Determination of the test frequency causing significant hearing loss of the mine workers of an open cast chromite mine

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Abstract: *In this paper an attempt has been made to estimate the hearing loss of workmen (subjects) in an open cast chromite mines with respect to age, working experience and work stations. The study reveals that there is a significant difference among the different test frequencies with respect to hearing loss on both the ears of the subjects. The test frequency 4 kHz is found to be the most influencing frequency causing significant hearing loss on the right ear of the workmen due to age, work experience and work stations. While the test frequency, 6 kHz is found to be the most influential frequency causing significant hearing loss on the left ear of the subjects due to age and work station. Moreover, there is no significant difference of hearing loss exhibited to the subjects on both ears at test frequency of 4 kHz due to work experience.*

Keywords: *Asymmetry hearing loss, high fence, noise induced hearing loss.*

I. Introduction

Exposure to excessive noise is a major cause of hearing disorders worldwide, 16% of the disabling loss in adults is attributed to occupational noise [1-4]. Excessive noise can damage several cell types in the ear and lead to tinnitus, temporary or permanent hearing loss. Noise induced hearing loss is a sensory neural hearing loss as a result of chronic exposure to excessive sound [5] over a long period of time. A review of the earlier works reveals that many attempts have been made to evaluate the noise generation due to transportation [6,7] and aircrafts [8,9] and its annoyance [10-12] to the people living nearby. Similarly, investigation of different noise sources and its noise levels has also been made in the Gold mines [13], Stone quarry [14], Textile mills [15], Coal mines [16], Bauxite mines [17], Power plants [18] and Steel plants [19]. There are many environmental factors [20] which affect hearing [21] sensitivity, but hearing loss [22,23] is mainly associated with age [24,25], exposure [26] to different noise sources and working at different stations [27,28] and the hearing loss has been evaluated systematically for claiming compensation [29,30] by the workmen.

Therefore, this paper aimed to estimate the hearing loss at 4, 6 and 8 KHz (this frequency range henceforth be referred as high fence) of the subjects based on their age, working experience and working areas of a chromite mine. Audiometry data from 2002 to 2008 of 500 subjects have been used to estimate the hearing loss. The study also sought to find the most influential test frequency which causes the hearing loss significantly with respect to age, experience and work stations of the subjects.

II. Materials and Methods

2.1 Study Area

The mine site in the Sukinda valley is located in the Jajpur district in the state of Odisha, India. The mine produces chromite ore of both friable and lumpy varieties with a chrome ore beneficiation (COB) plant at the mine site. The mine is 130 km from Bhubaneswar, the state capital of Orissa, 65 km from NH-5 and 52 km from JK Road, the nearest railway station.

2.2 Study Design

A cross sectional study of hearing threshold of the mine workers of a chromite mine was carried out with the aim of gaining insight into factor associated with hearing loss. The audiometric data of 500 mine workers were taken from the records of the hospital at the mine. The subjects were included in the study having audiometry data at 0.5, 1, 2, 4, 6 and 8 KHz frequency for the period 2002 to 2008. Such audiometry data of all the mine workers were considered in the statistical analysis and if completed data of some subjects were not available from the hospital records than those subjects have been excluded in the design study. Since, the shift and duration of work hours affect noise exposure level, monitoring of noise level was performed in the mine site, inside the cabin and 7 m away from the Heavy Earth Moving Machineries (HEMMs) and also at different ambient locations from 7 AM to 10 PM to know the noise levels in these areas. The study period for monitoring of noise levels at different locations was from 2008 to 2010. Though, the period of audiometry data and that of monitoring of noise levels are not same, but the present study estimated the noise levels at different locations to know the likely exposure of noise by all subjects.

