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Research Article

Acoustic safety assessment of palm oil mill workers

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ABSTRACT

Mechanization of work processes in agro-based industries through the employment of improved tools and/or equipment powered by either fuel or diesel engines reduce tedium and drudgery on the workers as well as improve the overall productivity and production. However, it also leads to health threat to the workers through environmental noise pollution. This study assessed the occupational noise exposure of workers in three different palm oil mills. The noise level was measured using a noise metering device (model 1352) and noise descriptors (L10, L50, L90, Lav, LAeq, Total Sound Pressure Level (Tspl), DOSE (%) and TWA). The occupational health effects of noise exposure were deduced using a semi-structured questionnaire. The noise exposure was assessed during the palm nut digestion, and nut and pulp separation job operations as the noise emanates from the diesel powered engine, palm nut digester and nut and pulp separator. The average noise levels obtained from the palm oil mills during palm nut digestion, 99.36 (SD = 4.16) dBA and pulp separation, 98.18 (SD = 3.07) dBA, exceeded the recommended 85 dBA for an 8-hour exposure period permissible noise exposure limit standard by the NIOSH. The independent t-tests for noise level between off-working and working periods disclosed $p < 0.05$ – significant noise exposure. The self-reported effect of the noise exposure level on the workers was interference with communication - 100%, tinnitus - 70%, ringing sensation - 76.75%, and noise stress - 73.30% of the workers. This research will inform the operators of the need for appropriate personal protective equipment usage and equip Government regulatory agencies to make appropriate regulations in order to protect oil mill workers.

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INTRODUCTION

The oil palm tree is one of the economic crops in Nigeria whose by-products has crucial role in food production, raw materials provision for industries, income generation, employment set up, foreign exchange earnings, and national economic development [1]. Among the oil palm tree products are palm oil. Dada et al. [1] documented that before the 1970s, palm oil alone was one of the major sources of foreign exchange earning to Nigeria. Its significance was observed between the year 1950 and 1960 as the palm oil produced in Nigeria made an average of 34% of total world palm oil export in the world. The physical strenuous and repetitive activities involved in the palm oil production process affected the interest in its production. With the mechanization of the work process in most agro-based industries, palm oil production industry inclusive [2], the overall productivity and production process, as well as the reduction in tedium and drudgery from the work processes, has been positively affected. This transformative component of development in itself has significantly and necessarily improved physical stress issues in the work environments [3].

Some of the industrial machines acquired and used in most work processes are adapted with internal combustion engines while some due to the electric power supply challenge in the nation, are alternatively powered by fuel or diesel engines which inescapably generate noise in the work environment as such poses health threat to the workers [4-7]. Tekin et al.'s [8] studies observed that even though exposure to excessive noise pollution in the work environment affects the workers' health, the study concluded that there was no statistically significant difference in the attention level of the workers before and after

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machine operations. Ibhadode *et al.* [9] stated that encouragement of industrialization in the face energy insufficiency or crisis prevalent in most third world nations, Nigeria inclusive, effectuates environmental noise pollution through diverse privately owned and operated sources of power. The noise intensity being emitted by industrial machinery during job operations cannot be overemphasized as it is classified among the occupational hazards that significantly affect the health of workers in most work environments [10, 11].

The harmful effect of exposure to the high intensity of noise on the workers' health may be immediate, long-term or both. This covers a range of psychological, physiological, and perhaps pathological responses [12]. Occupational diseases caused by exposure to noise are stated to be preventable. To address the issue of noise in the working environment, the background information on the work factors should be assessed. The steps in an effective noise exposure prevention program consist of the identification of sources of noise, the intensity, effects and the proposed appropriate precautionary and/or control measures. Oil palm mill has come to stay considering that palm oil is an important product in world trade [13] and is playing an important role in Nigerian economy [14]. Previous scientific studies on noise level measurements and evaluations found in the works of literature in different occupational dispensations included evaluation and analysis of the intensity of noise from various generators in the commercial areas [15], distraction effect of excessive noise pollution from mining machines during mining operations [8], assessment of noise emission from vibrator-block factories and the impact on human health [16], and occupational noise exposure in an amassed sawmill site was evaluated and analyzed by Azodo et al. [17]. However, no publicly available published literature was found that assessed the occupational exposure of workers in the palm oil mill.

