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EFFECTS OF NOISE AND VIBRATION ON SUBJECTS EXPOSED TO ELECTRICAL POWER GENERATING SET POLLUTION

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. A calibrated vibration meter and a sound level meter were used in the study. Information on users' perception of vibration, auditory and non-auditory health effects associated with exposure to vibration and noise, was obtained and subjected to Chi-square test at 5% level of significance. The results of this study indicated a maximum value of vibration weighted root mean square (W_{RMS}) is 6.14 m/s^2, while the minimum is 0.01 m/s^2. Similarly, the maximum value of noise is 103.46 dBA, while the minimum is 80.72 dBA. The obtained maximum value of whole-body vibration (WBV) and noise level are higher than the recommended value. There was an association between the users' responses and some health effects at a p-value below 0.05. The results, indicates that the use of generators in the areas under study exposes users to some health risks.

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 most cases, these inventions and most times use them in ways that are detrimental to their health, thereby resulting in injury like, muscle weakness, fatigue, discomfort, hearing

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impairment, etc. Electric power generators are made to serve as standby power source during a power failure. However, due to the irregular power supply in Nigeria, generators have been the primary source of power in homes and commercial areas.[1] [2]

Exposure to noise causes detrimental effects on neuro-endocrine, cardiovascular, respiratory and digestive systems. Chronic exposure to noise causes fatigue and interferes with concentration, thus reducing work efficiency.[3] To deal with these effects on the human health, it is necessary to consider human vibration as a Whole Body Vibration (WBV) problem. WBV refers to the situation where the whole body is exposed to vibration through contact by the buttocks or feet, thereby causing health problems such as low back pain and discomfort. This vibration has different sources, affects different areas of the body and are characterized by different symptoms ranging from barely perceivable small levels, through uncomfortable high levels, and up to hazardous levels as in some off-road vehicles.[4] [5] It is widely believed that noise can reduce productivity, interfere with communication and concentration, and in high exposures may cause permanent hearing loss.[6][7] Thus, vibrations are perceived as a complement to loud noise in most community surveys of noise, and are found to be an important factor in determining annoyance. Symptoms reported among industrial workers regularly exposed include nausea, headaches, anxiety and changes in mood.[8] [9]

This research is therefore aimed at determining the health effects caused by the noise and vibration from generators on individuals who are constantly exposed to it. However, the following are the objectives of the study;

2. METHODOLOGY

Six different research sites were selected, which are all areas with high commercial activities where these electric generators are used extensively. Whole Body Vibration and Noise

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measurements were taken according to the measuring procedures outlined in International Standard Organization, ISO 2361-1; ISO 5349-1 and Health Safety Executive, HSE respectively. The vibration magnitude of the generators, were measured using a factory calibrated Vibration Meter, while the sound levels were measured using a factory calibrated Sound Level Meter (SLM). The vibration magnitudes and sound level of generators were obtained during the day (working hours).

The distance between the generators and the operators were obtained using a measuring meter rule. Acceleration levels were measured on the floor which served as a vibrating platform between the generator and the operator. This was done due to the fact that users are not sitting directly or in direct contact with the generators while in operation, as it is the case in a moving vehicle or truck. This required the use of an accelerometer connected to the vibration meter VM-6360. The connected digital accelerometer did the data recording, and finally connected to a personal computer to amplify and store vibration data.

3. RESULTS

Table 1: Vibration Exposure at One (1) Metrefrom Source (Daily exposure: 18.7 m/s2)

Measurement Location	**$a_{w\ m/s^2}$**	**w_{RMS} m/s^2**	**CF**	**EAV A(8)** **hrs**	**ELV A(8)** **hrs**
Eke Market	18.87	6.14	3.04	0:00	0:01
Awka Road Market	16.87	5.72	2.95	0:00	0:02
Oko Road Market	0.42	0.26	1.62	11:20	>24hrs

