SPATIAL AND STATISTICAL ANALYSIS OF ENVIRONMENTAL NOISE LEVELS IN THE MAIN CAMPUS OF THE UNIVERSITY OF LAGOS

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ABSTRACT: The increasing student population, developmental, and commercial activities within the University of Lagos's main campus have led to an increase in daily noise levels. These have disrupted the serenity and tranquillity of the campus environment. In this study, the noise levels within the campus were assessed at 34 locations to determine compliance with international standards for tolerable noise levels in different environments. For three days, noise levels at the stations were measured using the Extech 407730 sound level meter. In the analysis, noise level maps were produced using the Inverse Distance Weighted (IDW) interpolation, and the correlation between observed noise levels and noise limits were determined. The noise levels measured in the study area ranged from 41.9 - 96.6dBA. It was observed that the minimum noise levels were associated mostly with residential and conservation areas; while the maximum noise levels were mostly associated with commercial areas, vehicle parks, and transportation corridors. Generally, the noise levels exceeded the tolerable limits for academic, commercial, and residential areas set by the World Health Organisation (WHO) and the National Environmental Standards and Regulations Enforcement Agency (NESREA). The Pearson's correlation coefficients (r) between the average $L_{A\,eq}$ noise levels and both standards (WHO and NESREA) were derived as 0.63 and 0.58 respectively, indicating a slightly high positive correlation. These findings serve as a valuable knowledge base to inform the University management on the need to implement abatement measures aimed at maintaining the noise levels within tolerable limits.

Keywords: Geographic information system; Inverse distance weighted interpolation; Noise pollution; Pearson's correlation coefficient; Sound level.

تحليل مكاني وإحصائي لمستويات الضوضاء في الحرم الجامعي

ألفريد س الاديمومي، شوكوما ج اوكولي، باباتوندي م اوجيجبيلي، اولاجوكي دارامولا, ، جوهانسون ك اونيجبولا، رحمت اديبو، و ويميمو ادمينو

الملخص: أدى تزايد عدد الطلاب والأنشطة الإنمائية والتجارية داخل الحرم الجامعي الرئيسي لجامعة لاجوس إلى زيادة في مستويات الضوضاء اليومية. وقد أدت هذه الاضطرابات الضوضائية المتزايدة إلى الإخلال بسكينة بيئة الحرم الجامعي وهدوئه. في هذه الدراسة يتم تقييم مستويات الضوضاء في أربعة وثلاثين موقعًا محددًا داخل حرم جامعة لاجوس. وقد أجري اختبار التعرض للضوضاء لتحديد مدى موافقة بيئة الحرم الجامعي للمعايير الدولية فيما يتعلق بمستويات الضوضاء المقبولة في مختلف البيئات. تم قياس الحد الأدنى والحد الأقصى ومتوسط مستويات الضوضاء في المحطات لمدة ثلاثة أيام باستخدام مقياس مستوى الصوت Extech 407730. ورسمت خرائط مستوى الضوضاء عن طريق الاستنباط من معكوس المسافة المرجحة. وتراوحت مستويات الضوضاء التي تم قياسها في منطقة الدراسة بين 41.9 و 96.6 ديسيبل. ولوحظ أن الحد الأدنى لمستويات الضوضاء يرتبط في الغالب بمناطق سكنية ومناطق محمية؛ في حين أن الحد الأقصى لمستويات الضوضاء يرتبط في الغالب بالمناطق التجارية ومواقف السيارات وممرات النقل. وبشكل عام، تجاوزت القراءات مستويات الضوضاء الحدود المقبولة للمناطق الأكاديمية والتجارية والسكنية التي حددتها منظمة الصحة العالمية والوكالة الوطنية لتطبيق المعايير واللوائح البيئية. تشير معاملات ارتباط بيرسون بين متوسط مستويات الضوضاء ومعايير الضوضاء الصادرة عن المشرعين المذكورين أعلاه المقدرة بـ 0.63 و0.58 ديسيبل على التوالي، إلى علاقة متبادلة إيجابية مرتفعة قليلاً بين مستويات الضوضاء المقاسة وتلك المسموح بها دوليا. وتهدف هذه الدراسة لتكون نتائجها قاعدة معارف قيمة لإبلاغ إدارة الجامعة بضرورة تنفيذ تدابير خفض الضوضاء بهدف الحفاظ على مستوياتها في حدود مقبولة.

الكلمات المفتاحية: الضوضاء؛ موجات صوتية؛ تلوث سمعي؛ مستوى الصوت؛ معامل ارتباط بيرسون.

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NOMENCLATURE

I	Intensity of the sound wave (in W/m^2)
N	Number of measurements
n	Number of sampled points used for the IDW estimation
p	Power parameter
r	Pearson's correlation coefficient
S'	Arithmetic mean of the $L_{A\,eq}$ noise levels.
$\bar{S}$	$L_{A\,eq}$ values according to noise standards
S_1	Standard deviations of S'
S_2	Standard deviations of $\bar{S}$
t	Calculated t value
β	Sound level
λ_i	Influence (weight) of sample points
dB	Decibels
dBA	A-weighted sound level in Decibels
df	Degree of freedom
di	Distance between the point of interest and the sampled point
Eqn	Equation
H_0	Null hypothesis
H_1	Alternative hypothesis
I_o	Standard reference intensity (= 10^{-12} W/m^2)
IDW	Inverse Distance Weighted
LGA	Local Government Area
$L_{A\,eq}$	Average sound level
$L_{A\,min}$	Minimum sound level
$L_{A\,max}$	Maximum sound level
Max.	Maximum
Min.	Minimum
S/N	Serial number
NESREA	National Environmental Standards and Regulations Enforcement Agency
WHO	World Health Organisation

1. INTRODUCTION

Sound waves are sensations perceived by the auditory nerves from the impact of acoustic pulses reaching the ear. These sound waves travel through the air, causing vibrations along the path of propagation which can be detected by the auditory nerves and causes a sensation of hearing to humans and other animals (Goshu *et al.*, 2017). The intensity of sound waves, which can be described as the level of its impact on the auditory nerves and environment are generally known to decrease with increasing distance from the source (Hansen, 2001). The speed of sound in air is approximately 330m/s and depends on factors such as the temperature, pressure, and density of the medium (Paulet *et al.*, 2016; Sharma, 2017). Noise is a sensation that irritates the auditory nerves (Zannin, 2013), and is characterised by irregular vibration of the propagating acoustic media or unpleasant acoustic sensations to the hearer. Hence, a sound that may be acceptable to one hearer might be noise to another. Prolonged exposure to sound, which initially may be pleasing or acceptable to one, may also be classified as noise since the user may become irritated over time by it. Hence, the definition of noise is relative to individuals (Mehta *et al.*, 2012; WHO, 2019). The sound level of an acoustic wave is a measure of the intensity of the sound wave, measured with respect to a threshold level on an accepted scale. Noise constitutes a nuisance to many people today as noise pollution has greatly increased in our environment and can make people consider leaving urban areas to regions with less noise (Obaidat, 2008). All over the world, urbanity and industrialisation have intensified the problem of environmental noise (Gholami *et al.*, 2012).

