



## Research Article

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# Geospatial analysis of environmental noise levels in a residential area in Lagos, Nigeria

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**Abstract:** Noise is an inevitable part of daily life and has been identified as a cause of several health deficiencies across the world. It has increasingly become a significant concern on the health and well-being of people. Studies are required to advance knowledge on the sources and impacts of noise in residential neighbourhoods of Lagos State, Nigeria. Therefore, this study assesses the spatial variation of noise levels within a section of the Festac residential area in Lagos in line with noise limits specified by the World Bank Group International Finance Corporation (IFC) Environmental, Health, and Safety (EHS) Guidelines and the Nigerian National Environmental Standards and Regulations Enforcement Agency (NESREA) Noise Standards and Control guidelines for community noise. Data for this research come from a field study comprising measurements of noise levels from 6 observation stations and questionnaire survey with 200 respondents. The criteria for siting the stations was based on factors such as proximity to the roadside, land use and population density, while the questionnaire was administered at random to assess the peoples' level of awareness on the sources and effects of noise. A digital sound level meter was used to measure noise level variations over a period of 3 weeks for morning, afternoon and evening periods. The measured noise levels were analysed using Analysis of Variance (ANOVA) statistics and the Kriging Geostatistical interpolation technique. Also, logistic regression was used to determine the rela-

tionship between the respondents' perceptions to noise and noise levels. The results indicated that the mean noise levels were within the approximate range of 53.5 – 94.0dBA over the entire period. The highest mean noise levels occurred in the north-western part of the study area where a bus park is present. In general, the noise levels in the area surpass the recommended noise limit of 55dBA, and the logistic regression showed that morning, afternoon and evening mean noise levels were significant predictors of noise variation as perceived by the dwellers. Proper legislation to regulate human activities with respect to noise generation is highly recommended to the local, state and national legislators.

**Keywords:** noise level, noise mapping, geographic information system, Kriging interpolation

## 1 Introduction

Noise can be defined as unwanted sound, and it is produced from a multitude of sources. The responses of individuals to noise can vary widely in proportion to the number of activities producing the noise [1]. There are two very important attributes of sound or noise: loudness and frequency. Noise can be said to be loud if it has a larger pressure variation and can be weak if it has a smaller pressure variation. The frequency of sound is defined by the number of pressure variations per second. Because the human ear can detect a wide range of sound frequency levels from approximately 20 to 20,000 Hertz [2], they are measured on a logarithmic scale with units of decibels (dBA). For years, the assessment of environmental sound characteristics has been an important part of research in several fields [3]. It has been applied in areas such as acoustics [4, 5], urban design/planning [6–8], and environmental monitoring [9–11].

Noise is an inevitable part of our daily activities and has increasingly become a significant concern on the satisfaction of lives. Ozdemir *et al.* [12] define noise as the level of sound which exceeds the acceptable level and creates

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annoyance. Noise has also been described as sound without agreeable musical quality or as an unwanted or undesired sound [13, 14]. Environmental noise exposure is associated with an increased risk of negative psychological and physiological health issues [15]. Noise pollution has increasingly and consistently threatened the mental and physical health for urban populations worldwide [16, 17]. Noise is transmitted usually through a medium such as air [18, 19]; and may be perceived as undesirable or desirable when it reaches the ear. Noise can produce an undesired physiological or psychological effect in an individual and may also interfere with the social ends of an individual or group [1, 20–23]. According to Guski *et al.* [24], environmental noise annoyance is a retrospective judgement comprising of previous experiences with a noise source over a particular period, and there are three elements to the noise annoyance response: a frequently repeated disturbance caused by noise, an attitudinal/emotional response, and a cognitive response. Noise also leads to fragmented sleep, reduced sleep continuity and reduction in the total sleep time [25].

Noise emanates from different sources such as transportation [26], industrial activities [27], and the neighbourhood [28]. Elements of transportation noise include traffic density, aircraft noise and rail traffic noise [29]. Increase in vehicular traffic is also a source of noise pollution around the world especially in most cities. Industrial noise is produced by industrial machines from numerous industries, factories and mills. Noise can also be generated from apartments in a neighbourhood [30]. This sort of noise emanates from neighbourhood sources such as power generators, loudspeakers, radio sets, fireworks, the barking of dogs, parties, music, and television sets. In Nigeria, electricity power is very poor. As a result, there is an increase in the use of electricity generating equipment (generators) which has a confounding and harassing effect on human sensibilities. According to Akinbulire *et al.* [31], generating plants are used in many homes and workplaces as an alternative source of power supply. Noise is distinguished from other pollution categories due to its source and diffusion characteristics, which can adversely affect public health and environmental quality in the urban environment [12].

Noise mapping is commonly used for visualising noise level exposures, statistics of the affected population, the contributions of noise sources; and it is also a tool for the design of noise-control plans [32]. Several researches have deployed geospatial techniques for the mapping of field-observed noise pollution. For example, Oyedepo *et al.* [33] assessed and mapped noise pollution levels in Ota metropolis, Nigeria using Geographic Information System (GIS). A precision grade sound level meter was used for

the noise level measurement on some selected observation points. The noise map developed was based on the computed values of average equivalent noise for the selected locations and acceptability was determined based on the standards of the United States (US) Department of Housing and Urban Development. Xu *et al.* [34] proposed a hybrid GIS approach including a semi-supervised tensor completion algorithm and a neighbourhood-based noise level estimation technique for noise level prediction using urban data sources such as check-in data, route networks and points of interest. Their technique was capable of predicting noise levels using sparse measurements from smartphone users, and also outperformed other methods. Ibekwe [35] evaluated the environmental noise levels in Abuja municipality of Nigeria between January 2014 and January 2016 using mobile phones to promote a simple method for regular assessment of noise levels. A digital sound level meter was used to validate the measurements taken with the mobile phone software, and this confirmed the validity of mobile phones in monitoring environmental noise. In the findings, it was shown that the daily noise levels in Abuja municipality were above the recommended tolerable values by the World Health Organisation [36].

