

Poultry house hydrogen sulphide emissions and impacts to neighbourhood environment in Yola, Nigeria

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Abstract:

Poultry houses are associated with the generation and release of air contaminants such as hydrogen sulphide, ammonia, methane among others. Specifically, hydrogen sulphide is known for causing inflammation of the moist membranes of eyes and respiratory tract, olfactory neuron loss, and results in death at certain exposure rates. In Yola, there is a growing trend in the poultry farming. The emissions from the poultry houses need to be investigated. In the current work, hydrogen sulphide gas emission is measured in yepwa poultry house in Yola using GX 2009 portable multi – gas monitor detection device. Atmospheric statistical dispersion model is used to assess and validate the Hydrogen Sulphide emission behaviour and hence, its range of impact in the neighbourhood. Results show that the gas's effect perimeter is highest among the category of matured birds (8 to 12 weeks old), extending beyond level 4 dispersion coverage. This indicates a dispersion radius of up to 500 m perimeter. The observed result is compared to calculated model values that demonstrated the result feasibility. The emission and dispersion quantities are found to be below threat limits according to established standard limits. However, the current work investigated an emission of H₂S for a 30,000 capacity birds. This may not be a well representative quantity and coverage. While this is a milestone in this field, investigating a larger quantity would highlight for more representation of poultry farming in the study area and beyond.

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1. Introduction

The evolution of animal agriculture to meet the needs of a rapidly growing world population is evidenced by a consistent trend toward the replacement of small-to-midsize animal farms with large, industrial-scale animal feeding operations (AFOs) that maximize the number of animals confined per acre of land. A concentrated animal feeding operations (CAFOs) is a specific type of large-scale industrial agricultural facility that raises animals, usually at high-density, for the consumption of meat, eggs, or milk. Confinement of large numbers of animals in such operations can result in large loadings of animal feed- and waste-related substances (animal residuals) to the environment [1]. Although manure is consisting of important nutrients such as phosphorus (P) and nitrogen (N) [2], it may also contain heavy metals, pathogens, antibiotics, and other harmful substances that, in excess, may pose a risk to soil, air, and water quality [3]. Poultry feed as well as residue/wastes there from forms part of CAFOs problems and management.

Aside its richness in essential plant nutrients, poultry waste is used in the formulation of livestock feeds and raw material substrates for bio-gas production [4]. Maggots from poultry waste in the small-scale farms are used as feed in fish farming to reduce feed cost and increase yield

gain [4, 5]. However, this process must be well managed to eliminate the potential danger that can be caused to the lives of aquatic organisms' because animal droppings on the ground surface or sub-surface can contaminate the ground water and surrounding water bodies with toxic elements (such as nitrogen, phosphorus, copper and zinc) and pathogens through leaching and erosion. Similarly, animal droppings are arguably powerful to cause soil and air pollutions if the agronomic uptake of the receiving crop is less than the nutrient deposits [6, 7].

The choice of disposal technique varies from farmer to farmer as well as regions (Charles, 2008). In general, several studies have found evidence for multiple air pollutants as contributors to reported outcomes, including cardiovascular, respiratory, neurologic, and mortality end [8]. Therefore, issues related to the environment, human health, potential income gain and the quality of life for the poultry farmers as well as the people living near to and distant from urban poultry production operations make waste management a critical consideration for the long-term growth and sustainability of poultry production.

1.1 Poultry Manure Emissions

Manure quantity and characteristics are influenced by the species, age, diet and health of the birds and by

farm management practices. Estimates of the manure excreted by 1 000 birds per day (based on average daily live weights during the birds' production cycle) are approximately 120 kg for layer chickens, 80 kg for meat chickens, 200 to 350 kg for turkeys (grower females and grower heavy males, respectively), and 150 kg for ducks [1]. Extrapolations can be calculated to give general estimates for the number of birds in a given operation. More specially, excessive exposure to air pollution (Hydrogen Sulphide, Ammonia, and Methane from poultry houses) induces inflammation, oxidative stress, energy metabolism dysfunction and adverse health effects [9].

Therefore, this research work is meant to quantify Hydrogen Sulphide emissions in a farm in Yola, Nigeria and assess the health-related implication for neighbourhoods around the poultry farm. The study involves consideration of thirty thousand birds being a large scale CAFO gas (H_2S) emission basis according to Hribar, [10]. as appended.

