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Acoustic Comfort Evaluation of Residence that Uses Portable Electricity-Generating Plants

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Abstract:
The response of various sectors of the Nigerian economy to the epileptic state of power supply from the Nigerian electricity grid has greatly contributed to the acquisition and use of mobile power generation equipment as an alternative energy source. This study examined the acoustic impact of power generation facilities on residential environments in the greater Abeokuta area. The total noise emitted by each portable generator was measured at various distances of 1 meter each, starting at 1 m from the portable generator and up to 5 m from the previous measurement point. Measurements were taken 15-30 minutes before and after the operation of the portable power plant and 30-60 minutes during operation. Data was collected using a tape measure, a digital stopwatch and a GM 1352 sound level meter. The average results for noise emission during use of the generator were maximum (mean = 83.93 dBA, SD = 1.35) and minimum (mean = 71.72 dBA, SD = 0.85) at a distance of 1 m, which was much higher than the average environmental noise level before (mean = 47.36, SD = 0.75) and after (mean = 47.63, SD = 0, 75) generator operation. Analysis of noise level intensity for household acoustic comfort using the United States Department of Housing and Urban Development's recommended categories of typical noise levels for residential areas revealed that the outdoor noise levels of the assessed environment before and after use of portable power generation equipment were within LAeq ≤ 49 dBA and 49 < LAeq ≤ 62 dBA, which represent clearly and normally acceptable noise level limits for residential areas. However, the noise levels modified to ranges within of 62 < LAeq ≤ 76 dBA (normal) and LAeq > 76 dBA (clearly) unacceptable noise level when using portable power generators. This means that power plants pose a noise nuisance to the outside of the houses in which they are used to supply electricity, thereby affecting the acoustic comfort of that environment.

Keywords: Residence, electricity-generating, noise, acoustic comfort.

INTRODUCTION

An environment is considered comfortable when there are few or no annoyances or distractions during work or leisure activities, including environments that may physically or psychologically impair activity in that environment (Azodo and Adejuyigbe, 2013). According to Olokoaba (2005), noise is detrimental to both human health and the environment's ability to maintain comfort. Due to technological development, noise is one of the physical pollution factors that have a negative impact on human health. Noise is a stressor of such importance that it is an integral part of our environment, so much so that the term noise pollution refers to the dangers of noise in addition to the serious consequences of this modern development. (Azodo and Adejuyigbe, 2013).

According to Katsil (1998), noise pollution increases irritability in men, and the effects are multiple and interrelated. Noise disturbs people not only at home but also in inner cities, on the street and at various workplaces (van der Merwe, 2013). Urban centres are characterized by noisy environments associated with activity, which is why some people prefer to live in remote locations (Babawuya et al., 2016). Noise pollution in our environment is increasing rapidly and is one of the greatest threats to the quality of life at all levels (Okoro, 2014; Khaki et al., 2010). According to FEPA (1995) and WHO (1980), noise is produced when the sound power of a vibrating body exceeds levels considered safe for the environment. Noise fades away from its source as it spreads to more distant air particles (van der Merwe, 2013). When classifying noise by type, it falls into two main categories: industrial noise and residential noise (Jackson, 1990).

Residential noise has been described as noise emanating from any source other than factories (Muhammad et al., 2008). All citizens and residents are exposed to noise pollution from their homes as they return home from their daily activities to rest and recharge for the next day's challenges. The utilization of portable power generation systems demonstrates the importance of power generation systems in household activities. The role of portable power generation systems as an alternative source of energy contributes significantly to comfort, mechanization of household chores, joy and enjoyment of life. Studies have shown that the use of generators contributes significantly to environmental noise pollution (Iqbal and Lodhi, 2014; John and Dewan, 2015). If left uncontrolled, generator noise becomes a major problem at measured levels above 100 dBA (Aaberg, 2007).

The importance of residential generators must be within healthy dose exposure rates, regardless of the noise they generate (Azodo et al., 2018a). A review of the literature shows that quiet is a fundamental environmental health factor in residential areas, having a positive impact on residents' standard of living and well-being (Azodo et al., 2018a). Ohwovoriole et al. (2016) added that environments characterized by objectionable noise interfere with people's vital activities. The wide range of exterior noise levels demonstrated by Goodfriend (1977), ranging from the characteristic noise conditions of a busy city center to the quiet of the wilderness, shows that acoustic comfort is achievable. According to Mohd (2011), noise exposure has a greater impact on human health than other environmental stimuli.

