Advances in Research

11(4): 1-11, 2017; Article no.AIR.35668
ISSN: 2348-0394, NLM ID: 101666096

Effects of Noise and Vibration on Subjects Exposed to Electrical Power Generating Set Pollution

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Authors' contributions

This work was carried out in collaboration between all authors. Author AAA designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Authors NSC, OPC and APS managed the analyses of the study, literature searches and improved the final manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2017/35668
Editor(s):
(1) S. Sathish, Department of Mechanical Engineering, Annamalai University, India.
(2) Shi-Hai Dong, Professor of Department of Physics, School of Physics and Mathematics, National Polytechnic Institute, Building 9, Unit Professional Adolfo Lopez Mateos, Mexico.
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(2) Tomozei Claudia, "Vasile Alecsandri" University of Bacau, Romania.
(3) Zhao Hong, Lanzhou University of Technology, China.
Complete Peer review History: http://www.sciencedomain.org/review-history/20838

Original Research Article

Received 24th July 2017
Accepted 5th September 2017
Published 6th September 2017

ABSTRACT

This research assessed the level of health effects of noise and vibration on human health from the use of local electric generating sets. This is a common practice in most of our homes and business places in developing countries. Sample of trading places in Ekwulobia, Aguata Local Government Area, Anambra State, Nigeria were considered as case studies. In this study, a sound level and a vibration meter were employed to measure the noise and vibration levels. Information on how users perceive vibration, sound and health effects accompanied by exposure to vibration and noise was obtained and analyzed with Chi-square test at 5% significant level. The results of the analysis showed a maximum value of vibration weighted root-mean-square (WRMS) of 6.14 m/s2, and minimum of 0.01 m/s2. The maximum value of noise was at 103.46 dB(A), the minimum at 80.72 dB(A). The maximum value of WBV and noise level was shown to be higher than the recommended value. There was also a relation between the ways the users respond to vibration and noise as well

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as some health effects at a p-value less than 0.05. The results showed that the use of electric powered generators in the areas studied exposed users to some health risks.

Keywords: Vibration; noise; exposure; generating set; chi-square; markets; health effects.

1. INTRODUCTION

Technological developments have resulted in the invention of so many equipment and machines such as generating sets, vehicles, grinding machines, drilling machines among others. These machines produce noise, vibrations and noxious air emissions while in use. In some known cases, these inventions and their wrong use are harmful to health, as they could cause certain injuries like weakness of the muscles, fatigue, discomfort, hearing difficulties, among others. Electric power generating sets are designed as an alternative power source in the event of power outage. Unfortunately, epileptic power supply in Nigeria has turned the electric generators into the primary source of power in our homes and in most commercial environments [1,2].

Noise exposure causes some health risks as it affects neuro-endocrine, cardiovascular, respiratory digestive systems as well as disturbances. At a chronic level, noise may reduce concentration, thereby reducing work-related performance [3]. To deal with the health challenges posed by noise and vibration, it is pertinent to treat vibration as a Whole-Body-Vibration (WBV) problem. This is vibration experience where the whole body is exposed by contact with the feet or buttocks in a sitting position. WBV comes from various sources, affects various parts of the body and manifests various symptoms, which may be felt at very small levels or may become uncomfortably high, or cause some hazards, especially in some off-road vehicles [4,5]. Although noise can be productivity, it affects communication and concentration. If the exposure is too high, it may cause permanent hearing impairment [6,7]. In most community noise surveys, vibrations are seen as a complementary to loud noise; it is viewed as a major cause for annoyance. Among industrial workers regularly exposed to noise and vibration, reported symptoms were anxiety, nausea, headaches, and mood swing [8,9].

This research is therefore aimed at determining the health effects caused by the noise and vibration from generators on individuals who are regularly exposed to it.

2. METHODOLOGY

Six different research sites were selected, which are all areas with high commercial activities where these electric generators are used extensively. WBV and Noise measurements were carried out with strict observance of the outlined ‘International Standard Organization’s measuring procedures, ISO 2361-1; ISO 5349-1 and Health Safety Executive, HSE’ respectively. The magnitude of the vibration of the generators, were measured using a Vibration Meter, the sound levels were measured with a Sound Level Meter (SLM). The measurements were obtained during the day (within working hours, about 1400 hours).

The distance between the generator position and the generator users, were obtained with a meter rule. Acceleration levels were obtained on the floor which served as a vibrating medium between the generator and the users. An accelerometer was connected to the vibration meter (VM-6360) for the digital data recording, and finally connected to a personal computer for amplification of the recorded data.

Key terms applied in the Vibration and Noise measurement are defined below:

A-weighted decibel, ***dB(A)***; Weighted acceleration, a_w; Weighted Root-mean-square of the acceleration, W_{RMS}; Crest Factor, ***CF*** (the ratio of a_w to W_{RMS}); Exposure Action Value, ***EAV***; Exposure Action Limit Value, ***ELV.*** The **‘A(8)’** associated with EAV and ELV, respectively, indicates an eight-hour weighting a day.

