Original Article

An Overview of Industrial Employees' Exposure to Noise in Sundry Processing and Manufacturing Industries in Ilorin Metropolis, Nigeria

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Abstract: In this work, an overview of industrial employees' noise exposure level in five selected processing and manufacturing industries in Ilorin are evaluated and compared. Emphasis is given to noise emitted by individual industrial machinery from the selected industries. Event L_{Aeq} and LN cycle were studied to identify the noisy machines and to generate baseline data. Findings show that, hammer mill machine from mineral crushing mills produced the highest average noise (98.4 dB(A), electric generator1 (95.6 dB(A) from soft drink bottling industry, electric generator (97.7 dB(A)) from beer brewing and bottling industry, vacuum pump (93.1 dB(A)) from tobacco making industry and electric generator 2 (94.1 dB(A) from mattress making industry. The highest and lowest average noise exposure levels are recorded in mineral crushing mills (93.16 dB(A)) and mattress making industry (84.69 dB(A)) respectively. The study shows that at 95% confidence level, there is significant difference (p<0.05) in noise levels in the industries surveyed. The percentages of machines emit noise above FEPA and OSHA recommendation (90 dB(A)) are: soft drink bottling industry (83.3%), beer brewing and bottling industry (42.9%), tobacco making industry (71.4%), mattress making industry (11.1%) and minerals crushing mills (87.5%). In the past 20 years, the noise levels in soft drink bottling industry reduced by 0.58 dB(A) and that of beer brewing and bottling industry reduced by 9.66 dB(A). But that of mattress making industry increased by 2.69 dB(A). On the average, the noise level in these industries has reduced by 2.52 dB(A). The results of this study show that the noise control measures put in place have significant impact on the noise exposure level in the industries surveyed.

Key words: Noise, Noise pollution level, Industrial workers, Industrial machineries, NIHL

Introduction

Most machinery and manufacturing processes generate noise as an unwanted by-product of their output. Offensive industrial noises can generally be classified into one of four groups. They are; continuous machinery noise, high-speed repetitive actions that create intense tonal sound, flow-induced noise and the impact of a working tool on a work piece. Some typical specific examples of noise and vibration sources in the industrial envi-

rons include; combustion processes associated with furnaces, impact noise associated with punch processes, motors, generators and other electro-mechanical devices, unbalanced rotating shafts, gears, rotors, stators, steam or gas flows in piping systems, pumps, compressors, crushing machines, washing machines, vibrating panels etc[1]. The mechanisms of noise generation depend on the particularly noisy operations and equipment including crushing, riveting, punch presses, drilling, pneumatic equipment (e.g Jack hammer, chipping hammers etc), tumbling barrels, dividing and metal cutting such as punching, pressing and shearing, lathes, milling machines and

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grinders as well as filling machines, crowner machines, pumps, compressors, in-plant conveying systems etc. Equipment induced vibration is widely recognized as a health hazard. It is a physical stressor to which many people are exposed to at work place[2]. Sound fields in the workplace are usually complex, due to the participation of many sources: propagation through air (air-borne noise), propagation through solids (structure-borne noise), diffraction at the machinery boundaries, reflection from the floor, wall, ceiling and machinery surface, absorption on the surface etc.

Mechanized industry creates serious noise problems. It is responsible for intense noise indoors as well as outdoors. This noise is due to machinery of all kinds and often increases with the power of the machines. The noise may contain predominantly low or high frequencies, tonal components, be impulsive or have unpleasant and disruptive temporal sound patterns. The effect of sound pressure level generated depends on the type of the noise source, distance from the source to the receiver and the nature of working environment[3]. For a given machine, the sound pressure levels depend on the part of the total mechanical or electrical energy that is transformed into acoustical energy.

Generally, there is rise in noise levels which frequently goes along with increase output and productivity. The noise emission of industrial machinery rises non-linearly because of higher rotary and traveling speeds in machine parts. Industrial workers thus are exposed to these high noise levels because of their occupation. High level noise, not only hinders communication between workers, but, depending upon the level, quality and exposure duration of noise, it may also result in different type of physical, physiological and psychological effects on the workers[4, 5].

A number of studies have been carried out in last few decades to evaluate the occupational environment in processing and manufacturing industries and mining industries and oil and gas industries[4–10] and the results show that high percentage of industrial workers were exposed to more than 85 dB(A) noise levels. In spite of these studies, high noise levels have been traditionally taken for granted in industries in developing countries especially Nigeria. Ighoroje *et al.*[12] assessed the effects of occupational noise on hearing among selected industrial workers in Benin City, Nigeria. The subjects of this study are male and female workers in sawmills, food processing industries and marketers of recorded music who had been exposed to high levels of occupational noise for between 1–14 yr. The ambient noise levels in these workplaces was found to be over 90 dB(A) and the results showed that noise induced hearing impairment was present in 100% of the workers exposed for a period of 14 yr.

