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Assessment of noise-levels of generator-sets in seven cities of South-Southern Nigeria

Osagie Ibhadode [1*], I. T. Tenebe [2], P. C. Emenike [2], O. S. Adesina [3], A. F. Okougha[4] and F. O. Aitanke[5]

[1]*Building Research Department, Nigerian Building and Road Research Institute (NBRRI), Ota, Ogun state, Nigeria*
[2]*Department of Civil Engineering, Covenant University, Ota, Ogun state, Nigeria*
[3]*Dept. of Mathematical Science, Olabisi Onabanjo University, Ago-Iwoye, Ogun state, Nigeria*
[4]*Science Laboratory Technology Research Department, Nigerian Building and Road Research Institute (NBRRI), Ota, Ogun state, Nigeria*
[5]*Department of Production Engineering, University of Benin, Benin-City, Nigeria*
**Corresponding author email: osagie.ibhadode@gmail.com*

Noise pollution has been shown to be a global health hazard and this could be aggravated by the use of noise-emitting generators. Therefore, this study aims to determine the Sound Pressure Levels (*SPLs*), Sound Power Levels (L_W) as well as Noisiness of sixty different models with various Power-ratings from fourteen generator brands, commonly used in homes/offices in seven cities covering South-Southern Nigeria. The results obtained between January 2013–December 2015 showed that for nearly all generator brands, models and ratings, the values of *SPL* were above the Permissible Noise Exposure Limits (*PNELs*) recommended by *WHO*, *USEPA* and *EN* of $90dB(A)$, $75dB(A)$ and $70dB(A)$ respectively for $8hour$ daytime safe human exposure. Also, the 'Wilcoxon Signed Ranks Test' analyses showed that the three (3) alternative hypotheses $[H_a : SPL > 90dBA]$, $[H_a : SPL > 75dBA]$ and $[H_a : SPL > 70dBA]$ are statistically-significant and should be accepted – further implying that: the decibel-ratings of majority of these generator-models are evidently hazardous.

Keywords: Generator-models, Sound Pressure Level/Noise-Level, Noisiness, Sound Power Level (L_w), Permissible Noise Exposure Limit (*PNEL*)

Introduction

All over the world, as governmental leaders push for 'Quieter cities', which would result in increased tourism benefits and improved health conditions, amongst others, they are squarely faced with the diametrically-opposed issue of 'the need to boost industrialization while achieving/sustaining Energy-sufficiency'. Now, for most third-world countries like Nigeria, already plagued with the perennial problems of inadequate electricity generation, transmission and distribution, etc., any such attempt to boost industrialization, without first achieving 'Energy-sufficiency' may inevitably lead to 'Environmental Noise Pollution', as the citizenry will be forced to resort to alternative power sources, like portable Electric-Power Generating-sets, etc.

Ibhadode et al. 2016, reported that 'The average Noise Emission Level (Acoustic–rating) of all 34,200 Electric-power generator-sets, repeatedly measured for three (3) consecutive years, in three South-Southern Nigerian cities [of Port-Harcourt, Uyo and Calabar] was $93.0dB(A)$'.

Actually, Environmental noise pollution is currently receiving urgent global attention, despite the fact that, it might be difficult to quantify by numerical estimation, the extent to which the situation would degenerate in the near future (European Environmental Agency 2014; Aremu, Aremu, and Olukanni 2015). However, it should be noted that, it could significantly increase within urban areas, since based on recent Global Demographic Studies, it has been logically projected that, by the year 2050, about 75% of the entire world population would reside in urban localities (UN 2014; D'Alessandro and Schiavoni 2015). Quite frankly, a lot of studies have been carried-out on the subject of 'Noise Pollution' and the resulting health implications.

Brocolini, Parizet, and Chevret 2016 reported that intelligent dialogue, unintelligent discussion, as well as ringtones from phones and noise produced by gadgets such as printers, are capable of increasing annoyance levels in humans. He suggested that, owing to the aforementioned, care should be employed in the use of noisy machines and devices. Furthermore, Brocolini, Parizet, and Chevret 2016 showed how noise level effects may alter productivity and annoyance in open offices. This became necessary, since low-level noise-inhabitants still registered their disgust in open offices. Furthermore, findings from the research showed that, a reduction in memory-tasks looms, when uneducated discussions take place. Landstrom et al. 1995, showed that noise is a major nuisance factor in open-plan offices, even when the Noise-levels are below $65dB(A)$. These and a host of other uncited scientific literatures on the subject-matter, have made the authors in this present study greatly worried, since based on rough estimations made prior to this study, the noise-levels emanating from the incessant use of power-generators in the Study-area, were most likely to be higher than the safe recommended exposure limits, with the resulting effects detrimental to human health.

Also, Babisch (2014) revealed that continuous exposure to noise may lead to cardio-vascular diseases, loss of attention or reduced assimilatory capacity in children (WHO, Regional office for Europe, 2011). Tinnitus may result in early noise exposure in humans (Rosenhall and Karlsson 1991; Griest and Bishop 1998; Coles, Lutman, and Buffin 2000; Gates et al. 2000). Turner and Larsen (2016) studied noise effect on middle-aged rats over a twelve (12)-month period. In the study, 233 rats were exposed to 12 various combinations of noise intensity, duration and spectrum, while 46 unexposed rats served as control for the experimental process, the study then revealed the presence of ‘Tinnitus’ and ‘Hyperacusis’ in the exposed rats. Thus, it is clear from the aforementioned studies that, danger looms in areas, where Noise-pollution exceeds the recommended standard limits.

Nigeria–a key economic player and a regional power on the African continent, the West-African sub-region and the OPEC, is not left out of the dilemma of ‘Generator-induced Environmental Noise Pollution’. Regrettably, Nigeria’s situation is worsened by a crippling perennial energy (power) crisis. It is no longer news that, for several decades, and up until the time of publishing this research work, that although, Nigeria has an installed electricity-generation capacity of 6GW, yet, the nation’s apex electricity organization – the Power Holding Company of Nigeria (PHCN) has been persistently struggling to achieve a grossly inadequate, peak actual electricity-generation capacity of 3GW on the average. This acute energy supply-deficit has forced millions of Nigerians to independently resort to electricity-generators as their main source of electricity supply, on daily basis to drive business and domestic activities. It is noteworthy to mention that, as at the moment, the use of Power Generating-sets in majority of all Nigerian cities and towns, is now an established societal norm in the country – basically triggered by a gradual industrialization and a rapid population growth. These and several other contributory factors have considerably raised the ambient noise-levels in many Nigerian cities, and will most certainly negatively affect the health of the cities’ inhabitants.

Menkiti and Agunwamba (2015) studied noise pollution levels within households using a generator-set. The study revealed that, noise levels exceeded WHO standards. Oyedepo and Saadu (2008) investigated noise pollution levels within Ilorin city in Kwara state, Nigeria. The study showed that, in over 70% of the vicinities investigated, noise-levels exceeded the safety limits. Also, generator-sets have been identified as one of the major contributors to noise pollution (Oyedepo and Saadu 2008). The above citations notwithstanding, the present-day reality is that, in Nigeria, there is still a paucity of technical literature in this regard, particularly when compared to what is obtainable in the developed countries of the world. Furthermore, to the best of the authors’ knowledge and from extensive literature survey, it is noteworthy to mention that:

> majority of previous researchers on this subject, basically considered the Noise-ratings of generators in their study-areas, simply by conducting one or two noise-sampling survey(s) of a limited number of generators in a confined locality [i.e. one area of a town].