Chong et al. [18] opined that recognition and prevention of occupational noise risks are crucial for the improvement of occupational health risks perception and regulation in the work environment. It is therefore, necessary to assess the set of conditions, limits and forces which surround and have direct influence on the effective and efficient operation of mechanized palm oil production process. This study assessed the occupational noise exposure of palm oil mill workers using noise metering device and noise descriptors, as well as determine the subjective effects of the noise exposure of mechanized palm oil production process. This research provides the needed information for oil mill operators and Government regulatory agents to act on in order to improve the occupational health of oil mill workers.

MATERIALS AND METHOD

The physical occupational noise exposure measurement from mechanized palm oil process was conducted in three palm oil mills located in Ogidi, Idemili North Local Government Area of Anambra State, Nigeria (Figure 1). These palm oil mills were purposefully selected as study sites for this study. The palm oil mills identified by the names of the operators who also were the owners of the mills were identified with English alphabets A, B and C for this study. The geographical coordinates of the palm oil mills obtained with a handheld Garmin Global Positioning System (GPS) 72H (Garmin Ltd. Kansas, United States) are pre-sented in Table 1.

The palm oil operators were contacted at their work environ-ment and intimated about the study; the purpose, their detailed involvement in the study, as well as their permission. The consent

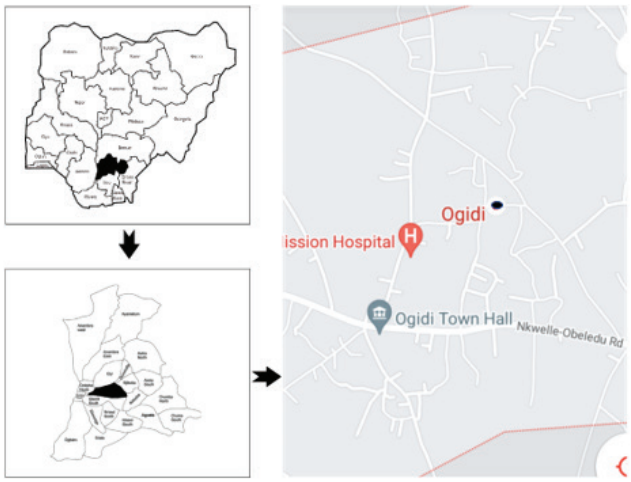

Figure 1. Map, showing the study site location.

Table 1. Geographical coordinates of the palm oil mills assessed

Palm oil mills	Geographical coordinates	
	Longitude	Latitude
A	N 6°8'42"	E 6°54'26"
B	N 6°9'20"	E 6°54'37"
C	N 6°8'47"	E 6°54'8"

was obtained verbally from the three palm oil mill owners. A pre-survey of the study site locations (palm oil mills) revealed that palm nut digestion, and nut and pulp separation were the mechanized palm oil production process common in the three palm oil mills. These machines were powered by diesel engines in the three palm oil mills. Other features found similar in three palm oil mills is the production floor layout of the palm oil mills. The factory sections showing the palm nut digester, nut and pulp separator and the diesel-powered engine used in the palm oil job operations is presented in Figure 2. The plant layout for the palm oil mills showing the points from which the measurement was obtained is presented in Figure 3 below. Table 2 explained the

Figure 2. The palm oil mills showing palm nut digester, nut and pulp separator and the diesel-powered engine.

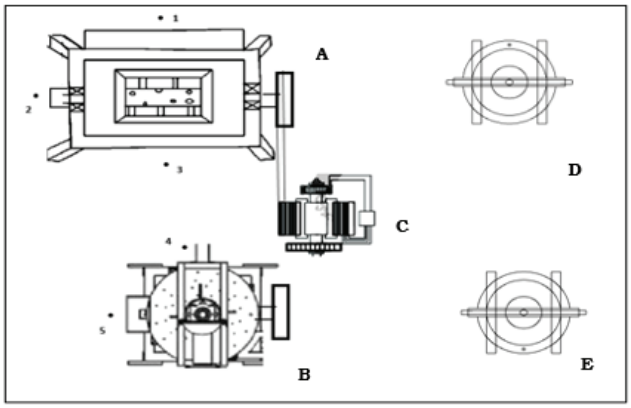

Figure 3. The schematic plan of the palm oil mills showing the measurement points (A= Pulp separator, B = Palm fruit digester, C = Diesel engine, D = Palm oil press E = Palm oil press).

measurements points noted in Figure 3 from which the reading where obtain in the palm oil mills.