1.2 Impacts of CAFO emissions to human

The most typical pollutants found in air surrounding CAFOs are ammonia, hydrogen sulphide, methane, and particulate matter, all of which have varying human health risks. Table1 provides information on these pollutants [10].

Table1 Typical pollutants found in air surrounding CAFOs.

CAFO Emissions	Source	Traits	Health Risks
Ammonia	Formed when microbes decompose undigested organic nitrogen compounds in manure	Colourless, sharp pungent odour	Respiratory irritant, chemical burns to the respiratory tract, skin, and eyes, severe cough, chronic lung disease
Hydrogen Sulphide	Anaerobic bacterial decomposition of protein and other sulphur containing organic matter	Odour of rotten eggs	Inflammation of the moist membranes of eye and respiratory tract, olfactory neuron loss, death
Methane	Microbial degradation of organic matter under anaerobic conditions	Colourless, odourless, highly flammable	No health risks. Is a greenhouse gas and contributes to climate change.
Particulate Matter	Feed, bedding materials, dry manure, unpaved soil surfaces, animal dander, poultry feathers	Comprised of faecal matter, feed materials, pollen, bacteria, fungi, skin cells, silicates	Chronic bronchitis, chronic respiratory symptoms, declines in lung function, organic dust toxic syndrome

1.3 Hydrogen Sulphide (H_2S)

According to EPA [11], no studies were identified which quantitatively determined the absorption of H_2S in humans or animals. However, the inhalation of high concentrations of H_2S (greater than 2000 ppm or 2780 mg/m³) can be fatal within seconds or minutes in both humans and animals. However, in the same report, exposures of 500 ppm and above caused deaths in mammals within 22 minutes duration.

1.3.1 Determination of Hydrogen Sulphide

According to Saksrithai and King [12], Hydrogen sulphide (H_2S), one of the volatile sulphur compounds (VSCs), has received a great deal of attention as one of the gaseous emissions associated with concentrated animal feeding operations (CAFOs) in poultry houses because of its low odour threshold ($H_2S=10$ ppb) and its negative impacts on human and animal health and the environment. However, its presence and concentration depend on its primary determinants such as S-containing amino acids, associated biological processes, microorganisms, and resulting interactions.

Hydrogen sulphide and other VOCs can result from the metabolic breakdown of poultry waste products, generally under low-oxygen conditions such as cases occurring when manure is allowed to ferment (anaerobically digest) in a pit beneath the birds, in an earthen lagoon or in other open-air containment. This type of waste operation is more common with swine or dairy

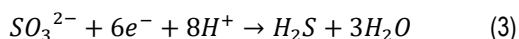
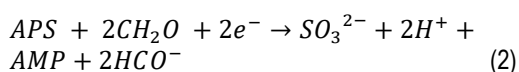
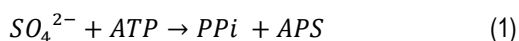
livestock than poultry, but may occur in some locations with layer operations. Under open-air fermentation, hydrogen sulphide and VOCs can be emitted into the atmosphere as pollutants, and can also be components of nuisance odour. Hydrogen sulphide can be dangerous to humans at certain concentrations. Donham and Thelin [3] reported that agitation of manure slurry in pits beneath animals can result in rapid elevation of ambient hydrogen sulphide to lethal concentrations, within seconds. The World Health Organization (WHO) notes an air quality guideline for hydrogen sulphide of 0.15 mg/m³ averaged over a 24-hour period as reported in Saksrithai and King [12].

1.4 Amino acids in feed:

Methionine is one of 13 essential amino acids required for growth of poultry. Since the presence of methionine in plant products is very low, it is the only amino acid that must be synthetically produced in a form of DL-methionine or methionine hydroxyl analogue (MHA) to add to poultry diets [12]. Accordingly, of 18.8% crude protein, 0.38% is methionine. Thus, the total S required by chicken is approximately 4.5% of the total protein. Investigation on the effect of different methionine sources (liquid MHA, DL methionine, dry MHA, and sodium methioninate aqueous solution) and revealed that various methionine sources gave rise to the different odour profiles, varying concentrations of H_2S , COS, CH_3SH , CH_3SSCH_3 , and $CH_3S_3CH_3$

