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A Survey of the Weekday Outdoor Noisescapes at Students' Hostels, University of Maiduguri, Nigeria using Android Smartphones

J. B. Ashalva[1], F. K. Abayomi[1], E. O. Francis[1], S. Ali[1,2], Y. H. Ngadda[1], M. Hassan[1] and A. Adamu[1]

[1]*Department of Physics, University of Maiduguri, Maiduguri, Nigeria*
[2]*Department of Physics, Abubakar Tafawa Balewa University, Bauchi, Nigeria*

Abstract: *Noise pollution has adverse impacts on the physical, social and psychological wellbeing of exposed individuals or wildlife. In this work, android-based smartphone measurements of the outdoor noise levels at three students' hostels of the University of Maiduguri, Nigeria was conducted in five weekdays. Two-minute recordings were made at selected commonly-use outdoor locations within the hostels every hour from 0500 to 2400. The noisescapes derived from the data obtained revealed similar patterns that consist of day- and night-times peaks differing only in magnitude across the subject hostels. The day-time peaks are associated with foot traffic going for or coming from classes, library, medical clinic, university administration, shops/markets, eateries, banks, vehicular traffic of workers going and coming from their offices, commercial tricycles transiting students and the commercial area. Whereas the night-time peaks are associated with foot traffic of residents returning from classes, laboratories and studio works, as well as residents going to and coming from shops/markets, sports fields, vehicular traffic of workers exiting their offices at the end of the official working day, as well as commercial tricycles. The differences in the day and night time noisescapes are attributed to the type and number of visitors socializing with the residents. Between the peaks, residents return for afternoon break, observe some form of siesta, perform noon and afternoon devotions, engage in individual study, but with a significant number exiting the hostel for meals, shops/markets, banking and seeking medical or administration attention. Significant number is also engaged academically in laboratory and studio works. Electricity supply idle the electricity generating sets of the commercial area limiting its contributions. These results may provide a better understanding of the public health implications of noise issues on an educational environment.*

Keywords: *Noisescapes; Outdoor Survey; Students' Hostel: Android.*

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I. Introduction

Sound is the subjective dimension of what we hear when vibrations reach our ears [1]. Noise, the unwanted sound from the surroundings, is an objective function of the pressure of those vibrations and is often measured using decibels (dB) and is mostly created by human activities [2]. It is a type of pollution that adversely impacts the physical, social and psychological wellbeing of exposed individuals [3,4]. This impact may be direct, depending on the duration and level of exposure, and causing or increasing the likelihood of hearing impairment, sleep disturbance, cardiovascular effects and cognitive functioning, especially in school children, and it negatively impacts wildlife, or indirect, resulting in decreased productive work output or school performance, and miserable feelings [5-9]. As enrollment into universities increases, campus hostel facilities are stretch beyond their carrying capacities, and consequently get legally and illegally overcrowded. Resulting from this situation is the increased consumption of material and energy resources, as well as increased pollution of the hostel environment, including noise pollution [10-12]. In a university hostel environment, the activities influencing the noisescape include normal chores of eating/cooking, fetching water, bathing, washing; conversation between occupants and between occupants and visitors; making and receiving phone calls; playing of stereo, radio and television sets; workings of electrical appliances such as fans, refrigerators, air conditioners, power generators; and foot and vehicular traffic within and passing by the hostel.

The variation of the noise impacting an environment with time is term its noisescape. Noisescape gives a schematic representation of the time variation of the background noise in an environment over which additional sounds are superimposed. The background noise impacting an environment varies with the on-going activities. The background noise also receives contributions from similar activities in nearby hostels. The measurement of the noise level is made with a sound level meter, an instrument, usually handheld, that measures the change in the air pressure produced by the sound wave passing through the environment in question. A sound level meter most have five characteristics elements, namely, a transducer which is a microphone, an electronic amplifier with calibrated attenuator for gain control, a frequency weighting or analyzing possibilities, a data storage facilities, and a display capacity. The international standard specifying sound level meter functionality and performances is the International Electrotecnical Commission, (2013) [13]. It specified three sound measuring instruments, namely, the conventional, the integrating-averaging and the integrating sound level meters. Similarly, the American National Standards Institute (ANSI) specified three sound level meters, Types 0, 1 and 2. Type 0 meter is being used in laboratories while Type 1 meter, with accuracy of ±1 dBA, is preferred for setting noise control standards and for precision measurements in the field. Type 2 meter, having accuracy of ±2 dBA, is the minimum recommended for general-purpose measurements [14].

The requirements for noise level measurements are increasingly being met by the ubiquitous smartphones, which are equipped, among other accessories/capabilities, with cameras, global positioning system, and built-in microphones, proximity and light sensors. These handheld devises have computing power comparable to those of desktop computers, and developers now offer many sound measurement applications using either the devices' built-in or externally connected microphones. Interest in such applications is growing among acoustic and environmental researchers and educators. Although the vast majority of smartphones use the android (85 %) and the iOS (14.7 %) operating systems, it is only devises using iOS systems either with built-in or external microphones that have been assessed to give 2 and 1 dBA differences respectively from reference sound level meter [15]. Nesaratnam and Taherzadeh (2014) considered the smartphone microphone inadequate for environmental noise measurement as it is designed primarily for speech that has limited frequency range of about 0.35 to 4.8 kHz [16]. Similarly, Murphy and King (2016) compared smartphone apps in controlled laboratory and field environments and noted that the apps performed worse in the field, and attributed this to the limited frequency range of the smartphone microphones [17]. Robinson and Tingay (2014) and Hawley and McClain in (2016) also attributed the poor performance of the smartphone sound measuring devices mainly to the built-in microphones [18,19]. Murphy and King (2016) examined different models of smartphones and operating systems with several sound measuring apps, and found significant inter-device variability with overall accuracy dependent on the age and condition of the smartphone and the built-in microphone, and concluded that smartphones are not quite ready to replace sound level meters [20]. Aumond et al. (2017) investigated android-based mobile devices for measuring urban noise pollution, and demonstrated that the noise levels measured with calibrated mobile phones correlate strongly with noise monitoring station and sound level meter measurements with root mean square errors smaller than 3 dBA [21]. Celestina et al. (2018) subjected an iOS-based smartphone equipped with professional-grade calibrated external microphone and concluded that the app-based sound level meter performs well enough to be used as an adequate measuring device [22].