Verbal conversation with the operators also revealed that the production process rate is affected by the number of customers per day which is higher in the dry seasons with an average of 600 – 700 kg of palm nuts handling per day. This guided the study period as it was conducted in February and March 2019.

The noise exposure level in the work environments was measured at the ears of the workers in the different duty positions of the workers during the palm nut digestion, and nut and pulp separation job operations. The physical measurement of the noise levels was done using Benetech Sound Level Meter (SLM) type GM1352 internally calibrated by Benetech (Shenzhen Jumaoyuan Science and Technology Co., Ltd., China). The response frequency of the SLM is 31.5 Hz – 8 kHz at an accuracy of ±1.5 dB. The resolution setting of the SLM is 0.1 dB. Its measurement range is SLM is 30 – 130 dB. The noise exposure level at the palm oil mills was measured and recorded before and during each of the work activity at an exposure time interval of 60 seconds using the Benetech sound level meter and a digital professional handheld liquid crystal display (LCD) stopwatch (Shenzhen, China) during the job operations.

Five sets of measurements were taken for each of the mechanized palm oil production operations, making a total of 10 readings for each of the palm mills and 30 readings for the three palm oil mills assessed. The measured sound level at the palm oil mills was computed and expressed as A-weighted equivalent sound pressure level (LAeq) using equation (1). The value obtained represented the total sound energy being produced throughout the assessment.

$$L_{Aeq} = 10log_{10}\left[\frac{1}{N}\sum_{I=1}^{N}\left(anti\ log\frac{L_{Ai}}{10}\right)\right] \quad (1)$$

Where

LAeq = A-weighted equivalent sound pressure level

LAi = A-weighted sound pressure level in dB

N = total number of measurements

The independent samples t-test analyses were used to establish if there was a significant statistical difference between (a) off- and working periods at the palm oil mills and (b) working periods at the palm oil mills and maximum permissible noise level exposure.

The workers' occupational noise exposure analysis was carried out on noise exposure limit recommended by National Institute for Occupational Safety and Health (NIOSH) for A-weighted decibel of 8-hr time-weighted average (85 dBA as an 8-hr TWA). The relation between exposure levels and duration was determined using equation (2)

$$T_{SPL} = \frac{480}{2^{(L-85)/3}} \quad (2)$$

Where

T_{SPL} = Exposure duration of the sound pressure level

L = exposure level and

3 = the exchange rate

The daily noise dose of occupational noise exposure was determined by the periods of different noise levels, the daily dose (D) by each of the participants by the relation

$$D = \sum\frac{C_n}{T_{SPL}} \quad (3)$$

Where

C_n = total time of exposure at a specific noise level, and

T_{spl} = exposure duration for which noise at this level becomes hazardous

The value obtained for the daily dose can be converted into an 8-hr TWA using the relation

$$TWA = 10.0 \times (log\frac{D}{100}) + 85 \quad (4)$$

The obtained Time Weighted Average (TWA) noise levels for each of the workers were subjected to acoustic safety and health risks analysis using equation (5). The output was classified as safe and unsafe noise exposure levels using the revised recommended standard criteria for occupational noise exposure by National Institute for Occupational Safety and Health presented in Table 3 as a guide.

$$TWA = \sum\frac{(wf_i \cdot t_i)}{\sum t_i} \in [0,1] \quad (5)$$

$$\begin{bmatrix} TWA_{unsafe} \text{ with } wf_i = \begin{bmatrix} 1\ if\ I_{sound\ level} > I_{85\ dBA} \\ 0\ if\ I_{sound\ level} \leq I_{85\ dBA} \end{bmatrix} \\ TWA_{safe} \text{ with } wf_i = \begin{bmatrix} 1\ if\ I_{sound\ level} < I_{85\ dBA} \\ 0\ if\ I_{sound\ level} \geq I_{85\ dBA} \end{bmatrix} \end{bmatrix}$$

Table 2. The noise level measurement points and the processing activity in the palm oil mills.