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Uga Road Market	3.45	1.25	2.76	0:10	0:53	65
Timber Market	4.05	1.42	2.85	0:07	0:38	66
Building Material Market	3.34	1.41	2.37	0:10	0:56	67

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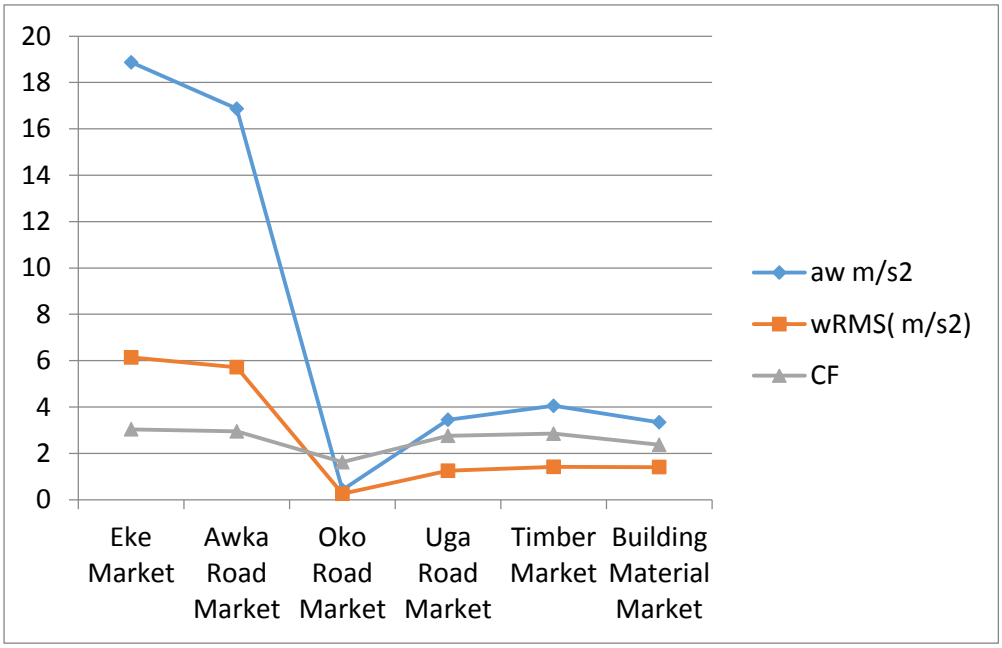

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72 Figure 1: Vibration Exposure at 1 metre from source

73 Table 2: Vibration Exposure at Two (2) Metresfrom Source(Daily exposure: 3.7 m/s2)

Measurement Location	**a_w** **m/s^2**	**w_{RMS}** **m/s^2**	**CF**	**EAV** **A(8)** **hrs**	**ELV** **A(8)** **hrs**
Eke Market	3.71	2.75	1.35	0:08	0:46

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Awka Road Market	3.34	2.17	1.54	0:01	0:56
Oko Road Market	0.23	0.09	2.56	>24hrs	>24hrs
Uga Road Market	0.83	0.54	1.54	2:54	15:21
Timber Market	1.02	0.75	1.36	1:55	10:10
Building Material Market	1.23	0.61	2.02	1:19	6:59