Yhdego[8] investigated the occupational noise exposure of workers in textiles industries in Tanzania. The results of the investigation indicate gross occupational exposure to noise in these industries where more than 30% of the workers are exposed to noise levels exceeding 90 dB(A). Kisku and Bhargava[10], looked into the major sources of noise producing machines of a thermal power plant. The results showed that lowest average noise (70.37 dB(A)) was found at control room while the highest average noise (95.91 dB(A)) at F.D fan. Compressors generate second highest noise of 89.98 dB(A).

Only few studies have been carried out in assessment of industrial noise exposure in Ilorin metropolis. In 1985, Saadu[13] assessed the occupational environment of news paper printing press, steel rolling mill, soft-drink bottling, match making, mattress making, beer brewing and bottling industries in Ilorin metropolis. The lowest average noise and highest average noise recorded were 82 dB(A) at mattress making industry and 98 dB(A) at beer brewing and bottling industry. The study concluded that the high noise level at beer brewing and bottling industry was due to occurrence of impulsive noise due to breaking of bottles.

This study is a follow up of the work of Saadu[13]. The prime objectives of this study are (i) to identify the major noise producing machines in some selected manufacturing and processing industries in Ilorin metropolis. (ii) to assess how much had been done over the years to combat excessive exposure of noise by industrial workers in these industries (iii) to identify and prioritize significant noise sources for which engineering/technical control can be considered. This study is considered necessary because it would allow a comparison of the measured levels with known levels already considered unsafe for man. Most of the machineries in use today in manufacturing and processing industries in Nigeria are more or less unchanged from the design of three decades ago. The only significant difference today, is that these machines now run at very high speeds. As might be anticipated, this trend towards greater speeds has resulted in higher noise levels, often exceeding 110 dB(A) in some operations. Except in industries where noise control measures are well put in place.

Materials and Methods

Study area

The study reported here was carried out at five manufacturing and processing industries (minerals crushing mills, soft drink bottling, beer brewing and bottling, tobacco making, and foam making industries) in October 2004 and June 2005 in Ilorin metropolis, the capital city of Kwara State, Nigeria. Figure 1 shows an overview of
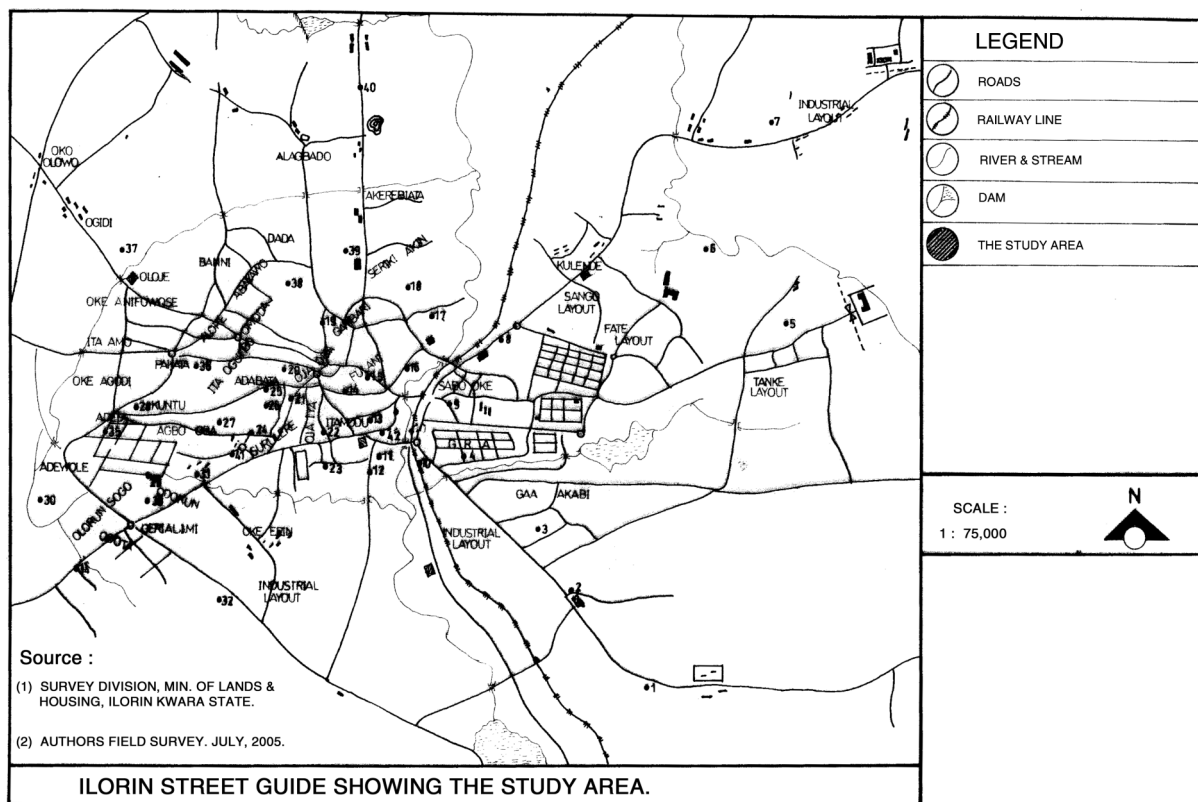
Fig. 1. Overview of Ilorin metropolis showing the locations of noise measurements.