The challenges posed by noise pollution cannot be overemphasised, as individuals, today are hardly aware of not just the negative consequences of long-term exposure to it, but what constitutes it (Luqman *et al.*, 2013). Generally, the populace tends to overlook several factors as significant contributors to increased sound levels in the environment (Obiefuna *et al.*, 2013). However, increased sound levels from sources we might deem justifiable could be sources of noise pollution, as the long-term effects are the same as that caused by repeated exposure to what many would personally term *irritating sound*. Noise emanates from different sources in the environment such as the neighbourhood (Niemann *et al.*, 2006; Laze, 2017), industrial activities (Bublić *et al.*, 2010), and transportation (Sotiropoulou *et al.*, 2020). These noise sources are most times unnoticed by individuals due to their active contribution to it, investment of time and concentration in daily activities and personal goals. Hence, the negative effects of not acknowledging increased noise pollution as a contributory factor to their health conditions and reduced quality of life are heightened (Nwobi-Okoye *et al.*, 2015). Noise is seen as a normal phenomenon by most urban dwellers and commuters, hence the reason for insufficient studies conducted on assessing its impacts, especially in Nigeria (Monazzam *et al.*, 2014). Industrial workers in particular face this challenge as the nature of their work entails long and intense work hours, which requires high concentration levels despite the noise emanating from the factories they work in (Zare *et al.*, 2018).

It is known that long term exposure to high sound levels and noise can lead to several medical conditions including increased blood pressure, irritation, hearing impairments to permanent deafness (Hatamzadi *et al.*, 2018). Increased urbanisation today causes increased sound levels due to traffic congestion and industrialisation, among other sources. Several studies have identified a very high correlation between impaired hearing, mental health issues, and annoyance of people and the noise levels they are consistently exposed to (Ouis, 2002; Babisch, 2011; Benocci *et al.*, 2016; Hammersen *et al.*, 2016; Alimohammadi *et al.*, 2019; Sonaviya *et al.*, 2019). High noise levels have also been associated with the changes in genes responsible for vascular functions, infiltration, and remodelling of vascular cells leading to acute cardiovascular diseases in people who are exposed to it (Munzel *et al*., 2018). Also, the auditory, reading and cognitive prowess of different learners in their learning environments are negatively impacted by high noise levels (Shield *et al*., 2003; Diaco, 2014). These and many other adverse effects of noise have led to the formulation of rules and several engineering solutions to manage and/or curtail its negative hazard on human (WHO, 2018; Taufner *et al*., 2020). Several engineering and non–engineering solutions have gained good recognition in the mitigation of noise (Science for Environment Policy, 2017). Non–engineering solutions are awareness and regulations aimed at reducing noise levels. Engineering solutions include the continuous advancements in vehicular engine technology, construction of roads with surface improvement, low–noise tyre technology, the introduction of hybrid electric vehicles, reduction of frictions along rail lines using acoustic grinding, adequate land-use planning/zoning based on compatible sound levels, and sound-proof technology in building and machinery (Oyedepo, 2013; Benocci *et al.,* 2016; Science for Environment Policy, 2017; Pueh *et al.,* 2019; Riboldi *et al.,* 2020*).* All these engineering solutions are hinged on adequate noise mapping using a variety of approaches (Pueh *et al*., 2019; Verma *et al.,* 2019; Sonaviya *et al.,* 2019; Alam *et al.,* 2020).

Noise pollution mapping is the determination of the noise level variations in an area to analyse the exposure of regions to unacceptable noise levels which exceed set standards. The literature is replete with research on noise pollution mapping, for example in Maisonneuve *et al.* (2010); Can *et al.* (2011); Ruge *et al.* (2013); Monazzam, *et al.*, (2014); Halperin (2014); Leao *et al.* (2014); Lee *et al.* (2014); Zuo *et al.* (2014); Aguilera *et al.* (2015); Carrier *et al.* (2016); Ragettli *et al.* (2016), and Gloaguen *et al.* (2019). The mapping generally involves measuring noise levels with a suitable device at various observation stations. Although noise generally emanates from defined sources, it varies continuously from the location of the source and gradually thins out in intensity at infinity. Hence, measurements of noise levels at every single point in a geographic region is an impracticable task. Usually, discrete measurements of the noise levels are made at various observation points (Nassiri *et al.,* 2016), well distributed throughout the study area to represent the variations in noise levels for the region. Then using a Geographic Information System (GIS), the noise level for all other points is interpolated from the values of the observation points measured in the course of the study. GIS can assimilate divergent sources of data making it a very versatile analytical tool for modelling continuous spatial data of environmental variables in natural resource management and biological conservation (Nwilo, 1998; Akeh and Mshelia, 2016). Although sound/noise levels data are often collected from point sources, GIS spatial interpolation techniques such as Inverse Distance Weighted (IDW) interpolation can be used in the estimation of continuous spatial data of phenomena over a region of interest to enhance well-informed decisions (Li and Heap, 2008; Farcas and Sivertun, 2009; Eason, 2013; Taghizadeh-Mehrjardi *et al.,* 2013).