Therefore, this study aims to (1) Determine the Noise-Levels (i.e. Sound Pressure Levels) [$SPL(dBA)$] of sixty (60) models of electricity-generators manufactured by fourteen (14) leading brands, with Power-ratings(KW) ranging from $0.5KW - 545.0KW$, which are commonly used/operated in the seven (7) cities of South-Southern Nigeria; (2) To obtain the Sound Power Levels [$L_w(W/m^2)$], Noisiness (Noy) and Usage-Periods (*Months*) of each of these sixty generator-models; (3) To ascertain the levels of compliance of the aforementioned noise-parameters with three global standards (WHO, USEPA and EN); and (4) To statistically analyze the possible deviation(s) of the generators’ *SPLs* from the three global standards’ recommended values.

Our primary research hypothesis was that:

> The basic Noise-Parameters (Sound Pressure Levels, Noisiness and Sound Power Levels) of most Generator-models commonly used in the seven (7) major cities of South-Southern Nigeria, do not conform to the decibel-rating requirements recommended by the World Health Organization (WHO), United States Environmental Protection Agency (USEPA) and European Norm (EN) for eight (8)-hour daytime safe human exposure.

The study-area

The Study-area is the South-Southern geo-political zone of Nigeria – a part of its oil-rich Niger-Delta region, being predominantly a natural combination of several oil-rich plateaus, lowlands, islands and water-bodies etc. It accounts for about 23% of Nigeria’s vast population, which was estimated to be one hundred and forty million (140,000,000) in year the 2016, and occupies a land mass (area) of 39,262 Km^2. Generally regarded as the mineral-resource base of the country, it sits atop vast reserves of crude-oil and natural gas, and might snowball into the tourism hub of West-Africa, in the foreseeable future, if the nagging issues [of Crude oil spillage, Militancy and Insecurity etc.,] are pragmatically and urgently addressed. On the map of Nigeria, as published by the National Space Research Development Agency (2016), it could be conspicuously spotted at the location where the $'Y - tail'$ of the ‘River Niger’ meets the Atlantic Ocean via the Gulf of Guinea. This study focuses on the major seven (7) cities of Port-Harcourt, Benin-City, Asaba, Warri, Yenagoa, Uyo, and Calabar in the six (6) states that make-up this geo-political zone (Figure 1).

Materials and methods

The experimental data presented here are the average values obtained after conducting ten (10) consecutive field-experiments, on each of sixty (60) actively running electricity-generators. These were the 60 generator-models that were commonly used/operated in the 60 identified distinct field-locations, evenly spread across the seven (7) cities [Port-Harcourt, Uyo, Calabar, Benin-City, Asaba, Warri and Yenagoa] of South-Southern Nigeria. This was within a study-period of three (3) years (1st January 2013 – 31st December 2015). The major considerations for designating the ‘prospective study-sites’ located within the study-area as ‘ideal field-locations’, included among other things: geographical spread, comparative degree of accessibility, availability of proximate neighbours and passers-by, relative frequency of usage (operation) of generator and willingness to co-operate with the investigation team. The experiments were carefully performed in accordance with the experimental procedures prescribed by the Occupational Safety and Health Agency (OSHA 2016), in its Technical [Field Operations] Manual, being specifically designed and produced for occupational/general sound (noise) measurements [20]. The empirical measurements for this research were basically obtained using the Integrated

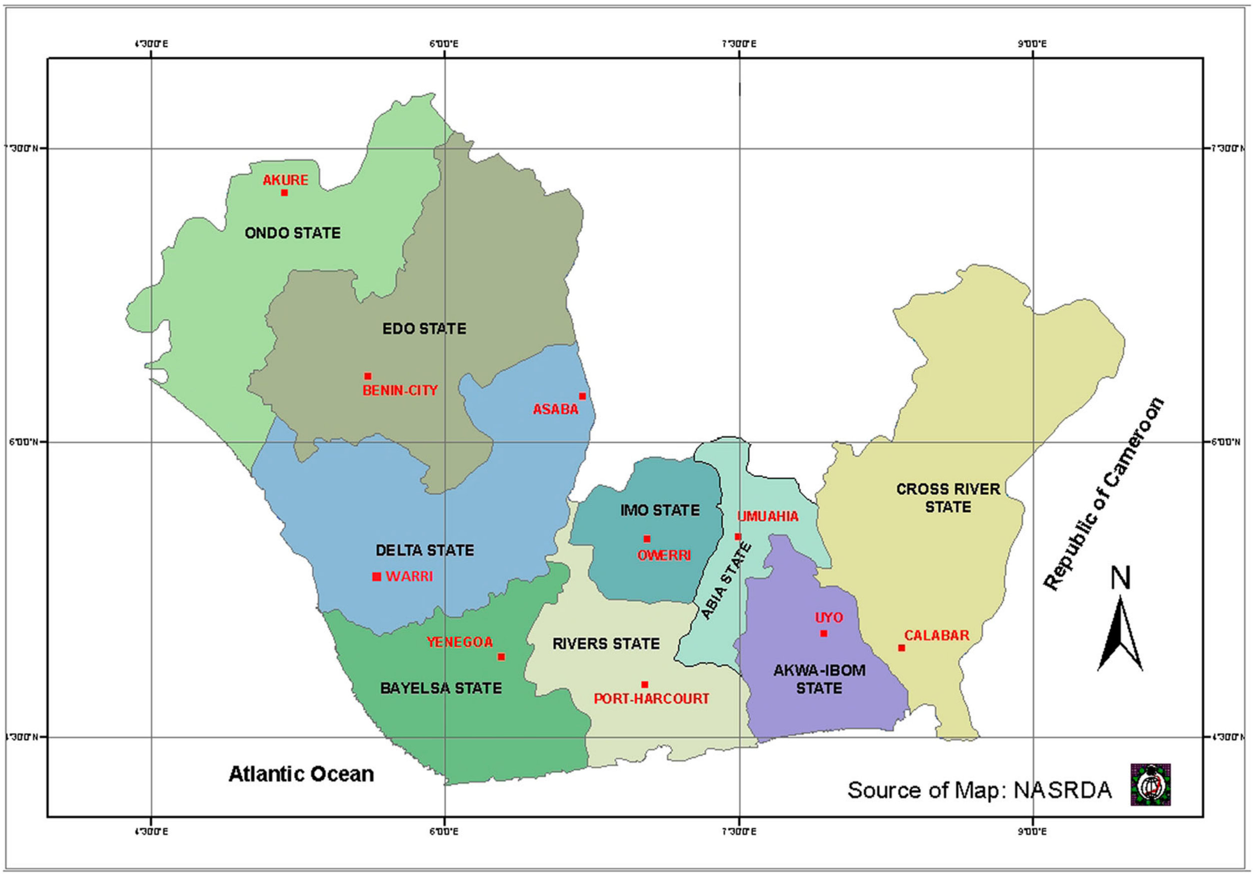


Figure 1: Map of Niger-Delta, showing the major Cities of the South-Southern Geo-political Zone of Nigeria [19].

'$CR811C$ Noise-Meter', a type 1 integrated sound level meter specifically adapted for precision measurements of time-integrated values in field surveys, with a frequency range of $25Hz - 16Hz$, a measurement range of $21dB(A) - 140dB(A)$ and an accuracy of $\pm 1dB(A)$. This particular instrument gives the 'A' frequency weighting Network (Scale), which most appropriately corresponds to the general response of the human ear to majority of commonly emitted sound frequency levels.