1.4.1 Sulphur Amino Acids in Biological process:

There are two possible pathways to form H_2S and CH_3SH in animals [11]. These pathways are bacterial degradation of the S-containing amino acids and bacterial reduction of sulphate ions. Microorganisms anaerobically decompose S-containing amino acids (cysteine/cystine and methionine) forming intermediate S-containing compounds that ultimately form H_2S and other VSCs. The enzyme responsible for this pathway is methionine gamma lyase, which is present in some organisms from archaea to bacteria to plants. H_2S , along with pyruvate and NH_3 , can also be released from the enzyme cysteine desulhydrase catalysing the α , β -elimination of L-cysteine. More specific bacterial degradation of complex organic matter is through a branch of strictly anaerobic genera of *Deltaproteobacteria*, sulphate-reducing bacteria (SRB). These SRB use hydrogen and organic compounds for growth while reducing SO_4^{2-} to H_2S/HS^- in the process. These redox reactions, where CH_2O represents a generic organic carbon compound, depict the outcome [13].



SRB may also use other volatile fatty acids such as acetate, propionate, butyrate, and lactate which serve as the final electron acceptor during cellular respiration, providing energy and promoting the growth of these bacteria [12].

1.5 Chicken exposure to H_2S

At 0.2% and 0.3%, birds had an increase in respiratory frequency but returned to normal within 30 minutes with H_2S exposure. All birds died within 15 minutes at 0.4% H_2S inhalation; this is equivalent to 4000 ppm. The researchers noted that chickens are less sensitive to H_2S than mammals, 500-1000 ppm leading to death. In the same study, they also examined the response of intrapulmonary CO_2 receptors to varying H_2S concentration (0.035-0.1% H_2S). H_2S caused an increase in intrapulmonary CO_2 receptors' discharge frequency and an increase in vertical sternal movements. This increase in discharge frequency inhibited carbonic anhydrase in the central respiratory neurons which led to apnea [14].

Kocaman, *et al.* [15] found that an increase in combination of CO_2 (950.0-1623.1 ppm), NH_3 (10.5-16.46 ppm), and H_2S (1.75-7.0 ppm) in poultry houses can decrease the feed conversion ratio (from 1.79 to 2.18 kg feed consumed/kg egg produced).

It is also reported in [12] and [14] that the concentration of H_2S (12 mg/kg) resulted in a significant decrease in carcass yield and a significant increase in the rate of water loss in breast and thigh. This result correlated with a decrease in pH values of breast and thigh. The researchers suggested that there should be less than 2 mg/kg of H_2S in the broiler houses from weeks 0-3 and less than 6 mg/kg of H_2S from weeks 4-6 for healthy broiler

production [16]. Ultimately, when investigating ways to negate the negative effects of H_2S , it is important to account for naturally occurring endogenous sources [12].

2. Methods

2.1 Air Sampling Equipment:

Four gases were air marked for sampling the concentration of ambient air contaminants around the case study area. Those air pollutants consist of Carbon monoxide (CO), oxygen (O_2), Hydrogen Sulphide (H_2S) and Methane (CH_4), by a GX 2009 portable multi – gas monitor detection device.

2.1.1 Sampling Procedure

Two sampling stations are mapped out namely stations 'A' and 'B'. Station 'A' represents locations within the poultry house (high population density area). While station 'B' represents a point close to the poultry farm saving as a control station. At station 'A', air samples are measured at randomly selected locations in the poultry house, four selected locations outside the poultry house are selected at random and the air pollutants were measured using the GX 2009, a unique and portable multi-gas monitor for detection of Carbon monoxide (CO), oxygen (O_2), Hydrogen Sulphide (H_2S) and Methane (CH_4).

2.2 Air pollution level

The recorded mean daily Concentration Level of air pollutants namely Carbon monoxide, Methane and Hydrogen sulphide in the study area as observed in the morning, afternoon and in the evening in different categories (young week 1-4, Intermediate week 4-8, Matured 8-12) of birds using GX 2009 mobile gas sensor are presented in Table 2.

