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PUBLIC HEALTH HAZARDS OF EQUIVALENT CONTINUOUS NOISE LEVELS AT INDUSTRIAL WORKPLACES IN JOS, NIGERIA

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ABSTRACT
The equivalent continuous noise levels of nine companies/industries in Jos-Bukuru metropolis were investigated using the *Brüel & Kjaer* Impulse Precision Sound Level Meter Type 2209 in conjunction with ⅓-Octave Filter set, Type 1616. The measurements showed that the noise was essentially broad-band, continuous and steady-state; and the equivalent continuous noise levels in all the workplaces, excepting one, were higher than the proposed 70dBA as an 8-hr time-weighted average. Sound exposure levels, daily noise doses, and time-weighted averages determined for the studied workplaces were considered high and capable of causing noise-induced hearing loss among the workers.
Keywords: Noise level, workplace, exposure risk, occupational hazard, impaired hearing.

INTRODUCTION
Noise in industrial environments has increased significantly over the years due to increased mechanization and there is corresponding increase in concern over this. Part of this concern stems from the recognition of noise as an environmental pollutant that could be damaging to individual well-being. More important is the mounting evidence that excessive noise causes not only hearing damage, accelerated deafness and decreased worker efficiency, but other severe physiological and psychological damage as well (Alberti, 1998; Berger *et al.*, 1978; Coles *et al.*, 1968; Cunniff, 1977; Ebeniro and Abumere, 1999). The effects of noise on human emotions range from negligible, through annoyance and anger to psychologically disruptive. Physiologically, noise can range from harmless to painful and to physically damaging (Kinsler *et al*., 1982). People who work in most manufacturing industries are very much exposed to high level noise. Some of these people are exposed to an average of 85dB or more. Often there is a lack of concern for these workers because not all cases of hearing impairment are apparent. The monitoring of worker's hearing on-the-job is usually poor and hearing loss had often been under reported. Many companies that needed hearing protection programs do not have them (Nash, 2000).Thus noise pollution which is a growing problem in the world today has both immediate and cumulative adverse effects on health. However, noise being a common environmental pollutant is almost an inescapable by-product of industrial mechanization. Unlike other forms of environmental pollutants, noise does not physically accumulate in the atmosphere but its effects are numerous (Priest, 1973). It has been demonstrated in so many studies that prolonged exposure to noise can result in a persistent shift in the threshold of hearing (Coles *et al.*, 1968; Passchier-Vermeer, 1974; Ward, 1975; Berger *et al*., 1978; Stevin, 1982; Alberti, 1998; Nash, 2000; Chagok and Gyang, 2012; Chagok *et al*., 2013). However, noise-induced hearing loss is a gradual, painless and cumulative phenomenon so much that the victim is hardly aware of what is happening until it is too late. In view of federal government interest in environmental protection as evidenced by the establishment of Federal Environmental Protection Agency (FEPA)

and National Environmental Standards and Regulations Enforcement Agency (NESREA), results would provide a concrete basis for advising the Federal, State and Local Governments in the country to enact practicably enforceable legislation – i.e. specifying levels aimed at controlling the noise levels experienced by citizens, the goal of which is the protection of the citizen's hearing. Exploratory studies of Chagok and Gyang (2012) involving some companies in Jos established a definite relationship between threshold shift and duration of exposure, the level and pattern of noise being invariant (on a cyclic daily basis) throughout the duration for a wide range of exposure. The relations so established permit the calculations of statistical distributions of noise-induced pure-tone threshold shift at various audiometric frequencies for a population exposed for a specified time to a specified noise level, including allowance for age. Chagok and Gyang (2013) therefore recommended for promulgation by regulatory agencies for occupational noise exposure 70dBA as an 8-hour time weighted average. The daily noise exposures in the mills consist of exposures to different noise levels for different durations and are therefore put in the form of noise dose (D). This permits a reliable estimation of the employees' daily equivalent exposure. The equivalent continuous noise level of a time-varying noise L_{eq} is given by Cunniff (1977) as

$$L_{eq} = 10\log_{10}\frac{1}{T}\int_0^t\left(\frac{P_a}{P_0}\right)^2 dt \quad \ldots\ldots\ldots\ldots (1)$$

This translates to

$$L_{eq} = 10log_{10}\left(t_1 x 10^{\frac{L_1}{10}} + t_2 x 10^{\frac{L_2}{10}} + \cdots + t_n x 10^{\frac{L_n}{10}}\right)/T \quad (2)$$

T is the total time, i.e. $\sum t_i$ and t_i is the time in hours the workers work in a section whose sound level reading is L_i.

To obtain an expression for the sound exposure level (L_E), the sound exposure, E, defined by Stevin (1982) as the time integral of the squared sound pressure $P^2(t)$ over a stated time T given in equation 2.2 was used.

$$E = \int_o^T P^2(t)dt \quad \ldots\ldots\ldots\ldots (3)$$

This is essentially an estimate of the sound energy associated with the noise over the time T. The sound exposure level is the expression in decibels of the ratio of the weighted sound exposure to the reference sound exposure. The reference sound exposure (E_0) is equal to the product of the squared reference sound pressure (P_0) of 20μP_a and the reference duration (t_0) of one second.