Noise sampling of electricity-generators

Ten (10) experimental measurements were repeatedly carried-out in each field-location, where only one (1) actively running (operated) generator was studied. For each generator, a measured radius of 1 m was mapped-out, from which multiple measurements of Sound Pressure Level (SPL) were taken at eight (8) different reading positions [i.e. the 4 sides and 4 edges]; with the antenna of the Noise-meter pointing steadily in the direction of the generator – being the sound source. All readings were taken between 0700hrs (07:00am) and 1900hrs (07:00pm), which coincides with the usual business hours of corporate/business generators-users and the active (non-sleeping) daily periods of individual/residential generator-users. The Noise-meter was calibrated immediately before and after each experimental measurement. Also, the Noise-meter was specifically configured in automatic mode to operate continually for a measuring time of one (1) hour, so as to ensure accuracy – by way of limiting human-errors, and to minimize stress on the part of the investigation team-members, since the instrument carefully tracks all sound-fluctuations or variations, records them in its built-in memory, and then accurately determines the mean value of Sound energy. In addition, 'Mean usage period' [from the 1st to 10th experiment] in $'Months'$ and 'Power-rating' in $'KW'$ were noted. Furthermore, the following precautions were carefully ensured during the experiments:

- Noise-sampling of each generator [in loaded condition] was performed in a designated 'field-location', where there was no other generator simultaneously being operated within close proximity.
- Other environmental noise sources [such as machineries, hi-fi sets, turbulent wind effects, humans (crowd), animals (dogs, cattle and frogs), road traffic, moving trains and aircrafts etc.] with potential for undue interference, were either eliminated temporarily or distanced from the field-location as much as was possible.
- No measurements were carried-out near any hard or reflective surfaces.
- No experiments were conducted under windy or rainy conditions.
- Where it was necessary, wind-screens were used to ensure accuracy.

Acquisition of other noise parameters

- Sound Power Level (L_W) was obtained by substituting values into the equation (1) below:

$$(L_W) = SPL + 10Log_{10}4\pi r$$

where $'SPL'$ is Sound Pressure Level; and $'r'$ is distance from generator to Noise-meter, being kept as a constant value of 1 m throughout the experiments. (Cory 2016).

Table 1: Selected noise-parameters, power-ratings and usage-periods of sixty (60) examined generator-models from fourteen (14) brands.

S/No	Generator-Brand	Generator-Model	Usage Period (*Months*)	Power-Rating (*KW*)	Sound Pressure Level (*SPL*) [$dB(A)$]	Noisiness (*Noy*)	Sound Power Level (L_w) [W/m^2]
G1	Brand 'A'	SH7600EX	15	4.5	95.0	49.0	106.0
G2		SV6500(S)	21	5.0	94.0	45.0	105.0
G3		SHX12000Di	18	5.6	87.0	27.5	98.0
G4		SHT11500	17	8.0	93.0	42.0	104.0
G5		SHT15D	13	9.6	85.0	23.0	96.0
G6	Brand 'B'	1200M	24	0.9	80.0	17.0	91.0
G7		2500M	20	1.8	93.0	42.0	104.0
G8		2500ES	15	1.8	85.0	23.5	96.0
G9		6900E	14	5.0	95.0	49.0	106.0
G10		6900RAS	14	5.0	95.0	49.0	106.0
G11		8100ES	16	6.0	93.0	42.0	104.0
G12	Brand 'C'	EG4000CX	20	2.6	91.0	36.5	102.0
G13		EG5000CX	20	3.2	91.0	36.5	102.0
G14		EG6500CX	13	4.0	88.0	29.5	99.0
G15		EM4000S	24	4.0	93.0	42.0	104.0
G16		EN7000Is	15	4.4	77.0	14.0	88.0
G17		EM5000S	22	4.5	94.0	45.0	105.0
G18		EM6500S	24	5.5	93.0	42.0	104.0
G19	Brand 'D'	EPG2400	45	1.0	73.0	76.0	84.0
G20		FPG3910EX	12	2.1	95.0	49.0	106.0
G21		ECO8990ES	17	6.0	101.0	76.0	112.0
G22		ECO10990ES	22	9.6	101.0	76.0	112.0
G23	Brand 'E'	TG950	60	0.5	80.0	17.0	91.0
G24		TG1000	36	0.7	82.0	19.5	93.0
G25		TG1700	48	1.0	81.0	18.5	92.0
G26		TG2700	60	2.0	93.0	42.0	104.0
G27		TG4700	12	3.5	94.0	45.0	105.0
G28		TG6700	12	5.0	95.0	49.0	106.0
G29	Brand 'F'	ECO1990S	12	1.2	95.0	45.0	106.0
G30		SPG2200	15	1.2	80.0	17.0	91.0
G31		SPG2900E2	19	1.8	93.0	42.0	104.0
G32		SPG7000SE	13	3.6	94.0	45.0	105.0
G33	Brand 'G'	SV2200	21	1.0	93.0	42.0	104.0
G34		SV3800E2	17	2.0	94.0	45.0	105.0
G35		SV5000E2	14	2.8	94.0	45.0	105.0
G36	Brand 'H'	KW2600003	21	2.0	91.0	36.5	102.0
G37		KW2600008	18	3.2	93.0	42.0	104.0
G38		KW2600852	15	5.0	94.0	45.0	105.0
G39		KW2600853	22	7.0	95.0	49.0	106.0
G40	Brand 'I'	JL2600E	36	1.6	93.0	42.0	104.0
G41		JL2800	28	2.0	94.0	45.0	105.0
G42		JL3600	30	2.5	96.0	51.0	107.0
G43	Brand 'J'	PV3000	36	2.0	94.0	45.0	105.0
G44		PS3650DX	30	2.5	93.0	42.0	104.0
G45	Brand 'K'	KW2600901	18	32.0	105.0	98.0	116.0
G46		KW2600902	15	48.0	105.0	98.0	116.0
G47		KW2600905	12	92.0	105.0	98.0	116.0
G48		KW2600917	13	92.0	94.0	45.0	105.0
G49		KW2600906	19	104.0	94.0	45.0	105.0
G50		KW2600920	16	128.0	92.0	40.0	103.0
G51		KW2600910	12	160.0	93.0	42.0	104.0
G52	Brand 'L'	DSFAE	12	72.0	101.0	76.0	112.0
G53		DHSAD	16	210.0	97.0	55.0	108.0
G54		DQHAB	18	270.0	95.0	49.0	106.0
G55		DQPAA	16	545.0	94.0	45.0	105.0
G56	Brand 'M'	KW2600858	14	10.8	104.0	98.0	115.0
G57		KW2602008	19	48.0	103.0	90.0	114.0
G58	Brand 'N'	ET950	35	0.7	79.0	14.6	90.0
G59		EF2600FW	14	1.6	95.0	49.0	106.0
G60		EF4000DE	17	3.5	84.0	23.5	95.0
Average (Mean) Values			**21**	**32.9**	**92.4**	**46.1**	**103.4**

- Noisiness was obtained as a conversion of SPL using the Kryter Scale (1959) in line with $ISO - R507$ (1966).

Then, the values of Rated-Power, Usage-Period,-SPL, Noisiness and L_w so obtained for each of the sixty (60) generator-models were collated, tabulated, and graphically illustrated, in order to obtain Table 1 and Figures 2–10. After which a statistical analysis was then carried-out using the tabulated data.