2.3 Audiometry Test

Screening audiometry was carried out by an audiometer (6025A of TRIVENI TAM-25 make) in a quiet environment by qualified technicians, audiologists, or physicians. The frequency range of the pure tone for air conduction measurement is 250 Hz to 8 KHz. The range of masking intensity is 0 to 100 dB having attenuator in steps of 5 dB. The 3% is the frequency accuracy of the instrument and that of hearing level of the instrument is 2 dB. Tests were conducted on the workers after a complete rest of 16 hours or more from their day shift. Audiometric air conduction tests were performed by presenting a pure tone to the ear through an earphone and threshold of hearing (dB) was recorded at which this tone was perceived 50% of the time. The better ear was first tested at 1 kHz and then at 2, 4, 6, 8 and 0.5 kHz in that order. Retest was done at 1 kHz in the first ear. In case, the test value was more than 5 dB or more acute than the original, a retest was done at the next frequency and so on. Audiometry tests were conducted in the opposite ear in the same manner except for retesting at 1 kHz. The duration of the presented tone was between 1-3 seconds. The same duration was maintained between the tones. The total time taken to perform the audiometry test of one subject was 3-5 minutes.

2.4 Noise Measurements

A digital sound level meter from M & K, Denmark (Bruel & Kjaer) was used throughout the entire noise survey. The accuracy of the frequency weighting of the instrument meets IEC 651 Type 2 which represents sound level meters suitable for general field applications. The measuring range is 25 to 130 dBA. The wide measurement range allows the instrument to be used for a diverse range of noise investigation where both high and low sound levels occur. Great care was taken to retain a distance between the instrument and the surrounding areas or any obstacles that could intensify or reduce the received noise. In this present study, the sound level meter was placed on rigid stand at 1.2 to 1.5 m above the ground surface, and 6 m away from the road side or 7 m away from the HEMMs, avoiding obstacles or reflecting objects. The air temperature varied between 19.38 and 34.31 ^{0}C and the wind velocity was less than 1.02 m/s. Measurements were taken in conditions of clear sky and a sustained wind to avoid any background noise level differences that were greater than 10 dBA.

2.5 Ambient Noise

To know the present noise situation in the mining areas, in the ambient and inside the cabin and 7 m away from the HEMMs, a systematic noise monitoring was performed in summer (June 2008) and in winter (November 2009) between 7 AM to 10 PM. However, for blasting operation noise survey was carried out for three consecutive days in April, 2010 and half an hour before and after the blasting operations at 100 m away from the blasting site. A time gap of 60 s was observed between two readings during the first monitoring and 15 s during second and third noise survey. The working areas of all the subjects (500) have been divided into four groups such as work zone, industrial area, commercial area, residential area and silence zone based on the administrative records as exhibited in Tables 1 (a & b). The minimum and maximum equivalent noise levels (L_{eq}) surveyed in theses areas have also been shown to know the likely exposure of each category of subjects. The equivalent noise level, L_{eq} over a particular monitoring time has been estimated using the following equation:

$$L_{eq} = 10 \log_{10} \sum 10^{Li/10}$$

Where

L_i = the ith sound pressure level, dBA
i = 1, 2, 3, ……, N
N = number of readings of a particular parameter

Tables 1 (a & b) show that the maximum L_{eq} levels at commercial area and minimum L_{eq} levels at residential area and silence zone exceeded the prescribed limits. Similarly, the maximum noise levels in case of large and medium HEMMs and also at the Operator's positions of the HEMMs was found to be even more than danger limit of 90 dBA.

In the present study, audiometric data of 500 subjects (481 males and 19 females) have been taken for the period 2002 to 2008 of an open cast chromite mining complex in Sukinda area in the state of Odisha (India). As the hearing loss of a subject begins at 4, 6 and 8 KHz frequency, the retrospective data have been used to estimate the possibility of a dip or notch at these frequencies due to exposure to different levels of noise by the subjects. The subjects were divided into 4 age groups, 8 experience groups and 5 work stations as depicted in the Table 1(c). It has been seen that the minimum age of the group is 29 years and maximum age is 59 years. Similarly, 4 years is the minimum working experience and 37 years is the maximum working experience of the group. The Table 1(c) shows the descriptive statistics of the subjects for both the ears at different frequency levels. To meet the research objectives, the data so obtained are analyzed through SPSS (16.0) package under Window–XP environment. Generalized Linear Model ANOVA, Post hoc analysis, Gabriel Multiple comparison for mean difference and paired t-test were used as statistical tools to meet the objectives of the present study.

