RESEARCH ARTICLE OPEN ACCESS

Assessment of noise pollution in selected sawmills in Port Harcourt

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ABSTRACT
A study on noise pollution in selected sawmills (Mile 3, Mile 1 and Rumuosi sawmills) in Port Harcourt was carried out. Physical measurements of the noise levels of sawmill machines, including Table Saw, Planing Machine,Stenner 48 Bandsaw, and Sharpening Machine, were made using a digital sound level meter. The background noise of the sawmills ranged 70.58 – 79.70 dBA in the order of Mile 3 > Mile 1 >Rumuosi. The average noise level of sawmill machines for Mile 3, Mile 1 and Rumuosi ranged 89.76±0.09- 100.49±0.20dBA, 89.81±0.13 - 97.00±0.46dBA and 89.76±0.07 -100.10±0.53dBA, respectively. In the three sawmills studied, the Sharpening machine recorded the least noise levelwhile the Planing machine had the highest. The noise dose (D) of the Sharpening machine at the three sawmills ranged 0.97 - 0.98, which is below the permissible limit of 1, while the D for Table Saw, Planing Machine and Stenner 48 Bandsawranged 1.86 - 4.27, which is in excess of 1. From the measured noise level and the estimated D, an empirical model that could predict the recommended time a worker is supposed to work with the identified sawmill machines was developed for each of the three sawmills. The values obtained for the hearing deterioration indexindicate that the risk of developing hearing loss after 35 years of exposure is likely to be in the order of Planing machine > Table saw >Stenner 48 bandsaw > Sharpening machine. It is concluded that there is noise pollution emanating from these sawmill machines.
Keywords: Sawmill; Sawing machines; Noise pollution; Noise dose; Hearing impairment

I. INTRODUCTION

Noise is asignificant environmental pollutant and a threat to the quality of man's atmosphere. It is considered by the World Health Organization to be the third most hazardous type of pollution, after air and water pollution (WHO, 2005). Exposure to excessive noise has negative impacts on the victims. The most common being hearing impairment in which the ability of the individual to hear and participate in conversation is greatly reduced (Baker, 1997).

Although hearing loss is the most clearly measurable health hazard, noise is also linked to other physiological and psychological problems(Yahaya et al., 2012; Agbalagba et al., 2013). It annoys, awakens, angers and frustrates people. It disrupts communication and individual thoughts, and affects performance capability. The resultant effect of excessive noise exposure has been studied in many fields. Wilkinson (2002) reported a study in which a person in distress in a noisy environment received no help from passersby because her cry could not be heard, while a similar person in a quiet environment was readily attended to. Baker (1997) reported that students in a quiet environment performed better than those in a noisy area because the students and teachers in the quiet school had fewer distractions and concentrated more on teaching and learning. High noise levels of sufficient duration can result in temporary or permanent hearing loss (Sincero and Sincero, 1996). This is generally associated with those working in industrial plants or operating machineries.

Noise pollution in several industrial workplaces has been extensively studied. Some of these studies investigated noise pollution in sawmills, printing presses, corn mills,oil mills, textile factories, integrated steel plants, feedmills, construction sites and combination of industrial sites (Boateng and Amedofu, 2004; Bedi, 2006; Hamoda, 2008; Kumar et al., 2008; Kerketta et al., 2009; Ali, 2011; Ampofo, 2012;Yahaya et al., 2012; Agbalagba et al., 2013). The noise level reported by these studies with diverse machineries and operating environments varied considerably. Generally, workplaces in the industrial sector have not only generated huge noise, they have equally witnessed enormous increase in number and diversification.

Wood work has been useful to human societies since ancient civilizations and will continue to play dominant roles in the world as the demand for wood products is on the increase (FPL, 2010). The building construction industry has also witnessed tremendous growth and wood from logs serves as a major construction material. However, lumber mills where logs are processed have been

identified as an extreme acoustic environment for workers (Davies et al., 2008). In particular, sawmill activities in lumber mills could generate appreciable amount of noise as a result of machine operation, cutting and sawing, and these activities occur every day for a long period of time. Nigeria is Africa's largest wood producer with an annual harvest of more than 100 million cubic meters (Aruofor, 2001). Sawmills are majorly domiciled in cities and they account for 93.32% of the total wood-based industries (Fuwape, 1998). However, there is scarcity of information on noise from sawmill activities within the cities in Nigeria.