Noise level measurement points	The concerned worker	Job operation involved
1	Oil mill worker	Collection of the palm fruit pulp
2	Oil mill worker	Collection of palm kernel
3	Machine operator	Feeding in the digested palm fruit in the palm fruit separator and monitoring the process
4	Machine operator	Feeding in the palm fruit in the palm nut digester and monitoring the process
5	Oil mill worker	Collection of the digested palm fruit

Table 3. Acoustic risks and safety analysis interpretation of the noise intensity level from lawnmowers on groundskeepers for 85 dBA as an 8-hr TWA

TWA noise levels	85 dBA as an 8-hr TWA exposure level interpretation
≤85dBA	safe noise exposure levels
≥85dBA	unsafe noise exposure levels

Where

TWA = Time weighted average noise levels

$wf_{i=}$ A-weighting factor variable which depends on $I_{sound\ level}$ values

t_i = Time in hours

The self-reported effect of noise exposures a result of the job operations in the palm oil mills was assessed using a questionnaire. The questionnaire was developed after a review of previous studies on the effect of noise on humans. The questionnaire covers the physical and physiological effect of noise on the participants. The questionnaire developed for this study was subjected to scrutiny for validity and reliability by two professionals in acoustic and human safety engineering. The questionnaire also underwent a pre-test for clarity and the precise presentation of questions. The questionnaire underwent a series of edits and modifications as suggested by the professionals regarding the objective of the study, who later gave their approval for the production of the final copy of the questionnaire used for the study. The proposed participants in this survey who were workers in the palm oil mills were contacted face-to-face for participation in the study by the researchers, informed of the study, its purpose, and procedure, and verbally assured of the confidentiality of their responses to the questionnaire. Responses were only obtained from contacts who agreed to participate in the study. The participation was voluntary, and as such, no incentive was offered. The analysis of the obtained data from the survey was carried out using Statistical Package for Social Science (SPSS 20.0) software and Microsoft Excel spreadsheet version 2001.

RESULTS AND DISCUSSIONS

The sources of the noise were mainly the diesel-powered engine (the power drive source), palm nut digester and nut and pulp separator. The palm nut digester and the nut and pulp separator machines were driven by diesel powered engine in the three palm oil mills assessed. The detailed noise level measured in the oil mill includes off work hours and working hours (Apendix 1) during the working hours two categories of measurements were made including noise level from palm nut digestion and noise level from pulp separation process (Apendix 2).

Table 4 shows the descriptive statistics of the noise level in three different palm oil mills during the job operation the palm nut digestion, and nut and pulp separation job operations.

The healthful and safe environment need of industry covers the business objectives as well as that of the individual employee. Deficiencies, inadequacies, and negation of the human factor's aspect for the effectiveness and efficiency of the workplace affect the whole work process. This study which focused on the acoustic safety of palm oil mill workers using a digital noise metering device and noise descriptors considered the intensity of noise for exposure duration as noise has the characteristics of negating the workers' health life in the work environment. The measured sound levels from the palm oil mills and the computed noise descriptors from the data obtained are presented in Table 5.

The variation of the measured noise level intensity between the off-working and the working hours analyzed using independent-sample t-test showed that the occupational noise levels during working process were statistically significantly higher (mean = 98.80 ± 3.75) when compared to off-working periods (mean = 59.60 ± 6.41) with $p < 0.001$ (Table 6). The obtained noise intensity level during the job operation (with mean value of 98.8 from 1800 measurements) was higher than the recommended permissible noise exposure limit standard by NIOSH (85). This implies that noise levels during the job operation superseded the recommended as permissible noise exposure limit standard.

