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Air Quality Index Assessment within the Vicinity of Kwali Abattoir in Federal Capital Territory, Abuja, Nigeria

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Abstract:
This study investigates air quality and spatial variations in pollutant concentrations at the Kwali Abattoir, Kwali Area Council, Abuja. The analysis focused on $PM_{2.5}$, PM_{10}, carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) and compared their mean concentrations to air quality standards set by NESREA and WHO. The Air Quality Index (AQI) was further analysed to evaluate health risks and provide a comprehensive understanding of air quality concerning abattoir activities. The research adopted an experimental design, utilizing observational and survey methods to collect primary data on air pollutants using MiniVol Portable Air Samplers and Crow Can gas detector meters. Sampling was conducted at six intervals daily 6 a.m.,10 a.m., 12 noon, 2 p.m., 6 p.m., and 8 p.m. over five days in August 2024. Results indicated that $PM_{2.5}$ and PM_{10} levels were highest on market days, particularly at the entrance and the animal roasting and waste dump areas. CO levels peaked in the animal roasting area on market days (3.33 ppm), while non-market day levels were significantly lower, averaging 0.50 ppm. NO_2 and SO_2 concentrations were generally within NESREA limits but occasionally exceeded WHO thresholds, particularly in high-activity zones like the animal roasting area. AQI analysis showed that pollutant levels on market days approached or exceeded WHO-recommended limits, posing potential respiratory health risks, especially for vulnerable populations. This study recommends emission control technologies and continuous air quality monitoring towards mitigating these impacts.

Keywords: Air Quality, Vicinity, Abattoir, Pollutants, Kwali

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1. Introduction

One of the basic requirements for human well-being, health and the environment is clean air. The current global economic development, industrialization, urbanization, increases in population, energy consumption, transportation and motorization have become the driving factors for increases in air pollution worldwide (Gao *et al.,* 2023). According to the World Health Organization (WHO) factsheet on ambient air quality and health, an estimated seven million premature deaths occur annually as a result of air pollution-related diseases, such as heart disease, lung cancer, chronic obstructive pulmonary disease and stroke, to mention a few. Air pollution is one of the most important environmental health risks of our time, with 9 out of 10 people worldwide breathing polluted air (WHO, 2021). An average person breathes over 3,000 gallons of air daily (Silva *et al.,* 2015). Air pollution can make breathing difficult.
Abattoirs are a major source of air pollution worldwide (WHO, 2021). In development countries, animals are roasted with kerosene and condemned tyres in the course of processing the meat for marketing leading to the

emission of carbon monoxide into the atmosphere. The blood from the slaughtered animals is left flowing on the ground with offensive odour causing pollution rendering health problems to the people living around (Silva *et al.,* 2015). Abattoirs are generally known all over the world to pollute the environment either directly or indirectly from their various processes (Anand *et al.,* 2021).

The pollutants released from the operations of abattoirs include particulate matter, ammonia, hydrogen sulphide, and volatile organic compounds, among others. Exposure to such pollutants has adverse effects on human health, leading to respiratory issues, cardiovascular problems, and other health complications (Magaji & Hassan, 2017). Monitoring the air quality near abattoirs can provide valuable information on the levels of these pollutants in the air, which can help in assessing the potential health risks for nearby residents. It can also help in identifying any regulatory compliance issues and implementing measures to reduce emissions from the abattoirs (Rahman *et al.,* 2023). Given the potential negative impacts on air quality, the Air Quality Index (AQI) is a widely used tool for measuring and reporting air quality levels, providing a standardized way to communicate the quality of the air and associated health effects to the public. By conducting a detailed assessment of the AQI within the vicinity of the Kwali Abattoir, researchers and stakeholders can gain valuable insights into the extent of air pollution, identify key pollutants of concern, and strategies to mitigate the potential risks posed by poor air quality (Gao, Wang & Zhang, 2023). Therefore, this study aims to investigate the impacts of abattoir operations on ambient air quality and human health. The findings of this study provide valuable insights into the air quality around the Kwali Abattoir, informing local authorities and stakeholders about the environmental impacts of abattoir operations. This information supports the development of policies and practices aimed at improving air quality and complying with environmental standards, directly contributing to Sustainable Development Goal (SDG) 11 (Sustainable Cities and Communities) and SDG 3 (Good Health and Well-Being) by enhancing urban environmental conditions and safeguarding public health. Additionally, the study aligns with SDG 12 (Responsible Consumption and Production) by addressing industrial pollution and advocating for more sustainable practices. Assessing the Air Quality Index in the vicinity of the Kwali Abattoir is vital for understanding the environmental and health impacts of its operations.

2. Methodology

2.1: Study Area

The Kwali Abattoir is located in Kwali town in the Federal Capital Territory (FCT) of Nigeria. Kwali is situated to the southwest of Abuja, the capital city of Nigeria. Kwali Area Council is located between Latitudes 8° 3' and 8°55' North of the Equator and Longitudes 6° 47' and 7°13' East of the Greenwich Meridian (See Figure 1). The Kwali climate is the hot, humid tropical type. It is such that its elements have ranges that are transitional from those of the southern and northern parts of the country. The area has distinct wet (March - October) and dry (November - February) seasons with an average annual rainfall of 1358.7mm and a mean temperature range of between 20.7^{0}C - 30.8^{0}C (Abaje *et al.,* 2016).). Kwali Area Council has a population of 86,174. Kwali LGA is home to a booming pottery, livestock business, crop production and serves as a means of livelihood for a substantial percentage of the inhabitants. Textile making is another key economic activity in Kwali LGA (Ishaya, 2008).

