Characterization and Effects of Noise Levels of Portable Generators Used in Residential Buildings in Ibadan Metropolis, Nigeria: A Case Study

Akeem B. Wahab

Department of Building, Faculty of Environmental Design and Management,

Obafemi Awolowo University, Ile-Ife, Nigeria

Corresponding author: **wahabak2002@yahoo.com**

http://dx.doi.org/10.5755/j01.sace.22.1.20175

JSACE 1/22

Characterization and Effects of Noise Levels of Portable Generators Used in Residential Buildings in Ibadan Metropolis, Nigeria: A Case Study

Received 2018/03/07

Accepted after revision 2018/06/18

The proliferation of generators used in urban settlements in Nigeria over the years has been a major source of concern to the health and comfort of building occupants. This study, therefore, assessed the impact of outdoor and indoor noise levels associated with the use of generators on the environment and building occupants. The study area, Ibadan Metropolis, was divided into core, transition and suburban zones. Five (5) residential buildings were purposively selected in each of the core, transition and suburban zones of the study area. Measurement of noise levels was taken with the use of a digital sound level meter with compliance to NESREA and OSHA standards. The outdoor noise levels before and during use of generators were taken at 0, 2 and 4m from external walls of the buildings sampled while the corresponding indoor noise levels were taken at the actively useable internal space; at a least distance of 1m from internal walls, 1.2 - 1.5m above floor level and 1.5m from windows. Descriptive and inferential statistics were used to analyse the data collected. The findings of the study revealed that the mean indoor noise levels of 79.97 dB, 87.4 dB during use of generators in residential buildings were highest in the core zone and above the permissible limits. The study concluded that there should be adoption of best house-keeping practices by positioning generators in properly built enclosure features; and efforts made to enforce sales and procurement of generators with noise abatement mechanisms that can conform to ISO 3744 and local codes so as to mitigate impact of its high noise levels on the health and comfort of building occupants.

Keywords: Generators, Impact, Noise Generation, Off-Grid Power Supply, Standards.

Introduction

In spite of Nigeria's huge resource endowment in energy and enormous investment in the provision of energy infrastructure, the performance of power sector has remained poor in comparison with other developing economies. According to World Bank (2005), Nigeria had the highest percentage of system losses at 33 to 41% with the lowest generating capacity factor at 20%, the lowest average revenue at US dollars of 1.56 KWh, the lowest rate of return at 8%, and the longest average accounts receivable period of 15 months when compared with those of 20% of other developing countries. As a result of this fundamental problem, households, businesses and industrial premises rely on their self-procured electricity from generators that have attendant operating and capital costs (Idiata *et al., 2010*; Awofeso, 2011).

Journal of Sustainable Architecture and Civil Engineering
Vol. 1 / No. 22 / 2018
pp. 49-63
DOI 10.5755/j01.sace.22.1.20175
© Kaunas University of Technology

A constant power supply is a critical component of every successful modern business, and where power failure happens more often and takes more time to fix, a reliable standby generator is really essential to power all the equipment and systems (Pabla, 2003; Gross, 1986). Today, the most common form of off-grid electricity supply are generators running on diesel or gasoline. Generators are used not only by rural households but also by the grid-connected households and industries as a more stable supplement to the grid power. The rural incidence of diesel generator in Nigeria is difficult to estimate, but 96 to 98% of the grid-connected firms are known for the ownership of private generators (Tyler, 2002).

The impacts of the various types of generators used by occupants of buildings are enormous on environmental quality and people's health. This has elicited major concerns among environmentalists and other players in the built environment (Obadote, 2009). The use of generators is very common in most parts of Nigeria, and most small-scale businesses that would have been essentially noiseless produce heavy noise pollution from generators (Akande and Ologe, 2001). This has resulted in the exposure of building users to a number of hazards associated with the use of generators in buildings. Common hazards are air, soil, noise and water pollution. These hazards do not only affect users of the generators but also affect people living in the neighbourhood. The main health risks, as identified by the World Health Organization (2004) include pain and hearing fatigue, hearing impairment including tinnitus, annoyance, interference with social behaviour (aggressiveness, protest and helplessness), sleep disturbance, cardiovascular effects and hormonal responses.

The operation of generators is associated with noise generation. In Nigeria, with the proliferation of generators in every nook and cranny, it becomes an issue that dependence on it as the only reliable source of power supply would create noise pollution. The common effects of noise pollution such as loss of hearing ability, headaches, interference with communication, nervousness, lack of concentration and insomnia and impairment of efficiency have all been identified and documented (Shapiro, 1993; Ebeniro *et al*. 1999; Avwiri and Nte, 2003; and Ahmad and Abubakar, 2012). Egunjobi (1988) in his study of urban environmental pollution reported that noise had interference on speech and communication; and concluded that at about 85 dB, people had to shout to be heard. Nwaogozie and Owate (2000) examined noise levels generated within the Port Harcourt refinery premises as being spatially well dispersed, and at the fenced boundaries, noise levels are well below FEPA's permissible limit of 90 dB. The WHO and FEPA respectively have noise limits set at 70-75 dB and 90 dB, and noise levels above these limits can cause health hazard to people in the environment. The transmission of noise into building spaces from installations like generators positioned outside may create indoor noise beyond limits approved by the WHO.

Researches related to the use of noise of generators in buildings were assessed. John *et al.,* (2016) examined generators used in buildings in institutional settings. Their findings showed that the mean noise level both indoor (60.26 dB) and outdoor (58.15 dB) respectively caused reported health problems like ear pains, headache and tiredness. According to Senanayake (2002), children between the age of 2 to 5 years in Sri Lanka were exposed to 73-78 dB and 70-73dB of noise from generators in day and night time respectively. Saber (2014) investigated noise pollution level in different environments in Erbil City and showed that in 177 sites that were examined, the indoor and outdoor sound pressure level were 87 dB and 105 dB respectively and thus caused hearing impediments; Salawu *et al.,* (2015) carried out assessment and control of near-field noise levels of the 650 VA power generator in a residential building in Moro Local Government of Kwara State, Nigeria and found that such generating sets should be positioned at least 3 meters away from buildings in order to be safe for use; Sellappan (2013) carried out a study on noise impacts associated with power generators used in construction activities of DCT project and found that the noise levels produced by them were much higher than the permissible limit while Peter (2013) investigated noise pollution in laboratory buildings and showed that noise from devices used in the laboratory that can lead to a variety of medical issues for the laboratory personnel can be reduced by selecting systems that are specifically designed with noise reducing components. Studies of Akindele and Adejumobi (2016); and Osagie *et al.,* (2018) on noise levels of generators in south southern part of Nigeria found sound pressure level above the set limit.