Using GIS to map noise pollution in the environment can provide beneficial information on the sources and magnitude of the dangers people are exposed to from these negative acoustic sources. Furthermore, it provides sufficient information to aid the implementation of pragmatic measures for curtailing the negative effects of continuous exposure to noise (Zannin, 2013; Lavandier *et al*., 2016). The University of Lagos is an academic institution with a very high student population and high level of commuter traffic, commercial, and social activities which have led to increased noise levels and disturbance within the campus. As an academic environment, the university has to be conducive to learning and research. Therefore, it is required to monitor the contributions of the various noise sources to the overall noise concentration level within the campus. This study aims to map noise levels at various locations within the University of Lagos main campus and assess conformity with international standards. The assessment is conducted in line with the guidelines of the World Health Organisation (WHO) and National Environmental Standards and Regulations Enforcement Agency (NESREA) – National Environmental (Noise Standards and Control) Regulations on acceptable noise levels in the environment. The specific objectives of the study are to determine the minimum, maximum and average noise levels at different environments within the university campus; analyse the noise level variations using IDW interpolation; compare the measured noise levels with the WHO and NESREA noise limits using statistical metrics such as Pearson's correlation coefficient and T-Test, and recommend measures for noise abatement and control.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is the University of Lagos's main campus, Akoka in Lagos Mainland Local Government Area (LGA) of Lagos State, Nigeria. The campus is located between longitudes 3º23'00"E – 3º24'30"E and latitudes 6º30'00"N – 6º31'30"N. It is a low-lying area located at the centre of Lagos metropolis; bounded to the east by the Lagos Lagoon and surrounded by densely populated built-up areas. As a citadel of learning, it has a growing student population, contains faculties and other academic and research infrastructure, including recreational facilities, religious buildings, restaurants, and residential buildings. Also, traffic congestion is a common occurrence immediately outside its gates. Consequently, the main campus is exposed to increased noise pollution levels.

2.2 Station Selection

Before embarking on a noise mapping study, the choice of observation points and periods of observation must be decided upon. The choice of observation periods is usually influenced by general activity levels of the study area (Alam, 2011). The measurements were spread around the campus at thirty-four locations in different environment types. It was ensured that the stations covered areas with different characteristics such as noise activity level, land use type, and presence of external noise sources. Hence, the locations were spread across academic, residential, recreational, commercial, religious, and conservation areas, including traffic junctions and vehicle parks. Consequently, the measurement stations were categorised into eight environment types as shown in Table 1. Figure 1 presents a map showing the spatial distribution of the measurement stations in the study area.

2.3 Noise Level Measurement

Sound/noise level is measured in decibels, denoted as dB. Sound level, β, is defined in Walker *et al.* (2014) using Eqn.1.

$$\beta = (10\ dBA)\ log(I/I_0) \qquad (1)$$

where*:*
I = intensity of the sound wave (in W/m^2)
I$_o$ = standard reference intensity (= 10^{-12} W/m^2)

The intensity (I) of a sound wave at a surface is the average rate per unit area at which energy is transferred by the wave through or onto the surface. The sound level depends on the intensity of the emitted waves which varies with the square of the distance from the source. For the noise level measurement, this study relied on the Extech 407730 Digital Sound Level Meter. The meter measures and displays sound/noise pressure levels in decibels from 40 to 130dB and it permits choices of “A” and “C” weighting. This device has a basic accuracy of $\pm$2dB and a digital display resolution of 0.1dB, measuring the minimum and maximum noise levels over time with its extended microphone windscreen (Extech, 2019). A-weighted continuous equivalent sound levels ($L_{A\,eq}$, $L_{A\,min}$, $L_{A\,max}$) were measured daily at the 34 stations for three days in the morning between 0800 – 1100 h and afternoon between 1300 – 1600 h. $L_{A\,eq}$ represents the average sound level, $L_{A\,min}$ is the minimum sound level and $L_{A\,max}$ is the maximum sound level. The measurements were made by occupying each measurement station for 2 minutes – with the microphone windscreen of the sound level meter placed in the direction of noise sources – recording instantaneous minimum and maximum noise levels detected over the period as well as the instantaneous noise levels at the slow response time. These were manually recorded, the $L_{A\,eq}$ values were computed from Eqn. 2 (Star–Orion South Diamond Project, 2010) and the arithmetic mean which is the average of $L_{A\,eq}$ measurements per station over the days were also computed for both morning and afternoon.

Table 1. The distribution of measurement stations by location.

S/N	Environment type	*N
1	Academic	9
2	Commercial/ industrial/ shopping	6
3	Conservation area	4
4	Hospital outdoor	1
5	Public outdoor	1
6	Recreational	1
7	Residential	3
8	Traffic	9
Total		34

*N – Number of measurement stations

$$L_{A\,eq} = 10\ log\left(\sum f_i * 10^{L_i/10}\right) \qquad (2)$$

where:
f_i = fraction of total time the constant level L_i is present
L_i = sound level in dBA

2.4 Quantitative Analysis

Following the measurement, the data in the field book was entered into a Microsoft Excel worksheet. The daily $L_{A\,min}$, $L_{A\,max}$ and $L_{A\,eq}$ noise levels for both morning and afternoon periods were summarised to generate the averages of the $L_{A\,min}$, $L_{A\,max}$ and $L_{A\,eq}$ noise levels for the entire period. The next stage of the analysis evaluated the compliance of the measured noise levels with the guidelines for noise levels specified by the World Health Organisation (WHO) in WHO (2019) and the National Environmental Standards and Regulations Enforcement Agency (NESREA) in the National Environmental (Noise Standards and Control) Regulations (2009). The WHO noise level guidelines for the environment types in this study as well as the National Environmental (Noise Standards and Control) Regulations (2009) are summarised in Table 2. The environment types include the academic areas (faculty complexes and schools), commercial/ industrial/shopping areas (supermarkets and shopping centres), conservation areas (gardens and parks), hospital outdoor (medical centre of the university), public outdoor (open-air/open space arena), recreational area (sports centre and parks) and the residential areas (staff quarters and students’ hostels).

