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EVALUATION OF ENVIRONMENTAL NOISE IN RESIDENTIAL ZONES OF PORT HARCOURT'

R. C. CHIDI[1], B. YORKOR[2] & A. A. OBAFEMI[3]

[1,2 and 3;] Center for Occupational Health, Safety and Environment, Institute of Petroleum Studies, Faculty of Engineering, University of Port Harcourt, Rivers State, Nigeria.

Lead Authors Email; crchidi@gmail.com

Abstract

This study evaluated environmental noise exposure in selected residential zones of Port Harcourt City, Nigeria, with the aim of determining ambient noise levels and assessing spatial and temporal variations in noise exposure. A mixed-methods approach was adopted. Environmental noise measurements were conducted over a seven-day period at twelve fixed locations across three residential zones Diobu, Old Government Residential Area, and Rumuola—representing high-, medium-, and relatively lower-density residential environments. Key noise descriptors, including equivalent continuous sound level (LAeq), maximum (Lmax), minimum (Lmin), statistical levels (L10 and L90), and day–evening–night level (Lden), were computed. Data analysis employed descriptive statistics, one-way Analysis of Variance (ANOVA) with Tukey post-hoc tests, exceedance indices, and graphical techniques. The findings revealed that environmental noise levels across all residential zones consistently exceeded both the Nigerian National Environmental (Noise Standards and Control) Regulations and World Health Organization guideline limits. Diobu recorded the highest mean LAeq (67.28 dB(A)) and the greatest exceedance margins, with statistically significant spatial differences in noise exposure ($F = 22.08$, $p < 0.001$). Noise exposure persisted across weekdays and weekends, with particularly elevated levels during evening and night-time periods. The study concludes that environmental noise in Port Harcourt City constitutes a chronic, spatially uneven, and health-relevant environmental challenge, highlighting the need for integrated urban planning, strengthened regulatory enforcement, improved energy infrastructure, and health-oriented noise management strategies.

Keywords:

Environmental Noise, Residential Zones, Port Harcourt'

1.0 Introduction

Noise pollution, broadly defined as unwanted or harmful sound, has become a pressing concern in urban environments worldwide. Although it does not accumulate in the environment like chemical pollutants, its impacts on human health and quality of life are immediate and far-reaching. The World Health Organization (WHO) identifies environmental noise as the second most significant environmental health threat in cities, after air pollution, and links it to a range of outcomes, including cardiovascular disorders, sleep disruption, learning difficulties in children, and psychological stress (WHO, 2018). Urbanization, industrial expansion, and population growth have intensified the noise environment in many cities. In developing countries, weak enforcement of environmental regulations and inadequate planning often exacerbate the problem (Olutumise et al., 2025). Residential areas, which are meant to provide peace and recovery, are increasingly affected by surrounding activities such as road traffic, commercial operations, religious events, and domestic energy generation.

While developed countries have, over several decades, successfully incorporated noise management and control measures into formal urban planning and environmental policy frameworks, such institutionalized integration remains relatively weak and inconsistently applied across many African cities. In Nigeria, empirical studies undertaken in major urban centres such as Lagos, Ibadan, and Enugu have repeatedly demonstrated that residential environmental noise levels frequently exceed the World Health Organization's recommended thresholds of 55 dB(A) for daytime exposure and 45 dB(A) during nighttime periods (Olayinka, 2019). However, although a number of investigations have addressed environmental noise pollution in Port Harcourt, the existing body of literature is largely constrained by limited spatial coverage, narrow methodological scope, or outdated data. Consequently, there remains a notable absence of comprehensive, systematic, and up-to-date assessments of residential noise exposure across the city as a whole, particularly in light of Port Harcourt's complex urban fabric characterized by intense industrial activity, expanding commercial zones, and densely populated residential areas.

Residential environments are designed to offer rest, safety, and comfort, yet in Port Harcourt, these functions are increasingly compromised by persistent noise. The city's residents are routinely exposed to sound from road traffic, small-scale businesses, religious activities, and domestic power generators. Evidence from global studies indicates that sustained exposure to excessive noise is associated with hearing impairment, hypertension, sleep disorders, and reduced productivity (Basner et al, 2018). Although the National Environmental Standards and Regulations Enforcement Agency (NESREA) have articulated national guidelines specifying permissible environmental noise exposure limits, the practical enforcement of these regulations across many urban centres remains weak and inconsistent. In addition, public awareness of the adverse health consequences associated with prolonged exposure to excessive noise is generally low, leading a significant proportion of urban residents to perceive environmental noise as an inevitable and normal feature of everyday city life. As a consequence, noise-related effects such as sleep disturbance, irritation, reduced concentration, and general physical and psychological discomfort are frequently reported in the literature as common experiences among urban dwellers.