While trying to assess the use of generating sets and the likely impacts that it can have on the environment, few other studies have been carried out on generators used in buildings in Nigeria and especially in the study area. Studies of Ana *et al*., (2014); Stanley *et al*., (2011); Komolafe (2011); Sonibare *et al*., (2014) did not focus on the likely indoor and outdoor noise effects through comparison with established standards that are associated with the use of generators in residential buildings; hence the need for this study. Thus, the aim of the study was to assess outdoor and indoor noise levels of generators used and its impact on the environment and building occupants.

Study Area

Ibadan is an urban centre located in the humid southwest of Nigeria which is the capital city of Oyo State and is also one of the fastest growing cities in the country (Ayeni, 1994). The study was carried out in Ibadan Metropolis, Oyo State which is a significant geographical entity in southwestern Nigeria (Fig. 1). The study area is characterized by residential and other types of buildings with the use of generators by the occupants since the study was urban-based as Ibadan was put in the category of a metropolitan urban centre according to the 2006 population centre. The geographical location of Ibadan falls between coordinates 7° 22' 47" North of the Equator and 3° 53' 0" East of the Greenwich Meridian. The entire area of Ibadan is largely well-drained, though many of its rivers are seasonal. Developed land increased from only 100 ha in 1830 to 12.5 Km^2 in 1931, 30 Km^2 in 1963, 112 Km^2 in 1973, 136 Km^2 in 1981 and 214 Km^2 in 1988 (Mabogunje, 1968). It is therefore capable of reflecting practices and attributes of the region. Its estimated population of 2,559,853 by the 2006 population census places the city in the category of a metropolitan urban centre (FGN, 2009). The study concentrated on the five local government areas that made up Ibadan Metropolis namely: Ibadan North, Ibadan North East, Ibadan North West, Ibadan South East and Ibadan South West. The local governments have a population of 1,343,147 (FGN, 2009) and the other six local governments that made up Ibadan Land were left out. The choice of the local governments was due to the fact that the research is urban-based and focused on the sustainability of generating sets used by residents/occupants of buildings that were within the metropolis of the study area.

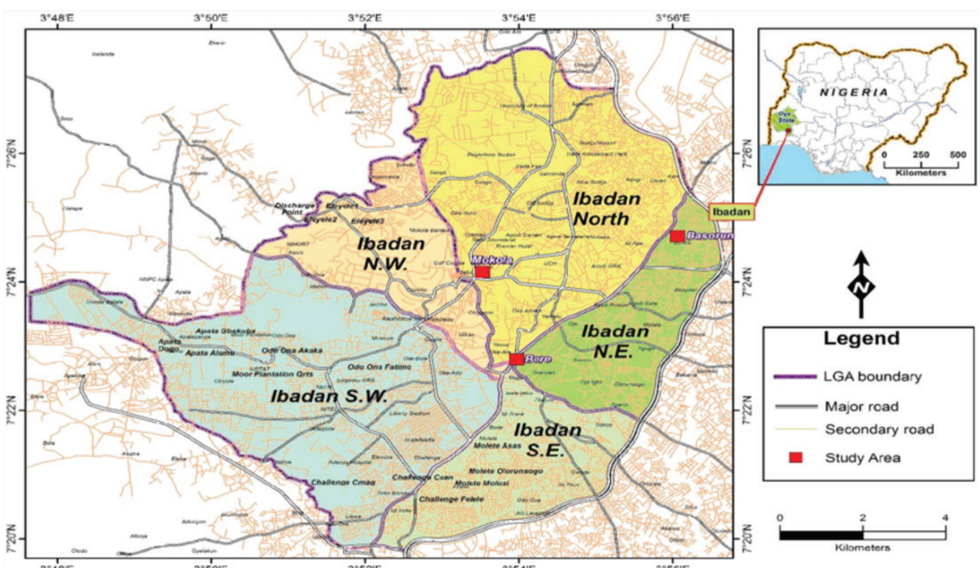


Fig. 1

Map of the Study Area, Ibadan Metropolis.

Source: Ibadan Google Map (2016)

Research Methodology

The sample frame for the study was made up of residential buildings that existed in the selected five local governments of Ibadan Metropolis occupied for residential purposes and where generating sets were used. A reconnaissance survey was carried out to get preliminary information on the types of generators used by the respondents and the most commonly used type were of the rating 0.6 KVA to 3.8 KVA, and thus selected for the study. The preliminary information obtained also included characteristics of generators used by the respondents in the study area. The study area was divided into a list of different residential/political wards determined and used for the purpose of the 2011 general elections by the (Oyo State Independent Electoral Commission, 2013). The multi-stage sampling technique was employed for the study. The first stage involved delineation of residential areas in Ibadan Metropolis into different zones based on age and other criteria. The technique of delineating residential areas in Nigeria involves the use of historical and physical attributes. It takes into consideration, a period of the emergence of a city or a section of a city, housing characteristics, environmental qualities and population per square kilometre (density) among others (Afon, 2008; Wojuade, 2012; Adigun 2013). Faniran (2012) among other authors had identified three (3) residential zones in Ibadan. These are: core, transition and suburban residential zones and were thus adopted for this study. The stratification made the heterogeneous nature of the study population to be reduced into residential/political wards of similar and homogeneous features.

Methods of Measurement

Five (5) houses were purposively selected in each residential density of the local governments in the study area for the measurement of noise level because of the seemingly restriction of the researcher to have access into buildings. This indicates selection of twenty-five (25) residential buildings in each zone and a total of seventy-five (75) residential buildings in the entire study area respectively. A GM1351 digital sound level meter was used to take noise levels. It measures noise between 30-130 dB, has an accuracy of 1.5 dB, frequency range of 31.5 Hz to 8.5 KHz and resolution of 0.1 dB. Each measurement was carried out before and during the use of the generating sets both outdoor and indoor (actively useable internal space) of the selected residential buildings. The digital sound meter was positioned at the working platform, at about 1.2-1.5 metres above ground level. Measurements of noise levels in the selected buildings were carried out before and during the use of the generators both indoor and at distances outdoor. Thus, noise measurements of the generators were taken to assess its contributory impact/effect on the environment and users of the buildings sampled.

