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Trade-Off between Steady-State Broadband Noise Levels and Time of Exposure for Zero Noise-Induced Hearing Loss

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Abstract

In this work expressions for damage risk criteria and trade-off between the sound pressure levels and times of exposure for zero noise-induced hearing loss were derived. The expression for the damage risk criteria was used to compute the criteria risk values at octave frequencies between 250Hz and 8000Hz for males and females. The expression for the trade-off was used to compute the maximum times of exposure for sound pressure levels from 65 dBA to 112 dBA. This trade-off between noise sound pressure levels and corresponding times of exposure obtained from this work were obtained from the damage risk criteria which were determined from empirical values. Results show that workers should not be exposed to noise levels that are more than 112 for more than one second if the workers' hearing is to be conserved. The expression supports the Equal Energy Hypothesis (EEH) and the 3dBA exchange rate.

Key Words: Trade-Off, Hearing Loss, Noise Levels, Broadband Noise, Induced noise.

1. Introduction

Considerable research has been done over the years on the dangers of sound noise (Coles et al., 1968; Kryter, 1973; Passchier-Vermeer, 1974; Ward, 1975; Cunniff, 1977; Berger et al., 1978; Schultz, 1978; Schultz, 1982; Stevin, 1982; Kinsler et al., 1982; Kryter, 1982a; 1982b; Alberti, 1998; Ebeniro and Abumere, 1999; Onuu and Menkiti, 1993; 1996; 1997; Menkiti, 1994; Onuu, 1999; Nash, 2000; Obisung et al, 2007) and the cause and effect relationship between noise exposure and noise-induced hearing loss has been appreciated with an empirical relation developed by Chagok and Gyang (2012) for the octave band frequencies important for speech recognition. The term noise is used to refer to an unpleasant or unwanted sound. However, in the context of the medical literature, noise has come to refer to an excessively intense sound capable of producing damage to the ear. The amount of sound that is capable of producing cochlear damage and subsequent hearing loss is related by the damage risk criteria which are based upon the equal energy concept. That is to say that it is the total sound energy delivered to the cochlea that is relevant in predicting injury and hearing loss. An intense sound that is presented to the ear for a short period of time and a less intense sound that is presented for a longer period of time will produce equal damage to the inner ear. Chagok (2010) recommended for promulgation by regulatory agencies for occupational noise exposure 70dBA as an 8-hour time weighted average.

The noise exposure level (L_E) derived by Chagok (2010) for A-weighted sound pressure level for duration of time T in seconds is given as

$$L_E = L_A + 10logT \quad \text{.. (1)}$$

2. Materials and Methods

Data were collected which permitted the establishment of a relationship between occupational noise exposure to the resulting noise-induced hearing loss. Physical measurement of sound levels was done on the shop floors of companies and at the sites of industries within Bukuru and Jos metropolis which were identified to use machinery that generate high levels of noise and had also granted permission for the research to be carried out in their premises as reported in Chagok and Gyang (2012). Overall A-weighted Sound Pressure Level and Sound Spectrum Levels were measured, at machine-operator positions in the companies/industries included in the research, using a *Brüel & Kjaer* Impulse Precision Sound Level Meter Type 2209 in conjunction with $\frac{1}{3}$-Octave Filter set Type 1616.

The Pistonphone Type 4220 which generates 124dB±0.2dB at a frequency of 250Hz was used to calibrate the sound level meter. Measurements were taken during the usual business hours of 8:00 am and 5:00 pm, when the companies/industries were in production. Care was taken so that the measurements were made with the minimum interference with normal working patterns as possible and none of the measurements was influenced by external noise, such as aircraft or road traffic noise. These measurements were repeated on subsequent visits to confirm the values obtained.

The audiometric tests were conducted by a trained audiometric technician, supervised by a consultant within the ENT Unit of Evangel Hospital; Jos using Beltone 112 Audiometer. The background noise levels during all tests satisfied the octave band level requirements of ANSI S3.1-1977. Five hundred and twenty four (524) workers were tested out of a total of seven hundred and ninety one (791) workers interviewed.

The audiometric test results obtained from this investigation showed that workers in some factories and industries in the Jos metropolis were being exposed to occupational noise hazards leading to a measurable NIHL over and above any age effect as reported in Chagok and Gyang (2012).

3. Results and Discussion

Normal regression equations

$$\sum L_{50\%} = Na + b\sum L_E \quad \text{.. (2)}$$

$$\sum L_E L_{50\%} = a\sum L_E + b\sum L_E^2 \quad \text{.. (3)}$$

were used for the evaluation of the values of the coefficients a and b as shown in table 1 which are used for the regression equation of $L_{50\%}$ on L_E

$$L_{50\%} = a + bL_E \quad \text{.............................. .... (4)}$$

From the regression equation of $L_{50\%}$ on L_E i.e. $L_{50\%} = a + bL_E$ with a and b given in Table 1, it is possible to assess at each test frequency, the risk of noise-induced hearing loss $L_{50\%}$ caused by exposure to a certain level of broad-band noise for a known duration.