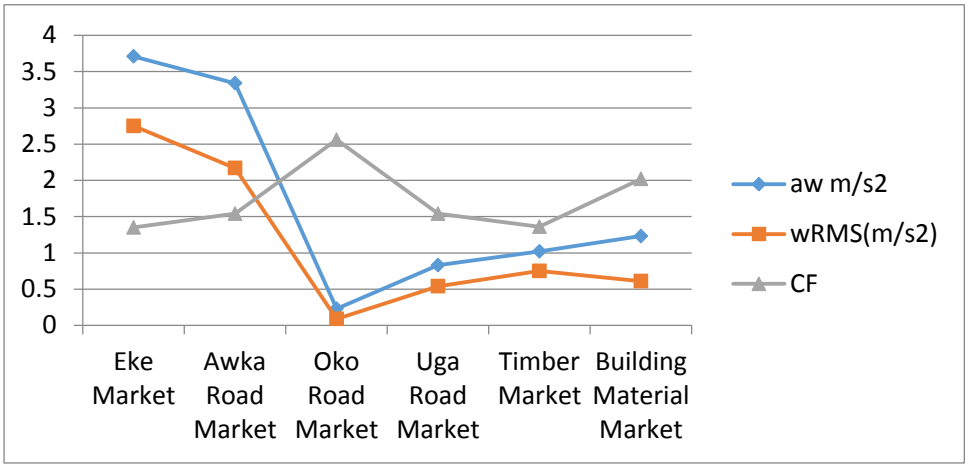

Figure 2: Vibration Exposure at 2 metres from source

Table 3: Vibration Exposure at Three (3) Metres from Source (Daily exposure: 1.3 m/s2)

Measurement Location	**a_w m/s^2**	**w_{RMS} m/s^2**	**CF**	**EAV A(8) hrs**	**ELV A(8) hrs**
Eke Market	1.32	0.82	1.61	1:08	6:04
Awka Road Market	1.13	0.65	1.74	1:33	8:17
Oko Road Market	0.003	0.01	0.3	>24hrs	>24hrs

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			0		78 [
Uga Road Market	0.14	0.04	3.50	>24hrs	>24hrs 79 80
Timber Market	0.12	0.07	1.71	>24hrs	>24hrs 81
Building Material Market	0.13	0.03	4.33	>24hrs	>24hrs 82 83

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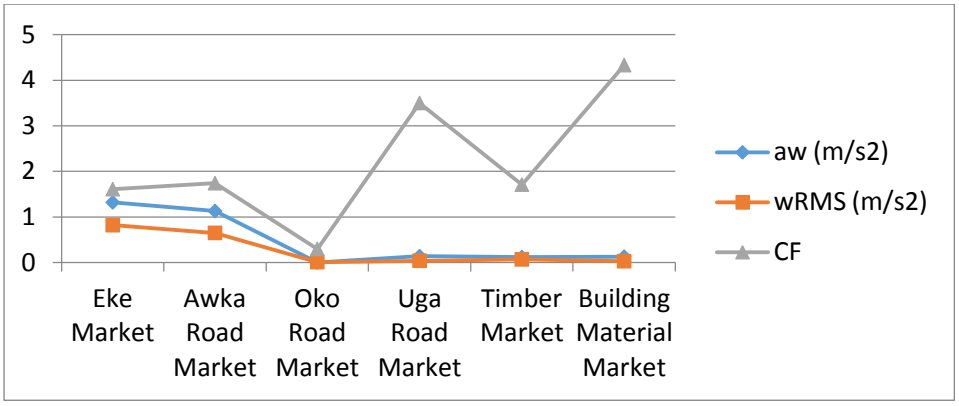

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87 Figure 3: Vibration Exposure at 3 metres from source

88 Table 4: 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

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Timber Market	90.60	93.80	92.11	0.42
Building Material Market	96.20	97.70	95.32	0.71

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90 Table 5: Noise Exposure at Three (3) Metres from Source

Measurement Location	**Minimum (dBA)**	**Maximum (dBA)**	**Mean (dBA)**	**Standard Deviation**
Eke Market	94.20	96.70	95.50	1.57
Awka Road Market	85.10	87.60	86.42	1.36
Oko Road Market	83.40	86.50	85.33	1.47
Uga Road Market	86.80	88.20	86.78	1.49
Timber Market	85.50	87.40	86.82	1.42
Building Material Market	89.10	93.30	91.67	1.43

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92 Table 6: Noise Exposure at Five (5) Metres from Source

Measurement Location	**Minimum (dBA)**	**Maximum (dBA)**	**Mean (dBA)**	**Standard Deviation**
Eke Market	87.40	90.20	89.45	0.99
Awka Road Market	80.50	82.70	81.35	0.87
Oko Road Market	79.10	81.40	80.72	1.43
Uga Road Market	83.60	85.40	84.21	0.86
Timber Market	81.00	82.60	80.84	0.65
Building Material	81.90	84.20	82.63	1.28