Table 1 (a): Area code, category of area, work settings and noise levels (dBA) in different areas

Area Code	Category of Area/Zone	Subjects Working at/in	L_{eq} Min.	L_{eq} Max.	Limits Day Time
A	Industrial[a]	Maintenance of Equipments, Store Yard (Loading), Quality Control-COBP and LOPP and Sewerage Treatment Plant.	53.31	72.29	75
B	Commercial[a]	Administrative Buildings (It is located near the Mine Quarry area), Mining Weigh Bridge, Project & Construction and Airfield.	58.33	78.65	65
C	Residential[a]	Main Gate of the Plant, Canteen, Guest Houses and Vocational Training Centre.	57.91	72.86	55
D	Silence Zone[a]	Hospital and Arm Guards	59.46	67.02	50

[a] The Noise Pollution (Regulation and Control) Rules, 2000 and its amendment, Ministry of Environment and Forests, Government of India, India. Day time is between 6 am to 10 pm.

Table 1 (b): Area code, category of area, work settings and noise levels (dBA) in different areas

Area Code	Category of Area/Zone	Subjects Working at/in	L_{eq} Min.	L_{eq} Max.	Limits Day Time
W	Work Zone[b]	(Mine Quarry, Chrome Ore Beneficiation Plant (COBP), Lumpy Ore Processing Plant (LOPP) and Operation of HEMMs)			
	Large HEMMs		65.88	97.23	-
	Medium HEMMs		77.50	95.12	-
	Light HEMMs		74.53	83.42	-
	Blasting Area		54.79	65.51	-
	Haul Roads		-	70.28	-
	COBP Area		54.79	74.79	-
	Cabin of HEMMs		56.48	100.56	-

[b] A working limit value of 85 dBA (warning limit) and 90 dBA (danger limit) for 8 hours exposure, Director General of Mines Safety, Circular No. 18 (Tech), December, 1975, Ministry of Labour and Employment, Government of India, India. Large HEMMs: Pay Loaders, JCB, Shovel with Rock Breaker, Poclain, and Giant Excavators; Medium HEMMs: Dozers, Dumpers and Trucks and Small HEMMs: All Drilling Machines.

Table 1 (c): Descriptive statistics of the subjects (500) in three demographic categories

Category	Subjects n	Subjects %	Age (years) Mean	Age (years) SD	Experience (years) Mean	Experience (years) SD
Age (years)						
20-30	13	02.6	29.92	0.28	10.54	0.78
31-40	168	33.6	36.02	2.61	12.85	3.17
41-50	208	41.6	45.38	2.72	18.04	4.73
51-60	111	22.2	53.87	2.36	26.81	7.60
Experience (years)						
0-5	02	0.4	37.50	3.54	4.00	1.41
6-10	56	11.4	35.21	5.41	9.911	0.29
11-15	174	34.6	39.73	5.77	13.09	1.39
16-20	127	25.4	44.91	4.81	17.63	1.34
21-25	59	11.8	47.73	3.75	22.61	1.39
26-30	29	5.8	51.00	2.38	27.59	1.48
31-35	45	9.0	54.67	2.44	33.29	1.31
>35	08	2.4	55.63	2.67	36.50	0.53
Working Area/Zone						
W	262	52.4	42.53	7.08	16.82	6.29
A	128	25.6	44.41	8.15	19.62	8.52
B	65	13.0	45.71	7.45	19.45	8.07
C	20	04.0	47.40	7.13	20.85	7.77
D	25	05.0	44.44	5.42	16.82	4.91
Total	500	100	43.72	7.45	18.05	7.28

III. Statistical Analysis

Descriptive statistics on t-test (2-tailed) of the whole subjects at high fence (4, 6 and 8 kHz) has been shown in Table 2.