Data analysis

Using '$SPSS - 23$ (Software Package for Statistics and Simulation-23)' the various degrees of non-conformity/ deviation of the $SPLs$ of the studied generators from the recommended global standard values of WHO [$90dB(A)$], USEPA [$75dB(A)$] and EN [$70dB(A)$] respectively, were determined, by conducting a non-parametric statistical test called 'The Wilcoxon Signed Ranks Test' on all the generators' $SPL - values$. This was done by stating a 'Null-Hypothesis $(H_0)'$ and an 'Alternative Hypothesis $(H_a)'$ to a significance-level (α), as follows:

$$\text{For WHO standard,}\quad H_0 : SPL = 90dBA,$$
$$H_a : SPL > 90dBA,$$
$$\alpha = 0.05\,[95\%\text{Confidence level}]$$

$$\text{For USEPA standard,}\quad H_0 : SPL = 75dBA,$$
$$H_a : SPL > 75dBA,$$
$$\alpha = 0.05\,[95\%\text{Confidence level}]$$

$$\text{For EN standard,}\quad H_0 : SPL = 70dBA,$$
$$H_a : SPL > 70dBA,$$
$$\alpha = 0.05\,[95\%\text{Confidence level}].$$

Results and discussion

The results shown in Table 1 are the experimentally-obtained average data of the usage-profiles [Power-ratings in 'KW' and Usage-periods in 'Months'] and selected Noise-parameters [Sound Pressure Level/Noise Level (SPL) in 'dBA', Perceived Noisiness in 'Noy' and Sound Power Level (L_w) in 'W/m^2'] of sixty (60) commonly-used electricity generators-models, manufactured by fourteen (14) leading brands [i.e. 'brands 1–14'] in the seven (7) metropolitan cities [Port-Harcourt, Benin-City, Asaba, Warri, Yenagoa, Uyo and Calabar] of the South-Southern Nigeria.

Table 2 shows the Permissible Noise Exposure Limits (PNELs) i.e. the standardized threshold values/limits [of Sound Pressure Level/Noise Level] recommended by three global standards/regulatory bodies [WHO, USEPA and EN] for eight (8) hour daytime safe human exposure to ambient noise. It also shows the calculated values of perceived Noisiness (Noy) and Sound Power Level (W/m^2)] that correspond to these PNELs.

A careful consideration of column 4 and column 5 data-sets in Table 1, shows that, for all sixty (60) examined generator-models: while the Power-ratings varied between 0.5 KW and 545.0 KW, with an average value of 32.9 KW; the usage (operational) periods differed between 12 months and 60 months, with an average value of 21 months. This is an indication that the examined generators ranged from 'portable size generators for domestic use' to 'Industrial-plant size generators for industrial-scale operations'; which were recently acquired/installed, or have been operated for not more than five (5) years – making them ideal [case-studies] to be considered, in view of the broad scope of this research work.

From Tables 1 and 2, it was observed that the calculated 'Sound power Levels (L_w)' [of all sixty (60) examined generators] ranged from a minimum value of 84.0 W/m^2 [S/No. G19 in Table 1] to a maximum value of 116.0 W/m^2 [S/Nos. G45, G46, and G47 in Table 1], with an overall combined mean value of 103.4 W/m^2. However, the maximum and mean values exceeded all three L_w values of 101.0 W/m^2 (WHO), 86.0 W/m^2 (USEPA) and 81.0 W/m^2 (EN) as is specified in Table 2.

Similarly, the determined 'Perceived Noisiness' [of all sixty (60) examined generators] varied between 14.0 *Noy*

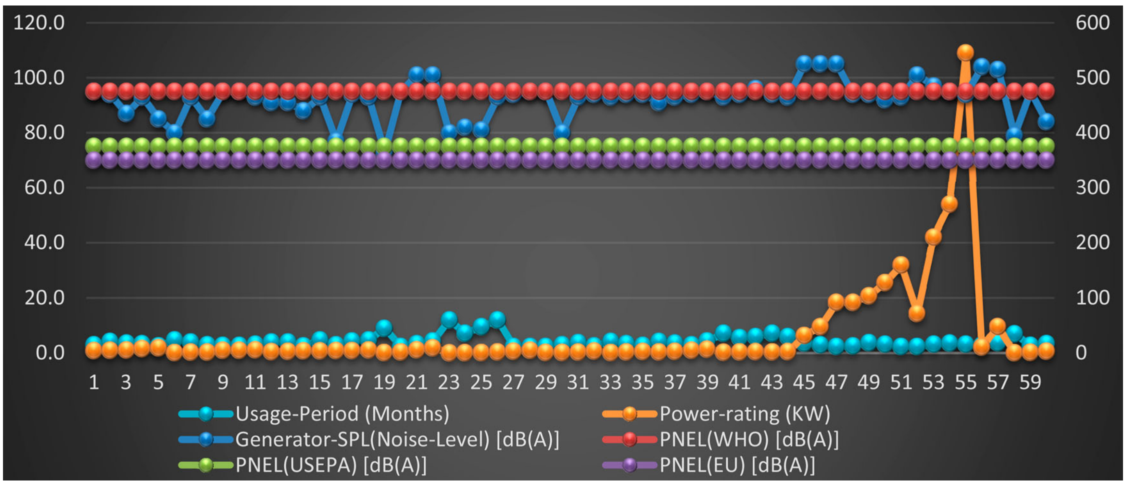


Figure 2: Graph of SPLs (Noise-levels) of sixty (60) Generators-models, with the 'PNELs' recommended by 'WHO', 'USEPA' and 'EN'.

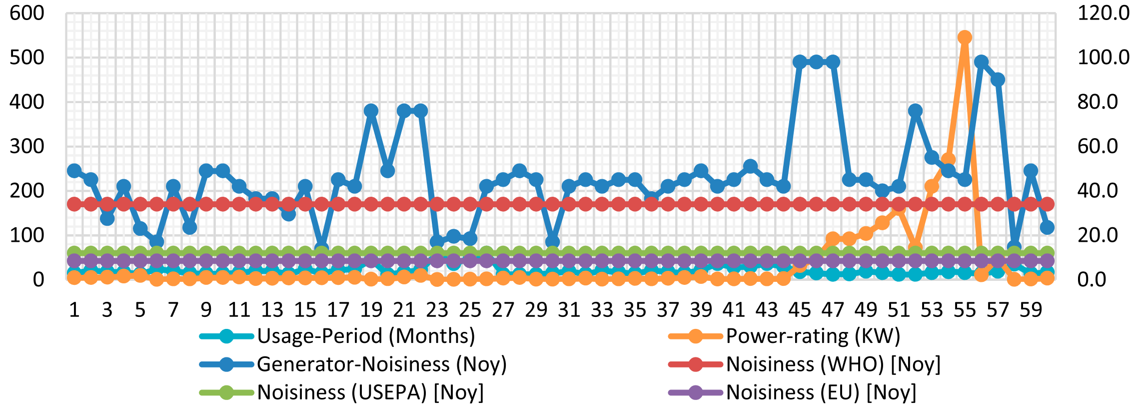


Figure 3: Graph of Noisiness of Sixty (60) Generator-models, with Noisiness-values corresponding to the 'PNELs' recommended by 'WHO', 'USEPA' and 'EN'.

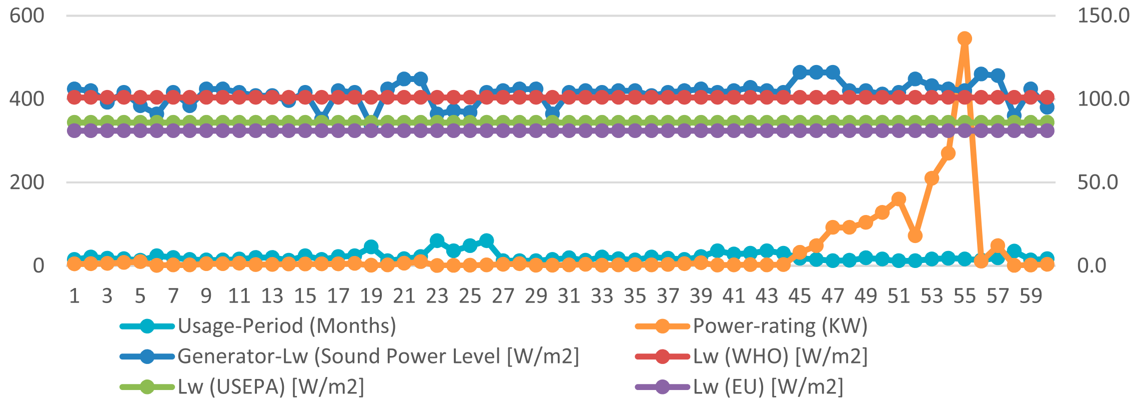


Figure 4: Graph of Lw(Sound Power Level) of Sixty (60) Generator-models, with 'Lw'- values corresponding to the 'PNELs' recommended by 'WHO', 'USEPA' and 'EN'.