3. RESULTS

3.1 Vibration and Noise Exposures

The values of vibration indicating factors gathered from different locations are presented in Fig. 1 and Fig. 2 respectively. Where a_w and w_{RMS} are the weighted acceleration and weighted root-mean-square acceleration, respectively.

The intervals from the source of the noise and vibration threats are of importance. The values of 1m distance, is shown in Fig. 1.

Fig. 1 shows exposure level at 1 m from source of vibration to the user. The Wrms value of the vibration is at its highest in Eke market, a value of 6.14 m/s^2.

Fig. 2 shows exposure level at 2 m from source of vibration to the user. The Wrms value of the vibration is at its highest in Eke market, a value of 2.75 m/s^2.

Fig. 3 shows exposure level at 3 m from source vibration to the user. The Wrms value of the vibration is at its highest in Eke market, a value of 0.82 m/s^2.

Fig. 4 shows the mean noise exposure at 1 m, 3 m and 5 m, respectively from the source of the noise. The mean noise exposure is at its highest in Eke market, a value of 103.46.

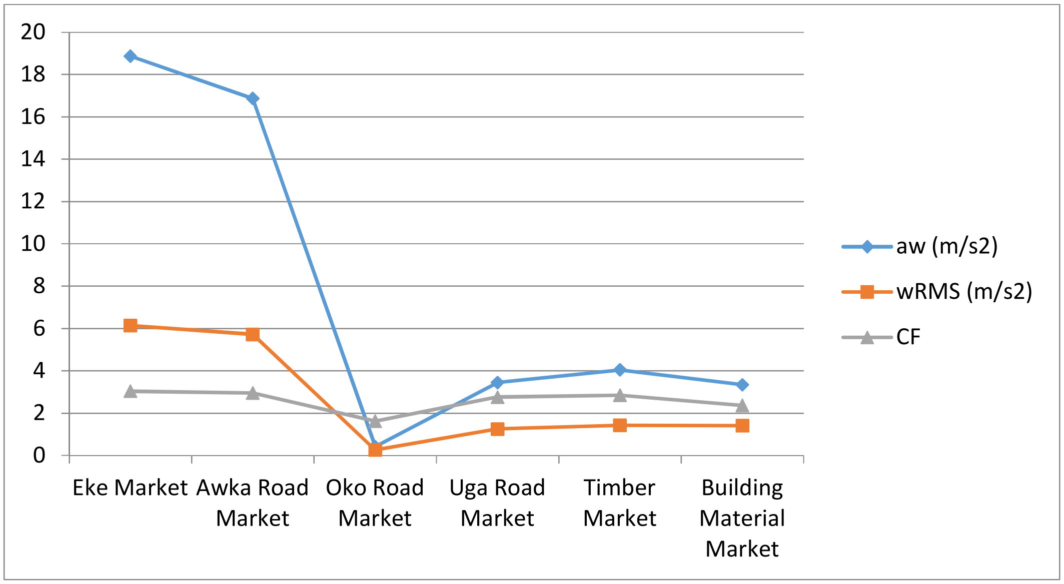

Fig. 1. Vibration Exposure at 1 m from source

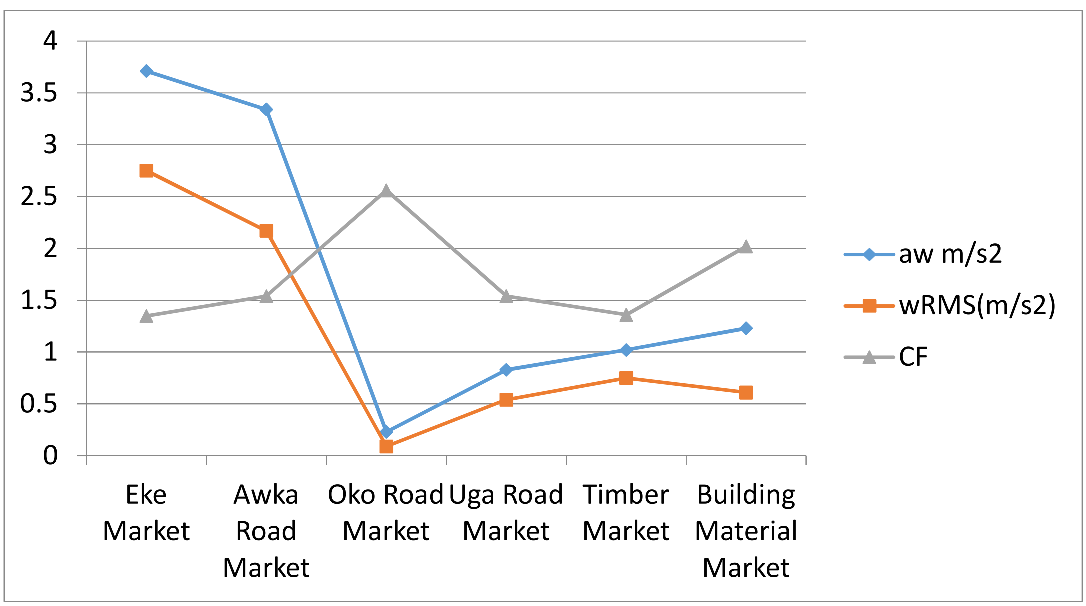

Fig. 2. Vibration exposure at 2 m from source

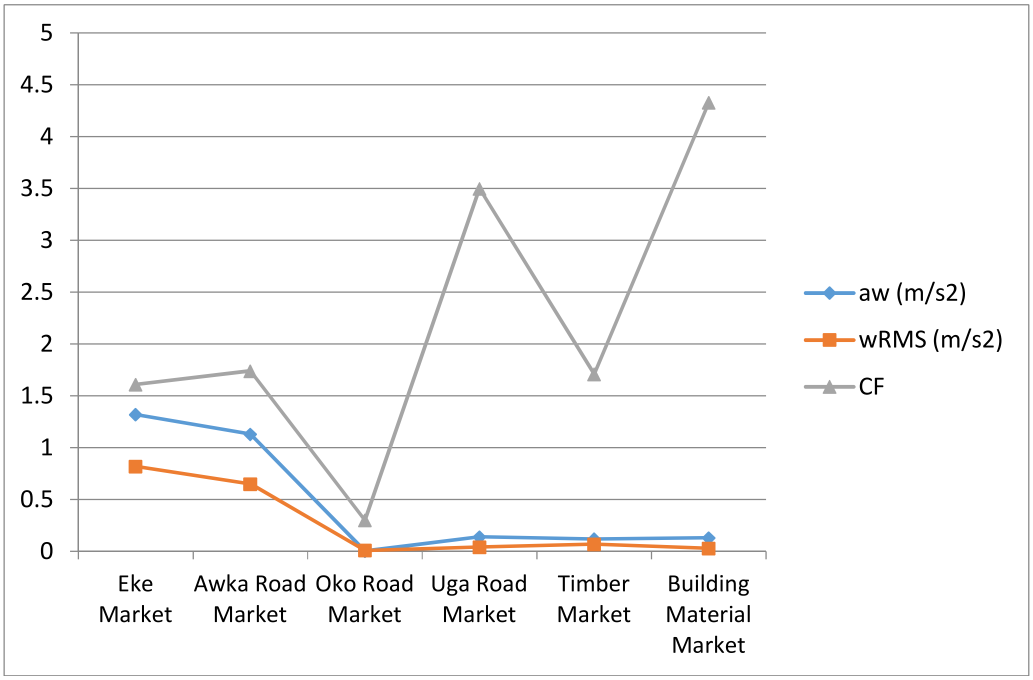

Fig. 3. Vibration exposure at 3 m from source

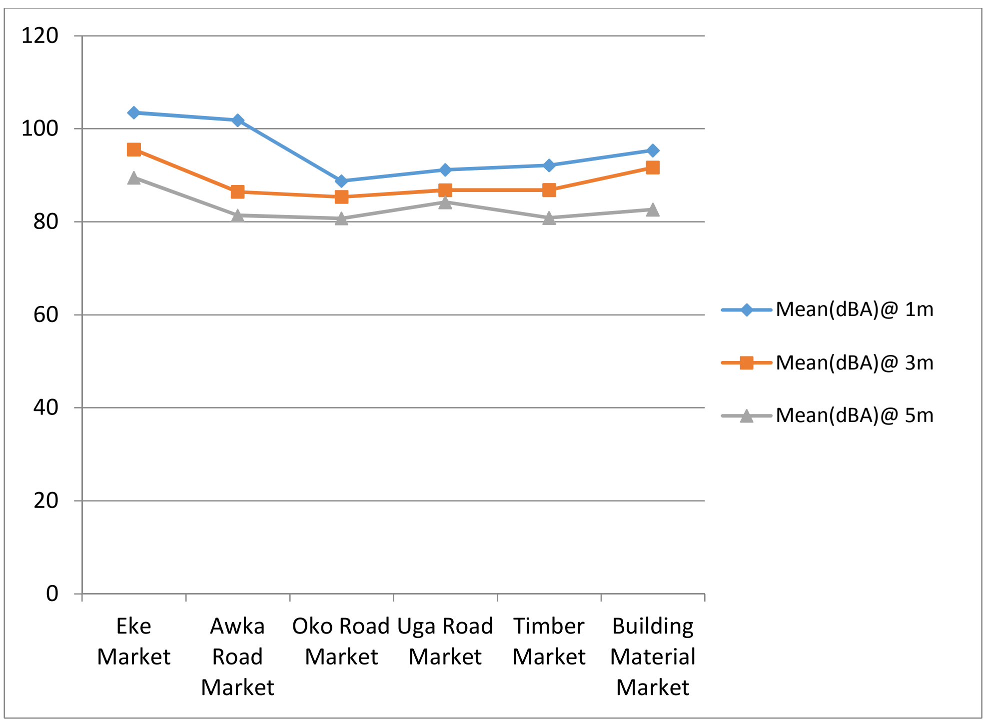

Fig. 4. Mean Noise Exposure at 1 m, 3 m and 5 m respectively, from source