Measurement of Outdoor Noise Level

In order to assess contributory effect and impact of the use of generating sets on the outdoor noise in the study area, three (3) measurements of outdoor noise level before and during the use of generators were taken at three points; 0, 2 and 4 m respectively from the external walls of residential buildings sampled in the study area and the mean values of the measurements were determined. 0 m was the point of location of the generator by the external walls of the buildings sampled.

In order to also assess contributory effect and impact of the use of generating sets on the indoor noise level in the buildings, three (3) measurements of indoor noise before and during the use of generators were taken in an actively used internal space in the residential buildings selected and the mean values of the readings were determined. The measurements were taken at a least distance of 1m from internal walls or other major reflecting surfaces, 1.2 -1.5m above floor level and 1.5m from windows of the buildings.

Clips of Fig. 2 show the GM1351 digital sound level meter that was used to take noise levels in the study area, the measurement of noise levels either before or during use of generators in sections of the buildings where the measurements were taken; while clips of Fig. 3 show the sections of generators used for the study, diagrammatic representation of the measurement of the indoor noise in an actively used internal space of the residential buildings selected and the measurement of the outdoor noise at 0, 2 and 4m respectively from the point of positioning of the generators in the study area (beside external wall of the buildings sampled).

Thus, descriptive and inferential statistical techniques such as frequency distribution, analysis of variance, t-test and trend analysis were used to analyse the mean values of the noise levels of the generators taken and also compared with the permissible limits of WHO and NESREA.

Fig. 2

Clips of sections of the GM1351 used for the measurement of noise levels

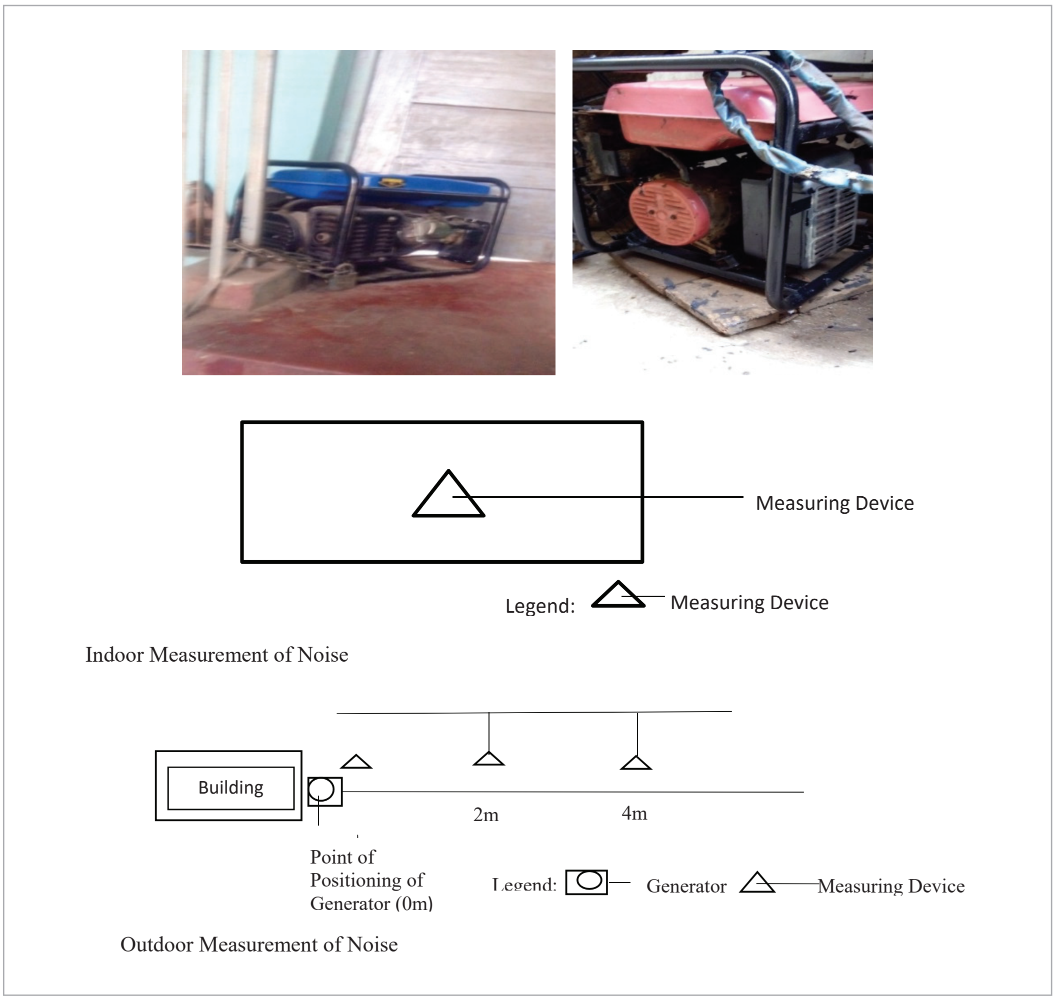


Fig. 3

Clips of sections of generators sampled and diagrammatic representation of the measurement of noise levels indoor and outdoor

Results and Discussions

Preliminary Information on the Characteristics of Generators

The preliminary information depicting the characteristics of the generators sampled for the measurement of noise levels in the study area obtained during the reconnaissance survey involved their years of use (age), ratings, type, cost and brand respectively. It was found that across residential buildings of the study area, 45.82% of the respondents had been using their generators for 3 years, 25.88% (2 years), 14.82% (1 year) and 6.74% (4 years); the rating limits of generators selected for the measurement was 0.6 – 3.8 KVA due to the types commonly procured which largely depended on the petrol as their fuel. A large proportion of respondents in the residential buildings across zones of the study area (35.95%) spent between N1,100 – N3,000 monthly in fuelling the generators sampled while different brands of generating sets sampled were used by the respondents across zones of the study area. Elemax brand of generator was largely used by the respondents 78(20.42%) and followed by 65(17.01%) that used Tiger brand of generator. Past studies of Ahmad and Abubakar (2012); FGN (2014) and NOI Polls (2015) also indicated that generating sets used would have different operating characteristics in terms of types, brand and cost of its fuel which would be borne by the users.

