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Air Quality Assessment of Some Selected Poultry Farms in Yenegoa, Nigeria

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Abstract
Air quality of some selected poultry farms in Yenagoa, Nigeria were assessed, with a focus on determining the concentration levels of ammonia (NH_3), carbon dioxide (CO_2), particulate matter (PM), oxygen (O_2) and their changes with changes in indoor air temperature, and relative humidity using a Multi-Gas Sensor, digital thermometer, and digital hygrometer. The indoor levels of these parameters (ammonia, carbon dioxide, particulate matter, oxygen, temperature and relative humidity) for the selected poultry farms namely; Azikoro, Opolo, and Tombia were assessed on a weekly basis for one month. The results revealed a slight variation in ammonia (NH_3) concentration levels in the selected poultry farms---Tombia, Opolo, and Azikoro with concentration values of 0.41ppm, 0.46, and 0.47 ppm respectively. There were significant variations in CO_2 concentration levels, with Azikoro recording the highest concentration value of 892.93 ppm and Opolo with the lowest concentration value of 608.21 ppm. Similarly, there were no significant variations in the concentration levels of particulate matter in the selected poultry farms. Their concentration levels varied from 33.5ppm to 35.5ppm. The noticeable variations in the concentration levels of HN_3, CO_2 and PM could be attributed to stock density, poor ventilation and sanitary conditions of the respective poultry farms. Oxygen (O_2) levels were generally stable across the three poultry farms. A positive correlation was observed between temperature and CO_2 concentration levels, temperature and ammonia concentration levels, indicating that warmer conditions may exacerbate pollutant buildup due to enhanced bird metabolism and inadequate ventilation. Additionally, relative humidity showed a weak negative correlation with CO_2 concentration levels but showed a weak positive relationship with PM concentration levels, suggesting that moisture may trap particulates in the air. The concentration levels of ammonia, carbon dioxide and the 24-hour average for PM_{10} in all the selected poultry farms were within the safe limit, except $PM_{2.5}$. Understanding the current state of indoor air quality in poultry farms is essential for developing strategies to mitigate the risks associated with poor air quality.

Keywords: Air Quality, Atmospheric Parameters, Poultry Pollutants.

Introduction

Good air quality (AQ) in poultry farms is crucial for maintaining the health and productivity of poultry, as well as the safety and well-being of poultry workers. Sharma et al. (2023) posited that air quality is the contamination of the environment by chemical, physical, or biological agents that modify the inherent properties of the atmosphere. The quality of air is often measured by the concentration of various gases and particulate matter that are present in the atmosphere. Waste from poultry farms releases harmful pollutants such as ammonia, methane, and hydrogen sulfide into the air, resulting in a deteriorated air quality status. The most concerned of these air pollutants in terms of air quality is ammonia (Bist et al., 2023). Poor ventilation in poultry houses often compounds these issues, trapping pollutants indoors and creating hazardous conditions. In poultry farms, the generation of high levels of harmful pollutants such as ammonia, carbon dioxide, methane, and particulate matter can severely affect both the poultry and the workers within such an environment. Bist and Chai (2022) noted that high level of PM has the potential to impair the health of workers and animals in broiler and cage-free layer houses. According to Landry (2024, August 9) “indoor air quality (IAQ) refers to the condition of the air within and around buildings and structures, particularly as it relates to the health and comfort of building occupants”. The Department of Animal and Food Sciences (n.d) listed contaminants in poultry farms to include “solid particles; microorganisms such as bacteria, fungi and viruses; and gases such as ammonia, hydrogen sulfide, and carbon dioxide”. These pollutants arise from the accumulation of poultry waste, feed, litter, and the respiratory activities of the birds. The World Health Organization (WHO) emphasizes that clean air is fundamental for human health and development, highlighting the necessity of stringent air quality standards to prevent disease and improve quality of life (WHO, 2005). The need for good air quality extends beyond human health, it impacts agricultural productivity, including poultry farming, where the quality of air within poultry houses can directly affect the health, growth, and productivity of the birds. Intensive poultry farming, combined with certain climatic conditions, often leads to poor indoor air quality and the release of harmful air pollutants. Gases such as ammonia (NH_3), methane (CH_4), hydrogen sulfide (H_2S), carbon dioxide (CO_2), in poultry houses are of particular concern due to their negative impact on poultry health, production, and human occupational safety (Reddy et al., 2007). Ammonia, methane, and hydrogen sulfide are primarily produced by the anaerobic breakdown of accumulated fecal matter in the poultry house, with emissions becoming particularly high in warm and humid conditions when ventilation is inadequate. These gases can sometimes reach dangerous levels, posing risks to both poultry and workers. Each of these gases have been noted to have adverse effects on respiratory health (Cole et al., 2000; Okoli et al., 2006). While oxygen is vital for respiration, carbon dioxide is produced through the birds’ respiratory processes. Poor indoor air quality is linked to several health issues, both for the birds and the workers. Exposure to high levels of ammonia reduces immune response, and poor growth rates in poultry. Ammonia can damage respiratory passage, resulting in serious lung problems, pulmonary edema and even death (Dasarathy et al., 2016). Heitzmann (2015) identified symptoms that are generally associated with poor indoor air quality to include cough or respiratory related illness, headache, chronic fatigue, dry eyes/throat, and nausea. Nandan et al. (2021) pointed out the U.S. Environmental Protection Agency’s list of common indoor air pollutants to include particulate matter, carbon monoxide, volatile organic compounds (VOCs), and biological contaminants. Cambra (2010) posited that the intensification of poultry production is often associated with higher levels of ammonia and dust, which can compromise bird health and welfare. For instance, ammonia acts as a respiratory irritant or toxicant (Smith et al., 2003; Wafi et al., 2011), while gases like carbon dioxide and carbon monoxide can cause asphyxiation, blood poisoning, anoxia, pulmonary edema, or sudden death (Okoli et al., 2006). Ammonia, a byproduct of uric acid breakdown in poultry manure, is one of the most concerning pollutants due to its pungent odour and corrosive nature. High levels of ammonia cause damage to mucous membranes of the respiratory system of birds and also enhance their level of susceptibility to respiratory problems (Sheikh et al., 2018). For farm workers, prolonged exposure to ammonia concentrations exceeding occupational safety limits can cause chronic respiratory conditions, including bronchitis and asthma (Kim et al., 2021). Similarly, exposure to hydrogen sulfide may result in pulmonary edema or sudden death (Adams et al., 2022). Hydrogen sulfide (H_2S) is a colorless gas with a characteristic rotten egg odour, produced from the anaerobic decomposition of organic matter containing sulfur, such as poultry manure. Hydrogen sulfide is highly toxic, and exposure to even low concentrations can cause irritation of the eyes, nose, and throat. Inhalation of Hydrogen sulfide in high concentration can lead to fatality (Bhomick & Somasekhara, 2014). For poultry, exposure to hydrogen sulfide can result in reduced feed intake, poor growth performance, and increased mortality rates. In poorly ventilated poultry houses, hydrogen sulfide can accumulate to dangerous levels, posing a significant risk to both poultry and farmworkers. Infectious microbial spores, chemical pollutants, irritants, and allergens can be present in both indoor and outdoor air, reducing quality of life and potentially causing diseases (Killebrew et al., 2010; Kusi et al., 2015). Particulate matter, consisting of fine particles of feed, feathers, and fecal matter, poses an additional challenge. These airborne particles often carry pathogens, exacerbating the risk of respiratory infections. Xu et al. (2022) study revealed a positive correlation between temperature, concentrations of air pollutants and indoor bacteria community, and could spread from confinement buildings to the ambient atmosphere through wind. Methane (CH_4), a potent greenhouse gas that is generated during the anaerobic decomposition of organic matter in poultry manure. Methane (CH_4) is said to be a powerful climate warmer, and is regarded as the second most significant greenhouse gases after CO_2 (Mar et al., 2022). The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) has it that CH_4 is 84 times stronger than CO_2 over 20 years (European Environmental Agency, 2023). Methane potency is due to the fact that the number of bonds between the atoms of methane is higher than that of CO_2 and such, “it can twist and vibrate in more ways that absorb infrared light on its way out of the Earth’s atmosphere” (Krol, 2023 December 7). In the context of indoor air quality in poultry farms, methane is less of a direct health hazard to poultry and farmworkers compared to ammonia and hydrogen sulfide, but its environmental impact is significant.

