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Evaluation and spatial noise mapping using geographical information system (GIS): A case study in Zaria city, Kaduna State, Nigeria

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Abstract

Background: Spatial noise level mapping using a geographical information system (GIS) is essential for the visual colour representation of noise analysis, which is a necessity for strategic planning and mitigating measures.

Methods: Extech noise meter (model 407750) was used for sound measurement and a GIS (inverse distance weighted) was used in 54 study locations for the spatial interpolation. The study was classified into five categories based on Nigeria's WHO standard and National Environmental Standards and Regulations Enforcement Agency (NESREA).

Results: For the $L_{DAY\ (D)}$, $L_{Evening\ (E)}$, $L_{Night\ (N)}$, and L_{DEN}, all the locations exceeded the WHO standard while 94.4%, 90.7%, 83.3%, and 83.3% of the locations exceeded the NESREA standard. The $L_{Day\ (D)}$ ranged from the minimum value of 67.6 dB (A) at the Ijaw residential area to the maximum value of 93.0 dB (A) at Kwangila site (1) intersection. The L_{Night} ranged from the minimum value of 63.3 dB (A) at Dogorawa residential area to the maximum value of 92.1 dB (A) at Kwangila site (1). The L_{DEN} ranged from the minimum value of 73.1 dB (A) at Hanwa residential areas to the maximum value of 97.2 dB (A) at Kwangila site (1). The noise quality rating ranged from satisfactory to unallowed noise quality grading. The selected intersections and residential areas with light commercial activities had the highest and lowest noise levels, respectively.

Conclusion: Efficient maintenance of silencers, planting trees with dense foliage, and strategic planning would be necessary panacea in curbing excessive noise.

Keywords: Noise, Nigeria, Strategic planning, Geographical information system, Spatial analysis

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Introduction

One of the greatest objectionable implications of industrialization, increase in population and economic growth is the exponential increase in anthropogenic activities. These have been found to necessitate an exponential surge in migratory automobile (traffic noise), commercial activities, domestic noise, generators, and negligence of strategic developmental plane, especially in developing countries. These have been acknowledged as sources of environmental noise pollution. Several findings have established that frequent release of noise to the environment, subsequently led to the deprivation of excellence and pristine of the ecosystem of any environment (1-9). Noise pollution is a momentous environmental problem that confronts developed and developing countries. Environmental noise pollution is an intrusive air pollutant, which dominates the auditory, and non-auditory effects on the unprotected inhabitants (6,8,9). Previous findings affirmed that there has been a high level of noise beyond the recommended threshold of the World Health Organization (WHO) globally, which is equivalent to the day noise levels and night noise limit surpassing 55 dB (A) (6,10-12). Globally several studies have associated high environmental noise exposure with headache, tinnitus, impairments of efficiencies (12-15), sleep disturbance (16), intuitiveness, cognitive prowess, annoyance (2,6,10), irritation, damage to auditory mechanisms structure, number of other health-related effects like physiological disorders (3,17), hypertension, and ischemic heart diseases (8,18,19).

The systematic measuring, and visually displaying of the spatial distribution of noise levels of any studied location, is denoted as noise mapping. The development of noise spatial mapping of any city is a requisite for digital evidence. The mapping of the study location with the computed observed noise level is the necessity for the developmental plan that facilitates strategic decisions in proffering mitigation measures (10,20,21). The Birmingham city council in 1999 accomplished a pilot report on mapping of noise in England, which was supported by the UK Government. The status of the study was made ready in early 2000. The core outcome of the study was the lodging of 3 million locations transversely, the 330 four-sided kilometers of the city were conducted in the day-time and night-time noise levels (2,5,6). The foremost international treaty, characterizations, and the foundation for mapping of noise were initiated in respect to the Environmental Noise Directive from the European Parliament and Council (Directive 2002/49/EC of 25 June 2002, often denoted to as the Green Paper) (2,4,9,22). The European member State according to the directive was mandated to develop strategic noise maps in their main environment specifically, adjacent to the commercial, residential, transport infrastructures, close to the light and heavy industrial sites. The focal obligation of the mandate is to create a diagnosis and investigation of noise pollution in Europe that would necessitate a proactive action plan and effective noise management. The word *'strategic'* is extremely imperative in this description, for the reason that the efficient administration and management of environmental noise is an obligation to be enacted for the long-standing in any study area. It demands that environmental noise data are highly essential, accurately associated with the authentic hazard of the distressing publics health (10,12-15).

In Shiraz (Iran), it was observed that the predisposed population to noise pollutions was susceptible to sleep disorders and declines in the quality of people's life (23,24). Several findings have established that although there has been a high focus on air pollution, traffic jams, and droughts by concerned individuals and organizations, not much-concerted efforts regarding the global effects of noise pollution have been made. As commendable as it is to focus on climate and drought as top ecological as a critical issue, there is a need to give pertinent attention to the emerging rise in noise pollution, which is emitted by anthropogenic activities. If this trend is not abated, the crisis of noise pollution is certain in the future as one of the ignored aspects of pollution in the environment (23). The third most harmful and dangerous type of environmental pollution in major cities and sub-urban cities worldwide aside air and water pollution as affirmed by the WHO, American Conference of Governmental Industrial Hygienists (ACGIH), National Institute for Occupational Safety, Health (NIOSH), and International Labour Organization (ILO) is noise pollution (23-27).

Noise mapping with the production of geographical information system (GIS) was initiated in the mid-90s. Two methodologies that were exercised for noise map production are in-situ noise level measurement and forecast modeling tools (20,21). GIS tools have made it possible for the generation of noise prediction maps concerning the geographical position of the public space (2,4,21). In Imam Khomeini and Mehrabad airports in Tehran province, the use of weighted overlay in GIS and multi-criteria decision making (MCDM) were deployed for the investigation of the spatial noise status while the computer-assisted noise abatement (CadnaA) model was considered for the computation of the sound levels (28-31). The new noise indicator, $L_{(A)DEN}$, which is the diurnal average sound equivalent, is recommended for noise mapping as affirmed by the Environmental Noise directive (2002/49/EC) in the new guidelines (2,4,9). In evaluating noise levels characterized by clusters, elements, hierarchies, and their relations, the analytic network process is deployed in the multi-criteria decision-making analysis (28-30).

In Nigeria, GIS noise-based mapping and diurnal sound level indicators are emerging trades as few comprehensive studies have been conducted, such as the University of Jos Noise Map (21), Mapping of noise pollution in Bariga, Lagos state (32), and noise mapping of the selected location in Ilorin metropolis by Oyedepo and Saadu (33). As recommended by the WHO and other concerned researchers on the need for a concerted effort by researchers in both developed and developing countries for frequent measurement, it is necessary to generate an environmental noise database and noise mapping of both urban and peri-urban areas as this would necessitate effective urban and peri-urban management (2,4,9,33,34). It will also provide a visual representation that would spur policymakers to make strategic policy in abating environmental noise pollution. This has necessitated the study on the evaluating and spatial noise mapping using Arch GIS for the noise average equivalent, for the day (L_D), for the evening (L_E), for the night (L_N), and diurnal mean (L_{DEN}) as recommended by the European Directive, 2002/49/EC and affirmed by the WHO for Sabon-Gari developmental area in Zaria Metropolis, Kaduna State, Nigeria, as there are inadequate detailed diurnal noise level indicators and spatial mapping of the studied location.