Table 1.   Locations of selected industries for the noise measurements in Ilorin metropolis

Locations	Industries
3	Minerals Crushing Mills
	Tobacco Making Industries
7	Beer Brewing and Bottling Industry
32	Soft Drink Bottling Industry
	Mattress Making Industry

Ilorin metropolis indicating the locations of noise measurements. Table 1 shows the locations of the selected industries for the measurements. Estimates of noise levels were determined in all the work areas of the industries using a Precision Grade Sound Level Meter. Data collection through the use of questionnaire was done by passive interview of the selected employees in the industries visited. The questionnaire comprises personal information of employee, noise exposure records and site information (history of machines).

Instrumentation and noise survey

The experimental apparatus employed in the recording of noise levels in this study consisted of Precision grade sound level meter (according to IEC 651, ANSI S1.4 type), 1/2- in condenser microphone and 1/3- octave filter with frequency range and measuring level range of 31.5 Hz- 8 kHz and 35- 130 dB respectively. The instruments were calibrated internally by the internal sound level calibrator before making measurements. The desired response of the Sound Level Meter (SLM) was set to A-weighting and "slow". When measurements were made, the microphone was located in such a way as not to be in acoustic shadow of any obstacle in appreciable field of reflected waves. Noise levels were measured at the level of the employees' heads while they kept their work posture.

Monitoring Locations

A total number of 74-industrial machineries were assessed for noise emission: Minerals crushing mills (16), Soft drinks bottling industry (12), Beer brewing and bottling industry (14), Tobacco making industry (14) and Mattress making industry (18). These locations are shown in Tables 2–6 with noise exposure pattern of noise sources/machines.

Subjects

The participants in the study were workers in minerals crushing mills, soft-drinks bottling, Beer brewing and bottling, tobacco making and foam making industries oper-

Table 2.   Noise exposure pattern of different machines in Minerals Crushing Mills in Ilorin metropolis

Monitoring Location	Noise source	No.	Noise Exposure Pattern
Generator house	Generator	1	Steady continous state
Vibratory crusher & Grinder operator site	Crusher	1	Steady cyclic state
	Vibratory miller	1	Steady cyclic state
	Blower	1	Steady continous state
	Electric motor	1	Steady continous state
	Vibratory grinder	1	Impulsive
Crushing & Sucking machine operator site	Crusher	1	Steady cyclic state
	Sucker	1	Impulsive
	Electric motor	1	Steady continous state
Vibratory grinding & Filling machine operator site	Blower	1	Steady continous state
	Filling machine	1	Impulsive
	Vibratory miller	1	Steady continous state
	Electric motor	1	Steady continous state
Hammer mill machine operator site	Milling machine	1	Steady cyclic state
	Electric motor	1	Steady continous state
	Hammer blow	1	Impulsive

Table 3.   Noise Exposure pattern of different machines in Soft drink Bottling Industry in Ilorin metropolis

Monitoring Location	Noise source	No.	Noise Exposure Pattern
Washing machine	Washing machine	2	
Operator site	Washing m/c I		Time varying/Impulsive
	Washing m/c II		Time varying/Impulsive
Case Parker operator site	Case Parking m/c	1	Time varying/Impulsive
Full-Sighter operator site	Full-Sighting m/c	1	Time varying/Impulsive
Generator house	Generator	2	
	Generator I		Steady continous state
	Generator II		Not in use
CO_2 Plant house	CO_2 Compressor	1	Steady continous state
	NH3 Compressor	1	Steady continous state
	Pumps	3	
	Pump I		Steady continous state
	Pump II		Steady continous state
	Pump III		Steady continous state
Boiler room	Boiler	1	Steady continous state
Filler & Crowner operator site	Filling & crowning m/c	1	Time varying/impulsive

ating in different locations in Ilorin metropolis. Workers aged between 25–50 yr who had spent between six months to seven years in any of the five industries visited were interviewed. A structured bio-data, daily noise exposure level and machine information questionnaire to elicit information from the selected workers was used. Administering of the questionnaire was done by passive interview of the employees in the industries visited. The questionnaire is of three divisions. This is shown in Table 7.