Table 2: t-test (2-tailed) of the whole subjects, n=500 at high fence

Ear	Mean Hearing Threshold (dB HL) at 4.0 kHz Mean	SD	t-value	*p*	6.0 kHz Mean	SD	t-value	*p*	8.0 kHz Mean	SD	t-value	*p*
Right	21.37	7.33	0.347	>0.01	23.48	7.37	0.258	>0.01	22.38	8.43	0.814	>0.01
Left	21.54	7.42			23.36	7.80			21.95	8.67		

i) A two tailed t-test was performed for the whole subjects between the left and right ears at high fence by assuming the following hypothesis:

Null Hypothesis (H_0): The hearing threshold does not differ between left and right ears at high fence.

Alternate Hypothesis (H_1): The hearing threshold differs between left and right ears at high fence.

Since, p>0.01, both the ears do not exhibit any significant hearing difference at 4, 6 and 8 kHz, the hypothesis is accepted at 1% level of significance. Thus, it can be concluded that asymmetric hearing loss may be attributed either in the left or the right ear at 4, 6 or 8 kHz.

Table 3: ANOVA for the hearing loss at high fence with different groups

Category	Mean Hearing Threshold Left Ear, dB HL			Mean Hearing Threshold Right Ear, dB HL		
	4 kHz	6 kHz	8 kHz	4 kHz	6 kHz	8 kHz
Age (years)						
21-30	16.15	18.08	15.77	16.92	18.08	15.38
31-40	18.45	20.74	17.59	18.21	20.57	17.92
41-50	22.16	24.18	23.09	22.31	24.28	23.85
51-60	25.68	26.40	27.09	29.91	27.03	27.21
p- value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Experience (years)						
<5	20.00	22.50	25.00	20.00	22.50	22.50
6-10	17.50	19.46	15.89	16.33	19.02	15.80
11-15	20.11	22.13	19.22	19.97	21.93	19.71
16-20	22.72	24.06	23.65	22.60	24.61	24.41
21-25	22.54	24.41	23.90	22.97	25.42	25.51
26-30	25.17	27.93	27.41	23.45	26.03	26.38
31-35	23.78	25.56	27.60	24.78	26.67	27.33
>35	29.38	30.00	29.38	30.00	29.38	28.75
p- value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Work Stations						
W	20.95	22.77	21.25	20.90	22.92	22.06
A	22.34	23.83	22.66	21.95	23.83	22.54
B	21.92	24.15	21.95	21.54	23.77	21.77
C	23.50	24.50	25.00	22.75	25.00	25.50
D	21.00	24.20	23.00	21.80	25.60	24.00
p- value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

ii) To test if there exists any significant difference at the test frequency on both the ears of the subjects with respect to age, experience and work station.

ANOVA was performed to find out any significant difference in hearing loss in both the ears at high fence and the most influential frequency was determined by using Gabriel multiple comparison method. Table 3 shows the hearing loss of the subjects with respect to the different groups of age, experience and work stations. The following hypothesis has been assumed to carry out ANOVA test for different groups:

Null Hypothesis (H_0): Various groups of age, years of experience and Work stations are independent with regard to hearing loss for both the ears of the workers at high fence.

Alternate Hypothesis (H_1): Various groups of age, years of experience and Work stations are dependent with regard to hearing loss for both the ears of the workers at high fence.

Since, p<0.01, various groups of age, years of experience and Work stations are dependent with regard to hearing loss for both the ears of the workers at high fence, the hypothesis is rejected at 1% level of significance.

iii) Post hoc analysis, Gabriel Multiple comparison for mean difference was used to find out the most influential frequency where a dip or notch is exhibited for different groups.

The Post hoc analysis was performed to find out the most significant frequency among all test frequencies. The results of the multiple comparisons of mean differences in hearing loss by Gabriel method at 4, 6, and 8 kHz have been depicted in Table 4.

iv) As the most significant frequency is 4 kHz for both right and left ears with respect to work experience, paired t-test was performed to evaluate any significant hearing difference of the group.