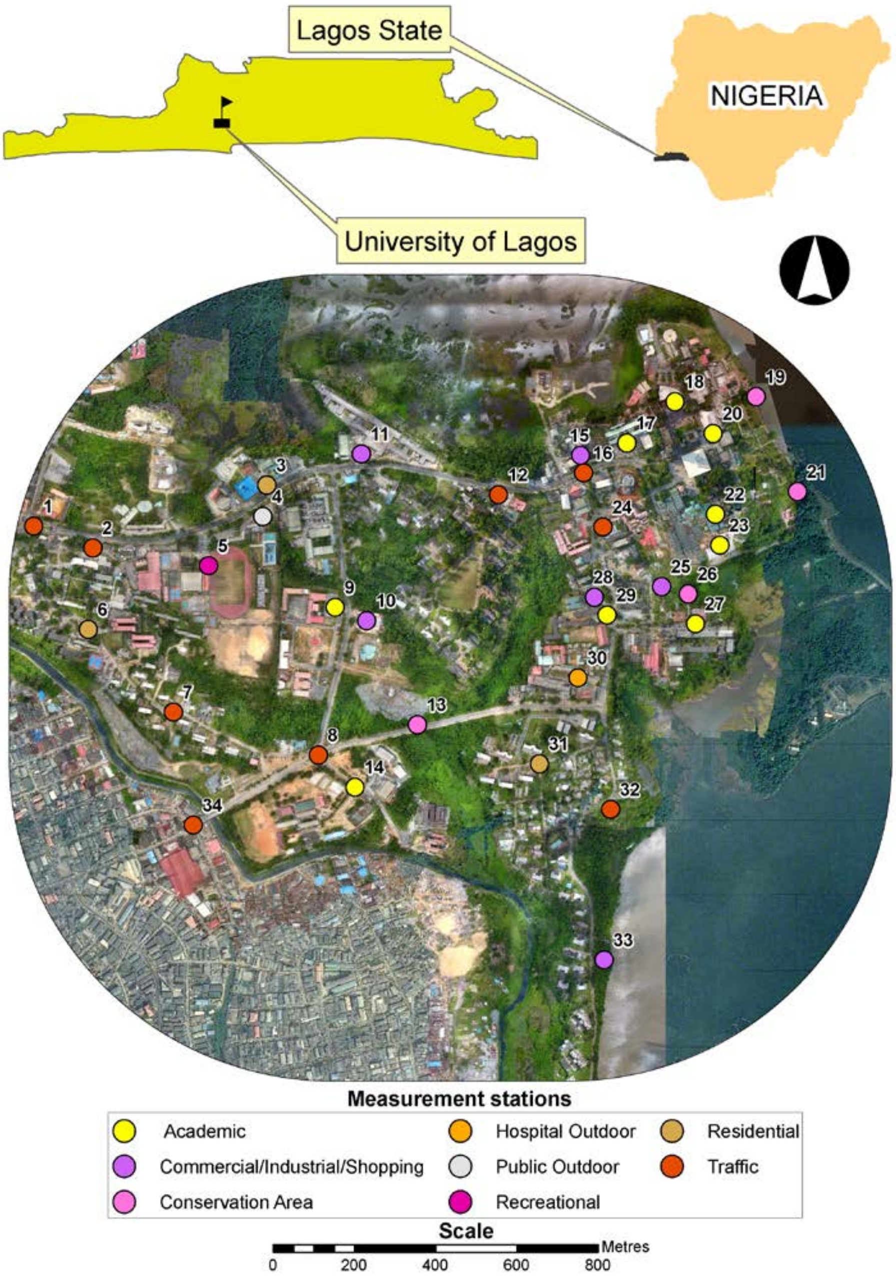

Figure 1. Spatial distribution of measurement stations in the study area.

Table 2. Noise Limits for the different locations.

S/N	Environment type	WHO (dBA)	NESREA (dBA)
1	Academic	55	45
2	Commercial/ Industrial/ Shopping	70	70
3	Conservation area	45	45
4	Hospital outdoor	45	45
5	Public outdoor	70	75
6	Recreational	70	75
7	Residential	55	50

(Source: NESREA, 2009; WHO, 2019)

Pearson's correlation coefficient (r) between the average of the noise levels within the campus and the average of the WHO and NESREA noise limits was calculated using Eqn. 3 (Dass, 2013).

$$r = \frac{\sum XY}{\sqrt{(\sum X^2)(\sum Y^2)}} \quad (3)$$

Where X and Y are the deviations of the measured average noise level and WHO/NESREA noise limit from their mean values respectively. Next, a two-tailed t-test at 0.01 level of significance was carried out to compare the results with the WHO noise limits using Eqns. 4 and 5 for t-test (Devore, 2012).

$$t = \frac{S' - \bar{S}}{\sqrt{\frac{S_1^2 + S_2^2}{N}}} \quad (4)$$

df (degree of freedom) = N – 1 (5)

where t is the calculated t value to be compared against the critical value obtained from the t-table.
$\bar{S}$ is the $L_{A\,eq}$ value according to noise standard.
S_1 and S_2 are the standard deviations of the $L_{A\,eq}$ values, S' and $\bar{S}$ respectively. For this analysis the sample size (N) is 34 – the number of measurements, the null hypothesis used was H_0: S' = $\bar{S}$, implying no significant difference exists between the measured noise levels and the WHO and NESREA limits. The alternative hypothesis is H_1: S' ≠ $\bar{S}$. Pearson's correlation analysis and t-test were executed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS) software.

2.5 *Generation of Noise Level Maps*

The noise data was imported from the Microsoft Excel worksheet into the ArcGIS environment where it was represented as point shapefiles. Using the Inverse Distance Weighted (IDW) tool in the Spatial Analyst toolbox, noise level surfaces were interpolated for the average morning and afternoon noise levels. In the IDW dialog box, the input point shapefiles were selected, the Z-value field was set to the mean noise levels and a variable search radius was set for the interpolation. The resulting interpolated surfaces were saved as TIFF images. According to Li and Heap (2008), "the inverse distance weighting or inverse distance weighted (IDW) method estimates the values of an attribute at unsampled points using a linear combination of values at sampled points weighted by an inverse function of the distance from the point of interest to the sampled points." The assumption is that sampled points closer to the unsampled point are more related to it than other sample points further away in their values. With IDW, the influence (weight) of sample points diminishes as distance increases, and the resultant spatial interpolation is local (Isaaks and Srivastava, 1989 in Li and Heap, 2008). The weights can be expressed as shown in Eqn. 6:

$$\lambda_i = \frac{1/d_i^p}{\sum_{i=1}^{n} 1/d_i^p} \quad (6)$$

Where *di* is the distance between the point of interest and the sampled point, *p* is a power parameter, and *n* represents the number of sampled points used for the estimation (Li and Heap, 2008). IDW is very applicable in this study due to the property of sound waves, whose intensity diminishes with increasing distance from the source of sound emission.

