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Research Article

An Evaluation of the Air Quality in the Vicinity of the Amosun Abattoir in Ibadan, Oyo State, Nigeria

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Abstract

This study investigates the ambient concentrations of selected air pollutants at the Amosun International Abattoir in Akinyele Local Government Area, Ibadan, Oyo State, comparing them with control values to assess their implications for human health and the environment. Parameters measured include temperature, relative humidity, formaldehyde, particulate matter, Total Volatile Organic Compounds (TVOCs), Carbon Dioxide (CO_2), Carbon Monoxide (CO), and the Air Quality Index (AQI). Results indicate that the abattoir had slightly higher temperatures (28.4°C vs. 27.25°C) and particulate matter levels (9.07 μg/m^3 vs. 8.47 μg/m^3) compared to control values. In contrast, CO_2 levels were notably lower (526.83 ppm vs. 622.12 ppm), suggesting effective ventilation. Formaldehyde levels were significantly elevated in the abattoir (0.1138 ppm vs. 0.0331 ppm), posing potential health risks, while TVOC levels were slightly reduced (0.4529 ppm vs. 0.4975 ppm) but more stable than control values. Variability in humidity was greater in the abattoir, affecting pollutant persistence and dispersion. The findings align with previous studies on the air quality impacts of industrial settings, underscoring the need for enhanced pollutant control measures, including improved ventilation and continuous air quality monitoring. The study concludes that effective management can mitigate potential adverse impacts, ensuring the protection of human health and environmental quality.

Keywords: Air pollutants, Abattoir, Formaldehyde, Particulate matter, Air Quality Index, Environmental health

Introduction

Background of the Study

Air pollution poses a significant threat to public health and environmental sustainability, particularly in urban areas with high industrial activity [1-2] The vicinity of Abattoir in Ibadan, Nigeria, exemplifies the challenges associated with industrial emissions and their impact on local air quality [1]. The World Health Organization (WHO) estimates that air pollution is responsible for 4.2 million deaths annually, with the majority occurring in low and middle-income countries1. In Nigeria, air pollution has been identified as a major public health challenge, with several studies reporting high levels of ambient and indoor air pollutants [2,3]. The situation is particularly concerning in urban areas, where rapid industrialization and urbanization have led to an increase in the emission of pollutants into the atmosphere [4].

Ibadan, a rapidly urbanizing city in southwestern Nigeria, has witnessed exponential growth in industrialization and urban development over the past few decades. The emergence of Abattoir as a key center for meat processing and distribution reflects the city's evolving economic landscape1. The operation of Abattoir and other industrial facilities in Ibadan contributes to the release of various pollutants into the atmosphere, including particulate matter, Volatile Organic Compounds (VOCs), and ammonia. These emissions pose significant environmental challenges, such as air quality degradation and ecosystem disruption [3]. Furthermore, exposure to air pollution from Abattoir and other industrial sources can have detrimental effects on public health, including respiratory illnesses, cardiovascular diseases, and adverse birth outcomes. Vulnerable populations, such as children and the elderly, are particularly at risk of experiencing the health impacts of poor air quality [4].

Despite the recognized importance of addressing air quality issues, regulatory frameworks governing industrial emissions in Nigeria are often inadequate or poorly enforced. The lack of stringent regulations and monitoring mechanisms exacerbates the challenges of managing air pollution in cities like Ibadan [5].

Particulate Matter (PM) is a major component of air pollution and consists of tiny particles suspended in the air4. These particles can vary in size and composition, with PM10 referring to particles with a diameter of 10 micrometers or less and PM2.5 referring to particles with a diameter of 2.5 micrometers or less. Exposure to particulate matter has been linked to respiratory and cardiovascular diseases, as well as increased mortality rates [5]. Abattoir operations, particularly those involving the transportation of animals and the burning of fossil fuels in generators and vehicles, can lead to the release of carbon dioxide (CO_2). CO_2 is a toxic gas primarily produced by the combustion of fossil fuels in vehicles, power plants, and industrial processes. Exposure to CO_2 can cause respiratory problems, especially in individuals with pre-existing respiratory conditions like asthma [6].

Another significant pollutant emitted by abattoir operations is carbon dioxide (CO_2). CO_2 is released during the burning of fossil fuels, especially high-sulfur coal and oil, and from industrial processes such as smelting and refining operations. Inhalation of CO_2 can lead to respiratory issues, including bronchoconstriction and aggravation of asthma symptoms.

Ozone (O_3), a gas found in both the upper atmosphere (stratosphere) and near the ground (troposphere), plays a crucial role in the Earth's atmosphere. Abattoir operations can indirectly contribute to the formation of ground-level ozone (O_3) through the emission of carbon oxides (CO_2) and Volatile Organic Compounds (VOCs). Ground-level ozone is formed when CO_2 and VOCs react in the presence of sunlight. Exposure to ground-level ozone can cause respiratory problems, including chest pain, coughing, and throat irritation5.

Lead (Pb) is a heavy metal that can cause neurological and developmental problems in children. It comes from sources such as leaded gasoline and industrial emissions. While not directly emitted by abattoir operations, lead (Pb) and Volatile Organic Compounds (VOCs) can be present in the surrounding environment due to transportation activities and industrial processes associated with the operation of abattoirs7. Lead exposure can cause neurological and developmental problems in children, while VOCs can have short- and long-term health effects, such as irritation of the eyes, nose, and throat, headaches, and damage to the liver, kidneys, and central nervous system [7].

Volatile Organic Compounds (VOCs) are organic chemicals that can have both short- and long-term health effects, such as eye, nose, and throat irritation, headaches, and damage to the liver, kidneys, and central nervous system. They come from sources such as paints, solvents, and cleaning products [8]. Carbon monoxide (CO_2) is a toxic gas that can cause headaches, dizziness, and nausea. The incomplete combustion of fossil fuels in vehicles and generators used in abattoir operations can release Carbon Monoxide (CO). CO is a toxic gas that can cause headaches, dizziness, and nausea upon inhalation [9]. Exposure to these air pollutants can have various health effects, including respiratory and cardiovascular problems, neurological and developmental problems, and an increased risk of cancer. It is crucial to Monitor and regulate air pollutants to safeguard human health and protect the environment [7]. This involves the collection of air quality data through monitoring stations and the establishment of air quality standards and guidelines by regulatory agencies. These standards and guidelines help to limit the concentration of pollutants in the air and minimize their adverse effects on human health and the environment [9].