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Market				

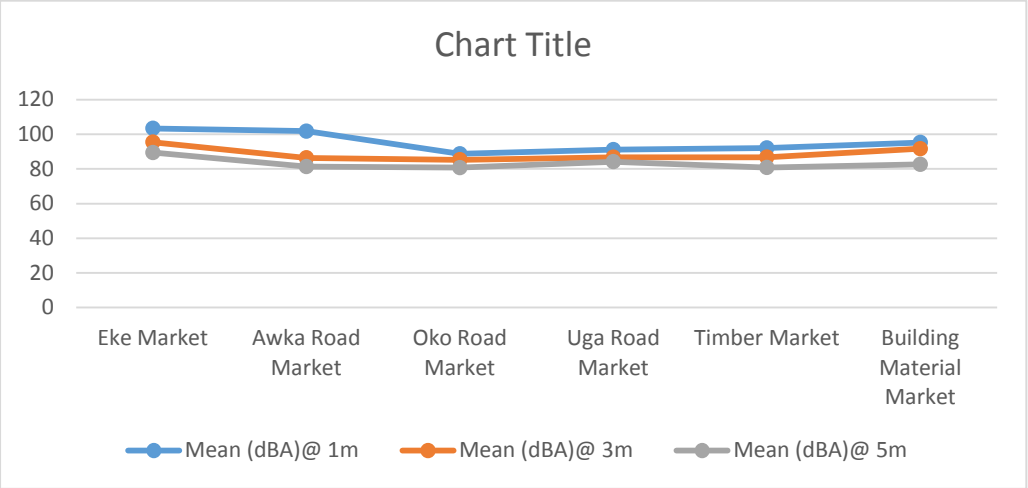

Figure 4: Mean Noise Exposure at 1 metre, 3 metres and 5 metres respectively, from source

Table 7: Demographic Characteristics of 20 respondents in each market (N=20)

Location	**Male (%)in N**	**female (%)in N**	**Age Range (years)**	**Mean Age (years)**
Eke Market	14(70)	6(30)	18-27	22.5
Awka Road Market	16(80)	4(20)	28-37	32.5
Oko Road Market	10(50)	10(50)	38-47	42.5
Uga Road Market	8(40)	12(60)	48-57	52.5
Timber Market	8(40)	12(60)	58-67	62.5
Building Material Market	6(30)	14(70)	68-77	72.5

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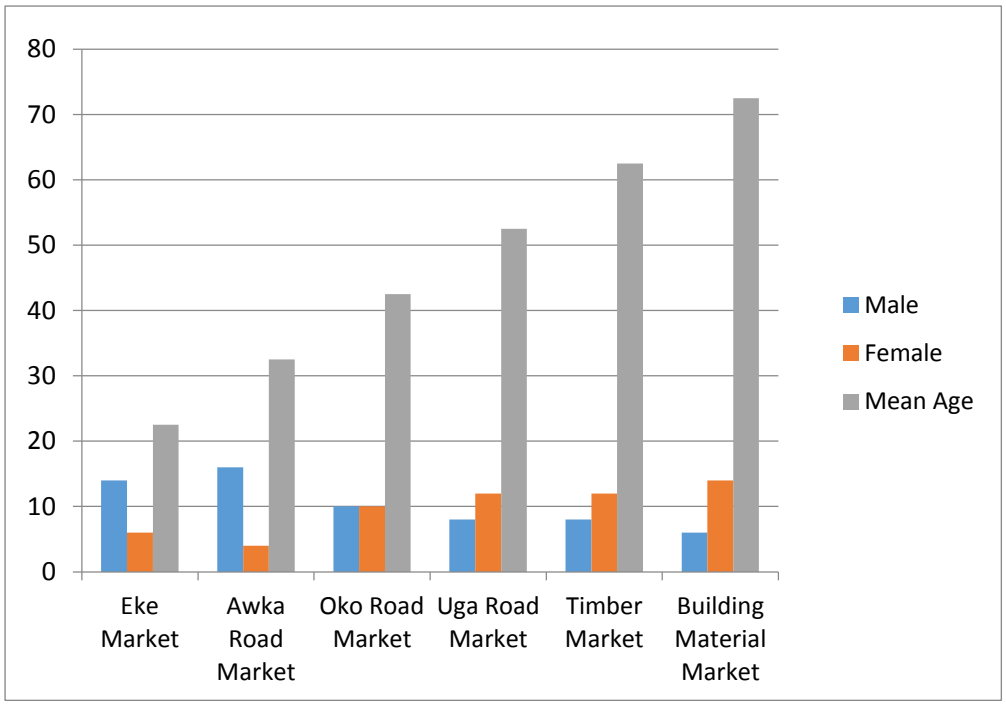