[S/No. G16 in Table 1] and 98.0 *Noy* [S/Nos. G45, G46, G47, and G56 in Table 1], with an overall combined mean value of 46.1 *Noy*, which also significantly exceeded all three Perceived-Noisiness values of 34.0 *Noy* (WHO), 12.0 *Noy* (USEPA), and 8.5 *Noy* (EN), as shown in Table 2.

Most importantly, a comparative analysis of the experimental results in Table 1, with the PNELs in Table 2 shows that, the average Sound Pressure Level/Noise Level (*SPL*) [of all sixty (60) examined generators] ranged from a minimum value of 73.0 *dB*(*A*) [S/No. G19 in Table 1] to a maximum value of 105.0 *dB*(*A*) [S/Nos. G45, G46 and G47 in Table 1], with an overall combined mean value of 92.4 *dB*(*A*). It is noteworthy that, of all the sixty (60) generators examined: only thirteen (13) generators' *SPLs* were lower than the $PNEL_{(WHO)}$ of 90

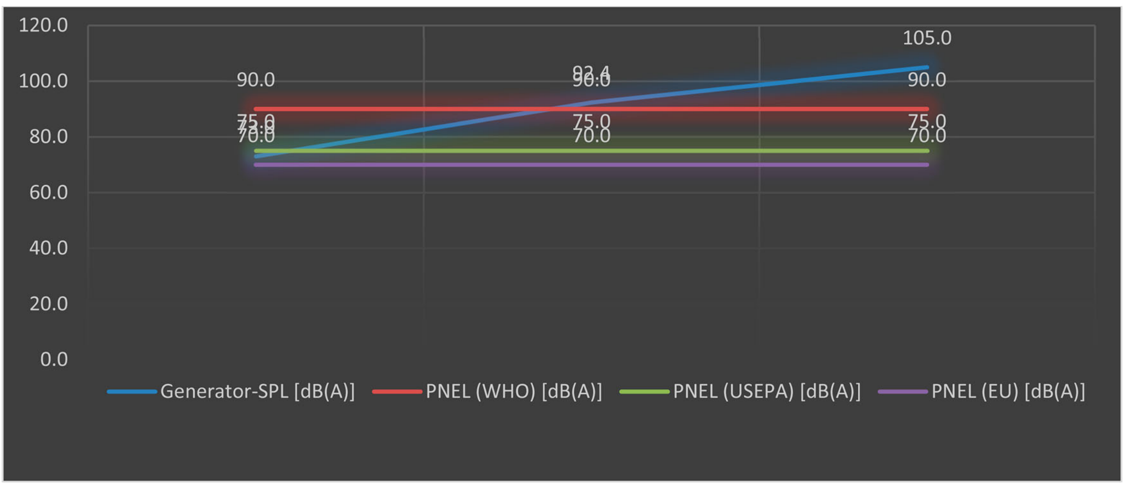


Figure 5: Graph of [Minimum, Average and Maximum values of] SPLs (Noise-levels) of Sixty (60) Generators, with the PNELs recommended by 'WHO', 'USEPA' and 'EN'.

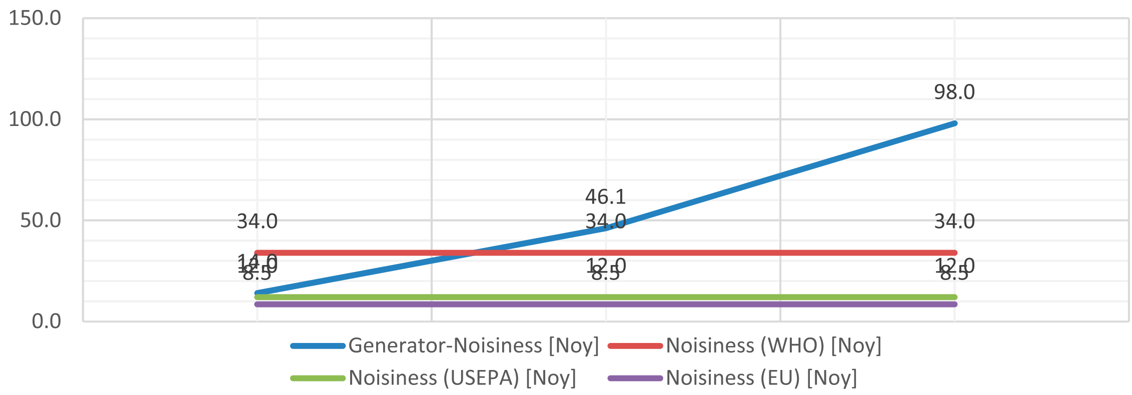


Figure 6: Graph of [Minimum, Average and Maximum values of] Noisiness of Sixty (60) Generators-models, with Noisiness-values corresponding to the PNELs recommended by 'WHO', 'USEPA' and 'EN'.

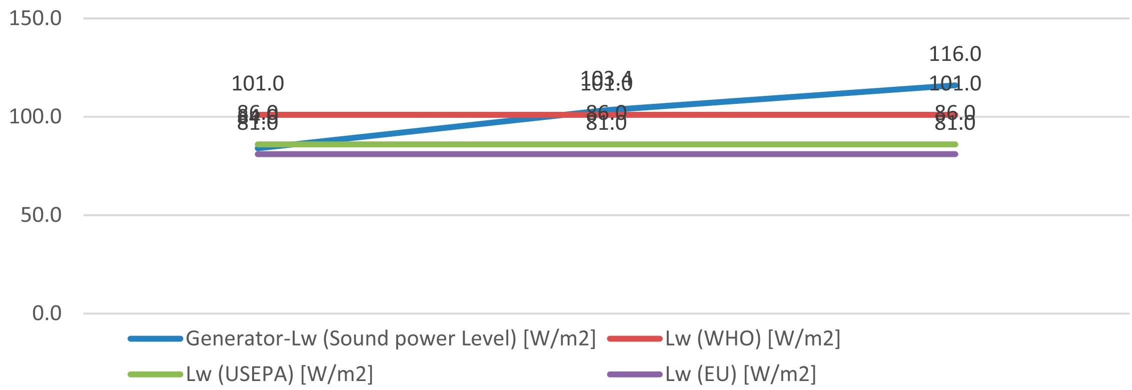


Figure 7: Graph of [Minimum, Average and Maximum values of] Lw(Sound Power Level) of Sixty (60) Generators-models, with Lw-values corresponding to the PNELs recommended by 'WHO', 'USEPA' and 'EN'.