Procedure for assessing employee's noise dose
Time-varying noise exposure
   In the case where workers experience time-varying

noise exposure because the noise is cyclical or varies unpredictably at their work station or because they move around the department or plant in performing their job, the ISO R1999[13] standard provides for summing the series of partial exposure that such workers receive during their work period. The noise levels so measured should be grouped in classes with width of 5 dB each, the level and total duration within the week being recorded for each class. The total duration of exposure of each class in a week is then converted to partial noise exposure index utilizing table of partial noise exposure indices. The composite noise exposure index is then added up and the corresponding equivalent continuous sound level,

Table 4. **Noise Exposure pattern of different machines in Beer brewing & Bottling Industry in Ilorin metropolis**

Monitoring Location	Noise source	No.	Noise Exposure Pattern
Washing machine	Washing machine	1	Time varying/impulsive
Operator site Case Parker operator site	Case Parking m/c	1	Time varying/Impulsive
Full-Sighter operator site	Full-Sighting m/c	1	Time varying/Impulsive
Generator house	Generator	2	
	Generator I		Steady continous state
	Generator II		Not in use
Production hall	Air Compressor	4	
	AC 1		Steady continous state
	AC 2		Steady continous state
	AC 3		Steady continous stste
	AC 4		Steady continous state
	NH3 Compressor	2	
	AMC 1		Steady continous state
	AMC 2		Steady continous state
	Pump	1	Impulsive
Boiler room	Boiler	2	
	BL 1		Steady continous state
	BL 2		Not in use
Filler & Crowner operator site	Filling & crowning m/c	1	Time varying/impulsive
Labeling machine operator site	Labeling m/c	1	Time varying

Table 5. **Noise Exposure pattern of different machines in Tobacco Making Industry in Ilorin metropolis**

Monitoring Location	Noise source	No.	Noise Exposure Pattern
Production hall	Vacuum pump	1	Steady continous state
	Vacuum compressor	2	
	VC 1		Steady continous state
	VC 2		Steady continous state
	Air compressor		Intermittent
	Automatic tobacco		
	Fixing machine	1	Steady continous state
	Mechanical fixing		
	Machine (LOF)	1	Steady/Cyclic
Generator house	Generator	6	
	Gen. 1		Steady continous state
	Gen. 2		Not in use (faulty)
	Gen. 3		Steady continous state
	Gen. 4		Steady continous state
	Gen. 5		Steady continous state
	Gen. 6		Steady continous state
Packaging machine operator site	Automatic packaging		
	Machine	1	Intermittent
Boiler room	Boiler	2	
	BL 1		Steady continous state
	BL 2		Steady continous state

L_{Aeq}, was read from the chart of relationship between equivalent continuous sound level and composite noise exposure index.

The above procedure was applied in computing the equivalent continuous sound level (non-impulsive noise), L_{Aeq}, in the industries surveyed. Tables 8–12 show the computed equivalent continuous sound level (L_{Aeq}) for the industries surveyed.

Table 6. Noise Exposure pattern of different machines in Mattress Making Industry in Ilorin metropolis

Monitoring Location	Noise source	No.	Noise Exposure Pattern
Sowing & Knitting hall	Sowing & Knitting m/c	9	
	SKM1		Steady continous state
	SKM2		Steady continous state
	SKM3		Steady continous state
	SKM4		Steady continous state
	SKM5		Steady continous state
	SKM6		Steady continous state
	SKM7		Steady continous state
	SKM8		Steady continous state
	SKM9		Steady continous state
	Cutting machine	1	Steady continous state
	Electric motor	1	Steady continous state
Generator house	Generator	2	
	Gen.1		Steady continous state
	Gen.2		Steady continous state
Automated foam			
Production machine	Automated foam		
Operator site	production m/c	1	Steady continous state
Inventory/packaging centre	Trolleys	4	
	TR1		Steady continous state
	TR2		Steady continous state
	TR3		Steady continous state
	TR4		Steady continous state

Table 7. Questionnaire or personal interview

(A) Personal Details (Employee's Bio data)

1. Name of Industry --------   2. Type -----------------

3. Address ---------------   4. Name of employee -----------

5. Age-------------   6. Post and duty perform ----------

7. Number of hours spent on operation per day ---------

8. Number of working days/week -----

9. Number of years/months spent -----

(B) Employee's Daily Noise Exposure Levels:

1. Steady continuous noise level -------   2. Impulse noise level ----------

3. Number of occurrence (per hour) of impulsive noise -------

(C) Employee's Working Environment:

1. Name of machine ----------   2. Date of installation ---------

3. Type of installation -----   4. Average working hour per day ----

5. Type of maintenance--------   6. Maintenance period -----------

7. Vibration assessment ----------

Impulse Noise Level

The new Draft International Standard, "Determination of occupational noise exposure and estimation of noise — induced hearing impairment" (ISO/DIS 1999–1981) stipulates that so far the un-weighted instantaneous sound pressure level does not exceed 145 dB(A), impulse noise and non-impulse noise should not be considered independently but should be included in the A-weighted daily noise exposure averaged on an equal energy basis.

The draft recommendation, in effect, permits the combination of exposures to different kinds of noise in the same daily duration for estimating the sound exposure level (SEL), L_{Aeq} (8 h), which is defined as equivalent A-weighted exposure level for an 8-h daily working period. This is given by[13]:

Table 8.   Exposure Records Table of Employee in Beer brewing and bottling industry

Noise Source	Noise Level in dB(A)		
	L_{A5}	L_{A95}	L_{Aeq}
Boiler	90.1	80.2	85.1
Air Compressor1	89.8	80.1	84.9
Air Compressor2	89.5	79.8	84.9
Air Compressor3	90.2	80.1	86.2
Air Compressor4	90.2	80.1	86.2
Ammonia Compressor1	89.8	80.1	84.9
Ammonia Compressor2	90.1	80.2	85.1
Pump	99.7	85.2	93.2
Electricity Generator	100.1	95.3	97.7
Filling & Crowning M/c	95.3	85.1	94.6
Washing M/c	94.9	85.2	92.5
Full Sighting M/c	94.8	85.1	92.8
Case Packing M/c	99.9	85.1	94.1
Labeling M/c	90.3	80.4	87.2
Mean	93.19	82.64	89.2

Table 9.   Exposure Records Table of Employee in Soft Drink bottling industry

Noise Source	Noise Level in dB(A)		
	L_{A5}	L_{A95}	L_{Aeq}
Boiler	89.9	80.3	85.6
Carbon Dioxide Compressor	89.7	80.3	85.4
Ammonia Compressor	95.2	85.1	92.2
Pump 1	94.8	84.9	89.5
Pump 2	94.8	84.9	89.5
Pump 3	95.1	85.2	90.9
Electricity Generator 1	100.2	90.2	96.5
Electricity Generator 2	Not in use	—	—
Filling & Crowning M/c	95.4	90.1	93.5
Washing M/c 1	94.8	85.1	92.5
Washing M/c 2	94.8	85.1	92.5
Full Sighting M/c	94.9	85.2	92.8
Case Packing M/c	99.7	85.1	94.1
Mean	94.94	85.13	91.18

$$L_{Aeq}(8h) = 10\log_{10}\left[\frac{1}{8}\sum_{j=1}^{j=q}\left(anti\log\frac{L_{Aj}}{10}\right)t_j \right.$$

$$\left. + \frac{1}{N}\sum_{i=1}^{i=k}\left(anti\log\frac{L_{Ai}}{10}\right)n_i\right] \qquad (1)$$

Where

L_{Aj} is the A-weighted sound pressure level of a continuous noise

t_j is the duration of L_{Aj} in hours, $\sum_{j=1}^{j=k} t_j = 8$ *hours*

q is the number of different values of L_{Aj}

L_{Ai} is the A-weighted sound pressure level (peak) of a single impulse noise

Table 10.   Exposure Records Table of Employee in Tobacco making industry

Noise Source	Noise Level in dB(A)		
	L_{A5}	L_{A95}	L_{Aeq}
Boiler 1	90.4	89.2	90
Boiler 2	94.8	89.8	90.6
Vacuum pump	105.1	80.1	94.2
Vacuum Compressor 1	94.9	85.1	91.4
Vacuum Compressor 2	95.1	85.2	92.5
Auto Fixing M/c	94.8	89.9	90.6
Mechanical Fixing M/c	84.7	83.6	84.8
Electricity Generator 1	104.8	80.1	92.9
Electricity Generator 2	Not in use	—	—
Electricity Generator 3	104.7	79.9	92.3
Electricity Generator 4	104.9	80.3	93.2
Electricity Generator 5	104.9	80.4	93.5
Electricity Generator 6	104.8	80.1	92.8
Air Compressor	90.1	80.2	84.9
Packing M/c (Automated)	90.1	85.3	88.5
Mean	97.44	89.23	90.87