Materials and Methods

Study Location

Study Area

Sabon-Gari developmental area was created in 1991 and is one of the developmental government areas in Zaria, Metropolitan City in Kaduna State, Nigeria. It has an area of 263 km^3 and a density of 1495/km^3. Its geographical coordinates are 11.1231°N, 7.7322°E. According to the National population census population of 2006, the population was about 291,358 and is estimated to be about 402 345 in 2019 using the growth rate of 3.2% from the National Census (NPC, 2006) (35). (Figure 1).

Materials

The Extech model with a manufacturing code of 407750 noise meter, which satisfied the international standard of ANSI and IEC, Class 2 integrating sound level meter was used for the measurement of the sound level; the noise meter was mounted on an LG-30 Tripod Stand solicitor for taking the measurements of the noise level. Global

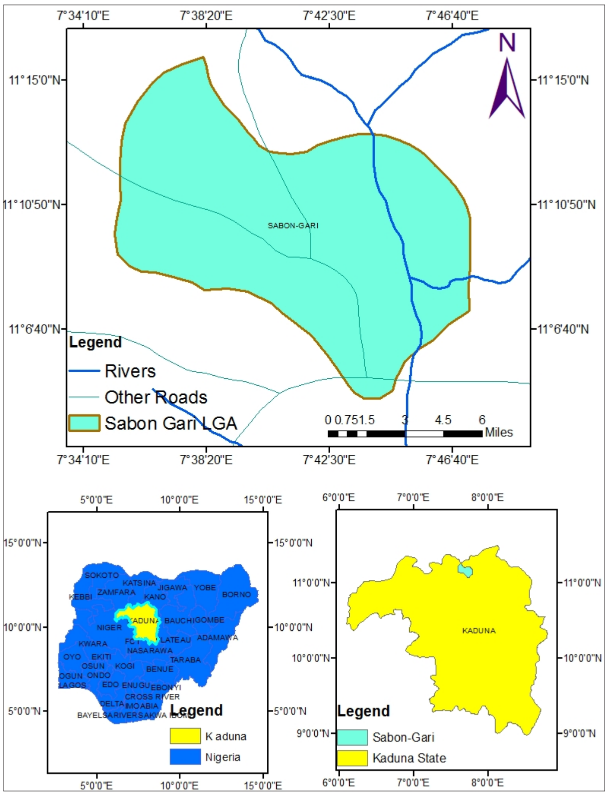

Figure 1. The study location of Nigeria and Kaduna State.

positioning system (GPS G 76) was used for uploading the coordinates (latitude and longitude) of the studied sites. The elevation of each of the sampling points was also taken using the GPS. ArcGIS version 10.5 software was used for the spatial mapping of the noise level of the study sites (Figure 2). Excel program version 2019 was used for the analysis.

Noise measurement

The study sites were purposefully selected based on the WHO and National Environmental Standard Regulation Enforcement Agency (NESREA) of Nigeria; which was based on the anthropogenic activities in each of the classified studied sites after one week of reconnaissance survey. The noise meter (Extech, model 407750) was calibrated at 94 dB (A) to ensure that it was within the calibration tolerance that was used for the measurement in each of the study locations. The Extech noise meter showed noise levels ranging from 0 to 130 dB (A) with an accuracy of ± 1.5 dB (A). The noise meter was mounted on the tripod stand in a horizontal position at a still position at least 1 to 3.5 m from slightly any acoustical reflection surface and 1.5 m above the ground (33,34,36). The data were collected at missed residential areas, markets, business areas, major streets/roads, missed residential areas, markets, business areas, plazas, and major intersections. GPS was deployed for the collection of the coordinates and the elevation in each study site. One-third octave band A-weighted sound pressure which is the frequency that synchronized well with the human auditory system, was measured over the giving 30-second interludes for 60 minutes for every sampling location. The noise level was measured in all the 54 selected study sites at 4 different times of the day and was classified based on different sites. The noise level equivalent ($L_{(A)EQ}$) were recorded and computed for morning measurement ($L_{(A)M}$, 7.30-8.30 AM), for afternoon measurement ($L_{(A)Aft}$, 1.0-2.00 PM), for evening measurement ($L_{(A)Ev}$, 5:00-6:00 PM) and for night measurement ($L_{(A)Night}$, 10:00-11.00 PM). This time interval was chosen as a result of the observation during the reconnaissance survey, which was based on the diurnal concentration of the anthropogenic activities as recommended by the WHO and NESREA standard, respectively, as seen in Tables 1-3. A total of 120 data was lodged at each of the one-hour interludes as it was affirmed that the measurements of 120 data may give the possibilities of 96 to 99% accuracy and precision

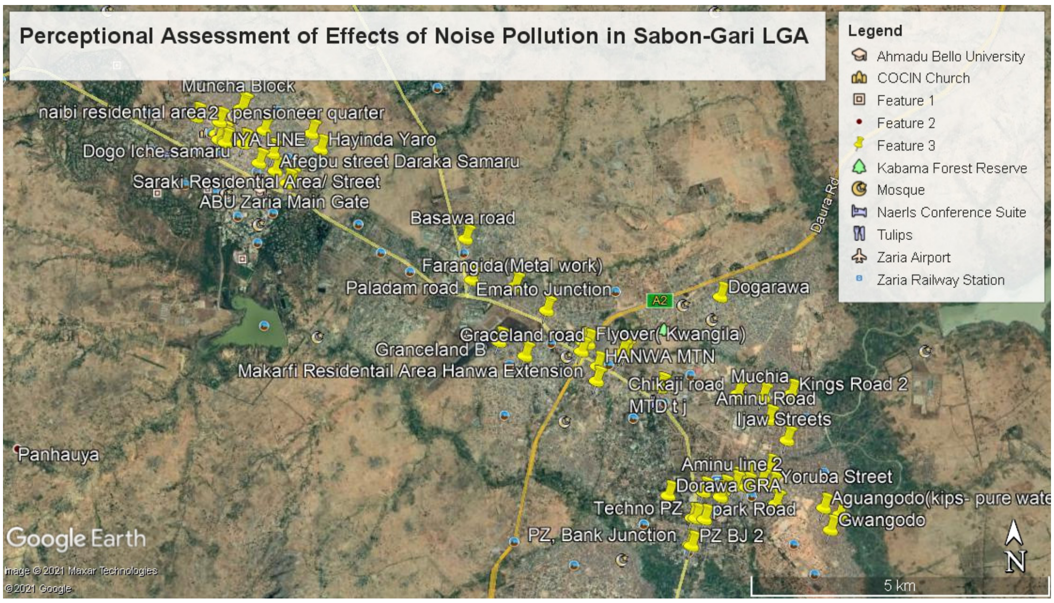

Figure 2. Pictorial views of the different studied sampling points.