Effects of Atmospheric Parameters and Poultry House Structures on Indoor Air Quality (IAQ)

Temperature and relative humidity (RH) significantly influence IAQ in poultry houses, with both parameters playing a role in pollutant dynamics and distribution. “Ammonia volatilization is increased with rising temperatures and can therefore be indirectly affected by warming caused by GHG emissions” (Wang et al., 2023). According to Wolkoff et al. (2021) “epidemiological and experimental studies have revealed the effects of the room temperature, indoor air humidity, and ventilation on human health, work and cognitive performance, and risk of infection”. The concentrations of indoor air pollutants are closely linked to factors such as bird density, housing type, feed composition, and the level of ventilation in the poultry house. Seasonal variations add to the complexity of managing IAQ in poultry farms. Extreme temperatures can also exacerbate ammonia and carbon dioxide accumulation in enclosed poultry houses, which further deteriorates indoor air quality (Zhao et al., 2015). During hot

seasons, poorly managed heat loads can cause birds to exhibit panting behavior, which, although a natural thermoregulatory mechanism, results in increased water loss and respiratory alkalosis (Mashaly et al., 2004). "Inadequate ventilation leads to high NH_3 concentrations in poultry houses, particularly in temperate regions during winter" (Swelum et al., 2021).
Abbas et al. (2011) study revealed that fluctuation of temperature inside a closed poultry house affects the performance of laying hens. The characterization of indoor microclimate involves the use of certain parameters such as actual air temperature, absolute humidity, maximum and minimum air temperature, maximum and minimum humidity, and relative humidity (Kalva, 2023). Poultry are highly sensitive to heat stress, as excessive heat can lead to decreased feed conversion efficiency, reduced egg size, and weakened immune responses (Mashaly et al., 2004). Warm seasons are associated with increase in indoor temperature which in turn enhances the chemical production of air pollutants due to the temperature's catalytic effect on chemical reactions (Ngwabie et al., 2011).
Studies have shown the relationship between concentration of pollutants and some atmospheric parameters as follows
The rate at which CO_2 concentration changes with temperature is often captured by an empirical exponent (α) in equation (1)

$$CO_2 = C \times \left(\frac{T}{T_o}\right)^{\alpha} \qquad (1)$$

Where T is the temperature, T_o is the reference temperature (often 25°C), and C is a constant that depends on specific environmental conditions. A typical value for α ranges from 0.05 to 0.15, depending on the system's sensitivity to temperature variations.

Similarly, the effect of relative humidity on CO_2 concentration can be modeled by an empirical exponent (β) in a similar form to equation (1).

$$CO_2 = C \times \left(\frac{RH}{RH_o}\right)^{\alpha} \qquad (2)$$

Where RH is the relative humidity, RH_o is the reference relative humidity (often 50%), and β is the exponent that describes the sensitivity of CO_2 to changes in relative humidity. Empirical studies suggest that the value of β typically ranges between 0.02 and 0.10.

PM concentration is related to temperature and relative humidity by equation (3)

$$PM = k.(T)^{a}.\,(RH)^{b} \qquad (3)$$

Where PM is the concentration of particulate matter (typically measured in micrograms per cubic meter, µg/m³), T is the temperature (in degrees Celsius, °C), RH is the relative humidity (as a percentage, 0-100%), k is a constant that depends on local environmental factors such as pollution sources, ventilation, and other specific conditions of the area.
a and b are empirical coefficients that determine the sensitivity of particulate matter concentration to temperature and relative humidity, respectively.

The concentration of PM in poultry houses can be modeled by considering emissions, temperature, relative humidity, and ventilation rate. PM concentration is related to these variables by equation (4).

$$PM = E \cdot \frac{1}{V} \cdot (T)^{a} \cdot (RH)^{b} \qquad (4)$$

Where PM is concentration of particulate matter (µg/m³), E is emission rate of particulate matter and precursors (e.g., NH_3) from poultry litter (µg/m³·h), V is the ventilation rate (m³/h), which dilutes the concentration of PM in the house, T is the temperature (°C), which influences the volatility of NH_3 and the rate of secondary particle formation. RH is the relative humidity (%), which affects the hygroscopic growth and deposition of particulate matter, a, b are empirical coefficients representing the sensitivity of PM to temperature and humidity, determined through experimental data.

In regions with minimal seasonal temperature variation, emissions tend to remain constant, provided airflow patterns are maintained (Gustafsson, 1999). Particulate matter (PM) emissions are strongly influenced by temperature, relative humidity (RH), and airflow. A positive correlation exists between PM and RH, but not between PM and temperature (Puma & Maghirang, 2000; Bunney et al., 2017). High RH accelerates microorganism reproduction and organic matter decomposition, exacerbating airborne pollutant concentrations (Nannen & Büscher, 2006).