Port Harcourt, the capital of Rivers State, illustrates these challenges. As Nigeria's foremost oil and gas hub, the city has undergone rapid demographic and infrastructural transformation. High traffic volumes, industrial activities, construction, and the reliance on petrol and diesel-powered generators due to erratic electricity supply are major contributors to rising noise levels (Emenike & Sampson, 2017). These factors collectively compromise the livability of residential neighborhoods. In Port Harcourt, several empirical investigations have examined aspects of environmental noise pollution; however, many of these studies have tended to concentrate on specific sites, single land-use categories, or short-term monitoring periods. Such approaches, while valuable, often provide limited insight into broader residential exposure patterns or the cumulative implications for public health. Consequently, there remains a need for more integrated, residential-zone–based assessments that adopt a spatial perspective, examining variations in noise exposure in relation to dominant urban activities and evaluating their potential impacts on residents'.

2. Methodology

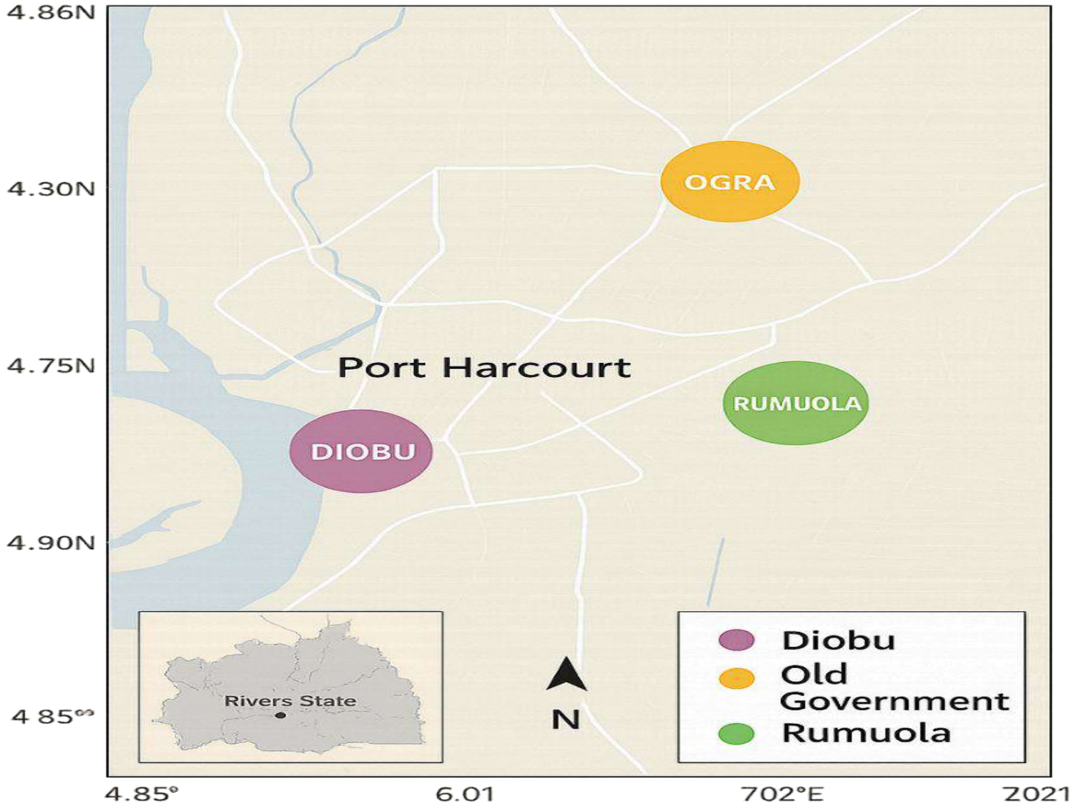
2.1 Research Design

The study adopts a mixed research design that integrates descriptive and cross-sectional survey approaches. The descriptive component focuses on the systematic measurement and characterization of the ambient acoustic environment in selected residential areas through the assessment of standard environmental noise indicators, with the aim of developing an accurate acoustic profile of the study locations. The cross-sectional aspect of the study involves the collection of environmental noise data over a defined and fixed monitoring period of seven consecutive days across spatially distinct residential zones.