In this study the noise associated with sawmill machines in selected sawmillsin Port Harcourt was assessed. The aim was to ascertain if the noise generated in the sawmills were within human tolerable limit. Physical measurements of noise levels of sawmill machines in the selected sawmills were made using a digital sound level meter. From the measurement data, vital noise indiceswhich reveal the health implications of certain noise levels on workers were estimated, and a model for predicting the recommended time a worker is supposed to work with a particular sawmill machine was developed.

II. MATERIALS AND METHODS

2.1. Study area

This study was carried out in Mile 3 (Timber Market), Mile 1 (Iloabuchi)and Rumuosi areas of Port Harcourt, Rivers State (Fig. 1). Mile 3 and Mile 1are located in Diobu, a densely populatedbusiness area,while Rumousi is located within a residential district.Mile 3 sawmill lies within latitude 4°48'24"N and longitude 6°59'36"E while Mile 1 sawmill lies within latitude 4°47'22"N and longitude 6°59'17"E. Rumuosi sawmill is situated in Obio-Akpor Local Government Area, with geographical coordinates of 4°52'51"Nand 6°56'36"E.Thestudied sawmills used machines such as Table Saw,Planing Machine, Stenner 48 Bandsaw and Sharpening Machine for its daily operations.

Thesawmills operate six days in a week and use the same members-of-staff throughout their operating periods. The sawmill workers are predominantly males with age range from 18 to 46 years and above. About 77.3% of the staff work for 7-8 hours, 12% work for 5-6 hours while 10.7% work for 9-10 hours throughout the sawmill operational working days. About 70% of the staff have been working in the various sawmills for more than 5 years. A total of 9 (12%) and 65 (86.7%) rated sawmill noise as noisy and very noisy respectively while only 1 (1.3%) claimed it is not so noisy. Therefore, a total of 98.7% of staff are dissatisfied with the level of noise in their workplace with some stating that they have tolerated the situation because it is their only source of livelihood. Though there are noise reduction devices, 52% of the staff claimed that they have never heard of such devices. About 85.3% of the staff expressed willingness to use the devices if provided while14.7% of the workers claimed that the management might not allow them use such protective devices because they are expected to keep their ears open to detect any faulty sound in the machines while operation is ongoing.