This study survey the outdoor noise levels, using android-running smartphone devices at students' hostels, compared with the previous work and with the international standard. The results obtained can be applied to identify the problem areas and to provide a better understanding of the educational and public health implications of noise issues on the university campuses.

II. Materials and Methods

Three students' hostels were selected on the main campus of the University of Maiduguri for the study. These are the Murtala Female Students' Hostel, the Block E Male Students' Hostel and the New Block B Male students' Hostel. The first hostel was selected because it was previously studied and therefore will serve as reference and allow for comparison. The two other hostels were selected because the authors have access and in effort to expand the study to include more sample hostels. Both hostels are 92 and 448 m respectively from the reference hostel. Other hostels located within the vicinity are Titanic Male Students' Hostel (500 m), Aisha Female Students' Hostel (568 m), and the BOT Female Students' Hostel (437 m) (Fig. 1).

The Murtala Female Students' Hostel is walled and is accessed through gates one of the campuses opposite NUGA sport field. It consists of five (5) blocks, one storey building and two hundred (200) rooms. The rooms are designed to accommodate five persons official residents, and is restricted to the opposite gender. Unofficial residents are numerous. A common room is provided for the entertainment of opposite gender when they call. Beside the noise generated from activities within the hostels, additional sources of noise in the hostel include the noise generated from vehicular traffic to and from administrative offices, sports fields and academic venues including the library, class rooms, lecture halls and laboratories. The water fetching point, being accesses by all residents and in close proximity to the common room, was selected as data observation point. Block E Male Students' Hostel consists of four identical blocks, E1, E2, E3 and E4 arranged in opposite to each other(E1 opposite to E4 and E2 opposite to E3 with a commercial road that beset into two equal half) having equal distance to each other, one(1) storey building and one hundred and sixty rooms in all the blocks capable of housing five student in each rooms It can be accessed from numerous directions including by students of other hostels transiting to the academic and commercial areas. The New Block B Male Students' Hostel consists of two identical blocks, B1 and B2, arranged in opposite to each other with five hundred meters far to each other having three (3) storey building and eight hundred (800) rooms. The rooms have capacity of four student per room but also holding numerous unofficial ones.

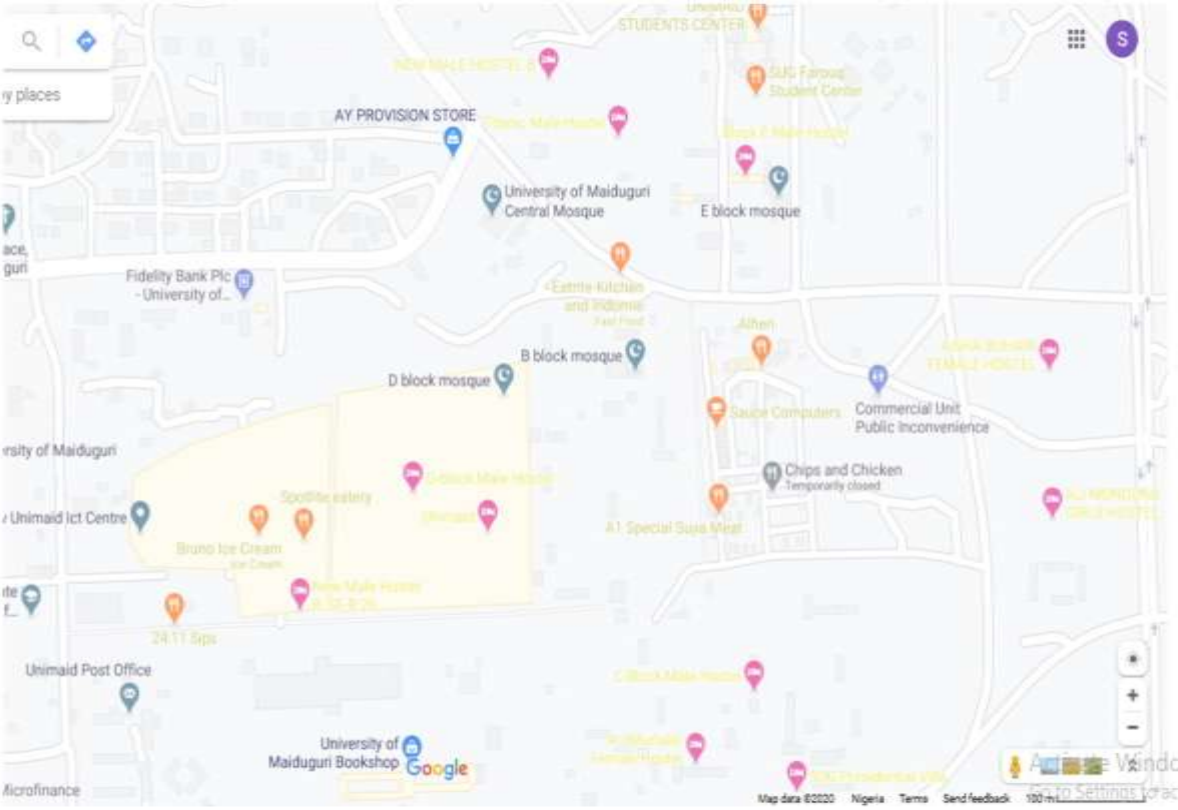

Figure 1: Students' hostels layout on University campus

The noise levels in the Murtala Female Hostel were recorded with an Infinix® Hot 6 smartphone, operated with Android v8.1.0 operating system, while that at the Block E Male Hostel was recorded with Gionee® F103 Pro smartphone operated with Android v6.0.0 operating system, and that of New Block B Male Hostel was recorded with Tecno® L8 smartphone operated with Andoid Lite1.0.0 operating system. A sound pressure level software application, the Keuwlsoft® SPL meter was downloaded from the Google® Playstore® and installed on each of the devices. The selection of this App, out of a plethora of many, was for the fact that Shallangwa et al. (2019) have used the same software to record the sound levels at the same Murtala Female Students' Hostel [23]. The use of the same App was therefore to enable the comparison of the new data set with the previous. Preparatory to the data collection, the smartphone devices were used to record the noise levels at same location at 2400. All three devices recorded values that did not agree, thus signifying that records from each of the devices will need to be harmonized before they can be compared.