Table 1. The WHO noise standard for community quality rating (20)

Leq (dBA)	Day time	Leq (dBA)	Night time
	Noise quality description		Noise quality description
0–30	Excellent quality (EQ)	0–30	Excellent quality
31–40	Very good quality (VG)	31–40	Very good quality
41–60	Good quality (GQ)	41–50	Good quality
61–75	Satisfactory quality (SQ)	51–65	Satisfactory quality
76–90	Unsatisfactory (UQ)	66–75	Unsatisfactory
91–110	Hazardous quality (HQ)	76–90	Hazardous quality
>111	Not allowed (NA)	> 90	Not allowed

(23). Excel sheet 2019, was used for the analysis of the noise equivalent level for $L_{(A)EQM}$, $L_{(A)EQA}$, $L_{(A)EQE}$, and $L_{(A)EQN}$. The data were collected from September 1, 2019 to December 6, 2019 from Monday to Saturday in all the 54 selected locations. All the environmental precautionary requirements were adhered to during the measurement period.

$$L_{EQn} = 10 * \log\{(10^{\frac{L_{n1}}{10}} + 10^{\frac{L_{n2}}{10}} + 10^{\frac{L_n}{10}})\} \quad (1)$$

$$L_D = 10 * \log_{10}\{ \frac{1}{3}[(10^{\frac{L_{AEQm}}{10}}) + (10^{\frac{L_{AeqA}}{10}}) + (10^{\frac{L_{AeqE}}{10}})]\} \quad (2)$$

$$L_E = 10 * \log_{10}\{ \frac{1}{2}[(10^{\frac{L_{AeqE}}{10}}) + 10^{\frac{L_{AeqN}}{10}})\} \quad (3)\ (33,34)$$

$$L_N = 10 * \log_{10}\{ \frac{1}{2}[10^{\frac{L_{AeqN}}{10}} + 10^{\frac{L_{AeqM}}{10}})\} \quad (4)\ (33,34)$$

$$L_{DEN} = 10 * \log \frac{1}{24}[12 * 10^{\frac{L_{day}}{10}} + 4 * 10^{\frac{l_{EV}+5}{10}} + 8 * 10^{\frac{L_{Night}+10}{10}}\}] \quad (5)\ (2,9)$$

where L_n stands for the number of noise readings taken; Lj = jth, for j = 1, 2, 3, 4, 5, 6. n of the numbers of reading lodged during measurement.

Equation (1) was used to compute noise equivalent for morning noise equivalent level ($L_{(A)EQM}$), afternoon noise equivalent level ($L_{(A)EQA}$), evening noise equivalent level ($L_{(A)EQE}$), and night noise equivalent level ($L_{(A)EQN}$).

Equation (2) was used to calculate the logarithmic equivalent average of $L_{(A)EQM}$, $L_{(A)EQA}$, and $L_{(A)EQE}$ during the day (L_D) measurement from 7 AM to 6 PM.

Equation (3) was used to calculate the logarithmic equivalent average for $L_{(A)EQE}$ and $L_{(A)EQN}$ during the evening (L_E) measurement from 6 PM to 11 PM.

Equation (4) was used to calculate the logarithmic average equivalent $L_{(A)EQM}$ and $L_{(A)EQN}$ during the night interval (L_N) measurement from 11 PM to 7 AM.

Equation (5) was used to calculate the logarithmic noise equivalent average for the daily average at each location with the addition of 5 dB (A) and 10 dB (A) to the evening and night time intervals, respectively, as a penalty for noise variations in severity (9).

Table 2. The WHO selected noise standard for community noise level (12)

Categorization	LAeq. (dB)	Night
Living outdoor area	*55	45
Daytime and evening	55	
Indoors, dwelling, and inside bedrooms	*35	
Industrial, commercial shopping, and traffic areas	*70	
Ceremonies and festivity	*100	
Public addresses (in and out)	*85	
Music through headphones	*85	
Impulse sounds from toys, fireworks, and firearms	-	

Table 3. Selected standard of environmental noise from the NESREA (37)

S/N	Facility	Maximum permissible noise limit dB (A) (Leq)	
		Day	Night
A	Any building used as a hospital, convalescent home, nursing home for the aged, sanatorium, and institutes of higher learning.	45	35
B	Residential buildings	50	35
C	Mixed residential (with some commercial and entertainment)	55	45
D	Residential + industry or small-scale production + commerce	60	50
E	Industrials outside perimeter fence	70	60
F	Commercial area	75	50

Method for spatial noise interpolation

The $L_{(A)Day}$, $L_{(A)Evening}$, $L_{(A)Night}$, $L_{(A)DEN}$, and coordinates were entered into Microsoft Excel and saved as CSV (comma delimited). The saved data were then imported into the ArcGIS environment by adding XY data, the environment was organized through the processing of the environmental extent, cell size, and output coordinate system. Analysis was performed using inverse distance weighted (IDW) interpolation technique. IDW was used instead of other interpolation techniques such as Kriging because it was assumed that, in IDW, the nearer a sample point was to the cell whose value was to be projected, the more closely the cell's value would resemble the sample point's value (36). In other words, the intensity of a variable such as sound levels in IDW reduces with distance toward other nearby variables while kriging provides an estimated intensity of an unknown variable based on the weighted average of adjacent observed variables.

The discussions of the findings were based on the WHO quality rating of noise levels, noise level standard based on anthropogenic activities, and NESREA on environmental noise.

Results

Tables 4 to 8 showed the results of noise measurement in different categorized locations with different anthropogenic activities. Table 4 presents the noise equivalent for the selected market, busy commercial areas, and their corresponding coordinates. Table 5 presents the diurnal noise level in the selected intersections and coordinates. Table 6 shows the diurnal noise level at 15 selected roads/streets. Table 7 presents the noise level in the selected mixed residential areas with commercial activities, and Table 8 shows the diurnal logarithmic noise level at different time intervals of the mixed residential area with commercial and light industrial activities. The noise level for day time intervals (L_D), evening time interval (L_E), night time interval (L_N), and the diurnal noise time intervals (L_{DEN}) were compared with the World Health Organization (WHO) standard, the WHO noise quality grading of each of the surveyed sites, and National Environmental Standards and Regulations Enforcement Agency (NESREA) of Nigeria are shown in Table 1-3, respectively.

Diurnal spatial noise mapping for L_D, L_E, L_N, and L_{DEN} distinctly

Noise Mapping of L_D time intervals of 7:30 AM to 5 PM

Table 4. Selected market and busy commercial areas and their corresponding quality rating

Location for sound data collection	Noise indicators dB (A)					Coordinates	
	L_{Aeq}	L_D	L_E	L_N	L_{DEN}	Latitude	Longitude
Perishable line (SM)	73.8(SQ)	78.2(UQ)	80.7(UQ)	78.8(HQ)	85.0(HQ	11.1611°	7.6578°
Iya line (SM)	79.2(HQ	84.1(UQ)	86.7(UQ)	85.1(HQ)	87.2(HQ	11.1609°	7.6482°
Saraki line (SM)	74.6(SQ)	78.7(UQ)	76.4(UQ)	74.5(UQ)	81.9(HQ	11.1611°	7.6446°
Daily Iya Line (SM)	69.8(SQ)	73.7(SQ)	74.3(SQ)	70.6(UQ)	73.7(UQ	11.1609°	7.6482°
Dogo and Dogp layi line (SGM)	74.4(SQ)	82.1(UQ)	83.9(UQ)	80.9(HQ)	87.2(HQ	11.1077°	7.7265°
Aminu Line (SGM)	82.8(HQ)	86.5(UQ)	86.0(UQ)	83.5(HQ)	92.9(HQ	11.1085°	7.7274°
Provison line (SM)	74.1(SQ)	79.2(UQ)	81.7(UQ)	79.2(HQ)	86.1(HQ	11.1073°	7.7266°
Lemu market	69.5(SQ)	78.6(UQ)	72.9(SQ)	64.0 (SQ)	73.5(UQ	11.1276°	7.7101°
Uma-Faruk Plaza	70.2(SQ)	72.1(SQ)	74.1(SQ)	71.8(UQ)	80.7(HQ	11.1068°	7.7215°
Techno PZ	85.6(HQ)	86.1(UQ)	88.4(UQ)	83.0(HQ)	93.5(HQ	11.1028°	7.7203°
Manchester line PZ	83.0(HQ)	86.2(UQ)	87.3(UQ)	84.5(HQ)	91.4(HQ	11.1029°	7.7198°
Albabello TC (PLC)	77.9(UQ)	80.6(UQ)	79.0(UQ)	72.5(UQ)	83.8(HQ	11.1064°	7.7246°

