Sound Pressure Level, Power Level, Noisiness and Perceived Noise Level of some commonly used Generators in Pankshin Metropolis of Plateau State, Nigeria

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Abstract

In this work, sound pressure levels of some generators in Pankshin town of Plateau State, Nigeria were measured. The sound power levels, noisiness, perceived noise levels of generators and people's attitude towards the noise were obtained. The sound pressure levels of the different generators were carried out using sound level meter type SL 4010 EUROLAB. The measured sound pressure levels range between 76dBA and 98dBA. The sound power levels range between 87dBA and 109dBA. The values of noisiness were in the range of 14noy and 60noy.The perceived noise levels (PNdB) were in the range of 78dBA to 99dBA. The generator sound was rated to range between moderately noisy and noisy whereas the annoyance rating ranges between slight annoyance and very much annoyance. The correlation coefficient for the generator noise and the noise rating was γ_1=0.589 whereas the correlation coefficient for generator noise sound pressure levels and annoyance rating by respondents was γ_1=0.729, both implying that the higher the noise level, the higher the noise rating and the higher the annoyance.

Keywords: Sound pressure level, sound power level, noisiness, perceived noise level, annoyance.

1. Introduction

Generators are used very commonly in shops, offices, homes, barbing and hair dressing saloons, handsets battery chargers, etc. in order to supply power during interruption or absence of power supply by Power Holdings Company of Nigeria (PHCN). These generators emit very high levels of noise in addition to noxious gas emission, making generator noise one of the major contributions to environmental noise pollution. Noise pollution in the world around us is a growing problem and the effects of noise range from psychological to physiological (Kinsle *et al*., 1982; Cunniff, 1977; Abumere *et al*, 1999). In recent years consumers of products and indeed the general public have begun to demand quieter environments and quieter products and several new proposals for noise limits have been introduced into standardization and regulatory processes (Chagok *et al.*, 2013).With increasing problem of environmental noise, emphasis shifted from a prediction of overt response to a prediction of annoyance. Annoyance, in turn was a variable inferred from responses to social surveys (Avery, 1982; Hazard, 1971; Lindvall and Radford, 1973).

Twenty one (21) commonly used portable generators of output rate ranging from 650 watts to 5 kilowatts were used in the research.

The sound power (W) is the acoustical energy emitted by the sound source per second, and is an absolute value given by

Power,

$$W = I \times S \qquad (1)$$

I is the intensity and S is the surface area

Sound power level

$$L_W = 10 \log_{10} \left(W / W_0 \right) \quad (2a)$$

Sound Intensity level,

$$LI = 10 \log_{10} \left(\frac{I}{I_0} \right) \quad (2b)$$

Expressing (2a) in terms of (1),

$$L_W = 10 \log_{10} \left(\frac{IS}{I_0 S_0} \right) \quad (3)$$

$$I_0 = 10^{-12} \qquad S_0 = 1m^2 \qquad \text{and}$$

$$L_W = 10 \log_{10} \left(\frac{I}{I_0} \right) + 10 \log_{10} \left(\frac{S}{S_0} \right)$$

$$= LI + 10 \log_{10} S$$

$$S = 4\pi r^2$$

Therefore,

$$L_W = LI + 10 \log_{10} 4\pi r^2$$

The sound intensity level is approximately equal to the sound pressure level (Smith et al, 1998). Therefore, the sound pressure level measurements in this work were used in the computation of sound power levels by using equation (4), r being the distance in meter from source. That is,

$$L_W = SPL + 10 \log_{10} 4\pi r^2$$

2. Materials and Methods

2.1 Physical Measurement

For the physical measurement of sound levels of the generators, the sound level meter type SL4010 EUROLAB which has a frequency range of $31.5H_Z$ – 8 kHz, operating on frequency weighting networks of A and C was used. The measuring level ranges from 30 – 130dB.The generators whose levels on the A-weighting network were investigated were placed on the ground in an open field. For each generator, the reading positions were at four different points on a radius of 1m and the average taken. The measurements were also taken for radii of 2m, 3m, 4m and 5m from the generator.