III. Results

The devices were used to record the average noise levels for two minutes at the stroke of the hour from 0500 to 2400, an interval spanning twenty hours. The recordings were made on Monday 8th, Wednesday 10th, Friday 12th, Tuesday 16th, and Thursday 18th, July 2019, thus covering the five working days of the week. The average for each hour was calculated from the five records. The difference between the 2400 reading of each device and the reference reading for the same time was taken to be the correction that all the readings of the devices were subjected to, that is readings of the devices were corrected by the subtraction of a constant factor equal to the difference between the devices' 2400 readings and the reference. Table 1, 2 and 3 gives the data for the three hostels.

Table 1: Hour noise levels (dBA) adjusted from records taken on Monday 1st, **(1)**, Wednesday 3rd, **(2)**, Friday 5th, **(3)**, Tuesday 9th, **(4)**, and Thursday, 11th, **(5)**, July 2019 at Murtala Female Students' Hostel

Hour	(1)	(2)	(3)	(4)	(5)	*Ave*
0500	42.90	45.11	43.70	47.06	44.61	44.68
0600	44.51	45.55	44.43	45.68	44.66	44.97
0700	53.76	55.61	55.56	54.55	52.40	54.38
0800	55.43	58.36	57.37	56.48	57.42	57.01
0900	58.15	57.30	56.85	61.59	60.78	58.93
1000	63.61	63.52	63.60	63.76	63.02	63.50
1100	61.71	64.52	55.38	64.42	63.59	61.92
1200	62.26	64.50	63.85	65.02	62.86	63.70
1300	56.42	57.70	60.78	58.59	58.14	58.33
1400	55.51	54.43	53.57	54.48	53.38	54.27
1500	55.93	54.66	54.17	55.35	58.01	55.62
1600	57.86	55.89	53.49	54.41	55.03	55.34
1700	67.22	65.49	67.54	65.88	65.23	66.27
1800	64.04	73.77	63.40	70.43	70.37	68.40
1900	66.72	74.87	67.81	71.75	70.38	70.31
2000	70.87	73.96	71.98	70.66	69.71	71.44
2100	53.34	53.24	56.13	58.33	53.40	54.89
2200	53.43	53.53	52.60	53.43	52.48	53.09
2300	44.51	44.71	42.71	43.46	43.66	43.81
2400	43.68	42.44	43.54	42.64	42.70	43.00

Table 2: Hour noise levels (dBA) adjusted from records taken on Monday 1st, **(1)**, Wednesday 3rd, **(2)**, Friday 5th, **(3)**, Tuesday 9th, **(4)**, and Thursday, 11th, **(5)**, July 2019 at Block E, Male Students' Hostel

Hour	(1)	(2)	(3)	(4)	(5)	*Ave*
0500	44.52	44.13	43.69	41.77	50.91	45.00
0600	46.52	44.85	44.14	44.06	46.89	45.29
0700	59.92	58.45	60.74	60.62	57.95	59.54
0800	54.49	53.30	52.34	53.45	51.89	53.09
0900	64.65	63.99	60.37	60.11	66.12	63.05
1000	60.12	66.14	65.47	61.25	66.98	63.99
1100	65.97	60.80	61.09	62.21	67.25	63.46
1200	63.35	61.32	67.70	61.08	65.99	63.89
1300	53.41	52.42	53.31	52.42	51.45	52.60
1400	52.68	53.48	51.54	52.64	52.66	52.60
1500	59.58	52.59	63.39	60.38	58.33	58.85
1600	66.72	67.31	66.61	64.18	73.18	67.60
1700	60.80	66.97	62.07	61.06	70.78	64.34
1800	71.06	73.50	62.92	63.63	72.52	68.73
1900	69.25	70.91	55.49	69.41	74.34	67.88
2000	60.90	60.57	58.89	60.34	54.95	59.13
2100	51.42	56.63	55.40	53.42	51.50	53.67
2200	53.77	53.55	54.54	55.21	51.34	53.68
2300	42.42	42.63	43.26	43.80	42.86	42.99
2400	43.36	44.53	42.44	43.32	41.36	43.00

Table 3: Hour noise levels (dBA) adjusted from records taken on Monday 1st, **(1)**, Wednesday 3rd, **(2)**, Friday 5th, **(3)**, Tuesday 9th, **(4)**, and Thursday, 11th, **(5)**, July 2019 at New Block B, Male Students' Hostel

Hour	(1)	(2)	(3)	(4)	(5)	*Ave*
0500	43.83	45.55	46.57	46.28	43.23	45.09
0600	45.83	46.99	44.89	42.83	44.97	45.10
0700	51.37	54.02	51.69	51.02	57.16	53.05
0800	54.80	53.77	51.82	52.83	60.18	54.68
0900	53.25	54.18	55.90	55.76	55.41	54.90
1000	60.35	64.86	63.23	63.50	67.01	63.79
1100	59.26	63.15	62.60	61.77	63.68	62.09
1200	64.62	62.80	62.56	61.17	63.31	62.89
1300	63.25	64.36	68.52	65.30	65.68	65.42
1400	62.62	63.03	64.97	62.09	52.61	61.06
1500	54.69	58.86	58.03	59.34	53.52	56.89
1600	52.70	52.08	52.91	51.96	52.74	52.48
1700	51.99	53.90	53.87	52.87	53.78	53.28
1800	65.07	71.74	60.69	58.06	64.38	63.99
1900	66.75	68.77	68.04	59.60	65.97	65.83
2000	63.85	65.19	63.80	63.21	61.86	63.58
2100	55.19	54.27	51.84	52.05	56.97	54.06
2200	53.25	52.70	51.98	52.32	52.76	52.60
2300	43.98	42.88	43.93	42.96	42.84	43.32
2400	43.25	42.70	41.98	44.32	42.76	43.00