Outdoor Noise Levels of Generators in the Residential Buildings

The measurements of outdoor noise levels before and during use of generators in the residential buildings sampled across zones of the study area shown in Tables 1 to 3 indicated that irrespective of the zone where residential buildings sampled were located, outdoor noise levels before the use of generators maintained a transit pattern of fluctuation in its readings at different points of measurements. This could be due to the dynamics of sound waves which can increase or decrease at any point of measurement based on the rate at which momentary air was set in motion. Tables 1 to 3 also showed that at the point of positioning of generators, by the external wall (0m), outdoor noise levels in residential buildings in the core zone were comparably highest during use of generators (102.7 dB) than the values taken in other zones and lowest in the transition zone (102.2 dB). However, at 2 and 4 m points of measurement from locations of generators during its use by the external walls of buildings, outdoor noise levels in the suburban zone fluctuated between ranges of 71.1 - 79.2 dB and 68.3 – 74.6 dB respectively. This was found to be related to the types of house-keeping practice adopted and level of compliance with physical planning laws by the respondents. Similarly, the outdoor noise measurements were significantly highest at the reference point, external wall of buildings (0 m) and lowest at the 4 m distance of positioning from the external walls of buildings. This could be due to the reduction in the pressure of the noise generated from the external walls where the generating sets were positioned (Tables 1 to 3).

The degree of variation of outdoor noise levels taken in the sampled residential buildings indicated that the mean levels of outdoor noise before or during use of generators were comparably highest in residential buildings in the core zone (52.34 dB, 98.47 dB). It was also found during the study that the type of generating set enclosure provided by the occupants of residential buildings in the core zone which affected their house-keeping practices informed the significantly high levels of outdoor noise measured during the use of generators in the core zone. The background noise varied disproportionately in buildings across the zones with the core zone having 47.3 - 63.5 dB. Results of the outdoor noise levels obtained from the noise measurement were also supported by findings of past studies of Stanley *et al*., (2016) which got 85.13 dB for the outdoor noise; John et al., (2016); Akindele and Adejumobi (2016) and Osagie et al., (2018) which got comparably higher levels of noise than the permissible limits during the use of generators.

Trend analysis carried out on the rate of change of outdoor noise measurements in the residential buildings sampled during use of generating sets indicated that the percentage decrease in the values of outdoor noise measured from the external walls of buildings to the 2 m point of measurement was 18.57%. It further indicated that there was 4.33% decrease from 2 to 4 m points of measurement and 22.09% decrease was found at the 4 m point of measurement from the points of the positioning of generators (0m), by external walls of the residential buildings.

Table 1

Outdoor Noise Levels Before and During Use of Generators in Residential Buildings in the Core Zone

Outdoor Noise Level (dB) Before and During Use of Generators at Different Points							
L.G.A	Residential Buildings	0m		2m		4m	
		Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)
IBN	1	56.3	101.3	55.9	83.1	55.2	78.3
	2	53.1	99.2	52.8	84.2	51.9	79.2
	3	59.3	87.3	60.4	79.3	58.3	77.3
	4	49.7	91.3	49.5	82.3	49.3	74.7
	5	53.1	102.1	53.0	84.2	51.6	76.2
IBNE	6	48.7	98.3	47.9	81.3	47.8	75.3
	7	63.4	103.4	64.5	86.4	63.6	78.4
	8	52.1	97.1	51.8	80.2	50.9	72.2
	9	48.3	92.4	48.0	77.4	49.8	75.2
	10	48.1	99.3	47.8	81.3	47.3	71.4
IBNW	11	51.4	102.7	49.3	82.5	49.2	76.5
	12	53.1	102.5	52.7	83.1	52.3	75.1
	13	49.9	97.8	49.9	84.8	48.5	75.8
	14	63.5	99.3	62.8	80.2	61.7	72.2
	15	52.1	102.1	48.8	83.3	48.1	74.3
IBSE	16	48.3	97.8	47.9	86.8	47.7	82.8
	17	63.5	99.2	63.1	84.2	62.8	75.2
	18	48.2	98.3	47.9	83.7	47.3	77.1
	19	49.3	93.6	48.7	79.6	48.4	76.3
	20	48.5	96.5	48.3	78.8	48.8	69.8
IBSW	21	52.3	101.2	51.1	84.2	50.9	78.7
	22	50.3	102.3	50.1	81.3	49.7	73.3
	23	48.7	99.6	51.2	83.8	47.2	77.8
	24	47.3	94.8	48.5	82.7	48.1	73.5
	25	50.1	102.3	52.3	86.3	50.6	78.6

* 0 m = Point of measurement from external wall of building
L.G.A. Local Government Area, IBN: Ibadan North, IBNE: Ibadan North East
IBNW: Ibadan North West, IBSE: Ibadan South East, IBSW: Ibadan South West

Table 2

Outdoor Noise Level Before and During Use of Generators in Residential Buildings in the Transition Zone

Outdoor Noise Level (dB) Before and During Use of Generators at Different Points							
L.G.A.	Residential Buildings	0m		2m		4m	
		Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)
IBN	1	46.3	99.3	46.0	83.7	46.1	77.1
	2	45.7	93.6	45.3	75.6	45.3	72.7
	3	48.3	97.4	47.9	79.4	47.6	73.3
	4	46.7	99.3	47.1	83.3	46.4	78.2
	5	47.6	97.2	47.2	82.5	46.8	76.0
IBNE	6	48.3	100.3	48.0	79.6	48.0	71.1
	7	46.1	93.7	46.1	78.3	45.9	72.3
	8	45.2	97.3	45.0	79.1	45.0	73.2
	9	46.3	98.3	46.2	79.6	45.7	72.4
	10	48.3	100.2	48.3	78.0	48.1	71.3
IBNW	11	50.3	101.3	49.6	82.3	49.6	75.1
	12	49.2	102.2	50.3	83.7	50.3	74.7
	13	46.3	99.6	45.9	78.1	45.1	73.3
	14	45.7	90.3	45.8	77.8	45.3	72.6
	15	46.2	97.2	45.6	76.3	45.1	71.8
IBSE	16	45.3	96.3	45.9	75.2	45.2	72.3
	17	42.5	93.2	44.1	72.9	43.7	71.1
	18	40.3	91.5	40.0	73.7	40.0	72.2
	19	43.6	98.7	43.2	76.6	43.1	74.5
	20	42.5	99.3	42.5	77.3	41.9	72.3
IBSW	21	45.3	101.2	45.1	79.1	45.1	75.2
	22	43.2	97.2	44.2	76.3	43.1	70.3
	23	42.1	98.3	41.8	81.2	42.0	75.5
	24	43.4	98.6	43.7	79.0	43.1	72.4
	25	42.1	93.5	42.0	70.8	41.8	68.3