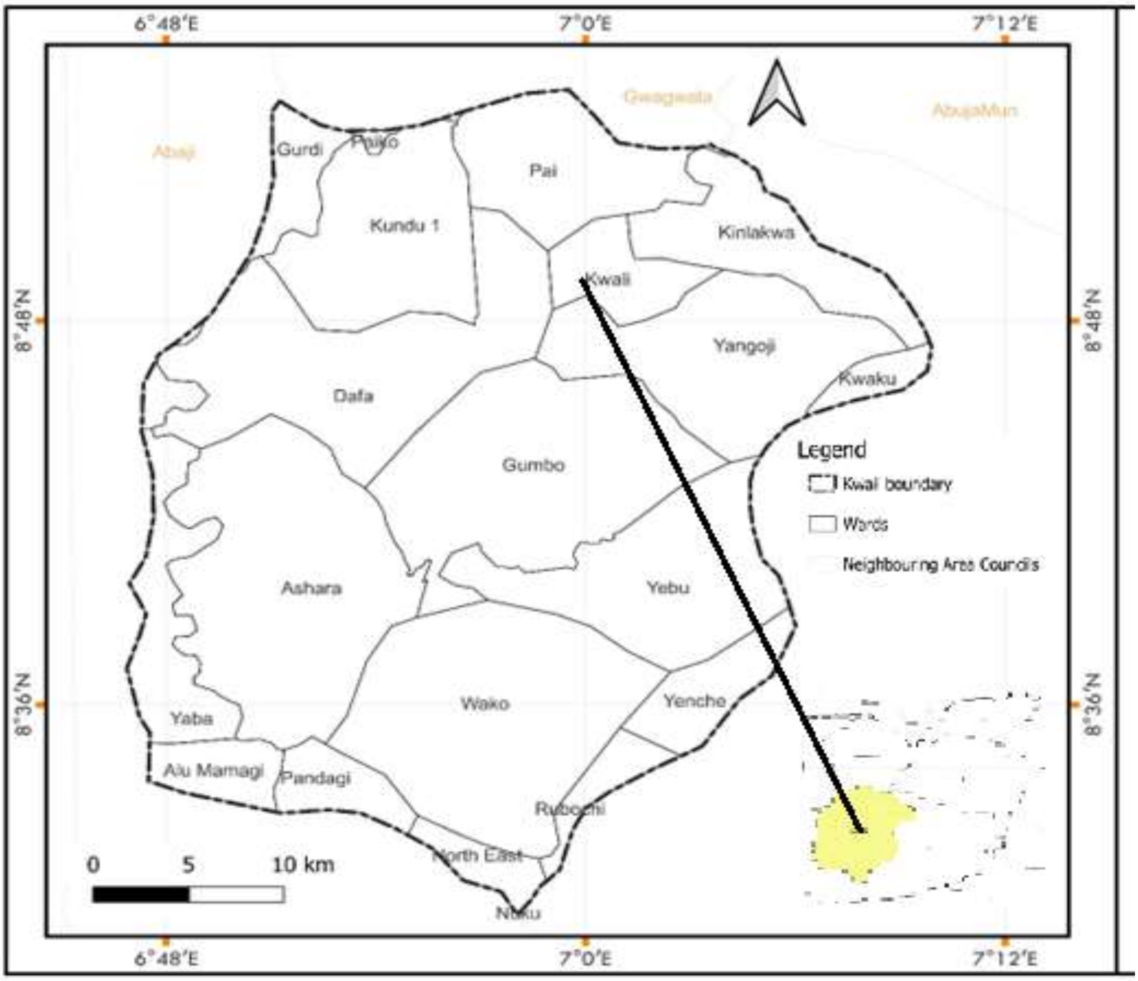

Figure 1: Locational Map of the study Area

2.2 Research Design

This study adopted experimental research design establishing connection between a situation's cause and effect. This is a causal design in which the influence of the independent variable on the dependent variable is observed.

2.3 Type and Sources of Data

The main source of data for this study is first-hand information from the field. The nature of the data is entirely numerical and quantitative. This includes measuring $PM_{2.5}$ and PM_{10} ($\mu g/m^3$), CO, NO_2 and SO_2 in the environment.

2.4 Sampling Frame and Sampling Techniques

A one-kilometre radius around the Kwali Abattoir serves as the sampling frame for evaluating the air quality around the facility; it covers areas where the abattoir's operations are likely to impact the quality of the air. Within this geographical boundary, specific points were chosen for air quality monitoring, such as the animal holding area, the slaughtering and processing sections, waste disposal or dumping sites and the abattoir's entrance and exit points. Neighbouring residential areas and public spaces were included as control sites to evaluate background pollution levels.

To document daily changes in air quality, sampling was done in the morning, noon and evening. Assessment was done on market days and non-market days.

The sampling points were spatially delineated using the Purposeful Predetermined Sampling approach. Furthermore, two sampling locations that were chosen to serve as control points for in-situ measurements of air pollutants were situated at proximate distances of 300 and 500 metres from the abattoir.