Mitigation Strategies

Reddy et al. (2007) opined that to ensure the safety of the birds and the poultry workers, the poultry farm requires frequent monitoring of its air quality. Mechanical ventilation systems, such as fans and air scrubbers, are commonly employed to maintain optimal air exchange rates and filter out airborne pollutants. National Research Council (2024) posited that effective ventilation systems, regular manure removal, and proper waste management practices are crucial in mitigating the risks associated with hydrogen sulfide emissions in poultry farms. Optimized ventilation systems can significantly reduce respiratory diseases by maintaining indoor air quality (IAQ) year-round (Elfman et al., 2011). Natural ventilation, achieved through openings in walls and roofs, is a cost-effective method for maintaining IAQ. But Puma and Maghirang (2000) noted that Natural ventilation is subject to outdoor wind speed and building topography, which complicates the estimation of pollutant emission rates. Kaimujjaman et al. (2023) opined that adopting an automated system for continuous monitoring of temperature and relative humidity in poultry farms would be a promising solution for reducing heat stress of the poultry. A number of studies have shown the need for maintaining even distribution of temperature throughout the poultry to minimize heat stress and increase productivity. Effective temperature regulation not only enhances poultry welfare but also minimizes environmental emissions such as ammonia and odor, contributing to sustainable poultry production (Ogink & Groot Koerkamp, 2001).

Materials and Method

Study Area

The study area is Yenagoa Local Government Area of Bayelsa State. It is located on latitude 4^o. 55' 29"N 6^o. 15' 5" E and has an elevation of 8 meters above sea level. Yenagoa has a total area of 1,698km^2, and it is mostly a swamp covered with a large number of mangroves plants. It has a tropical climate. The last census exercise of 2016 put the Yenagoa population figure at 352, 285 and a projected population figure of 524,400 in 2022.

Materials

Digital multi gas monitor (DMGM), digital particular matter monitor (DPMM), digital thermometer (DT), digital hygrometer (DH), Measuring tape (MT) and stop clock (SC) were materials employed in the study to obtain the required data.

Method

In this study, three (3) poultry farms namely Azikoro, Opolo, and Tombia in Yenegoa Local Government Area were selected for the study. In each of these poultry farms, multi-gas monitor, particular matter monitor, digital thermometer, digital hygrometer, were positioned 1.5m above the ground to determine ammonia (NH_3), carbon dioxide (CO_2), particulate matter (PM), and oxygen (O_2) concentration levels as well as the indoor temperature and relative humidity (RH) of the poultry farms. The Multi Gas Monitor was used to detect and measure the concentration of ammonia, carbon dioxide, particulate matter, and oxygen. Digital thermometer was used to monitor the ambient temperature of the poultry house while digital hygrometer was used to determine the relative humidity levels in the selected poultry farms. The taking of sampling timing intervals were made possible with help of a stop clock. The assessment was done on a weekly basis for a period of one (1) month.

Results and Discussion

Figures 1, 2, and 3 are bar charts showing the concentration levels of ammonia, carbon dioxide, particulate matter and oxygen levels in the selected poultry farms under study.

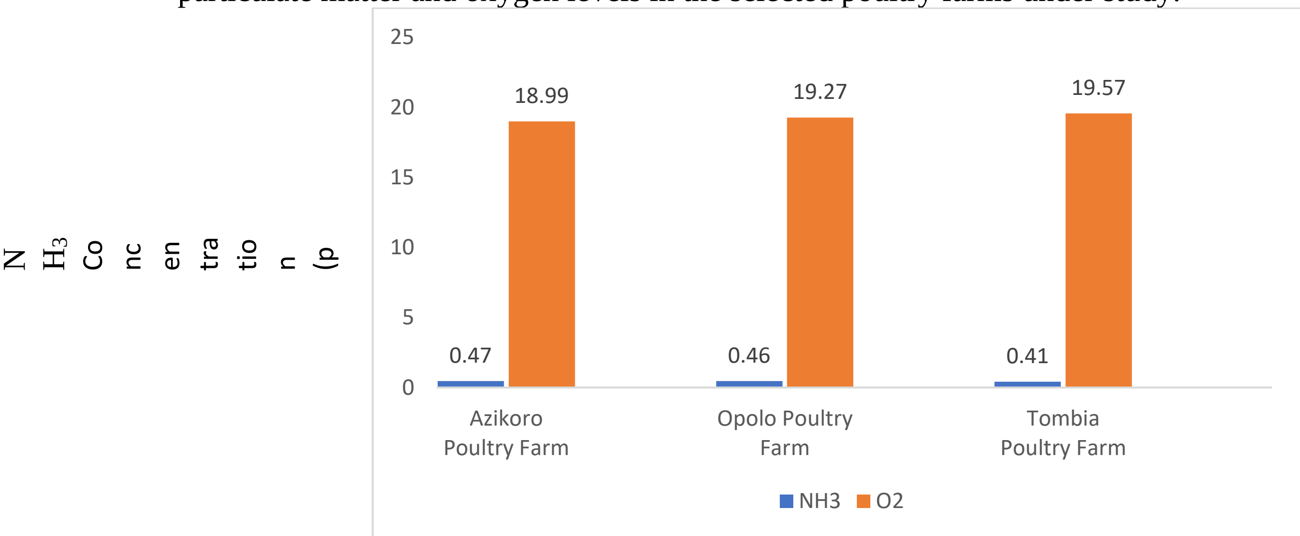

Figure 1: Concentration levels of ammonia (NH_3) and oxygen (O_2) in the selected poultry farms

Figure 1 shows variation in ammonia (NH_3) concentration levels and relatively stable oxygen levels in the three poultry farms. Azikoro poultry farm has the highest ammonia level of 0.47 ppm, which is only marginally higher than Opolo poultry farm with concentration level of 0.46 ppm while Tombia poultry farm has the lowest ammonia concentration of 0.41 ppm. Ammonia (NH_3) concentration levels within safe limit and a stable oxygen (O_2) level are necessary for optimal bird health and productivity. Ammonia is a harmful byproduct of poultry waste. High levels of ammonia can irritate the respiratory system and compromise immune function, leading to increased susceptibility to diseases and reduced growth rates of birds. When ammonia levels are kept low, birds can breathe easier, reducing stress and promoting better overall health, which translates into improved feed conversion rates and weight gain.