3. RESULTS AND DISCUSSION

3.1 *Assessment of Noise Levels*

Tables 3 and 4 show the averages of the $L_{A\,min}$, $L_{A\,max}$ and $L_{A\,eq}$ noise levels at all environment types for the morning and afternoon periods respectively. Generally, higher $L_{A\,eq}$ noise levels are associated with the afternoon period than during the morning period in the following environments: commercial/ industrial/shopping, conservation, hospital outdoor, public outdoor, and recreational areas. However, the converse is the case in academic, residential, and traffic environments where the higher $L_{A\,eq}$ values occur in the morning period and lower noise levels in the afternoon period. The higher morning noise levels and lower afternoon noise levels at traffic environments can be attributed to the early morning rush experienced by students, university staff, and visitors coming into the school to get to their various destinations. Hence, large numbers of people in queues for vehicles and increased vehicular traffic and human activity at those locations are the norm in the morning. Figure 2 presents the average of the $L_{A\,min}$ and $L_{A\,max}$ noise levels at all measurement locations or stations for the morning and afternoon periods respectively while Figure 3 presents the average of the $L_{A\,eq}$ noise levels at all measurement locations for the morning and afternoon periods, respectively.

In the morning, the highest mean noise levels occur at Station 1 (University Main Gate, 77.67dBA) and Station 12 (Centre for Information Technology and Systems Bus Park, 76.33dBA).

The lowest mean noise levels occur at Station 37 (Academic Staff Quarters at Ozolua, 59.88dBA) and Station 24 (Lagoon front close to the University Guest House, 60.62dBA). In the afternoon, the highest mean noise levels occurred at Station 1 (University Main Gate, 74.55dBA) and Station 5 (Sports Centre, 74.23dBA). The lowest $L_{A\,eq}$ value occurred at Station 15 (in the vicinity of the International School, 56.85dBA) and Station 6 (in the vicinity of Kofo Students residential hostel, 58.55dBA). In both morning and afternoon periods, some of the highest noise levels were observed at the main gate of the campus. This is because there is a continuous stream of vehicles moving in and out of the school through the main gate. Also, outside the main gate is the intersection of the University road and St. Finbarr's road which are very busy roads in Lagos Mainland. Changes in the general activity levels in the school led to slight variations in noise levels at other stations between the morning and afternoon observations. These variations were most evident along non-traffic junctions/roundabouts on roads in the school.

Figures 4 and 5 show the average noise level maps for the morning and afternoon periods respectively. It is observed that there is a clustering of high noise levels at student residential and academic buildings in the afternoon period. This can be explained by the

Table 3. Average of the $L_{A\,min}$, $L_{A\,max}$ and $L_{A\,eq}$ noise levels at all environment types for the morning period.

Environment type	*N	Average noise level (dBA)		
		$L_{A\,min}$	$L_{A\,max}$	$L_{A\,eq}$
Academic	9	61.25	74.52	67.41
Commercial/ Industrial/ Shopping	6	64.45	70.68	67.59
Conservation area	4	60.62	63.37	62.06
Hospital outdoor	1	61.73	61.73	61.73
Public outdoor	1	64.38	64.38	64.38
Recreational	1	64.17	64.17	64.17
Residential	3	59.88	70.42	64.53
Traffic	9	61.25	77.67	69.95
Total	34	59.88	77.67	66.88

Table 4. Average of the $L_{A\,min}$, $L_{A\,max}$ and $L_{A\,eq}$ noise levels at all environment types for the afternoon period.

Environment type	*N	Average noise level (dBA)		
		$L_{A\,min}$	$L_{A\,max}$	$L_{A\,eq}$
Academic	9	56.85	69.88	63.55
Commercial/ industrial/ shopping	6	65.77	73.65	71.22
Conservation area	4	59.8	64.95	62.1
Hospital outdoor	1	65.7	65.7	65.7
Public outdoor	1	65.15	65.15	65.15
Recreational	1	74.23	74.23	74.23
Residential	3	58.55	68.33	62.43
Traffic	9	63.05	74.55	68.38
Total	34	56.85	74.55	66.34

timing of the afternoon observations (1300 – 1600 h), in which activity level including traffic and the early morning buzz is reduced. Visitors and students are expected to be at their destinations and lecture halls/classes respectively. This results in an accumulation of students and visitors in academic buildings and/or their respective destinations. In the afternoon, there is a decline in noise levels at the International School area due to a reduction in early morning commuting and commercial activities just outside it. Generally, students are expected to be in classes during the afternoon, hence the reduced and relatively stable noise levels for the region compared to its morning noise levels.

The Faculty of Science experiences reduced noise levels in the afternoon. This is attributed to the decline in the mass movement of students to and from lecture halls and laboratories in the afternoon. It can be seen that the lowest noise levels occur at relatively isolated regions including some residential buildings, the lagoon front of the school, and some locations at the outer fringes of the campus boundary. These low noise levels can be attributed to the minimal activity level occurring at such locations. The residential and conservation areas in the university environment are well vegetated and as such could have also contributed to the low noise level due to the dampening effect of green trees on noise dispersion (Mansouri *et al*., 2006). The residential areas with such low noise levels are located some distance away from the centre of the school, and in fact, away from any faculty or major activity hub. Conversely, regions with the highest noise levels were located at the major activity hubs of the school. These include hostels; traffic junctions where the noise is largely attributable to vehicles; shopping complexes with a lot of commercial activity; the university's Sports Centre and major car parks. This is in line with the submission of Sulaiman *et al*. (2018) that an increase in noise level is significantly caused by an increase in traffic volume. In another study by Olayinka and Abdullahi (2010), traffic noise was identified as the major source of noise in their study area.

3.2 Comparison with WHO and NESREA Noise Limits

Figure 6 shows a graph of the average noise levels against the WHO and NESREA noise limits. It can be seen that average noise levels generally exceeded the environmental standards set by the WHO for most regions in the study area. The implication is that the WHO standard that is acceptable for the environmental health of the people living in the University of Lagos is generally exceeded and this threatens the sensibilities of the community. A few of the measurement stations had nearly equal noise levels as the WHO noise levels, and some slightly. A total of 11 stations had average noise levels lower than the WHO standard while 23 stations had noise levels higher than the WHO standards. The noise levels at 12 stations exceeded the limits with values as high as 10 – 19dBA. These stations were mostly found in the academic and conservation environments. In the same vein, a total of 14 stations had average noise levels lower than the NESREA standard while 20 stations had noise levels higher than the NESREA standard. The noise levels at 15 stations exceeded the limits with values as high as 10 – 22dBA. These stations were mostly found in the academic and conservation environments.