Null Hypothesis (H_0): There is no significant hearing threshold at 4 kHz in either ear due to work experience.

Alternate Hypothesis (H_1): There is significant hearing threshold at 4 kHz in either ear due to work experience.

Since, $p>0.01$, so it may be inferred that there is no significant difference in hearing loss for both the ears at 4 kHz with 1% level of significance with respect to experience. Thus, concluded that there is no significant hearing loss in the experience group.

Table 4: Post doc analysis for Hearing Loss at high fence and with different groups

Frequency pair, kHz	Right Ear		Left Ear	
	Absolute Mean Difference	*p-value*	Absolute Mean Difference	*p-value*
Age Group				
8 and 6	0.8233	<0.01	0.9759	<0.01
8 and 4	1.0760	<0.01	0.5349	<0.01
6 and 4	1.8993	<0.01	1.5108	<0.01
Experience Group				
8 and 6	0.2965	<0.01	0.2965	<0.01
8 and 4	1.3960	<0.01	1.3960	<0.01
6 and 4	1.6925	<0.01	1.6925	<0.01
Different Work Stations				
8 and 6	0.8231	<0.01	0.9091	<0.01
8 and 4	1.4613	<0.01	0.8387	<0.01
6 and 4	2.2826	<0.01	1.7478	<0.01

IV. Results

The maximum L_{eq} levels at commercial area and minimum L_{eq} levels at residential area and silence zone exceeded the prescribed limits. Similarly, the maximum noise levels found to be even more than danger limit of 90 dBA for large and medium HEMMs and also at the Operator's positions of the HEMMs.

From Table 4, it is clear that the most significant frequencies with respect to the hearing loss of age are 4 and 6 kHz for the right and left ears, respectively at 1% level of significance. In case of experience groups, the most significant frequency is 4 kHz for both the ears at 1% level of significance. Similarly, the most significant frequencies are 4 and 6 kHz for the right and left ears, respectively, in respect of working stations at 1% level of significance. With paired t-test, *p*-value is found to be >0.01 and so it may be inferred that there is no significant difference in hearing loss for both the ears at 4 kHz with 1% level of significance with respect to experience.

V. Discussion

From Tables 1(a & b), it is found that the subjects are exposed to noise levels more than the prescribed standards those working at large, medium and inside the Cabins of HEMMs, Administrative Buildings, Weigh Bridge, Project and Construction Area, Airfield and Hospital.

The t-test reveals that there is no significant difference in hearing loss on both ears due to age, experience and various work stations at all test frequencies and thus, asymmetric hearing loss may be attributed in either ear. However, from ANOVA test, it is clear that there exists a significant difference among all the test frequencies with respect to hearing loss. The hearing loss is found to be not homogeneous i.e. it is dependent in respect of age, experience and working stations. In other words, hearing loss is increasing for every 10 years interval of age, for every 5 years of work experience and with different work stations at high fence. The most influential frequency with respect to age for the right and left ears are found to be at 4 and 6 kHz, respectively. In case of different working experience, 4 kHz is found to be the most influential frequency for both the ears. Similarly, 4 and 6 kHz are the most significant frequencies for right ear and left ear, respectively for the subjects working at different working areas. This asymmetry [31] hearing loss may be attributed to the presence of a subgroup (Operators of the Heavy Earth Moving Machineries) who generally exposed to higher noise level i.e., more acoustic energy of the sound reaching to the right ear [9,32,33] than to the left ear. It has also been found that though the cabin of the HEMMs is air conditioned, operator of the vehicle always keeps the door open for more comfort and easy drive. Therefore, the right ear is exposed outside and possible asymmetric hearing loss.

Since, the most significant frequency is 4 kHz for both right and left ears, paired t-test was performed to evaluate whether there is any significant difference between the right and left ears of the subjects with reference to experience. With paired t-test, *p*-value is found to be >0.01 and so it may be inferred that there is no significant difference in hearing loss for both the ears at 4 kHz with 1% level of significance with respect to experience.