Figs. 5 and 6 show the generator users' perception of vibration and noise effects, respectively from the test experiment.

Table 1 shows the Whole Body Vibration effects experienced by Generator users in the population of 120 candidates selected for the investigative test, 20 samples from each of the markets. From the table, the most predominant vibration effect associated with generator use is back pain and fatigue, a value of 32.

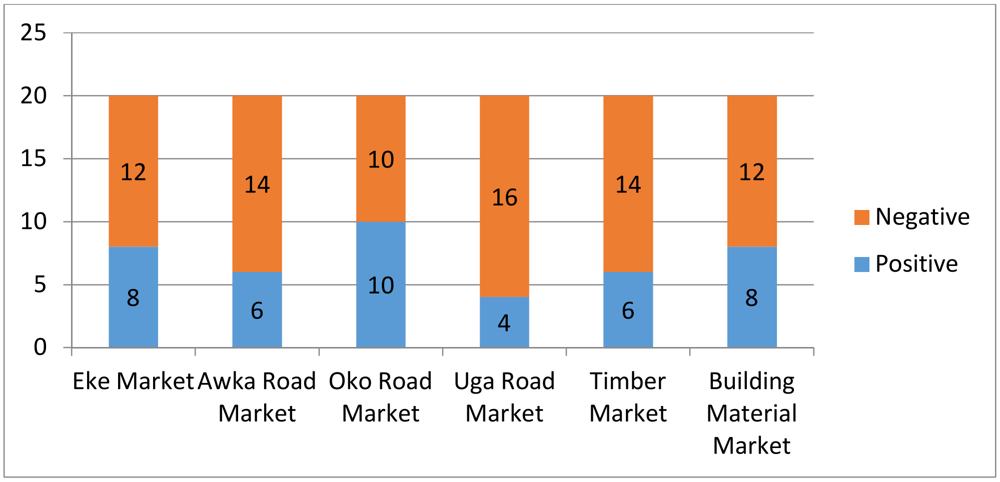

Fig. 5. Users' perception of vibration effects

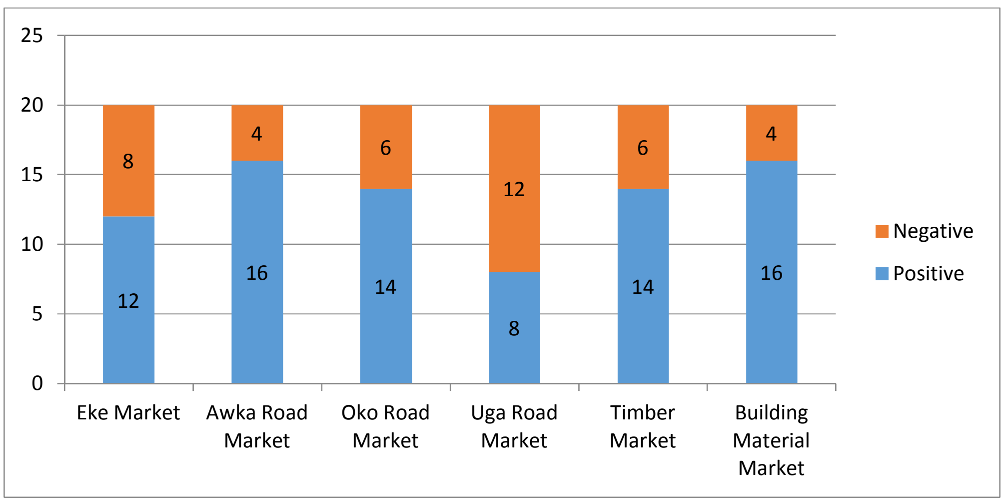

Fig. 6. Users' perception of noise effects

Table 1. Whole body vibration effects experienced by generator users (N = 20)