Pearson's correlation coefficient (r), between the average $L_{A\,eq}$ noise levels and the WHO noise standards was derived as r = 0.63. This value indicates a slightly high positive correlation between the measured noise levels and the WHO limits. Going further with the t-test analysis, the computed value of t was 3.10, whereas the critical value from the t-table was 2.73. Since this calculated value of t exceeds the acceptable bounds of the t-distribution at 33df (n=34), there is a significant difference between the measurements and the limits set by WHO. The computed Pearson's correlation coefficient of 0.63 shows a positive correlation between the average noise levels and the WHO standards at the measurement stations.

The t-test revealed significant differences between the average noise levels and the WHO standards. Pearson's correlation coefficient between the average

$L_{A\,eq}$ noise levels and the NESREA noise standards was derived as r = 0.58. This value indicates a slightly high positive correlation between the measured noise levels and the NESREA limits. The computed value of t was 2.81, whereas the critical value from the t-table was 2.73. Since this calculated value of t exceeds the acceptable bounds of the t-distribution at 33df (n=34), there is a significant difference between the measurements and the limits set by NESREA. The computed Pearson's correlation coefficient of 0.58 shows a positive correlation between the average noise levels and NESREA standards at the measurement stations. The t-test revealed significant differences between the average noise levels and NESREA standards. Figure 7 presents a map showing a classification of measurement stations based on standards for noise limits.

Special emphasis is placed on the hostel residential areas and academic buildings (especially faculties of learning) since it is expected that many of the students spend a good part of their daily academic lives within these two environments. It was observed that the average noise levels for these regions of interest are unacceptable to a large extent, particularly in faculties. Hence, students are exposed to unacceptable noise levels, which could hamper concentration levels and academic performances. Furthermore, outside the Health Centre, the noise level is significantly greater than the acceptable noise standards. This might pose a problem to patients and health care officers/medical personnel as well. However, it should be noted that the noise level measurements in this study were taken outdoors; and not within the Health Centre or any other building.

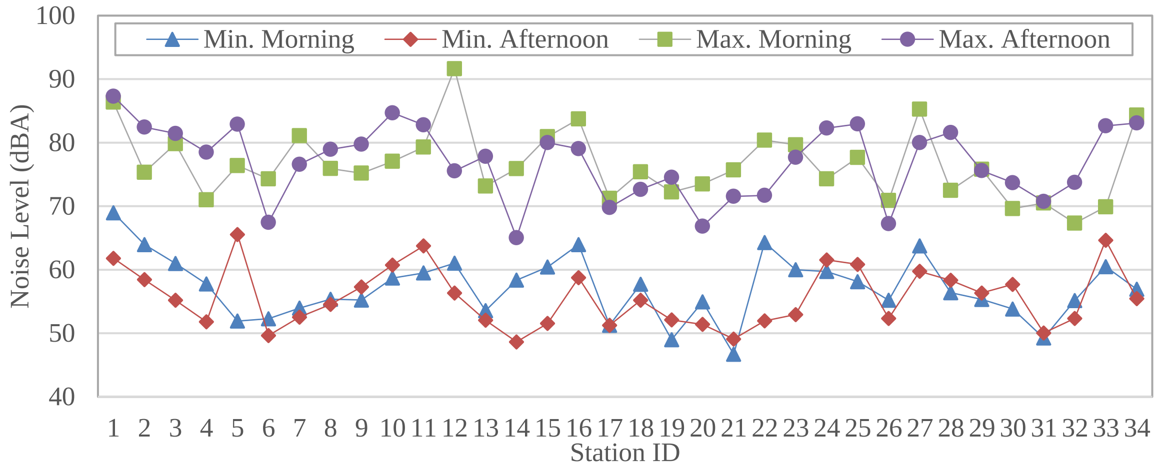

Figure 2. Average of the $L_{A\,min}$ and $L_{A\,max}$ noise levels – morning and afternoon.

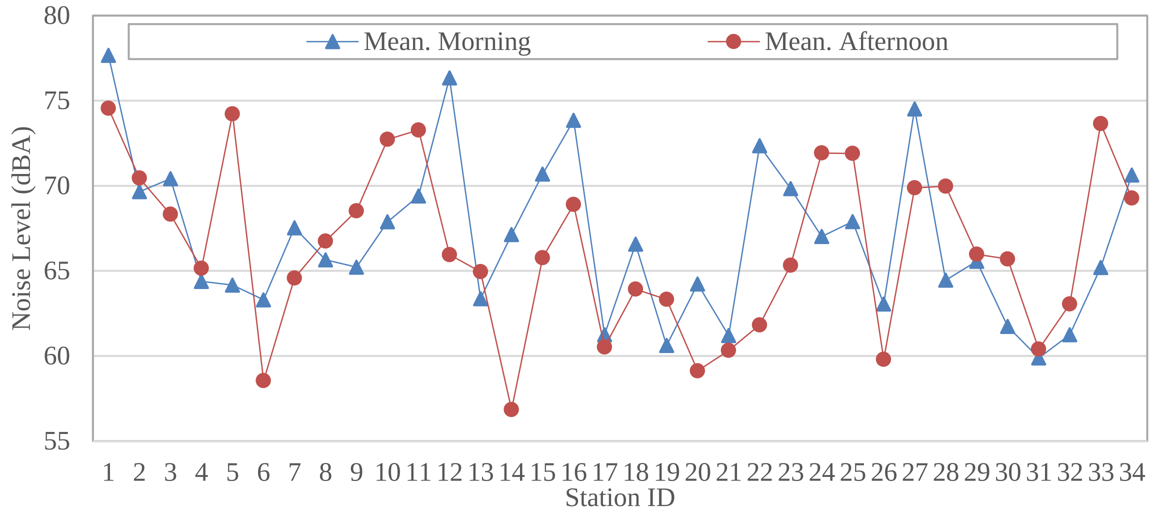

Figure 3. Average of the $L_{A\,eq}$ noise levels – morning and afternoon.