2.2 Study Area

The study was carried out within the Port Harcourt Metropolis, the administrative and economic centre of Rivers State, Nigeria, located in the Niger Delta region. Geographically, Port Harcourt lies between latitudes 4°45′N and 4°55′N and longitudes 6°55′E and 7°05′E. The city is situated on a low-lying coastal plain characterized by predominantly flat terrain, high humidity, and heavy rainfall, which are typical features of the humid tropical rainforest climate (Weli & Adekunle, 2018). This climate profile influences acoustical propagation, as high moisture levels and dense atmospheric conditions support long-distance sound transmission, intensifying environmental noise in residential areas (Pierce, 2019; Berglund et al., 1999).

Port Harcourt's urban structure reflects a complex mix of rapid population growth, industrial expansion, and unplanned spatial development. The city is home to approximately 1.8–2.1 million residents, making it one of the most densely populated urban areas in southern Nigeria. Land-use patterns are highly integrated, with residential, commercial, transportation, and industrial activities often co-located in congested areas. This urban form has been shaped by the city's strategic role as Nigeria's oil and gas industry hub, attracting diverse economic activities, labor migration, and infrastructural growth (Gobo & Ubong, 2022). To appropriately capture the spatial variability of noise exposure, three residential zones representing distinct urban typologies and population densities were purposively selected: Diobu (high density), Rumuola (medium density), and Old GRA (low density). These neighborhoods reflect socio-economic diversity, differing infrastructure quality, varied land-use patterns, and contrasting noise-source intensities. See Figure 2.1



2.3 Population and Sampling Techniques

The target population comprised all residential buildings and their occupants within the geographic boundaries of the Port Harcourt metropolis. A robust multi-stage sampling methodology was adopted to ensure comprehensive geographical coverage, representativeness, and the technical feasibility of securing continuous long-term acoustic data. In the first stage of the sampling process, three distinct residential noise exposure zones High, Medium, and Low were purposefully selected. These zones included Diobu, Rumuola, and Old GRA. The selection was informed by preliminary site reconnaissance, available land-use maps, and expert judgment regarding their anticipated noise profiles and proximity to dominant noise-generating sources (Emenike & Sampson, 2017). In the second stage, systematic random sampling was employed to select monitoring locations within each of the three exposure zones. Four fixed monitoring points were systematically selected per zone, resulting in a total of twelve (12) fixed acoustic monitoring locations. The locations were evenly spaced and, where appropriate, aligned along defined transects to ensure that the collected acoustic data adequately captured the spatial variability of ambient environmental noise within each zone. For duration and frequency sampling, acoustic measurements were conducted continuously and without interruption at each of the twelve fixed locations for a minimum of seven (7) consecutive days, equivalent to 168 hours. This monitoring duration enabled the differentiation between typical weekday noise patterns and the potentially distinct noise characteristics observed during weekends (Friday to Sunday). Such differentiation is a mandatory requirement for the accurate computation of the day–evening–night noise indicator (L_{den}) (WHO, 2018). In terms of acoustic data volume, this sampling framework yielded a statistically robust dataset comprising continuous 24-hour noise measurements across twelve fixed locations over seven days. This provided a comprehensive long-term acoustic profile suitable for subsequent environmental noise analysis and health risk assessment.

2.4 Nature and Sources of Data

The study relied on an integration of primary and secondary data sources to provide both objective acoustic evidence and the necessary regulatory and public health context. Quantitative primary data formed the core of the research and was generated through objective, continuous field-based acoustic measurements. These data consisted of time-weighted sound pressure levels, expressed in A-weighted decibels [dB(A)], which were logged consistently throughout the entire monitoring period. The resulting raw acoustic datasets constituted the basis for the subsequent computation of all relevant noise indices, including the equivalent continuous sound level (L_{eq}), maximum sound level (L_{max}), day–evening–night level (L_{den}), nighttime noise level (L_{night}), and background noise level (L_{90}). In addition to the instrumental measurements, a socio-acoustic survey was conducted to capture residents' subjective perceptions of environmental noise and its perceived effects.