WBV effects	Eke market % in N	Awka road market% in N	Oko road market% in N	Uga road market % in N	Timber market % in N	Building material market % in N	Row total
Back pain	12(60)	8(40)	4(20)	0(0)	6(30)	2(10)	32
Fatigue	8(40)	6(30)	2(10)	8(40)	2(10)	6(30)	32
Abdominal pain	4(20)	2(10)	0(0)	6(30)	4(20)	2(10)	18
Irritability	4(20)	0(0)	0(0)	8(40)	4(20)	2(10)	18
Anxiety	6(10)	8(40)	4(20)	2(10)	0(0)	6(30)	26
Visual dysfunction	3(30)	2(10)	0(0)	4(20)	4(20)	0(0)	13
Gait difficulty	0(0)	0(0)	0(0)	0(0)	0(0)	6(30)	6
Shock	2(10)	0(0)	4(20)	4(20)	8(40)	6(30)	24
Column Total	39	26	14	32	28	30	**169**

Table 2. Chi-square (χ^2) table for WBV effects

Observed value (O)	Expected value (E)	O-E	$(O-E)^2$	$(O-E)^2/E$
12	7.38	4.62	21.3444	2.89219512
8	4.92	3.08	9.4864	1.92813008
4	2.65	1.35	1.8225	0.68773585
0	6.06	-6.06	36.7236	6.06
6	5.3	0.7	0.49	0.09245283
2	5.68	-3.68	13.5424	2.38422535
8	7.38	0.62	0.3844	0.05208672
6	4.92	1.08	1.1664	0.23707317
2	2.65	-0.65	0.4225	0.15943396
8	6.06	1.94	3.7636	0.62105611
2	5.3	-3.3	10.89	2.05471698
6	5.68	0.32	0.1024	0.01802817
4	4.15	-0.15	0.0225	0.00542169
2	2.77	-0.77	0.5929	0.21404332
0	1.49	-1.49	2.2201	1.49
6	3.41	2.59	6.7081	1.96718475
4	2.98	1.02	1.0404	0.34912752
2	3.2	-1.2	1.44	0.45
4	4.15	-0.15	0.0225	0.00542169
0	2.77	-2.77	7.6729	2.77
0	1.49	-1.49	2.2201	1.49
8	3.41	4.59	21.0681	6.17832845
4	2.98	1.02	1.0404	0.34912752
2	3.2	-1.2	1.44	0.45
6	6	0	0	0
8	4	4	16	4
4	2.15	1.85	3.4225	1.59186047
2	4.92	-2.92	8.5264	1.73300813
0	4.31	-4.31	18.5761	4.31
6	4.62	1.38	1.9044	0.41220779
3	3	0	0	0
2	2	0	0	0
0	1.08	-1.08	1.1664	1.08
4	2.46	1.54	2.3716	0.96406504
4	2.15	1.85	3.4225	1.59186047
0	2.31	-2.31	5.3361	2.31
0	1.38	-1.38	1.9044	1.38
0	0.92	-0.92	0.8464	0.92
0	0.5	-0.5	0.25	0.5
0	1.14	-1.14	1.2996	1.14
0	0.99	-0.99	0.9801	0.99
6	1.07	4.93	24.3049	22.7148598
2	5.54	-3.54	12.5316	2.26202166
0	3.69	-3.69	13.6161	3.69
4	1.99	2.01	4.0401	2.03020101
4	4.54	-0.54	0.2916	0.06422907
8	3.98	4.02	16.1604	4.06040201
6	4.26	1.74	3.0276	0.71070423
$\sum[(O-E)^2/E] = \chi^2 = 91.361209$				**91.361209**

Critical value **= 49.802**

DOF **= 35** Prob**. = 0.95**

p- value**= 0.00000063**

Note: Expected value (E) = [Row Total * Column Total] / N

Table 2 shows the summary of Chi-square table for vibration health effects experienced by generator users in the population of 120 candidates tested. The values are summarized below:

$\chi^2 = 91.361209$
Critical value = 49.802
DOF = 35
Prob. = 0.95
p- value = 0.00000063

Fig. 7 below shows Bar chart stating WBV effects experienced by generator users.

Table 3 below shows the noise health effects experienced by generator users in a population of sample of 120 candidates, 20 from each of the markets. As observed from Table 3, communication interference has the highest value of 72.