Note: SM= Samaru Market, SGM= Sabon-Gari Market, PZ= Peterson Zachosin, TC= Trading company, HQ= Hazardous quality, NA= Not allowed quality, UQ= Unsatisfactory quality, and SQ= Satisfactory quality (20), the WHO standard, 70 dB (A) and NESREA standard for day and night, 75 dB (A) and 50 dB (A), respectively.
The one-way ANOVA test for variance, $P<0.05$.

Table 5. Evaluation of LDEN selected intersections with their respective quality

Selected Major Streets and Roads	Noise Level Index dB (A)					Coordinates	
	L_{Aeq}	L_D	L_E	L_N	L_{DEN}	Latitude	Longitude
Kw I (1)	92.5 (NA)	93.0(NA)	91.3(NA)	92.1(NA)	98.2(NA)	11.1292°	7.7041°
Kw I (2)	90.2(NA)	90.9 (NA)	90.5(NA)	89.3(HQ)	95.1(NA)	11.1265°	7.7035°
Kw I (3)	90.6 (NA)	90.7 (NA)	92.7(NA)	91.2(HQ)	96.2(NA)	11.1289°	7.7035°
Bank I PZ (1)	86.1(HQ)	87.2 (HQ)	84.2(HQ)	84.4(HQ)	90.0(NA)	11.0888°	7.7192°
Bank I PZ (2)	88.7(HQ)	84.4(HQ)	83.6(HQ)	82.8(HQ)	90.2(NA)	11.0990°	7.71961°
Emanto I	85.6(HQ)	86.0(HQ)	85.7(HQ)	83.5(HQ)	93.5(NA)	11.1352°	7.6980°
MTD I	84.8 (HQ)	86.7(HQ)	84.1(HQ)	81.6(HQ)	88.7(HQ)	11.1227°	7.7075°
ABU I (1)	84.0(HQ)	84.6(HQ)	82.3(HQ)	83.8(HQ)	88.6(HQ)	11.1548°	7.6588°
(ABU) I (2)	82.8 (HQ)	83.6(HQ)	81.4(HQ)	83.4(HQ)	88.0(HQ)	11.1552°	7.6571°

Note: HQ= Hazardous quality, NA= Not allowed quality, UQ= Unsatisfactory quality, and SQ= Satisfactory quality. Kw= Kwangilar Intersection, PZ= Peterson Zachoson, I= Intersections, ABU= Ahmadu Bello University, the WHO standard 70 dB (A) and NESREA standard for day and night is 75 dB (A) and 50 dB (A), respectively.

Table 6. Evaluation of L_D, L_E, L_N, and L_{DEN} in the selected roads/streets with their respective quality rating

Site	Noise level index dB (A)					Coordinates	
	L_{Aeq}	L_D	L_E	L_N	L_{DEN}	Latitude	Longitude
Chikaji R	80.1(UQ)	81.9(UQ)	83.9(UQ)	82.9(HQ)	92.3(HQ)	11.1229°	7.7172°
Park R	85.0(UQ)	88.6(UQ)	86.9(UQ)	85.5(HQ)	95.6(HQ)	11.0999°	7.7202°
Aminu (2)	81.1(UQ)	83.1(UQ)	82.8(UQ)	81.2(HQ)	88.1(UQ)	11.1077°	7.7265°
Randan K	82.6(UQ)	85.6(UQ)	85.3(UQ)	81.1(HQ)	89.0(UQ)	11.1279°	7.7094°
KINGS R	80.6(UQ)	82.4(UQ)	81.3(UQ)	80.4(HQ)	87.2(UQ)	11.1203°	7.7246°
Lagos S	82.7(UQ)	85.1(UQ)	84.8(UQ)	81.7(HQ)	89.1(UQ)	11.1082°	7.7304°
Club S	78.8(UQ)	81.4(UQ)	81.1(UQ)	77.4(HQ)	85.1(UQ)	11.1101°	7.7319°
Yoruba	77.5(UQ)	80.3(UQ)	76.8(UQ)	77.5(HQ)	86.1(UQ)	11.1074°	7.7322°
Cemetery	75.3(UQ)	77.3(UQ)	76.5(UQ)	69.7(UQ)	81.9(UQ)	11.1101°	7.7319°
Geace LR	71.3 (SQ)	72.8(UQ)	74.3(SQ)	72.9(UQ)	79.5(UQ)	11.1277°	7.6944°
Leather RR	76.2 (UQ)	77.9(UQ)	77.5(UQ)	71.4(UQ)	83.2(UQ)	11.1561°	7.6573°
Naibi Street	80.4(UQ)	81.7(UQ)	82.7(UQ)	81.5(HQ)	88.1(UQ)	11.1609°	7.6510°
Dogo-iche S	79.8(UQ)	81.5(UQ)	85.1(UQ)	80.3(HQ)	87.1(UQ)	11.1609°	7.6510°
Paladan R	81.4(UQ)	86.9(UQ)	81.4(UQ)	79.8(HQ)	86.9(UQ)	11.1393°	7.6863°
Saraki S	77.7(UQ)	83.2(UQ)	80.0(UQ)	79.1(HQ)	84.1(UQ)	11.1578°	7.6534°

Note: HQ= Hazardous quality, NA= Not allowed quality, UQ = Unsatisfactory quality, and SQ= Satisfactory quality. R= Road, KR= Kanu Road, S= Street, GLR= Grace L and Road. The WHO standard for day and night noise levels of 70 dB (A), 45 dB (A), and NESREA standard of 60 dB (A) and 50 dB (A).