However, air pollution is a significant environmental challenge that affects public health and the environment. Abattoir operations contribute to air pollution through the emission of various pollutants, including nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, lead, and volatile organic compounds [10]. These pollutants can have adverse effects on human health and the environment, highlighting the importance of implementing measures to mitigate emissions from abattoir operations and improve air quality in surrounding areas [11]. Abattoir operations, vital for meat processing and food production, bring forth significant challenges regarding air pollution and public health3. These challenges necessitate research and intervention to effectively address the issues at hand. Abattoir emissions degrade air quality in surrounding areas, releasing pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), lead and Volatile Organic Compounds (VOCs) [9]. These emissions contribute to the formation of ground-level ozone and particulate matter, exacerbating respiratory problems and posing health risks to nearby communities [12]. Furthermore, exposure to pollutants from abattoir operations can adversely affect public health, particularly among vulnerable populations such as children, the elderly, and individuals with pre-existing respiratory conditions. Long-term exposure to abattoir emissions is associated with respiratory illnesses, cardiovascular diseases, and neurological problems [13]. Moreover, abattoir emissions have adverse environmental impacts, contributing to acid rain, smog formation, and ecosystem disruption. Lead contamination from abattoir emissions can compromise soil and water quality, posing risks to aquatic life and agricultural productivity [14,15] In addition to public health concerns, regulatory challenges also hinder effective management of abattoir emissions. Weak enforcement of regulations governing abattoir emissions contributes to environmental and health risks. Inadequate regulatory frameworks fail to control pollution from abattoir operations adequately [12,16] Therefore, this study seeks to address this gap by systematically evaluating the concentrations of key air pollutants in and around Amosun Abattoir, Ibadan.

Hence, the findings of the study will be useful in promoting a healthier and safer environment for the workers, and nearby residence.

The rationale for conducting this study lies in the pressing need to comprehensively investigate the impact of abattoir operations on air quality and public health in Amosun Abattoir. As crucial components of the food processing industry, abattoirs play a significant role in urban environments. However, they also emit pollutants that can degrade air quality and pose health risks to nearby communities [2]. More so, existing research has touched upon the broader topic of industrial emissions, but there remains a notable gap in understanding the specific contributions of abattoirs to air pollution and associated health risks. This study aims to address this gap by conducting a thorough investigation into the sources and types of pollutants emitted by abattoirs, as well as their potential health and environmental impacts.

The findings of this study hold substantial potential benefits for various stakeholders, including policymakers, environmental agencies, and public health officials. By providing evidence-based insights into the magnitude and nature of abattoir emissions, the study can inform the development of targeted mitigation strategies and regulatory measures. These measures can ultimately contribute to improving air quality and protecting public health in communities affected by abattoir operations. Therefore, given the relevance of the study to environmental management, public health, and urban planning, its findings will be of direct interest to policymakers and stakeholders. By addressing these critical issues, the study aligns with broader efforts towards sustainable development and environmental stewardship, underscoring its significance and relevance in current discourse.

Aim and Objectives of the Study

The aim of this study is to evaluate air quality in the vicinity of the Amosun Abattoir in Ibadan, Oyo State, Nigeria.

Specific Objectives

i. To determine the concentration levels of key air pollutants, including carbon dioxide (CO2), carbon monoxide (CO), particulate matter (PM2.5), temperatures, formaldehyde, total volatile organic compounds (TVOC), relative humidity and air quality index (AQI) in the vicinity of Amosun Abattoir.

ii. To identify the sources and emission pathways of air pollutants associated with Amosun Abattoir operations, including slaughtering, transportation, and waste disposal activities.

iii. To compare the concentrations of air pollutants measured in the vicinity of Abattoir against National and International air quality standards and action levels.

Research Question

i. What are the concentration levels of key air pollutants, including carbon dioxide (CO2), carbon monoxide (CO), and particulate matter (PM2.5) temperatures, formaldehyde, total volatile organic compounds (TVOC), relative humidity and air quality index (AQI) in the vicinity of Amosun Abattoir , in the vicinity of Amosun Abattoir?

ii. What are the sources and emission pathways of air pollutants associated with Amosun Abattoir operations, including slaughtering, transportation, and waste disposal activities?

iii. How does the concentrations of air pollutants measured in and around the Abattoir compare against National and International air quality standards and action levels?

Materials and Methods

This section delineates the methodology utilized in evaluating air quality within the vicinity of Amosun Abattoir, located in Ibadan. The assessment aims to comprehensively analyze various air pollutants, their concentrations, and potential health implications for residents and workers in the area. The methodology encompasses a multi-faceted approach involving data collection, analysis techniques, and instrumentation to ensure a robust assessment of air quality parameters.

Study Area

The Ibadan Central Abattoir, also known as Amosun Central Abattoir, is located at Longitude 7°36’29” N and Latitude 3°54’53” E [17]. This expansive facility in Amosun Village, Akinyele Local Government Area in Ibadan, spans 15 hectares and boasts the title of the largest abattoir in West Africa. With provisions for both manual and mechanical slaughtering of cattle, pigs, goats, and sheep, it features an extensive network of roads covering about five kilometers within the abattoir. Additionally, the facility offers ample parking space that can accommodate more than 200 vehicles and 50 articulated trucks simultaneously [18].