Figure 5: Demographic Characteristics Respondents

Table 8: Users' perception of vibration effects (N=20)

Response	Eke Market % in N	Awka Road Market% in N	Oko Road Market % in N	Uga Road Market% in N	Timber Maket% in N	Building Material Market % in N	**Total**
Yes	8(40)	6(30)	10(50)	4(20)	6(30)	8(40)	42
No	12(60)	14(70)	10(50)	16(80)	14(70)	12(60)	78

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114 Table 9: User' perception of noise effects (N = 20)

Response	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	**Total**
Yes	12(60)	16(80)	14(70)	8(40)	14(70)	16(80)	80
No	8(40)	4(20)	6(30)	12(60)	6(30)	4(20)	40

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116 Table 10: WholeBody 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	0(0)	0(0)	0(0)	0(0)	0(0)	6(30)	6

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difficulty							
Shock	2(10)	0(0)	4(20)	4(20)	8(40)	6(30)	24
Column Total	39	26	14	32	28	30	**169**

Table 11: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

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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

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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** Critical value = **49.802** DOF = **35** Prob**. = 0.95** p- value= **0.00000063**				**91.361209**
Note: Expected value (E) = [Row Total * Column Total] / N				

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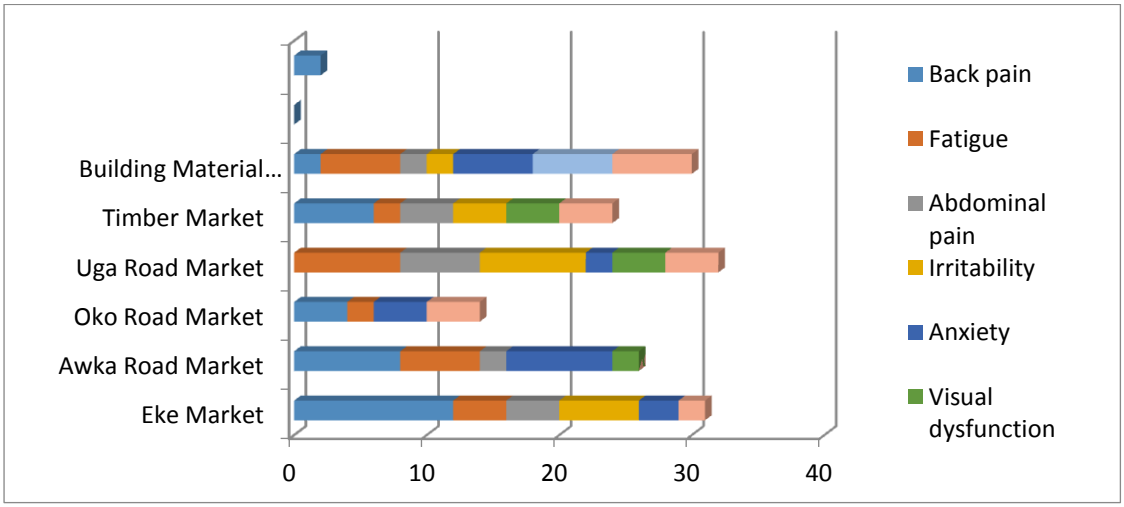