Table 7. Evaluation of LDEN selected residential areas with their respective quality rating

		L_D	L_E	L_N	L_{DEN}	Latitude	Longitude
Government reservation areas	67.7(SQ)	69.2(SQ)	70.1(SQ)	67.3(UQ)	74.4(SQ)	11.106325°	7.7164°
DOGORAWA	71.3(SQ)	73.5(SQ)	73.9(SQ)	63.3(UQ)	78.9(UQ)	11.136287°	7.7244°
Graceland (2)	66.4(SQ)	68.5(SQ)	67.9(SQ)	66.1(UQ)	73.1(SQ)	11.129888°	7.6904°
Gwado	71.1(SQ)	72.7(SQ)	73.1(SQ)	70.2(UQ)	77.4(UQ)	11.103034°	7.7426°
Hanwa Residential	66.8(SQ)	70.9(SQ)	67.8(SQ)	65.8(UQ)	73.1(SQ)	11.1229°	7.70860°
Agwangodo	71.0(SQ)	73.9(SQ)	75.5(UQ)	72.4(UQ)	79.5(UQ)	11.100768°	7.7411°
Muchia	74.4(SQ)	78.0(UQ)	78.4(UQ)	76.0(UQ)	83.0(UQ)	11.120931°	7.7311°
Ijaw residential area	66.2(SQ)	67.6(SQ)	68.8(SQ)	66.7(UQ)	73.2(SQ)	11.159731°	7.6630°
Afegbu Daraka	69.7(SQ)	72.2(SQ)	71.5(SQ)	70.8(UQ)	77.8(UQ)	11.164636°	7.6375°
Galadima	69.3(SQ)	71.4(SQ)	73.6(SQ)	71.7(UQ)	78.3(UQ)	11.164631°	7.6375°

Note: GQ= Good quality, HQ= Hazardous quality, NA= Not allowed quality, UQ= Unsatisfactory quality, and SQ= Satisfactory quality (WHO, 1999), Anomohanran (34) The WHO and NESREA standard for day and night noise levels of 55 dB (A) and 45 dB (A), respectively.

Table 8. Evaluation of L_{DEN} of the selected mixed residential/light industries areas with their respective quality rating

Site	Noise level index dB (A)					Coordinates	
	L_{Aeq}	L_D	L_E	L_N	L_{DEN}	Latitude	Longitude
Dasa Block Hydayaro	73.8 (SQ)	77.4(UQ)	77.6(UQ)	72.6(SQ)	80.8(UQ)	11.1578°	7.6574°
Muncha Block	72.9 (SQ)	77.9(UQ)	78.6(UQ)	73.2 (SQ)	81.4(UQ)	11.1657°	7.6507°
Farangida MW	77.1(UQ)	82.2(UQ)	81.7(UQ)	76.6(UQ)	85(UQ)	11.1383°	7.6930°
Kips (Pure water)	85.5(UQ)	92.3(UQ)	92.2(HQ)	88.9(HQ)	92.3(HQ)	11.1063°	7.7348°
Sawmill	76.9(UQ)	82.4(UQ)	86.9(UQ)	85.7(HQ)	92(HQ)	11.1623°	7.6616°
Pensioners Q (MTN)	76.3(UQ)	76.1(UQ)	76.7(UQ)	76.7(UQ)	83(UQ)	11.1210°	7.7054°
Hanwa (MTN)	73.7 (SQ)	73.6 (SQ	73.9(UQ)	73.8 (SQ)	80.2(UQ)	11.1262°	7.7053°
Sawmill	76.9(UQ)	82.4(UQ)	86.9(UQ)	85.7(HQ)	92.0(HQ)	11.1073°	7.7247°

Note: GQ= Good quality, HQ= Hazardous quality, NA= Not allowed quality, UQ= Unsatisfactory quality, and SQ = Satisfactory quality MW= Metal works, M= Mask, the WHO standard for day and night noise level of 55 dB (A) and 45 dB (A), respectively, while NESREA standard for day and night noise level of 60 dB (A) and 50 dB (A).

Figure 3 shows the spatial noise level of the color-dispersion of the selected locations as presented in Tables 4 to 8 for the day time interval (L_D) from 7 AM to 5 PM. The light green, light yellow, light red, and red noise color represent various noise levels in different surveyed sites. The red and light red ranging from 80.4 dB (A) to 93.2 dB (A) represent the sites with high noise levels with a quality rating of unsatisfactory quality to hazardous quality rating. It represented the flashpoints such as Kwangila (A49), PZ (A36), Palladan (A26), Park road (A44), Muchia road (A53), Lagos street (A48), and Sabon-gari market. While the green and yellow range from 67.9 dB (A) to 80.3 dB (A) with a quality rating from satisfactory to unsatisfactory quality with sites such as Graceland residential areas, Government reservation areas (GRA), Hanwa as presented in Tables 4 to 6.

Noise mapping of L_E time intervals of 5 PM to 11 PM

Figure 4 shows the special noise map during the evening time interval (L_E), the noise spatial color dispersion quality range from satisfactory quality to hazardous quality in general as seen in Tables 4 to 8. The surveyed sites with red and orange spatial color dispersion had a high noise level ranging from 80.3 dB (A) to 92.5 dB (A) concentration with a quality rating from unsatisfactory to hazardous in comparison with green and yellow color coding with variations of noise levels ranging from 65 dB (A) to 80.2 dB (A) with a quality rating from satisfactory to unsatisfactory in the different surveyed sites.

Noise mapping of L_N time intervals of 11 PM to 7 AM

Figure 5 presents the night interval (L_N) noise color-coding mapping of the noise levels of different locations. The noise levels ranging from 63.4 dB (A) to 77.1 dB (A) had the highest satisfactory quality with less anthropogenic activities; nevertheless, the noise level exceeded the WHO, NESREA standards such as Graceland (A45), Hanwa residential area (A34), Government residential area (A43), and Dogorawa residential area (A44). The noise levels ranging from 77.2 dB (A) to 91.5 dB (A) with

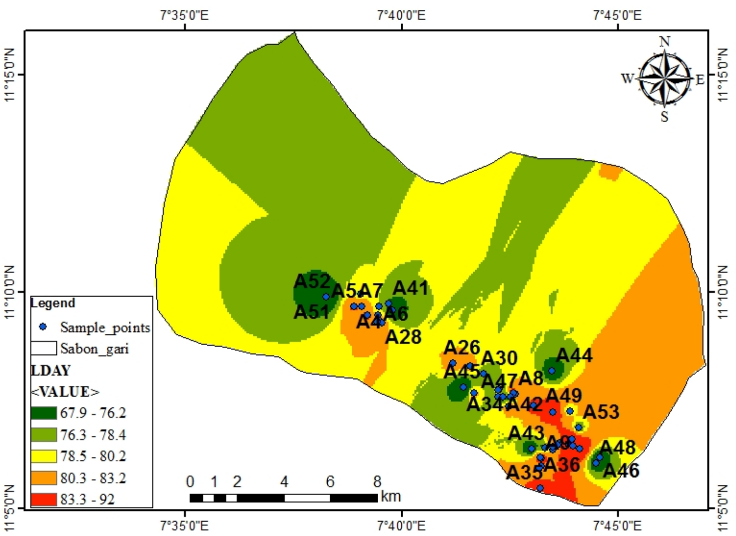

Figure 3. L_D noise level mapping using a time interval of 7.30 AM to 6 PM.