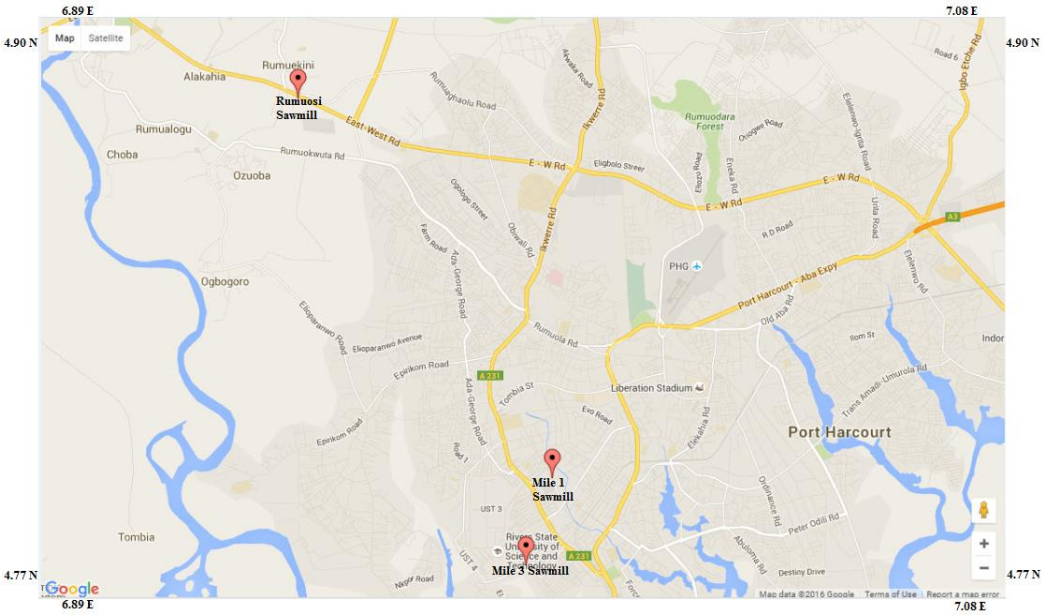

Fig. 1 Map of Port Harcourt showing the studied sawmills

2.2.Noise measurements

Noise levels in A-weighted decibel (dBA) were measured from the different machines at the three sawmills using a Sound Level Meter (SLM), with Model number SL1361, which gives instant real time readings. The desired response of the SLM was set at slow with a range of 30-130dB. A stop watch was used to monitor measurement duration. The noise measurements were taken at 10 secs intervals for 5 mins to get 30 discrete sets of data that were subjected to Leq equation (see Section 2.3) to get an overall value. This was done for five days at each sawmill to get five different readings. The SLM was held 1.5m from the ground in accordance with the Canadian Centre for Occupational Health and Safety noise measurement procedure for standing working position and 1.1m for sitting working position.

2.3. Estimation of equivalent continuous noise level, noise pollution level, noise dose and hearing deterioration index

The equivalentcontinuous noise level (L_{eq}), theconstant noise level over a given period that produces the same amount of A-weighted energy as fluctuating level over the same time frame,was computed using Equation (1). The average of the daily L_{eq} values was estimated using Equation (2).Reference time (T), the total time a worker should be exposed to a noise level, was determined using Equation (3). Noise dose (D), the total exposure of a worker to noise during a working day, was calculated using Equation (4). The Hearing deterioration index (HDI), the percentage risk of developing a hearing handicap and median loss in hearing capacity incurred with exposure, was estimated using Equation (5) (Bies and Hansen, 2010; Balaji et al., 2016; Tripathy, 2008; Kiely, 2007).

$$L_{eq} = 10 \log_{10}\left[\frac{1}{T}\sum_{i=1}^{n} 10^{0.1L_i} t_i\right] \quad (1)$$

where T is the time period over which L_{eq} is determined, n is number of samples, L_i is noise level at the i^{th} sample and t_i is the fraction of total time.

$$L_p = 20 \log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} 10^{L_i/20}\right) \quad (2)$$

where L_p is the average L_{eq}, n is the number of readings and L_i is the dailyL_{eq}.

$$T = \frac{8}{2^{(L-90)/5}} \quad (3)$$

where L is the measured A-weighted sound level.

$$D = \frac{C}{T} \quad (4)$$

where C is the total time of exposure to a specific noise level (in this study, an exposure time of 8 hours was assumed).

$$HDI = 10 \log_{10}\left(\int_0^t 10^{L/20} dt\right) \quad (5)$$

where L is the mean exposure level (dBA) and t is the time of exposure in years.

2.4. Development of a predictive model

A predictive model was developed using XL STAT software. Parameters such as the Equivalent continuous noise level (L_{eq}), Noise dose (D) and Reference time (T) were calculated independently and later regressed using XL STAT software to develop a model. The model developed for each of the three sawmills could be used to predict the reference time that a worker is supposed to be exposed to a constant noise in each sawmill.

III. RESULTS AND DISCUSSION

3.1. Background noise level

The average background noise levels of the three studied sawmills are presented in Fig. 2. The background noise levelsof the sawmills are below the Federal Ministry of Environment (FMEnv) and Occupational Safety and Health Administration (OSHA)recommended standard of 90 dBA for 8 h/day (FEPA, 1991; OSHA, 1993). Among the sawmills, the background noise level is in the order of Mile 3 sawmill>Mile 1 sawmill>Rumuosi sawmill. Thisvariation can beattributed to the nature of the environment hosting the sawmills. While Mile 3 and Mile 1 sawmills arelocated in highly populated business areas, Rumuosi sawmill is located in a residential area. Based on these locations, it is likely that people would be exposed to the noise generated from the sawmills.

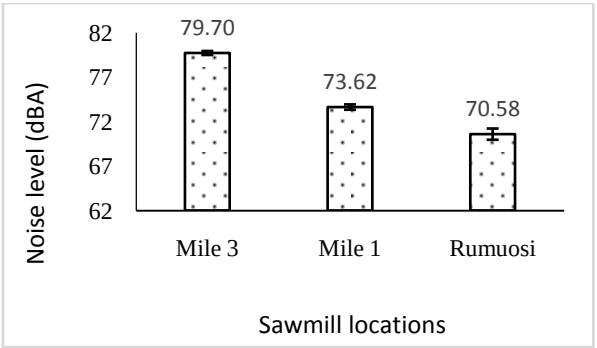

Fig. 2 Background noise levels of selected sawmills

3.2. Equivalent continuous noise level ofthe studied sawmills

Figure 3 presents the average noise levels of machines in the studied sawmills. The average noise levels of machines at Mile 3sawmill ranged 89.76±0.09- 100.49±0.20dBA with the highest