The A-weighted equivalent sound pressure level (LAeq) computed so as to obtain a single constant noise level value that represented an equivalent total sound energy the palm oil mills workers were exposed to during their job operation over the assessment period showed a range of 94 - 109, 94.4 - 106.4, 96 - 108 dBA for

Table 4. Descriptive statistics of the measured noise level during the off hours and working hours

Descriptive statistics	A			B			C		
	OH	PD	PS	OH	PD	PS	OH	PD	PS
Max	78.50	108.5	112.5	81.20	107.3	114.6	75.9	107.7	111.6
Min	50.00	93.00	91.8	51.70	93.00	91.8	48.40	94.70	94.70
Mean	59.82	97.88	99.35	61.56	97.87	99.33	57.61	98.79	99.41
SD	6.33	3.04	4.52	6.39	3.26	4.91	5.90	2.81	2.75

Note: OH= Off working hours, PD = Palm nut digestion, PS = Pulp separation

Table 5. Descriptive statistics of the measured noise level during the off hours and working hours

Descriptive statistics	A		B		C	
	OH	WH	OH	WH	OH	WH
Max	78.50	114.60	81.20	111.60	75.90	107.70
Min	50.00	91.80	51.70	93.00	48.40	94.70
Mean	59.82	99.34	61.56	97.88	57.61	99.09
SD	6.33	4.71	6.39	3.18	5.90	2.77

Note: OH= Off working hours, WH= Working hours

Table 6. Independent sample t-test for noise level between off-working and working periods

Descriptive statistics					t-test for Equality of Means		
Measurement periods	**N**	**Mean**	**SD**	**SEM**	**T**	**Df**	***P*-value**
Off-working	1800	59.67	6.41	0.15	-223.42	3598	0.00
Working hour	1800	98.80	3.75	0.09			

palm oil mill A, B and C respectively. The daily dose (D) of the noise exposure for each of the palm oil mills as a result of the job operations showed that a maximum daily dose of 208.3% for palm oil A, 130.8% for palm oil B and 174.5% for palm oil C while the minimum daily dose was 52.9% for palm oil A, 52.7% for palm oil B and 53.0% for palm oil C. To ascertain the workers' safety, the value obtained for the daily dose was converted to an 8-hr TWA. The workers' occupational noise exposure analysis carried out on noise exposure limit recommended by National Institute for Occupational Safety and Health (NIOSH) for A-weighted decibel of 8-hr time-weighted average (85 dBA as an 8-hr TWA) gave a range of 90.3 - 105.8, 90.3 - 98.1 and 90.3 - 102.5 dBA (Table 7). This showed that the occupational noise exposure on the workers in the three-palm oil exceeded the noise exposure limit recommended by National Institute for Occupational Safety and Health (NIOSH) for A-weighted decibel of 8-hr time-weighted average (85 dBA as an 8-hr TWA) which was not healthy for the workers. L_{10}, the noise descriptor, represented the mean of the lower limit of the fluctuating noise value obtained in this study, and it was recorded for the palm oil mill A. The upper limit of the noise level (L_{90}) to which the workers were exposed when compared to the three palm oil mills, A, B, and C, showed that the value obtained for palm oil mill A was the highest. Other analyses of the noise descriptors, including L_{50}, L_{av}, T_{spl}, DOSE (%), and TWA, were present in Table 7. The result of the noise descriptor analysis presented in the table showed that workers in palm oil mill A were exposed to the highest noise level values, with average values recorded as L_{Aeq} (101 dBA), L50 (98.6 dBA), L_{max} (105.5 dBA), and T_{spl} (27 dBA).and a noise dose percentage of 80.3. This study is proof that the frequent increase in the sophistication of machinery, which replaces manual labor in our industries relentlessly, adds to the degree of noise pollution in every corner of the world's environment.