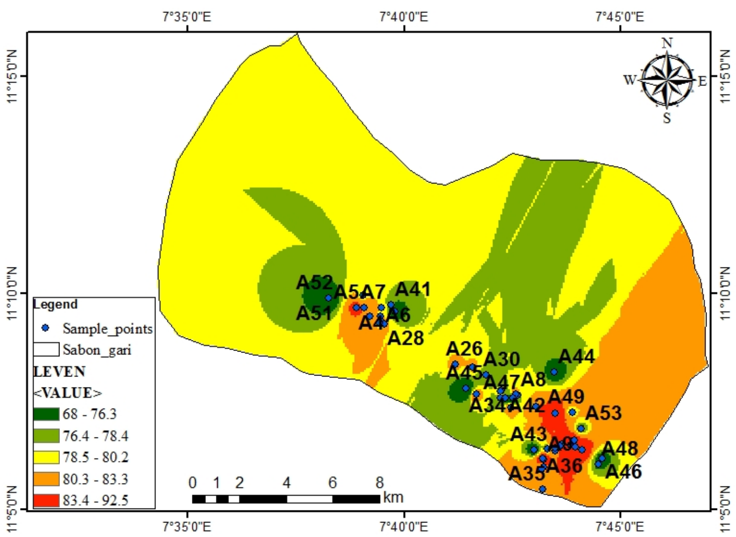

Figure 4. Spatial noise map for the evening interval from 6 PM to 11 PM.

the quality rating from unsatisfactory to unwanted quality were shown with flashpoints such as Kwangila, Park road, Tecno PZ, and Lagos street.

The diurnal logarithmic mean of L_D, L_E, L_N time intervals (L_{DEN}) noise mapping of the 24 hours

Figure 6 shows the logarithmic diurnal mean for L_{DEN} (L_D, L_E, and L_N) of the spatial dispersions of noise level mapping of different sites. The noise level ranging from 73.3 dB (A) to 76 dB (A) with noise quality rating from satisfaction quality to unsatisfactory quality, which had the least ranging of dispersion of satisfactory quality, while unsatisfactory quality and hazardous quality, had the highest dispersion across the surveyed sites with a noise level ranging from 76 dB (A) to 98 dB (A), which represented the flashpoints as were discussed earlier.

Discussion

Table 4 accounted for the logarithmic diurnal noise level of the selected major market and busy commercial areas. For the logarithmic noise equivalent for each of the locations, (L_{EQ}), 10 sites representing about 83.3% exceeded the WHO standard and two surveyed sites representing 16.7% exceeded the NESREA standard. The noise level ranges from the maximum value of 85.6 dB (A) at PZ Tecno to the minimum value of 69.4 dB (A) at Lemu market. The $L_{day(D)}$ time intervals exceeded the WHO standard in all the surveyed locations while it exceeded the NESREA standard in 10 sites (83.3%) out of 15 selected sites with a maximum value of 86.5 dB (A) at the Aminu line at Sabon-Gari market to the minimum value of 72.1 dB (A) at Umar Faruk Plaza. For the $L_{Evening\ (E)}$, time intervals exceeded the WHO standard in all the surveyed sites and for the NESREA standard by about 10 surveyed sites (83.3%) of the selected sites with the maximum value of 88.4 dB (A) at Tecno PZ to the minimum value of 72.9 dB (A) at Lemu Market. For the $L_{Night\ (N)}$, time intervals, 91.7% of the selected sites (11 sites) exceeded the WHO standard and 66.7% (8 sites) exceeded the NESREA standard with a maximum value of 85.1 dB (A) at the Iya

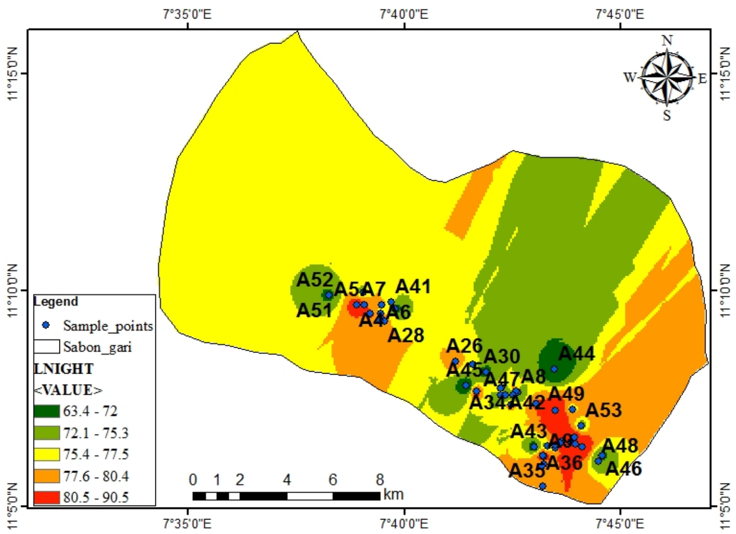

Figure 5. $L_{Night\ (N)}$ noise level mapping using GIS for Sabon-Gari LGA, using a time in intervals of 11 PM to 7.30 AM.

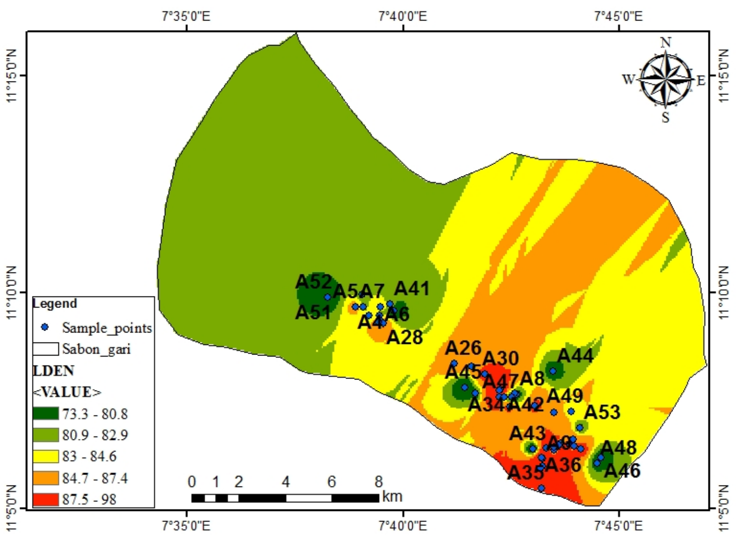

Figure 6. The diurnal L_{DEN} average noise level mapping for the summation of day time, evening, and night time intervals, respectively.

line in Samaru Market to the minimum value of 64 dB (A) at Lemu market. For the diurnal logarithmic mean of L_D, L_E, and L_N time intervals which is represented as L_{DEN}, it exceeded the WHO standard in all the surveyed sites and 83.3% of the surveyed site (10 sites) exceeded the NESREA standard. While it ranged from the maximum value of 93.5 dB (A) at Tecno PZ to the minimum value of 73.5 dB (A) at Lemu market. In a related study conducted in the selected markets, shopping centers in commercial areas in Panag (38,39), in Federal Capital Territory (FCT) Abuja (34), and Illorin (33), and in Akwai-Ibom (40). The L_D, L_N, and L_{DN}, with a different approach in their studies exceeded the WHO and NESREA standard in most of the surveyed sites as presented in Tables 2 and 3, (though without consideration to the evening noise level intervals (L_E)) (12, 38). The noise quality grading showed that 43.3% of surveyed sites were of unsatisfactory quality, 66.7% were of hazardous quality while 3.3% were of unallowed noise quality, for the L_{EQ}, L_D, L_E, L_N, and L_{DEN}. The noise quality grading was according to the related noise grading in a study conducted in FCT Nigeria, though in which the L_E was not considered (34) and a related study in Owerri Metropolis (41). The variation of noise level from maximum to minimum and quality grading were as a result of the variation of the concentrations of traffic, commercial activities, generators, hawking, grinding machines, and human population in different selected commercial areas (3,11,33,42). These findings are consistent with the results of a related study conducted in Nigeria (3,23,28,33,34,43), in Penang and the WHO noise quality classifications (3,22,38,39).