Table 1: Sampling Point

CODE	Description	Latitude	Longitude
SP1	Abattoir's Entrance/Exit Point	8.819691	7.030708
SP2	Slaughtering/Processing Section	8.819469	7.031205
SP3	Animal Roasting Area	8.819503	7.030845
SP4	Waste Dumpsite	8.819152	7.031246
SP5	Animal Holding Area	8.819038	7.030889
C1	Control 1	8.81998	7.035329
C2	Control 2	8.82289	7.022512

Source: Author's Research (2024).

2.5 Data Collection/Air Quality Monitoring

The air quality was assessed in the morning (7:00 AM – 9:00 AM), noon (12:00 PM – 2:00 PM), and evening (5:00 PM – 7:00 PM) on three market days and two non-market days of the week. To measure these contaminants, portable air quality equipment that was calibrated before each usage was used. All equipment was calibrated correctly, and duplicate measurements were made for at least 10% of the samples to guarantee the quality of the data.

Table 2: Adopted instrument for the study

S/No	Instrument	Model	Purpose
1	Global Positioning System	GPSmap 60Cx	To obtain sampling points
2	Portable VOC Monitor	Series 500	To record hourly VOCs
3	HAZE Dust Particulate Monitor	GAXT-D-DL	To record hourly PM concentration
4	Bosean Multi-Gas Detector	GAXT-S-DL	To record hourly SO_2, NO_2 and CO_2
5	Datasheet/Notepad/Pen	40 leaves/bic	For writing
6	Qgis	Version 38	To develop an imagery map
7	ArcGIS Pro	Version 3.0	To produce the study area

Source: Researcher's compilations, (2024).

2.5 Method of Data Analysis

Descriptive and inferential statistics were used to analyse the data gathered and compared with the NESREA and WHO hourly exposure limits, the mean concentration of the criterion pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2 and SO_2) was also rated for outdoor concentration using the air quality index. The study employed statistical techniques, such as time-series analysis and daily averages, to detect patterns and noteworthy distinctions between market and non-market days, as well as between various periods of the day using mean and standard deviation.

i. Mean *eq3.1*

$$\bar{X} = \frac{\sum X}{N}$$

Where: $\bar{X}$ = Mean

$\sum$ = Summation of the entire data points in the data set

N = Number of data points in the data set

Standard Deviation **eq3.2**

$$\delta = \sqrt{\sum \frac{(X - \bar{X})^2}{N}}$$

Where: δ = Standard Deviation

$\sum$ = Summation of the entire data points in the data set

X = Value of the ith point in the data set

$\bar{X}$ = The mean value of the data set

N = Number of data points in the data set

Conformity to NESREA and WHO Standard

The measured criteria pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2, SO_2 and VOCs) in the respective sampling points, were compared to the NESREA and WHO hourly limit for human exposure as presented in Table 3.

Table 3: WHO and NESREA standard

Parameter		NESREA		WHO	
		Guideline Value	Averaging Period	Guideline Value	Averaging Period/Time Base
CO		10 ppm 11.4 µg/m^3	1 – hour	25 ppm	1 – hour
SO_2		24.08 ppm 26 µg/m^3	1 – hour	0.175 ppm 500 µg/m^3	10mins
NO_2		0.01 ppm 26 µg/m3	1 - hour	0.175 ppm 500 µg/m3	10mins
$PM_{2.5}$		80 µg/m^3	1 – hour	25 µg/m^3	Annual
PM_{10}		250 µg/m^3		50 µg/m^3	24 – hour

Source: Researcher compilation 2024.

Assessment of PM Pollution Index

The Air Quality Index (AQI) calculates the daily air quality and looks at the effects of air quality on health. Six categories represent escalating levels of health concern on this AQI. To ascertain the state of the air, the AQI computation results were run through the air quality rating table, as shown in Table 3.4. The index concentration of the pollutant is represented as a percentage of the applicable standard, in this case, the WHO and NESREA limits. The AQI was determined in this investigation using the following formula, which was provided by the US EPA (2014):

$$\text{Index} = \frac{\textbf{Pollution Concentration}}{\textbf{Pollution Standard Level}}\ \boldsymbol{x}\ \mathbf{100} \qquad \text{eq4}$$

Table 4: Air Quality Rating Table

Air Quality Index (AQI) Values	Levels of Health Concern	Colours
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Source: USEPA, 2014.

Each category of the pollutant levels corresponds to a different level of health concern:

- Good - the AQI value in a given community is between 0 and 50. Air quality is satisfactory and poses little or no health risk.

- Moderate - the AQI is between 51 and 100. Air quality is acceptable; however, pollution in this range may pose a moderate health concern for a very small number of individuals. People who are unusually sensitive to ozone or particle pollution may experience respiratory symptoms.
- Unhealthy for Sensitive Groups - when AQI values are between 101 and 150, members of sensitive groups may experience health effects, but the general public is unlikely to be affected.
- Unhealthy - everyone may begin to experience health effects when AQI values are between 151 and 200. Members of sensitive groups may experience more serious health effects.
- Very Unhealthy - AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.
- Hazardous - AQI values over 300 trigger health warnings of emergency conditions. The entire population is even more likely to be affected by serious health effects.

3. Results and Discussion

3.1: Temporal Air Quality in Around Kwali Abattoir on Market and Non-Market Days

The temporal concentrations of Carbon Monoxide (CO), Particulate Matter 10 micrometres (PM_{10}), Particulate Matter 2.5 micrometres ($PM_{2.5}$), Sulfur Dioxide (SO_2), and Nitrogen Dioxide (NO_2) for sampling points in and around Kwali abattoir on market and non-market days in Kwali Area Council of the FCT.