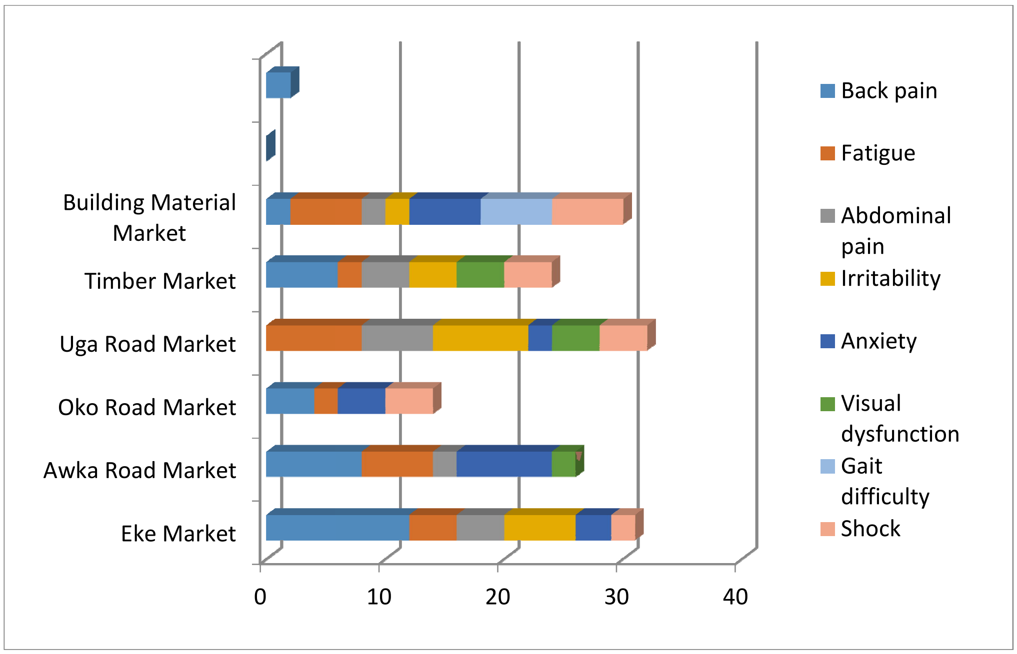

Fig. 7. Whole body vibration effects experienced by generator users

Table 3. Noise health effects experienced by generator users (N=20)

Noise effects	Eke market % in N	Awka road market % in N	Oko road market% in N	Uga road market% in N	Timber market% in N	Building material market% in N	ROW total
Depression	6(30)	10(50)	2(10)	0(0)	4(20)	0(0)	22
Difficulty in concentration	14(70)	0(0)	10(50)	12(60)	8(40)	2(10)	46
Headache	10(50)	6(30)	8(40)	14(70)	4(20)	8(40)	50
Auditory dysfunction	6(30)	2(10)	0(0)	0(0)	4(20)	0(0)	12
Annoyance	10(50)	4(20)	6(30)	2(10)	6(30)	4(20)	32
Mood swing	14(70)	8(40)	2(10)	0(0)	4(20)	2(10)	30
Comm. Interference	16(80)	12(60)	18(90)	10(50)	4(20)	12(60)	72
Sleep disturbance	10(50)	8(40)	2(10)	0(0)	4(20)	8(40)	32
Column total	86	50	48	38	38	36	**296**

Table 4 below shows the summary of Chi-square table for noise health effects experienced by generator users in the population of 120 candidates tested. The values are summarized below:

χ^2 = 87.8947273
Critical value = 43.773
DOF = 30
Prob. = 0.95
p-value = 0.00000014

Table 4. Chi-square (χ2) table for noise effects

Observed value (O)	Expected value (E)	O-E	$(O-E)^2$	$(O-E)^2/E$
6	6.33	-0.33	0.1089	0.01720379
10	3.5	6.5	42.25	12.0714286
2	3.83	-1.83	3.3489	0.87438642
0	3.17	-3.17	10.0489	3.17
4	2.83	1.17	1.3689	0.48371025
0	2.33	-2.33	5.4289	2.33
14	13.24	0.76	0.5776	0.04362538
0	7.32	-7.32	53.5824	7.32
10	8.02	1.98	3.9204	0.48882793
12	6.62	5.38	28.9444	4.37226586
8	5.92	2.08	4.3264	0.73081081
2	4.88	-2.88	8.2944	1.69967213
10	14.39	-4.39	19.2721	1.33927033
6	7.95	-1.95	3.8025	0.47830189
8	8.71	-0.71	0.5041	0.057876
14	7.2	6.8	46.24	6.42222222
4	6.44	-2.44	5.9536	0.92447205
8	5.3	2.7	7.29	1.3754717
6	3.45	2.55	6.5025	1.88478261
2	1.91	0.09	0.0081	0.00424084
0	2.09	-2.09	4.3681	2.09
0	1.73	-1.73	2.9929	1.73
4	1.55	2.45	6.0025	3.87258065
0	1.27	-1.27	1.6129	1.27
10	3.92	6.08	36.9664	9.43020408
4	5.09	-1.09	1.1881	0.23341847
6	5.58	0.42	0.1764	0.0316129
2	4.61	-2.61	6.8121	1.47767896
6	4.12	1.88	3.5344	0.85786408
4	3.39	0.61	0.3721	0.10976401
14	8.64	5.36	28.7296	3.32518519
8	4.77	3.23	10.4329	2.18719078
2	5.23	-3.23	10.4329	1.99481836
0	4.32	-4.32	18.6624	4.32
4	3.86	0.14	0.0196	0.00507772
2	3.18	-1.18	1.3924	0.43786164
16	20.73	-4.73	22.3729	1.07925229
12	11.45	0.55	0.3025	0.02641921
18	12.55	5.45	29.7025	2.36673307
10	10.36	-0.36	0.1296	0.01250965
4	9.27	-5.27	27.7729	2.99599784
12	7.64	4.36	19.0096	2.48816754
$\sum[(O-E)^2/E] = \chi^2$ =87.8947273				**87.8947273**
Critical value **= 43.773**				
DOF **= 30**				
Prob. **= 0.95**				
p- value**= 0.00000014**				
Note: Expected value (E) = [Row Total * Column Total] / N				