Secondary data were utilized to support contextual interpretation, regulatory benchmarking, and health-risk evaluation of the measured environmental noise levels. These data sources included the Nigerian National Environmental (Noise Standards and Control) Regulations, 2009 (NESREA), which provided legally enforceable national noise limits, and the World Health Organization's Environmental Noise Guidelines (2018), which supplied internationally recognized health-based exposure thresholds for environmental noise. Additional secondary data consisted of peer-reviewed epidemiological and environmental acoustics studies addressing noise exposure, annoyance, sleep disturbance, and cardiovascular health outcomes in urban residential settings.

2.5 Instruments for Data Collection

The primary instrument employed in this study was a precision acoustic monitoring device specifically designed for high-fidelity, long-duration environmental noise measurements. An integrating sound level meter (ISLM) with advanced data-logging capabilities was utilized to ensure continuous and accurate recording of ambient sound levels. Specifically, a Casella CEL-62X integrated sound level meter, conforming to Class 1 precision standards, was used for all field measurements. This instrument was selected due to its high measurement accuracy, stability, and suitability for long-term environmental noise monitoring in complex urban settings. The use of a Class 1 ISLM was considered essential for this study, as it provides superior precision and reliability, which are critical requirements for rigorous academic research and for compliance with international noise assessment standards.

2.5.1 Key Acoustic Specifications of the Sound Level Monitoring Instrument

To ensure accuracy, reliability, and compliance with international environmental noise assessment standards, the sound level monitoring instrument selected for this study was required to meet specific acoustic performance criteria. These specifications were essential for capturing both short-term noise events and long-term ambient noise trends across varying residential environments. The key acoustic specifications considered in the selection of the instrument are outlined below.

a. **Measurement Range;** The sound level meter was required to feature a wide dynamic measurement range, typically spanning from 20 dB to 140 dB. This range is necessary to accurately capture low-level background noise during quieter periods as well as high-intensity noise events associated with traffic surges, electricity generator operation, and intermittent urban activities.

b. **Frequency Weighting Capability;** The instrument was required to support A-frequency weighting [dB(A)], which closely corresponds to the sensitivity of the human auditory system. A-weighting is the internationally accepted standard for environmental noise assessment and is particularly relevant for evaluating potential health and annoyance effects associated with community noise exposure.

c. Data Logging Interval; The instrument was required to possess advanced data-logging capabilities, allowing for the recording of key acoustic metrics such as equivalent continuous sound level (Leq) and statistical noise descriptors (Ln) at short logging intervals, typically every 5 or 15 minutes. This temporal resolution enables detailed post-processing and facilitates the identification of specific noise events, including generator start-ups and traffic peaks, while supporting robust time-based analysis of environmental noise patterns.

2.6 Validity and Reliability of the Instrument

The rigorous validation and reliability procedures are integrated into the methodology to guarantee the integrity of the acoustic measurements.

2.7 Method of Data Collection

The data collection process followed a systematic and time-controlled protocol designed to minimize external interference and ensure data completeness. An initial site reconnaissance was conducted at all twelve selected locations to verify site accessibility, assess power availability, evaluate equipment security conditions, and identify dominant local noise sources such as electricity generators, traffic corridors, and commercial activities. Following reconnaissance, instrument deployment was carried out in accordance with the standardized procedures described in Section 3.6. Integrating sound level meters were securely installed at each site to minimize the risk of theft or displacement and were fitted with weather-resistant windscreens to protect the microphone from moisture and wind-induced distortion. Continuous noise monitoring was then conducted uninterrupted for a minimum duration of seven (7) consecutive days at each location. Routine daily site visits were undertaken during the monitoring period to perform field calibration checks, verify equipment functionality, document ambient conditions, and record any atypical noise events, including construction activities or localized disturbances. Upon completion of monitoring at each site, all recorded acoustic data were downloaded to a designated computer system, immediately backed up, time-stamped, and archived. Raw data files were preserved without modification to ensure traceability, verification, and auditability of the acoustic measurements.