3.1.1: $PM_{2.5}$ Concentrations in and Around Kwali Abattoir on Market and Non-Market Days

Table 5 shows the mean concentration of $PM_{2.5}$ at various locations around the Kwali abattoir over five market days. The highest $PM_{2.5}$ levels are recorded at the abattoir's entrance and exit points, with an average of 34.19 µg/m³, the slaughtering and processing area had 30.42 µg/m³, which is still relatively high but lower than the entrance point, the animal roasting area records an average $PM_{2.5}$ level of 32.34 µg/m³, the waste dump site had a mean value of 27.56 µg/m³, the animal holding area had a mean value of 27.36 µg/m³ while the $PM_{2.5}$ concentration at the Control 1 (C1) was 16.53 µg/m³ and for Control 2 (C2) was 13.81 µg/m³. Higher concentration of $PM_{2.5}$ were observed to be higher Abattoir's Entrance/Exit Point (AE/EP), Slaughtering/Processing Section (S/PS) and Animal Roasting Area (ARA) compared with the values obtained at Control 1 (C1) and Control 2 (C2). Findings from the non-market days, depict that mean $PM_{2.5}$ concentration at the entrance/exit point on non-market days is 19.13 µg/m³, lower than the five-day average of 34.19 µg/m³ observed during market days; the slaughtering/processing section (S/PS) is 19.21 µg/m³, which is slightly higher than the entrance point; animal roasting area 21.07 µg/m³,vat the waste dump site had a mean value of 20.77 µg/m³, the animal holding area had a mean value of 20.74 µg/m³, the mean value of 14.35 µg/m³ was recorded at Control 1 and 11.54 µg/m³ for Control 2. These values reflect cleaner air, confirming that the abattoir's activities are the primary source of increased particulate matter in the immediate vicinity. The overall mean (**26.03** µg/m³) shows that $PM_{2.5}$ is higher during market days and lower on non-market days with an overall mean value of 18.12 µg/m³.

The findings from Kwali abattoir suggests that the facility contributes to localized air pollution, especially in areas where intensive activities such as slaughtering, processing and roasting occurs which are extremely pronounced during the market days. These observations affirm the findings of Ishaya *et al.* (2017) and Zhao *et al.* (2019). Waste management processes at abattoirs, such as the handling and disposal of animal carcasses and by-products, can also release particulate pollutants (Nock *et al.,* 2020; Zhao *et al.,* 2019).

3.1.2: PM_{10} Concentrations in and Around Kwali Abattoir on Market and Non-Market Days

Table 5 shows the mean concentration of PM_{10} at various locations around the Kwali abattoir over five market days. The Abattoir's Entrance/Exit Point (AE/EP) had a mean PM_{10} concentration of 48.53 ug/m³, Slaughtering/Processing Section (S/PS) has a five-day average of 37.80 ug/m³, animal roasting area (ARA) had a mean value of 38.34 ug/m³ across the days, waste dump site (WDS) had a mean value of 42.51 ug/m³, animal holding area (AHA) shows had a mean value of 34.93 ug/m³, the control sites (C1 and C2), located away from abattoir activities, recorded significantly lower pollutant levels, averaging 16.27 ug/m³ and 15.94 ug/m³, respectively. Findings during the five non-market days, the mean concentration of PM_{10} at various locations around the Kwali abattoir shows that the Abattoir's Entrance/Exit Point (AE/EP) had a mean PM_{10} concentration of 24.22 ug/m^3, Slaughtering/Processing sites (S/PS) has a five-day average of 23.26 ug/m^3, animal roasting area (ARA) had a mean value of 24.95 ug/m^3 across the days, waste dump site (WDS) had a mean value of 23.74 ug/m^3, animal holding area (AHA) shows had a mean value of 23.26 ug/m^3, the Control 1 site had mean value of 16.76 µg/m^3 and the Control 2 site had a mean value of 14.76 µg/m^3, confirming the impact of localized abattoir activities on pollutant levels.

The Kwali Abattoir on non-market days had an overall mean PM_{10} value of 21.51 µg/m^3 which is lower than the market days overall mean PM_{10} value of 33.47 µg/m^3. This finding aligns with studies highlighting how abattoirs, waste dumps, traffic flow, tend to have high levels of particulate matter due to dust and emissions (Wang *et al.,* 2020). The lower than the entrance but still elevated, which may be attributed to activities like meat processing that release particulate pollutants, as observed in related studies on processing sites (Dada *et al.* 2020). Ifeoluwa & Adeola, (2018) also affirms that abattoir waste dumps, release pollutants through decomposition and burning activities that leads to high concentrations of PM_{10} (Ifeoluwa & Adeola, 2018). Meanwhile, the potentially due to less intense activities, which corroborates studies that suggest holding areas generally emit lower pollutants (Lee *et al.,* 2022; Ishaya & Omede, 2022).