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123 Figure 6: Whole Body Vibration Effects experienced by Generator users

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Table 12: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	**RowTotal**
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**

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145 Table 13: Chi-square ($\chi 2$) 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

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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**				

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p- value= **0.00000014**	
Note: Expected value (E) = [Row Total * Column Total] / N	

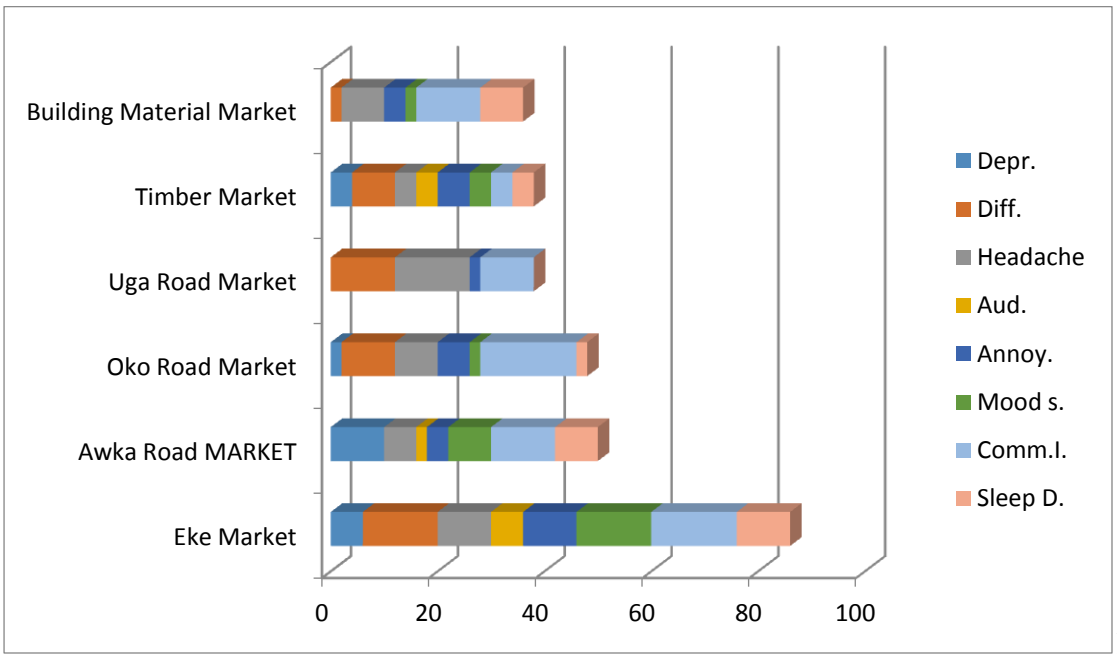

Figure 7: Noise Health Effects experienced by Generator users

4. DISCUSSION

4.1. User's Response Analysis

Users' responses from Table 8 indicate that majority of the respondents are not aware that the vibration of generators while in operation can be detrimental to their health (p-value < 0.05). However, users' responses in Table 9 indicate that majority of respondents are well aware of the adverse effects of noise exposure from their generators (p < 0.05).

Majority of the respondents think they are prone to hazards from generator use in terms of noise, and surprisingly few proportion of respondents felt vibration from generators have no significant effect on their health. Hence, this study has found that despite high level of awareness of hazard of noise induced hearing loss, due to use of generators, majority of the

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respondents did nothing to protect themselves from the hazard because of ignorance on the measures that need to be taken.

4.2. Vibration Exposure Analysis

Also the findings from this study in Table 1 shows that generator users in Eke Market, Awka Road Market, Uga Road Market,Timber Market and Building Material Market are exposed to WBV as the $\mathbf{w_{RMS}}$acceleration at 1m away from the generator is above the recommended daily exposure limit value (ELV) of 1.15m/s^2, while $\mathbf{w_{RMS}}$ is below recommended exposure action value (EAV) of 0.5m/s^2 in Oko Road Market.