2.8 Methods of Data Analysis

Data generated from both the field-based acoustic measurements and the questionnaire survey were systematically organized, coded, and analysed using the Statistical Package for the Social Sciences (SPSS) Version 26, Microsoft Excel, and Python. A structured, multi-stage analytical approach was employed to ensure that the results were statistically robust, meaningful, and aligned with the study objectives. The analysis comprised descriptive, inferential, and correlational statistical procedures, as outlined below.

2.8.1 Descriptive Statistics and Acoustic Calculations

Descriptive statistics were first employed to provide a clear overview of the acoustic environment across the sampled residential zones. Measures such as the Mean (M) and Standard Deviation (SD) were computed for the equivalent continuous sound levels (LAeq) recorded during both daytime and nighttime monitoring sessions. This phase of the analysis enabled a preliminary understanding of the central tendencies and variability in environmental noise exposure, thereby facilitating initial comparisons among high-, medium-, and low-density residential areas.

Equivalent Continuous Sound Level (Leq, T): The equivalent continuous sound level was calculated for hourly intervals, daytime (07:00–19:00), evening (19:00–22:00), night-time (22:00–07:00), and full 24-hour periods using the standard acoustic expression:

$$L_{eq,T} = 10\log_{10}\left[\frac{1}{T}\int_0^T \frac{p_A^2(t)}{p_0^2}\,dt\right] \tag{2.2}$$

where: $L_{eq,T}$ is the equivalent continuous A-weighted sound pressure level over time period T, expressed in decibels [dB(A)]; $p_A(t)$ is the instantaneous A-weighted sound pressure at time t, measured in pascals (Pa); p_0 is the reference sound pressure, equal to 20 μPa (2×10^{-5} Pa); T is the total measurement duration, expressed in seconds (s) and t is the time variable, expressed in seconds (s)

Day-Evening-Night Level (L_{den}): The day–evening–night noise level was computed by applying penalty corrections of +5 dB for evening and +10 dB for nighttime measurements to reflect increased human sensitivity during these periods. This calculation enabled the derivation of a composite 24-hour exposure metric suitable for health-impact assessment:

$$L_{den} = 10\log_{10}\left[\frac{1}{24}\left(12\cdot 10^{\frac{L_{day}}{10}} + 3\cdot 10^{\frac{L_{evening}+5}{10}} + 9\cdot 10^{\frac{L_{night}+10}{10}}\right)\right] \tag{2.3}$$

where: L_{den} is the day–evening–night noise level, expressed in decibels [dB(A)]; L_{day} *is the* average A-weighted sound level during the daytime period (07:00–19:00), expressed in dB(A); $L_{evening}$ is the average A-weighted sound level during the evening period (19:00–22:00), expressed in dB(A); L_{night} is the average A-weighted sound level during the night-time period (22:00–07:00), expressed in dB(A); and The +5 dB and +10 dB penalty factors account for increased human noise sensitivity during evening and night periods, respectively.

Statistical Noise Levels (Ln): Statistical percentile noise levels, including L10 (the sound level exceeded for 10% of the measurement duration, typically associated with intermittent or intrusive noise events) and L90 (the sound level exceeded for 90% of the time, representing background noise conditions), were calculated to characterize the temporal variability and dynamic structure of the acoustic environment.

3 Results and Discussions

3.1 Spatial Distribution of Ambient Environmental Noise

3.1.1 Overall Noise Levels Across Residential Zones

Ambient environmental noise across the three residential zones Diobu, Old Government Residential Area, and Rumuola were summarized using the equivalent continuous sound level (LAeq), maximum sound level (Lmax), and minimum sound level (Lmin). Table 4.1 presents the aggregated descriptive statistics over the seven-day monitoring period.

Table 3.1 Spatial Variation of Acoustic Descriptors Across Study Zones

Zone	Mean LAeq (dB(A)	SD	Mean Lmax (dB(A)	Mean Lmin (dB(A)	Mean L10 (dB(A)	Mean L90 (dB(A)
Diobu	67.28	5.59	81.02	53.92	74.46	59.56
OGRA	63.52	5.61	77.59	50.93	70.50	55.22
Rumuola	61.57	5.49	75.67	49.37	68.66	54.38