Table 5: Air Quality in and Around Kwali Abattoir over Five Market and Non-Market Days

		Mean $PM_{2.5}$		**Mean PM_{10}**		**Mean CO**		**Mean** NO_2		Mean SO_2	
S/No	**Sampled points**	**MD**	**NMD**	**MD**	**NMD**	**MD**	**NMD**	**MD**	**NMD**	**MD**	**NMD**
1	Abattoir's Entrance/Exit Point (AE/EP)	34.19	19.13	48.53	24.22	1.84	0.74	0.011	0.012	0.003	0.003
2	Slaughtering/Processing Section (S/PS)	30.42	19.21	37.80	23.26	1.39	0.6	0.013	0.01	0.002	0.002
3	Animal Roasting Area (ARA)	32.34	21.07	38.34	24.95	3.33	1.05	0.020	0.032	0.002	0.002
4	Waste Dump site (WDS)	27.56	20.77	42.51	23.74	2.72	0.48	0.007	0.006	0.002	0.002
5	Animal Holding Area (AHA)	27.36	20.74	34.93	22.88	1.24	0.4	0.005	0.006	0.002	0.002
6	Control 1 (C 1)	16.53	14.35	16.27	16.76	1.07	0.12	0.000	0	0.001	0.001
7	Control 2 (C 2)	13.81	11.54	15.94	14.76	1.01	0.12	0.000	0	0.001	0.001
Daily Mean		**26.03**	**26.03**	**33.47**	**21.51**	***1.80***	**0.50**	**0.008**	**0.01**	**0.064**	**0.002**

Source: Researcher fieldwork and Analysis, 2024.

3.1.3: CO Concentrations in and Around Kwali Abattoir on Market and Non-Market Days

The mean concentrations of carbon monoxide (CO) at various sampled points within Kwali Abattoir on market days revealed that the animal roasting area (ARA) had the highest mean value of 3.33 ppm, waste dump site (WDS) records 2.72 ppm, at the abattoir's entrance/exit point (AE/EP) shows a moderate CO level with a five-day average of 1.84 ppm, at the animal holding area (AHA) and the slaughtering/processing section (S/PS) have lower CO averages of 1.24 ppm and 1.39 ppm respectively while the control sites, located away from the abattoir operations, register the lowest CO averages, with Control 1 at 1.07 ppm and Control 2 at 1.01 ppm.

CO concentration in ARA is the highest with five days mean value of 1.052 ppm, the AE/EP had a mean value of 0.74 ppm, S/PS and WDS had lower means of 0.6 ppm and 0.48 ppm, respectively, The AHA and the control points (C1 and C2) reported the lowest CO concentrations, with C1 and C2 at 0.12 ppm. On non-market days, the average concentrations of CO at Kwali Abattoir are markedly lower across all sampled points compared to market days, with an overall five-day average of 0.50 ppm compared to the market days mean 1.80 ppm. This trend indicates that reduced operational activity significantly decreases CO emissions, consistent with research showing that emissions in abattoir areas are tied to activity levels (Garcia *et al.,* 2020). This also supports *Lee et al.* (2022), who observed that areas with minimal activity maintain lower ambient CO levels, indicating that market-day activities significantly impact emissions across the abattoir, especially where combustion is involved.

3.1.4: NO_2 Concentrations in and Around Kwali Abattoir on Market and Non-Market Days

The analysis of NO_2 levels at Kwali Abattoir on market days reveals notable variability across different sampled points, with an overall five-day average of 0.008 ppm. The highest mean concentration at the ARA with 0.020 ppm, at the AE/EP and S/PS had mean NO_2 concentrations of 0.011 ppm and 0.013 ppm, respectively. WDS and AHA displayed lower NO_2 concentrations, with mean values of 0.007 ppm and 0.005 ppm respectively. The control points, C1 and C2, recorded negligible NO_2 concentrations (0.000 ppm) for both market and non-market days, highlighting that natural ambient levels of NO_2 remain very low in the absence of human activity, as observed in other studies of similar environments by Lee et al. (2022). In the non-market days, the highest NO_2 levels was recorded at the ARA with a mean value of 0.032 ppm, AE/EP and S/PS had mean NO_2 concentration of 0.012 ppm and 0.01 ppm, respectively. The WDS and AHA show minimal NO_2 levels, with both averaging around 0.006 ppm, indicating very low emissions from these sources on non-market days. NO_2 concentrations at Kwali Abattoir on non-market days had overall mean of 0.01 ppm. It is obvious that combustion attributed to processes associated with animal roasting is glaring in this study as also observed by Garcia *et al.* (2020) and Ishaya *et al.,* 2023a) noted that combustion-based activities typically result in elevated NO_2 emissions due to the burning of organic matter.

3.1.5: SO_2 Concentrations in and Around Kwali Abattoir on Market and Non-Market Days

SO_2 measured across various sampled points at the Kwali Abattoir on market days depicts and overall mean of 0.064 ppm. The ARA and WDS exhibit SO_2 of 0.20 ppm for each point while S/PS and AHA depicted means of 0.00-0.05 ppm likely influenced by intermittent use of fuel or activities involving animal waste. Conversely, at the AE/EP, C1 and C2 depicted no measurable SO_2 emissions throughout the sampling period, suggesting minimal or no direct emission sources in these locations. On the non-market days across various sampled locations shows an overall mean of SO_2 concentration of 0.002 ppm, ranging from 0.001 to 0.003 ppm per day. This reduction in SO_2 levels on non-market days indicates a correlation between market activities and elevated SO_2 emissions, as noted by prior studies on abattoir operations and emissions patterns (Chen *et al.,* 2016). AE/EP displayed mean of 0.003 ppm, S/PS), ARA and WDS recorded equally low SO_2 means with all approximately 0.002 ppm highlighting that on non-market days, emissions remain minimal across these areas, likely due to limited combustion activities and waste handling (Jones *et al.,* 2022). C1 and C2 showed SO_2 readings of approximately 0.001 ppm meaning unaffected by the abattoir's operational processes. These control readings further emphasize that SO_2 emissions are significantly influenced by specific abattoir activities predominantly occurring on market days (Johnson & Liu, 2019). The minimal SO_2 levels on non-market days suggest that reducing abattoir activities correlates with lower atmospheric SO_2 concentrations, which aligns with findings on the impact of intermittent combustion and waste management activities on air quality in abattoir environments (Ishaya *et al.,* 2023a).