The multibillion naira abattoir, designed in line with best practices to ensure proper animal slaughtering and handling in the most hygienic environment, has facilities that will ensure that thousands of people work for a livelihood without invading each other’s space and is the response of the Oyo State Government to mitigate the unsanitary and dangerous circumstances in which meat is produced across abattoirs in Ibadan; from Bodija to Gege, Alesinloye, Monatan and Onibu Ore Communities [19].The Amosun central abattoir has two surface and underground tanks that produce 600,000 liters of water daily; there are four extra tanks for emergency situations. It has a holding pen that can accommodate 5000 cows at a time; a lairage; a mechanized slaughter slab; two conventional slabs that can accommodate 2000 cows at once; a goat section with facility to hold 300 goats; separate space for animal burning; intestines and cow head processing; a clinic; a veterinary office; a police post and a site for cow sheathes [20]. Other facilities at the Amosun Abattoir includes 32 toilets, bathrooms and changing rooms, a canteen, big cold rooms to keep meat, incinerator, a 1000 meat stalls, shopping complex for other commodities, water storage facilities in excess of 700, 000 litres; three ready water tankers, an in-house security unit in addition to police post, administrative building, information center, solar powered external lighting, connected to power grid and generating sets that can work 24 hours at a stretch [20].

Readings

Identification of Readings Locations: Areas or zones within Abattoir was selected as sampling locations. These areas was the representative of the various activities and potential sources of air pollution within the Abattoir, such as Slaughterhouse Operations, Meat Processing Activities, Waste Management, Energy Consumption, Transportation, Dust and Odor, Chemical Usage.

Determination of Readings Size: The appropriate number of sampling points was determined to ensure the study's representativeness and statistical validity. The sample size was taken into account the size of the Abattoir, the variability of activities, and other factors that may influence air quality. Practical constraints and available resources was also considered in determining the final sample size.

Randomization or Stratification: The sampling points was selected using either a randomization or stratification approach. Random selection involves assigning each potential sampling point a number and using a random number generator to determine the sampling points. Alternatively, stratification involves dividing the Abattoir into distinct zones or categories based on specific criteria, such as land use or potential pollution sources, and selecting sampling points within each zone. The chosen approach depended on the objectives of the study and the available information about the areas within the Abattoir.

Selection of Air Quality Parameters: Specific air quality parameters was selected for assessment. These parameters include indoor and outdoor relative humidity, temperature, particulate matter (PM2.5) and Carbon dioxide (CO_2) and Carbon monoxide (CO). The selection of these parameters was based on their relevance to air quality assessment and their association with potential sources of pollution within Abattoir.

Readings Frequency and Duration: Readings was conducted at different times (Morning and Afternoon) to capture variations in air quality. The frequency and duration of sampling were determined based on factors such as diurnal variation in air quality and the objectives of the study. Adequate sampling periods was established to obtain representative measurements at each sampling point.

Data Collection: Field measurements was carried out at the selected readings locations according to the established sampling plan. Standard procedures for data collection was followed, ensuring consistency and accuracy. Relevant information, including readings dates, times, weather conditions, and locations, were recorded for each data collected.

Quality Control: To ensure the reliability and accuracy of the collected data, quality control measures was implemented. These measures includes calibrating sampling equipment, using blank samples as controls, and following appropriate quality assurance/ quality control protocols. These steps help maintain the integrity of the collected data and minimize any potential biases or errors.

Selected Air Quality Parameters

Relative Humidity (Outdoor): Relative humidity is a measure of the moisture content in the air. Indoor relative humidity reflects the moisture levels within buildings, while outdoor relative humidity indicates the atmospheric moisture levels.

Temperature (Outdoor): Temperature refers to the degree of hotness or coldness in the air. Indoor temperature represents the thermal conditions within buildings, while outdoor temperature reflects the ambient temperature in the surroundings.

Particulate Matter (PM2.5): Particulate Matter (PM) refers to solid or liquid particles suspended in the air. PM2.5 represents particles with a diameter of 2.5 micrometers or smaller, while PM10 represents particles with a diameter of 10 micrometers or smaller. These parameters are crucial for assessing air pollution and its health impacts.

Carbon Monoxide (CO): Carbon Monoxide is a colorless and odorless gas produced by incomplete combustion of fuels. It is primarily emitted from vehicle exhaust and can have adverse effects on human health.

Carbon Dioxide (CO_2): Carbon dioxide (CO_2) is a colorless and odorless gas that is a natural component of Earth's atmosphere. It is released into the atmosphere through various natural processes, including respiration by animals and plants, volcanic activity, and the decay of organic matter. CO_2 is also a byproduct of human activities, especially the burning of fossil fuels like coal, oil, and natural gas.

Equipment Used

Air quality detector (Henan Bosean) was used in measuring CO_2, CO, temperature, relative humidity, and particulate matter.

Readings Frequency and Duration

In determining the readings frequency and duration for air readings at each location; diurnal variations were used to capture the selected parameters for the study.

Diurnal Variations

Diurnal variations refer to the daily patterns of air quality parameters that occur throughout a 24-hour period. To capture these variations adequately, readings should be conducted multiple times during a day. Consider the following: For parameters affected by diurnal variations, such as temperature and relative humidity, readings were collected at least two times a day: morning and afternoon. For parameters influenced by human activities or emissions, such as CO_2 and CO, readings include both peak and off-peak periods. This involve conducting readings during rush hours, business hours, or times when specific activities (e.g., construction, industrial processes) are expected to occur.

Data Recording

The collected data was recorded systematically to maintain proper documentation and facilitate analysis. The following information was recorded:

Parameters Measured

Specify the air quality parameters measured, including Relative Humidity (RH), Temperature, PM2.5, CO2 and CO.

Procedure for Parameter's Measurement: The step-by-step procedure used for collecting measurements of CO_2 (carbon dioxide), CO (carbon monoxide), temperature, relative humidity, and particulate matter using an air quality detector. This procedure ensured accurate and reliable data collection for assessing the air quality in the study area.

Materials Required: Air quality detector (capable of measuring CO_2, CO, temperature, relative humidity, and particulate matter).

Preparation

a. Ensured that the air quality detector is properly calibrated according to the manufacturer's instructions before starting measurements.

b. Checked the detector's power source or batteries to ensure they have sufficient charge.