Measurements were taken during the usual business hours of 8:00 am and 5:00 pm, when the generators were in operation. Care was taken so that the measurements were made with the minimum interference with normal working patterns as possible. These measurements were repeated on subsequent visits to confirm the values obtained. Care was taken to ensure that none of the measurements was influenced by external noise, such as aircraft or road traffic noise. Sound pressure levels (dB) were converted to noisiness (noy) and subsequently to perceived noise levels ($PNdB$) using the scale developed by Kryter (1959). Using equal noisiness contours, the decibel scale was converted into a series of increments given in noy from the chart at the right of the graph; the noy scale was converted into Perceived Noise Level ($PNdB$).

2.2 Subjective Assessment

To assess the subjective impact of noise on the respondents who come close to the generators, a questionnaire was used. The researchers asked the respondents questions and entered their responses into the questionnaire although a few respondents completed the questionnaire on their own. This helped to avoid incomplete responses, non-return of questionnaire, loss of questionnaire, misunderstanding of the questions and other shortcomings on the part of the respondents.

3. Results and Discussion

3.1 Sound Pressure Levels (Physical Measurement)

The sound pressure levels at various distances were measured and the corresponding sound power levels were calculated. The sound pressure levels at 1m were used to determine the sound power levels, noisiness and the perceived noise levels of the generators.

The results show that the sound pressure level of most of the generators is high (80dBA or more). Only generators G_8 and G_{12} have levels less than 80dBA. The power level, noisiness and perceived noise level (PNdB) are all functions of the sound pressure levels. Table 1 shows the sound pressure levels, the power levels, noisiness and the perceived noise levels of the various types of generators.

4. Social survey

The questionnaire was used to assess the attitudes of the respondents towards the noise. As provided for in the questionnaire, respondents had the options of rating the generator noise as noisy, moderately noisy, quite, or even declined to comment or were ignorant. The overall noise rating of the generators were calculated by introducing scale values, x, in the form of numbers to represent the employees' generator noise rating. The numbers x=4,3,2,1,0 represent noisy, moderately noisy, quite, declined to comment and ignorant respectively and n is the number of responses. Table 2 shows the overall noise rating of the generators. Essentially, the noise rating of the generators shows that they are rated to be either moderately noisy or noisy. Similarly, the overall rating of annoyance was calculated by the introduction of scale values, x, in the form of numbers to represent the respondents' annoyance rating. The numbers x=4,3,2,1,0 represent extremely annoyed, very much annoyed, moderately annoyed, slightly annoyed and not at all annoyed respectively and n is the number of responses. Table 3 shows the overall rating of noise annoyance by respondents. The annoyance ranges between slightly and very much. To obtain the correlation coefficient for the objective and subjective measurements of the Generators noise rating, the A-weighted sound pressure levels of the generator noise in Table 1 and average noise rating in Table 2 are reproduced in Table 4. The A-weighted sound pressure levels (objective measurements) are the x-variants and the noise ratings by the respondents (subjective responses) are the y-variants. Results show that sound pressure level and the noise rating are about 59% correlated. Similarly, the correlation coefficient for the A-weighted sound pressure levels of the generators and the annoyance rating by respondents was obtained. The A-weighted sound pressure levels of the generator noise in table 1 and the annoyance rating in table 3 are reproduced in table 5. The A-weighted sound pressure levels (objective measurements) are the x-variants and the annoyance ratings by the respondents (subjective responses) are the y-variants. The correlation is about 73%.

Using the Pearson point product correlation coefficient;

$$\gamma = \frac{\Sigma xy - \frac{(\Sigma x)(\Sigma y)}{n}}{\sqrt{\left[\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right]\left[\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right]}} \tag{6}$$

$$\gamma = \frac{6273.51 - \frac{(1822)(72.15)}{21}}{\sqrt{\left[158832 - \frac{(1822)^2}{21}\right]\left[248.60 - \frac{(72.15)^2}{21}\right]}}$$

$$= 0.589$$

Using the Pearson point product correlation coefficient as in equation (6)

$$\gamma = \frac{3413.56 - \frac{(1822)(38.85)}{21}}{\sqrt{\left[158832 - \frac{(1822)^2}{21}\right]\left[76.47 - \frac{(38.85)^2}{21}\right]}}$$