In order to prevent negative effects, the World Health Organisation (WHO) recommends avoiding exposure to noise levels over 53 decibels. There are maximum acceptable noise levels (continuous equivalent sound levels –  $L_{Aeq}$ ) for different environments recommended by the World Bank Group International Finance Corporation (IFC) Environmental, Health, and Safety (EHS) Guidelines 2007 ([www.ifc.org/ehsguidelines](http://www.ifc.org/ehsguidelines)). According to the IFC, noise impacts in residential areas (outdoors) should not exceed 55dBA during daytime (7pm–10pm) and 45dBA at nighttime (10pm – 7am). The IFC noise guidelines “are widely accepted and used for developing offsite sound level limits in jurisdictions without regulatory environmental noise criteria, or for proposed projects seeking financing from the World Bank Group or other large-scale financing organisations” (<http://www.noise-ordinances.com/canadian-noise-regulations-and-bylaws/>). Maximum permissible noise limits ( $L_{Aeq}$ ) for various land uses such as religious worship centres, factories, residences, commercial business districts, place of entertainment, and construction sites are also enumerated in the Nigerian National Environmental Standards and Regulations Enforcement Agency (NESREA) Noise Standards and Control guidelines for community noise [37]. For mixed residential areas, the maximum permissible noise limits specified by NESREA are 55dBA at daytime (6am – 10pm) and 45dBA at nighttime (10pm – 6am). Other countries have also introduced noise regulations and guidelines. For example, the Envi-

ronmental Noise Guideline - Stationary and Transportation Sources – Approval and Planning (NPC-300) by the Ministry of the Environment and Climate Change, Canada, Noise Control (General) Regulations 1989 by the China - Hong Kong Special Administrative Region, and the Noise Regulation Law No. 98 of 1968 and No. 91 of 2000 by the Ministry of the Environment, Government of Japan. In 2002, the European Union issued the Environmental Noise Guidelines Directive (2002/49/EC) to improve the noise situation in Europe, and since the year 2012, noise levels on major transportation routes and in all agglomerations in Europe need to be recorded [38]. Following the Parma Declaration on Environment and Health in 2010, member states in the WHO European Region called on the WHO to develop updated environmental noise guidelines [15]. The WHO Environmental Noise Guidelines for the European Region were subsequently released in 2018.

Like many other megacities in the world, noise pollution in Lagos State, south-western Nigeria has negatively impacted the productivity of the urban dwellers and contributed to poor mental health [39, 40]. The environmental noise situation within residential areas of Lagos, Nigeria can best be described as chaotic as there are no standard measures for regulating noise levels. Consequently, residents across the state have to contend with a daily barrage of debilitating noise from a multitude of sources. Research into noise level variation in residential areas of the state can serve to inform the state health bodies and environmental regulatory agencies on measures to curtail this scenario. In response, this study assesses the spatial variation of noise levels within a section of Festac residential area in Lagos, Nigeria and evaluates the noise level conformity in line with the World Bank Group IFC (EHS) 2007 and NESREA 2009 guidelines on acceptable noise levels in the residential environment. The study has the following objectives: to determine the minimum ( $L_{A\min}$ ), maximum ( $L_{A\max}$ ) and continuous equivalent noise levels ( $L_{Aeq}$ ) at different locations within the residential area; to analyse the noise level variations using kriging spatial interpolation; to analyse the relationship between noise levels in the morning, afternoon and evening periods, and to compare the measured noise levels with the guidelines for noise levels in residential areas. Environmental noise is also associated with annoyance [24, 41], sleep disturbances [25], disruptions to cognition [42], and other adverse health effects. Therefore, a further objective is to evaluate the awareness of residents to the sources and effects of the noise through a questionnaire survey considering frequency of fuzzy responses on annoyance levels and frequency of boolean responses on various sources of noise;

and to evaluate the relationship between residents' perceptions of noise sources and the measured noise levels.

## 2 Methodology

### 2.1 Study area

The study was conducted in a section of Festac Town in Amuwo–Odofin Local Government Area (LGA) of Lagos State metropolis, Nigeria in West Africa. Figure 1 shows a map of the study area. Festac is geographically situated between Latitudes  $6^{\circ}22'23''$  –  $6^{\circ}28'52''$ N and Longitudes  $3^{\circ}16'03''$  –  $3^{\circ}18'09''$ E, and covers a large area of 1770 hectares. Festac Town is a Federal Housing Estate constructed in 1977 and located along the Lagos – Badagry Expressway in Lagos. The over 5,000-unit housing estate has metamorphosed into a city-within-a-city and now serves as the headquarters of Amuwo–Odofin LGA [43]. The town was built in a grid network consisting of seven major roads/boulevards or avenues. Overtime, the beauty, allure and aestheticism of Festac Town have been eroded due to poor maintenance and decaying infrastructure. In a recent report on the estate, Bakare [43] noted that many of the windows in the housing units were broken, the gates were visibly rotten, and the general aesthetics of an ideal housing unit were lacking. It has also been reported that power supply is also irregular making many residents resort to generating sets with its attendant high cost of fuel.