Setting up the Detector

a. Placed the air quality detector on a stable surface in the area where measurements will be taken.

b. Ensured that the detector is positioned at an appropriate height and location to represent the air quality of the surrounding environment.

CO_2 Measurement

a. Power on the air quality detector and select the CO_2 measurement mode.

b. Allow the detector to stabilize and obtain a stable reading.

c. Record the CO_2 concentration displayed on the detector's screen.

CO Measurement

a. Since air quality detector can measure CO, I selected the CO measurement mode.

b. Allowed the detector to stabilize and obtain a stable CO reading.

c. Recorded the CO concentration displayed on the detector's screen.

Temperature and Relative Humidity Measurement

a. Choose the temperature and relative humidity measurement mode on the detector.

b. Allowed the detector to stabilize and display accurate temperature and humidity readings.

c. Recorded the temperature and relative humidity values shown on the detector.

Particulate Matter Measurement

a. Since air quality detector can measure particulate matter (PM), I selected the PM measurement mode.

b. Ensure that the detector's inlet is not obstructed and is exposed to the surrounding air.

c. Allowed the detector to collect particulate matter data for a sufficient duration (consult the detector's manual for recommended measurement time).

d. Record the particulate matter concentration displayed on the detector's screen.

Post-Measurement Steps

a. Power off the air quality detector.

b. If necessary, repeat the measurements at different times or locations for a comprehensive assessment of air quality.

Data Analysis and Interpretation

a. Transferred the recorded data to a computer or analysis software for further analysis.

b. Compared the collected measurements with relevant air quality standards or guidelines to assess the environmental conditions.

Safety Precautions

a. I followed safety guidelines while working with air quality detectors, especially if dealing with potentially hazardous environments.

b. Wore appropriate protective gear if required.

Data Sheets

a. Used standardized data sheets or electronic records to enter the collected data accurately and consistently.

b. Double-checked the entered values for accuracy and completeness.

c. Ensured the data sheets or electronic records are securely stored for future reference and analysis.

N.B: By maintaining comprehensive and well-organized records, it becomes easier to analyze the data, detect patterns or trends, and draw meaningful conclusions about the air quality levels at different areas within Abattoir, Ibadan.

Data Validation

Data validation procedures was implemented to ensure the integrity of the analysis results. Quality control data, calibration data, and instrument performance checks were reviewed to identify any outliers, inconsistencies, or potential errors. Results will be validated based on established acceptance criteria and standard procedures.

Data Analysis

The collected air quality data undergo two statistical methods to derive meaningful insights and draw conclusions. The following statistical methods were applied to analyze the air quality data:

Descriptive Statistics:

i. Calculate measures of central tendency (mean, median) and variability (standard deviation, range) for each air quality parameter.

ii. Generate frequency distributions, histograms, or box plots to visualize the data distribution.

Inferential Statistics:

i. Conduct hypothesis testing to assess significant differences or relationships between different variables.

ii. Perform t-tests, Analysis of Variance (ANOVA), or non-parametric tests to determine if there are significant differences in air quality parameters among different readings locations or time periods.

iii. Examine correlations between air quality parameters using correlation analysis, such as Pearson correlation or Spearman rank correlation.

Ethical Considerations

This study on the assessment of ambient air quality levels at Amosun Abattoir, requires careful attention to ethical considerations. Firstly, an informed consent was obtained from all participants, including Abattoir workers. Participants will be provided with clear information about the study's purpose, procedures, potential risks, and benefits, allowing them to make an informed decision about their participation.

Institutional approval from the Abattoir administration or ethics committee were obtained, complying with any specific guidelines or regulations for conducting research within the Abattoir premises. Proper reporting and dissemination of findings will be carried out, respecting the privacy and confidentiality and obtaining permission before sharing the results. By addressing these ethical considerations, the study will be conducted with integrity, respecting the rights and well-being of the participants involved.

Limitations of the Study

The following are the limitations considered for this study on the assessment of ambient air quality levels at Abattoir, Ibadan:

Readings Size and Representativeness

The study's findings was limited by the size and representativeness of the readings. Due to resource and time constraints, it may not be feasible to collect air quality data from every area or zone within the Abattoir. Therefore, the selected readings points may not fully represent the entire Abattoir, potentially limiting the generalizability of the results to other areas.

Time Constraints

Conducting a comprehensive assessment of air quality levels at Abattoir required significant time and resources. However, time constraints limit the duration of data collection or the number of readings points. This limitation could affect the study's ability to capture variations in air quality over longer time periods or across a wider range of locations. Hence, future studies can consider addressing these limitations to further enhance the understanding of air quality levels at Amosun Abattoir, Ibadan.

Results and Discussion of Findings

Ambient concentrations of various air pollutants, including Temperature (TEMP 0C), Relative Humidity (RH%), Formaldehyde (HCHO), Particulate Matter (PM2.5 μg/m^3), Total Volatile Organic Compounds (TVOC mg/m3), Carbon Dioxide (CO_2 PPM), Carbon Monoxide (CO mg/m3), and Air Quality Index (AQI), were monitored in the vicinity of the AMOSUN International Abattoir over a period of 30 days. Measurements were taken both in the morning and afternoon each day to capture variations in pollutant levels throughout the day. The results for these parameters are presented in both tabular and graphical formats, providing a comprehensive overview of the environmental conditions and air quality in the study area.

Ambient Concentration for Selected Air Pollutants for Both Control and Main Values in the Abattoir

The study compared the ambient concentrations of selected air pollutants between control values and initial measurements taken within the abattoir (See Table 1) The mean temperature in the abattoir was 28.4°C, slightly higher than the control value of 27.25°C. The standard deviation was similar for both (4.18 for the abattoir and 4.09 for the control), indicating comparable variability in temperature. The standard error was 0.54 in the abattoir and 0.53 in the control, while the variance was 17.50 in the abattoir compared to 16.70 in the control. This suggests a marginal increase in temperature within the abattoir environment, likely due to ongoing activities that generate heat, with only slight differences in variability and precision.