Figures 2, 3 and 4 give the plots of the average noise levels (broken lines) and the corresponding noisescapes (solid lines) at the three hostels involved. The noisescape for the Murtala Female Hostel (Figure 2) varies between 43.00 at midnight and 71.44 dBA in the evening. Starting at 44.68 dBA between 0500 to 0700 when the residents wake up, performing such noise generating activities as morning devotions and such chores in preparation for the days' activities including walking along corridors, fetching water, bathing, dressing and eating. As electric power is in supply up till 0600, there may be contributions from use of appliances such as fans, radio sets as well as smartphones. Between 0700 and 0800, although electricity supply is switched off and contributions from electrical appliances are excluded, the noisescape rises to 54.38 dBA. The rise is attributed to more residents waking up and performing similar activities as the previous, while early risers move out of the hostel for early morning classes that may start by 0700. The noisescape further rises to 63.70 dBA between 0800 and 1300, despite electric power being out of supply till 1100. The rise therefore does not have influence from electrical appliances but is made up of foot traffic going for or coming from activities including classes, library; medical attention; administration; and shopping, eateries, markets, banking. There are also contributions from vehicular traffic going by the hostel wall arising from residents boarding and alighting tricycles, workers going and coming from their offices, and a trickle of visitors. Despite the availability of electricity between 1300 to 1600 hours, the noisescape drops to 54.27 dBA, further supporting the earlier inference that electricity-powered appliances contribute minimally to the noisescape. Residents within this period observe some form of siesta or engage in individual study, but with the vast majority exiting the hostel for meal, shopping. A significant number are also engaged academically in laboratory and studio works.

The noisescape between 1400 and 2100 reaches a peak of 71.44 dBA, receiving contributions from such activities of the residents as foot traffic from classes, laboratory and studio works, going to and coming from shops and markets and other personal activities. It also receives contributions from residents exiting the hostel to the sports fields that are just across the road. There are also contributions from vehicular traffic of staff members exiting their offices and passing by the hostel at the end of the official working day, as well as commercial tricycles bringing and removing residents. There is also contribution from visitors to the hostel socializing with the residents. The noisescape drops between the intervals 2100 to 2200 and 2200 to 2400 to values of 54.89 and 43.00 dBA respectively. This is attributed to residents ending socialization visits, engaging in personal studies, and eventually retiring for the night. A difference of 7.74 dBA is also observed between the day- and night-times peaks. This is interpreted to indicate that residents generate only moderate noise when not entertaining visitor, while a lot more noise is generated when they receive visitors that are mostly opposite gender, although it could also that residents engage in more noise-generating activities during the two periods. A striking similarity is observed between this noisescape and that mapped by Shallangwa et al. (2019) for the same hostel (Figure 5). Both have the day- and night-time peaks, with the latter nearly equal [23]. The difference between the day-time peaks may be indicating an increase in residents' population.

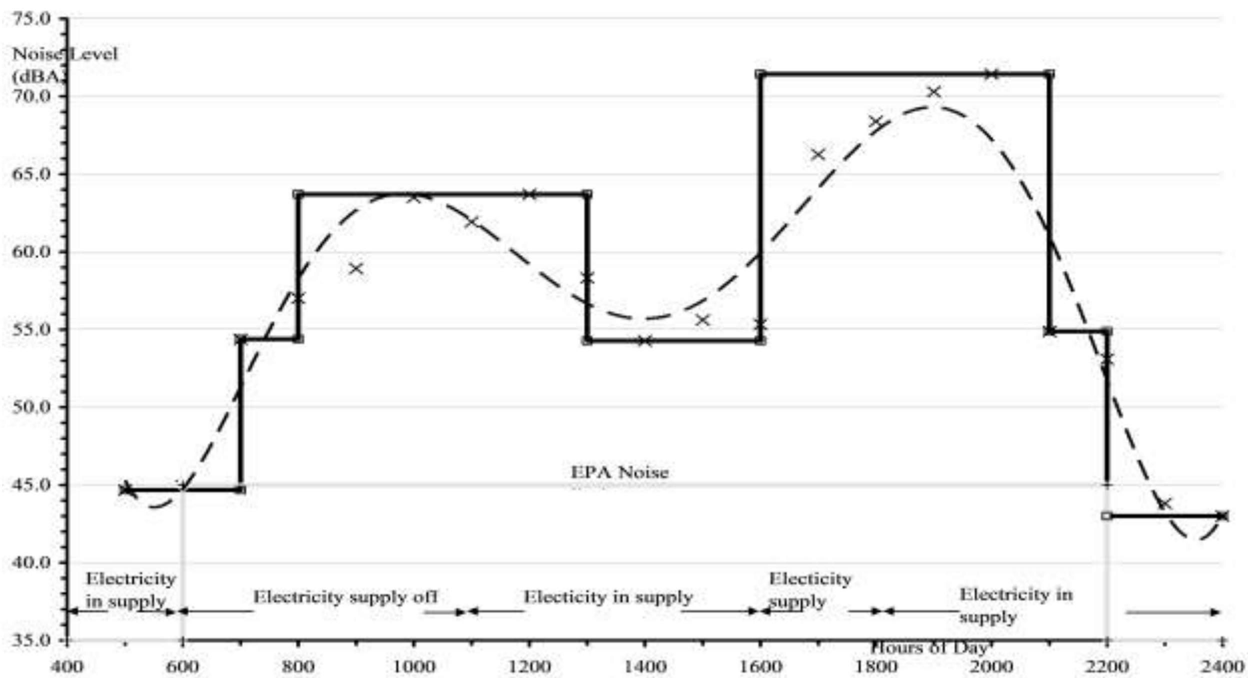

Figure 2: The 2019 Noisescape in Murtala Female Students' Hostel

Figure 3 gives the noisescape for Block E, Male Students' Hostel, and shows a noisescape varying between 43.00 at midnight and 68.73 dBA evening. It began at 45.00 dBA between 0500 and 0600. As in the previous hostel, activities generating noise include residents waking up and performing morning devotions and similar chores. As electric power is in supply within the period, the noisescape receives contribution from electricity operated-appliances, including smartphones. Between 0600 and 0800, the noisescape rises to 53.09 dBA, arising from more residents waking up and engaging in activities as morning devotion and chores preparatory to the activities of the day. There is also contribution from residents moving out of the hostel for early morning activities as well as from commercial tricycles commuting students and other workers. There is little or no contribution from the commercial area located nearby, as well as, from contribution from electricity-powered appliances as the supply is switched off. The noisescape further rises to 63.89 dBA between 0800 and 1300, despite the absence of electricity supply up till 1100. The rise, as in the case of the previous hostel, is attributed to activities of residents' traffic going for or coming from classes, library; medical attention; administration; and shopping, eateries, markets, banking. Similarly also, there are contributions from vehicular traffic going by the hostel arising from residents boarding and alighting tricycles, workers going and coming from their offices. Although there is no electricity supply between 0900 and 1100, and therefore no contribution from electricity-powered appliances, there is the contribution from the commercial area especially at the latter part of the period.