Work situation characteristics which comprise of what happens to the individual in his work environment as a human is one of the greatest assets visible in any organization essential for achieving the set tangent. The identification of the effects of noise intensity which is imperative in understanding the relationship between the workers and the work environment as the judicious commitment to the whole system of safe work process and environment for the reduction of accidents at work and rates of occupational diseases makes the whole system economically active populations [19]. The acoustic safety analysis for the noise exposure done with a one-tailed criterion (see equation 5) following the recommended exposure time guideline for continuous time-weighted average noise exposure split into two bins (unsafe and safe noise intensity level) for A-weighted decibel of 8-hr time-weighted average (85 dBA as an 8-hr TWA). The time-weighted average which indicates the safety and the occurrence frequency of noise exposure to sound pressure showed absolute unsafe noise exposure level above the NIOSH limit (Table 8).

The detrimental effect of a high level of noise on human health has both immediate and long-term effects on the workers. The range of self-reported effect of the noise exposure level on the 30 workers from the three palm oil treadmills who participated in this study were interference with communication, tinnitus, ringing sensation, and noise stress (Figure 1). This study depicts that occupational noise affects human health and well-being.

Table 7. Descriptive statistics of the computed noise descriptors

Descriptive statistics	L10	L50	L90	Lmax	LAeq	Tspl	DOSE (%)	TWA
Palm oil mill A								
Max	102.9	109.2	112.6	114.6	109	64.7	208.3	105.8
Min	92.2	92.2	92.2	92.2	94	3.4	52.9	90.3
Mean	96.4	98.6	103	105.5	101	27	80.3	93.0
Palm oil mill B								
Max	101.8	105.3	108.8	111.6	106.4	55.1	130.8	98.1
Min	93.3	94	94.9	95.2	94.4	4.5	52.7	90.3
Mean	96	97.5	100.3	101.9	98.6	27.5	60.7	91.1
Palm oil mill C								
Max	101	108.3	111	112.6	108	38.1	174.5	102.5
Min	95	95.6	96.5	96.7	96	3.8	53.0	90.3
Mean	97.4	98.9	101.4	102.8	99.8	20.0	57.0	90.7

Table 8. The A-weighted decibel of 8-hr time-weighted average safety analysis

Palm oil mills	Noise exposure levels (dBA)	Operation Characteristics	Frequency(percentage)
A	93.0	Unsafe	60(100%)
B	91.1	Unsafe	60(100%)
C	90.7	Unsafe	60(100%)

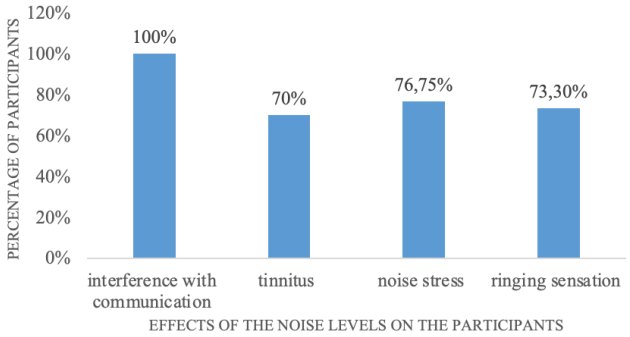

Figure 1. Effects of the noise levels on the palm oil mill workers.

CONCLUSION

The identification of noise intensity and its effects on the occupational health of the palm oil mill workers were measured and analyzed using the noise descriptors (L10, L50, L90, Lav, LAeq, Total Sound Pressure Level (Tspl), DOSE (%), and TWA). The values obtained were high when compared to the noise exposure limit recommended by the National Institute for Occupational Safety and Health. Further analysis of the data showed an unsafe noise exposure level above the recommended noise exposure limit in the palm oil mills. The self-reported effect of noise exposure as a result of the job operations in the palm oil mills was assessed using a questionnaire that showed that the level of noise exposure in the palm oil mills translated into interference with communication, tinnitus, ringing sensations, and noise stress effects on workers. Considering the crucial role palm oil plays in human food availability, foreign exchange earnings, and national economic development, workers' health must be protected from the ill effects of noise. This study, therefore, recommended the use of personal protective devices such as ear mufflers to reduce the intensity of noise exposure for the workers.

CONFLICT OF INTEREST

The authors declare no potential conflicts of interest regarding the research, authorship and/or publication of this article.

DATA AVAILABILITY

The data used to support the findings of this study are included within the article.

AUTHOR'S CONTRIBUTIONS

All authors are contributed equally to bring out this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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