Relative humidity levels in the abattoir averaged 61.8%, slightly lower than the control value of 62.53%. However, the abattoir exhibited a higher standard deviation of 14.62 compared to 11.01 in the control, indicating more fluctuation in humidity levels within the abattoir. The standard error was 1.89 in the abattoir and 1.42 in the control, while the variance was 213.72 in the abattoir, significantly higher than the control variance of 121.27. This suggests that, although average humidity levels are similar, the abattoir environment experiences more variability.

Formaldehyde concentrations were notably higher in the abattoir, with a mean of 0.1138 ppm compared to the control mean of 0.0331 ppm. The standard deviation was 0.1362 in the abattoir and 0.0236 in the control, highlighting substantial variability in the abattoir. The standard error was 0.0176 in the abattoir compared to 0.0030 in the control, with variances of 0.0185 and 0.0006, respectively. These results indicate a significant increase in formaldehyde levels in the abattoir, with more considerable fluctuations likely due to specific activities or materials present.

The concentration of particulate matter showed a slight increase from the control (8.47 $\mu g/m^3$) to the abattoir (9.07 $\mu g/m^3$). The standard deviation was similar for both (3.84 in the abattoir and 3.83 in the control), reflecting comparable variability in particulate levels. The standard error was 0.50 in the abattoir and 0.49 in the control, while the variance was nearly identical (14.74 in the abattoir and 14.66 in the control), suggesting stable but slightly elevated particulate levels in the abattoir. TVOC levels were slightly lower in the abattoir (0.4529 ppm) compared to the control (0.4975 ppm), with a reduced standard deviation of 0.0843 in the abattoir versus 0.2286 in the control. The standard error was 0.0109 in the abattoir, significantly lower than the 0.0295 in the control, with variances of 0.0071 and 0.0523, respectively. These findings suggest that while the abattoir may not significantly increase VOC levels, the concentrations present are more consistent and stable.

Carbon dioxide levels were significantly lower in the abattoir, with a mean of 526.83 ppm compared to 622.12 ppm in the control. The standard deviation was 44.60 in the abattoir, much lower than 111.86 in the control, indicating less variability. The standard error was 5.76 in the abattoir, compared to 14.44 in the control, with variances of 1,989.16 and 12,512.85, respectively. This suggests a notable decrease and more consistent levels of CO_2 in the abattoir environment. Carbon monoxide concentrations were slightly lower in the abattoir, with a mean of 5.27 ppm compared to 5.55 ppm in the control. The abattoir's standard deviation was 1.48, less than the control's 1.78, indicating reduced variability. The standard error was 0.19 in the abattoir versus 0.23 in the control, with variances of 2.20 and 3.17, respectively. This points to relatively stable and slightly lower CO levels within the abattoir. The AQI was slightly higher in the abattoir, with a mean of 19.00 compared to 17.82 in the control, reflecting a modest increase in overall air pollution levels. The standard deviation was 3.82 in the abattoir, lower than 5.58 in the control, suggesting more stable air quality conditions. The standard error was 0.49 in the abattoir, compared to 0.72 in the control, with variances of 14.61 and 31.14, respectively (Table 1).

Table 1: Ambient Concentration for selected air pollutants for both Control and main values in the Abattoir.

Variable		Mean	Std Dev	Std Error	Variance
control	temp	27.25	4.08646	0.52756	16.69915
	RH_	62.53333	11.01227	1.421678	121.2701
	HCHO	0.033117	0.023606	0.003048	0.000557
	PM2_5ug_m3	8.466667	3.828823	0.494299	14.65989
	TVOC	0.497467	0.228645	0.029518	0.052279
	CO2	622.1167	111.8609	14.44117	12512.85
	CO	5.55	1.779592	0.229744	3.166949
	AQI	17.81667	5.579902	0.720362	31.13531
	temp	28.4	4.183098	0.540036	17.49831
Main	RH_	61.8	14.61924	1.887335	213.722
	HCHO	0.1138	0.136163	0.017579	0.018541
	PM2_5ug_m3	9.066667	3.839433	0.495669	14.74124
	TVOC	0.452933	0.084292	0.010882	0.007105
	CO2	526.8333	44.59998	5.757833	1989.16
	CO	5.266667	1.482859	0.191436	2.19887
	AQI	19	3.822325	0.49346	14.61017

Note*: Fieldwork Survey, 2024.

Ambient Concentration of Selected Air Pollutants for Morning and Afternoon Measurements

The analysis compares ambient concentrations of selected air pollutants in the abattoir during morning and afternoon periods. The metrics include mean, standard deviation, standard error, and variance for each parameter, providing a detailed view of how pollutant levels fluctuate between these times. The mean temperature was slightly higher in the morning (28.18°C) compared to the afternoon (27.47°C). Both periods showed similar variability, with standard deviations of 4.08°C in the morning and 4.24°C in the afternoon. The standard error was nearly the same for both periods, indicating consistent precision in temperature measurements. The variance was slightly higher in the afternoon, suggesting a marginally greater fluctuation in temperature during this time.

Relative humidity levels were slightly higher in the morning (62.92%) than in the afternoon (61.42%). The morning measurements had a standard deviation of 12.74 and an afternoon standard deviation of 13.11, indicating that humidity levels fluctuate more in the afternoon. The higher variance and standard error in the afternoon suggest more significant variability in humidity levels during this period. Formaldehyde concentrations were higher in the morning, with a mean of 0.0878 ppm compared to 0.0591 ppm in the afternoon. The morning data showed greater variability, with a standard deviation of 0.1241 versus 0.0811 in the afternoon. The higher variance and standard error in the morning reflect increased formaldehyde emissions during this time, likely due to morning activities in the abattoir.

Particulate matter levels were higher in the morning (9.8 μg/m^3) than in the afternoon (7.73 μg/m^3). The morning had a standard deviation of 3.97 and the afternoon had a standard deviation of 3.41, suggesting slightly more fluctuation in particulate levels during the morning. The variance was also higher in the morning, indicating greater variability in particulate matter levels during this period. TVOC concentrations were marginally higher in the morning (0.4916 ppm) compared to the afternoon (0.4588 ppm). However, the variability was similar between both periods, with standard deviations of 0.1755 in the morning and 0.1704 in the afternoon. The variance and standard error were also comparable, suggesting that VOC emissions are relatively stable throughout the day.