Table 11.   Exposure Records Table of Employee in Mattress making industry

Noise Source	Noise Level in dB(A)		
	L_{A5}	L_{A95}	L_{Aeq}
Electricity Generator 1	99.8	85.3	95.6
Electricity Generator 2	100.1	85.4	96.8
Automated foam production M/c	84.8	80.1	82.8
Trolley 1	89.9	80.3	84.4
Trolley 2	89.9	80.3	84.4
Trolley 3	90.1	80.4	84.9
Trolley 4	89.9	80.3	84.4
Sowing & Knitting M/c 1	84.8	80.1	82.8
Sowing & Knitting M/c 2	85.1	80.1	83.1
Sowing & Knitting M/c 3	84.8	80.1	82.8
Sowing & Knitting M/c 4	84.8	80.1	82.8
Sowing & Knitting M/c 5	84.8	80.1	82.8
Sowing & Knitting M/c 6	84.8	80.1	82.8
Sowing & Knitting M/c 7	84.8	80.1	82.8
Sowing & Knitting M/c 8	85.1	80.1	83.1
Sowing & Knitting M/c 9	85.1	80.1	83.1
Cutting M/c	90.2	80.2	85.1
Electric Motor	90.3	80.3	86.2
Mean	88.28	80.75	85.04

n_i is the frequency of occurrence of L_{Ai}

k is the number of different values of L_{Ai}

N is the number of values of L_{Ai} given by

$$N = \sum_{i=1}^{i=k} n_i$$

The noise exposure records of the workers in the soft drink bottling industry, minerals crushing mills and beer brewery and bottling industry were computed based on

the above equation. Tables 13 and 14 show the noise expose records.

Table 15 shows the computed L_{Aeq} (8 h) for minerals crushing mills, soft drink bottling industry and beer brewing and bottling industry where impulse noise occurred.

Table 12. Exposure Records Table of Employee in Solid Minerals crushing mills in Ilorin Metropolis

| Noise Source | Noise Level in dB(A) | | |
	L_{A5}	L_{A95}	L_{Aeq}
Electricity Generator	104.8	89.8	94.8
Vibratory Crushing M/c	105.1	90.2	101.4
Vibratory Grinding M/c	105.1	90.3	101.5
Vibratory Milling M/c	104.9	90.1	100.2
Blower 1 (Vibratory Grinding M/c)	95.1	84.9	90
Electric motor 1	95.2	85.1	91.4
Crush Feeding M/c	100.4	80.3	94.6
Sucking M/c	105.1	90.4	98.1
Electric Motor 2	95.1	84.9	91.6
Filling M/c	95.1	80.4	93.2
Blower 2 (Filling M/c)	94.9	80.1	87.1
Vibratory Milling M/c 2	95.2	80.1	91.4
Electric Motor 3	95.2	80.2	91.6
Hammer Mill M/c (Hammer Blow)	105.3	85.4	104.5
Milling M/c	100.1	90.2	94.4
Electric Motor	95.2	80.2	91.4
Mean	99.49	85.16	94.83

Results

A total number of 74-industrial machineries were assessed for noise emission: minerals crushing mills (16), soft drink bottling industry (12), beer brewing and bottling industry (14), tobacco making industry (14) and mattress making industry (18). The observed noise levels recorded during survey work for different machines in all the industries surveyed are presented in Tables 8 to 12. The noise exposure records are recorded in the form L_{Aeq} and L_N cycle. L_N cycle represents that N% of the time the noise level was below the given value of X viz. For example, boiler in beer brewing and bottling industry: L_{A5} represents that 5% of the measured time the noise level was above 90.1 dB(A) and L_{A95} represents that 95% of the measured time the noise level was below 80.2 dB(A) (Table 8). The range of the noise levels (L_{Aeq}) for the five industries is 82.8 to 104.5 dB(A) and the overall mean is 90.17 dB(A). L_{A5} and L_{A95} range from 84.8 to 105.3 dB(A) and 79.9 to 95.3 dB(A) respectively. The

Table 15. Computed impulse noise exposure

Industry	Impulse Noise Exposure (L_{Aeq} (8 h)) dB(A)
Minerals crushing mills	110.9
Soft drink bottling industry	106.7
Beer brewing & bottling industry	105.9

Table 13. Continuous Noise Exposure Records

| Exposure Levels in dB(A) | Duration of Exposure in Hours | | |
	Operators in the minerals crushing mills	Operators in the soft drink bottling industry	Operators in the Beer brewing & bottling industry
105	3.4		
100	3.5	3.0	2.5
95	4.5	3.5	3.0
90	3.9	4.0	3.5
85	3.0	2.5	2.3
80	3.3	2.4	3.1
	=21.6	=15.4	=14.4