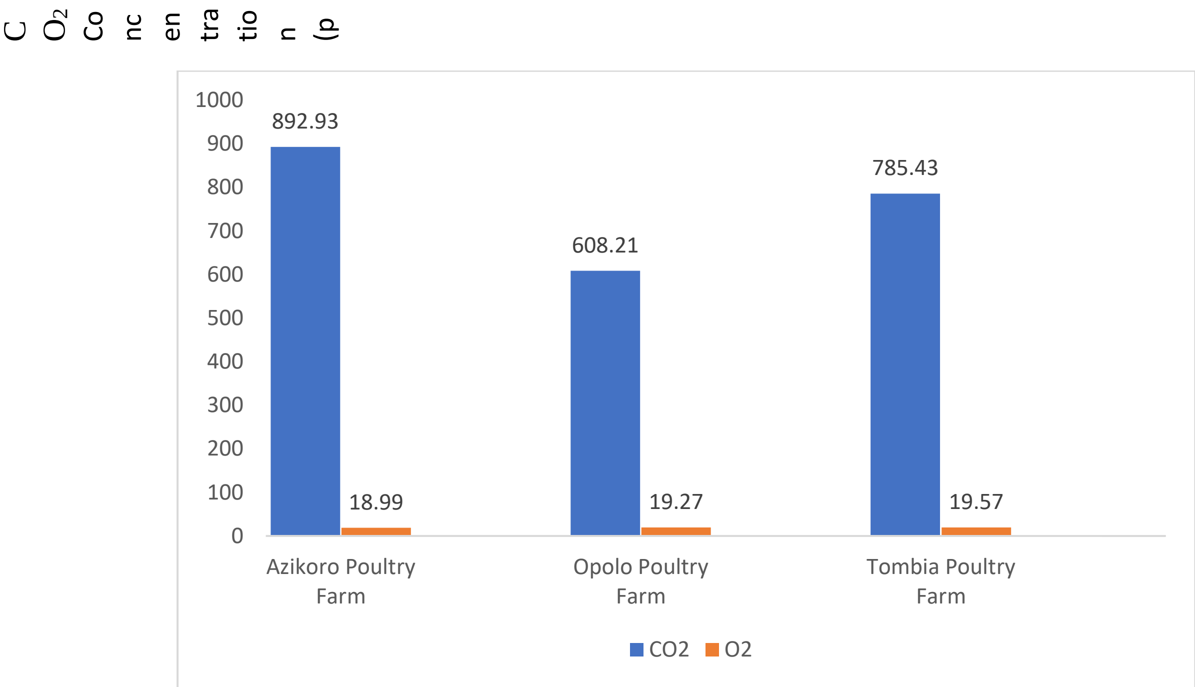

Figure 2: Concentration levels of carbon dioxide (CO_2) and Oxygen (O_2) in the selected poultry farms

In figure 2, CO_2 shows a significant variation in their concentration levels, while oxygen level remains relatively stable. Azikoro poultry farm has the highest CO_2 concentration level of 892.93 ppm, followed by Tombia poultry farm with concentration level of 785.43 ppm, while Opolo poultry farm has a concentration level of 608.21 ppm. The three poultry farms have a fairly stable oxygen level. The variation in carbon dioxide (CO_2) concentration level could be linked to differences in ventilation or stocking density in the poultry farms. Elevated carbon dioxide (CO_2) concentrations in poultry farms can significantly impact the health, growth, and overall productivity of birds.

Chronic exposure to high CO_2 concentrations can compromise the immune system, making birds more susceptible to diseases and infections (Source). The physiological response of poultry to elevated CO_2 levels includes an increase in respiratory rate as the birds attempt to compensate for the reduced oxygen availability (Source). This can lead to a condition known as hyperventilation, where birds breathe faster to expel excess CO_2, resulting in increased stress and energy expenditure (Source). This stress not only affects the health of individual birds but can also impact flock dynamics, leading to aggressive behaviors and reduced social cohesion (Source). Elevated CO_2 levels can alter the gut microbiota in poultry, negatively affecting nutrient absorption and overall gut health (Source). In extreme cases, prolonged exposure to high CO_2 can result in increased mortality rates within flocks (Source).

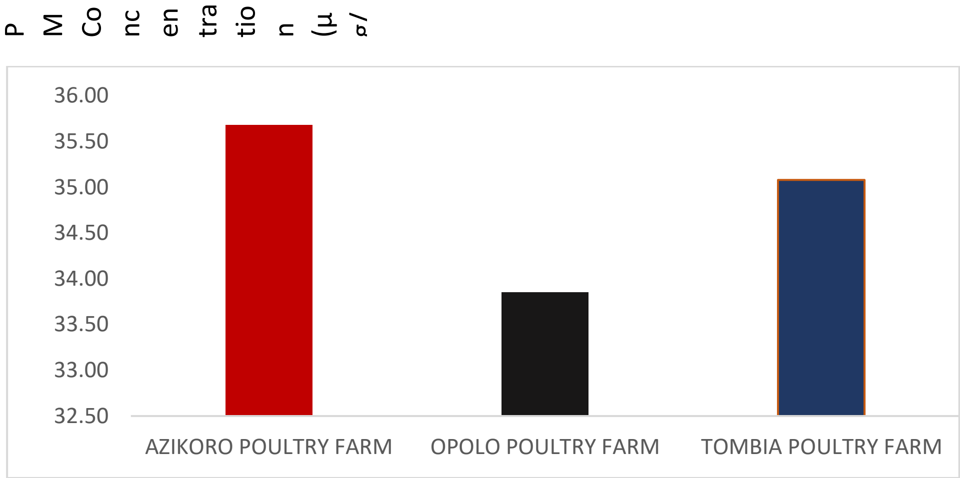

Figure 3: Concentration levels of particulate matter (PM) in the selected poultry farms

Figure 3 is a bar chart comparing particulate matter (PM) concentration levels in the selected poultry farms—Azikoro, Opolo, and Tombia. In figure 3, Azikoro poultry farm has the highest PM concentration value of 35.5 µg/m^3, indicating the poorest air quality among the three poultry farms. Tombia poultry farm follows with a PM concentration value of 34.5 µg/m^3, suggesting a slightly better but still concerning air quality. In contrast, Opolo poultry farm has the lowest PM concentration level of 33.5 µg/m^3, though it still requires monitoring to maintain optimal conditions. The variation in PM levels may be linked to factors such as ventilation efficiency, waste management practices, and stocking density in each farm. Elevated PM levels can negatively impact poultry health, leading to respiratory issues, and can also affect the well-being of farm workers. Therefore, farms with higher PM concentrations may benefit from improved air filtration and stricter cleanliness protocols.