Despite electricity being in supply, the noisescape drops to 52.6 dBA between 1300 and 1600. The residents within this period return for afternoon break, performing noon and afternoon devotions, resting, eating, personal study and similarly activities as those of the residents of the previous hostel. The availability of electricity supply limiting the contributions from the commercial area as their power generating sets are not in use. Between 1600 and 2100, the noisescape peaks to 68.73 dBA, despite electricity being out of supply between 1600 and 1800. Contributing to this peak are the activities of the residents socializing within themselves after the day's activities; from power generating sets of business centers in the commercial area; from vehicular traffic of members of staff passing by the hostel while exiting the campus at the end of the official working day; and from commercial tricycles bringing back and removing residents. Between the intervals 2100 to 2200 and 2200 to 2400, the noisescape rapidly drops to 53.67 and 42.99 dBA respectively, when the residents end the socialization, engage in personal study, and gradually retire for the night. A 4.74-dBA difference between the day- and night-times noisescape peaks suggests active noise-generating activities at night for this hostel, probably a gathering involving non-residents.

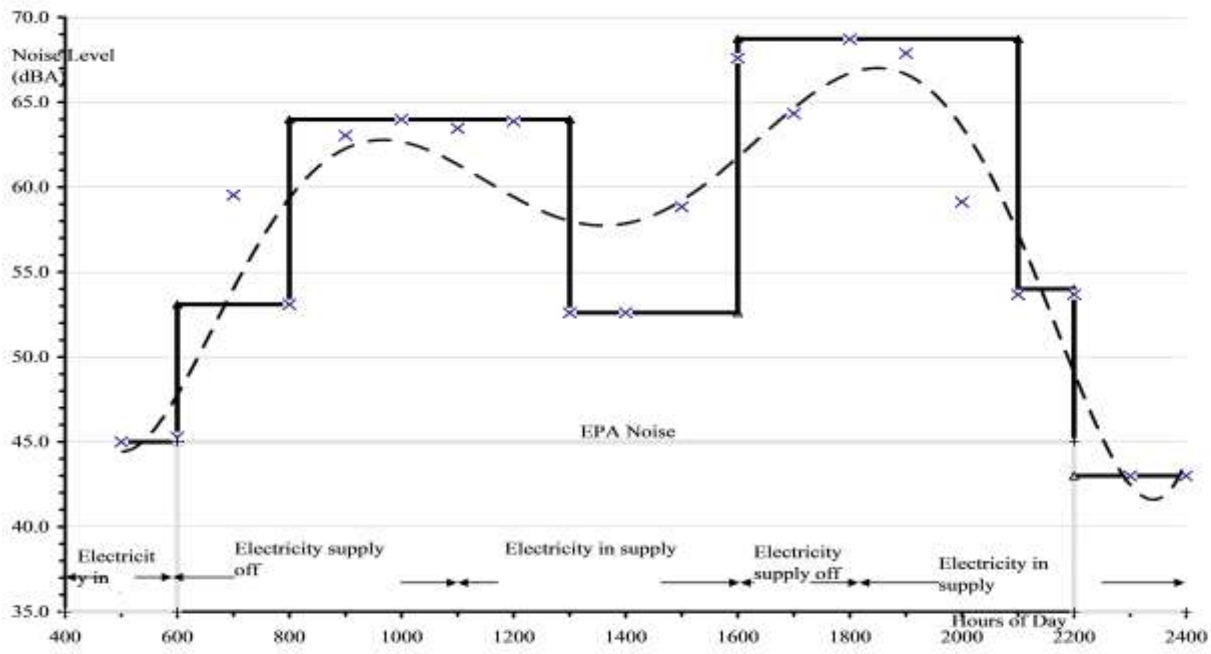

Figure 3: The 2019 Noisescape in Block E Male Hostel

Comparing this noisescapes with that of the female hostel shows that more female students rise up early compared to the male students, probably because females take longer time to prepare compared to the males. However, the two afternoon peaks are about the same, indicating similar activities of near equal magnitude. The female hostel's evening peak of 71.44 dBA, is at least 2.71 dBA higher than that of this hostel. This is interpreted to indicate more collection of noise generating activities at the female hostel compared to the male hostel, probably opposite gender socialization. Both noisescapes appear to decline in similar manner at the end of the day, indicating similar activities.