Table 14. Impulse Noise Exposure Records

| Exposure Levels (Peak) in dB(A) | Estimation number of occurrence per day | | |
	Operators in the minerals crushing mills	Operators in the soft drink bottling industry	Operators in the Beer brewing & bottling industry
115	45		
110	28	50	40
105	63	60	50
100	52	44	45
95		30	47
	=188	=184	=182

impulsive noise varied from 105.9 to 110.9 dB(A) (Table 15), mainly due to crushing of solid minerals at minerals crushing mills and the breaking of bottles in the bottling industries. The daily noise exposure of workers in the industries surveyed except at beer brewing and bottling industry and mattress making industry exceeded the maximum exposure limits of 90 dB(A) recommended by FEPA[14] and OSHA[15].

As at the time of this measurement, the highest and lowest average equivalent continuous noise levels were 94.83 dB(A) and 85.04 dB(A) at minerals crushing mills and mattress making industry respectively. The major source of noise and the noisiest machine at mineral crushing mills was hammer blow machine (104.5 dB(A)) followed by vibratory grinding machine (101.5 dB(A)). All these machines emitted impulsive noise exposure pattern. At soft drink bottling industry, the major source of noise was electric generator (96.5 dB(A)) followed by Case packing machine (93.8 dB(A)). At tobacco making industry, vacuum pump produced the highest noise (94.2 dB(A)). This is followed by electric generator 5 (93.5 dB(A)). At beer brewing and bottling industry, the noisiest machine was electric generator (97.7 dB(A)) followed by filling and crowning machine (94.6 dB(A)). At mattress making industry, the highest noise producing machine was electric generator 2(96.8 dB(A)) followed by electric generator1 (95.6 dB(A)). Workers working in these environments and in other areas where noise exposure levels is greater than 90 dB(A), the possibility of developing a chronic health hazard problem is very high. This is because after the subjects are exposed to high noise levels, they come out from the noise source after their duty hours to an environment of lower noise level; hence, physiological change and psychological stress occurred in their system.

Analysis of Variance (ANOVA) for single factor experiment using F-distribution was carried out on L_{Aeq}. The F-value calculated is 6.19. The F-value tabulated at 95% confidence level is 2.508[16]. Since F-value tabulated is less than F-value calculated, it implies there is a significant difference ($p < 0.05$) in noise exposure levels in the industries surveyed. The result of this survey shows that 83.3% of the machines in soft drink bottling industry produced noise above 90 dB(A), while in beer brewing and bottling industry, tobacco-making industry, mattress-making industry, and minerals crushing mills, the percentage of machines that emitted noise above 90 dB(A) are 42.9%, 71.4%, 11.1% and 87.5% respectively. Based on Occupational Safety and Health Administration (OSHA) criteria, the computed daily Time Weighted Average (TWA) exposure of the industries surveyed ranges between 73.83 to 95.94 dB(A).The highest exposure to 8-h time weighted average (TWA) noise is expe-

rienced by the operator of washing machine II in soft drink industry.

Discussion

This study assessed noise emitted by various machines in selected processing and manufacturing industries in Ilorin metropolis. The average equivalent continuous noise level (L_{Aeq}) for the industries surveyed ranges between 85.04–94.83 dB(A). The workers in these industries generally work for at least 8 h/d and 6 d/wk (48 h/wk) are exposed to a high noise level. The noise exposure levels in these industries are excessively high as compared to the maximum permissible noise exposure limit of (i) 85–90 dB(A) for 40 h/wk, as suggested by ISO[17], (ii) 90 dB(A) for 40 h/wk allowed in United Kingdom[18], Denmark[19], Canada[20] and (iii) 85 dB(A) for 85 h/wk allowed by Occupational Safety and Health Act (USA)[21]. Such a high level of noise not only hinders the communication between the workers, but its long term exposure may also result in ill-effects, especially on permanent hearing threshold shift.

The hazardous nature of industrial noise in Nigeria laid credence to the formulation of permissible levels/standards by the Federal Environmental Protection Agency (FEPA) to which an employee may be subjected to[14]. The FEPA guideline is shown in Table 16. But this guideline has been violated in some processing and manufacturing industries in Nigeria due to inefficiency of the statutory body in enforcing and implementing the regulatory laws to limit high level of occupational noise and the unawareness of the workers about the ill-effects of high level of noise.

In order to assess how much had been done over the years to combat excessive exposure of noise by industrial workers in the industries surveyed, the results of this study is compared with that of Saadu[13] carried out in 1985 in the same industries. Table 17 shows the average L_{Aeq} of this study designated as 2005 and that of Saadu[13] designated as 1985.

