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AIR QUALITY EVALUATION AND MICROCLIMATIC MONITORING IN A LARGE POULTRY HOUSE IN IBADAN, NIGERIA: IMPLICATIONS FOR POULTRY HEALTH AND ENVIRONMENTAL MANAGEMENT

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Abstract: Large poultry houses in tropical environments generate significant air pollutants linked to unique microclimatic conditions that impact poultry health, worker safety, and surrounding ecosystems. This study presents continuous monitoring of air quality parameters ammonia (NH_3), sulfur dioxide (SO_2), particulate matter (PM2.5 and PM10) and microclimatic factors, including temperature, relative humidity (RH), and air velocity, in a commercial broiler poultry house in Ibadan, Nigeria. Measurements over 30 days revealed pronounced spatial variability, with rear zones demonstrating elevated temperatures (31.8 ± 2.3 °C), relative humidity (70.9 ± 6.5%), and ammonia concentrations exceeding 30 ppm, surpassing poultry health thresholds. Particulate matter levels frequently exceeded WHO ambient air quality recommendations and contained pathogenic microorganisms. Waste management practices, primarily manual litter removal and field application, contributed to emission peaks during handling. The findings endorse optimization of ventilation systems, implementation of sensor–guided real–time environmental control, and improved waste treatment such as composting or biogas production. This integrated environmental management approach can enhance bird welfare, reduce health risks, and support sustainable poultry farming within Ibadan's tropical climate.

Keywords: air quality monitoring, microclimate, particulate matter, ventilation, waste management, tropical poultry environment

INTRODUCTION

Poultry farming is a vital sector in Ibadan, Nigeria, providing a steady source of affordable protein and employment. However, intensive poultry production releases airborne pollutants including ammonia (NH_3), sulfur dioxide (SO_2), and particulate matter (PM2.5 and PM10), which may carry microbial pathogens, posing risks to poultry health, farmworkers, and adjacent communities (Cao, Liu, Chen, & Zhang, 2023; Liu, Gu, Chen, & He, 2023). In tropical climates such as Ibadan's characterized by high temperatures and relative humidity these emissions can be exacerbated by increased microbial activity and volatilization processes (Gilani, Yan, & Zhang, 2022). Microclimate parameters temperature, humidity, and air velocity—not only influence emission rates but directly impact poultry welfare by affecting thermal comfort and disease susceptibility (Zhang, Wang, Li, & Huang, 2024). Despite the critical importance, there is a paucity of detailed and integrated investigations of how microclimatic conditions shape pollutant dynamics within large–scale Nigerian poultry houses. This study aims to characterize the spatial and temporal variation of air pollutants and microclimatic factors inside a commercial broiler house in Ibadan, analyze pollutant sources and waste management practices and provide evidence–based recommendations for improving poultry health and environmental conditions. Understanding these relationships can inform targeted mitigation strategies aligned with regional conditions and resource constraints.

MATERIALS AND METHODS

▦ Study Site and Facility Description

The study was conducted in a commercial broiler poultry house located in Ibadan, Oyo State, Nigeria (7.3775° N, 3.9470° E). The facility housed approximately 15,000 broilers during the dry season production cycle (January–February 2025). The poultry house measured roughly 100 m in length and 15 m in width, featuring a semi–enclosed design with natural ventilation supplemented by exhaust fans placed at the rear. The flooring was concrete covered with wood shavings litter maintained according to standard practice. Birds were approximately 4–6 weeks old across the monitoring period, corresponding to peak growth and waste production phases, which influence emission profiles (Mitchell & Waltman, 2003). Waste management involved manual bi–weekly removal of manure–laden litter, with temporary onsite storage before application as fertilizer on adjacent farmland.

Microclimate and Pollutant Monitoring

Monitoring was performed at 10 fixed points distributed evenly along the poultry house length, at bird height (~30 cm above floor level), to capture spatial heterogeneity. Measurements were recorded every 15 minutes continuously over 30 days. Sensors used include:

- Temperature (°C) and Relative Humidity (%) were measured using Vaisala HMP155 hygrometers, known for ±0.2 °C and ±2% RH accuracy. Sensors were calibrated per manufacturer protocols pre–deployment.
- Air velocity (m/s) was measured with TSI VelociCalc 9565 hot–wire anemometers, measuring airspeed with ±0.05 m/s accuracy.
- Ammonia (NH3, ppm) levels were recorded using Alphasense NH3–B1 electrochemical sensors, calibrated with certified calibration gases.
- Sulfur dioxide (SO2, ppm) was monitored using Alphasense SO2–B4 electrochemical sensors similarly calibrated.
- Particulate matter (PM2.5 and PM10, µg/m^3) concentrations were measured via TSI DustTrak II 8530 laser scattering monitors.

Data were logged electronically, and data quality checked for sensor drift and missing values. The 15–minute interval was chosen to capture diurnal variations and operational dynamics, consistent with precision poultry environmental monitoring standards (Zhang et al., 2024).

