculture, Private Bag 0027 Gaborone, Botswana

INTRODUCTION

Air hygiene is an important factor to be considered in intensive poultry production as it has considerable impacts on the health and well-being of farm animals and staff as well as the outdoor environment of the farming enterprises (Cargill and Hartung, 2001; Radon *et al.*, 2002). An adequate environment within the poultry houses is a very important requirement for success in the poultry industry. In poultry houses environmental conditions mean physical (heat, humidity and air movement) and chemical factors (ammonia and carbon dioxide and other gases in the compound of the air).

Chickens through their wastes generate different forms of air pollutants, including ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), hydrogen sulphide (H_2S) and nitrous oxide (NO_2) gases, as well as, dust (Kocaman *et al.*, 2005). Gases such as carbon dioxide, NH_3 and CH_4 may accumulate and reach toxic levels if adequate ventilation is not maintained. These different air pollutants may cause risk to the health of both chickens and farm workers. Poor environments normally do not cause disease directly but may reduce the chickens' defences, making them more susceptible to existing viruses and bacteria (Quarles and Kling, 1974).

Aerial NH_3 in poultry facilities is usually found to be the most abundant air contaminant. Ammonia concentration varies depending upon several factors including temperature, humidity, animal density and ventilation rate of the facility. Chickens exposed to NH_3 show reductions in feed consumption, feed efficiency, live weight gain, carcass quality and egg production (Charles and Payne, 1966; Quarles and Kling, 1974; Reece and Lott, 1980). Humidity and temperature also have impacts on air quality. Ventilation is an important consideration for controlling heat, humidity and gas concentrations.

Sterling *et al.* (2003) correlated environmental temperature with many measures of performance including feed and water consumption, body weight, egg production, feed conversion and egg weight. Ellen *et al.* (2000) showed that reduction in egg production under heat stress may be related to altered respiratory pattern, while Sterling *et al*. (2003), showed that reduction in environmental temperature, leads to consumption of more feed in order to maintain body heat.

Studies on the effects of dust in animal housing generally indicate potential for adverse effects on the health, growth and development of animals (Janni *et al*., 1985; Feddes *et al*., 1992). Repairable aerosol particles within poultry housing have been shown to decrease bird growth (Butler and Egan, 1974), increase disease transfer within flocks and condemnation of meat at processing plants (Simensen and Olson, 1980). In poultry laying houses, optimal relative humidity should be between 60 and 70%. In case of low relative humidity, concentration of dust particles may increase and may be followed by a corresponding increase in respiratory diseases among chickens (Kocaman *et al*., 2006).

This study was conducted to determine the relationship between environmental factors such as temperature, relative humidity, moisture content of litter and wind speed, structural dimension and concentration of gases in selected intensively managed poultry farms at Port Harcourt, Rivers State, Nigeria.

MATERIALS AND METHODS

Study area

The study area, Port Harcourt, is the capital of Rivers State, Nigeria. It is located in the South-south geopolitical zone of Nigeria; bound by latitude 4^o 44\` to $4^o$ 52\` N and longitudes 6^o 56\` to $7^o$ 07\` E. The climate falls within the sub-equatorial climate belt. It has a mean yearly temperature of 30 ^oC, relative humidity of 80-100% and a mean yearly rainfall of about 2327 mm (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 age of the farm, age of birds, breed, flock size and proximity to residential areas among others. The husbandry system practiced in farms 1, 2, and 3 were deep litter system, while in farm 4 battery cage and deep litter systems were practiced with other livestock such as pig, fish and goat production.

Husbandry methods employed in the farms

Table 1 shows the husbandry methods employed in the various poultry farms. Flock age in different farms studied ranged from 5 to 8 weeks in the broiler farm, 23 to 58 weeks in the layer farm and 9 to 20 weeks in the pullet farm. 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 to 1450 in broiler farm, 500 to 3000 in layer farm and 350 to 8000 in the pullet farm.