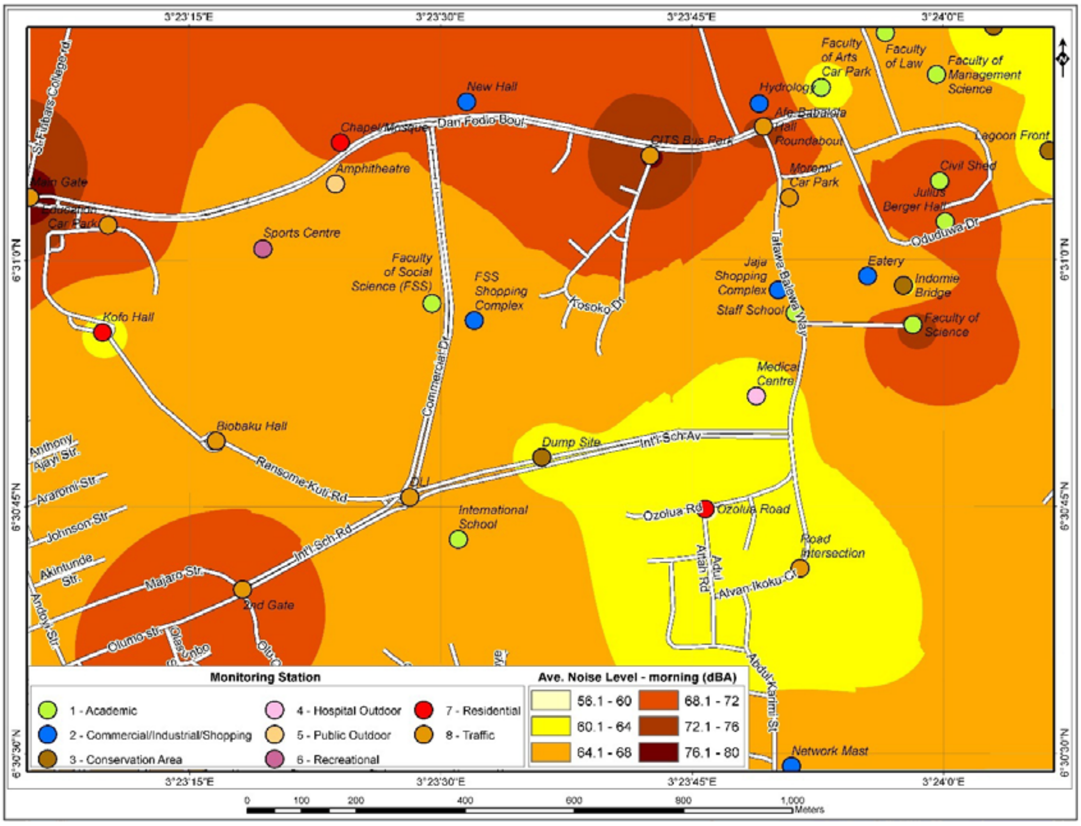

Figure 4. Map of Inverse Distance Weighted Interpolation of average noise levels - morning.

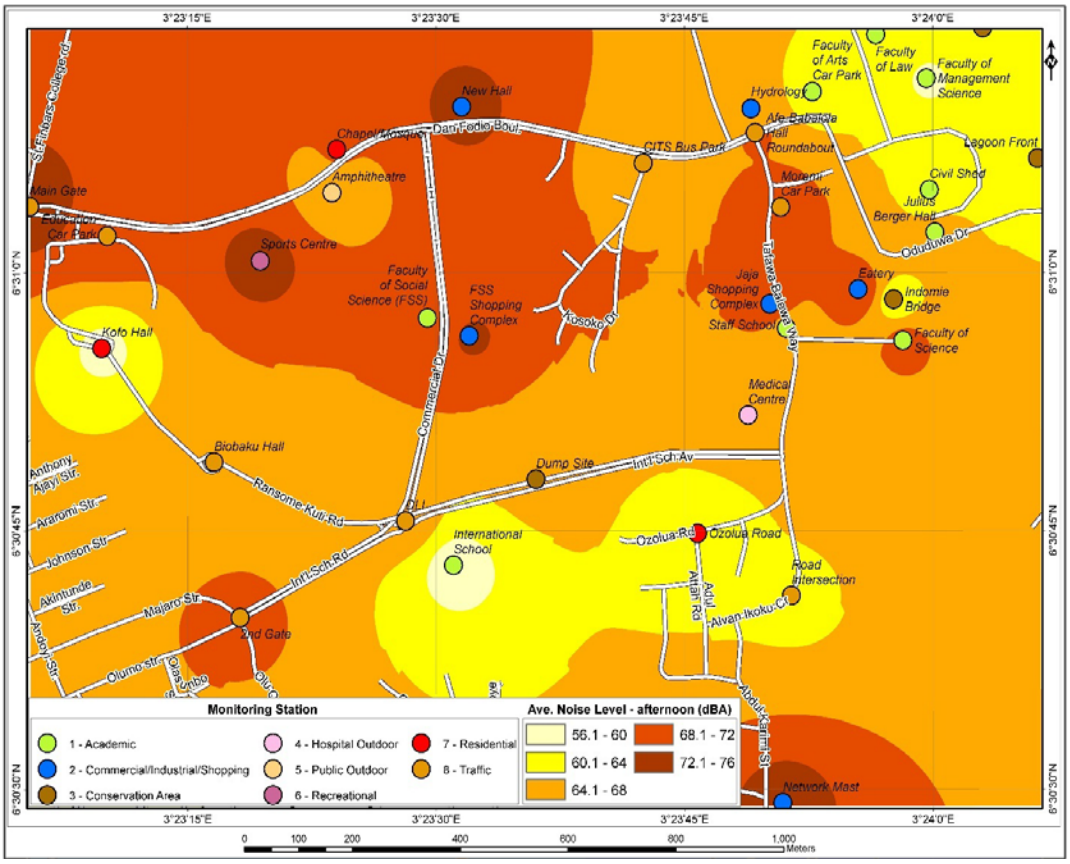

Figure 5. Map of Inverse Distance Weighted Interpolation of average noise levels - afternoon.