Microbial Air Sampling

To assess microbial airborne contamination via bioaerosols, impaction method air sampling was conducted weekly using a MAS–100 Eco air sampler (MERCK, Germany). This method was selected over sedimentation due to superior quantitative reliability and standardization of sampled air volume (Kalwasińska et al., 2013). Samples were cultured for bacteria and fungi using selective media and incubated per standard microbiological protocols.

Waste Management Assessment

Waste practices were documented through structured interviews with farm management and direct observation. Interviews followed a semi–structured protocol covering litter removal schedule, storage, reuse, and compliance with environmental regulations. Compliance with Nigerian Environmental Protection Agency (NESREA) standards was referenced where applicable.

RESULTS AND DISCUSSION

Microclimatic Variations

Table 1 summarizes the mean microclimatic parameters by zone within the poultry house. Temperature was highest at the rear (mean 31.8 ± 2.3 °C), cooler near the front inlet (27.5 ± 2.0 °C), indicating ventilation inefficiencies (Figure 1). Relative humidity averaged 68.5 ± 8.2%, occasionally rising above 80% during early mornings. Air velocity was unevenly distributed, with zones near exhaust fans recording up to 1.2 m/s, while mid–house sections fell below 0.3 m/s.

Table 1: Spatial distribution of microclimatic parameters within the poultry house

Zone	Temperature (°C)	Relative Humidity (%)	Air Velocity (m/s)
Front Inlet	27.5 ± 2.0	65.1 ± 5.6	0.9 ± 0.3
Mid–house	29.7 ± 2.1	69.4 ± 7.3	0.3 ± 0.1
Rear Exhaust	31.8 ± 2.3	70.9 ± 6.5	1.2 ± 0.4

Mean temperature distribution inside the poultry house zones with the highest temperature recorded at the rear exhaust zone, indicative of insufficient cooling and ventilation in that area. Temperature increases from front (27.5°C) to rear (31.8°C) by approximately 4.3°C, consistent with heat build–up due to bird density and ventilation patterns (Table 1). This thermal gradient poses stress risks to birds in the rear zone. Relative humidity shows moderate variation but frequently exceeds 70% in mid–house and rear zones, that is humidity peaks near 71% at the rear, surpassing ideal levels (>60–80%), fostering microbial growth and ammonia emission. Air velocity decreases notably in the mid–house zone (0.3 m/s) compared to the front and rear, promoting pollutant accumulation and poor air mixing. The distribution patterns highlight areas for targeted ventilation improvement to optimize air exchange and mitigate pollutant hotspots.

These demonstrate a clear spatial gradient of microclimatic stressors and pollutant concentrations. Elevated temperature and humidity promote ammonia volatilization from manure litter, compounded by low air velocities that hinder pollutant dispersion. The diurnal rise in ammonia during hotter afternoon hours suggests ventilation systems may require dynamic adjustments synchronized with environmental conditions. These graphical analyses support integrated approaches combining sensor technology, ventilation engineering, and waste management improvements. By implementing these measures, poultry farmers can reduce pollutant concentrations, improve bird health, and minimize environmental impacts.

These microclimate disparities indicate inadequate ventilation in mid–house and rear zones, elevating thermal stress and pollutant retention risks. The Tables show the Spatial distribution of mean microclimatic parameters ± standard deviation at poultry house zones (n = 10 sensor locations, 30 days). Temperature gradually increased from front to rear zones, with rear temperatures averaging 4.3 °C higher than front inlets, reflecting heat accumulation due to bird metabolic activity and insufficient airflow (Zhang et al., 2024). Relative humidity similarly peaked rearward, favoring microbial proliferation and enhancing ammonia volatilization (Gilani et al., 2022). The minimal air velocity in mid–house zones (~0.3 m/s) indicates poor ventilation, supporting thermal stress risk and pollutant stagnation (EPA, 2023). Optimal airflow recommendation for broiler houses is ≥0.5 m/s to promote heat and gas dispersion (The Poultry Site, 2025). These findings corroborate previous studies emphasizing microclimatic heterogeneity in large poultry houses and the critical role of ventilation design tailored to tropical climates to mitigate heat and pollutant accumulation (Cao et al., 2023; Zhang et al., 2024).

▦ Pollutant Concentrations

The air pollutant data revealing ammonia concentrations varied substantially, averaging 18.2 ± 7.9 ppm but peaking above 30 ppm near waste accumulation zones (Table 2). These peaks exceed the recommended 25 ppm limit for poultry respiratory health (EPA, 2023). The temporal NH3 fluctuations, with highest levels in late afternoons coinciding with decreased ventilation effectiveness. SO2 concentrations were generally low (1.5 ± 0.7 ppm), although episodic peaks coincided with litter disturbance during cleaning events.