Structural measurements of poultry houses

Table 2 shows the measurements of poultry houses used for the study. The mean values obtained were 21.95, 3.88, 10.23 and 0.65 m for the length, height of the roof, width and height of side wall, respectively. The highest value recorded in length of house was 49.98 m obtained from FC2 and FC3 respectively, while the lowest value of 5.79 m was obtained from FA1 and FB1 respectively.

Measurement of environmental factors of poultry farms

A random sampling of poultry litter was made in each of the poultry pens. The moisture content of the litter was analyzed within 24 hours of collection using AOAC (1990) method. The temperature readings were taken in the morning (9 – 11 am) and afternoon (1 – 3 pm) in each poultry pen using mercury in glass thermometer. Relative humidity readings were determined with a hygrometer (Praziosonshtgro Multithern model). The measurement was carried out every 6 minutes at a height of 2 m upward of the poultry house floor. The wind speed of the area was measured hourly using the Beaufort wind scale.

Measurement of concentration of aerial pollutants in the poultry pen

Measurement of the concentration of CH_3, NO_2, CH_4, carbon monoxide CO, H_2S and sulphur dioxide (SO_2) 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 systems. The buildings were chosen to be representative of their type. Each house was monitored at 6 hours interval.

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 0.5 and 1.5 m 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 location were later pooled to obtain the mean for each pen.

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

Data analyses

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. Where significant differences were observed, mean were separated using least square difference method (Steel and Torrie, 1980). The computer software used was statistical package for social scientists (SPSS, 2003).

Furthermore, inferential statistics employed include the use of multiple regression models (Equation (i) and (ii) and stepwise multiple regression analysis as employed by Obayelu and Adeniyi (2006) to determine the relationships between environmental factors, structural dimensions and concentration of gases in poultry pens in the study area in order to identify factors that are critical to concentration of gases.

Table 1: Husbandry methods employed in poultry pens

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

Table 2: Structural measurements of poultry houses used in the study

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

Equation (i): The regression model for environmental factors.

$Y = a + xb_1 + x_1b + \ldots\ldots\ldots\ldots xn + c$

Where; Y = Dependent variable; x = Independent variable; x_1 = Temperature; x_2 = Relative humidity; x_3 = Moisture content of litter; x_4 = Wind speed; a = regression constant; b = regression coefficient; c = error term.

Equation (ii): The regression model for building dimension.

$Y = a + xb_1 + x_1b + \ldots\ldots\ldots\ldots xn + c$

Where; Y = Dependent variable; x = Independent variable; x_1 = Height of the roof; x_2 = Width of the pen; a = regression constant; b = regression coefficient; c = error term.

RESULTS AND DISCUSSION

Correlation of structural dimensions to gas concentrations in broiler farm

The multiple linear regression equations to predict aerial pollutant gas concentrations from poultry houses dimension in the broiler farm are shown in Table 3. Predicted H_2S gave the highest coefficient of determination (r^2) of 0.459, while predicted NH_3 gave the least r^2 of 0.001. The correlation (r) between the concentration of aerial pollutants and poultry house dimensions ranged from 0.036 for NH_3 to 0.678 for H_2S and were not significant ($p< 0.05$).

Using the standardized coefficient of the regression equation as shown in Table 3, NH_3 and N_2O had the highest standardized value of 2.294 and 3.554 of width respectively, while the height had a negative value of -3.88 and -5.60 respectively, showing an inverse relationship.

This means that a decrease in height and increase in width increases NH_3 and N_2O concentrations. SO_2, CH_4, H_2S and CO had the highest standardized value of 6.909, 3.030, 1.06 and 0.88 of height respectively, while the width recorded negative values of -1.83, -3.79, -5.26 and -0.149, respectively, showing an inverse relationship. This implies that an increase in height and a decrease in width will decrease the concentration of these aerial pollutant gases.