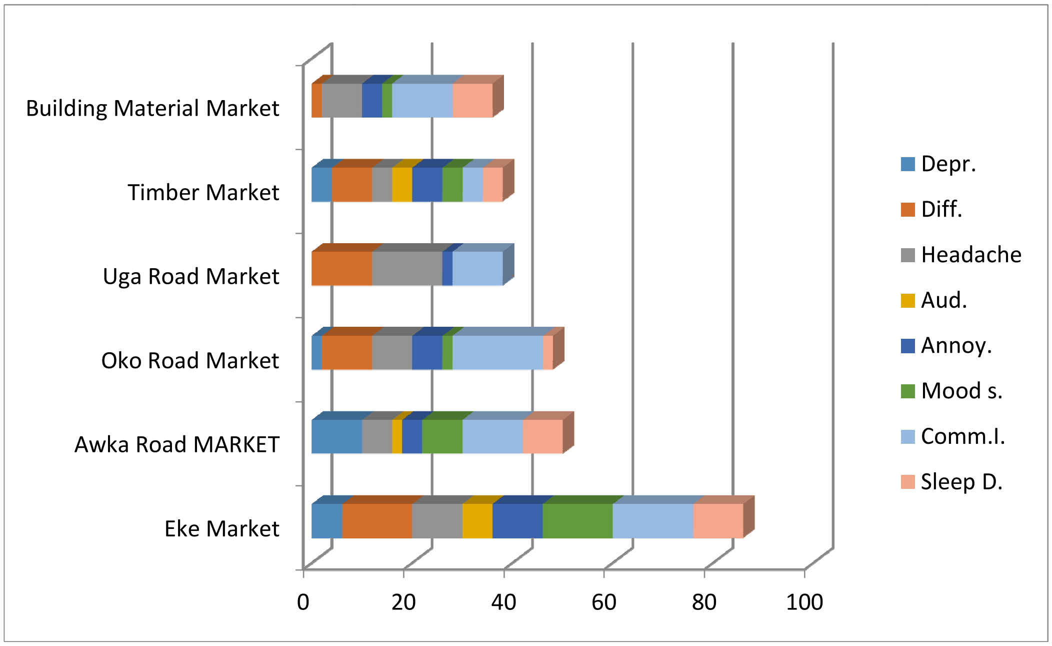

Fig. 8. Noise health effects experienced by generator users

Table 5. Noise exposure at one (1) metre from source

Measurement location	Minimum (dBA)	Maximum (dBA)	Mean (dBA)	Standard deviation
Eke Market	102.20	105.40	103.46	2.10
Awka Road Market	102.70	102.80	101.80	1.42
Oko Road Market	87.10	88.40	88.73	0.73
Uga Road Market	89.40	92.10	91.15	1.46
Timber Market	90.60	93.80	92.11	0.42
Building Material Market	96.20	97.70	95.32	0.71

4. DISCUSSION

4.1 User's Response Analysis

The responses from the generator users showed that majority of the users did not know that the vibration of generators affects their health (p-value < 0.05). On the contrary, some generator users' responses showed that majority of them are knew the negative effects of noise exposure from their generators (p < 0.05).

Many of the users believe they were exposed to generator noise hazards, and surprisingly few percentages of them felt vibration from generators do not affect their health. However, this study has shown that despite the high level of awareness of noise induced hearing difficulty, they did nothing to protect themselves from the hazard because of ignorance of the necessary precautions to take.

4.2 Vibration Exposure Analysis

It is observed from this study that generator users in Eke Market, Awka Road Market, Uga Road Market, Timber Market and Building Material Market were exposed to WBV as the w_{RMS} acceleration at 1 m away from the generator exceeds the recommended daily exposure limit value (ELV) of 1.15 m/s^2, the w_{RMS} is less than the recommended exposure action value (EAV) of 0.5 m/s^2 in Oko Road Market.

Due to the short distance to generators, majority of the users in Eke Market showed that WBV affects them; especially back pain. More so, the effects of vibration on generator users depend upon so many factors: physical, biodynamic and individual factors. A similar study, [10] showed that the effects of vibration depends on the magnitude and length of exposures.