value recorded for the Planing machine and the lowest value recorded for the Sharpening machine. The average noise levels of machines at Mile 1sawmill ranged89.81±0.13 - 97.00±0.46dBA while those of Rumuosi sawmill ranged89.76±0.07 - 100.10±0.53dBA, with the highest and lowest values also recorded for the Planing machine and Sharpening machine, respectively. Although the Planing machine at Mile 1sawmill recorded the highest value, it's value was reasonably lower compared with those of Mile 3 and Rumuosisawmills. This lower value could be attributed to the design of the Planing machine found at Mile 1 sawmill which has a box-like shape,different from the common open Planing machine found at Mile 3 and Rumuosi sawmills. At Rumuosi sawmill, the noise level recorded for the Table saw was relatively higher compared with those of Mile 3 and Mile 1 sawmills. This higher value could be ascribed to the power generating sets positioned closely to the Table saw at Rumuosi sawmill which was not the case at the other sawmills. The Stenner 48 bandsaw and Sharpening machine which were of the same brand and age and kept in similar environment had similar noise level.

Except for the Sharpening machine, all the machines at the three sawmills have noise levels above the recommended standard of 90 dBA for 8 h/day. Hence, only the Sharpening machine is supposed to be operated for 8 h/day by a worker. The other machines are supposed to be operated for less than 8 h/day as follows: Planing machine (1.88, 3.20 and 1.98 h/day), Table saw (3.23, 3.53 and 2.39 h/day) and Stenner 48 bandsaw (3.66, 4.22 and 4.34 h/day) for Mile 3, Mile 1 and Rumuosi sawmill, respectively (Tripathy, 2008). Therefore, operating the Planing machine, Table saw and Stenner 48 bandsaw for the normal 8 h/day could lead to hearing impairments and/or physiological damages on workers.

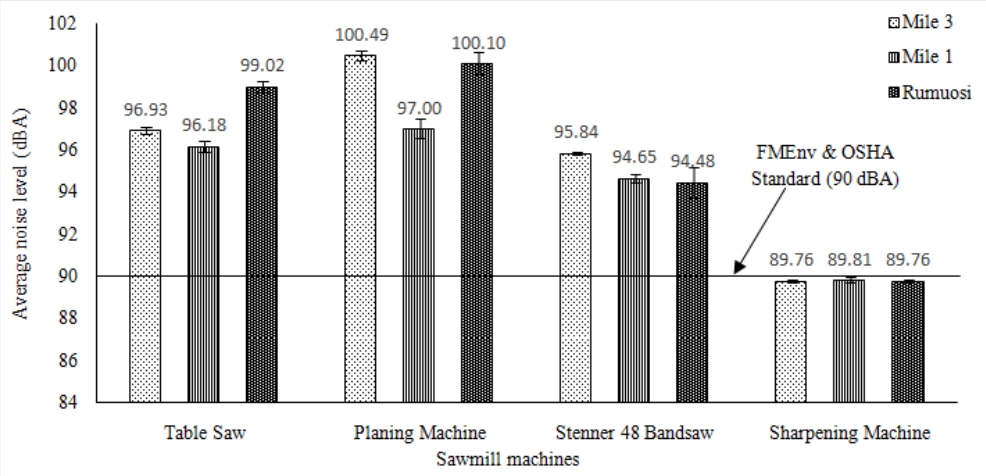

Fig. 3 Average equivalent continuous noise levels of machines in the studied sawmills

3.3. Noise indices of the studied sawmills

Table 1 compares the noise dose, reference time and hearing deterioration indexfor 35 yearsof machines in the studied sawmills. The Sharpening machinein the sawmills had noise dose (D) between 0.97 and 0.98 which is below the FMEnv and OSHA permissible limit of 1, and reference time (T) between 8.21 and 8.27 hwhich is higher than the maximum daily working hour of 8 h. Therefore, the risk of workers having a hearing damage while operating the Sharpening machinecould be negligible. However, the Planing machine, Table saw and Stenner 48 bandsaw have noise doses (1.86 – 4.27) in excess of the permissible limit of 1 and reference times (1.87 – 4.30 h) well below maximum daily working hour of 8 h. This indicates that there could be risk of hearing damage over time on workers operating these machines.Also, the values obtained for the hearing deterioration index (HDI) ranged from 60.32-60.35 for Sharpening machine to 62.68-63.36 for Stenner 48 bandsaw to 63.53-64.95 for Table saw to 63.94-65.69 for Planing machine, indicating that the risk of developing hearing loss after 35 yearsof exposure is likely to be in the order of Planing machine > Table saw >Stenner 48 bandsaw > Sharpening machine.