* 0 m = Point of measurement from external wall of building

Table 3

Outdoor Noise Level Before and During Use of Generators in Residential Buildings in the Suburban Zone

Outdoor Noise Level (dB) Before and During Use of Generators at Different Points							
L.G.A.	Residential Buildings	0m		2m		4m	
		Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)
IBN	1	41.2	93.7	41.1	71.1	42.5	68.3
	2	42.5	96.3	41.3	74.2	41.1	71.0
	3	43.7	98.3	44.5	75.2	44.2	71.2
	4	45.2	99.3	44.8	76.0	43.7	72.4
	5	44.7	98.3	44.6	72.2	45.2	69.3
IBNE	6	46.3	100.2	45.8	71.8	45.8	70.1
	7	43.6	101.2	44.2	72.3	42.9	69.6
	8	47.2	97.8	46.9	75.2	45.8	73.2
	9	42.3	96.8	42.0	77.3	42.0	74.4
	10	45.3	99.2	45.3	73.6	44.8	71.3
IBNW	11	44.3	98.7	44.1	76.4	43.7	74.2
	12	46.2	97.6	46.7	72.3	45.8	69.8
	13	43.2	98.5	43.0	79.2	43.0	74.1
	14	42.7	96.3	42.4	76.5	42.3	73.3
	15	44.3	98.1	45.1	76.1	43.8	72.2
IBSE	16	46.2	99.2	46.0	78.3	45.9	74.6
	17	43.1	88.1	43.1	73.0	42.7	68.9
	18	42.3	97.6	42.0	76.1	42.0	73.5
	19	46.2	98.3	45.8	77.2	45.2	73.1
	20	44.5	99.2	42.3	75.1	42.0	71.2
IBSW	21	46.5	102.3	46.7	77.0	45.8	73.4
	22	43.1	98.3	43.1	79.2	43.0	70.6
	23	46.2	100.1	46.1	75.1	45.9	70.3
	24	45.3	99.3	45.3	74.8	45.0	67.0
	25	45.6	98.3	45.4	73.3	45.3	75.5

* 0 m = Point of measurement from external wall of building

Indoor Noise Levels of Generators in the Residential Buildings

Table 4 showed that prior to the use of generators in residential buildings, indoor noise levels were comparably lowest (42.3 dB) in buildings in the suburban zone and highest in buildings (44.2 dB) in the core zone. During the use of generators, the indoor noise level was least in the suburban zone (66.2 dB) and also highest in the core zone (79.7 dB). This was discovered to be due to the distances of the positioning of generators, house-keeping practices adopted, typology of buildings and profile of the respondents in the buildings sampled. The mean deviation of indoor noise levels before use of generators (50.34 dB, 47.91 dB) and during use of generators (70.20 dB, 65.18 dB) were obtained in core and suburban zone respectively. Results of the indoor noise levels obtained from the noise measurement were also supported by findings of past studies of John et al., (2016) and Stanley *et al.*, (2016) which got 60.26 dB 74 dB respectively for the indoor noise due to the use of generating sets which were comparably higher than the permissible limits set by statutory bodies like WHO. Thus, diagrammatic representation of the mean values of noise character/spectra in different zones of the study area on the outdoor and indoor noise levels in various places of the study area are shown in Fig. 3 and 4 respectively.

Trend analysis showed the likely differences in the rate of change of indoor noise levels before and during the use of generators in the residential buildings sampled. The analysis showed that the percentage increase in the values of indoor noise in residential buildings in the core, transition and suburban zone before and during use of generator was 39.90%, 36.09% and 32.10% respectively.

Fig. 3

Mean outdoor noise levels before and during use of generators in zones of the study area

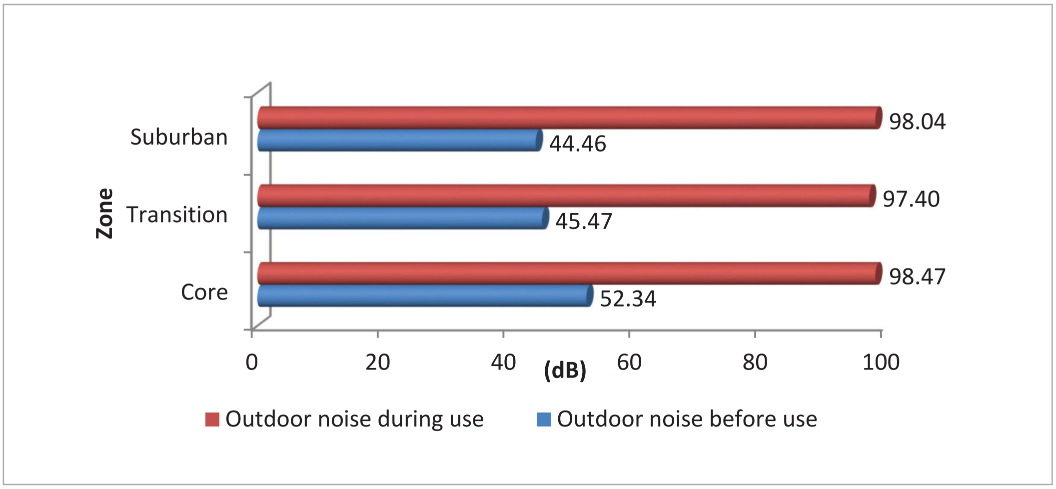
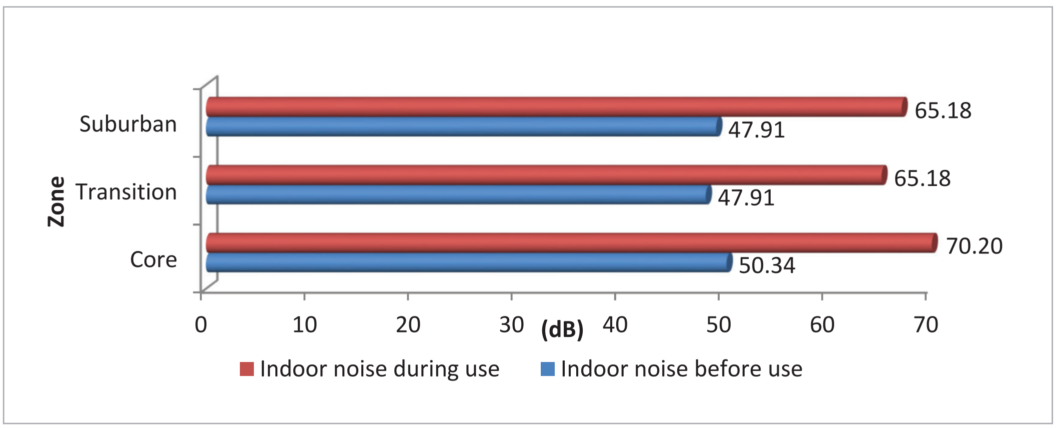