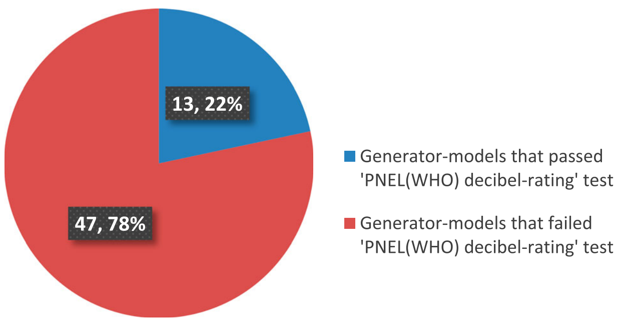


Figure 8: Pie-chart illustration of Performance-Assessment of the Sixty (60) Generator-models, based on the 'PNEL(WHO) decibel-rating' test.

dB(*A*) [Table 2], while only one (1) generator's *SPL* fell below the $PNEL_{(USEPA)}$ of 75 *dB*(*A*) [Table 2], and none fell below the $PNEL_{(EN)}$ of 70 *dB*(*A*) [Table 2]. Thus, forty-seven (47) generators [78%] failed the '$PNEL_{(WHO)}$ decibel-rating test', fifty-nine (59) generators [98%] failed the '$PNEL_{(USEPA)}$ decibel-rating test', and all sixty (60) generators [100%] failed the '$PNEL_{(EN)}$ decibel-rating test', for eight (8)-hour daytime safe human exposure to environmental noise (sounds) (See Tables 1 and 2 and Figures 2–10). Candidly, prolonged/continuous exposure to sounds [particularly machinery/engine noises] of such order/magnitude of decibel-ratings, will result in the aforementioned hazardous consequences/end results

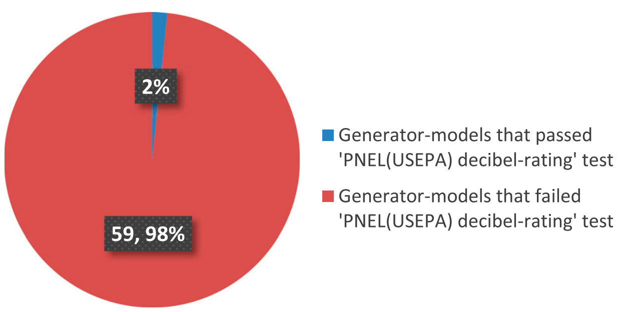


Figure 9: Pie-chart illustration of Performance-Assessment of the Sixty (60) Generator-models, based on the 'PNEL(USEPA) decibel-rating' test.

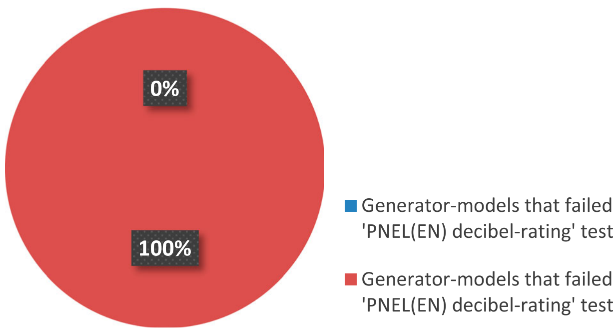


Figure 10: Pie-chart illustration of Performance-Assessment of the Sixty (60) Generator-models, based on the 'PNEL(EN) decibel-rating' test.

Table 2: Permissible Noise Exposure Limits (PNELs) for Eight (8)-Hour Daytime Safe Human- Exposure to Environmental Noise, as recommended by the 'WHO' 'USEPA' and 'EN'.

Noise − Parameter	*WHO − recommended*	*USEPA − recommended*	*EN − recommended*
PNEL or *SPL* [dB(A)]	90.0	75.0	70.0
Noisiness (*Noy*)	34.0	12.0	8.5
L_w (W/m^2)	101.0	86.0	81.0

Table 3: Wilcoxon Signed Ranks Test for *SPL* of 60 Generators with respect to $PNEL_{(WHO)}$.

Ranks

		N	Mean Rank	Sum of Ranks
$SPL_{gen} - PNEL_{(WHO)}$	Negative Ranks	13[a]	40.92	532.00
	Positive Ranks	47[b]	27.62	1298.00
	Ties	0[c]		
	Total	60		

[a]$SPL_{gen} < PNEL_{(WHO)}$
[b]$SPL_{gen} > PNEL_{(WHO)}$
[c]$SPL_{gen} = PNEL_{(WHO)}$

Test Statistics[b]

	$SPL_{gen} - PNEL_{(WHO)}$
Z	−2.828[a]
Asymp. Sig. (2-tailed)	.005

[a]Based on negative ranks.
[b]Wilcoxon Signed Ranks Test.

which include Tinnitus, reduced mental alertness/attentiveness, noise-annoyance, mood swings/unruly behaviours, hearing impairment and in some extreme cases – outright deafness etc.

Following the 'SPSS-23' generated results of the 'Wilcoxon Signed Ranks Test' analysis of the '*SPL* data', shown in Table 3 above, with respect to the WHO standard $PNEL_{(WHO)}$ of $90dB(A)$: for the sixty (60) generators examined, n is 59, tie is 0, Positive-Ranks $[SPL_{gen} > PNEL_{(WHO)}]$ is 47, and the negative-Ranks $[SPL_{gen} < PNEL_{(WHO)}]$ is 13. Thus, the alternative hypothesis $[H_a : SPL_{gen} > 90dBA]$ is statistically-significant and should be accepted at $z = -2.828, n = 59, p = 0.005 < 0.05$; while the null hypothesis $[H_0 : SPL_{gen} = 90dBA]$ should be rejected.

From the 'SPSS-23' generated results of the 'Wilcoxon Signed Ranks Test' analysis of the '*SPL* data', shown in Table 4 above, with respect to the USEPA standard $PNEL_{(USEPA)}$ of $75dB(A)$: for the sixty (60) generators examined, n is 59, tie is 0, Positive-Ranks $[SPL_{gen} > PNEL_{(USEPA)}]$ is 59, and Negative-Ranks $[SPL_{gen} < PNEL_{(USEPA)}]$ is 1. Consequently, the alternative hypothesis $[H_a : SPL_{gen} > 75dBA]$ is statistically-significant and should be accepted at $z = -6.741, n = 59, p = 0.000 < 0.05$; while the corresponding null hypothesis $[H_0 : SPL_{gen} = 75dBA]$ should be rejected.

Also, in Table 5 above, is the 'SPSS-23' generated result of the '' analysis of the '*SPL* data'. Now, with respect to the EN standard $PNEL_{(EN)}$ of $70dB(A)$: for the

Table 4: Wilcoxon Signed Ranks Test for *SPL* of 60 Generators with respect to $PNEL_{(USEPA)}$.

Ranks

		N	Mean Rank	Sum of Ranks
$SPL_{gen} - PNEL_{(USEPA)}$	Negative Ranks	1[a]	1.50	1.50
	Positive Ranks	59[b]	30.99	1828.50
	Ties	0[c]		
	Total	60		

[a]$SPL_{gen} < PNEL_{(USEPA)}$
[b]$SPL_{gen} > PNEL_{(USEPA)}$
[c]$SPL_{gen} = PNEL_{(USEPA)}$

Test Statistics[b]

	$SPL_{gen} - PNEL_{(USEPA)}$
Z	−6.741[a]
Asymp. Sig. (2-tailed)	.000

[a]Based on negative ranks.
[b]Wilcoxon Signed Ranks Test.

Table 5: Wilcoxon Signed Ranks Test for *SPL* of 60 Generators with respect to $PNEL_{(EN)}$.