Different responses from different sectors of the Nigerian economy to the epileptic power supply situation in the country contributed significantly to the import rate of power plants. The acquisition and use of power generation facilities as alternative energy sources are increasing year by year and thus contribute significantly to noise pollution in the environment (Okoro, 2014). Roughly divided into engines, alternators, fuel systems, exhaust voltage control systems, control panels, and frames, generators are useful devices made up of many parts.

In engine-driven generators, the heat and pressure produced by the combustion of fuel mixed with air are converted into mechanical energy by the combustion process and parameters affecting combustion (Kass, 2008). Engine reciprocation produces noise and vibration (Aaberg, 2007). A rotary generator produces electricity through the mechanical movement of an internal combustion engine's piston-crank system and the pressure fluctuations caused by the exothermic reaction of the hot expanding gas (high-temperature, high-pressure oxidized fuel) in the combustion chamber. Each vibration and movement produce a series of alternating stages of compression and rarefaction that travel through the air and are perceived by the human ear as sound. Studies have shown that users of portable power generation systems are more likely to install them near their homes, where they are exposed to noise and vibration (CPSC, 2006; Ashmore and Dimitroulopoulou, 2009). On the other hand, the proximity of power generation facilities can introduce noise into living spaces and affect the acoustic comfort of surrounding households (Azodo et al., 2018a).

The intensity of the sound produced by devices depends on the receiver's distance from the source, the type of environment and the type of noise source (Khaki et al., 2010). The principle of sound propagation generally consists of three interconnected elements: the source, the transmission path and the receiver. The transmission path is always via a material medium or outdoors to the recipient. This can be continuous or intermittent, but it can also be of low or high frequency, making it undesirable for normal hearing (Chattomba, 2010). Chattomba (2010) stated that most transient hearing loss occurs within the first two hours after exposure. The effects of noise on the ears are of three categories: acoustic trauma, permanent and transient hearing loss (Melamed et al., 2001). Noise exposure can also be a serious source of stress on the auditory and non-auditory systems, as well as the nervous system of exposed individuals. Emphasis on the impact of noise levels beyond 70 to 75 decibels as found in the world health organization's exposure limit explained that the health challenges beyond these limits causes rise in the blood pressure, challenges with emotions and behavioural effect. Prolonged exposure to high levels of noise above 85 dBA can cause hearing loss (Khaki et al., 2010).

Chronic exposure to noise in residential, work, and some recreational settings can result in numerous health effects (Camp and Davies, 2012). The sound level meter measures the average reading over a period of time, t, in dB. The running time (t) is displayed at the bottom of the screen (Adie et al., 2012). When sound is generated by a source, its decibel level drops with respect to the distance from that source (LSA, 2006). The unresolved scourge in limited access to quality and quantity electricity in the nation with a significant number of households own and operate generators due to these shortfalls with it attended it serves as power main source of power supply triggered this research. Therefore, this study measured and evaluated the acoustic comfort of residence that uses portable electricity-generating plants according to the United States Department of Housing and Urban Development (HUD) to analyse the outdoor noise of various residents.

MATERIALS AND METHOD

This cross-sectional study of noise levels from electricity power generation facilities used by residents of Abeokuta was selected using a systematic random sampling technique. A total of 150 portable generators were evaluated in the homes visited. Noise emission sampling data collection was conducted from households where the portable power generation systems were installed on residents' balconies, including bungalows and multi-storey buildings. The noise emission of each mobile power generation unit was measured at different distances of 1 m from the previous measurement point, starting at a distance of 1 m from the power generation unit. The vertical measurement height considered for sound level measurements was 1.5 m above the floor. The maximum and minimum distances from measurements were 5 meters and 1 meter, respectively. Measurements were taken at three different times during the run (30–60 min after the start of the load run time) and 15–30 min before and after the generator was switched on and off, respectively. The data collection period is based on the routine use of the informed portable power generation system between 8:00 p.m. and 11:00 p.m.

The noise levels emitted by the outdoor portable generators of the various houses surveyed were measured using a Benetech digital sound level meter model GM 1352 (Shenzhen Jumaoyuan Science and Technology Co., Ltd., China) (Figure 2). The factory calibrated digital noise level meter from Benetech is preset to a slow response mode with an accuracy of 1.5 dB and a measurement resolution of 0.1 dB in the frequency range from 31.5 Hz to 8 kHz and measures noise levels from 30 to 130 dBA. Benetech digital sound level meters are equipped with a A-weighting noise level scale as standard adapted for industrial and environmental noise emissions assessment because it correlates with human auditory perception and response.