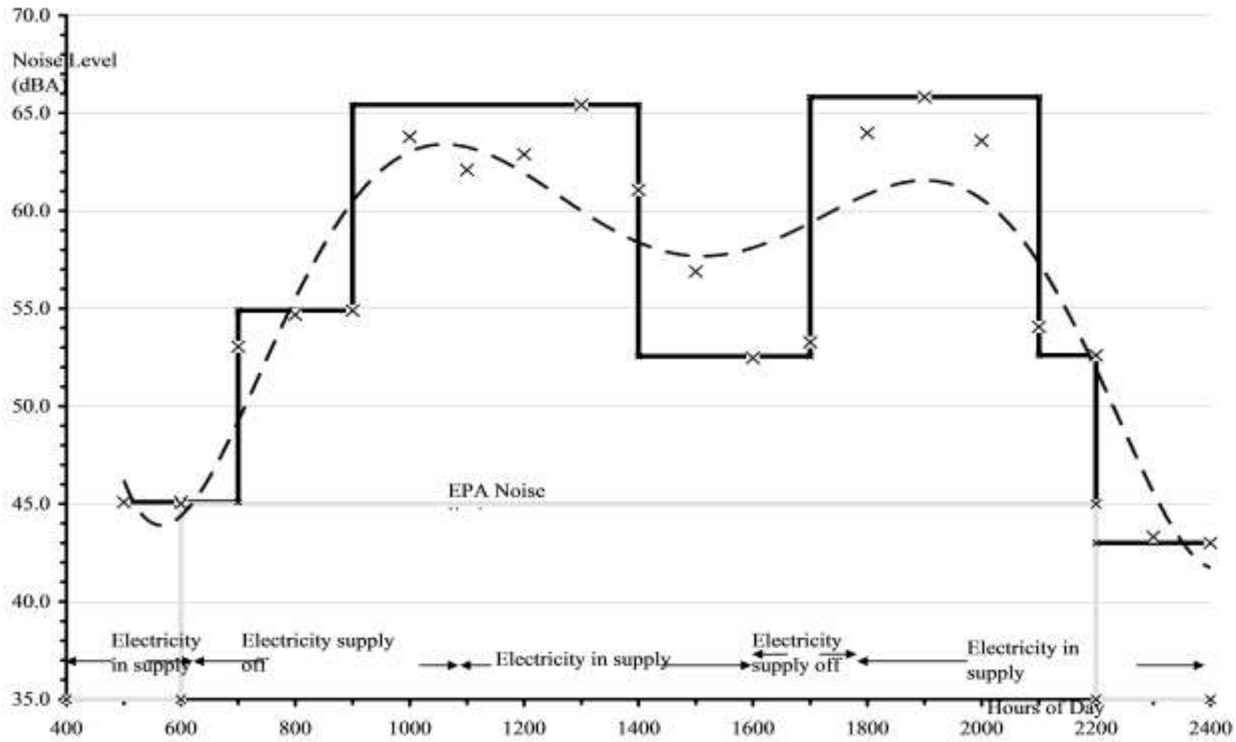

Figure 4: The 2019 Noisescape in New Block B Male Hostel

The noisescape for New Block B, Male Students' Hostel (Figure 4) varies between 43.00 and 65.83 dBA. It starts at 45.09 dBA between 0500 and 0700 when students wake up for the day and perform such noise generating activities as performing the morning devotions, fetching water to bath, dressing and preparing for the day. Human foot traffic from students moving out of the hostel for early morning lectures. Electricity is in supply up till 0600. Although electricity is not in supply, the noisescape rises to 54.90 dBA between 0700 and 0900 as more students wake up and engage in similar activities as the early-risen residents. Between 0900 and 1400, the noisescape rises to the day-time peak of 65.42 dBA. Activities of the residents are similar to those of the two previous hostels, going and coming from lectures, studios, laboratories, and library; going and coming from markets, shops, banks, clinic; and activities of passers-by going and coming from surrounding facilities in private and commercial vehicles and on foot. It is to be noted that electricity is in supply up till 1600. The noisescape drops to 52.55 dBA between 1400 and 1700 despite electricity being in supply up till 1600. Residents within this period retire from academic activities for activities including noon and afternoon devotions, lunch, personal study, siesta, visit to and from friends and course mates.

The noisescape again rises to a night peak of 65.83 dBA between 1700 and 2100 with residents involved in varied noise generating activities including walking back from academic area, performing such chores similar to those of the residents of the two previous hostels. Contributions are also received from commercial tricycles bringing and removing residents from out-of-hostel activities. The noisescape drops to values of 52.50 and 43.00 dBA between 2100 and 2200 and between 2200 and 2400 respectively, similar to the patterns of drops in the two previous hostels for similar times. A 0.40-dBA difference between the day- and night-times noisescape peaks suggests similar activities, namely, absence of gathering that generates excessive noise.

Comparatively the morning noisescape rise for this hostel takes 4 hours to reach the day-time peak, while those of the other hostels take 3 hours. This is interpreted to indicate that residents take longer time to wake up, prepare and go out for the activities of the day, probably due to inadequate supply of required resource, such as water. It could also indicate trespass by residents of other hostel as the hostel is on the walking route of residents of a number of other hostels to the core academic areas. Furthermore, the day-time peak for this hostel (65.42 dBA) is higher than those of the two previous hostels (63.70 and 63.99 dBA), indicating higher noise-generating activities. This again is attributed to residents of other hostels trespassing through the hostel on their way back from core academic areas. The difference in the night-time peak (65.83 dBA) for this hostel and those of the two previous hostels (71.44 and 68.73 dBA) is attributed to absence of socializing gatherings. Finally, the decay of the noisescapes at the three hostels in similar time intervals is interpreted to indicate retiring from all forms of socialisation and the engaging in personal study or going to sleep across the hostels in similar pattern.

IV. Discussion

The microphones that come with Android smartphones are designed to detect human speech that has a frequency range of about 0.35 to 4.8 kHz and do not meet requirements for sound measurements [16]. Measurements made with such devices are therefore inaccurate, eliminating sounds of lower frequencies and amplifying other sounds of higher frequencies. The cumulative effect of the microphone inadequacy on the noise detected is likely to be systematic, shifting the readings by a particular magnitude. On the assumption that the smartphone introduces a systematic shift to the noise levels recorded, albeit of unknown magnitude, data collected with the device can still be useful in delineating the pattern of the variation of the noise with time. The established noisescapes therefore link the noise-generating activities of the residents of the hostels.

Shallangwa et al. (2019) smartphone-mapped the noisescape at the Murtala Female Students' Hostel, University of Maiduguri, Nigeria, one of the three hostels involved in this study, and recorded a noisescape that can be broken into five sections (Figure 5) ranging in magnitude between 43 and 71.67 dBA matched to various activities of the residents [23].