Figures 4, 5, 6, 7, 8, and 9 show correlations between indoor atmospheric parameters (temperature and relative humidity) and concentration levels of NH_3, CO_2, and PM respectively.

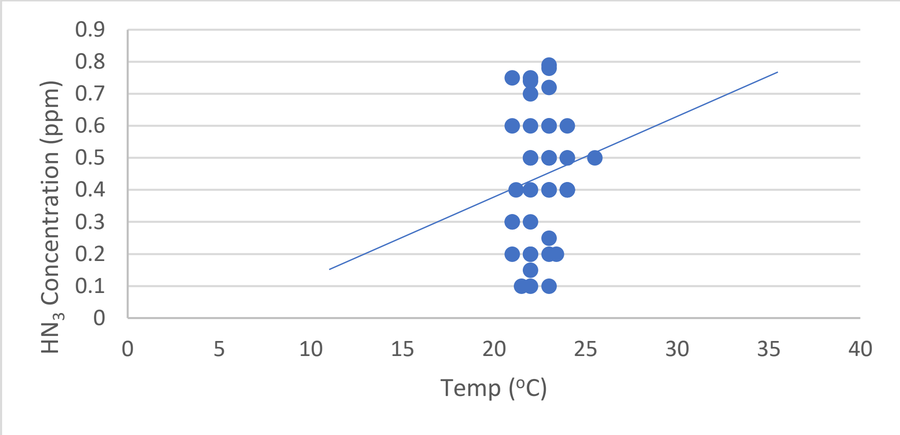

Figure 4: Correlation plot between ammonia (NH_3) concentration levels and temperature (T)

The scatter plot shows a positive correlation between temperature (°C) and ammonia (NH_3) concentration (PPM) in the poultry farms. As the temperature increases, there is a noticeable rise in ammonia levels, as indicated by the upward trend of the data points and the positive slope of the trend line. The data points are concentrated between 15°C and 25°C, with ammonia levels ranging from approximately 0.2ppm to 0.7 ppm. This relationship suggests that higher temperatures may contribute to an increase in ammonia production or accumulation within the poultry environment, which could have implications for air quality and animal welfare. Higher levels of ammonia within poultry environments can cause a range of health issues, including respiratory irritation and increased susceptibility to infections in birds. It also poses risks to farm workers, who are exposed to the same environment.

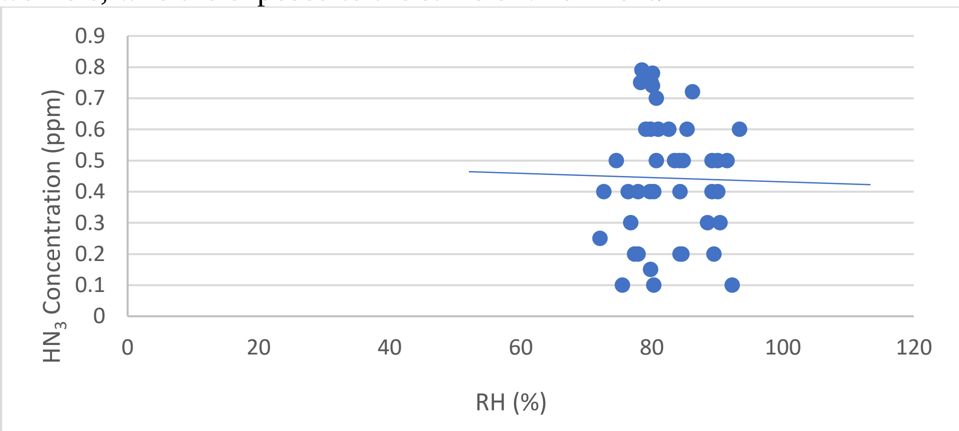

Figure 5: Correlation plot between ammonia (NH_3) concentration levels and relative humidity (RH)

The scatter plot shows a weak negative correlation between relative humidity RH (%) and ammonia (NH_3) concentration levels in the poultry farms. As relative humidity increases, ammonia levels appear to decrease marginally, as indicated by the downward trend in the line of best fit. Most data points are clustered between 70% and 90% relative humidity, with ammonia concentrations ranging from approximately 0.1 ppm to 0.8 ppm. However, the trend is not strong, suggesting that relative humidity has a weak influence on ammonia levels in this case. While relative humidity might play a role in reducing the volatility of ammonia to some extent, it is unlikely to be the primary factor in managing ammonia concentrations in the poultry farms under study. Therefore, relying solely on humidity control to mitigate ammonia emissions would be insufficient. The weak negative correlation between relative humidity and ammonia could be attributed to the fact that ammonia volatilization is primarily temperature-dependent. Although high humidity may reduce dust and particulate matter in the air, which can also carry ammonia, it does not directly impact the chemical processes that lead to ammonia release from manure. In managing indoor air quality in poultry farms, the primary focus should likely be on maintaining optimal temperature levels and ensuring adequate ventilation. Humidity management may still play a supplementary role, particularly in ensuring comfort for the birds and reducing dust levels, but its impact on ammonia concentrations seems limited in comparison to temperature. Proper ventilation, alongside effective temperature and humidity control, is essential to limit the buildup of harmful gases like CO_2 and NH_3, thereby promoting better health outcomes for both poultry and farm workers.

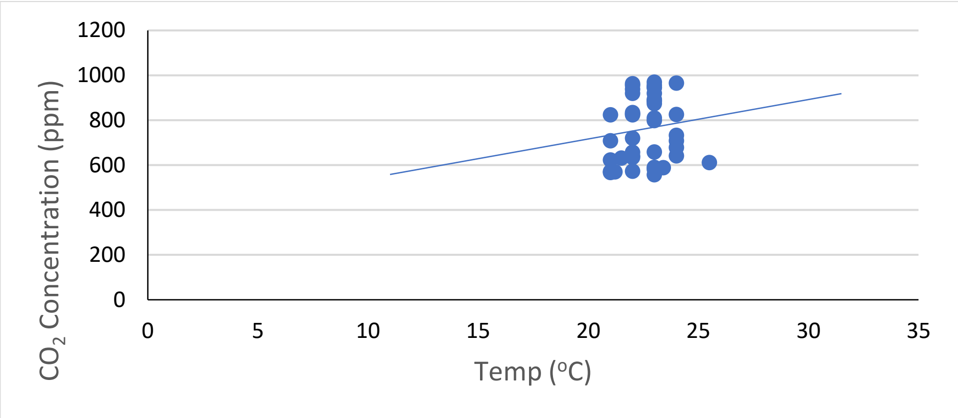

Figure 6: Correlation plot between carbon dioxide (CO_2) concentration levels and temperature (T)