Table 5 showed the diurnal noise level of the selected major intersections for the surveyed sites. The logarithmic diurnal equivalent average L_{EQ}, L_D, L_E, L_N, and L_{DEN} for each of the studied intersections exceeded the WHO and NESREA standard as presented in Tables 2 and 3. L_{EQ} ranged from the maximum value of 92.5 dB (A) at Kwangila site (1) to the minimum value of 82.8 dB (A) at ABU site (2). The L_D ranged from the maximum value of 93.0 dB (A) at Kwangila site (1) to the minimum value of 83.6 dB (A) at ABU site (2). The L_E ranged from the maximum value of 92.7 dB (A) at Kangilar site (3) to the minimum value of 81.4 dB (A) at ABU main gate site (2). The L_N ranged from the maximum value of 92.1 dB (A) at Kwangila site (1) and the minimum value of 81.6 dB (A) at ABU main gate site (2). For the L_{DEN} which was the diurnal average of L_D, L_E, and L_N, its range from the maximum value of 97.2 dB (A) at Kwangila site (1) and the minimum value of 88 dB (A) at ABU main gate site (2). For the noise quality grading of the road intersections, about 66.7% (6 sites) for the L_{EQ}, L_D, and L_E was graded as hazardous quality whereas 33.3% (3 sites) was graded as unallowable quality, for the L_{EQ}, L_D, L_E, and L_N, about 88.9% (8 sites) was graded as hazardous quality, while 11.1% was graded as unallowable quality. For the L_{DEM}, 33.3% (3 sites) was graded as hazardous noise level while 66.7% (6 sites) was graded as unallowable quality. The quality grading was consistent with the WHO quality grading and the findings of the study conducted in FCT Abuja Nigeria (34) and in Owerri Metropolis (40) where the noise quality of most of the selected study sites was beyond the acceptable standard. It was also observed that noise levels at the road intersections were higher in comparison with those in the commercial surveyed sites. The variations in the noise level for L_{AEQ}, L_D, L_E, L_N, and L_{DEN} from maximum to minimum were a result of the concentrations of human activities in the surveyed sites. Related studies by the WHO (2,6,14), NESREA standard of Nigeria noise level (3,7), Oyedepo abd Saadu (33), Okwudili et al (41), and other related studies affirmed that when noise level exceeded the recommended standard, the exposed populations could be predisposed to the effects of noise pollution, which might be physiological and psychological effects of noise pollution (9,12-15,23,24,40,43-48), as reaffirmed by this study.

Table 6 presented the logarithmic equivalent average, $L_{(EQ)}$, L_D, L_E, L_N, and L_{DEN} for the 15 purposeful selected roads/streets noise surveyed. The L_{EQ}, L_D, and L_E in the 15 surveyed sites exceeded the WHO standards while in 14 sites (93.3%), they exceeded the NESREA standards. The L_{EQ} ranged from the minimum value of 71.3 dB (A) at Graceland to the maximum value of 85.0 dB (A) at Park road. The L_D logarithmic equivalent ranged from the minimum value of 72.8 dB (A) at Graceland road to the maximum value of 88.6 dB (A) at Park road. For the L_E, it ranged from the minimum value of 74.3 dB (A) at Graceland road to the maximum value of 86.9 dB (A) at Park road. For the $L_{Night(N)}$, it ranged from the minimum value of 71.4 dB (A) at Leather Research road to the maximum value of 85.5 dB (A) at Park road. While about 12 studied sites (80%) exceeded the NESREA standard and 3 surveyed sites (20%) were within the compared standards. The L_{DEN} logarithmic diurnal average ranged from the minimum value of 79.5 dB (A) at Grace land road to the maximum value of 95.7 dB (A) at Park road; it exceeded the WHO and Nigeria specification (NESREA) in all the 15 surveyed sites. These were affirmed with other related findings, though with different approaches (13,18,20,22,23,40-42). For the quality grading of the noise level of Table 6, for the L_{EQ}, L_D, and L_E, 100% of the study site was rated as unsatisfactory sound quality. For the $L_{(A)Night}$, 20% was graded as unsatisfactory quality while 80% (12 surveyed sites) was classified as hazardous noise quality. For the L_{DEN}, 13.3% (2 surveyed sites) was graded as hazardous quality and 87.3% (13 sites) were graded as unsatisfactory noise quality as emphasized by Anomohanran (34) and Okwudili et al (41). The differences in the diurnal noise level for the 15 locations were necessitated as a result of variations of sources of noise as discussed in Tables 4 and 5. The results of this study are consistent with the results of a related study conducted by the European Noise Commission in some

European countries (2,8,9,16), in the United States (5), in some states in Nigeria (3,13,17,18,39-50), in Kenya (45) and selected studies in Iran (23,47); presenting that noise level exceeded the national recommended standard and the WHO specified standard. This result is consistent with the result of this study and its related health consequences as outlined previously. It was observed that the diurnal noise levels in the major intersections as shown in Table 5 were relatively higher than that as shown in the selected roads/streets as shown in Table 5 and seen in the diurnal mean range of the L_{DEN}.

Table 7 showed the logarithmic equivalent average, L_{EQ}, L_D, L_E, L_N, and L_{DEN} for each of the 10 purposeful selected residential areas for the surveyed sites. For the L_{EQ}, the minimum value ranged from the minimum value of 66.2 dB (A) at Ijaw residential area to the maximum value of 74.4 dB (A) at Muchia area. L_D logarithmic equivalent average ranged from the minimum value of 67.6 dB (A) at Ijaw area to the maximum value of 78.0 dB (A) at Muchia. The L_E ranged from the minimum value of 67.8 dB (A) at Hanwa to the maximum value of 78.4 dB (A) at Muchia. The L_N ranged from the minimum value of 63.3 dB (A) at Dogorawa to the maximum value of 76 at Muchia. The L_{DEN} logarithmic average for each location ranged from the minimum value of 73.1 dB (A) at Grace land to the maximum value of 83.0 dB (A) at Muchia. The noise level exceeded the WHO standard and NESREA, respectively (22,33). Some researchers such as Oyedepo and Saadu (33), Omubo-Pepple et al (46), Anomohanran (34), Ononugbo et al (49), Akpan (40), Kiani Sadr et al (28), Negahdari et al (23), Okwudili et al (41), the WHO (25), and Motelleani et al. (27), reported the prevalence of high noise levels in their respective studies and corresponding attendant health consequences. Table 5 showed the minimum noise level compared to Tables 2 to 4 and 6 of the categorized surveyed sites, which were a result of the less concentration and variation of human activities in the different surveyed sites as highlighted in the previous discussion. Regarding the quality grading, the logarithmic equivalent average $L_{(EQ)}$ was satisfactory in all the locations. For the L_D, 9 surveyed sites (90%) were of satisfactory quality and one site (10%) was of unsatisfactory quality. For the L_E, 8 surveyed sites (80%) were of satisfactory quality while 2 surveyed sites (20%) were of unsatisfactory quality. For the L_N, all the locations were of unsatisfactory quality which was a result of the proximity of the residential areas to sources of noise such as roads/streets, generators, and commercial activities. For the L_{DEN}, 4 surveyed sites (40%) were of satisfactory quality while 6 surveyed sites (60%) were of unsatisfactory quality. This corroborated well based on the classification of Table 1a, as well as the study conducted in FCT Abuja Nigeria (34) and Owerri Metropolis in Imo State (41).