Figure 1: Map showing the location of the study area

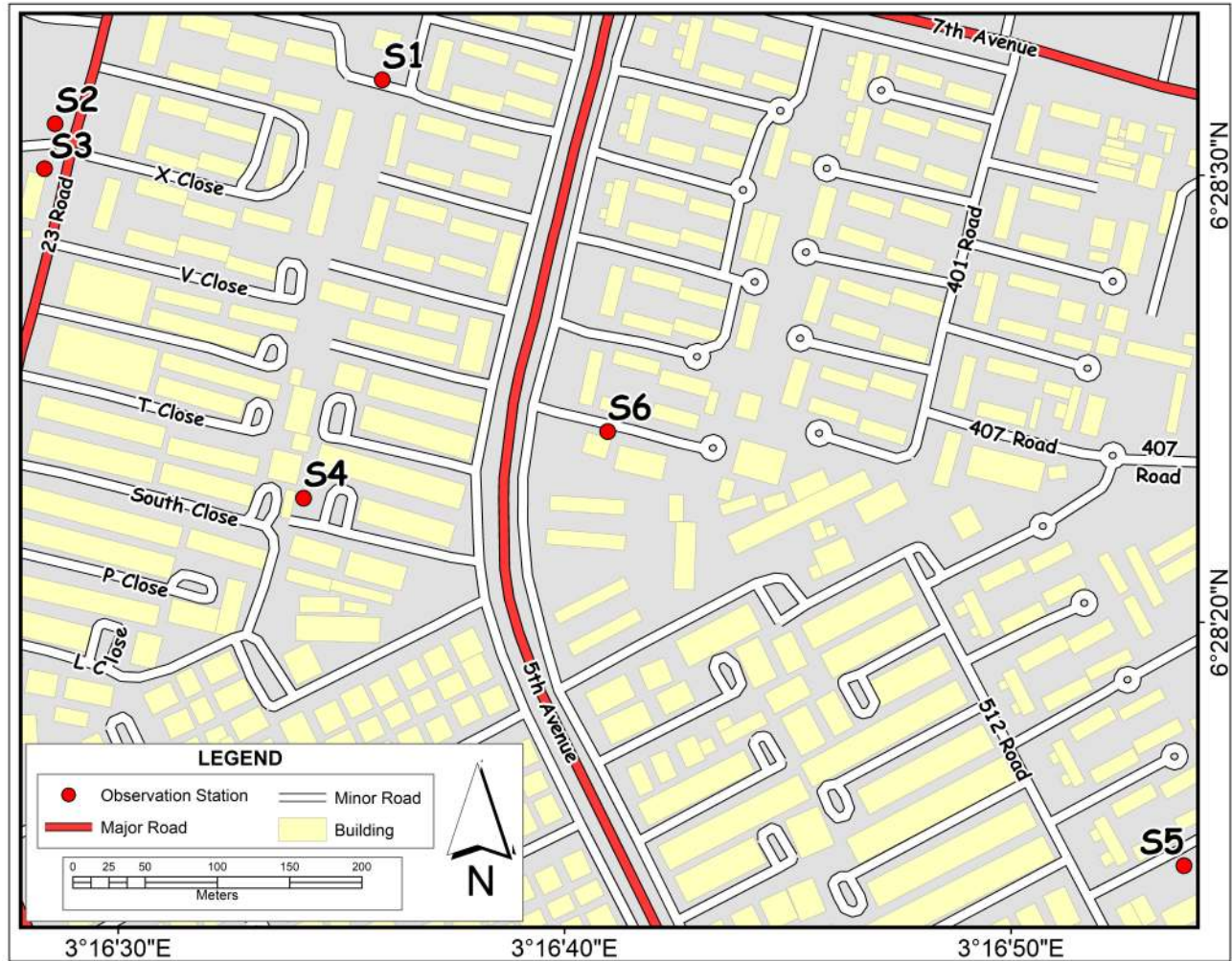


Figure 2: Map showing the spatial distribution of the observation stations

Table 1: Observation stations and codes

ID	Location name	Station code
1	Residential/open space (stone field)	S1
2	Residential/Oyinlola market (23 road)	S2
3	Residential/Bus park (Last bus stop)	S3
4	Low density residential area (5 <sup>th</sup> avenue)	S4
5	High density residential area (512)	S5
6	Residential/religious area (5 <sup>th</sup> avenue)	S6

Despite all these setbacks, transportation and commercial activities are thriving in the midst of the residences. The combination of commerce, busy transportation and the emergence of generators has turned the area into a residential soundscape that requires urgent attention.

## 2.2 Station selection

Six stations were selected for this study based on the sampling by land use category according to Brown and Lam [44]; with other selection criteria based on proximity to the road side, road intersections, land use types and population density (Figure 2). Each station was selected to capture unique environmental types as shown in Table 1. However, locations with sound-reflective surfaces were avoided due to their influence on measured sound pressure levels.

Figure 3 presents a view of some observation stations.



Figure 3: View of some observation stations (a) Station 5 (b) Station 1 (c) Station 3 and (d) Station 2

### 2.3 Noise measurement procedure

Data on noise level measurement were collected at the six stations (S1 to S6) over a period of 3 weeks from 19 August to 8 September 2019 using a digital sound level. There were interruptions caused by rainfall on a few days. However, a total of 114, 123 and 118 noise level readings were recorded for the morning, afternoon and evening period respectively. The sound level meter is a type II, portable direct noise measuring device according to IEC 651 specifications. A type II sound level meter is a general-purpose grade for field use with a tolerance of  $\pm 1.0$  dB for measuring noise at work and in basic environments. The sound level meter is an integrated averaging sound level handheld meter with 30 – 130 dB measuring range. The instrument is fitted with a microphone digital sound level meter set on A-weighting which according to Onuu and Inyang [45] is recommended by many agencies. A-weighted continuous equivalent sound level ( $L_{Aeq}$ ), instantaneous minimum ( $L_{A\min}$ ), and maximum ( $L_{A\max}$ ), sound level measurements were taken for a period of 10 minutes per

station for three weeks daily. This procedure was carried out across three periods in the morning, afternoon and evening which are between 7:00 – 8:30 am, 12:00 – 2:00 pm, and 7:00 – 8:30 pm respectively. These periods are among the busiest periods and are fairly representative of environmental noise variations within the study area at daytime. In this study, the  $L_{Aeq}$  was the noise indicator that was considered. The  $L_{Aeq}$  is the logarithmic or energy-averaged noise level which was computed from the instantaneous noise levels,  $L$ , at slow response time (30s) for a period of 10 minutes using equation 1 [33, 46] and the arithmetic mean which is the average of  $L_{Aeq}$  measurements for all stations over the 21 days was also computed for morning, afternoon and evening [47, 48].

$$L_{Aeq} = 10 \log \left( \sum f_i \cdot 10^{L_i/10} \right) \quad (1)$$

Where:

$f_i$  = fraction of total time the constant level  $L_i$  is present

$L_i$  = sound level in dBA

## 2.4 Questionnaire Survey

Using a convenience sampling technique, a structured questionnaire was administered to 200 respondents between the ages of 18 and 65 years at the neighbourhood of the six stations. The convenience sampling (a non-probability sampling technique that entails distributing the questionnaires to respondents/residents who are easy to contact or reach) method was adopted. Of the 200 recipients of the questionnaire, 181 were successfully retrieved. The questionnaire extracted the basic social and demographic characteristics (gender, age, location of residence etc.), neighbourhood noise awareness (is there a problem of noise pollution? - yes/no, do you experience daily noise disturbance? - yes/no), degree of annoyance level from noise (low: 0-2, moderate: 3-5, high: 6-8 and very high: 9-10), sources of noise (vehicles - yes/no, people - yes/no, animals - yes/no, religious places - yes/no, household mechanical and electrical devices as well as other sources such as music and fireworks - yes/no), impacts of noise in the environment and health effects of noise (do you experience headache from noise pollution? - yes/no, does noise pollution result in loss of sleep/insomnia? - yes/no, does noise pollution cause stress? - yes/no). These questions are similar to those in the works of Okokon *et al.* [41], Paiva *et al.* [49] and WHO [50]. The questionnaire items addressed annoyance levels, sources of noise and the effect of the noise on the health of the residents. The respondents' age range of 18 – 65 years is within the working age range in Nigeria. Also, it is believed that individuals within this age bracket have good situational awareness of their surroundings and can provide clear and accurate responses. After the survey, the questionnaire responses were subjected to descriptive statistics.

## 2.5 Quantitative analysis

Noise data was analysed using descriptive statistics and one-way analysis of variance (ANOVA) to test for the temporal variation in the level of noise (morning, afternoon and evening periods). The null hypothesis ( $H_0$ ) is that there is no significant difference in the noise levels within the morning, afternoon and evening periods. The alternative hypothesis implies a significant variation in the noise levels within these periods. The next analysis considered a binary logistic regression to evaluate the relationship between the respondents' perceptions on various noise sources and observed noise levels. The mean values for the morning, afternoon and evening periods were used as the independent continuous variables while the dependent or-

dinal variable was binary. The binary variable was determined from the respondents' boolean responses (yes/no – 1/0) to the noise sources as presented in the questionnaire. Logistic regression analysis is a statistical technique which evaluates the relationship between various predictor variables which could be either categorical or continuous and an outcome which is binary (dichotomous). It is based on central mathematical concept of the logit – the natural logarithm of an odds ratio [51, 52]. It is suitable for describing and testing/validating hypotheses on relationships between a categorical outcome variable and one or more categorical/continuous predictor variables. The simple logistic model has the form as shown in equation 2 [51]:

$$\text{Logit}(Y) = \text{natural log}(odds) = \ln\left(\frac{\pi}{1-\pi}\right) = \alpha + \beta X \quad (2)$$

Taking the antilog of equation 2 on both sides, one derives an equation to predict the probability of the occurrence of the outcome of interest as follows (equation 3):

$$\pi = \text{Probability}(Y = \text{outcome} | X = x, \text{ a specific value of } X) = \frac{e^{\alpha + \beta x}}{1 + e^{\alpha + \beta x}} \quad (3)$$

where  $\pi$  is the probability of the outcome of interest or “event”,  $\alpha$  is the Y intercept,  $\beta$  is the regression coefficient, and  $e = 2.71828$  is the base of the system of natural logarithms. While Y is always categorical, X can either be categorical or continuous. For the regression, the questionnaire responses were analysed to isolate the proportion of respondents that affirmed the presence of noise sources and their impacts. The percentage of the number of responses to “Yes” based on the total number of respondents for the stations was determined which represented the probability of noise from the sources as presented. The average of the probabilities from all the noise sources was computed to determine the probability of noise from the surroundings of the stations, and interpolation was done for the probability values. In line with Akkala *et al.* [53], a grid of additional sample points was created with which the interpolated noise levels and probability values were extracted using the Spatial Analyst tool in ArcGIS software environment. The categorical responses from the respondents represent the dependent variable while the noise levels for morning, afternoon and evening are the covariates (independent variables). The logistic regression model tool on SPSS was deployed for the analysis.

## 2.6 Generation of noise level maps

According to Sonaviya and Tandel [54], noise maps are very useful for the identification of noise sources. The sur-

face distribution of the mean noise levels at the six stations was represented graphically using Ordinary Kriging (OK) interpolation. Kriging is a widely used Geostatistical interpolation technique [55] that considers autocorrelation (the statistical relationship among measured points) [56]. With kriging, visually appealing models can be created from data that is irregularly spaced [57]. The application of Kriging interpolation for noise mapping has been shown in previous studies [58–60]. The statistical theory of kriging is well established and it can estimate errors point-by-point [55]. These attributes make it suitable for the present study. Ordinary kriging is the primary method in the kriging family [61] and the most recommended univariate method of kriging [62, 63]. It is also the most commonly applied for large spatial datasets [57]. The general assumption of OK interpolation is that of random spatial processes with stationarity, and it aims to provide a non-biased estimate with minimisation in the error variance [61, 64–67]. The OK formula is given by Harman *et al.* [60] and Wu *et al.* [61]:

$$Z(x) = \sum_{i=1}^n W_i Z_i \tag{4}$$

where  $Z(x)$  is the estimated value at a predicted point,  $Z_i$  is the observed value at point  $i$ , and  $W_i$  is the weight value assigned at point  $i$ . In the OK system, the weight value ( $W_i$ ) is assigned by considering the distance between sampled and unsampled points, and the spatial correlation between these points [61]. To ensure that the results are not biased, the following condition must be maintained:

$$\sum_{i=1}^n W_i = 1 \tag{5}$$

The expression for the error variance ( $\sigma^2$ ) also follows from Wu *et al.* [61]:

$$\sigma^2 = \frac{\sum_{i=1}^n (Z(x) - Z_i)^2}{n} \tag{6}$$

where  $n$  is the number of data points. For the error variance to be minimised, the derivatives of Eqn (6) over each weight should equal zero. A process of variography is used in OK for modelling the spatial autocorrelation of the datasets to assign weights and this can lead to better point interpolations, but since it involves many user decisions, the results are still subjective [62, 63]. The default settings for kriging can be adopted to produce an accurate model, or the model can be custom-fit to the dataset by selecting an appropriate variogram model [57, 68]. The OK interpolation for the noise maps was implemented with the Spatial Analyst extension in ArcGIS 10.4 software using a spherical semivariogram model and a search radius that included all known points.