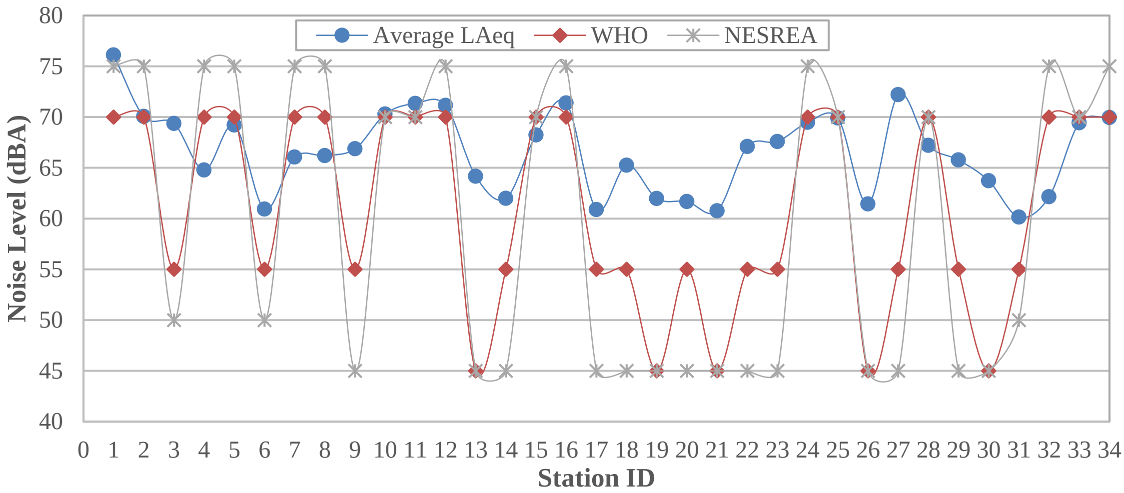

Figure 6. Average noise levels against WHO and NESREA noise standards.

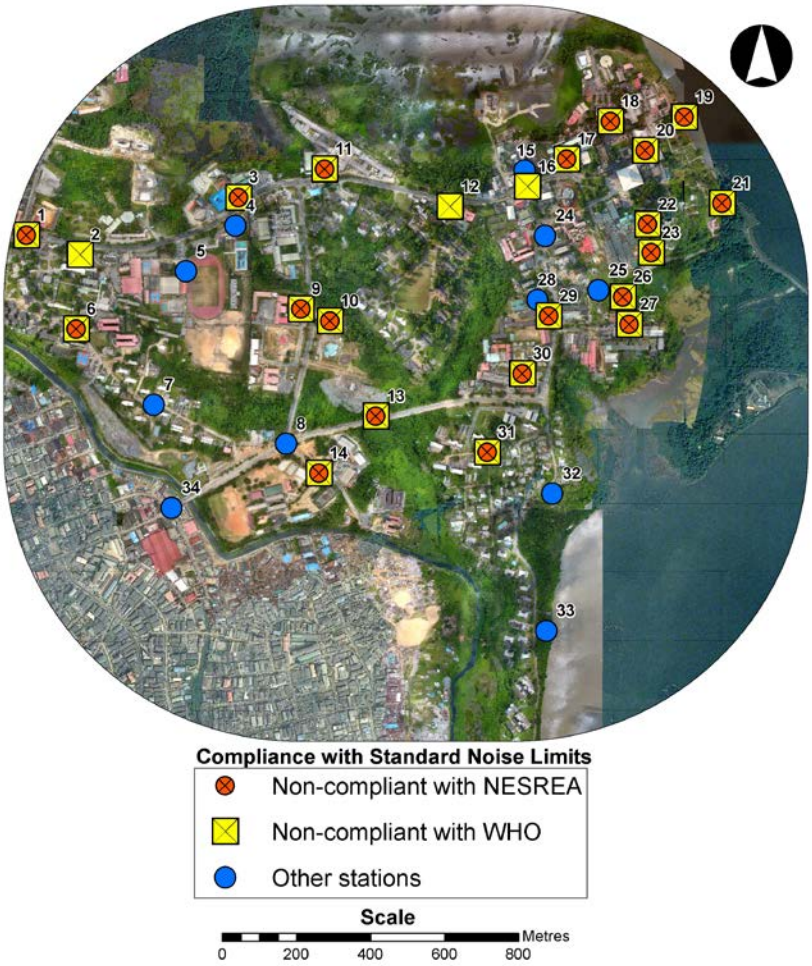

Figure 7. Classification of measurement stations based on standards for noise limits.

4. CONCLUSION

Environmental noise assessment and analysis from this study has revealed that noise levels obtained from the various environments, in general, failed to conform to acceptable environmental noise standards by WHO and NESREA. Inferring from the analysis of morning and afternoon observations, it was detected that noise level was averagely higher in the morning than the afternoon period and this is usually concentrated at the university gate, the university main road, the various classroom areas, and the student residential areas. This could be as a result of workers and students rushing to resume work and class early in the morning. Comparing the noise level for morning and afternoon at the two gates of the university, it was observed that average noise levels between 68.1 – 72 dBA were recorded at the second gate. However, the buffer area covered by this noise level range was higher in the morning compared to the afternoon observation. Conversely, the main gate, Sports Centre, New Hall, and Faculty of Social Science Shopping Complex recorded higher noise levels in the afternoon observation divergent to the trend of result from the general outcome of the research. This suggests that the areas need immediate attention to mitigate potential health problems that could affect the performance of the students and workers residing in the campus.

Furthermore, Pearson's correlation coefficient (r) of 0.63 was derived between the observed average noise levels and the WHO noise standard. Between the average noise levels and NESREA noise standards, the coefficient of correlation was 0.58. These values show a slightly high positive correlation between the measured noise levels and standards. Significant variation exists between the measured noise levels, and the WHO and NESREA noise standards. Hence, it could be inferred from this study that the health of the various groups of people living in the environment is in danger. However, a consistent noise modelling investigation should be continued in the region to frequently assess the noise pollution level. A continuous data gathering in this regard can help to establish a very good mathematical model to predict the noise level status of the study area. Specific regions of interest, the student inhabited areas (residential and academic buildings), showed much higher noise levels than acceptable noise standards. The University of Lagos environment is exposed to significantly higher levels of noise than it is deemed appropriate for healthy living. Hence, adequate measures must be taken to curb this menace of noise pollution currently being experienced. Immediate and definite measures are required. Knowing the implications of noise pollution to the health of a society, proper legislation to regulate human activities concerning 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.

This study aimed to assess the variations in environmental noise levels within the University of Lagos in line with international standards. The interpretation from the predicted noise level maps was limited by the number of observations and measurement stations. Another limitation was the length of observation which could have been longer but for logistical and budget constraints. Notwithstanding, the findings serve as a knowledge resource to inform a better understanding of noise level variations within a university campus. The awareness of the members of the university community to sources and effects of noise and their perceptions of its impacts is considered in another study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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