We now seek to establish the damage risk criteria at the octave band frequencies between 250Hz and 8000Hz to preserve hearing at the frequencies important for good speech recognition. This damage risk criterion (called New Damage Risk Criterion NDRC) would be based on the empirically derived expression (equation) using data collected from exposure to noise.

For zero (0) noise-induced hearing loss at any octave band frequency (for 10 years of exposure) we have from equation (4)

$$0 = a + b(L_A + 10log10)$$

$$L_E = L_A + 10logT$$

This gives

$$L_A = \frac{-a-10b}{b} \quad \text{... .... (5)}$$

The values for the damage risk criteria obtained by the use of equation (5) in conjunction with the values of coefficients a and b in table 1 are as shown in table 2

These are the sound pressure levels at and/or below which, there would be no noise-induced hearing loss in male and female for ten (10) years of exposure. This New Damage Risk Criteria (NDRC) for noise hazard follows from the empirically derived expression. It would be observed that the NDRC for females is higher than for males except for 8000Hz where that for males is higher and at 1000Hz where they are equal.

It is intuitively reasonable to consider and use L_A at 4000Hz (resonant frequency of the ear; noise-induced hearing loss begins to show at this frequency and spreads to other frequencies) i.e. 70 dBA and for simplicity in practical implementation, this value is used as the "damage risk criterion" and as the base value for the evaluation of the trade-off between the noise levels and the time of exposure for zero noise-induced hearing loss.

By using the 70 dBA damage risk criterion in equation, we obtain

$$L_E = 70 + 10\log(8x60x60) = 115dBA$$

In order to obtain the maximum time for a given A-weighted sound pressure level we use

$$L_A + 10logT = 70 + 45$$

This gives

$$L_A - 70 = 45 - 10logT$$

$$= 10log(8x60x60) - 10logT$$

$$= 10log\left(\frac{8x60x60}{T}\right)$$

Rearranging,

$$(L - 70)0.1 = log\left(\frac{8x60x60}{T}\right)$$

$$\left(\frac{L-70}{3}\right)0.3 = log\left(\frac{28800}{T}\right)$$

$$\left(\frac{L-70}{3}\right)log2 = log\left(\frac{28800}{T}\right)$$

$$log2^{\frac{(L-70)}{3}} = log\left(\frac{28800}{T}\right)$$

$$2^{\frac{(L-70)}{3}} = \frac{28800}{T}$$

This gives the time T as

$$T_{(s)} = \frac{28800}{2^{\frac{(L-70)}{3}}} \quad second \quad \ldots\ldots (6)$$

$$T = \frac{480}{2^{\frac{(L-70)}{3}}} \quad minute \ldots\ldots (7)$$

$$T = \frac{8}{2^{\frac{(L-70)}{3}}} \quad hr \quad \ldots\ldots (8)$$

Table 3 shows the combination of sound pressure level(L_A) and the corresponding duration (T) (in hours, minutes and seconds) that no worker exposure should exceed as obtained by the use of any of equations (6), (7) or (8).

4. Conclusion and Suggestion

This work derived an expression for the trade-off between the sound pressure levels and times of exposure for zero noise-induced hearing loss. Maximum times of exposure were computed for sound pressure levels from 65 dBA to 112 dBA. This trade-off between noise sound pressure levels and corresponding times of exposure obtained from this work were obtained from the damage risk criteria which were determined from the empirical values. Results show that workers should not be exposed to noise levels that are more than 112 for more than one second if the workers' hearing is to be conserved. The expression supports the Equal Energy Hypothesis (EEH) and the 3dBA exchange rate. From this work, the following suggestions are made:

(i) Employers should provide hearing protection
(ii) Employers should develop the habit of using the hearing protection provided
(iii) Noise assessment of workplaces should be carried out regularly

References

Alberti, P.W. (1998). Hearing Conservation *In:* Peter W. Alberti and Robert J. Ruben (eds), Otologic Medicine and Surgery, Churchill Livingstone Inc. pp. 253-271

Berger, E.H., Royster, L.H. and Thomas, W.G. (1978). Presumed Noise-Induced Permanent Threshold Shift Resulting from Exposure to an A-Weighted Leq of 89dB. *Journal of the Acoustical Society of America* 64(1): 192-197.

Chagok, N.M.D. (2010) Studies of Occupational Noise Hazards in Jos. PhD Thesis. University of Jos, Jos-Nigeria. 172p

Chagok, N.M.D and Gyang, B.N. (2012). An Exploratory Study on Hearing Loss due to Exposure to Steady-State Broadband Noise. *Biological and Environmental Sciencies Journal for the Tropics* 9(3): 34-41

Coles, R.R.A., Garinther, G.R., Hodge, D.C, and Rice, C.G. (1968). Hazardous Exposure to Impulse Noise. *Journal of the Acoustical Society of America* 43: 336-343.