At 2 m distance away from the generator, the W_{RMS} values of WBV at Eke Market and Awka Road Market are greater than the risk level of 1.15 m/s^2 which may lead to serious health effects. W_{RMS} acceleration in Uga Road Market, Timber Market and Building Material Markets are a little greater than the recommended EAV value, which may result to health risks if the exposure is up to 3 hours at Uga Road Market, 2 hours at Timber Market and 1 hour at Building Material Market respectively, if caution is not taken. However, at Oko Road Market clear effects are noted as the WRMS is less than the recommended EAV of 0.5 m/s^2. Based on these results, users at Oko Road Market will experience no health effects of WBV.

At 3 m, W_{RMS} values in Eke Market and Awka Road Market are greater than the recommended EAV of 0.5 m/s^2, which shows that there exist a tendency of WBV effects in about an hour. In the case of Oko Road Market, Uga Road Market, Timber Market and Building Material Market, respectively, the W_{RMS} value showed there is no possible WBV effect. This proved that the possible health challenges posed by WBV to users tend to decrease with distance.

During measurements it was also noticed that the vibration from some generating sets in the markets have been reduced by mounting them on a platform with dampers. Consequently, vibrations could not pass much via the floors, as it was almost impossible for the accelerometer to record much vibration on the floor of such platforms. Some highly rigid support structures may withstand a greater amount of ambient vibration [11]. Hence, majority of the users could not feel WBV effects. The small fraction of them who felt back pain, fatigue may be due to the nature of work they do, moving goods from one place to the other.

4.3 Noise Exposure Analysis

The mean noise levels emitted from generators at 1 m in Eke Market, Awka Road Market, Oko Road Market, Uga Road Market, Timber Market, Building Material Market were 103.46, 101.80, 88.73, 91.15, 92.11 and 95.32 dB(A), respectively (see Table 5). Comparing this with the 'HSE 2005 regulations of human tolerance to noise level 85 dB(A)', the results showed critical public health effects and could lead to serious auditory problems like hearing dysfunction. Other conditions such as annoyance may also take follow.

Due to the relatively short distance of respondents to the generator, majority of respondents in Eke Market and Oko Road Market experience difficulty in concentration, communication Interference as well as headache. Some related studies showed that high level of noise may result to some sleep-related and rest difficulties, leading to mood swing, irritability, headache and annoyance on part of the community members [12,13]. Perhaps, this may be the reason for the non-auditory cases found among generator users in this study.

Away from generators, a distance of 3m, it was recorded that the average noise levels at Eke Market, Awka Road Market,Oko Road Market, Uga Road Market, Timber Market, Building Material Market were 95.50, 86.42, 85.33, 86.78, 86.82 and 91.67 dB(A) , respectively. Although there was decrease in the mean noise levels at 3m, it could still result in serious auditory impairment.

The mean noise levels at 5m away from generators in Eke Market, Awka Road Market, Oko Road Market, Uga Road Market, Timber Market, and Building Material Market were 89.45, 81.35, 80.72, 84.21, 80.84 and 82.63. The results showed with increase in distance away from generators, noise levels appear to decrease appreciably. More so, the average noise levels at Eke Market suggested some health risks, as it remained above the recommended maximum noise level of 85dB(A).

4.4 Chi-square (χ^2) Analysis

The chi-square analysis showed that calculated values of Chi-Square (χ^2), [WBV = 91.36 and noise = 87.895] at 0.05 significant level for 30 and 35 degrees of freedom are greater than critical values (49.802 and 43.773, respectively) of Chi-Square (χ^2) at P-values of 0.00000063 and 0.00000014, respectively. This is so because the p-value is below 0.05 ($p\text{-value} < 0.05$), implying that operating generator sets affects the human health significantly in terms of WBV and Noise.

5. CONCLUSION

Noise and vibration are some of the intolerable disturbances associated with operational machines like electric powered generators. The study revealed that there is a high rate of generator use among people in the community of interest. This exposed them to vibration and noise-caused health problems. It is interesting to note that damage done to human body by the noise and vibration decreased with distance from source due to damping effect. Obviously, the study concluded that some generator users did not take cognizance of the vibration-related health issues their inappropriate use of generators had caused them; the few that were knew about it, did not know how to help themselves out. This study therefore offers the generator users a guide on the appropriate ways to use their generators in such a manner that eliminate or reduces significantly noise and vibration health issues.

6. RECOMMENDATIONS

In view of the effects of noise and vibrations, it is therefore, recommended that generator users should take precautionary measures like wearing proper hearing protection devices (such as ear muffs) to protect their ears. They should as well use rubber mats and shoes with thick rubber sole as well as recommended anti-vibration hand-gloves. Occupational health and safety management should be carried out to prevent adverse health effects in generator users. In addition health education on the hazards of generator use should be promoted in our society to improve user's awareness.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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