### 3 Results and discussion

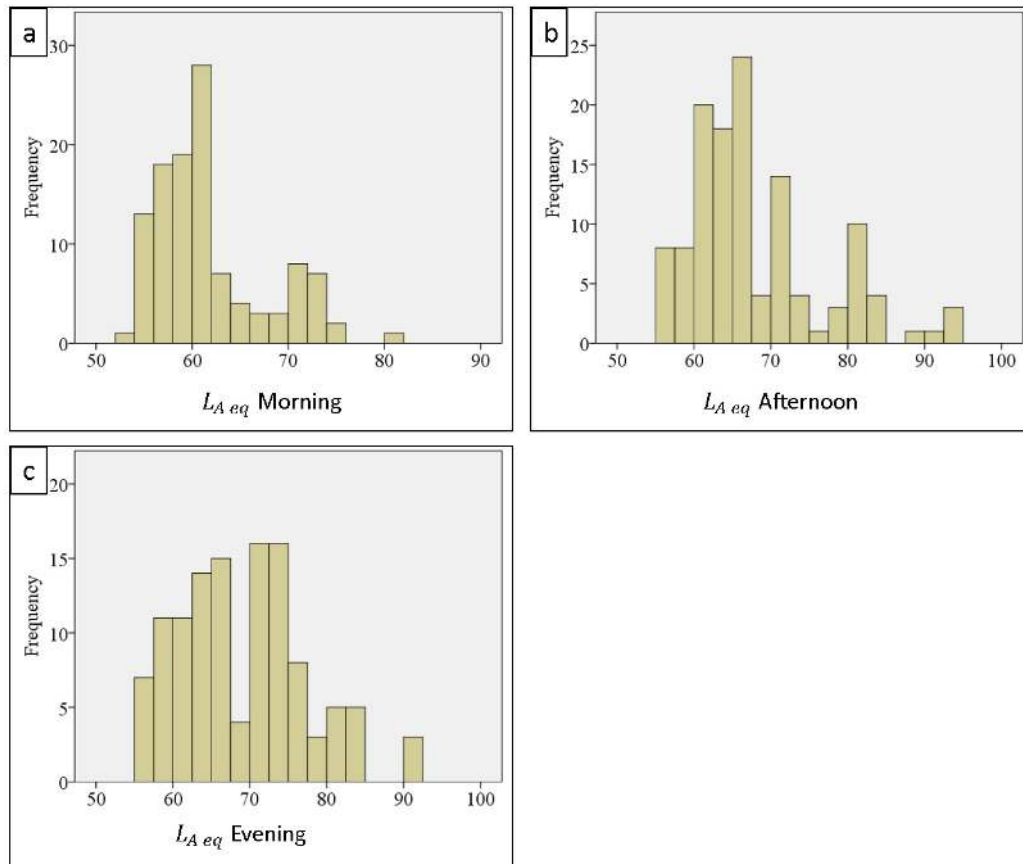
#### 3.1 Noise level analysis

Figure 4 shows a fairly normal distribution in the variation of daily noise levels at the three periods of observation. In the morning, the mean noise level was 61.81dBA, and the noise levels ranged from 53.50 – 81.6dBA. In the afternoon, the mean noise level was 68.06dBA, and the noise levels ranged from 55.00 – 94.00dBA and in the evening, the mean noise level was 68.88dBA, and the noise levels ranged from 55.30 – 92.00dBA.

Table 2 shows descriptive statistics of noise levels at all stations for the morning period. The count (N) is the number of daily observations for all stations in 3 weeks per period of the day. The highest mean noise levels were observed on Sunday (64.53dBA) and Friday (62.18dBA) while the lowest mean noise levels were observed on Wednesday (60.75dBA) and Thursday (61.12dBA). During the week, the highest noise levels were observed on Monday and Friday while Sunday had the highest noise level on the weekend.

**Table 2:** Descriptive statistics of  $L_{Aeq}$  noise levels – morning

Day	N	Mean $L_{Aeq}$	SD	SE	95% Confidence Interval for Mean		Min $L_{Aeq}$	Max $L_{Aeq}$
					Lower Bound	Upper Bound		
Mon	18	62.15	6.22	1.47	59.06	65.25	53.50	74.30
Tue	18	61.42	5.06	1.19	58.90	63.94	54.80	71.70
Wed	18	60.75	6.00	1.42	57.76	63.73	54.40	73.90
Thu	18	61.12	5.19	1.22	58.54	63.70	54.40	71.70
Fri	18	62.18	6.11	1.44	59.15	65.22	55.40	73.70
Sat	12	61.23	5.23	1.51	57.91	64.55	54.90	75.00
Sun	12	64.53	7.98	2.30	59.46	69.60	54.20	81.60
Total	114	61.81	5.90	0.55	60.72	62.90	53.50	81.60



**Figure 4:** Variation in daily noise levels at the three periods of observation (a) morning (b) afternoon and (c) evening

The Standard Deviation (SD) values of noise level on weekdays range from 5.06 – 6.22dBA while for the weekend, it ranged from 5.23 – 7.98dBA. There is some level of consistency in the mean noise levels on weekdays, as the range does not exceed 1.43dBA. The lowest SDs and SEs are observed on weekdays: Tuesday (SD: 5.06dBA; SE: 1.19dBA) and Thursday (SD: 5.19dBA; SE: 1.22dBA). This suggests that the samples observed on Tuesday and Thursday have a tighter grouping with the means. The highest SDs and SEs are observed on Sunday (SD: 7.98dBA; SE: 2.30dBA). These high SDs on the weekend shows that the noise level values are not repeatedly close and suggest that neighbourhood activity does not pick up fast on the weekend mornings. The high SEs show that the sample measurements are highly spread far apart from the mean. Overall, the highest morning noise levels of 75.00dBA and 81.60dBA were recorded on Saturday and Sunday respectively. The explanation for this might be attributed to the fact that residents do not get to leave home early on Saturday mornings. As such, more people at home and in the neighbourhood on weekend mornings mean more noise activity going on at such times. Figure 5 presents the mean  $L_{Aeq}$  for the morning period derived by kriging interpolation.