The results indicate clear spatial differences in environmental noise exposure across the study areas. Diobu recorded the highest mean LAeq (67.28 dB(A)), indicating the greatest ambient noise burden among the three zones. This zone is characterized by high population density, mixed residential–commercial land use, congested traffic conditions, and intensive reliance on electricity generators, all of which contribute to elevated noise levels. In contrast, Rumuola exhibited the lowest mean LAeq (61.57 dB(A)), reflecting comparatively quieter background conditions. The Old Government Residential Area recorded intermediate values (63.52 dB(A)), consistent with its planned residential structure but increasing commercial and institutional activities. Across all zones, mean Lmax values exceeded 75 dB(A), indicating frequent peak noise events associated with intermittent sources such as vehicular horns, generator start-ups, commercial activities, and traffic surges. Meanwhile, Lmin values remained relatively high, suggesting limited periods of acoustic relief, even during quieter times of the day.

3.1.2 Distribution of LAeq by Residential Zone (Boxplot Analysis)

The boxplot figure 4.1 shows that Diobu not only has the highest median LAeq but also exhibits a wider interquartile range and several high-end observations. This indicates greater variability and more frequent extreme noise events compared to the other zones. Rumuola displays a comparatively narrower distribution, reflecting more stable and lower background noise conditions. Such variability patterns are typical of unplanned or high-density urban districts where commercial, residential, and transport noise sources coexist (Basner et al., 2014).

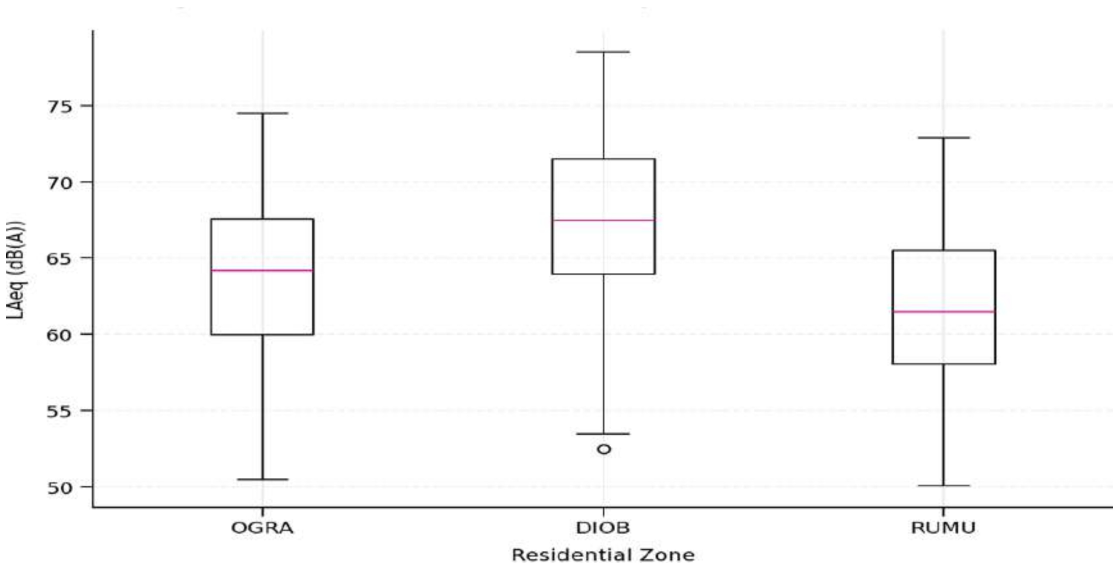


Figure 3.1: Boxplot showing the distribution of equivalent continuous sound levels (LAeq) across the three residential zones—Diobu, Old Government Residential Area, and Rumuola. The figure illustrates differences in median noise levels and variability, with Diobu exhibiting the highest central tendency and the widest spread of observations, indicating greater and more variable environmental noise exposure.