Carbon monoxide levels were slightly higher in the morning (5.52 ppm) compared to the afternoon (5.3 ppm). Both periods had similar standard deviations (1.64) and standard errors (0.21), indicating consistent levels of CO with only minor differences between the two times. Carbon dioxide concentrations were higher in the morning, with a mean of 580.15 ppm, compared to 568.8 ppm in the afternoon. The morning had higher standard deviation (102.34) and variance (10,473.86), suggesting greater variability in CO_2 levels. The reduction in both mean and variance in the afternoon indicates decreased CO_2 emissions or improved dispersion during this period.

The AQI was slightly higher in the morning (18.85) compared to the afternoon (17.97). The morning measurements had a standard deviation of 4.66, while the afternoon had a higher standard deviation of 4.93. The variance was also higher in the afternoon, indicating more fluctuation in overall air quality during this period (Table 2,3).

Table 2: Ambient Concentration of Selected Air Pollutants for Morning and Afternoon Measurements.

Variable		Mean	Std Dev	Std Error	Variance
morning	Temp	28.18333	4.081756	0.526953	16.66074
	RH_	62.91667	12.74162	1.644936	162.3489
	HCHO	0.087833	0.124145	0.016027	0.015412
	PM2_5ug_m3	9.8	3.973642	0.512995	15.78983
	TVOC	0.4916	0.175546	0.022663	0.030816
	CO	5.516667	1.641534	0.211921	2.694633
	CO2	580.15	102.3419	13.21228	10473.86
	AQI	18.85	4.664416	0.602174	21.75678
Afternoon	Temp	27.46667	4.236511	0.546931	17.94802
	RH_	61.41667	13.1062	1.692004	171.7726
	HCHO	0.059083	0.08109	0.010469	0.006576
	PM2_5ug_m3	7.733333	3.409193	0.440125	11.6226
	TVOC	0.4588	0.170378	0.021996	0.029029
	CO	5.3	1.639554	0.211665	2.688136
	CO2	568.8	92.62313	11.95759	8579.04
	AQI	17.96667	4.929904	0.636448	24.30396

Note*: Fieldwork Survey, 2024.

Table 3: WHO Standard for the Selected Air pollutants parameters.

Parameters	WHO Standard
Temperature (°C)	8-11°C
Relative Humidity	30-70%
Formaldehyde (HCHO)	10 $\mu g/m^3$
PM2_5ug_m3	10 $\mu g/m^3$
Total Volatile Organic Compounds (TVOC)	100 $\mu g/m^3$
Carbon Monoxide (CO)	10 mg/m^3
Carbon Dioxide (CO_2)	1000 ppm
Air Quality Index (AQI)	0-50 (good)

Comparison of Air Pollutant Concentrations with WHO Standards

The average temperature in the abattoir was 27.25°C during the control period and 28.4°C during the initial period. These values exceed the WHO recommended range of 8-11°C for ambient temperatures (See Table 4). This indicates that the temperatures in the abattoir are significantly higher than the standard, which could potentially impact the comfort and health of the facility's occupants. The relative humidity levels were 62.53% in the control period and 61.8% in the initial period, both of which fall within the WHO standard range of 30-70%. This suggests that the humidity levels in the abattoir are well within acceptable limits, providing a comfortable and stable environment in terms of moisture content.

Formaldehyde concentrations measured 0.0331 $\mu g/m^3$ in the control period and 0.1138 $\mu g/m^3$ in the initial period. Both values are significantly below the WHO standard of 10 $\mu g/m^3$. This indicates that formaldehyde levels in the abattoir are well within safe limits, posing minimal health risks related to this pollutant. The average concentrations of particulate matter were 8.47 $\mu g/m^3$ in the control period and 9.07 $\mu g/m^3$ in the initial period. These levels are below the WHO standard of 10 $\mu g/m^3$, suggesting that particulate matter is at acceptable levels and does not pose a significant health risk. TVOC levels were measured at 0.4975 $\mu g/m^3$ in the control period and 0.4529 $\mu g/m^3$ in the initial period, both of which are well below the WHO standard of 100 $\mu g/m^3$. This indicates that TVOC concentrations are within a safe range, reflecting good air quality in terms of volatile organic compounds.

The average CO_2 concentrations were 622.12 ppm in the control period and 526.83 ppm in the initial period. These values are below the WHO standard of 1000 ppm. This suggests that CO_2 levels are well within acceptable limits, contributing to a healthy indoor air environment. Carbon monoxide levels were 5.55 mg/m^3 in the control period and 5.27 mg/m^3 in the initial period, both of which are below the WHO standard of 10 mg/m^3. This indicates that CO concentrations are within safe limits, minimizing potential health risks. The AQI values were 17.82 in the control period and 19.00 in the initial period, both of which fall within the "Good" category according to WHO standards (0-50). This reflects that the overall air quality in the abattoir is satisfactory and does not pose significant health concerns (Table 4) (Figure 1).

Table 4: Comparison of the Concentration of the selected Air pollutants with WHO Standard.

Variable		Mean	Std Dev	Std Error	Variance	Who Standard
Control	temp	27.25	4.08646	0.52756	16.69915	8-11°C
	RH_	62.53333	11.01227	1.421678	121.2701	30-70%
	HCHO	0.033117	0.023606	0.003048	0.000557	10 $\mu g/m^3$
	PM2_5ug_m3	8.466667	3.828823	0.494299	14.65989	10 $\mu g/m^3$
	TVOC	0.497467	0.228645	0.029518	0.052279	100$\mu g/m^3$
	CO2	622.1167	111.8609	14.44117	12512.85	1000ppm
	CO	5.55	1.779592	0.229744	3.166949	10mg/m^3
	AQI	17.81667	5.579902	0.720362	31.13531	50 (good)
	temp	28.4	4.183098	0.540036	17.49831	8-11°C
Main	RH_	61.8	14.61924	1.887335	213.722	30-70%
	HCHO	0.1138	0.136163	0.017579	0.018541	10 $\mu g/m^3$
	PM2_5ug_m3	9.066667	3.839433	0.495669	14.74124	10 $\mu g/m^3$
	TVOC	0.452933	0.084292	0.010882	0.007105	100$\mu g/m^3$
	CO2	526.8333	44.59998	5.757833	1989.16	1000ppm
	CO	5.266667	1.482859	0.191436	2.19887	10mg/m^3
	AQI	19	3.822325	0.49346	14.61017	0-50 (good)

Note*: Fieldwork Survey, 2024.