A digital stopwatch model PC-396 (Shenzhen Super Deal Co., Ltd., China) (Fig. 3) was used to measure the time of the measurement intervals. Sound levels were measured and recorded at five distances (1 - 5 m) from each residential portable generator, with two 2-minute intervals at each point, yielding 20-minute readings for each point measured distance from the generator. Sound level measurements include maximum and minimum noise level values in dB. The measured distance was determined with a retractable tape measure model B300-AG (Shangqiu Dinglian International Trade Co., Ltd.) (Figure 1).

Figure 1:
A measuring tape

Figure 2:
Benetech digital sound level meter

Figure3:
A digital stopwatch

The owners of the portable power generation systems used in the research were contacted to obtain their consent to include these systems in the study sample. Only where permission was granted was included in this study. The objective of the study was provided for the proposed households. The noise levels obtained from the evaluated portable power generation systems were compared to typical noise level scales and US Department of Housing and Urban Development (HUD) recommended residential noise levels to analyze outdoor noise for various occupants. The HUD categories of the typical noise levels were $L_{Aeq} \leq 49$ dBA for clearly acceptable, $49 < L_{Aeq} \leq 62$ dBA for normally acceptable, $62 < L_{Aeq} \leq 76$ dBA for normally unacceptable and $L_{Aeq} > 76$ dBA for clearly unacceptable noise levels (Babawuya et al., 2016). The analysis was performed using the Statistical Package for Social Science Version 20.0 and the Microsoft Office Excel version 2010.

RESULTS AND DISCUSSION

Of the 150 households visited with research proposals and permits to assess the noise emission level of their portable power generation system, only 93 agreed and kept their appointments for portable power system measurements. This resulted in a response rate of 62%, which was used as 100% in this study. A sample summary of noise emission levels, statistically analyzed and recorded for each of the 93 homes, is presented as the mean, standard error of the mean, standard deviation, minimum, and maximum (Table 1).

Table 1. Statistical analysis of the portable electricity-generating plant noise emission level samples obtained at each of the ninety-three residences

Measurement distance (m)	Minimum (dBA)	Maximum (dBA)	Mean (dBA)	Standard error of mean (dBA)	Standard deviation (dBA)
Noise level before portable electricity-generating plant usage					
1	34.10	75.90	47.36	0.75	10.27
2	34.60	75.00	47.72	0.64	8.75
3	34.20	73.80	47.38	0.67	9.15
4	34.10	75.80	46.18	0.69	9.39
5	34.00	80.30	47.35	0.74	10.11
Noise level during portable electricity-generating plant usage					
1	40.00	117.90	83.93	1.35	18.42
2	42.00	118.00	81.92	1.29	17.57
3	40.50	118.00	77.25	1.10	14.99
4	41.70	117.60	74.70	0.98	13.40
5	41.90	114.90	71.72	0.85	11.62
Noise level After portable electricity-generating plant usage					
1	34.00	80.80	47.63	0.75	10.25
2	34.40	90.60	45.96	0.71	9.74
3	34.00	96.60	46.23	0.71	9.66
4	34.00	97.40	45.96	0.73	9.94
5	34.00	99.60	47.42	0.94	12.85

Outdoor environmental noise level results of the various portable electricity-generating plants assessed in different households before and after the portable electricity-generating plant usage time showed that both maximum and minimum noise levels obtained fell within the noise level ranges of LAeq ≤ 49 dBA for clearly acceptable and 49 < LAeq ≤ 62 dBA for normally acceptable at the five different distances (1-5 meters) from which the measurements were taken (Tables 2 and 3; 6 and 7). Powering on the portable electricity-generating plant showed that there was a change in the noise level of the various assessed household during the portable electricity-generating plant usage time. The measured noise level changes observed showed that most outdoor environments changed to 62 < LAeq ≤ 76 dBA and LAeq > 76 dBA, which are normally unacceptable and unacceptable noise level ranges for recommended noise level for residential areas (Tables 4 and 5). This study showed that in most households the measurement during portable electricity-generating plant usage is higher than the clearly unacceptable noise obtained in the residents assessed. The values that were within the noise levels of LAeq > 76 dBA were 64 (68.8%), 49 (52.7%), 33 (35.5%), 26 (28.0%) and 17 (18 .3%) at distances of 1, 2, 3, 4 and 5 meters were shown to be above the 70-decibel limit for outdoor noise levels set by the World Health Organization and above the 70-75 dB (A) level accepted by the Environmental Protection Agency (EPA). Also, when comparing with the allowable noise levels specified in the Environmental Protection Act, the Residential Area Code, during the day from 6 a.m. to 9 p.m. and at night from 9 p.m. to 6 a.m., the obtained results were 55 and 45 decibels, respectively (Okoro, 2014). The noise level data values analyzed correspond to a range of apparently acceptable and normally acceptable noise levels observed only before and after use of portable power generation systems. This study agrees that noise from power plants increases the average ambient noise level and the A-weighted noise level of the environment in which the portable power generator operates (Okoro, 2014). This study also agreed with the study by Babawuya et al. (2016) agree that high noise levels resulting from the use of portable power generation systems affect the outdoor activities. This means that the power plants that provide the electricity are located outside the house, which leads to noise pollution and acoustic comfort of homes.