Figure 5 reveals the highest mean  $L_{Aeq}$  noise levels occurring in the region around Station 3 where a bus park is present. The lowest noise levels occur around Station 2 and in the immediate vicinity of Station 4. The presence of a bus park around Station 3 might lead to high vehicular activity during the morning rush-hour along 23 Road as pedestrians and residents depart for work and business. The environment around stations 1, 4, 5 and 6 are generally in the range of 60.1 – 64dBA.

Table 3 shows descriptive statistics of  $L_{Aeq}$  noise levels at all stations for the afternoon period. The highest mean noise levels were observed on Thursday (70.79dBA) and Saturday (72.24dBA) while the lowest mean noise levels were observed on Wednesday (66.90dBA) and Sunday (63.07dBA). The SD values of noise level on weekdays range from 6.64 - 26.96dBA while for the weekend, it ranges from 4.96dBA to 11.25dBA respectively. Unlike the morning period, there is a wider variation in the noise levels on afternoon weekdays indicative of more heightened and irregular activity at this period. The highest SDs and SEs are observed on Wednesday (SD: 9.15dBA; SE: 2.36dBA), Thursday (SD: 11.20dBA; SE: 2.64dBA), and Friday (SD: 6.84dBA; SE: 1.61dBA). The lowest SD and SE is observed on Sun-



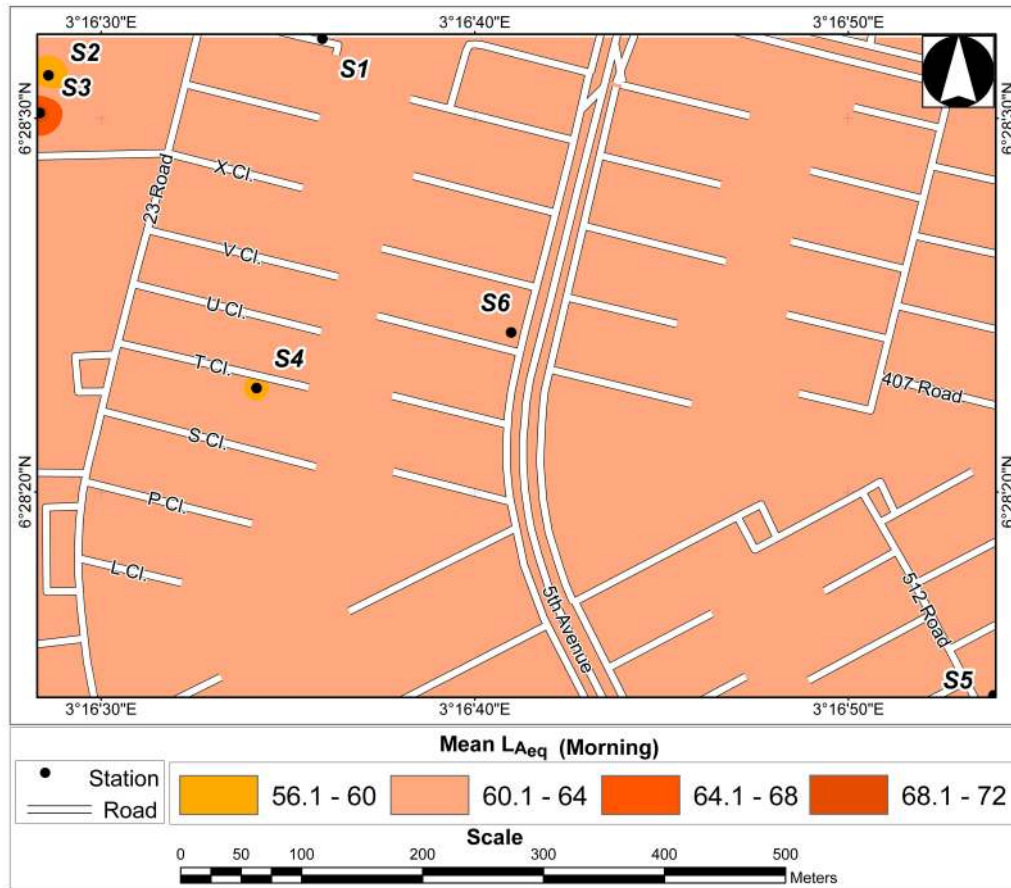


Figure 5: Mean  $L_{Aeq}$  for the morning period derived by kriging interpolation

Table 3: Descriptive statistics of  $L_{Aeq}$  noise levels – afternoon

Day	N	Mean $L_{Aeq}$	SD	SE	95% Confidence Interval for Mean		Min $L_{Aeq}$	Max $L_{Aeq}$
					Lower Bound	Upper Bound		
Mon	18	67.59	7.76	1.83	63.73	71.46	56.80	84.30
Tue	18	67.04	6.64	1.56	63.74	70.35	59.70	79.80
Wed	15	66.90	9.15	2.36	61.83	71.97	55.40	83.70
Thu	18	70.79	11.20	2.64	65.22	76.36	55.80	93.50
Fri	18	68.62	6.84	1.61	65.22	72.02	57.20	88.10
Sat	18	72.24	11.25	2.65	66.64	77.83	58.40	94.00
Sun	18	63.07	4.96	1.17	60.60	65.54	55.00	72.60
Total	123	68.06	8.77	0.79	66.50	69.63	55.00	94.00

day (SD: 4.96dBA; SE: 1.17dBA). Saturday and Thursday are days with the highest maximum noise levels of 94.00dBA and 93.50dBA respectively.

Figure 6 presents the mean  $L_{Aeq}$  for the afternoon period derived by kriging interpolation. The highest noise levels are observed at Stations 2 and 3. However, the afternoon noise levels at both stations are significantly higher in the afternoon than what was observed in the morning period. The pattern shows that the noise level diminishes

with increasing distance from both stations. Noise levels at Stations 5 and 6 which were within the range of 60.1 – 64dBA in the morning period are now in the higher range of 64.1 – 68dBA during the afternoon.

