Original Article

Hearing Threshold, Loss, Noise Levels and Worker's Profiles of an Open Cast Chromite Mines in Odisha, India

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Abstract

Objectives: **The aims of the study were to describe the noise levels at an open cast chromite mine in Odisha, India, and the hearing threshold of its workers and to associate their hearing loss with their age, work station and length of employment at the mine.**

Method: **We performed a cross-sectional study of the hearing threshold of chromite mine workers. Audiometric data from 500 subjects was collected at the mines' hospital in the Sukinda Valley of Jajpur, Odisha, India. The latest audiometry data available for the period 2002 to 2008 was used in the analysis. Audiometric screening was performed using an audiometer (TRIVENI TAM-25 6025A) in a quiet environment by qualified technicians, audiologists or physicians. Tests were conducted on the subjects after they had completely rested for 16 hours or more after their day shift.**

Results: **A maximum of 262 subjects (52.4%) were employed in the work zone area and a minimum of 2 subjects (0.4%) had less than 5 years working experience. The age of the subjects ranged from 29 to 59 years and their working experience ranged from 4 to 37 years. The subjects' average mean hearing thresholds at 4, 6 and 8 kHz were 21.53 dBA, 23.40 dBA and 21.90 dBA, respectively. The maximum L_{eq} and L_{90} levels exceeded the prescribed limits for commercial, residential and silence zones. The maximum Leq levels exceeded 95 dBA for large and medium heavy earth moving machineries (HEMMs), both outside and at the operator's position. Hearing loss due to the subjects' work experience was found to be greater than that attributable to age and workstation.**

Conclusion: **In our study population, the maximum noise levels for large and medium HEMMs and inside the cabins of HEMMs were found to be more than 95 dBA. This indicates that operators in this particular chromite mine at Odisha, India were exposed to noise levels exceeding 95 dBA for more than 10% of the monitoring time. The subjects' hearing loss was also found to increase for every 10-year age interval and that for every 5 years of work experience at high fence. The subjects' age and experience are significantly associated with hearing loss at all levels for frequencies of 4.0, 6.0, and 8.0 kHz, with older and more experienced workers having a higher incidence of hearing loss.**

Keywords: *hearing loss, noise, presbycusis*

Introduction

Hearing loss is associated with numerous factors (1–8), primarily age (9–11), exposure to various sources of noise (12,13) and length of time exposed to noise (14,15). It has been reported that when male steelworkers are exposed to 90–99 dBA noise levels, their hearing ability is significantly affected (1), with a mean shift of 6.8–7.8 dB after 6–8 years. The incidence of presbycusis (9) in subjects aged 65 years and older is 37.8% and 8.3% for the ≥ 27 dB HL criterion and the ≥ 41 dB HL criterion, respectively. There is also a significant difference in the hearing threshold of men and women aged 65 years and older. The noise-induced hearing loss (NIHL) is significant at 4 kHz, a well-established clinical sign (4,7,12,14). This frequency is also considered the typical notch frequency where hearing loss has its maximum dip when compared with other high fence frequencies. The degree of association is even stronger when the intensity of the noise and the temporary hearing threshold shift are high (16).

The aims of the study were to describe the hearing threshold based on audiometry data and noise levels in various areas of an open cast chromite mine in Odisha, India. The study also

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sought to find an association between hearing loss and the various profiles of workers at an open cast chromite mine from 2002 to 2008.

Materials and Methods

Study area

The mine site is located in the Sukinda valley of Jajpur, Odisha, India. The mine produces chromite ore in both friable and lumpy varieties and has a chrome ore beneficiation (COB) plant. The mine is located 160 km from Bhubaneswar, the state capital of Odisha, 65 km from National Highway 5 (NH-5) and 52 km from JK Road, the nearest railway station.

Study design

A cross-sectional study of the hearing threshold of the chromite mine workers was conducted with the aim of gaining insight into the factors associated with hearing loss. Audiometric data from 500 subjects were obtained from the mine hospital's records. Subjects with audiometry data for 0.5, 1, 2, 4, 6, and 8 kHz frequencies for the period 2002 to 2008 were included in the study and divided into five broad categories as shown in Table 1. The audiometry data for the above period was used in the statistical analysis.

Audiometry test

Screening audiometry was performed using an audiometer (TRIVENI TAM-25 6025A) in a quiet environment by qualified technicians, audiologists, or physicians. Tests were conducted on the subjects after they had completely rested for 16 hours or more after their day shift. Audiometric air conduction tests were performed by presenting a pure tone to the ear through an earphone. The hearing threshold (dB) was recorded at the frequency at which a particular 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. Retests were performed at 1 kHz in the first ear. When the test value exceeded 5 dB or was more acute than the original, a retest was performed 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 1–3 seconds. The same duration was maintained between the tones. The total time required to perform the audiometry test by a subject was 3–5 minutes.