Correlation of structural dimensions to gas concentration in layer farm

The multiple linear regression equations to predict aerial pollutant gas concentrations from poultry house dimensions in layer farm are shown in Table 4. Predicted CH_4 gave the highest coefficient of determination (r^2) of 0.447, while predicted CO gave the least r^2 of 0.003. The correlation coefficient (r) between the concentration of aerial pollutants and poultry house dimensions ranged from 0.057 for CO to 0.668 for CH_4 and were not significant ($p< 0.05$). From the standard coefficient of the regression equation, the width recorded the highest standardized value of 1.861 and 3.95 for H_2S and SO_2, respectively, while height recorded 1.579 and 2.571 showing a direct relationship. This means that increasing the width and height will reduce the concentration of the gases.

As for NH_3 and N_2O, the width had the highest value of 9.417 and 5.844 respectively, while height had -1.61 and -4.21 showing an inverse relationship, indicating that a decrease in height and a increase in width of the building will decrease NH_3 and N_2O concentrations. Similarly, CH_4 and CO gases concentration showed an inverse relationship with height and width measurements of the building.

Correlation of structural dimensions to gas concentration in pullet farm

The multiple linear regression equations to predict the concentration of aerial pollutants from poultry house dimensions in pullet farms are shown in Table 5. Predicted SO_2 gave the highest coefficient of determination (r^2) of 0.854, while predicted NH_3 gave the least r^2 of 0.215. The correlation (r) between the concentration of aerial pollutant and poultry house

Table 3: Multiple linear regression of building dimension to gas concentration in broiler farm

Aerial pollutant	Prediction equation	Coefficient determination (r^2)	Coefficient of correction (r)	SE
HN_3	0.555-3.88H+2.294W	0.001	0.036	0.502
H_2S	0.138+1.06H-5.26W	0.459	0.678	0.049
SO_2	0.434+6.909H-1.83W	0.365	0.604	0.346
CO	7.237+0.88H-0.149W	0.304	0.552	5.268
N_2O	6.208-5.60H+3.554W	0.359	0.599	0.037
CH_4	1.75+3.03H-3.79W	0.281	0.530	0.465

NH3= Ammonia; H2S= Hydrogen sulphide; SO2=Sulphur Dioxide; CO=Carbon monoxide; N2O=Nitrous oxide; CH4=Methane, H=Height of the roof; W= Width of the wall; SE= Standard error

Table 4: Multiple linear regression of building dimension to gas concentration in layer farm

Aerial pollutant	Prediction equation	Coefficient determination (r^2)	Coefficient of correction (r)	SE
HN_3	1.338-1.61H+9.417W	0.004	0.066	1.330
H_2S	0.150+1.579H+1.861W	0.013	0.113	0.221
SO_2	0.692+2.571H+3.95W	0.164	0.405	0.366
CO	18.543+3.233H-4.22W	0.003	0.057	0.579
N_2O	5.795-4.21H+5.844W	0.099	0.315	0.157
CH_4	3.764-9.07H-3.25W	0.447	0.668	0.807

NH_3 = Ammonia; H_2S= Hydrogen sulphide; SO_2 = Sulphur Dioxide; CO = Carbon monoxide; N_2O = Nitrous oxide; CH_4 = Methane, H = Height of the roof; W = Width of the wall; SE = Standard error.

Table 5: Multiple linear regression of building dimension to gas concentration in pullet farm

Aerial pollutant	Prediction equation	Coefficient determination (r^2)	Coefficient of correction (r)	SE
HN_3	1.144+0.11H-2.13W	0.215	0.464	0.212
H_2S	1.355-5.192H+4.071W	0.242	0.492	0.180
SO_2	3.549+0.296H-5.70W	0.854	0.924	0.125
CO	1.723+2.588H-0.328W	0.794	0.891	2.419
N_2O	3.569+4.01H-6.95W	0.628	0.792	0.036
CH_4	9.329+0.129H-1.68W	0.585	0.765	0.193

NH_3 = Ammonia; H_2S = Hydrogen sulphide; SO_2 = Sulphur Dioxide; CO = Carbon monoxide; N_2O = Nitrous oxide; CH_4 = Methane, H = Height of the roof; W = Width of the wall; SE = Standard error.