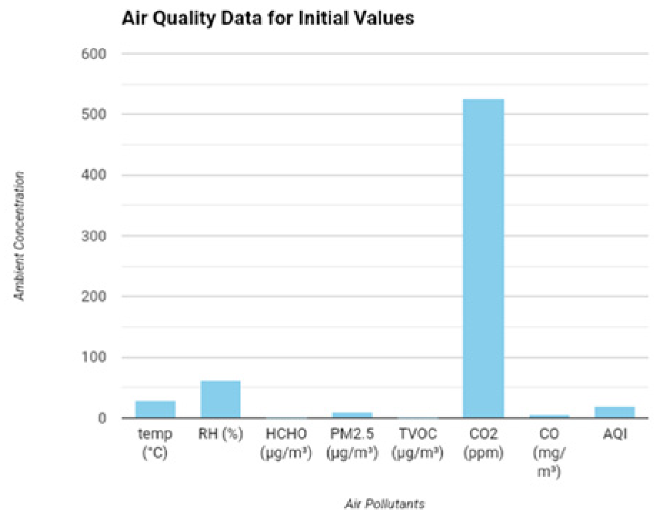

Figure 1: Comparison of Ambient Air Pollutant Concentrations (Main Value) with WHO Standards.

Discussion of Findings

Air quality within industrial environments, such as abattoirs, plays a crucial role in ensuring the health and safety of workers and surrounding communities. Poor indoor air quality, characterized by elevated levels of pollutants like formaldehyde, particulate matter, and carbon monoxide, can lead to a range of adverse health effects, from respiratory irritation to chronic diseases [21,22]. The study assessed the ambient concentrations of selected air pollutants at Amosun International Abattoir, located in Akinyele Local Government Area, Ibadan, Oyo State. Temperature measures the average kinetic energy of particles in a substance, indicating how hot or cold the environment is. It is usually measured in degrees Celsius (°C). The study found a marginal increase in temperature within the abattoir, averaging 28.4°C compared to the control value of 27.25°C. This temperature difference, although slight, can affect the abattoir environment by enhancing the volatility of organic compounds and potentially increasing the emission rates of certain pollutants22. Higher temperatures in such settings could also exacerbate heat stress among workers, influencing occupational health [23]. Relative humidity is the amount of moisture in the air relative to the maximum amount the air can hold at that temperature, expressed as a percentage (%). Relative humidity was slightly lower in the abattoir (61.8%) than in the control (62.53%), but with greater variability. This higher fluctuation in humidity may be attributed to the abattoir's operational activities, which can influence moisture levels. Variations in humidity can affect the rate of chemical reactions in the air, influencing pollutant formation and persistence [23,24]

Formaldehyde is a colorless, flammable gas with a strong odor, commonly used in industrial applications and as a preservative. It is measured in parts per million (ppm). Formaldehyde concentrations were notably higher in the abattoir (0.1138 ppm) compared to the control (0.0331 ppm). Formaldehyde is a known respiratory irritant and a potential carcinogen, classified as Group 1 by the International Agency for Research on Cancer [25]. Elevated formaldehyde levels can significantly impact respiratory health, causing symptoms such as throat irritation, cough, and in long-term exposure, increased cancer risk [26]. The substantial variability in formaldehyde levels suggests sporadic or process-specific emissions, possibly linked to waste decomposition or other abattoir activities. Particulate matter consists of tiny particles or droplets in the air, including dust, dirt, soot, and smoke. PM is typically categorized by its size, such as PM2.5 (particles with diameters of 2.5 micrometers or smaller). The study reported a slight increase in particulate matter (PM) levels in the abattoir (9.07 $\mu g/m^3$) compared to the control (8.47 $\mu g/m^3$). Particulate matter, especially fine particles (PM2.5), is associated with respiratory and cardiovascular diseases and can exacerbate conditions like asthma27. The marginal increase observed may reflect emissions from activities like burning or vehicle movement within the abattoir premises. Although the levels are only slightly elevated, consistent exposure could still pose health risks, particularly for vulnerable populations such as workers.

TVOCs are a group of organic chemicals that are emitted as gases from certain solids or liquids, including solvents, paints, and fuels. They are measured in parts per million (ppm). TVOC levels were slightly lower in the abattoir (0.4529 ppm) compared to the control (0.4975 ppm), with more consistent concentrations in the abattoir environment. TVOCs encompass a wide range of organic chemicals, many of which can cause health effects, including headaches, dizziness, and even long-term health issues such as liver and kidney damage [27]. The stability of TVOC concentrations in the abattoir may suggest controlled or less variable emission sources compared to the outdoor control environment. Carbon dioxide is a colorless, odorless gas naturally present in the atmosphere. Elevated CO_2 levels indoors can indicate poor ventilation and can cause discomfort, reduced cognitive function, and at very high levels, health issues such as respiratory acidosis [26,27]. The concentration of CO_2 was significantly lower in the abattoir (526.83 ppm) than in the control (622.12 ppm). Elevated CO_2 levels can indicate poor ventilation and are often used as a proxy for indoor air quality assessment. Lower CO_2 levels in the abattoir may reflect better ventilation or air exchange rates, which can mitigate the buildup of pollutants [28]. However, maintaining low CO_2 levels alone does not ensure the absence of other harmful pollutants. Carbon monoxide levels were slightly lower in the abattoir (5.27 ppm) compared to the control (5.55 ppm). CO is a colorless, odorless gas that can cause severe health effects, including headaches, dizziness, and in extreme cases, death due to its ability to interfere with oxygen transport in the body [26]. The reduced variability in CO levels within the abattoir suggests more stable emission sources, possibly related to consistent operational practices.