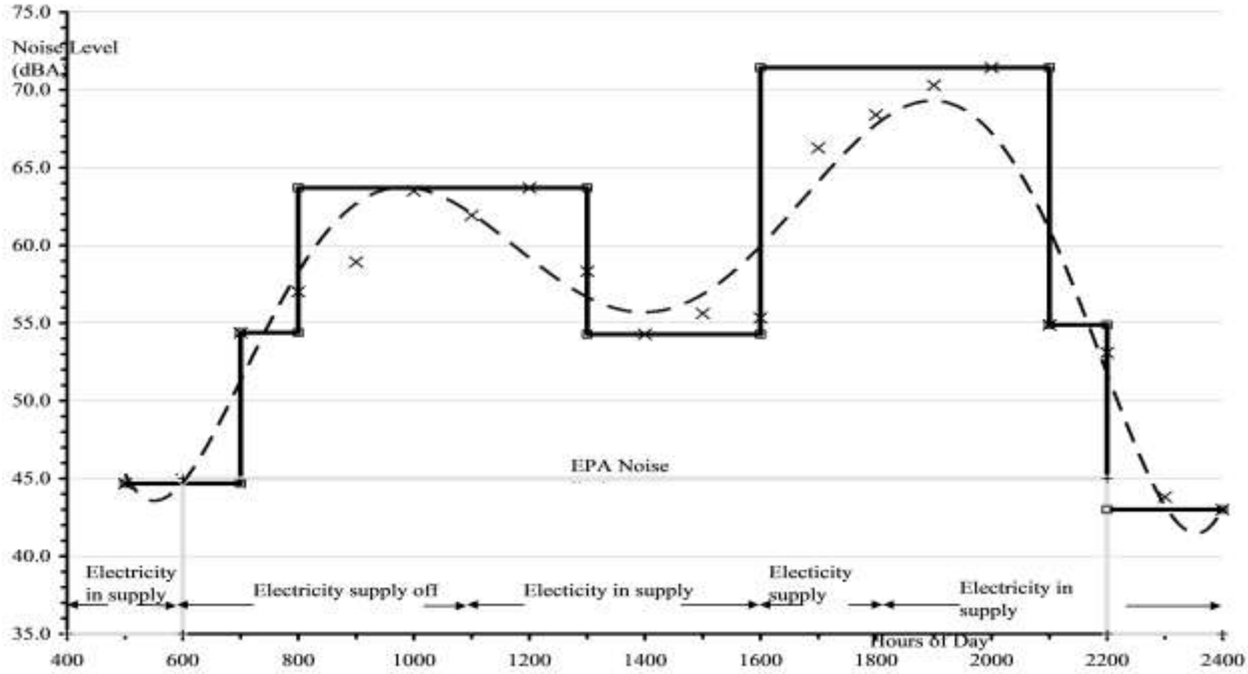

Figure 5: 2018 noisescape at the Murtala Female Students' Hostel (After Shallangwa et al., 2019)

Lavandier and Barbot (2003) have investigated the optimal sampling time for the urban acoustic environment and concluded that for areas with high traffic noise, such as the boulevards, five-minute recordings in each hour of the twenty-four-hour day are sufficient to delineate the necessary descriptors of the acoustic field, whereas for quieter locations, fifteen-minute window is more appropriate [24]. Brocolini et al. (2013) also investigated similar time and concluded that durations of between ten- and twenty-minutes are sufficient to discriminate the main features of the acoustic field, while the ten-minute duration is the most appropriate [25]. Compared to these reports, a two-minute recording window was used in this study and has delineated two acoustic highs within the twenty-hour day. The shortness of the recording window may suggest that further features of the noisescape, besides the one delineated, might have been missed. It could also mean that the parameter being described, the noisescape is adequately described by the two-minutes sampling interval, while other descriptors need longer sampling interval. These include the equivalent A-weighted sound pressure level in a stated interval, L_{Aeq}, the minimum, L_{AMin}, the 1-percentile, L_{A1}, the 10-percentile, L_{A10}, the median, L_{A50}, the 90-percentile, L_{A90}, the 99-percentile, L_{A99}, the maximum, L_{Amax} or the day and night continuous equivalent sound pressure level, L_{Adn}.

Although the National Environmental (Noise Standards and Control) Regulations (2009) in Nigeria have set the day- and night-times noise limits, it has not differentiated between indoor and outdoor noise limits, and between indoor with opened or closed windows [26]. The noise levels encountered in this study, albeit, measured with uncalibrated smartphones, exceed the limits at all times. Because the measurements were made outdoor, however, it is possible, depending on the design of the windows and doors of the hostel rooms that lower noise levels may be encountered indoor with opened and/or closed windows and doors as materials of the window and door coverings have various attenuation abilities. With glass and wood having attenuations of 2.6 and 3.8 % respectively [27], glass-paneled windows, would attenuate the midnight noisescape from 43 to 41.88 dBA within the rooms, while a flush door with double wood panel would attenuate the midnight noisescape to 39.80 dBA. Similarly also, the night-time noisescape peaks at the Murtala Female Students' Hostel, the Block E Male Students' Hostel and the New Block B Male students' Hostel would be attenuated from 71.44, 68.73 and 65.83 to 69.58, 66.94 and 64.12 dBA respectively by glass panel windows in the rooms, while double panel doors would attenuate the noisescapes to 64.40, 61.95 and 59.34 dBA.

Although the environmental regulating authorities have always set noise limits for schools, usually along with hospitals, convalescence homes, homes for the aged and sanitaria, assessments of the noise levels in schools environments are few and far apart, and assessments in the schools hostel environments are even further apart. Assessment of noise in school environments are usually, and understandably, for classrooms and lecture halls, where teacher – student interactions take place, and for offices. Otutu (2011) investigated environmental noise within Campus of Delta State University, Abraka, Nigeria and observed a noise level well above the limit set by the authority with an average of 87 dBA that is attributed to come largely from the power generating sets of business centres operating on campus [28]. Ideriah (2015) also assessed the ambient day indoor and outdoor noise levels in University of Science and Technology, Port Harcourt, Nigeria and recorded noise levels above that set by the authority, ranging between 47.8 and 103.2 dBA, with highest readings coming from the power generating sets of the University [29]. Similarly, a mean noise level of 73.6 dBA on Covenant University, Ota, Nigeria was recorded with the highest reading around the institution's Daniel Hall, and is attributed to contributions from vehicular traffic neighboring the hall [30].