Ranks

		N	Mean Rank	Sum of Ranks
$SPL_{gen} - PNEL_{(EN)}$	Negative Ranks	0^a	.00	.00
	Positive Ranks	60^b	30.50	1830.00
	Ties	0^c		
	Total	60		

[a] $SPL_{gen} < PNEL_{(EN)}$
[b] $SPL_{gen} > PNEL_{(EN)}$
[c] $SPL_{gen} = PNEL_{(EN)}$

Test Statistics[b]

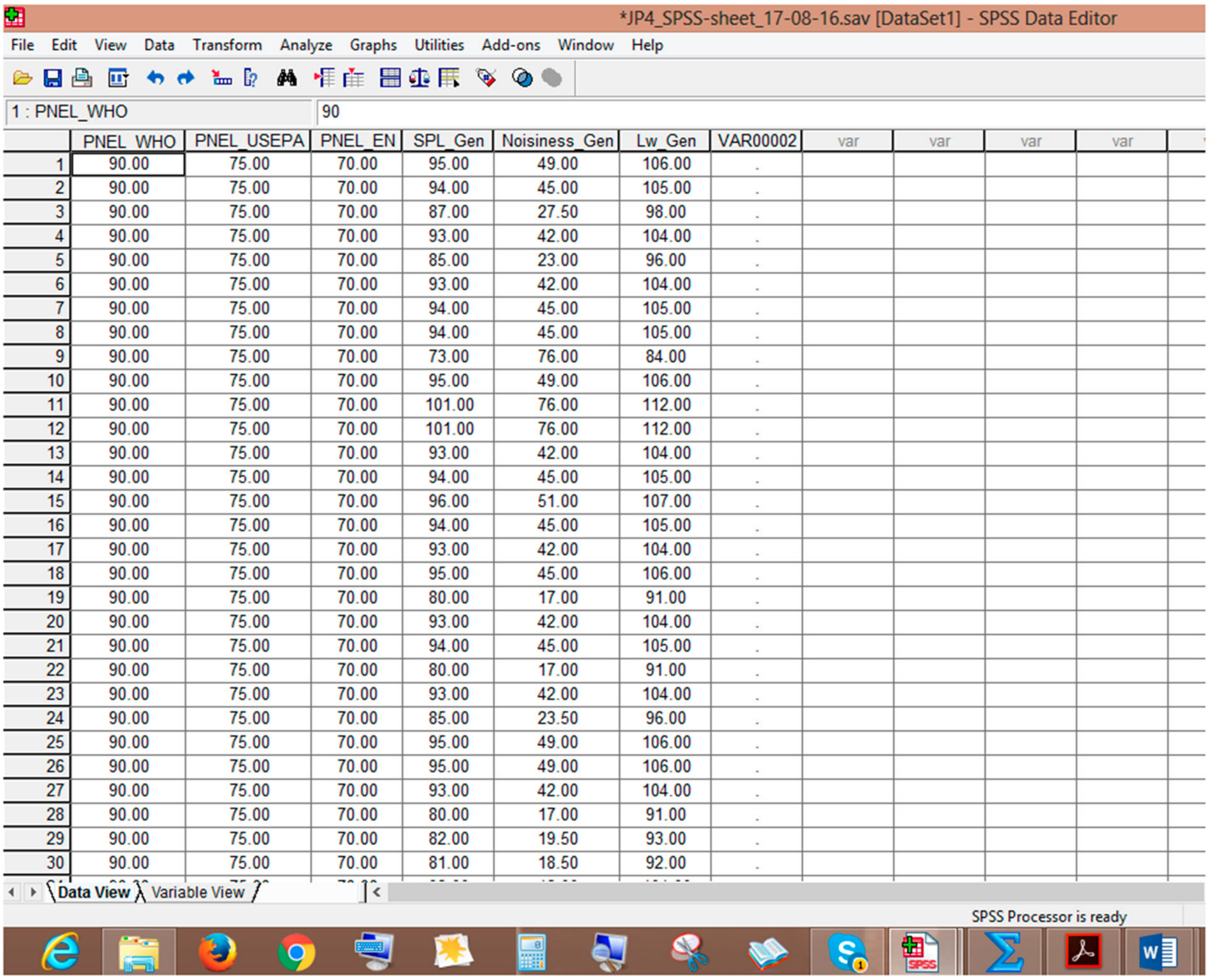
	$SPL_{gen} - PNEL_{(EN)}$
Z	-6.752^a
Asymp. Sig. (2-tailed)	.000

[a] Based on negative ranks.
[b] Wilcoxon Signed Ranks Test.

sixty (60) generators examined, n is 59, tie is 0, Positive-Ranks $[SPL_{gen} > PNEL_{(EN)}]$ is 60, and the Negative-Ranks $[SPL_{gen} < PNEL_{(EN)}]$ is 0. Thus, the alternative hypothesis $[H_a : SPL_{gen} > 70dBA]$ is statistically-significant and should be accepted at $z = -6.752, n = 59, p = 0.000 < 0.05$; while the corresponding null hypothesis $[H_0 : SPL_{gen} = 70dBA]$ should be rejected.

Conclusion and recommendations

In this study, measurements of selected noise-parameters of electricity-generators commonly used in the seven (7) cities [Port-Harcourt, Benin-City, Asaba, Warri, Yenagoa, Uyo, and Calabar] of South-Southern Nigeria have been assessed, and the experimental results showed that: Sound Power Levels ranged from $84W/m^2 - 116W/m^2$, and Noisiness ranged from $14Noy - 98Noy$, while Sound Pressure



	PNEL_WHO	PNEL_USEPA	PNEL_EN	SPL_Gen	Noisiness_Gen	Lw_Gen	VAR00002	var	var	var	var
1	90.00	75.00	70.00	95.00	49.00	106.00	.				
2	90.00	75.00	70.00	94.00	45.00	105.00	.				
3	90.00	75.00	70.00	87.00	27.50	98.00	.				
4	90.00	75.00	70.00	93.00	42.00	104.00	.				
5	90.00	75.00	70.00	85.00	23.00	96.00	.				
6	90.00	75.00	70.00	93.00	42.00	104.00	.				
7	90.00	75.00	70.00	94.00	45.00	105.00	.				
8	90.00	75.00	70.00	94.00	45.00	105.00	.				
9	90.00	75.00	70.00	73.00	76.00	84.00	.				
10	90.00	75.00	70.00	95.00	49.00	106.00	.				
11	90.00	75.00	70.00	101.00	76.00	112.00	.				
12	90.00	75.00	70.00	101.00	76.00	112.00	.				
13	90.00	75.00	70.00	93.00	42.00	104.00	.				
14	90.00	75.00	70.00	94.00	45.00	105.00	.				
15	90.00	75.00	70.00	96.00	51.00	107.00	.				
16	90.00	75.00	70.00	94.00	45.00	105.00	.				
17	90.00	75.00	70.00	93.00	42.00	104.00	.				
18	90.00	75.00	70.00	95.00	45.00	106.00	.				
19	90.00	75.00	70.00	80.00	17.00	91.00	.				
20	90.00	75.00	70.00	93.00	42.00	104.00	.				
21	90.00	75.00	70.00	94.00	45.00	105.00	.				
22	90.00	75.00	70.00	80.00	17.00	91.00	.				
23	90.00	75.00	70.00	93.00	42.00	104.00	.				
24	90.00	75.00	70.00	85.00	23.50	96.00	.				
25	90.00	75.00	70.00	95.00	49.00	106.00	.				
26	90.00	75.00	70.00	95.00	49.00	106.00	.				
27	90.00	75.00	70.00	93.00	42.00	104.00	.				
28	90.00	75.00	70.00	80.00	17.00	91.00	.				
29	90.00	75.00	70.00	82.00	19.50	93.00	.				
30	90.00	75.00	70.00	81.00	18.50	92.00	.				

Figure 11: Screen-shot of recommended Global Standard ['$PNEL_{(WHO)}$', '$PNEL\,(USEPA)$' and '$PNEL_{(EN)}$'] values and generators' Noise Parameters' ['$SPL_{(gen)}$', '$Noi\sin ess_{(gen)}$' and '$L_{W_{(gen)}}$'] data inputted into the SPSS sheet, prior to performing the non-parametric 'Wilcoxon Signed Ranks test'.

Levels (Noise-levels) ranged from $73dB(A) - 105dB(A)$. Thus, the generators studied have been shown to be major noise emitters in these cities. This opinion is validated by the statistical illustrations in 'Figures 8–10', and the results of the Wilcoxon Signed Ranks test. Consequently, it could be stated that, majority of electricity-generators operated in these seven (7) cities of Nigeria were hazardously noisy, since $78\%, 98\% and 100\%$ of them had noise-levels that exceeded the $WHO, USEPA and EN$ recommended Permissible Noise Exposure Limits ($PNELs$) for $8 hour$ daytime safe human exposure, with values of $90dBA, 75dBA and 70dBA$ respectively.