Table 4 shows descriptive statistics of noise levels at all stations for the evening period. The highest mean noise levels were observed on Saturday (74.13dBA) and Monday (69.49dBA) while the lowest mean noise levels were observed on Tuesday (56.73dBA) and Friday (50.39dBA). With



Figure 6: Mean  $L_{Aeq}$  for the afternoon period derived by kriging interpolation

Table 4: Descriptive statistics of  $L_{Aeq}$  noise levels – evening

Day	N	Mean $L_{Aeq}$	SD	SE	95% Confidence Interval for Mean		Min $L_{Aeq}$	Max $L_{Aeq}$
					Lower Bound	Upper Bound		
Mon	18	69.49	9.82	2.32	64.60	74.37	55.60	83.60
Tue	15	68.07	4.48	1.16	65.59	70.56	60.70	73.90
Wed	18	68.51	6.66	1.57	65.19	71.82	57.90	79.80
Thu	18	68.98	7.62	1.80	65.19	72.77	58.60	82.60
Fri	13	69.77	8.44	2.34	64.67	74.87	57.10	91.30
Sat	18	74.13	10.22	2.41	69.05	79.21	55.60	92.00
Sun	18	63.32	5.65	1.33	60.51	66.12	55.30	74.10
Total	118	68.88	8.23	0.76	67.38	70.38	55.30	92.00

the exception of Saturday, higher noise levels are generally observed on weekdays with pronounced night parties likely due to a high number of relaxation centres and hotels in the study area. Although initially designed as a residential area, there are now hotels spread around Festac. The SD values of noise level on weekdays range from 4.48 – 9.82dBA while for the weekend, it ranges from 5.65 – 10.22dBA. The highest SDs and SEs are observed on Monday (SD: 9.82dBA; SE: 2.32dBA), Friday (SD: 8.44dBA; SE:

2.34dBA), and Saturday (SD: 10.22dBA; SE: 2.41dBA). The lowest SD and SE are observed on Tuesday (SD: 4.48dBA; SE: 1.16dBA). Friday and Saturday are days with the highest maximum noise levels with a record of 91.30dBA and 92.00dBA respectively. These high noise levels might be attributed to the likely increase of people at relaxation centres and hotels on Fridays and Saturdays. Figure 7 presents the mean  $L_{Aeq}$  for the evening period derived by kriging interpolation.



Figure 7: Mean  $L_{Aeq}$  for the evening period derived by kriging interpolation

Table 5: Analysis of variance

		Sum of squares	df	Mean square	F	Sig.
Morning	Between groups	129.212	6	21.535	0.607	0.725
	Within groups	3798.638	107	35.501		
	Total	3927.850	113			
Afternoon	Between groups	944.407	6	157.401	2.162	0.052
	Within groups	8444.136	116	72.794		
	Total	9388.543	122			
Evening	Between groups	1082.226	6	180.371	2.928	0.011
	Within groups	6837.936	111	61.603		
	Total	7920.163	117			

It is not unusual that in the evening, the highest noise levels are observed at Stations 2 and 3. However, the map shows some new trends. The generally high noise levels in the evening might be explained by the potential for heightened activity on Friday and Saturday evenings when residents seek outdoor relaxation after a work-filled weekend. With more people outdoor and vehicles on the road, the localised domains of point sources are levelled out as noise becomes very pervasive.

Table 5 presents the results of the analysis of variance tests. The analysis reveals that there are significant differences in noise levels within the evening period. A further investigation using the Tukey’s Post hoc test showed that the significant variation in the means of the evening noise levels occurred between Saturdays and Sundays only. No significant differences in mean noise levels were detected within the morning and within the afternoon periods respectively. This confirms the trend of inconsistent varia-

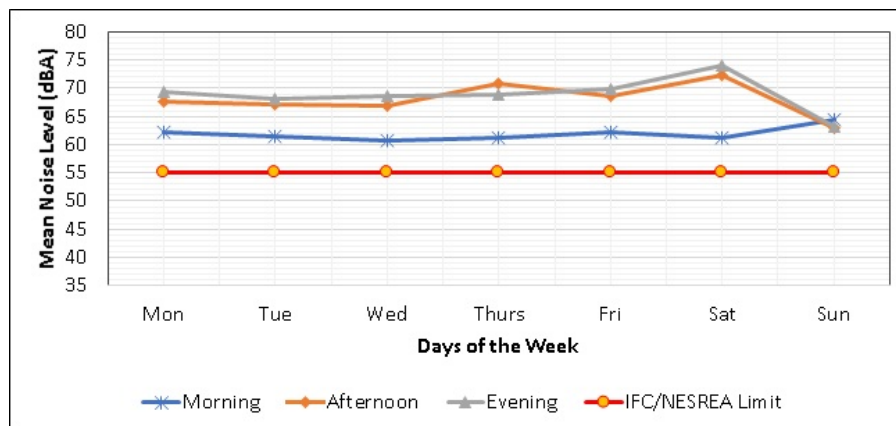


Figure 8: Comparison of the observed mean noise levels against the IFC EHS and NESREA limit

tion in noise levels observed especially in the afternoon and evening periods.

### 3.2 Assessment in line with noise guidelines

The observed noise levels were further analysed in line with the guideline of 55dBA for maximum allowable noise levels in residential areas as specified by IFC EHS and NESREA guidelines for daytime noise. Figure 8 shows the visual comparison of the observed mean noise levels against the limit. The noise levels in the morning are consistent during the weekdays and weekends around 60-65dBA. On all days, the morning, afternoon and evening mean noise levels are generally higher than the given limit. However, a much longer observation period would be required for a far-reaching conclusion.