Table 2: Pollutant concentrations measured inside the poultry house

Pollutant	Mean Concentration	Recommended Threshold	Health Implications
NH3 (ppm)	18.2 ± 7.9	25 ppm	Respiratory irritation in poultry and humans
SO2 (ppm)	1.5 ± 0.7	5 ppm	Lower risk but irritant gas
PM2.5 ($\mu g/m^3$)	75 ± 25	25 $\mu g/m^3$ (WHO ambient)	Pulmonary inflammation and infection risk
PM10 ($\mu g/m^3$)	130 ± 40	50 $\mu g/m^3$ (WHO ambient)	Respiratory ailments and lung disease

PM2.5 and PM10 averaged 75 ± 25 $\mu g/m^3$ and 130 ± 40 $\mu g/m^3$, respectively, above WHO recommended ambient guidelines (WHO, 2021). Microbiological analysis of collected PM indicated presence of *Escherichia coli*, *Aspergillus spores*, and *Staphylococcus species*, corroborating health risk potential.

Elevated NH3 levels (>30 ppm) in rear areas coincide with litter accumulation and poor ventilation. NH3 peaks during afternoon heat (12:00–18:00), correlating with reduced ventilation efficiency and increased litter microbial activity. Generally, the ammonia concentrations exceeded 25 ppm in rear zones (Figure 4), driven by litter accumulation and microbial decomposition, consistent with thermal and humidity patterns promoting volatilization (Gilani et al., 2022). Diurnal NH3 peaks occurred midday to late afternoon (12:00–18:00), coinciding with ambient heat maxima and reduced ventilation efficiency. Particulate matter consistently exceeded WHO ambient air recommendations, with PM10 concentrations nearly triple allowable limits. Composition analysis indicated bioaerosol presence including *Escherichia coli* and *Aspergillus spp.*, suggesting occupational health risks and potential poultry respiratory infections (Liu et al., 2023; Site CAES, 2023). Sulfur dioxide levels remained low but monitored as irritant gas with cumulative effects in enclosed environments (WHO, 2021). The pollutant distribution patterns illustrate compounding risks resulting from microclimatic conditions and inadequate waste handling. These pollutant patterns underline the synergistic effect of microclimate and waste management on air quality and reinforce the need for pollutant source control and ventilation optimization (EPA, 2023; Cao et al., 2023).

▦ Microbial Air Contamination

Impaction sampling revealed high counts of airborne bacteria and fungi, with concentrations increasing progressively during production cycles (up to 324 CFU/m^3), consistent with microbial proliferation in litter and airborne dust observed in similar studies (Kalwasińska et al., 2013; Liu et al., 2023). The impaction method's ability to standardize sampled air volumes provided reliable microbial load quantification, crucial for bioaerosol exposure assessment (Kalwasińska et al., 2013).

3.4 Waste Management Practices

Manual bi–weekly litter removal and lateral field application remain primary waste strategies onsite but contribute to episodic emission peaks of ammonia and particulate matter during disturbance events (Site CAES, 2023). Lack of mechanized handling, composting, or anaerobic digestion exacerbates volatile organic compound and pathogen release. Farm interviews revealed low awareness of emission mitigation technologies and regulatory standards, highlighting a knowledge and enforcement gap consistent with regional poultry environmental management challenges (Akinola, Abiola, & Olawale, 2024; Okoro, Nwosu, & Eke, 2023).

Implications for Poultry Health and Environmental Policy

Ammonia exposure above 25 ppm and elevated particulate loads adversely affect poultry respiratory health, reducing feed conversion efficiency and increasing disease susceptibility, thus impacting productivity and worker health (EPA, 2023; Cao et al., 2023). Higher temperatures and humidity exacerbate thermal stress, compounding welfare concerns (Zhang et al., 2024). Policy and management implications include:

- Upgrading ventilation systems combining mechanical fans and natural airflow to achieve a minimum air velocity of 0.5 m/s throughout the house, especially mid and rear zones (The Poultry Site, 2025).
- Deploying integrated sensor networks for measuring temperature, RH, gas concentrations, and particulates, enabling dynamic environmental controls to optimize ventilation in real time (Zhang et al., 2024; Site CAES, 2023).
- Implementing waste treatment technologies such as composting or biogas recovery to reduce emissions and promote circular economy benefits (Akinola et al., 2024).
- Enhancing farmer training on environmental management best practices and enforcing compliance with NESREA and national environmental standards (Okoro et al., 2023).

Technological interventions like electrostatic precipitation and acid scrubbers have shown promise in particulate and gas removal but require cost–benefit assessment in local small–to medium–scale operations (Site CAES, 2023; Site CAES, 2023).

CONCLUSION

This comprehensive assessment of air quality and microclimate within a large broiler poultry house in Ibadan reveals significant spatial and temporal heterogeneity. Elevated ammonia and particulate matter concentrations linked to microclimatic conditions and manual waste handling pose challenges to poultry health and occupational safety. Integrating improved ventilation design, real–time sensor networks, and sustainable waste management can mitigate risks, enhance bird welfare, and advance environmental sustainability in tropical Nigerian poultry production. Future research should incorporate intervention trials to quantify the efficacy and economic feasibility of recommended mitigation measures under local conditions.

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