Table 6 showed the diurnal noise equivalent for L_{EQ}, L_D, L_E, and L_{DEN} for mixed residential with commercial, light traffic, and industrial activities. The logarithmic mean equivalent (L_{EQ}) ranged from the maximum value of 85.5 dB (A) at Kips pure water to the minimum value of 73.7 dB (A) at Hanwa (MTN mast). The L_D ranged from 92.3 dB (A) at kips pure water to 73.6 dB (A) at Hanwa (MTN) mask. The L_E ranged from the maximum value of 92.2 dB (A) at Kips pure water to the minimum value of 73.9 dB (A) at Hanwa (MTN) mask. The L_N ranged from the maximum value of 88.9 dB (A) at Kips pure water to the minimum value of 73.2 dB (A) at Muncha block. The logarithmic diurnal average, L_{DEN} ranged from the maximum value of 92.3 dB (A) to the minimum value of 80.2 dB (A) at Hanwa (MTN) mask. For the WHO quality rating, for the logarithmic equivalent $L_{(EQ)}$, 3 surveyed sites (about 37.5%) were of satisfactory quality, while 5 surveyed sites (62.5%) were of unsatisfactory quality. For the daytime intervals (L_D), one site (about 12.5%) was satisfactory quality while 7 sites (87.5%) were of unsatisfactory quality. For the noise level during the evening noise time interval (L_E), 7 sites (about 87.5%) were of unsatisfactory quality while one site (12.5%) was of hazardous quality. For the nighttime intervals (L_N), 3 locations (37.5%) were of satisfactory quality, 2 sites (25%) were of unsatisfactory quality, while 3 sites (37.5%) were of hazardous quality. For the diurnal logarithmic mean $L_{(DEN)}$, 5 sites (62.5%) were of unsatisfactory quality while 3 sites (7.5%) were of hazardous quality. The findings are consistent with the results of related studies conducted by Anomohanran (34), on the environmental noise pollution in the selected mixed residential areas in FCT, the capital city of Nigeria, and Okwudili et al. in Owerri in Imo state (41). The diurnal variations in noise level from one surveyed site to the other sites were necessitated as a result of the nature of anthropogenic activities.

Figures 2 to 5 showed the spatial color dispersion of noise levels in surveyed sites for the L_D, L_E, L_N, and L_{DEN} logarithmic mean. The red and orange color dispersion represented the sites with a high noise level such as Kwangila intersection, Park roads, Muchia roads, commercial areas, and Tecno PZ, respectively, which was referred to as flashpoints. While the green and yellow color show sites with moderate and unsatisfactory grades with a less concentration of anthropogenic activities such as Hanwa, GRA, Dogorawa, Ijaw, and Gwado, respectively. The noise color variation of dispersion was necessitated by differences in the natural concentration of human activities such as commercial activities, generators, discotheques, hawking, loudspeakers, hooting, and traffic noise in the different surveyed sites. It was also observed that the nighttime noise level dispersions had the highest good quality grading in comparison with the L_D and L_E, this was as a result of the reductions of anthropogenic activities while the L_{DEN} which was the diurnal logarithmic summation of L_D, L_E, L_N had the highest unsatisfactory color noise dispersion. Most of the surveyed sites were predisposed to noise levels beyond the compared standard with its attendant health consequences. This study corroborated well with related studies by Oyedepo and Saadu (33), Akitunde et al. (21), Anomohanran (34), Akintuyi et al. (32), Setianto and Triandini (36), De kluijver and Stoter (16), Kiani Sadr et al (28), and Negahdari (23). They observed and suggested that sites, where noise level exceeded the national standard and the WHO standard (22,42) as well thought out in this study, might be susceptible to various health-related effects of noise such as presbycusis, annoyance, hearing impairment, headache, cardiovascular diseases, sleep disturbances, depreciation of mental capability and other noise-associated health hazards (12,23-31,50). The L_{DEN} noise spatial color dispersion mapping followed the recommendation by the European directive of community noise 2002 (2,31,32,48) and it is related to spatial noise mapping in Port Harcourt (3), Lagos state (32), the University of Jos in Nigeria (21), Nairobi, Kenya (45), chukgyu in Korea (31), and Kiani Sadr et al (28).

Conclusion

The evaluated measured noise level of the surveyed sites and spatial quality mapping of the Sabon- Gari Area in Zaria Metropolitan city revealed that the quality rating ranges from satisfactory quality to unsatisfactory quality. The highest spread of dispersion was related to unsatisfactory noise quality. The night-time noise level (L_N) had the highest spread of satisfaction in the special noise mapping in contrast with day time intervals (L_D), evening time intervals (L_E), night time intervals (L_N), and the L_{DEN}. There were no observable excellent, very good, and good noise level quality grading of all the surveyed sites. Some of the flashpoints were at Kwangila, PZ areas, Sabon-Gari Market, Park Road, Aminu road, Lagos Street, King's Road, ABU main gate, and MTD junction. The diurnal logarithmic average of all the studied locations exceeded the WHO standard and 98.1% exceeded the NESREA specifications with the maximum value of 98.2 dB (A) at Kwangila intersections to the minimum value of 73.1 dB (A) at Graceland and Ijaw residential area, respectively. The noise equivalent for $L_{Day\ (D)}$ and $L_{Evening\ (E)}$ was high in most of the surveyed sites in comparison with the $L_{night\ (N)}$. The diurnal variation of the noise level intensities was a result of variations of concentrations of anthropogenic activities from the different surveyed sites. This could suggest that the predisposed populations were subjected to the health-related effect of environmental noise, which could range from physiological effects to phycological effects such as hearing impairment, annoyance, stress, distraction, aggressiveness, restlessness, information distortion, tinnitus, facilitation of mental illness, impaired efficiency, and cardiovascular diseases. The predominant sources of noise during these studies were traffic, generators, commercial, noise from light industries, construction noise, and domestic noise activities, respectively.

Resourceful maintenance of silencers and vehicle suspensions to decrease rolling stocks will facilitate the mitigation of traffic noise in both urban and suburban areas. Deliberate emphasis on the importance of ear protective devices by recipients where noise pollution exceeded the recommended standard would serve as an extenuating measure to the effects of environmental noise pollution by government and non-government agencies. Planting of trees with dense foliage has been established to be very effective in absorbing the acoustic noise and installation of noise barriers where noise pollution has been well-known to be above the recommended threshold.

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Ethical issues

The ethical attention for the study was well-thought-out and obtained from panel professionals from Department of Water Resources and Environmental Engineering, Ahmadu Bello University Zaria Kaduna State, Nigeria, in September 6, 2019.

Competing interests

The authors declare that there is no conflict of interests.

Authors' contributions

Idoko Abraham Apeh contributed to conceives, developed the design, filed work, analysis, and drafting of the manuscript. Prof. Bamidele Igboro contributed to supervision. Saulawa Badrudden Sani performed supervision, and Chukwuemeka Eneogwe performed drafting of the manuscript.

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