The subjects, grouped in Sensitive Zone are mainly Staff Nurses, Hospital Attendants and Drivers working in the hospital and Arms Guards. The mean age of this group is found to be more than the mean age across all the subjects. Thus, the hearing threshold may not be always noise-induced, it may be due to Presbycusis also. However, this group works in the hospital and is located near the mining complex and lot of loaded/empty dumpers and trucks ply through this area. Therefore, hearing loss of the subjects has been estimated for which one of the reasons of hearing loss may be attributed to the noise generation by heavy earth moving machineries including dumpers and trucks when plying everyday through this station.

VI. Recommendations

The following recommendations suggested to minimise exposure to different noise source and also to reduce hearing loss:

i) The subjects whose hearing loss is found to be at 6 kHz, the working areas of the subjects should be changed to lesser noisy areas to reduce the exposure level.
ii) Provisions for regular audiometry test of all the subjects should be conducted to identify the hearing loss of those subjects occurring at 6 kHz.
iii) Periodic maintenance of all the HEMMs is essential to keep all the vehicles in good condition and less noisy.

VII. Conclusion

In our study population, the maximum noise levels for large and medium HEMMs and inside the cabin of HEMMs were found to be more than 95 dBA. Hearing loss is increasing for every 10 years interval of age, for every 5 years of work experience and with different work stations at high fence. Age and experience of subjects have significant difference with hearing loss at 4.0, 6.0 and 8.0 kHz. The study also reveals that there is a significant difference among the different test frequencies with respect to hearing loss on both the ears of the subjects. The test frequency 4 kHz is found to be the most influencing frequency causing significant hearing loss on the right ear of the workmen due to age, work experience and work stations. While the test frequency, 6 kHz is found to be the most influential frequency causing significant hearing loss on the left ear of the subjects due to age and work station. The characteristic frequency due to noise induced hearing loss is 4 kHz where a dip or notch occurs. In the present study also, this frequency is the most influential frequency among different groups of workmen and are the relatives of some of the general public. Therefore, the general public can participate in reducing the noise induced hearing loss of these workmen by advocating them the causes of hearing loss, sources of hearing loss and also how to reduce it by using hearing protective devices while at work.

References

1. Prince MM, Stayner LT, Smith RJ, Gilbert SJ. A re-examination of risk estimates from the NIOSH Occupational Noise and Hearing Survey (ONHS). J Acoust Soc Am 1997;101:950-63.
2. May JJ. Occupational Hearing Loss. Am J Ind Med 2000;37:112-20.
3. Prince MM, Gilbert SJ, Smith RJ, Stayner LT. Evaluation of the Risk of Noise Induced Hearing Loss among unscreened male Industrial Workers. J Acoust Soc Am 2003;113:871-80.
4. Picard M, Girard SA, Simard M, Larocque R, Leroux T, Turcotte F. Association of work-related accidents with noise exposure in the workplace and noise–induced hearing loss based on the experience of some 240,000 person-years of observation. Accident Analysis Prevention 2008;40:1644-52.
5. Bauer ER, Babisch DR. Limestone Mining-Is it noisy or not? Minerals Engineering 2006;58:37-42.
6. Don CG, Rees IG. Road traffic sound level distributions. J Sound Vibrat 1985; 100:41-53.s
7. Finegold LS, Finegold MS. Development of Exposure-Response Relationships between Transportation Noise and Community Annoyance. Presented at the Japan Net-Symposium on “Annoyance, Stress and Health Effects of Environmental Noise”: 2002. p.1-16.
8. Hoeger R. Aircraft noise and Times of Day: Possibilities of redistributing and influencing noise exposure. Noise Hlth 2004;6:55-8.
9. Satish, Kashyap RC. Significance of 6 kHz in noise induced hearing loss in Indian Air Force Personnel. Indian J of Aero Med 2008;52:15
10. Ouis D. Annoyance Caused by exposure to road traffic noise: An Update. Noise Health 2002;4:69-79.
11. Waye KP, Ohrstrom E. Psycho-acoustic characters of relevance for annoyance of wind turbine noise. J Sound Vibration 2002;250:65-73.
12. Coles RRA, Lutman ME, Buffin JT. Guidelines on the diagnosis of noise-induced hearing loss for medicolegal purposes. Clinical Otolaryngology & Allied Sciences 2000;25:264-73.
13. Amedofu GA. Hearing impairment among workers in a surface Gold Mining Company in Ghanna. Afr J Hlth Sci 2002;9:91-7.
14. Pal AK, Mukhopadhyya AK, Agarwal SC. Portable diamond cutter for sawing Kotah stone - A case study on its noise emission and control. Noise Vibrat Worldwide 2006;37:26-32.
15. Tiwari RR, Pathak MC, Zodpey SP. Low Back Pain among Textile Workers. Indian J Occup Environ Med 2003;7:27-9.
16. Pal AK, Ghosh S, Saxena NC. Noise status in coal mining complexes. Proceedings of the 7th National Symposium on Environment, ISM, Dhanbad, India; 1998. p.74-81.
17. Kisku GC, Barman SC, Kidwai MM, Bhargava SK. Environmental impact of noise levels in and around opencast bauxite mine. J Environ Bio 2002;23:51-6.