Table 1 Comparison of noise dose, reference time and hearing deterioration index of machines in the selected sawmills.

Sawmill machines	Mile 3			Mile 1			Rumuosi		
	D (-)	T (h)	HDI (-)	D (-)	T (h)	HDI (-)	D (-)	T (h)	HDI (-)
Table saw	2.61	3.06	63.91	2.35	3.40	63.53	3.49	2.29	64.95
Planing Machine	4.27	1.87	65.69	2.64	3.03	63.94	4.06	1.97	65.49
Stenner 48 Bandsaw	2.25	3.56	63.36	1.90	4.20	62.77	1.86	4.30	62.68
Sharpening Machine	0.97	8.27	60.32	0.98	8.21	60.35	0.97	8.27	60.32

3.4. Predictive model for the recommended time in the studied sawmills

A mathematical relationship that could predict the appropriate recommended time for working with a particular sawmill machine was developed. This was done by testing a non-linear model,Equation (6), using XL STAT which is an Add-ins function of the Microsoft Excel tool Pak (2011 version). Equations (7) – (9) are the mathematical relationships gotten for predicting the recommended time a worker is supposed to work with the identified sawmill machines at the studied sawmills, and have R^2 values as high as 0.98. Equation (7) is the model for predicting the recommended time for machines in Mile 3 sawmill while Equations (8) and (9) are for machines in Mile 1 and Rumuosi sawmills, respectively. Although the models have a common root, they differ slightly. This is due to the variations in Leq and D values computed for the various sawmills. Thus, Equations (7) – (9) are site specific models which may depend on the brand and age of machines.

$$Y = a_o + a_1 x_1 + a_2 x_1^2 + a_3 x_2 + a_4 x_2^2 + \ldots \quad (6)$$

where Y is the daily recommended time of exposure, $a_o, a_1, a_2, a_3, a_4, \ldots a_n$ are constants which depend on sawmill machines, $x_1$and x_2 are theLeq and D, respectively.

$$\mathbf{T_{mile\ 3} = 630.27528 - 12.93717Leq - 1.37883D + 0.06709Leq^2} \quad (7)$$

$$\mathbf{T_{mile\ 1} = 791.695594 - 16.72198Leq - 3.59996D + 0.08947Leq^2 + 0.14714D^2} \quad (8)$$

$$\mathbf{T_{rumuosi} = 653.29763 - 13.44502Leq - 1.46036D + 0.06990Leq^2} \quad (9)$$

IV. CONCLUSIONS

The noise levels of three sawmills have been measured and compared. The background noise of the sawmills ranged 70.58 – 79.70 dBAin the order of Mile 3 > Mile 1 >Rumuosi. The average noise level of sawmill machines for Mile 3, Mile 1 and Rumuosi ranged 89.76±0.09-100.49±0.20dBA, 89.81±0.13 - 97.00±0.46dBA and 89.76±0.07 - 100.10±0.53dBA, respectively. The average noise levels of all the machines of the studied sawmills, with the exception of the Sharpening machine, were found to be higher than the FMEnv and OSHA recommended value of 90 dBA for 8 h/day. These noise levels could cause hearing loss and/orpsychological effect to employees of these sawmills as well as people doing business within the vicinity of the sawmills.The noise dose (D) of the Sharpening machine at the three sawmills ranged 0.97 - 0.98, which is below the permissible limit of 1. On the contrary, the D of the other machines ranged 1.86 - 4.27, which is in excess of 1. The values obtained for the hearing deterioration index indicate that the risk of developing hearing loss after 35 years of exposure is likely to be in the order of Planing machine > Table saw >Stenner 48 bandsaw > Sharpening machine.Above all, a model was developed that could predict the recommended time a worker is supposed to work with the identified sawmill machines for each of the three sawmills.Although the models have a common root, they differ slightly due to the variations in the equivalent continuous noise level and noise dose values of the machines at the different sawmills.