3.2 Temporal Variations in Environmental Noise

3.2.1 Weekly Noise Trends (Time Series Analysis)

The temporal variation of environmental noise across the seven-day monitoring period is illustrated in Figure 3.2, which presents the mean daily LAeq values for each residential zone. The time-series data reveals that noise exposure remains relatively stable throughout the week, though distinct mid-week peaks (Wednesday through Friday) were observed in Diobu. These peaks likely reflect the sustained intensity of commercial activities and mid-week logistical movements characteristic of high-density urban corridors. While a marginal reduction in LAeq was noted during weekend mornings across all zones, these periods of relative quiet were short-lived. By weekend evenings and nights, noise levels across the study areas most notably in Diobu and the Old Government Residential Area—returned to elevated states. This trend is largely attributable to the localized surge in social activities, the operation of entertainment venues, and the prolonged use of private generators during weekend hours. These findings confirm that environmental noise exposure in Port Harcourt is not merely a by-product of work-related transit, but is determined by a complex interplay of spatial land-use characteristics and temporal behavioral patterns. Such observations align with documented trends in other rapidly urbanizing African cities, where infrastructural deficits and informal commercial patterns drive persistent acoustic stress (Adewale & Hassan, 2020).

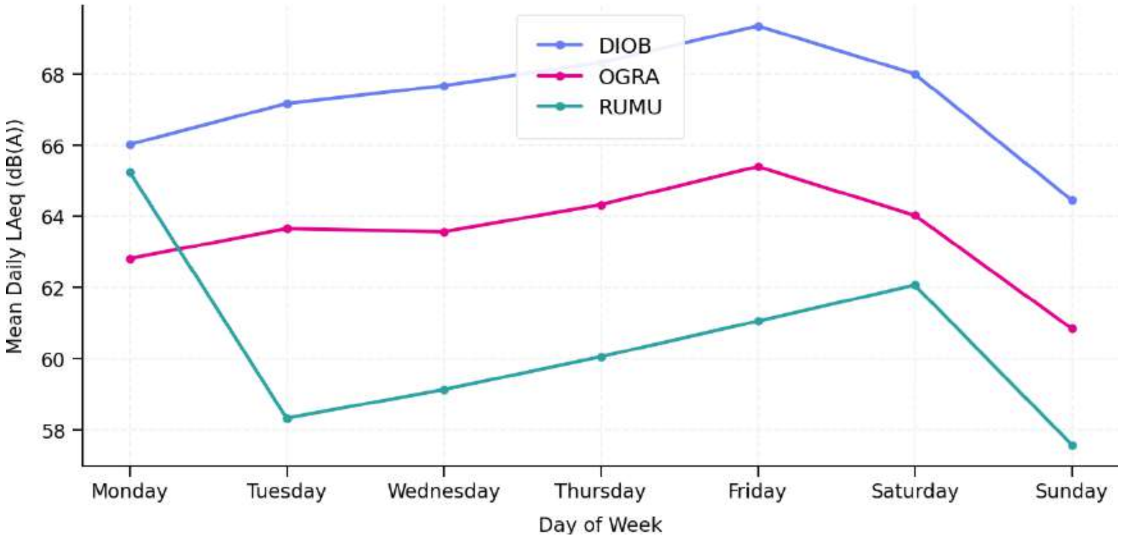


Figure 3.2. Temporal variation of mean daily equivalent continuous sound levels (LAeq) measured across Diobu, Old Government Residential Area, and Rumuola over the seven days monitoring period.

3.2.2 Diurnal Noise Variation

To examine the temporal fluctuations in environmental noise, LAeq values were categorized into distinct time-of-day periods: morning, afternoon, evening, and night. The distribution of noise exposure across these intervals is illustrated using the boxplots in Figure 3.3 which provide a visual representation of the median levels and statistical dispersion for each period. Analysis of Figure 3.3 reveals that evening periods (18:00–21:00) recorded the highest median LAeq values and the greatest degree of variability. This peak reflects the combined acoustic impact of intensified traffic congestion, the widespread onset of private generator usage, and increased social activities. While night-time (22:00–07:00) noise levels were lower than evening peaks, they remained consistently elevated. Specifically, in Diobu and the Old Government Residential Area, these levels stayed significantly above the World Health Organization (WHO) recommended night-time threshold of 45 dB(A). These findings suggest that the acoustic environment in Port Harcourt fails to reach restorative levels during biologically sensitive hours. The persistent nature of this noise burden, largely attributable to continuous generator operation and late-night vehicular movement, indicates that residents are deprived of the nocturnal quite necessary for psychological and physiological recovery.