When the noisescape in an environment has been defined and its make up identified, one question that needs to be answered is how much noise is too much for the environment. Limiting noise levels in environments are set by national, local, or even municipal authorities using international standards of measurement. Two types of limits have been defined to restrict the noise levels in environments. These are the fixed limits, the most common, and relative limits [31]. In Nigeria, the National Environmental (Noise Standards and Control) Regulations (2009) used the fixed limit to set the day- (6:00 am - 10:00 pm) and night- (10:00 pm - 600 am) times maximum noise levels in buildings used as hospitals, convalescence homes, homes for the aged, sanitariums and institutes of higher learning, conference rooms, public libraries, environmental or recreational sites as 45 and 35 dBA respectively [26]. The Ghana Environmental Protection Agency similarly used the fixed limit to define the day- and night-times noise limits as 55 and 50 dBA respectively for educational and health facilities [32]. The Indian Noise Pollution (Regulation and Control) Rules, 2000 has limited the day- and night-times noise levels in what it described as Silence Zones, defined as 100 meters around hospitals, educational institutions and courts to 50 and 40 dBA respective. The European Union Harmonization Laws in its Regulation on Assessment and Management of Environmental Noise in Turkey also used the fixed limit to define the upper noise limits in classrooms with closed and opened windows as 35 and 45 dBA respectively, and 40 dBA for theater halls and 55 dBA for dining halls [33].

The Singapore National Environment Agency (SEPA, 1999) also used fixed limits but identified the noise by its source, as well as by its time persistence, and broke the time period into three intervals instead of the usual two, namely, day (7.00 am to 7.00 pm), evening (7.00 pm to 11.00 pm) and night (11.00 pm to 7.00 am) [34]. Factory noise that is continuous or over 5 minutes have limiting noise levels of 60, 55 and 50 dBA and 65, 60 and 55 dBA respectively for the three time intervals for noise sensitive premises, defined to include hospitals and schools. Construction works noise that persist for 12 hours and that lasting 5 minutes have limiting noise limits of 60, 50, 50 dBA and 75, 55, 55 dBA respectively for the three time intervals for hospital, schools, institutions of higher learning and homes for aged. The Australian Environmental Protection Authority on the other hand uses the relative limit to define the noise limits in an environment (AEPA, 2013). In defining the limit, the slow, L_{A10}, the fast, L_{A90}, and the average, L_{AEq} components of the noise are assessed, and limiting noise level for the environment in question is defined from the additional noise impacting the environment from any of the identified components [35]. Sowah et al. (2014) assessed the noise levels in schools around the Teshie-Nungua area of Accra, Ghana and recorded maximum and minimum levels of 95.8 and 51.6 dBA with about 90 % of pupils being exposed to levels above 72.5 dBA that is attributed to vehicular traffic as the schools are being located in mixed commercial and semi-commercial areas. Bulunuz et al. (2017) recorded average noise levels of 74.56 and 82.18 dBA at break times in private and public primary schools located in the district of Bursa, Turkey, and noted that these are far in excess of the limits set by the law [36]. Thattai et al. (2017) measured noise levels across the SRM University, South India, and observed levels above the 50 dBA limit set by the regulatory authority at morning and evening periods as well as 20 % higher levels during the later half of the semester compared to the early half [37]. The University of Sulaimani, Kurdistan Region, Iraq achieved noise reduction by the spacing facilities and relocating faculties to a new campus removed from city noise in the old campus [38]. Wiese (2018) observed ambient noise levels in classrooms that exceed national and international recommended values in a primary school in Cloetesville, Stellenbosch, South Africa, and attributed this to the layout of the school [39]. The noise level in four halls of residence of the University of Cape Coast, Ghana were assessed (Essandoh et al., 2011) and same-gender halls were found to have noise levels below the specified limits, while the mixed-gender halls exceeded it, probably arising from cross-gender socialization [32]. Orola and David (2019) also assessed the noise levels in selected hostel rooms of students of the Obafemi Awolowo University, Ile Ife, Nigeria in relation to the window-to-external wall area and window-to-floor area ratios. Noise levels recorded range between 27.75 to 56.29 dBA, with an average of 48.77 dB, while contributing indoor activities include roommates chatting, door slamming, noise from electrical/electronic appliances and phone calls. Contributing outdoor sources include religious, sporting and common-room activities, as well as corridor human and vehicular traffic, power generator and neighboring-rooms noises. In general, the indoor noisescape may approach the set limits with closed windows and door, and the rooms may be more suitable for individual study [40].

V. Conclusion

Although recognized to have shortcomings, the smartphone devices have been used to measure noise levels at three students' hostels in the University of Maiduguri, Nigeria. These shortcomings include among others that the devices microphones did not meet the standard for sound level measurements, hence, the noise levels measured are, assumed, to have systematic error of measurement, and that measurement window of two minutes is shorter than the recommended five- to twenty-minutes needed to delineate the necessary descriptors of the acoustic signal. In spite of these however, the measurements have been used to define the average noise levels which in turn are used to delineate the noisescapes at the subject hostels.

The noisescapes at the three hostels, besides exceeding the limit set by the authority responsible, displayed similar patterns that vary mainly in magnitude. Each grows from low values close to, but above the set limit early in the morning to a day-time peak, then decline to an afternoon low. The growth is associated with increasing number of residents rising from night rest, prepare and exit the hostels for the activities of the day, while the decline in linked to residents engaging in low noise-generating activities including siesta, noon and afternoon devotions, exiting the hostels for laboratory and studio works, as well as, for shops/markets, banks and university administration. The Noisescapes thereafter grow to night-time peaks that are higher than the corresponding day-time peaks. It is attributed to such activities of the residents as foot traffic of residents returning from classes, laboratory and studio works, going to and coming from shops/markets and other personal activities. It also receives contributions from residents going to and coming from the sports fields, and from vehicular traffic of staff members exiting their offices and passing by the hostels at the end of the official working day, as well as commercial tricycles bringing and removing residents. There are also foot and vehicular traffic contributions from visitors socializing with the residents. The noisescapes drop to their lowest values in similar patterns that are attributed to ending socialization visits, engaging in personal studies, and eventually retiring for the night. Electricity supply does not appear to influence the noisescape.

The shortcoming of the set noise limit to differentiate indoor between indoor and outdoor conditions may result in excess outdoor noise that, would, with appropriate door and window paneling, allow for the achievement the set limits within the hostels rooms.

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