Tables 2: Mean concentration of air pollutants (ppm)

Category of birds	H_2S		
	M	A	E
Young(1-4weeks) inside	3.57	3.50	3.97
Young(1-4weeks) outside	1.60	1.43	2.07
Intermediate (4-8weeks) inside	109.60	124.87	172.47
Intermediate (4-8weeks) outside	63.10	67.77	89.97
Matured (8-12 weeks) inside	411.57	218.03	370.3
Matured (8-12 weeks) outside	130.17	83.87	112.8

Key; M= Morning, A=Afternoon, E=Evening

3. Results verification

To assess the effect of the gas dispersion coverage or effect perimeter, a data comparison was performed using the statistical parameters recommended by Augusto, *et al.* [17]: fractional bias (FB), normalized mean square error ($NMSE$), correlation coefficient (R), geometric mean bias (MG), geometric variance (VG) and fraction of predictions within a factor of two of observations ($FAC2$). Results were then compared with H_2S values quantified in the study site. The statistical parameters are presented in Equations 1 to 6 indicating the behaviour of the gas as accounted by Augusto, *et al.* [17]:

$$FB = \frac{(\overline{C_o} - \overline{C_p})}{0.5(\overline{C_o} + \overline{C_p})} \quad (4)$$

$$NMSE = \frac{(\overline{C_o} - \overline{C_p})}{\overline{C_o C_p}} \quad (5)$$

$$R = \frac{(\overline{C_o} - \overline{C_p})(\overline{C_p} - \overline{C_o})}{\sigma C_p \sigma C_o} \quad (6)$$

$$MG = \exp(\overline{\ln C_o} - \overline{\ln C_p}) \quad (7)$$

$$VG = \exp[(\overline{\ln C_o} - \overline{\ln C_p})^2] \quad (8)$$

FAC2= fraction of data that satisfy: $0.5 \leq \frac{C_p}{C_o} \leq 2.0$ (6)

where C_p is the computed predictions, C_o is the average over observations, $\overline{C_p}$ is the average over predictions, and σ the standard deviation over the dataset. This methodology assumes that mean bias is within $\leq 30\%$ of the mean (i.e., roughly $|FB| < 0.3$ or $0.7 < MG < 1.3$). The random value is about a factor of two to three of the mean (i.e., roughly $NMSE < 1.5$ or $VG < 4.0$). The fraction of predictions within a factor of two of observations is about 50% or greater (i.e., $FAC2 \geq 0.5$).

4. Discussions

4.1 Validity of the detected result

Results from the detected and observed data are presented in Table 3. According to the statistics, the methodology proposed is valid to study the gas dispersion within the vicinity of the poultry house. These parameters lay within the limits, except for VG. Moreover, since $FAC2 = 51\%$ and the dataset variance is not great, the linear parameters have a better fit when comparing the

dispersion model to obtained value. Parameter FB shows a positive sign, close to ideal and within limits. Its value indicates a slight overestimation of H_2S concentrations by the chosen method. $NMSE$ is also within validation limits. Correlation coefficient (R) does not indicate a strong correlation between computed and quantified data. However, a linear relation between both exists, and is directly proportional and has statistical significance at a 95% confidence level ($p = 0.05$). MG is within acceptable limits, considering 30% error margin around ideal values. The $FAC2 = 51\%$ shows that 51% of the data are within interval $0.5 \leq C_p/C_o \leq 2.0$, a satisfactory outcome. Since $FAC2$ is a robust tool, this parameter is important on models' evaluation and validation as it is not deeply affected by much deviations. Such results are considerable due to limitations and simplifications in numerical models [17].

Table 3 Statistical parameters for validation

Parameter	Study Area	Ideal fit	Validation limits
FB	0.08	0	$-0.3 \leq FB \leq 0.3$
NMSE	0.59	0	≤ 1.5
R	0.65	1	close to 1
MG	0.86	1	$0.7 \leq MG \leq 1.3$
VG	4.75	1	≤ 4.0
FAC2%	51	100	≥ 0.5

4.2 H_2S dispersion

Figure 1 presents the dispersion perimeter of the gas within the neighbourhood of the poultry hose. The dispersion from the birds is categorized into 1 to 4 for both inside and outside dispersion in the morning, afternoon and evening as indicated earlier.