As a result of the user's short distance to generators, majority of the respondents in Eke Market indicated they experienced WBV effects; especially back pain, (see Table 10). However, the effects of vibration on generator users depend upon so many physical, biodynamic and individual factors. A similar study,[10] showed that magnitude of the effect of vibration depends on the severity and length of exposures.

At 2 metres away from the generator (Table 2), the observed W_{RMS}values of WBV at Eke Market and Awka Road Market is well above the risk level of 1.15m/s^2 which can lead to adverse health effects. W_{RMS} acceleration in Uga Road Market, Timber Market and Building Material Market are slightly above the recommended EAV value, which may lead to likely health risks if the exposure is up to 3 hours at Uga Road Market, 2 at Timber Market and 1 hour at Building Material Market respectively, and caution is not taken. However, at Oko Road Market clear effects are experienced as the observed W_{RMS} is below the recommended EAV of 0.5m/s^2. Based on these results, users at Oko Road Market will experience no health effects of WBV.

At 3 metres (see Table 3), W_{RMS} values in Eke Market and Awka Road Market are above the recommended EAV of 0.5m/s^2, which presents a tendency of experiencing WBV effects in

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about an hour. In the case of Oko Road Market, Uga Road Market, Timber Market and Building Material Market, respectively, the observed W_{RMS} value shows there is no possible effects. This indicates that the likely health effects of WBV experienced by users tend to reduce with distance.

It was also observed during measurements that the vibration of some generating sets in the markets have been minimized by mounting them on an isolated platform (to attenuate vibration). As a result vibration could not travel much through the floor, thus it almost impossible for the accelerometer to sense much vibration on the floor. A highly rigid support structure can tolerate a greater amount of ambient vibration.[11] Hence, majority of respondents (see Table 10) could not experience WBV effects. The few who experienced back pain, fatigue and other effects may be as a result of the nature of their work which requires moving of goods from one place to another.

4.3. Noise Exposure Analysis

The mean noise levels emitted from generators at 1m 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 dBA, respectively (see Table 4). In comparison with HSE 2005 regulations of human tolerance to noise level (85dBA), these results have serious public health implications and could result in deleterious auditory conditions such as hearing impairment. Non auditory conditions such as annoyance may also occur.

Due to the relatively short distance of respondents to the generator, majority of respondents in Eke Market and Oko Road Market experiencedifficulty in concentration, communication Interference as well as headache (see Table 11). Similar studies revealed that high noise levels can cause insufficient sleep and rest which can also lead to mood shifts, irritability,

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headache and tertiary annoyance on members of the community.[12][13] This may be responsible for the non-auditory responses observed among respondents in this study.

At 3metres away from generators, it was observed that the mean noise levels in 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 dBA , respectively (Table 5). Although there was decrease in the mean noise levels at 3 metres, it could still result in serious auditory impairment.

The mean noise levels at 5metres 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 respectively as shown in Table 6. These results indicate with distances away from generators, noise levels tend to reduce considerably. However, the mean noise levels at Eke Market still poses some health risks, which is the result of the environment as the remained above the recommended 85dBA.

4.4. Chi-square (χ^2) Analysis

From the chi-square analysis of Tables 8 -11, calculated values of Chi-Square (χ^2) [WBV = 91.36and Noise = 87.895] at 0.05 alpha level of significance with 30 and 35degrees 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-value < 0.05), implying that operating generator sets affects the human health significantly in terms of WBV and Noise.

5. CONCLUSION

Vibration and noise are physical disturbances that occur generally in machines (including generators). This study has shown that there is a high prevalence of the use of generators among people in the study area, thus, exposing them to both vibration and noise induced

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health effects. However, exposure damage to human body reduces with distance from generators as a result of damping effect. Also, this study confirmed that some users of generators are unaware of the vibration effects of generators on their health while a considerable number of the users are aware that high noise level has negative effects on their health.

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