Fig. 4

Mean indoor noise levels before and during use of generators in zones of the study area



It further indicated that in all the residential buildings sampled in the study area, the percentage increase in the values of indoor noise before and during use of generators was 36.03%. This indicates the range of percentage increase of indoor noise levels that the occupants of residential buildings in the study area could be exposed to.

Table 4

Indoor Noise Levels Before and During Use of Generators in Residential Buildings

L.G.A	Bldgs.	Core Zone		Transition Zone		Suburban Zone	
		Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)	Before Use (dB)	During Use (dB)
IBN	1	47.2	68.7	48.5	67.6	42.3	61.2
	2	49.3	69.5	49.3	62.4	45.2	63.4
	3	50.1	71.3	47.4	61.5	43.2	58.2
	4	48.2	65.6	50.3	68.1	45.8	66.2
	5	51.3	72.1	45.9	67.5	47.2	62.1
IBNE	6	48.6	69.6	51.2	67.6	43.5	55.7
	7	49.7	69.3	50.5	68.3	46.2	60.1
	8	51.2	72.2	48.2	63.7	49.1	64.3
	9	47.6	65.0	47.3	62.5	47.2	64.7
	10	44.2	69.9	51.3	73.2	45.1	60.0
IBNW	11	60.8	72.5	53.6	75.3	48.2	63.2
	12	66.2	78.2	49.2	69.1	43.7	53.4
	13	49.3	69.3	50.3	72.6	46.3	60.7
	14	48.5	66.5	46.3	65.7	45.1	62.4
	15	53.7	79.7	48.2	63.1	46.2	56.2
IBSE	16	49.6	69.3	47.3	65.2	48.2	63.8
	17	51.3	72.0	46.2	60.2	45.2	60.3
	18	47.6	65.3	43.1	61.3	49.6	55.4
	19	48.3	69.7	47.2	62.1	45.5	62.3
	20	47.6	68.3	48.7	63.6	46.7	60.1
IBSW	21	50.4	69.6	43.5	62.5	42.3	51.2
	22	48.2	71.3	46.2	62.7	43.7	58.4
	23	51.3	73.5	45.3	61.2	47.2	63.2
	24	49.7	68.2	47.6	60.3	45.3	61.5
	25	48.6	67.5	45.2	62.4	46.7	63.4

Comparison of Noise Levels in Buildings Sampled with the Statutory Limits

The study assessed the impact of the use of generators in the study area by comparing values of noise measured both outdoor and indoor, before and during the use of generators in residential buildings in the study area. One Sample T-test statistical technique was used to analyse contributory effect of generators through the level of deviation of noise before and during use from the limits set by WHO (2000)/NESREA (2009) in residential buildings. The result of the analysis as contained in **Table 5** showed that in the residential buildings, the T-test indicated that there

Table 5

Comparison of Noise Levels in the Residential Buildings Sampled with the WHO Standards

Comparison of Outdoor Noise Levels in the Residential Buildings						
One –Sample Test						
Test Value = 50						
Variables	T	Df	Sig (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Outdoor Noise Before Use	-4.597	74	.000	-2.57200	-3.6869	-1.4571
Outdoor Noise During Use	123.310	74	.000	47.97067	47.2079	48.7334
One-Sample Statistics						
	N	Mean	Std. Deviation	Std. Error Mean		
Outdoor Noise Before Use	75	47.4280	4.84558	.55952		
Outdoor Noise During Use	75	97.9707	3.31527	.38281		
Test value of WHO(2000) = 50dB						

Comparison of Indoor Noise Levels in the Residential Buildings						
One –Sample Test						
Test Value = 35						
Variables	T	Df	Sig (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Indoor Noise Before Use	34.712	74	.000	13.72133	12.9337	14.5090
Indoor Noise During Use	60.300	74	.000	31.86133	30.8085	32.9142
One-Sample Statistics						
	N	Mean	Std. Deviation	Std. Error Mean		
Indoor Noise Before Use	75	48.7213	3.42330	.39529		
Indoor Noise During Use	75	66.8613	4.57590	.52838		
Test value of WHO (2000) = 35dB						

was significant difference in the outdoor noise levels measured and the WHO (2000)/NESREA (2009) standards; (test value = 50 dB) at 0.001 level of significance. The mean values of outdoor noise before use and during use were 47.43 dB and 97.97 dB respectively and the corresponding mean differences from the 50 dB set standards were -2.57 dB and 47.97 dB, before and during use of generators respectively. This indicated that noise impact due to the use of generators on the environment during its use could cause environmental pollution; affect the comfort of occupants and also subject them to hearing-related problems. It was further shown that at 95% confidence interval, the upper difference between the noise limit set by the WHO (2000) and the values measured was -1.46 and 48.73 respectively before and during use of generators. The relationship of the comparison is $t = -4.597$, $p < 0.001$ –before use; and $t = 123.310$, $p < 0.001$ –during use. The exposure of building occupants to the hazards and environmental imbalance as found in this study were similar to past works of Akande and Ologe (2001), World Health Organization (2004) and Obadote (2009) on the associated effects of dependence on building services items.