The scatter plot provided shows a positive correlation between temperature (°C) and carbon dioxide (CO2) concentration levels in the poultry farms. As temperature increases, the CO_2 concentration tends to rise as well, indicating a potential link between warmer temperatures and higher CO_2 concentration levels in the environment. The data points are clustered mostly between 18°C and 25°C, with CO_2 levels ranging from approximately 600 ppm to over 900 ppm. The upward trend line further supports the positive relationship between these two variables. This relationship may be attributed to several factors, including the metabolic processes of the poultry themselves, which generate CO_2 as a byproduct of respiration. Higher temperatures can also lead to increased ventilation requirements, as birds may struggle with heat stress, further influencing $CO_{2\ \text{concentration}}$ levels due to changes in airflow and barn design. Higher ambient temperatures may impact litter decomposition rates, potentially releasing more CO_2 into the environment.

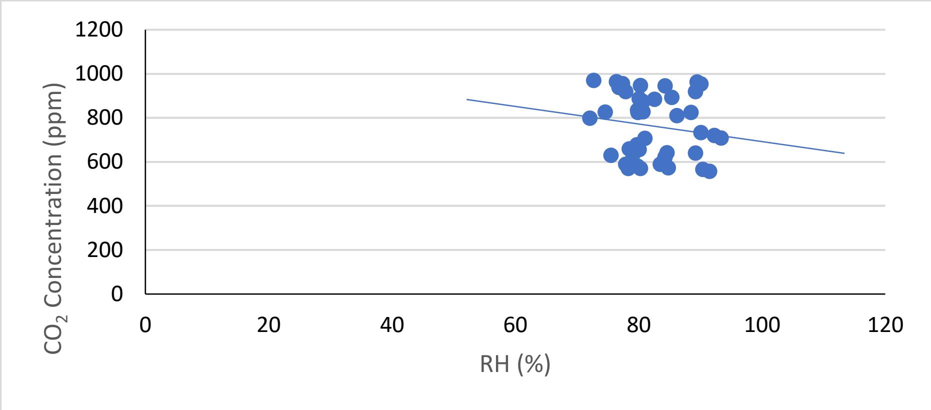

Figure 7: Correlation plot between carbon dioxide (CO_2) concentration levels and relative humidity (RH)

Figure 7 is a scatter plot showing a positive correlation between temperature (°C) and carbon dioxide (CO_2) concentration levels (ppm) in the selected poultry farms. The plot shows that as temperature increases, the CO_2 concentration tends to rise as well, indicating a potential link between warmer temperatures and higher CO_2 concentration levels in the environment. The data points are clustered mostly between 18°C and 25°C, with CO_2 levels ranging from approximately 600 ppm to over 900 ppm. The upward trend line further supports the positive relationship between these two variables. This relationship may be attributed to several factors, including the metabolic processes of the poultry themselves, which generate CO_2 as a byproduct of respiration. Higher temperatures can also lead to increased ventilation requirements, birds may struggle with heat stress, further influencing CO2 levels due to changes in airflow and barn design. Higher ambient temperatures may impact litter decomposition rates, potentially releasing more CO_2 into the environment.

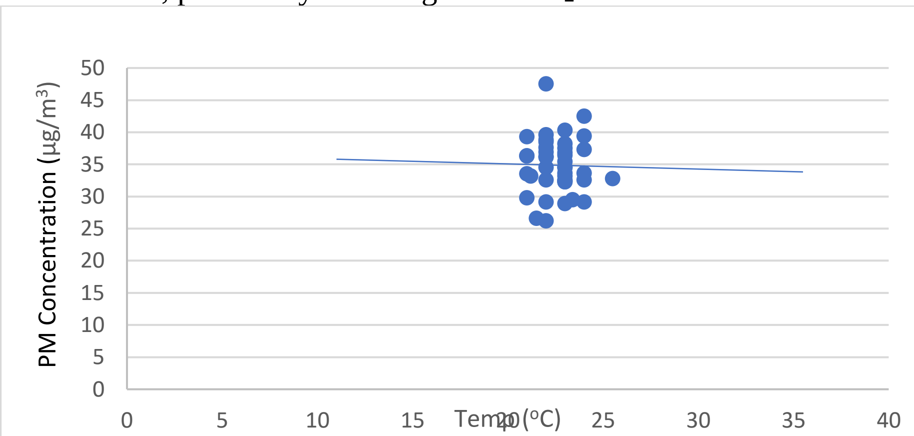

Figure 8: Correlation plot between particulate matter (PM) concentration levels and temperature (T)

The scatter plot reveals a weak negative correlation between temperature and particulate matter (PM) concentration. As the temperature slightly increases, the PM concentration tends to decrease, although the relationship is not strong, as indicated by the flat slope of the trend line. The majority of data points are clustered between 20°C and 25°C, with PM concentrations ranging from 30 to 40 µg/m^3.The weak correlation can be attributed to several factors, such as higher temperatures potentially increasing wind speed and air dispersion, which might help reduce PM concentrations. Thermal effects on air quality, such as the vertical mixing of air layers, could dilute PM levels.

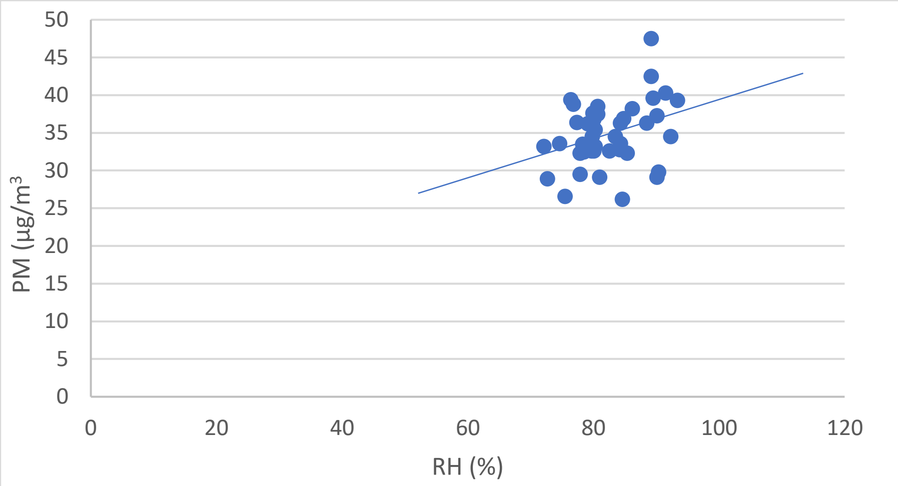

Figure 9: Correlation plot between particulate matter (PM) concentration levels and relative humidity (T)