A glance look at Table 17 reveals that noise levels at

Table 16. Noise Exposure Limits for Nigeria (FEPA)

Duration per Day (Hours)	Possible Exposure Limits (dB(A))
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Table 17. Climatic variation of industrial noise exposure levels

S/No	Industry	Mean Noise Level (L_Aeq) dB(A)	
		1985	2005
1	Soft drinks bottling Industry	91	90.42
2	Mattress making industry	82	84.69
3	Beer brewing & bottling industry	98	88.34

Soft drink bottling industry reduced by 0.58 dB(A) and that of beer brewing and bottling industry reduced by 9.66 dB(A). But that of mattress making industry increased by 2.69 dB(A). The overall statistical analysis using t-distribution, t_{cal} = 3.79 and t_{tab} = 2.92 at 95% confidence level[22]. Since $t_{cal} > t_{tab}$, there is significant difference ($p<0.05$) in noise exposure level in the industries surveyed between 1985 and 2005. This shows that noise control measures put in place in some of these industries have significant effect in abating the employees' noise exposure level. On the overall average, the noise level reduced by 2.52 dB(A). Some of the control measures put in place as observed and from information received from personal interview of workers during the survey in some of these industries include: (i) regular servicing and maintenance of machine parts (ii) replacement of worn-out parts (iii) provision of proper acoustic lining to reduce noise reflection in the production hall (ii) vacuum pump room is sound-proofed sealed and provided with louver-air intake.

Policy Guidelines on Machinery Operation

Despite the fact that the overall analysis of this study shows that the noise exposure level has reduced by 1.92 dB(A) in the past 2-decades in the industries surveyed, the present state of noise level is still dangerous to human health. Due to adverse effects of noise and vibration of industrial machines on the industrial employees and environment, it is highly necessary to employ means to minimize the noise and vibration emit by these industrial machineries, as it is not possible to eliminate these occupational hazards. The following recommendations are made in order to further reduce noise exposure level: (i) Green belt design (GBD). A wide green belt of thick vegetation can be produced around the factory premises. This will absorb to a large extent and dissipate sound energy and thus act as buffer zone. A tree belt 50 m wide and of different height can reduce the noise level up to 20–30 dB(A)[23, 24]. GBD will reduce the noise intensity by creating obstruction in its transmission path. (ii) Sound absorbing material. Outer surfaces of control room should be covered with sound absorbent material

e.g glass wool (higher density) covered with perforated aluminum sheet. Also, multiple wall construction with enclosed air spaces provides considerably more attenuation than the single-wall mass law will predict[24]. (iii) Fabrication of new engines. Designing and Fabrication of new engines and by setting a noise limits at least 5–10 dB(A) below the prescribed standard can be helpful in controlling noise exposure level[25]. Also, transmission control may be achieved by covering room walls with acoustic tiles as sound absorbers. (iv) noise protective measures. The irregular/not use of safety measures are a common scenario in most of the industries where rules and regulations are liberal hence authority can make it mandatory to use one or other type of noise protective measure at noisy places. Employees must be made aware and educated about noise nuisance through adequate publicity. Normal duty hours can be reduced at high noise generating sources. Preferably, shifting of duty from equipment to another on alternate days as not to operate same equipment every day should be practiced.

Conclusion

In this study, we have described the level of noise pollution in selected processing and manufacturing industries in Ilorin metropolis. The average noise exposure level (L_Aeq) in minerals crushing mills, soft drinks bottling, beer brewing and bottling and tobacco making industries is found to be above 85 dB(A). This noise level is well above the healthy noise level of 60 dB(A) recommended by World Health Organization (WHO). The workforce in the industries included in this study are at high risk of developing noise induced hearing loss (NIHL) and other associated ailments due to excessive occupational exposure to noise.

There is need to develop and apply a well defined, comprehensive and enforceable noise regulation. The limit of 90 dB(A) for 8 h/d stipulated by OSHA (also stated by Nigerian Factories Act 1960) has to be followed with a caution as working hours in most of the processing and manufacturing industries in Nigeria are 8 h/d and 48 h/wk. Total working hours per week in Nigeria are about 20% more than those in USA or European countries (operating 40 h/wk).

In order to provide safety measures to the workers in these industries, the limit of 90 dB(A) for 40 h/wk has been recommended in old industries in this study. It is also suggested that (i) Outer surfaces of control room should be covered with sound absorbent material e.g glass wool (higher density) covered with perforated aluminum sheet. Also, multiple wall construction with enclosed air spaces should be provided. This provides considerably more attenuation than the single-wall. (ii) A wide green

belt of thick vegetation can be produced around the factory premises. (iii) Designing and Fabrication of new engines and by setting a noise limits at least 5–10 dB(A) below the prescribed standard. (iv) Noise protective measures should be put in place.

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