However, from this study, the various factors responsible for the poor acoustic performance of these generators include, but are not limited to: (1.) Factory defects due to poor QA/QC (Quality Assurance/ Quality Control) in the Production-lines of Generator factories overseas. These may have occurred, while attempting to meet (satisfy) the excessively high demand for generators from Nigeria, in view of the nation's lingering Energy (Power) sector crises. (2.) The quality of the component parts of the various models and brands of generators. (3.) The electrical-loads applied on the generators, which contributed to the noise-levels of the generators. Thus, as was observed in many of the field-locations, the higher the applied load, the higher the Noise-level (SPL) of the generator. Also, some generators of low capacities (Power-ratings) when subjected to high loads exhibited high noise-levels. (4.) Usage profile being a determinant of noise-level of the generators. This is because even when 'wear and tear' was evident, some users refused to 'do-away' with their generators, so long as it was still working. (5.) Maintenance culture which has to be improved upon, so as to increase the sound-damping efficiency of the generators.

Thus, from the aforementioned, it is evident that an overwhelming majority of these generators, pose a serious potential risk/danger to the health and general wellbeing of the cities' residents (Figures 11 and 12). Therefore, the following are recommended:

- Government should put in place a policy to drastically reduce the importation and sales of electricity-generators with high noise emission levels, while discouraging the continued usage (operation) of old, unserviceable and hazardously-noisy generators.
- Statutory Bodies and Regulatory agencies like the 'Standards Organization of Nigeria (SON), Council for

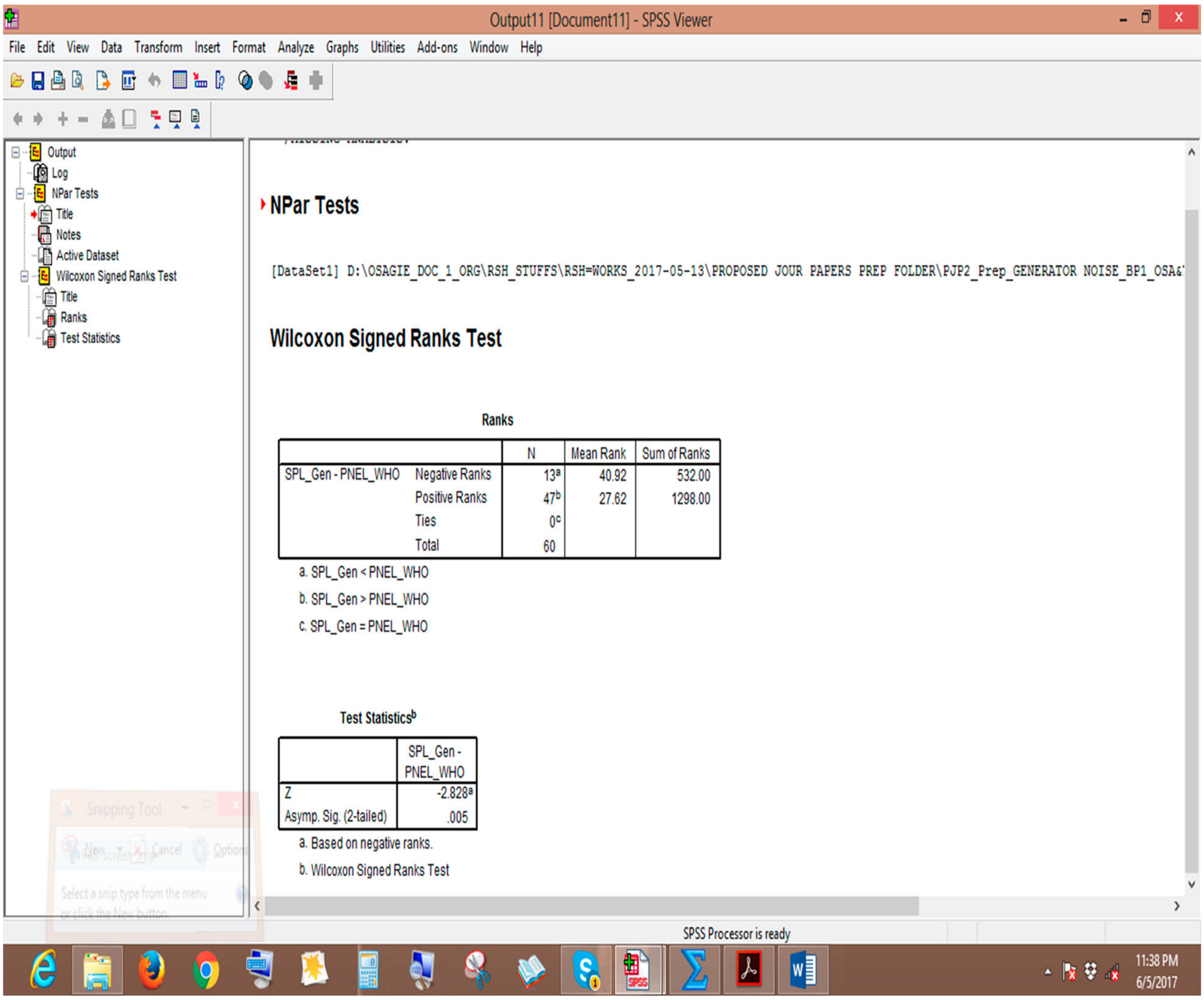


Figure 12: Screen-shot of 'Wilcoxon Signed Ranks test' results displayed on the SPSS sheet, after performing this non-parametric two-related sample test analysis on the already inputted generators' Noise parameters' data.

the Regulation of Engineering in Nigeria (COREN), The Nigerian Society of Engineers (NSE), National Environmental Standard and Regulation Enforcement Agency (NESREA) and Manufacturers Association of Nigeria (MAN) etc., should synergize, and then insist on strict compliance with relevant industrial/environmental standards and current best practices; while strategically interfacing (liaising) with countries that are major manufacturers and importers of electricity-generators to Nigeria.

- Generators should be run (operated) in noise-absorbent locations, and far from people, at a minimum distance of seven (7) metres.
- 'Resource-Sharing' should be encouraged amongst people residing in the same/nearby premises/neighbourhoods, [where possible]. This will help to maximize resources, as well as reduce noise pollution. This means that, depending on their relative electricity-requirements and proximity, 'Generator-user1' and 'Generator-user2' within the same premises/neighbourhoods, could be serviced simultaneously by 'Generator1', while 'Generator2' is non-operational and vice-versa; thereby reducing generator-emitted noise-pollution within a locality.
- Generator-manufacturers should clearly specify the decibel-ratings (Noise-levels) of their products, while the Generator-buyers should be properly educated on how to purchase generators with low noise emission levels.
- Government should create the much-needed awareness and embark on public-enlightenment campaigns and sensitization workshops/seminars focused on the 'Hazardous consequences of undue exposure to high noise levels'.
- Research institutes and Universities in Nigeria should collaborate to venture into other technically-related areas of Research and Development (R&D) such as 'the Spectral Content of Generator-noise' and 'Sound-damping and Sound-proofing of Electricity-Generators through Reverse-Engineering (RE) and/or Nano-technology etc.

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Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Osagie Ibhadode http://orcid.org/0000-0002-9990-1014
I. T. Tenebe http://orcid.org/0000-0002-5862-6511
P. C. Emenike http://orcid.org/0000-0001-6778-6413
O. S. Adesina http://orcid.org/0000-0003-1476-8080

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