The One-Sample T-test also indicated that mean values of indoor noise before and during usage were 48.72 dB and 66.86 dB (test value = 35 dB), while mean difference in the indoor noise before and during usage were 13.72 dB and 31.86 dB respectively. It was further shown that at 95% confidence interval, the upper difference between the noise limit set by the WHO (2000) and the values of noise measured were 14.51 and 32.91, before and during use respectively (Table 5). The results obtained from the analysis revealed that there was a significant difference in the outdoor noise level in residential buildings during the use of generators than the corresponding indoor noise levels during the use of generating sets. The relationship of the result is ($t = 34.712$, $p < 0.001$-before use; and $t = 60.300$, $p < 0.001$- during use for the indoor values).

The results of the outdoor and indoor noise levels associated with the use of generators obtained showed anthropogenic implications of its use above limits set by statutory bodies. The findings of Rao *et al*. (1988); Nailong *et al*. (2008); Fuller *et al*. (2012); Paravathi and Gopalakrishnan (2003) also showed that the use of generator set produced noise levels above permissible limits approved and it exposed the personnel to potential hazards. Also, Nailong *et al*. (2008); Nwaogozie and Owate (200); in their studies found that people can be exposed to noise from different activities that will cause pollution/environmental hazards and medical effects.

Conclusion and Recommendations

The results obtained from the study established that outdoor and indoor measurements were highest in residential buildings in the core zone either before or during the use of generating sets. This was found to be directly related to the levels of compliance of the building occupants to the house-keeping practices, building typology, physical planning statute, and their socio-economic characteristics. Reduced outdoor noise levels were measured at distance limits beyond 2 m from the external walls of buildings across zones of the study area during the use of generators. The study showed that there was a significant difference in the indoor noise level in the residential buildings sampled and the standards set by the World Health Organisation (WHO) and National Environmental Standards and Regulations Enforcement Agency (NESREA). In view of the exposure of building occupants to noise level above standards set by regulatory bodies and dependence on generators as means of power supply in buildings, there is need to license sale of generating sets with noise abatement mechanisms and properly tested at the point of manufacturing so as to guarantee that their operational performance conform to ISO 3744 and existing local codes. Building occupants should also adopt best house-keeping practices by positioning them in properly built enclosure features (generator house) located away from external walls of their buildings so as to dampen noise generated. This will allow fair compliance with the ordinance of NESREA.

References

Adigun, F.O., Abolade, O. and Akeju, E. Death By Breath: Case of Indoor Air Pollution in Akure, Nigeria. In Issues in the Built Environment, Afon A.O. and Aina O.O (Eds), Obafemi Awolowo University Press, Ile-Ife, 2013; 81-100.

Afon, A.O. Intra-Urban Variation in Solid Waste Storage Practice in Nigerian Traditional City: The Case of Ogbomoso. Journal of The Nigerian Institute of Town Planners, 2008; XXI(1): 104-129.

Ahmad, M.T. and Abubakar, H. Economic Implications of the Use of Generators as Alternative Energy Source of Energy in Kano Metropolis, Nigeria. International Journal of Research in Commerce, Economics and Management, 2012; 2(2). 28-33.

Akande, T.M., and Ologe, F.R. Awareness of Commercial Grinding Machine Operators in Ilorin to Noise-Induced Hearing Loss. Tropical Journal of Health Sciences, 2001; 8(1): 28-31.

Akindele, O.A. and Adejumobi, D.O. Mitigating the Use of Electric Generators: An Operative Model of Distance and Greening Buffers. Greener Journal of Science, Engineering and Technological Research, 2016; 6(3): 70-77. https://doi.org/10.15580/GJSETR.2016.3.052416098

Ana, G., Olowolade, A.T., Abimbola, A.F., Ige, O. and Nriagu, J.O. Generator Emissions Profile and the Lung Function Status of Workers within Selected Small-Scale Business Premises in Ibadan, Nigeria, Global Health Perspectives, http://dx.doi.org/10.5645/ghp2014.02.003, 2014.

Aviviri, G.O. and Nte, F.U. Environmental Sound Quality of Some Selected Flow Stations in Niger Delta of Nigeria. Journal of Applied Science of Environmental Management, 2003; 7(2): 75-77.

Awofeso, N. Generator Diesel Exhaust: A Major Hazard to Health and the Environment in Nigeria. Amer J Respiratory Critical Care Med, 2011; 183, 11437-1438. https://doi.org/10.1164/ajrccm.183.10.1437

Ayeni, B. The Metropolitan Area of Ibadan, its Structure and Growth, In: Filani, M.O., Akintola, F.O. and Ikporukpo,C.O. (eds) Ibadan Region. Rex Charles Publications, Ibadan, 1984; 72-84.

Ebeniro, J.O., Abumere, O.E. and Ogbodo, S.N. Investigation of Environmental Noise within Port Harcourt City Metropolis, Nigeria. Journal of Physics, 1999; 2: 129-132.

Egunjobi, L.E. Environmental Issue and Management. In: Sanda, P.O. and Odemerno, F.O. (Eds.) Nigeria Development. Evans Publishers, Ibadan, Nigeria, 1988.

Faniran, G.B. Residents' Perception of the Monthly Environmental Sanitation in Ibadan, Nigeria. An Unpublished M.Sc. Thesis, Department of Urban and Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria, 2012.

Federal Government of Nigeria (FGN) Federal Republic of Nigeria Official Gazette, Legal Notice on the Publication of 2006 Census Final Results, pp. B1-B39; 2009.

Federal Government of Nigeria (FGN). Budget Proposal Details, Budget Office of the Federation, Federal Republic of Nigeria, Abuja, 2014.

Fuller, C.R., Papenfuss, C. and Saux, T.D. Active-Passive Control of Portable Generator Set Radiated Noise. Proceedings of Acoustics, 21-23 November, Fremantle, Australia, 2012; 1-7.

Gross, C.A. Power System Analysis, Second Edition, John Wiley and Sons, New York, 1986; 64-65.

Ibadan Google Map. Map of Ibadan Metropolis, 2016.

Idiata, D.J., Omoruyi, F.O., Agbonalor, N.N. and Ohonba, S.U. Environmental Effects of Fossil Fuel Usage. The Nigeria Academic Journal, 2007; 13(2): 11-18.