=0.729

5. Conclusion and Recommendation

An assessment of sound pressure levels of noise emitted by generators was carried out in Pankshin town of Plateau State. The noise levels show that, except for two, the levels were above the maximum threshold recommended by international regulatory agencies. From the objective measurements of different types of generators, the Noise Levels range between 76 dBA to 98dBA. Their Noisiness and perceived Noise Level (PNdB) were also determined using the noy chart. Assessment of subjective response was also carried out and results show that the noise rating by respondents ranges between moderately noisy and noisy whereas the annoyance rating ranges between slight annoyance and very much annoyance. The calculated correlation coefficients show that the higher the noise levels, the higher the noise rating and the annoyance. The following recommendations are made:

Generator companies should specify the noise levels of generators and regulatory agencies must insist on compliance. An investigation into the spectral content of generator noise should be conducted. Importantly, regular and periodic awareness program on the potential dangers of exposure to high levels of noise should be mounted by relevant agencies.

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Table 1. Generator Sound Pressure Level, Power Level, Noisiness and Perceived Noise Level

	Generator Type and Power rating	Usage Period (months)	Loading Status (%)	Sound Pressure Level (SPL)	Sound Power Level (L_w)	Noisiness (Noy)	Perceived Noise Level (PNdB)
G_1	SPS2900	2	0	86	97	26	87
G_2	KC3000	6	0	87	98	27	88
G_3	SV2940E	36	5	94	105	45	95
G_4	SPG3000E^2	24	25	91	102	41	93
G_5	TG2700	36	0	97	108	51	98
G_6	DG1000	12	15	81	92	18	82
G_7	JL3600	12	4	86	97	27	88
G_8	RT1000	12	0	78	89	16	80
G_9	TG1150	12	17	82	93	21	84
G_{10}	1900DX	12	7	88	99	28	89
G_{11}	JL6600	12	0	93	104	42	94
G_{12}	TG950	12	12	76	87	14	78
G_{13}	SPG2500	2	0	87	98	27	88
G_{14}	LL3GF-4A	24	0	88	99	28	89
G_{15}	TG1000	12	12	82	93	21	84
G_{16}	JL2800	12	0	94	105	45	95
G_{17}	SS3600	12	0	88	99	28	89
G_{18}	LG1000	24	0	80	91	17	81
G_{19}	SH1200DX	24	0	85	96	25	86
G_{20}	EC6500CX5	48	0	98	109	60	99
G_{21}	SV3500E2	6	0	81	92	18	82

Table 2. Overall Rating of Generator Noise

	Number of Responses in each Generator Noise Rating							
Generator	Noisy (4)	Moderate (3)	Quiet (2)	Ignorant (1)	Refused to comment (0)	Response Per Generator	Weighted Rating. ∑(nx)	Ave. value ∑(nx)/n
G_1	9	15	1	2	0	27	85	3.15
G_2	12	8	1	1	0	22	75	3.41
G_3	8	11	1	0	0	20	67	3.35
G_4	18	10	0	0	0	28	102	3.64
G_5	13	6	1	0	0	20	72	3.60
G_6	13	10	0	0	0	23	82	3.57
G_7	12	7	0	1	0	20	70	3.50
G_8	9	9	3	0	0	21	69	3.29
G_9	11	9	0	0	0	20	71	3.55
G_{10}	12	8	1	0	0	21	74	3.52
G_{11}	14	7	0	0	0	21	77	3.67
G_{12}	6	8	2	2	0	18	54	3.00
G_{13}	10	10	2	3	0	25	77	3.08
G_{14}	13	13	0	1	0	27	92	3.41
G_{15}	5	3	1	0	0	09	31	3.44
G_{16}	16	7	1	0	0	24	87	3.63
G_{17}	12	9	1	0	0	22	77	3.50
G_{18}	9	9	1	1	0	20	66	3.30
G_{19}	12	9	1	0	0	22	77	3.50
G_{20}	15	7	0	0	0	22	81	3.68
G_{21}	5	9	0	0	0	14	47	3.36