### 3.3 Perceptions of respondents on sources and effects of noise

Results from the questionnaire survey showed that 72.71% of the respondents acknowledged the effects of noise generated from locations, predominantly caused by generator sets and loud music in the residential areas (open spaces). The different age groups also agree that noise generated from different activities affect them. Major sources of noise pollution in Festac Town vary with the different land uses. The analysis showed that 40.30% indicated that the noise level in their neighbourhood is extremely annoying, 34.81% indicated that the annoyance noise level is moderately high, 14.36% indicated that the annoyance noise level is low while 10.50% did not respond to the question. This corroborates the submission by Lam *et al.* [69] that annoyance is largely determined by noise disturbance

and perceived noisiness. Transportation and commercial activities are major sources of noise Station 2 (Bus park). In the high-density areas, transportation activities and activities from households are major sources of noise. Religious activities and generator sets are the major sources of noise at Station 6. In terms of the awareness of the neighbourhood noise levels, 72.21% of the residents viewed neighbourhood noise as a problem and are annoyed by it, 81.22% acknowledged that they experienced daily disturbance of noise. The majority of the respondents indicate that the residents in Festac Town are very much aware of the noise. Another 48.4% of the respondents exposed to noise report occurrence of sleep disturbance especially when the noise level is too high. When asked about their coping strategies, they revealed that they are forced to leave their houses or distract themselves, ignore the noise, move away from the noise or close the windows. Studies have shown that sleep-insufficiency is shown to increase blood pressure [70, 71]. About 57.45% of the respondents claim that they are affected by the noise levels; they experience stress most when trying to communicate and then lose concentration while busy.

The result showed that 51.93% of the respondents were aware of government regulations/laws on noise pollution; 39.23% claimed that they were not aware of such regulations/laws. In Nigeria, enforcement of regulations against noise pollution is weak; this encourages people not to consider noise as a pollutant, and take it as part of daily life. The present situation of noise pollution in this area poses a severe health risk to the residents. Some people are unable to make the connection between noise and disease. Despite the evidence, Nigerian societies are becoming increasingly more polluted with noise. This study shows that the noise level measured should be considered a major environmental concern. Apart from traffic noise, other in-

trusive noise sources include loudspeakers, grinding machines, power generators and human conversation. The perception of respondents based on these noise sources and the noise levels was analysed using the logistic regression. The morning, afternoon and evening mean noise levels were significant predictors of noise variation as perceived by the dwellers ( $p < 0.05$ ). The test of the intercept ( $p < 0.05$ ) suggests that the model with the intercept is necessary to the data. The Hosmer-Lemeshow (H-L) test which is an inferential goodness-of-fit test was further carried out and it yielded chi-square statistic of 1.894 and was insignificant ( $p > 0.05$ ), suggesting that the model was well fit to the data. In other words, the null hypothesis of a good model fit to data was accepted. Based on the model, the log of the odds of the noise disturbance on the dwellers was negatively related to the morning and evening noise levels ( $p < 0.05$ ) and positively related to the afternoon noise levels ( $p < 0.05$ ). The relationship between the log of the odds of the noise disturbance on the dwellers and the morning noise levels was not significant. Equation 7 was generated:

$$\begin{aligned} \text{Logit}(Y) = & -4.701 \times \text{Morning noise levels} & (7) \\ & + 3.682 \times \text{Afternoon noise levels} \\ & - 2.093 \times \text{Evening noise levels} + 188.927 \end{aligned}$$

Where Y is the probability of noise disturbance to dwellers (determined from questionnaire)

## 4 Conclusions

This study has been able to statistically and spatially assess the environmental noise distribution in a residential area of Festac Town. Empirical noise level data were collected to estimate the magnitude of noise at various locations in the study area. The noise levels obtained from this study across the residential area of Festac Town have failed to conform to the acceptable environmental noise guidelines of the IFC EHS and NESREA. The morning, afternoon and evening mean noise levels are generally higher than the 55dBA limit. This was confirmed by the logistic regression which showed that the morning, afternoon and evening average noise levels were significant predictors of noise variation as perceived by the dwellers. The analysis revealed that there were significant differences in noise levels within the evening period whereas, no significant differences in mean noise levels were detected within the morning and within the afternoon periods respectively. The evening period experienced the highest mean noise level of 68.88dBA, followed by the afternoon period with 68.06dBA and the morning with the mean noise level of

61.81dBA. Significant variation exists between the recommended noise limit and the observed noise levels in the study area. Findings also show that, in the morning, the highest mean noise levels (68.1-72dBA) occur in the north-western part of the study area where a bus park is present and the central, eastern and southern parts of the study area generally have lower mean noise levels (60.1 – 64dBA). The afternoon period has the highest noise levels (76.1 – 80dBA) observed at the north-western part of the study area. However, the noise levels in the region are significantly higher in the afternoon than in the morning period. Noise levels in the central, eastern and southern parts which were generally within the range of 60.1 – 64dBA in the morning period are now in the higher range of 64.1 – 68dBA in the afternoon. In the evening, the highest noise level (72.1 – 76dBA) is observed in the north-western region of the study area.

Public perception as gathered from the questionnaire survey shows the emotional stress and disorientation caused by the noise pollution in the environment. Hence, it could be inferred from this study that the health of several groups of people living in the environment is in danger. It is recommended that similar studies as this be conducted in other residential areas of Lagos State to frequently assess the noise pollution level. The Festac environment is exposed to significantly higher levels of noise than it is deemed appropriate for healthy living. It is obvious that the scenario in Festac is a direct consequence of a failure in land use and physical planning by the government. As evident from the questionnaire survey, the uncontrolled noise is a source of vexation and annoyance to some dwellers. Also, since there are wide variations in noise even within residential areas, existing guidelines on noise should be updated to provide guides on tolerable noise levels within the different classes of residential neighbourhoods such as low density, medium density and high density. It is also recommended that vulnerable sub-groups in the state (children and the elderly) should be considered in the development of noise management strategies. Adequate measures must also be taken to curb this menace of noise pollution currently being experienced. Immediate and definite measures are required. For example, the government can ensure that full costs associated with lowering the levels of noise pollution are catered for by those responsible for the source of noise. Also, it is important to address the source of the noise through environmental impact assessments that considers noise and other pollutants. Knowing the implications of noise pollution to the health of a society, proper legislation to regulate human activities with respect to noise generation is highly recommended to the local, state and national legislators.

Noise is damaging but can be controlled drastically to create a good environment.

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