Figure 9 is a scatter plot showing a weak positive correlation between relative humidity and particulate matter (PM) concentration (in PPM). As relative humidity increases, the PM concentration tends to rise, as indicated by the upward slope of the trend line. Most data points are clustered between 60% and 100% RH, with PM concentrations ranging from 30 to 45 µg/m^3, though there is some variability at higher humidity levels. This positive correlation suggests that higher humidity may contribute to elevated PM levels, possibly due to the binding of particulate matter with water molecules or the condensation of moisture trapping PM in the air. In environments where air quality is a concern, managing both humidity and particulate matter becomes important, as increased humidity could exacerbate PM pollution levels.

Implication of Results

Ammonia: Ammonia concentration levels in all the selected poultry farms for the period under study were far below the "Occupational Safety and Health Administration (OSHA) airborne permissible exposure limit (PEL) of 50 ppm averaged over a 8-hour work shift, National Institute of Occupational Safety and Health(NIOSH) airborne recommended exposure limit (REL) of 25 ppm averaged over a 10 hour work shift, and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) of 25 ppm averaged an 8-hour work shift" (New Jersey Department of Health(NJDH), 2007). This means that ammonia gas would not pose any serious health problems to both the birds and the poultry workers if the measured levels in the selected poultry farms are maintained.

Carbon dioxide: The concentration levels of CO_2 in the selected poultry farms for the period under study were below recommended exposure limit (REL) of 5000 ppm averaged over a 10-hour work shift, permissible exposure limit of 5000 ppm averaged over an 8-hour work day established by NIOSH and OSHA, respectively. They were also within the indoor acceptable levels of 400 – 1100 ppm recommended by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHARAE) for indoor environment (CO_2 Meter, 2024 August 9).

Particulate matter: The concentration levels of PM in the selected poultry farms for the period under study were above the WHO annual average allowable limit of 5 µg/m^3 and 24-hour average allowable limit of 15 µg/m^3 new guidelines of 2021 for $PM_{2.5}$. They were also above the WHO allowable annual average of 15 µg/m^3 but less than the stipulated allowable 24-hour average of 45 µg/m^3 for PM_{10}. This requires adequate monitoring of PM levels to prevent any potential health problems in the birds and poultry workers.

Conclusion

Understanding the current state of indoor air quality in poultry farms is essential for developing strategies to mitigate the risks associated with poor air quality. Good air quality (AQ) in poultry farms is crucial for maintaining the health and productivity of poultry, as well as the safety and well-being of poultry workers.

References

Abbas, T., Yousuf, M., Mohamedahmed, E., & Hassabo, A. (2011). Effect of fluctuating ambient temperature on the performance of laying hens in the closed poultry house. *Research Opinions in Animal and Veterinary Sciences*, *1*, 245-257.

Adams, R., Idemudia, B. I., Imarhiagbe, E. E., Ikhajiagbe, B., Ukpebor, E., & Ekhaise, F. O. (2022). Comparative assessment of indoor and outdoor air environment of poultry farms in Edo State, Nigeria. *Studia Universitatis Babeș-Bolyai Biologia*, 107-130.

Bist, R. B., Chai, L. (2022). Advanced strategies for mitigating particulate matter generations in poultry houses. *Applied Sciences 12*(22), 11323.

Bist, B. R., Subedi, S., Chai, L., & Yang, X. (2023). Ammonia emissions, impacts, and mitigation strategies for poultry production: A critical review. *Journal of Environmental Management*, *328*, 2023, 116919. https://doi.org/10.1016/j.jenvman.

Bhomick, P., & Somasekhara, K. (2014). Sources and effects of hydrogen sulfide. *Journal of Applicable Chemistry*. *3*. 914-918.

Bunney, P. E., Zink, A. N., Holm, A. A., Billington, C. J., & Kotz, C. M. (2017). Orexin activation counteracts decreases in non exercise activity thermogenesis (NEAT) caused by high-fat diets. *Physiology & Behavior*, *176*, 139-148.

Cambra, L, M. (2010). *Control of particulate matter emissions from poultry and pig houses* (Doctoral dissertation) Universitat Politècnica de València Cole, D., Todd, L., & Wing, S. (2000). Concentrated swine feeding operation and public health: a review of' occupational community health effects. Environ. *Health Perspect. 108*(8): 685-699.

CO_2 Meter. (2024, August 9). Carbon dioxide levels chart, Gas Measurement Experts. www.co$_2$meter.com

Cole, D., Todd, L., & Wing, S. (2000). Concentrated swine feeding operation and public health: a review of' occupational community health effects. Environ. *Health Perspect. 108*(8), 685-699

Dasarathy, S., Mookerjee., P. R., Rackayova, V., Rangroo Thrane., V., Vairappan, B., P Ott, P., CF Rose, F. C. (2016). Ammonia toxicity: from head to toe*? PMC PubMed*, *32* (2):529–538. doi: 10.1007/s11011-016-9938-3

Department of Animal and Food Sciences (n.d). Chapter 7 - Air Quality. Martin-Gatton College of Agriculture, Food and Environment. https://afs.ca.uky.edu/poultry/chapter-7-air-quality

Elfman, L., Wålinder, R., Riihimäki, M., & Pringle, J. (2011). Air quality in horse stables. *Journal of Environmental Science & Health Part A*, *46*(6), 606-612.

European Environmental Agency (2023). Briefing methane emissions in the EU: the key to immediate action on climate change. Retrieved from https://www.eea.europa.eu /publications/methane-emissions-in-the-eu.

Gustafsson, G. (1999). Factors affecting the release and concentration of dust in pig houses. *Journal of Agricultural Engineering Research*, *74*(4), 379-390.

Heitzmann, B. (2015). Challenges, considerations, and concerns of indoor air quality. *Pennsylvania Housing Research Center*, 1 – 4. https://www.phrc.psu.edu/assets/docs/Publications/ PHRC%20IAQ%20BB%20FINAL.pdf

Kaimujjaman, M.D., Hossain, M.D., & Khatun, Mst. (2023). A smart automation system for controlling environmental parameters of poultry farms to increase poultry production. 10.1007/978-981-99-1916-1_6.