Table 6: Multiple linear regression relating environmental factors to concentration of aerial pollutants

Aerial pollutant	Prediction equation	r^2	SE	F	Sign.
NH_3	-21.962+0.744X1-3.35X2+4.86X3+8.92X4	0.734	21.301	4.824	0.035
H_2S	-1.709+0.110X1-2.37X2+8.24X3+2.38X4	0.532	5.408	1.989	0.201
SO_2	9.173+0.465X1-0.291X2+1.55X3+7.18X4	0.661	18.493	1.356	0.339
CO	-85.013+1.786X1+0.616X2-2.31X3-1.03X4	0.402	66.471	1.175	0.399
N_2O	-1.60 + 6.87X1-6.58X2+6.26 X3+ 3.13X4	0.507	3.253	0.507	0.733
CH_4	-21.404+0.461X1+7.46X2+3.95 X3+3.98X4	0.712	17.088	4.335	0.045

X1= Temperature; X2=Relative humidity, X3= Moisture content of litter, X4=Wind speed; F= F- ratio; Sign.= Significant level; SE=Standard error.

dimensions ranged from 0.464 for NH_3 to 0.924 for SO_2 and were significantly different ($p<0.05$). From the standard regression equation, height had the highest standardized value of 0.11, 0.129, 0.296, 2.588 and 4.01 for NH_3, CH_4, SO_2, CO and N_2O, respectively, while width recorded -2.13, -1.68, -5.70, -0.328 and -6.95 respectively, showing an inverse relationship. This implies that an increase in height, with decrease in width will decrease the concentration of the gases.

Thus, this study showed that the relative contribution of poultry house dimension to the concentration of aerial pollutants and further explained the rate of increase of these pollutants due to changes in house measurements. The relative magnitude of the regression coefficient obtained in the pullet farm shows that SO_2, CO, N_2O and CH_4 were highly related (92.4, 89.1, 79.2 and 76.5%), while H_2S and NH_3 were moderately correlated with house measurements (49.2 and 46.4%). This indicates that increasing the height or reducing the width will lower the concentration of the gases. This finding is in line with Okoli *et al*. (2004) who reported that increasing the width and height of the pen will result in relative lowering of the concentrations of the pollutant gases.

Similarly, in the layer farm, CH4 was highly related with house measurement (66.8%), while N_2O, H_2S, CO, NH_3 and SO_2 were poorly correlated with house measurements. In broiler farm, however, H_2S, SO_2, N_2O, CO and CH_4 were highly related with house measurement (67.8, 60.4, 59.9, 55.2 and 53.0%), while NH_3 was poorly correlated with house measurements. These values indicate average rate of increase or decrease of aerial pollutant gas concentrations with respect to the average rate of increase or decrease in the building dimensions.

Correlation of gas concentration to environmental factors

The results of the correlation of environmental factors and concentration of gases showed that r^2 for the collective effects of all the independent variables (temperature, relative humidity, moisture content of the litter and wind speed) were 0.734, 0.532, 0.661, 0.402, 0.507 and 0.712 for NH_3, H_2S, SO_2, CO, N_2O and CH_4 respectively (Table 6). This indicates that about 73.4,

Table 7: Stepwise multiple regression relating environmental factors to aerial pollutants

Aerial pollutants	X (%)	X1 (%)	X2 (%)	X3 (%)	X4 (%)	X1, X2 (%)	X1, X3 (%)	X1, X4 (%)	X2, X4 (%)	X1, X2, X3 (%)	X1, X2, X4 (%)
NH_3	85.7	--	--	--	0.6	--	85.0	--	--	--	85.6
H_2S	72.9	9.4	--	62.1	0.7	--	71.5	--	--	--	72.2
SO_2	66.1	41.4	--	7.8	--	56.9	--	--	--	64.7	--
CO	63.4	--	5.3	--	35.0	--	--	56.8	62.1	--	66.1
N_2O	47.4	46.2	0.2	--	--	--	47.0	--	--	47.2	--
CH_4	84.4	--	1.0	--	--	--	83.2	--	--	84.2	--

