DAILY NOISE DOSE AS AN 8-HOUR TIME-WEIGHTED AVERAGE FOR HEARING CONSERVATION

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Abstract

In this paper, the dose range of 20% to 30000000% was considered corresponding to a time-weighted average range of 63dBA to 124.8dBA. This range represents a typical exposure dosage range in most industries/companies in Jos (Chagok, 2010) and possibly Nigeria and other developing countries. The doses and their corresponding time-weighted averages confirm the 3dBA doubling rate and also support the Equal Energy Hypothesis (EEH).

Index Terms: Daily, dose, equivalent noise level, hearing conservation, hearing loss, noise, time-weighted average.

Introduction

Noise is a common environmental pollutant and 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). 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). Generally, today's environment exposes each of us to noise levels that may damage our hearing, interfere with activities in our daily lives and may degrade the quality of our life-style. Therefore, noise effects are no longer studied simply as constituting an occupational health problem, in which a workman's hearing, is damaged due to long-term exposure on the job, instead it encompasses all effects of noise including both in-door and outdoor environments inhabited by beings (Chagok *et al.*, 2013b). 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.*, 2013a). The greater the intensity of the noise the greater the probable threshold shift is intuitively reasonable and factually demonstrable from the results of investigations where different noise-exposed groups were studied under common

audiometric and test protocol (Chagok and Gyang, 2012; 2013).

An important part of any noise control program is the establishment of appropriate criteria for the determination of an acceptable solution to the noise problem. Thus, where the total elimination of noise is impossible, appropriate criteria provide a guide for determining how much noise would be acceptable. At the same time, criteria provide the means for estimating how much reduction will be required. The required reduction in turn provides the means for determining the feasibility of alternative proposals for control, and finally the means for estimating the cost of meeting the relevant criteria (Smith *et al*., 1996). From the systematic studies of Chagok and Gyang (2013), it has been possible to establish 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) recommended for promulgation by regulatory agencies for occupational noise exposure 70dBA as an 8-hour time weighted average. This was not, however, put in the form of noise dose. The daily noise exposures in the mills consist of exposures to different noise levels for different durations. To quantify the noise exposure, the daily noise dose (D) was used. 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

$$L_{eq} = 10log_{10}\left(t_1x10^{\frac{L_1}{10}} + t_2x10^{\frac{L_2}{10}} + \cdots + t_nx10^{\frac{L_n}{10}}\right)/T \quad \ldots (1)$$

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.

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

$$D = \left[\frac{t_1}{\tau_1} + \frac{t_2}{\tau_2} + \frac{t_3}{\tau_3} + \cdots + \frac{t_n}{\tau_n}\right] x100 = \left[\sum \frac{t_i}{\tau_i}\right] x100 \ldots (2)$$

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.

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

$$TWA = 10log\left(\frac{D}{100}\right) + 70 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The 70 in equation (2) comes from the recommended occupational noise exposure of 70dBA as an 8-hr time-weighted average.

Methods and Materials

Pure tone audiometry was used to establish hearing thresholds at 250Hz, 500Hz, 1000Hz, 2000Hz, 4000Hz and 8000Hz for noise exposures. Chagok and Gyang (2012; 2013) reported the measurement of A-weighted Sound Pressure Levels and Sound Spectrum Levels, at machine-operator positions in companies/industries 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 empirical study of Chagok and Gyang (2012; 2013), a damage risk criteria of 70dBA was proposed for exposure to steady-state broad-band noise by regulatory agencies and was used to compute the monaural impairment and handicap for exposure to noise (Chagok *et al.*, 2013c). Results of the empirical work were used for the computation of the daily dose (D) and the time-weighted average (TWA).

Results and Discussion

Dose range of 20% to 30000000% was considered and corresponding time-weighted average range of 63.0dBA to 124.8dBA computed are as shown in table 1. This range corresponds to the typical exposure dosage range in most industries/companies in Jos (Chagok, 2010). From the table, it may be noted that a dose of 100% corresponds to a time-weighted average of 70dBA, an 8-hr time-weighted average at and or below which there will be no noise-induced hearing loss. Interestingly, a dose of 200% corresponds to a time-weighted average of 73dBA, confirming the 3dBA doubling rate. This is also true for all the computed values. Noise-induced hearing loss begins to occur at any dose higher than 100%, i.e. at any time-weighted average higher than 70dBA.

Table 1: Dose (D) and Time-Weighted Average (TWA) for Noise Exposure

Dose (%)	TWA (dBA)	Dose (%)	TWA (dBA)	Dose (%)	TWA (dBA)
20	63.0	2500	84.0	400000	106.0
30	64.8	3000	84.8	450000	106.5
40	66.0	3500	85.4	500000	107.0
50	67.0	4000	86.0	600000	107.8
60	67.8	4500	86.5	700000	108.5
70	68.5	5000	87.0	800000	109.0
80	69.0	6000	87.8	900000	109.5
90	69.5	7000	88.5	1000000	110.0
100	70.0	8000	89.0	1100000	110.4
110	70.4	9000	89.5	1200000	110.8
120	70.8	10000	90.0	1300000	111.1
130	71.1	12000	90.8	1400000	111.5
140	71.5	13000	91.1	1600000	112.0
150	71.8	14000	91.5	1800000	112.6
170	72.3	16000	92.0	2000000	113.0
200	73.0	18000	92.6	2200000	113.4
250	74.0	20000	93.0	2400000	113.8
300	74.8	25000	94.0	2600000	114.1
350	75.4	30000	94.8	2800000	114.5
400	76.0	35000	95.4	3000000	114.8
450	76.5	40000	96.0	3500000	115.4
500	77.0	45000	96.5	4000000	116.0
600	77.8	50000	97.0	4500000	116.5

650	78.1	60000	97.8	5000000	117.0
700	78.5	70000	98.5	6000000	117.8
750	78.8	80000	99.0	7000000	118.5
800	79.0	90000	99.5	8000000	119.0
900	79.5	100000	100.0	9000000	119.5
1000	80.0	110000	100.4	10000000	120.0
1100	80.4	120000	100.8	12000000	120.8
1200	80.8	130000	101.1	14000000	121.5
1300	81.1	140000	101.5	16000000	122.0
1400	81.5	150000	101.8	18000000	122.6
1500	81.8	160000	102.0	20000000	123.0
1600	82.0	180000	102.6	22000000	123.4
1700	82.3	200000	103.0	24000000	123.8
1800	82.6	250000	104.0	26000000	124.1
1900	82.8	300000	104.8	28000000	124.5
2000	83.0	350000	105.4	30000000	124.8

Conclusion and Recommendations

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. Equation (2) or table 1 could be used to estimate the values for the dose (d) and the corresponding time-weighted average (TWA). 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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