John, O.O., Godson, R.A., and Oyewale, M.M. Noise from Portable Electric Power Generators in an Institutional Setting. International Journal of Environmental Monitoring and Analysis, 2016; 115-120.

Komolafe, A. Availability of Generators for Electricity Supply to Selected Large Residential and Office Buildings in Kaduna and Abuja, Nigeria. An Unpublished M.Sc. Thesis Submitted to the Department of Building, Faculty of Environmental Design, Ahmadu Bello University, Zaria, Nigeria, 2011.

Mabogunje, A.L. Urbanization in Nigeria, University of London Press, London, 1968.

Nailong, Z. Wentong, Y. and Renyuan, F. Noise Control Technology for Generator Sets in Enclosures, Frontiers of Mechanical Engineering in China, 2008; 3(4): 377-384. https://doi.org/10.1007/s11465-008-0051-0

National Environmental Standards and Regulations Enforcement Agency. Noise Standards and Control Regulations, National Environmental Standards and Control, Federal Republic of Nigeria Official Gazette, B1312, 2009.

NOIPoll. A Report of the NOIPolls Limited: Power Supply to Nigerians Averages 4.9hours Daily. www.moi-polls.cm/root, 2015

Nwaogozie, J.L. and Owate, I.O. Noise Pollution Modelling of Port Harcourt Refinery, Technical Journal of The Nigerian Society of Engineers, 2000; Part 1 and 2: 92-104.

Obadote, D.J. Energy Crisis in Nigeria. Rasheen Publisher, Lagos, Nigeria, 2009.

Occupational Safety and Health Act. Occupational Safety and Health Act, Laws of the Federation of Nigeria, OSHA, 18001, Schedule XII. Oyo State Independent Electoral Commission 2013; Political Wards in Ibadan, 2004: www.oysiec.org, Accessed on 11/8/2014.

Osagie, I., Tenebe, I.T., Emenike, P.C., Adesina, O.S., Okougha, A.F. and Aitanke, F.O. Assessment of Noise-Levels of Generator-Sets in Seven Cities of South-Southern Nigeria. African Journal of Science, Technology, Innovation and Development, 2018; 10(2): 125-135. https://doi.org/10.1080/20421338.2017.1400711

Pabla, A.S. Electric Power Distribution, Fourth Edition, Sixth Reprint, Tata McGraw-Hill Publication Ltd., New Delhi, 2003; 35-37.

Parvathi, K. and Gopalakrishnan, N.A. Studies on Control of Noise from Portable Power Generator. In: Martin, J.B., Suresh, M.V. and Kumaran, V.T. eds., Proceedings of the Third International Conference on Environment and Health, Chennai, India, December 15-17, 2003; 328-338.

Peter, F. Noise Pollution in the Laboratory. Parker Hanninfin Corporation and Separate Division, www.parker.com/fns/balstonlabgasgenerators

Rao, G. Rao, R.P. and Srinivas, D.K. Noise Level Emitted by a Portable Electric Generator. Indian Journal of Environmental Protection, 1988; 8: 287-289.

Saber, S. Environmental Noise with Solutions. Journal of Advanced and Applied Sciences, 2014; 1(2): 6-14.

Salawu, M.A., Ibrahim, B.B. and Sharafa, S.B. Studies on Control of Hazardous Noise from Portable 650 VA Power Generator. Advances in Physics Theories and Applications, 2014; 44: 92-98.

Sellappan E. Noise Effects of Generator Sets at Construction Sites. International Journal of Occupational Safety and Health, 2013; 3(2): 12-17.

Senanayake, M.P. Noise from Power Generators: Its Impact on the Health of Five Children Below Two Years of Age. Sri Lanka Journal of Child Health, 2002; 31: 115-117. https://doi.org/10.4038/sljch.v31i4.754

Shapiro, S.A. Rejoicing the Battle Against Noise Pollution. Issues of Science and Technology, National Academy of Science University of Texas, 1993; IX.

Sonibare, J.A., Jamiu, A.A., Bamidele, S.F., Ismaila, O.L., Lukuman, A.J., and Olusesan, A.A. Ambient Noise from Off-Grid Diesel Engine Electric Power Generators in an Urban Environment. International Journal of Management of Environmental Quality, 2014; 25(2): 185-199.

Stanley, A.M., Mbamali, I.M. and Dania, A.A. Effect of Fossil-Fuel Electricity Generators on Indoor Air Quality in Kaduna, Nigeria. Symposium on Indoor Air Quality in Developing Countries (Ed.) Carter et al, June 6-7, Austin, TX 78712, 2011; 46-50.

Stanley, A.M., Mbamali, I., and Dadu, D.W. Impact of Electric Power Generators' Variables on Noise-Level Generation in Indoor Building Environments. International Journal of the Constructed Environment, 2016; 8(1): 17-29. https://doi.org/10.18848/2154-8587/CGP/v08i01/17-29

Tyler, G. Public and Private Electricity Provision as a Barrier to Manufacturing Competitiveness: Africa Region Findings, World Bank, March, 2002; http://www.worldbank.org// afr/findings/english/find221.pdf

Wojuade, C.A. Evaluation of Accessibility to Social and Economic Activities in Ibadan, Nigeria. Unpublished Ph.D Thesis Submitted to the Department of Urban and Regional Planning, Obafemi Awolowo University, Ile-Ife, Nigeria, 2012.

World Bank. The Environment Matters, Washington D.C., USA, pp.28-36, 2004.

World Bank. Energy Sector Management Assistance Programme in Nigeria: Expanding Access to Rural Infrastructure: Issues and Options for Rural Electrification, Water Supply and Telecommunications, The International Bank for Reconstruction and Development, Washington D.C., USA, 2005.

World Health Organization. Guideline Values for Community Noise in Specific Environment: TtRB Session, An Agenda for Transportation Noise, Management Policies in the United States, 10 January, Washington DC, USA, 2000.

About the Author

AKEEM B. WAHAB

Senior Lecturer

Obafemi Awolowo University Faculty of Environmental Design and Management Department of Building

Main Research Area

Building Services, Building Management System and Environmental Sustainability

Address

Ile-Ife,
Nigeria
Tel. +2348033713670
E-mail: wahabak2002@yahoo.com