X = All variables; X1 = Temperature; X2 = Relative humidity; X3 = Moisture content of the litter, X4 = Wind speed; X1,X4 = Temperature and wind speed; X2,X4 = Relative humidity and wind speed; X1,X2 = Temperature and Relative humidity; X1,X3 = Temperature and Moisture content of the litter; X1,X2,X3 = Temperature, Relative humidity and Moisture content of litter; X1,X3,X4 = Temperature, Moisture content of litter and Wind speed

Appendix I: t- value for the regression coefficients on environmental factors to gas concentration

Arial pollutant	X1	X2	X3	X4
NH3	1.870	-0.141	2.805	0.517
H2S	1.092	-0.393	1.870	0.544
SO2	1.346	-1.409	1.034	0.480
CO	1.439	0.831	-0.427	-1.921
N2O	1.131	-0.181	0.236	0.119
CH4	1.446	0.392	2.842	0.288

X1 = Temperature; X2 = Relative humidity; X3 = Moisture content of the litter; X4 = Wind speed

53.2, 66.1, 40.2, 22.4 and 71.2% of the variance of the dependent variables are being explained by the independent variables. In other words, only 26.6, 46.8, 33.9, 59.8, 77.6 and 28.8% of NH_3, H_2S, SO_2, CO, N_2O and CH_4 are not explained by the independent variables.

Also, the F - ratio value of 4.824 and 4.335 for NH_3 and CH_4 showed that a significant relationship existed between the concentration of gases and the selected environmental factors at $p< 0.05$.

Data obtained were subjected to stepwise multiple regression (Table 7) to determine the contribution of some of the independent variables and identify the one having the highest contribution. The computed results showed that all the variables contributed about 85.7, 72.9, 66.1, 63.4, 47.4 and 84.4% of NH_3, H_2S, SO_2, CO, N_2O and CH_4, respectively. While the combined effect of temperature (X1), moisture content of the litter (X3), and wind speed (X4) contributed 85.6, 72.2 and 66.1% of NH_3, H_2S and CO respectively, the combined effect of temperature (X1), relative humidity (X2) and moisture content of the litter (X3) contributed 64.7, 47.2 and 84.2% of SO_2, N_2O and CH_4, respectively.

Similarly, the combined effect of temperature (X1), and moisture content of the litter (X3) contributed 85.0, 71.5, 47.0 and 83.2% of NH_3, H_2S, CO, N_2O and CH_4, respectively. The combined effect of temperature (X1) and moisture content of the litter contributed 85.0%, showing the highest effect on NH_3 concentration. The combined effect of temperature (X1) and relative humidity (X2) contributed 56.9%, while temperature only contributed 41.4% on SO_2 concentration. This finding is in agreement with the report of Kocaman *et al*. (2006) who stated that humidity and temperature also have impacts on air quality.

Again, the combined effects of temperature and wind speed contributed 56.8%, while wind speed contributed 35.0% on CO concentration. The moisture content of the litter contributed the highest effect on H_2S concentration. From the standard coefficient of regression equation, moisture content of the litter has the highest standard coefficient and also the highest t – values of 2.842 and 2.805, while relative humidity has a negative value (Appendix I), showing an inverse relationship. This means that as relative humidity increases, NH_3, H_2S, SO_2 and N_2O concentration decrease in the pen.

Conclusions

The study concluded that because of differences in livestock buildings structural measurements, natural ventilation and other interacting factors in the tropical farming environment, variations are bound to occur in terms of concentrations and emission rates of aerial pollutants. Therefore, further studies are needed to fully understand the interaction between the key features of building design, environmental factors and management to control aerial pollutants in the tropical environment.

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