That is, $E_0 = P_0^2 t_0 = P_0$ …… (4)

The A-weighted sound exposure level L_{AE} is therefore

$$\begin{aligned} L_{AE} &= 10\log\left(\int_o^T P^2(t)dt \Big/ P_o^2\right) \\ &= 10\log\left[\left(\frac{P}{P_o}\right)^2 T\right] \\ &= \log\left(\frac{P}{P_o}\right)^2 + 10\log T \\ &= L_A + 10\log T \quad \ldots\ldots\ldots\ldots (5) \end{aligned}$$

When the daily noise exposure consists of periods of different noise levels, the daily dose (D) shall not equal or exceed 100, as calculated according to

$$D = \left[\sum \frac{t_i}{\tau_i}\right] x100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

t_i is the total time of exposure at a specified noise level and τ_i is the exposure duration for which noise at this level becomes hazardous. Time τ_i was derived (Chagok et al., 2013a) as

$$\tau_i = \frac{28800}{2^{\frac{(L-70)}{3}}}\ s \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The daily dose can be converted into an 8-hr time weighted average (TWA) according to the expression

$$TWA = 10log\left(\frac{D}{100}\right) + 70 \quad \ldots\ldots\ldots\ldots (8)$$

The 70 in equation (4) comes from the recommended occupational noise exposure

of 70dBA as an 8-hr time-weighted average (Chagok and Gyang, 2013).

MATERIALS AND METHODS

Chagok and Gyang (2012; 2013) reported the measurement of A-weighted Sound Pressure Levels and Sound Spectrum Levels, at machine-operator positions in some companies/industries in Jos, Nigeria using *Brüel & Kjaer* Impulse Precision Sound Level Meter Type 2209 in conjunction with ⅓-Octave Filter set, Type 1616 and the audiometric tests of selected workers carried out using Beltone 112 Audiometer. The background noise levels during all tests satisfied the octave band level requirements of ANSI S3.1-1977. From the outcome of these empirical studies, a damage risk criteria of 70dBA was proposed for exposure to steady-state broad-band noise by regulatory agencies (Chagok and Gyang, 2013) and was used to compute trade-off between equivalent noise levels and time of exposure for zero noise-induced hearing loss (Chagok *et al*., 2013a). Also, monaural impairment and handicap for exposure to noise were computed (Chagok *et al.*, 2013b). In this work, these results were used for the computation of the daily noise dose (D) and the time-weighted average (TWA) of the companies/industries.

RESULTS AND DISCUSSION

The equivalent sound pressure levels of the work environments in the companies/ industries were determined using equation (2) as employees were not confined to only one work station. The time that a typical employee spent at a location was estimated from data supplied (during interview) by the foremen and supervisors of the companies/industries. Table 1 shows the equivalent continuous noise levels of the workplaces obtained using equation (2), exposure level obtained using equation (5), noise dose obtained using equation (6) and the time-weighted average obtained using equation (7). In all the companies/ industries except D_2, the equivalent continuous noise level is more than 70dBA with very high dosages in percentages. This implies that the work environments were capable of causing noise annoyance and noise-induced hearing loss. It may be noted that the time-weighted average (TWA) is approximately the same with the equivalent continuous noise level (L_{eq}).

Table 1: Time-Weighted Average (TWA) and Dose (D) for the Companies/Industries

MILL	L_A	L_{AE}	D%	TWA
A_1	92	137	12100.84	90.82
A_2	87	132	5088.34	87.07
A_3	90	135	10176.68	90.08
B_1	85	130	3200.00	85.05
B_2	89	134	8067.23	89.98
C_1	89	134	8067.23	89.07
C_2	86	131	4033.61	86.06
D_1	75	120	317.50	75.02
D_2	67	112	50.00	66.99
E_1	102	147	169411.76	102.29
E_2	106	151	411428.57	106.14
E_3	104	149	261818.18	104.19
F_1	100	145	102857.14	100.12
F_2	98	143	65454.55	98.16
F_3	97	142	32359.55	95.10
G_1	94	139	25714.29	94.10
G_2	88	133	6857.14	88.36

CONCLUSION

The noise dosage in most work environments in companies/industries is not known and workers may be exposed to noise levels that may be damaging to their hearing mechanism resulting to noise-induced hearing loss. Physical measurements of sound noise pressure levels showed that most factory workers are exposed to hazardous levels of noise. For hearing conservation, the dosage of industries/companies in which workers work must always be less than 100%. However, if the dosage is more than 100%, hearing protection must be provided by the employers and the employees are encouraged to use them. The authors suggest that:

i. Noise assessment of workplaces be carried out regularly.

ii. Employers should provide hearing protection and employees should develop the habit of using the hearing protection provided if the dosage assessed is 100% and above.

iii. Regulatory agencies must also be alive to their responsibilities of ascertaining that companies/ industries comply with the standards.

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