Table 3. Overall Rating of Noise Annoyance

Generator	Respondents' Noise Annoyance Rating							
	Extre-mely (4)	Very Much (3)	Mode-rately (2)	Slig-htly (1)	Not at all bothered (0)	Total	Weighted Rating. Σ(nx)	Ave. Response Rating. Σ(nx)/n
G_1	0	0	5	22	0	27	32	1.19
G_2	0	1	12	8	1	22	35	1.60
G_3	0	13	6	1	0	20	52	2.60
G_4	0	12	15	1	0	28	67	2.39
G_5	0	12	5	3	0	20	49	2.45
G_6	0	0	15	8	0	23	38	1.65
G_7	0	4	15	1	0	20	43	2.15
G_8	0	0	7	14	0	21	28	1.33
G_9	0	0	9	11	0	20	29	1.45
G_{10}	0	0	9	12	0	21	30	1.45
G_{11}	0	13	7	1	0	21	54	2.57
G_{12}	0	0	8	10	0	18	26	1.44
G_{13}	0	5	19	1	0	25	54	2.16
G_{14}	0	6	18	3	0	27	57	2.11
G_{15}	0	0	5	4	0	9	14	1.56
G_{16}	0	17	7	0	0	24	65	2.71
G_{17}	0	0	21	1	0	22	43	1.95
G_{18}	0	0	10	10	0	20	30	1.50
G_{19}	0	0	9	13	0	22	31	1.41
G_{20}	0	17	5	0	0	22	61	1.77
G_{21}	0	0	6	8	0	14	20	1.43

Table 4. Variants for Calculating Correlation Coefficient between Generator Sound Pressure Level and Noise Rating by Respondents

GENERATOR TYPE	Xi (dBA)	Y_i	X_i^2	Y_i^2	X_iY_i
G_1	86.00	3.15	7396	9.92	270.90
G_2	87.00	3.41	7569	11.63	296.67
G_3	94.00	3.35	8836	11.22	314.90
G_4	91.00	3.64	8281	13.25	331.24
G_5	97.00	3.60	9409	12.96	349.20
G_6	81.00	3.57	6561	12.74	289.17
G_7	86.00	3.50	7396	12.25	301.00
G_8	78.00	3.29	6084	10.82	256.62
G_9	82.00	3.55	6724	12.60	291.10
G_{10}	88.00	3.52	7744	12.39	309.76
G_{11}	93.00	3.67	8649	13.47	341.31
G_{12}	76.00	3.00	5776	9.00	228.00
G_{13}	87.00	3.08	7569	9.49	267.96
G_{14}	88.00	3.41	7744	11.63	300.08
G_{15}	82.00	3.44	6724	11.83	282.08
G_{16}	94.00	3.63	8836	13.18	341.22
G_{17}	88.00	3.50	7744	12.25	308.00
G_{18}	80.00	3.30	6400	10.89	264.00
G_{19}	85.00	3.50	7225	12.25	297.50
G_{20}	98.00	3.68	9604	13.54	360.64
G_{21}	81.00	3.36	6561	11.29	272.16
TOTAL	$\sum X = 1822$	$\sum Y = 72.15$	$\sum X^2 = 158832$	$\sum Y^2 = 248.60$	$\sum XY = 6273.51$

Table 5. Variants for calculating Correlation Coefficient between Generator Sound Pressure Level and Noise Annoyance by Respondent

GENERATOR TYPES	Xi (dBA)	Y_i	X_i^2	Y_i^2	X_iY_i
G1	86.00	1.19	7396	1.42	102.34
G2	87.00	1.60	7569	2.56	139.20
G3	94.00	2.60	8836	6.76	244.40
G4	91.00	2.39	8281	5.71	217.49
G5	97.00	2.45	9409	6.00	237.65
G6	81.00	1.65	6561	2.72	133.65
G7	86.00	2.15	7396	4.62	184.90
G8	78.00	1.33	6084	1.77	103.74
G9	82.00	1.45	6724	2.10	118.90
G10	88.00	1.43	7724	2.04	125.84
G11	93.00	2.57	8649	6.60	239.01
G12	76.00	1.44	5776	2.07	109.44
G13	87.00	2.16	7569	4.67	187.92
G14	88.00	2.11	7744	4.45	185.68
G15	82.00	1.56	6724	2.43	127.92
G16	94.00	2.71	8836	7.34	254.74
G17	88.00	1.95	7744	3.80	171.60
G18	80.00	1.50	6400	2.25	120.00
G19	85.00	1.41	7225	1.99	119.85
G20	98.00	1.77	9604	3.13	173.46
G21	81.00	1.43	6561	2.04	115.83
TOTAL	$\sum X = 1822$	$\sum Y = 38.85$	$\sum X^2 = 158832$	$\sum Y^2 = 76.47$	$\sum X_iY_i = 3413.56$