Table 2. Maximum noise level of portable electricity-generating plants analysis for residential areas recommended before usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	36 (38.7%)	43 (46.2%)	14 (15.1%)	0 (0%)
2	35 (37.6%)	46 (49.5%)	12 (12.9%)	0 (0%)
3	36 (38.7%)	43 (46.2%)	14 (15.1%)	0 (0%)
4	38 (40.9%)	42 (45.2%)	13 (14.0%)	0 (0%)
5	33 (35.5%)	47 (50.5%)	13 (14.0)	0 (0%)

Table 3. Minimum noise level of portable electricity-generating plants analysis for residential areas recommended before usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	90 (96.8%)	2 (2.2%)	1 (1.1%)	0 (0%)
2	92 (98.9%)	1 (1.1%)	0 (0%)	0 (0%)
3	90 (96.8%)	3 (3.2%)	0 (0%)	0 (0%)
4	91 (97.8%)	2 (2.2%)	0 (0%)	0 (0%)
5	90 (96.8%)	1 (1.1%)	1 (1.1%)	1 (1.1%)

Table 4. Maximum noise level of portable electricity-generating plants analysis for residential areas recommended during usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	6 (6.5%)	0 (0%)	23 (24.7%)	64 (68.8%)
2	1 (1.1%)	0 (0%)	43 (46.2%)	49 (52.7%)
3	1 (1.1%)	0 (0%)	59 (63.4%)	33 (35.5%)
4	1 (1.1%)	0 (0%)	66 (71.0%)	26 (28.0%)
5	1 (1.1%)	0 (0%)	75 (80.6%)	17 (18.3%)

Table 5. Minimum noise level of portable electricity-generating plants analysis for residential areas recommended during usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	2 (2.2%)	1 (1.1%)	48 (51.6%)	42 (45.2%)
2	2 (2.2%)	2 (2.2%)	48 (51.6%)	41 (44.1%)
3	3 (3.2%)	0 (0%)	64 (68.8%)	26 (28.0%)
4	2 (2.2%)	1 (1.1%)	70 (75.3%)	20 (21.5%)
5	3 (3.2%)	2 (2.2%)	84 (90.3%)	4 (4.3%)

Table 6. Maximum noise level of portable electricity-generating plants analysis for residential areas recommended after usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	36 (38.7%)	37 (39.8%)	18 (19.4%)	2 (2.2%)
2	40 (43.0%)	40 (43.0%)	12 (12.9%)	1 (1.1%)
3	46 (49.5%)	36 (38.7%)	9 (9.7%)	2 (2.2%)
4	40 (43.0%)	42 (45.2%)	10 (10.8%)	1 (1.1%)
5	43 (46.2%)	39 (41.9%)	0 (0%)	11 (11.8%)

Table 7. Minimum noise level of portable electricity-generating plants analysis for residential areas recommended after usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	90 (96.8%)	3 (3.2%)	0 (0%)	0 (0%)
2	92 (98.9%)	1 (1.1%)	0 (0%)	0 (0%)
3	93 (100.0%)	0 (0%)	0 (0%)	0 (0%)
4	93 (100.0%)	0 (0%)	0 (0%)	0 (0%)
5	93 (100.0%)	0 (0%)	0 (0%)	0 (0%)

CONCLUSION

The results of this study on the acoustic comfort levels of users of power generation system revealed that the external noise level of the environment studied before and during the operation of the portable electricity-generating plant was well within the acceptable range (clearly and normally acceptable noise level limits within $L_{Aeq} \leq 49$ dBA and $49 < L_{Aeq} \leq 62$ dBA, respectively) for the noise level of the residential area, which then changed to normal ($62 < L_{Aeq} \leq 76$ dBA) and clearly ($L_{Aeq} > 76$) unacceptable noise level ranges for the operation of power generation system. Considering that the residential sector encompasses many households is a sector for recreation or relaxation in the economic system, as people retire to their various homes for relaxation, refreshment, and preparation for the next day's activities, and in other places a degree of rest and acoustic comfort to achieve this purpose. For portable power generation systems that employ efficient sound absorption materials to lower noise emissions to acceptable levels, sound insulation is necessary. This is because both the acoustic and non-acoustic effects of noise from these systems on human health must be addressed.

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