ACKNOWLEDGEMENTS

The Authors wish to thank the Centre for Occupational Health, Safety and Environment,University of Port Harcourt for sponsoring this research.

REFERENCES

[1]. Agbalagba E.O., Akpata A.N.O., Olali, S.A. (2013) Investigation of noise pollution levels of four selected sawmill factories in Delta State, Nigeria. Advances in Applied Acoustics Journal, 2(3): 83 – 90.

[2]. Ali, S.A. (2011) Industrial noise levels and annoyance in Egypt. Applied Acoustics, 72(4): 221–225.

[3]. Ampofo, D.K. (2012) Evaluation of noise levels of corn mills Ablekuma north sub-metro, Accra.M.Sc Dissertation at Kwame Nkrumah University of Science and Technology, Kumasi.

[4]. Aruofor, R.O. (2001) The Nigerian forestry outlook study, September 24, 13 - 15.

[5]. Baker, D.E. (1997) Noise: the invisible hazard. Department of Agricultural Engineering,

[6]. Universityof Missouri, Columbia.

[7]. Balaji, R., Rajasegaran, R., John, N.A., Venkatappa, U.S. (2016) Hearing impairment and high
[8]. blood pressure among bus drivers in Puducherry. Journal of Clinical and Diagnostic Research, 10(2): 8-10.
[9]. Bedi, R. (2006) Evaluation of occupational environment in two textile plants in northern India with specific reference to noise. Industrial Health, 44: 112-116.
[10]. Bies, D. A. and Hansen, C. H. (2010)Engineering noise control, 4th ed.Spon Press (Taylor and Francis), Abington, UK, pp 58.
[11]. Boateng, C. A. and Amedofu, G. K. (2004) Industrial noise pollution and its effects on the hearing capabilities of workers: a study from sawmills, printing presses and corn mills. African Journal of Health Science, 11: 55-60.
[12]. Davies, H.W., Teschke, K., Kennedy, S.M., Hodgson M.R. and Demers P.A. (2008)Occupational noise exposure and hearing protector use in Canadian lumber mills. Journal of Occupational and Environmental Hygiene, 6(1): 32-41.
[13]. Federal Environmental protection Agency, FEPA (1991): Guidelines and Standard for Industrial Noise, FEPA, pp 52.
[14]. FPL (Forest Products Laboratory) (2010): Wood handbook-wood as an engineering material, general technical report FPL-GTR-190, United States Department of Agriculture, U.S.A.
[15]. Fuwape, J.A. (1998) Developments of wood-based industries in Nigeria.Foresea Miyazaki, 2: 575-585.
[16]. Hamoda, M.F. (2008) Modeling of construction noise for environmental impact assessment. Journal of Construction in Developing Countries, 13(1): 79-89.
[17]. Kerketta, S., Dash, P.K. and Narayan, L.T.P. (2009) Work zone noise levels at Aarti steel plant, Orissa and its attenuation in far field. Journal of Environmental Biology, 30(5): 903-908.
[18]. Kiely, G. (2007) Environmental engineering. McGraw-Hill Publishing Company Limited, New
[19]. Delhi, pp 390-419.
[20]. Kumar, G.V.P., Dewangan, K.N. and Sarkar, A. (2008)Noise exposure in oil mills. India Journal of Occupational and Environmental Medicine, 12(1): 23-28.
[21]. Occupational Safety and Health Administration, OSHA (1993) Permissible Noise Level recommended for eight hours of work per day.
[22]. Sincero, A.P. and Sincero G.A. (1996)Environmental engineering: a design approach. Prentice-Hall of India Private Limited, New Delhi, pp 686 – 743.
[23]. Tripathy, D.P. (2008) Noise pollution. A.P.H. Publishing Corporation, New Delhi, pp 41-77.
[24]. WHO (2005) Occupational noise: assessing the burden of disease from work-related hearing impairment at national and local levels. Environmental Burden of Disease Series, No. 9, World Health Organization, Switzerland.
[25]. Wilkinson, H.R. (2002) Avoiding hearing losses on the farm. Michigan State University Extension.
[26]. Yahaya, M., Chukwufumnanya, R.O. and Odunola, E.A. (2012) Assessment of noise levels generated in some feed mills in Ibadan, Nigeria. Research Journal in Engineering and Applied Sciences, 1(3): 156 – 159.