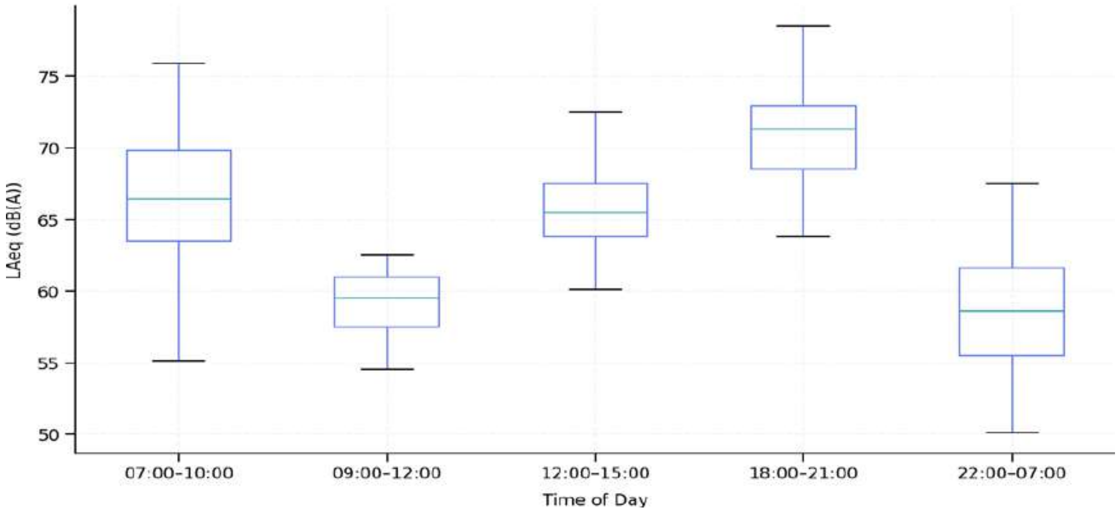


Figure 3.3. Boxplot showing the distribution of equivalent continuous sound levels (LAeq) across different time-of-day periods (morning, afternoon, evening, and night) aggregated across all monitoring locations.

3.3 Evaluation of Key Environmental Noise Descriptors

3.3.1 Equivalent Continuous Sound Level (L_{Aeq})

The computed LAeq values across all zones consistently exceeded both national (NESREA) and international (WHO) guideline limits for residential environments. This indicates conditions of chronic exposure to excessive environmental noise. Diobu recorded the highest daytime and nighttime LAeq values throughout the monitoring period, followed by the Old Government Residential Area and Rumuola, suggesting that even the "quieter" residential typologies are failing to meet health-based acoustic standards.

3.3.2 Day–Evening–Night Noise Level (Lden)

Lden values, which include penalty adjustments for evening (+5 dB) and night (+10 dB) periods to account for increased sensitivity, demonstrated substantially higher cumulative noise exposure. These elevated values, particularly in Diobu, suggest heightened long-term annoyance potential and an increased risk of adverse health effects, such as cardiovascular issues and sleep disturbance, in line with established WHO environmental noise evidence (WHO, 2018).

3.3.3 Statistical Noise Levels (L10 and L90)

Statistical percentile indicators were computed to differentiate between background and intrusive noise. L10 values captured frequent intermittent noise events, such as traffic surges and generator start-ups, while L90 values represented the elevated background noise floor. The narrow margin between L10 and L90 observed in Diobu indicates a state of persistent noise dominance rather than occasional disturbances. This lack of a "noise gap" suggests that residents have limited opportunities for acoustic respite.

4. Conclusions

A major conclusion drawn from this study is that environmental noise has become a chronic and deeply entrenched feature of the residential environment in Port Harcourt City. Across all three residential zones assessed—Diobu, Old Government Residential Area, and Rumuola—

measured equivalent continuous sound levels (LAeq) consistently exceeded both national regulatory limits and internationally recognised health-based guideline values. It was concluded that the mean environmental noise levels across all zones were substantially above the Nigerian National Environmental (Noise Standards and Control) Regulations daytime limit as well as the World Health Organization recommended guideline value for residential settings. The persistence and uniformity of these exceedances indicate that environmental noise in Port Harcourt is not a localized or episodic problem confined to a few high-activity corridors. Rather, it reflects a sustained urban environmental condition that subjects' residents to continuous acoustic stress. Prolonged exposure of this nature is particularly concerning, as it increases the likelihood of cumulative adverse effects, especially when experienced repeatedly over long durations and across multiple daily cycles, thereby reinforcing environmental noise as a significant urban health challenge.

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