3.2: Conformity of Pollutants to Established NESREA and WHO Hourly Limit for Human Exposure on Market and Non-Market Days

The average hourly recorded concentration of air pollutants around the different sections of the Kwali Abattoir was subjected to comparison with the NESREA and WHO limits for hourly human exposure.

3.2.1: Conformity of $PM_{2.5}$ Emissions to NESREA and WHO Limit for Hourly Human Exposure

Figure 2 depicts the comparative result of $PM_{2.5}$ concentrations (in μg/m^3) at the Kwali Abattoir across different sampled points on market and non-market days, benchmarked against the NESREA and WHO air quality standards (NESREA, 2011; WHO, 2005). On market days, $PM_{2.5}$ levels exceed the WHO recommended limit of 25 µg/m^3 at all sampled points, with values ranging from 27.36 µg/m^3 at the AHA to 34.19 µg/m^3 at the AE/EP. On non-market days, $PM_{2.5}$ at all sample points fell below NESREA and WHO set limits. C1 and C2s shows relatively lower $PM_{2.5}$ concentrations on both market and non-market days, with values well below both WHO and NESREA limits. This suggests minimal background pollution, further emphasizing the impact of specific abattoir activities on air quality during market days (Jones & Smith, 2021). These suggest that abattoir activities on market days contribute significantly to particulate matter emissions, presenting potential health risks for workers and visitors in these areas as observed by Sharma *et al.,* (2020) and Lin & Li, (2018).

Figure 2: A Comparison of $PM_{2.5}$ on Market and Non-Market Days Against WHO and NESREA Standards

3.2.2: Conformity of PM_{10} Emissions to NESREA and WHO Limit for Hourly Human Exposure

PM_{10} concentrations (µg/m^3) at the Kwali Abattoir on market and non-market days across various sampled points all fell within the permissible set limits of NESREA and WHO. Though PM_{10} concentrations on market days were close to the WHO recommended limit of 50 µg/m^3 at several sampled points, with the highest levels recorded at the AE/EP (48.53 µg/m^3) and the WDS (42.51 µg/m^3). Other locations, such as the ARA (38.34 µg/m^3) and S/PS (37.80 µg/m^3), also shows concerns. These readings suggest that increased abattoir activities on market days lead to higher particulate matter emissions, potentially posing health risks to workers and visitors in these areas (NESREA, 2011; WHO, 2021). C1 and C2 for both and market and non-market days exhibit lower PM_{10} levels on both market and non-market days (See Figure 3).

Figure 3: A Comparison of PM_{10} on Market and Non-Market Days Against WHO and NESREA Standards

3.2.3: Conformity CO Emissions to NESREA and WHO Limit for Hourly Human Exposure

Figure 4 depicts that CO concentrations in mg/m^3 at on market days were notably higher across all sampled points compared to non-market days but the concentrations CO on market and non-market days were below the permissible limits sets by NESREA and WHO. On non-market days, CO concentrations drop significantly across all sampled points, as expected due to reduced operational activities. Studies such as those by Ali *et al.*

(2019) and Ogunbileje *et al.* (2020) have shown that abattoir activities, including roasting and waste processing, contribute to CO levels, particularly on market days when operations are intensified. The ARA records the highest concentration at 3.33 mg/m^3, followed by the WDS at 2.72 mg/m^3. Control points (C1 and C2) exhibit minimal CO levels consistently on both market and non-market days, indicating that localized CO emissions are primarily due to abattoir activities, similar to findings by Ede and Edokpa (2017).

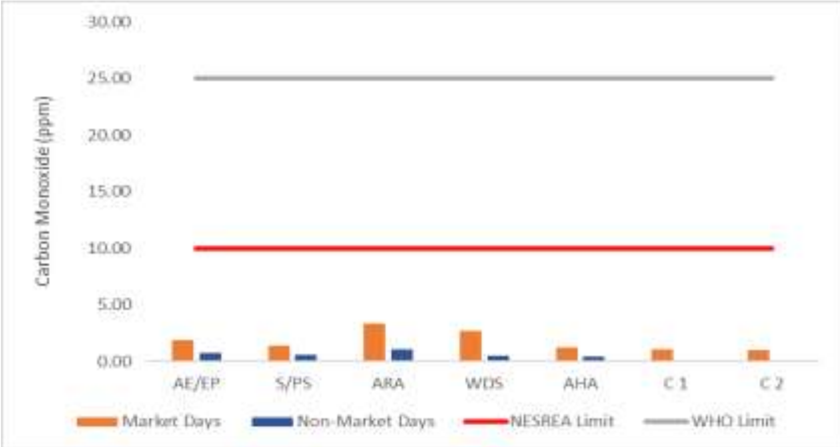

Figure 4: A Comparison of CO on Market and Non-Market Days Against WHO and NESREA Standards

3.2.4: Conformity of NO_2 Emissions to NESREA and WHO Limit for Hourly Human Exposure

Figure 5 shows no variations in concentrations of NO_2 across different sampling points on market and non-market days all within the permissible NESREA limit of 0.07 ppm and WHO limit of 0.05 ppm. This is of less concern human health as abattoir activities impacts on NO_2 concentration is less as also observed by Okeola *et al.* (2020).