Cunniff, P.F. (1977). Environmental Noise Pollution New York: John Wiley and Sons 210p.

Ebeniro J.O. and Abumere O.E. (1999). Environmental Noise Assessment of an Industrial Plant. *Nigerian Journal of Physics* 11: 97-106.

Kinsler, L.E., Frey, A.R., Coppers, A.B. and Sanders, J.V. (1982). Fundamentals of Acoustics 3 edn. New York: John Wiley and Sons, 480p.

Kryter, K.D. (1973). Impairment to Hearing from Exposure to Noise. *Journal of Acoustical Society of Americ.* 53: 1211-1234.

Kryter, K.D. (1982a). Community Annoyance from Aircraft and Ground Vehicle Noise. *Journal of the Acoustical Society of America* 72 (4): 1222-1242.

Kryter, K.D. (1982b). Rebuttal by Karl D. Kryter to Comments by T.J. Schultz. *Journal of the Acoustical Society of America* 72 (4): 1253-1257.

Menkiti, A.I. (1994). Noise Studies in an Oil Drilling Environment. *Nig. Journal of Physics* 6: 16-26

Nash, J.L. (2000). What is wrong with Hearing Conservation. *Occupational Hazards* 62(1): 41-44.

Obisung, E. O. Onuu, M.U. and Menkiti A. I. (2007). Levels and Spectra of Aircraft Noise and People's Reaction in some Nigerian Cities. *Nigerian Journal of Physics* 19(2): 223 – 236.

Onuu M.U. (1999). Environmental Noise control: Review and Assessment of Theories and Models. *Nig. Journal of Physics* 11: 91-96.

Onuu, M.U. and Menkiti, A.I. (1993). Spectral Analysis of Road Traffic Noise in Parts of South-Eastern Nigeria. *Nig. Journal of Physics* 5: 1-9.

Onuu M.U. and Menkiti A.I. (1996). Analysis of Nigerian Community Response to Road Traffic Noise. *Journal of Science Engineering and Technology* 3: 536-547

Onuu M.U. and Menkiti A.I. (1997). Acoustic Power Spectra of (Mixed) Road Traffic Noise Sources in South-Eastern Nigeria. *Nig. Journal of Physics* 9: 15-19.

Passchier – Vermeer, W. (1974). Hearing Loss due to Steady-State Broad Band Noise. *Journal of the Acoustical Society of America* 56(5): 1585-1593.

Schultz, T.J. (1978). Synthesis of Social Surveys on Noise Annoyance. *Journal of the Acoustical Society of America* 64(2): 377-405

Schultz, T.J. (1982). Comments on K.D. Kryter's Paper, Community Annoyance from Aircraft and Ground Vehicle Noise. *Journal of the Acoustical Society of America* 72 (4): 1243-1252.

Stevin, G.O. (1982). Spectral Analysis of Impulse Noise for Hearing Conservation purposes. *Journal of the Acoustical Society of America* 72(6): 1845-1854

Ward, W.D. (1975). Acoustic Trauma and Noise-Induced Hearing Loss. *In:* D.B. Tower Raven(ed), Human

Communication and its Disorders. New York: John Wiley and Sons. pp 221-229.

Table 1 Values of the Coefficients a and b

Frequency Hz	a		b	
	M	F	M	F
250	-21.24	-17.82	0.30	0.24
500	-29.55	-20.18	0.39	0.26
1000	-44.96	-30.47	0.55	0.37
2000	-21.89	-37.08	0.36	0.45
4000	-51.43	-36.23	0.64	0.45
8000	-50.21	-20.26	0.60	0.27

Table 2 Values of the L_A at the octave band frequencies

Frequency Hz	$L_A(dBA)$	
	M	F
250	61	64
500	66	68
1000	72	72
2000	51	72
4000	70	71
8000	74	65

Table 3 Combination of sound pressure levels and duration that no worker exposure should exceed

Sound Pressure Level (L_A) dBA	**Duration (T)**		
	Hours Seconds		Minutes
65	25	23	54
66	20	10	31
67	16	0	0
68	12	42	57
69	10	8	45
70	8	0	0
71	6	20	59
72	5	2	23
73	4	0	0
74	3	10	29
75	2	31	11

76	2	0	0
77	2	35	14
78	1	15	35
79	1	0	0
80	0	47	37
81	0	37	47
82	0	30	0
83	0	23	48
84	0	18	53
85	0	15	0
86	0	11	54
87	0	9	26
88	0	7	0
89	0	5	57
90	0	4	43
91	0	3	45
92	0	3	58
93	0	2	22
94	0	1	52
95	0	1	29
96	0	1	10
97	0	1	29
98	0	0	44
99	0	0	35
100	0	0	28
101	0	0	22
102	0	0	17
103	0	0	14
104	0	0	11
105	0	0	8
106	0	0	7
107	0	0	5
108	0	0	4
109	0	0	3
110	0	0	2
111	0	0	2
112	0	0	1