Kalva, O. (2023). The role of microclimate in the formation of indoor air pollution. *Thermal Science*, *27*, 105-105. 10.2298/TSCI220215105K.

Killebrew, K., Gugerty, M. K., & Plotnick, R. (2010). Poultry market in West Africa: *J. Agric. Stud. 4* (2), 7-13.

Krol, A. (2023, December 7). *What makes methane a more potent greenhouse gas than carbon dioxide? Climate Portal.* https://climate.mit.edu/ask-mit/what-makes-methane-more-potent-greenhouse-gas-carbon-dioxide

Kusi, L.Y., Agbeblewu, S., Anim, I., & Nyarku, K.M. (2015). The challenges and prospect of the commercial poultry industry in Ghana: A synthesis of literature. *Int. J. Manag. Sci. 5*(6), 476-489.

Landry, J. (2024, August 9). *Indoor air quality and lung health: An Overview (2024)*. Retrieved December 22nd, 2024 from https://www.respiratorytherapyzone.com/author/john-landry/

Mar, A. K., Unger, C., Walderdorff, L., & Buttler, T. (2022). Beyond CO2 equivalence: The impacts of methane on climate, ecosystems, and health. *Environmental Science & Policy*, *134*, 2022, 127-136. https://doi.org/10.1016/j.envsci.2022.03.027

Mashaly, M. M., Hendricks, G. L., Kalama, M. A., Gehad, A. E., Abbas, A. O., & Patterson, P. H. (2004). Effect of heat stress on production parameters and immune responses of commercial laying hens. *Poultry Science*, *83*(6), 889-894. https://doi.org/10.1093/ps/83.6.889

Nannen, C., & Büscher, W. (2006). Einfluss der Tieraktivität auf Staubfreisetzung und Partikelemissionen-Untersuchungen in Mastschweine-Ställen. *Landtechnik*, *61*(1), 36-37.

Nandan, A., Siddiqui, N. A., Singh, C., & Aeri, A. (2021). Occupational and environmental impacts of indoor air pollutants for different occupancy: A review. *Toxicology and Environmental Health Sciences*, *13*(4), 303-322.

National Research Council. (2024). Air emission from animal feeding operations: Current knowledge, future needs. Washington, DC. The National Academic Press. Https://doi.org/10.17226/10586

New Jersey Department of Health. (2007). *Ammonia*. Hazardous Substances Fact Sheet. https://nj.gov

Ngwabie, N. M., Jeppsson, K. H., Gustafsson, G., & Nimmermark, S. (2011). Effects of animal activity and air temperature on methane and ammonia emissions from a naturally ventilated building for dairy cows. *Atmospheric Environment*, *45*(37), 6760-6768.

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.

Ogink, N. W. M., & Groot Koerkamp, P. W. G. (2001). Comparison of odour emissions from animal housing systems with low ammonia emission. *Water Science and Technology, 44*(9), 245-252.

Oyetunde, O., Thomson, R., & Carlson, H. C. (2018). Effects of ammonia on the health and production of poultry. *Avian Diseases*, 62(3), 345–352.https://doi.org/10.1637 /avdi.012018

Puma, M. C., & Maghirang, R. G. (2000). A macroscopic model for predicting dust concentration distribution in swine buildings. *Indoor and Built Environment,9*(3-4), 182-191.

Reddy, R. A., Praveen, P., Prasadini., P., & Anuradha (2007). Assessment of air quality in a poultry house. *Journal of Industrial Pollution Control, 23* (2), 369-372.

Sharma, A. K., Sharma, M., Sharma, A. K., & Sharma, M. (2023). Mapping the impact of environmental pollutants on human health and environment: A systematic review and meta-analysis. *Journal of Geochemical Exploration*, 107325.

Sheikh, U.I., Nissa, S.S., Zaffer, B., Bulbul, H. K., Akand, H.A., Ahmed, A.H., Hasin, D., Hussain., I., & Hussain, A.S. (2018). Ammonia production in the poultry houses and its harmful effects. *International Journal of Veterinary Sciences and Animal Husbandry, 3*(4), 30-33

Smith, K.R., Kims, S., Recendez, J.J., Teague, S.V., Menache, M.G., Grubbs, D.E., Sioutas, C., & Pinkerton, K.E. (2003). Airborne particles of the California central valley alter the lungs of healthy adult rats. Environ. *Health Perspective, 111*(7), 902 – 908.

Swelum, A.A., El-Saadony, T.M., Abd El-Hack, E.M., Ghanima, A.M.M., Shukry, M., Alhotan, A.R., Hussein, S.O.E., Suliman, M.G., Ba-Awadh, H., Ammari, A.A., Taha, E.A., El-Tarabily, A.K.(2021). Ammonia emissions in poultry houses and microbial nitrification as a promising reduction strategy. *Science of The Total Environment,781*(2021), 146978, https://doi.org/10.1016/j.scitotenv.2021.146978

Wafi, S. R.S., Ismail, M.R., & Ahmed, E.M. (2011). A case study of the climate factor on thermal comfort for hostel occupants in Universiti Sains, Malaysia (USM), Penang, Malaysia. *J. Sustain. Dev. 4*(5), 50 - 60.

Wolkoff, P., Azuma, K., & Carrer, P. (2021). Health, work performance, and risk of infection in office-like environments: The role of indoor temperature, air humidity, and ventilation. *International Journal of Hygiene and Environmental Health. 233*. 113709. 10.1016/j.ijheh .2021.113709

World Health Organization. (2005). *Air quality guidelines: Global update 2005*. Copenhagen

Wang,X., Zhu, H.,Yan, B., Chen, L., Shutes, B., Wang, M., Lyu, J., Zhang, F.(2023). Ammonia volatilization, greenhouse gas emissions and microbiological mechanisms following the application of nitrogen fertilizers in a saline-alkali paddy ecosystem, *Geoderma*, *433*(2023),116460. https://doi.org/10.1016/j.geoderma.2023.116460.

Xu, X., Zhou, W., Xie, C., Zhu, Y., Tang, W., Zhou, X., & Xiao, H. (2022). Airborne bacterial communities in the poultry farm and their relevance with environmental factors and antibiotic resistance genes. *Sci Total Environ. 2022 Nov 10, 846*, 157420. doi: 10.1016/j.scitotenv.2022.157420.

Zhao, Y., Shepherd, T. A., Li, H., & Xin, H. (2015). Environmental assessment of three egg production systems–Part I: Monitoring system and indoor air quality. *Poultry Science, 94*(3), 518-533. https://doi.org/10.3382/ps/peu076