Figure 5: A Comparison of NO_2 on Market and Non-Market Days Against WHO and NESREA Standards

3.2.5: Conformity of SO_2 Emissions to NESREA and WHO Limit for Hourly Human Exposure

Figure 6 shows that SO_2 concentrations at the Kwali Abattoir recorded for market days across various sampling points were within NESREA limit of 0.175 ppm and the WHO limit of 24.08 ppm. On market days, ARA and WDS recorded the highest concentrations, each at 0.20 ppm which slightly above the NESREA limit. However, they remain significantly below the WHO limit, suggesting that the concentrations do not pose a serious health risk according to WHO guidelines. Other points, such as AHA, showed lower SO_2 concentrations of 0.05 ppm on market days, while AE/EP, S/PS, C 1, and C 2 recorded no detectable SO_2 levels (0.00 ppm) on market days. This pattern emphasizes the influence of market activities on air quality but suggests no immediate health risk from SO_2 exposure under current conditions (Adejumo & Olaoye, 2020; NESREA, 2017; WHO, 2021).

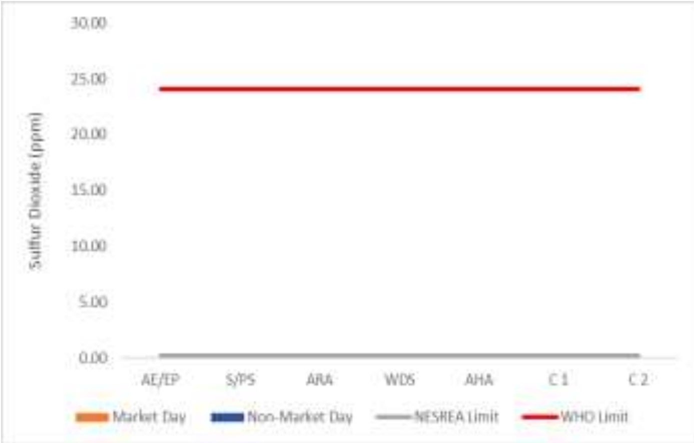

Figure 6: A Comparison of SO_2 Market and Non-Market Days Against WHO and NESREA Standards

3.4: AQI of pollutants in relation to the WHO limit for hourly human exposure

AQI results for $PM_{2.5}$, PM_{10}, CO, NO_2 and SO_2 on market and non-market days reveal notable variations that compare with USEPA standards, indicating potential health impacts linked to some pollutants. On market days, $PM_{2.5}$ concentrations across Abattoir's Entrance/Exit Point (AE/EP), Slaughtering/Processing Section (S/PS), Animal Roasting Area (ARA), Waste Dump Site (WDS) and Animal Holding Area (AHA) depicts AQI (101 to 150) that is Unhealthy for Sensitive Groups while the control sites (C1 and C2) had a moderate AQI (51-100). On non-market days, $PM_{2.5}$ concentrations across Abattoir's Entrance/Exit Point (AE/EP), Slaughtering/Processing Section (S/PS), Animal Roasting Area (ARA), Waste Dump Site (WDS), Animal Holding Area (AHA) and Control Point 1 (C1) depicts moderate AQI (51 to 100). It is obvious that market activities elevate fine particulate matter, heightening respiratory risks, especially for sensitive populations.

On market days, PM_{10} concentrations across Abattoir's Entrance/Exit Point (AE/EP), Slaughtering/Processing Section (S/PS), Animal Roasting Area (ARA), Waste Dump Site (WDS) and Animal Holding Area (AHA) depicts moderate quality for human health with AQI of 51 to 100 while the control sites (C1 and C2) had a good AQI ranging between 0-50 which heathy for human respiration. While on non-market days

PM_{10} at Abattoir's Entrance/Exit Point (AE/EP), Slaughtering/Processing Section (S/PS), Animal Roasting Area (ARA), Waste Dump Site (WDS) and Animal Holding Area (AHA) depicts AQI that is Unhealthy for Sensitive Groups. On non-market days, PM_{10} concentrations across all the sampling points recorded good (0-50) AQI except for day 1 at the Animal Roasting Area (ARA) a moderate AQI (51 to 100) was recorded.

On market days At the Animal Roasting Area (ARA) on Day 1 and Day 4 had a moderate (51-100) SO_2 AQI, while Day 2, 3 and 5 SO_2 AQI that is Unhealthy for Sensitive Groups (101-150). During market days also at the WDS the AQI is Unhealthy for Sensitive Groups (101-150) for Day 1, 2, 3 and 4 while it is moderate for Day 3 and 4 in the Animal Holding Area (AHA). On non-market days, SO_2 AQI was observed "good" for all sampling points. In the same vein, the AQI recorded for CO and NO_2 for all sampling points and market and non-market days were good for human respiratory health (See Table 6). These findings suggest that market activities significantly increase both particulate and gaseous pollutants, adversely impacting air quality and posing health risks, especially on market days with high activity levels this is in agreement with the findings of Adejumo & Olaoye (2020).

Table 6: AQI of pollutants in relation to WHO limits for hourly human exposure.