18. Kisku, GC and Bhargava, SK. Assessment of noise level of a medium scale thermal power plant. Indian J Occup Environ Med 2006;10;133-9.
19. Kerketta S, Dash PK, Narayan LTP. Work zone Noise levels at Aarati steel plant, Orissa and its attenuation in far field. J Environ Biol 2009;30:903-8.
20. Mills JH, Going JA. Review of Environmental Factors Affecting Hearing. Environ Hlth Pers 1982;44:119-27.
21. Patil RR. Community-based occupational/ environmental health Studies: The challenges and the dilemmas. Indian J Occu Environ Med 2006;10:85-6.
22. Joshi SK, Devkota S, Chamling S, Shrestha S. Environmental Noise Induced Hearing loss in Nepal. Kathmandu Univ of Medical J 2003;1:177-83.
23. Bistrup ML. Prevention of Adverse Effects of Noise on Children. Noise Health 2003;5:59-64.
24. Rosenhall, U. The Influence of Ageing on Noise-Induced Hearing Loss. Noise Health 2003;5:47-53.
25. Albera R, Lacilla M, Piumetto E, Canale A. Noise-induced health loss evolution: Influence to age and exposure to noise. Eur Arch Otorhinolaryngol, 2010;267:665-71.
26. Leong ST, Laortanakul P. Monitoring and assessment of daily exposure of roadside workers to traffic noise levels in an Asian city: A case study of Bangkok streets. Environ Moni 2003;85:69-85.
27. Boateng CA, Amedofu GK. Industrial noise pollution and its effects on the hearing capabilities of workers: A study from saw mills, printing presses and corn mills. Afr J Hlth Sci 2004;11:55-60.
28. Joy GJ, Middendorf PJ. Noise exposure and hearing conservation in U.S. Coal Mines – A surveillance report. J Occup Environ Hygiene 2007;4:26-35.
29. Coles RRA, Burns W, King PF. Assessment of hearing disability: Discussion paper. J Royal Soc Med 1983;76:1032-7.
30. Pal AK, Saxena NC. Societal cost of community noise. Proceedings in the National Seminar on Environmental Engineering with special emphasis on Mining Engineering. NSEEME-2004, March, 2004, ISM Dhanbad, India; 2004. p.1-8.
31. Backus, BC and Williamon, A. Evidence of noise-induced hearing loss among orchestral musicians. International Symposium on Performance Science, Published by the AEC, 2009. p.225-30.
32. McBridge DI, Williams S. Audiometric notch as a sign of noise induced hearing loss. J Occup Environ Med 2001;58:46-51.
33. Royster JD, Royster LH, Killion MC. Sound exposure and hearing threshold of Symphony orchestra musicians. J Acoust Soc of Am 1991;89:2793-2803.