The AQI is an index used to communicate how polluted the air currently is or how polluted it is forecast to become. It considers multiple pollutants, including PM, CO, SO_2, NO_2, and ozone. Higher AQI values indicate worse air quality and greater health concern. The AQI was slightly higher in the abattoir (19.00) compared to the control (17.82), indicating a modest increase in overall air pollution. A higher AQI corresponds to greater levels of air pollutants that can pose health risks, particularly for sensitive groups such as the elderly, children, and those with pre-existing health conditions [28]. The lower variability in AQI within the abattoir suggests a relatively stable pollution profile, possibly due to controlled activities or emissions.

The findings of this study are consistent with other research that has identified abattoirs as sources of various air pollutants due to the nature of their operations, including meat processing, waste management, and cleaning activities [29]. Similar studies have also reported elevated levels of formaldehyde and particulate matter in abattoirs, linked to specific operational emissions [9]. However, the observed lower CO_2 levels contrast with findings from some indoor air quality studies that typically associate poor ventilation with higher CO_2 concentrations [30].

Moreover, the study's results on stability align with research indicating that controlled environments with predictable sources often display less variability in concentrations30. This pattern was evident in the abattoir, suggesting that while the levels of some pollutants like formaldehyde were higher, others like TVOCs were stable, likely due to regulated processes. Furthermore, the study ambient air quality parameters measured at Amosun International Abattoir were compared with the World Health Organization (WHO) standards, evaluating the implications for human health and environmental conditions. The average temperature in the abattoir was found to be 27.25°C during the control period and 28.4°C during the initial period. These temperatures are significantly higher than the WHO's recommended range of 8-11°C for indoor environments. This finding indicates that the abattoir's temperature conditions are much warmer than what is considered comfortable and safe. High temperatures can negatively impact the comfort and health of workers by causing heat stress, reducing cognitive performance, and increasing metabolic rates. It may also influence the volatility of certain pollutants, potentially affecting overall air quality [31].

Relative humidity levels in the abattoir averaged 62.53% during the control period and 61.8% during the initial period. Both values fall within the WHO's recommended range of 30-70% for indoor environments. This suggests that the humidity levels in the abattoir are within acceptable limits, providing a comfortable and stable environment regarding moisture content. Appropriate humidity levels are important because they help prevent the growth of mold and other biological contaminants, contributing to good indoor air quality and minimizing respiratory irritation [32]. Formaldehyde concentrations measured 0.0331 μg/m^3 in the control period and 0.1138 μg/m^3 in the initial period. These concentrations are significantly below the WHO guideline limit of 10 μg/m^3. This finding indicates that formaldehyde levels in the abattoir are well within safe limits, posing minimal health risks related to this pollutant. This is consistent with other studies suggesting that formaldehyde concentrations in controlled industrial settings can be effectively managed through proper ventilation and emission control measures [33].

The average concentrations of particulate matter were 8.47 μg/m^3 during the control period and 9.07 μg/m^3 during the initial period. Both levels are below the WHO standard of 10 μg/m^3, indicating that particulate matter in the abattoir is within acceptable limits and does not pose a significant health risk. Particulate matter, especially fine particles like PM2.5, is a major concern in occupational health because it can penetrate deep into the lungs and bloodstream, causing respiratory and cardiovascular diseases. Therefore, maintaining levels below the WHO standard is crucial for protecting worker health [34]. The levels of total volatile organic compounds (TVOCs) were 0.4975 μg/m^3 in the control period and 0.4529 μg/m^3 in the initial period, both well below the WHO standard of 100 μg/m^3. This indicates that TVOC concentrations in the abattoir are within a safe range, reflecting good air quality concerning volatile organic compounds. Low TVOC levels are essential because high concentrations can cause a range of health effects, from short-term irritation of the eyes, nose, and throat to long-term impacts on the liver, kidneys, and central nervous system [35].

The average concentrations of carbon dioxide in the abattoir were 622.12 ppm during the control period and 526.83 ppm during the initial period. These values are below the WHO standard of 1000 ppm, suggesting that CO_2 levels are well within acceptable limits. Proper management of CO_2 is crucial in indoor environments because elevated concentrations can lead to symptoms like headaches, dizziness, fatigue, and impaired cognitive function [36]. The results indicate adequate ventilation in the abattoir, contributing to a healthy indoor air environment. Carbon monoxide concentrations in the abattoir were 5.55 mg/m^3 in the control period and 5.27 mg/m^3 in the initial period, both below the WHO standard of 10 mg/m^3 for an 8-hour average. This indicates that carbon monoxide levels in the abattoir are within safe limits, minimizing potential health risks. Carbon monoxide is a colorless, odorless gas that can interfere with the body's ability to transport oxygen, leading to serious health effects such as heart and brain damage at high levels. The findings suggest effective combustion control and ventilation practices in the abattoir, keeping CO concentrations within safe boundaries [37].

The Air Quality Index (AQI) values were 17.82 during the control period and 19.00 during the initial period. Both values fall within the "Good" category according to WHO standards, which range from 0 to 50. This reflects that the overall air quality in the abattoir is satisfactory and does not pose significant health concerns. The abattoir's effective environmental management practices contribute to maintaining pollutant levels at safe thresholds for workers. Hence, the comparison of ambient air quality parameters in Amosun International Abattoir with WHO standards shows that most pollutant levels are within acceptable limits, except for temperature, which is significantly higher than recommended. The findings suggest that the abattoir environment is generally safe in terms of air quality. However, addressing the elevated temperatures through improved ventilation or other temperature control measures could further enhance worker comfort and health. Continuous monitoring and proactive measures to manage temperature and air quality will help maintain a safe and healthy environment for all occupants.

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Conflict of Interest

None.

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