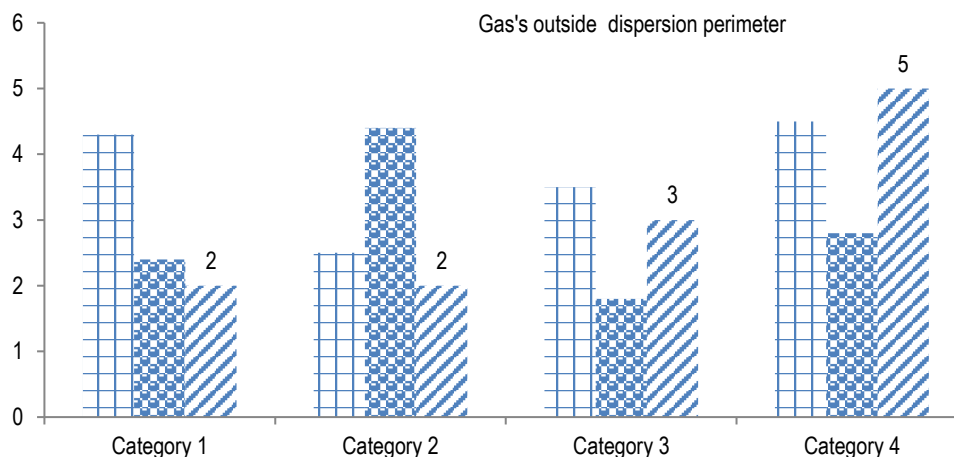


Figure 1: Hydrogen sulphide outside dispersion perimeter

The behaviour of Hydrogen Sulphide dispersion pattern is lengthiest among the matured birds extending beyond level 4 in the evening, approximately level 3 in the afternoon and highest in the morning up to level 5. This could be associated with the rigorous feeding of the birds overnight alongside the metabolic activities both of the birds, the waste and those of the contents from the concentrated feeds. All categories display varying but a pattern that is perhaps characterized by a slow rate of

dispersion of the gas between one another. One aspect that could be responsible for that behaviour is because of the period within which the sampling was conducted. That was in the advent state of the rainy season which is marked by very low movement of the winds and high humidity. In this sense the dispersion coverage is within the perimeters of slightly beyond 500 m according to EPA standards of gas dispersion coverage [18].

4.3 Concentration Level of H_2S

Release of the gas in all the categories were processed and presented into five as shown in Figure 2 below. Categories one is compressed to constitute a

combination of inside and outside gas exposure. While remaining four were allowed to stand on as inside and outside independent entities of gas emission.

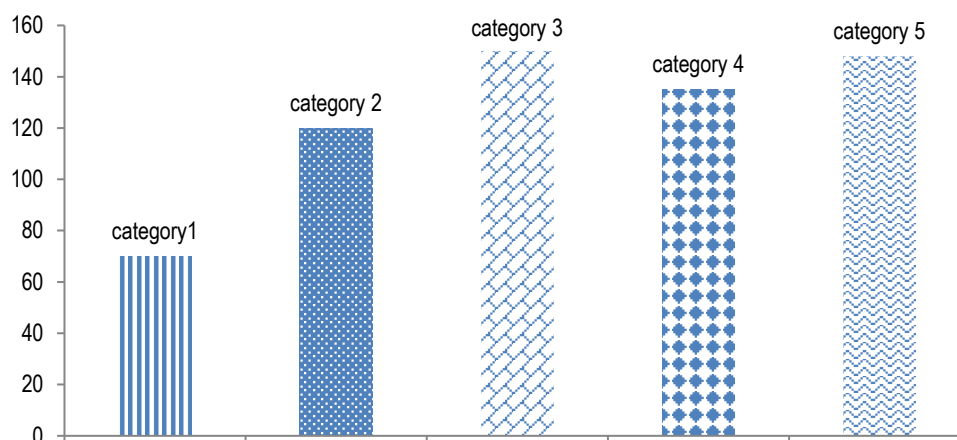


Figure 2: Emission levels fog all categories

Figure 2 shows that all categories level of exposure is within a safe limit. A similar finding was also reported by Tariwari, *et al.* [19].

5. Conclusions

Hydrogen Sulphide gas dispersion coverage for specific study area was investigated and determined. The observed result is compared to calculated model values that demonstrated the result feasibility. The emission and dispersion quantities are found to be below threat limits according to established standard limits. According to the statistics, the methodology proposed is valid to study the gas dispersion within the vicinity of the poultry house. Since the dispersion coverage is only meant for 30,000 birds in a specific area, it is recommended to conduct investigation for a greater number of birds as well as coverage so that a more representative outcome could realize.

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