	Market Day						Non-Market Days				
$PM_{2.5}$	**Locations**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**		**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**
	AE/EP	138.20	137.40	135.08	136.44	136.60		83.68	76.04	73.48	78.28	71.08

	S/PS	122.08	121.76	119.96	120.04	124.48	79.60	75.96	77.60	74.68	76.44
	ARA	132.12	132.72	128.88	123.08	129.92	87.04	84.08	73.04	94.20	83.08
	WDS	104.80	108.44	111.52	117.76	108.60	83.84	83.56	74.88	86.56	86.48
	AHA	107.16	103.48	112.48	107.56	116.44	83.00	82.00	80.76	85.92	83.08
	C 1	65.76	65.68	63.08	68.88	67.12	61.04	49.76	53.36	65.60	57.32
	C 2	53.32	52.44	60.64	56.68	53.08	42.08	44.44	48.52	46.72	48.96
PM_{10}	AE/EP	97.36	97.26	98.44	108.60	83.61	48.88	49.48	47.58	47.98	48.24
	S/PS	73.88	77.12	76.88	78.60	71.48	47.50	45.96	46.18	47.10	45.90
	ARA	78.58	86.22	66.38	79.82	72.42	51.50	49.54	50.20	50.48	47.76
	WDS	89.84	89.76	84.64	79.96	80.94	49.32	46.34	46.70	50.28	44.72
	AHA	79.38	70.48	63.12	69.42	66.94	46.22	44.42	46.40	46.02	45.78
	C 1	32.66	32.62	31.96	32.38	33.12	35.78	32.46	33.00	34.16	32.24
	C 2	31.44	31.76	32.44	32.40	31.32	30.22	30.02	28.44	28.72	30.20
CO	AE/EP	8.04	8.00	7.56	7.08	6.2	3.20	2.80	2.4	3.6	2.8
	S/PS	5.76	3.96	4.88	6.2	7.04	2.40	3.60	2.8	1.6	1.6
	ARA	12.04	12.48	11.96	14.68	15.52	4.48	4.00	4.36	4	4.2
	WDS	11.56	11.08	11.2	10.56	9.96	1.60	2.40	1.2	2	2.4
	AHA	5.76	5.32	4.36	4.88	4.48	1.20	1.20	1.6	2	2

	C 1	4.32	4.20	4.24	4.2	4.36	0.40	0.40	0.8	0.4	0.4
	C 2	4.04	3.96	4.08	4	4.12	0.40	0.40	0.8	0.4	0.4
NO_2	AE/EP	2.40	2.20	0.20	6.00	0	0.011	0.001	0.03	0	0
	S/PS	2.00	3.00	0.00	8.00	0	0.015	0	0.04	0	0
	ARA	6.40	1.40	4.00	8.00	0	0.007	0.02	0.04	0	0
	WDS	1.20	1.40	0.20	4.00	0	0.007	0.001	0.02	0	0
	AHA	1.20	0.60	0.80	2.00	0	0.003	0.004	0.01	0	0
	C 1	0.00	0.00	0.00	0.20	0	0	0	0.001	0	0
	C 2	0.00	0.00	0.00	0.20	0	0	0	0.001	0	0
SO_2	AE/EP	0.57	1.14	2.29	1.71	2.29	0.57	5.71	0.57	1.14	0.57
	S/PS	1.14	2.86	3.43	2.29	4.00	0.57	1.71	2.29	1.14	0.57
	ARA	76.00	126.29	167.43	68.00	120.57	1.14	0.57	1.71	1.14	0.57
	WDS	114.29	194.29	125.71	120.00	5.14	0.57	0.57	1.14	2.29	0.57
	AHA	1.71	6.29	57.71	64.57	8.57	0.57	1.71	1.14	0.57	1.14
	C 1	0.57	1.71	1.14	0.57	0.57	0.57	0.57	1.14	0.57	0.57
	C 2	0.57	0.57	1.14	0.57	1.71	0.57	0.57	0.57	0.57	1.14

Source: Researcher Fieldwork and Analysis, 2024.

4. Conclusion

This study carried out a comprehensive Air Quality Index (AQI) assessment Within the Vicinity of Kwali Abattoir in Federal Capital Territory of Nigeria. By examining $PM_{2.5}$, PM_{10}, CO, NO_2 and SO_2 levels against the standards of NESREA and WHO, the study reveals significant pollutant fluctuations between market and non-market days. The Air Quality Index (AQI) results indicate that pollutant levels on market days frequently exceeded health-based thresholds, posing potential respiratory risks, particularly for vulnerable populations.

5. Recommendations

Based on the findings and conclusion from this study, it is recommended that;

i. The abattoir management should adopt emission control technologies, such as air filters or scrubbers, to reduce particulate matter and gaseous emissions,

ii. The abattoir should improve waste handling, storage, and disposal methods can significantly reduce air pollutants generated by abattoir activities. Implementing controlled waste disposal practices, such as composting and anaerobic digestion, could lower emissions of harmful gases like CO and SO_2.

iii. There should be continuous air quality monitoring should be mandated for the abattoir and surrounding areas, with pollutant levels assessed against NESREA and WHO guidelines. This would allow for timely identification of air quality issues and ensure compliance with environmental standards.

iv. There should be training programs for abattoir staff on pollution prevention and proper waste management practices that can contribute to reduction of emissions. Educating workers about the health impacts of poor air quality can further motivate adherence to best practices in daily operations.

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