Noise measurements

A digital sound level metre (M & K, Bruel & Kjaer, Denmark) was used throughout the entire noise survey. The sound level metre was placed 1.2 to 1.5 m above the surface of the ground and 6 m away from the side of the road, avoiding obstacles and reflecting objects. The air temperature varied between 19.38 and 34.31 °C, and the wind velocity was less than 1.02 m/s. Measurements were taken under clear skies and sustained wind conditions to avoid any background noise level differences greater than 10 dBA (17).

Ambient noise

Systematic ambient noise monitoring was performed at all stations in the summer (June

Table 1: Area code, category of area, and work settings

Area Code	Category of Area/ Zone	Subjects Working at/in	Number of Subjects
W	Work zone	Mine quarry, chrome ore beneficiation plant (COBP), lumpy ore processing plant (LOPP), and operation of HEMMs	262
A	Industrial area	Maintenance of equipments, store yard (loading), quality control-COBP and LOPP and sewerage treatment plant	128
B	Commercial area	Administrative Buildings (It is located near the Mine Quarry area), Mining Weigh Bridge, Project & Construction and Airfield	65
C	Residential area	Main Gate of the Plant, Canteen, Guest Houses and Vocational Training Centre	20
D	Silence zone	Hospital and Arm Guards	25

2008) and winter (November 2009) between 0700 and 2200 hours. For blasting operations, the survey was conducted half an hour before and after the blasting operations at a distance of 100 m from the blasting site for three consecutive days in April, 2010. As shown in Table 1, the working areas were categorized based on the individual administrative records. Table 2 shows the descriptive statistics of 500 subjects in the demographic categories of age (4 groups), experience (8 groups) and working area (5 groups). Table 3 shows a summary of the various noise parameters in the work zone, the industrial area, the commercial area, the residential area and the silence zone. A time gap of 60 seconds was observed during the first monitoring between two consecutive readings and 15 seconds during the second and third noise survey.

Noise parameters

The noise levels were quantified in terms of various sound levels, with L_{10}, L_{90}, and L_{eq} defined as follows:

L_{10} : maximum noise level measured for more than 10% of the monitoring time.

L_{90} : minimum noise level measured for more than 90% of the monitoring time, also designated as background noise.

L_{eq} : the equivalent noise level over a particular monitoring time period.

The following equation was used to estimate L_{10}, L_{90} and Leq values (18):

$$L_{av} = 10 \log_{10} \sum 10^{Li/10} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where ;

L_{av} = average noise level of L_{10}, $L_{90,}$ and L_{eq} in dBA

L_i = the i_{th} sound pressure level in dBA

i = 1, 2, 3, ……, N

N = the number of readings of a particular parameter

In the present study, audiometric data from 500 subjects was obtained for the period 2002–2008 to evaluate the possibility of a dip or a notch at high fence frequencies (i.e. at 4, 6, and 8 kHz) due to the subjects' exposure to different levels of noise. The subjects' ages varied between 29 and 59 years and their working experience ranged from 4 to 37 years.

Data were entered and cleaned using SPSS version 16.0 for Windows. We described the data using means, standard deviations, frequencies and percentages where applicable. Line plots were used to depict the hearing thresholds for different frequencies. The associations between the subjects' age, workstation and work experience and their hearing loss were assessed using the Chi-square test. The results were deemed significant if the *P*-values were less than 0.05 (2 tailed).

Results

The codes and categories for the various areas and the work settings of the open cast chromite mine are shown in Table 1. The profiles of the 500 subjects with respect to age, work experience and hearing threshold are shown in Table 2.

Equation 1 was used to evaluate the different noise parameters (viz., L_{10}, L_{90}, and L_{eq}) at each station. The summary of these noise parameters is presented in Table 3. We found that the maximum L_{eq}, and L_{90} levels exceeded the prescribed limits (19) in commercial, residential and silence zones. The maximum noise levels were found to be more than 90 dBA (19), the warning limit for large and medium HEMMs, both at 7 m away from the equipment and at the operator's position. The maximum value of L_{10} was found to be 100.92 dBA inside the cabin. Almost all of the subjects had been exposed to this type of noise; thus, without personal ear protection equipment, a change in hearing threshold from their normal hearing is unavoidable.

Figures 1 to 3 indicate the variation in hearing loss for all subjects at all test frequencies with respect to age, experience and work station. The audiograms indicate bilateral hearing loss, no hearing loss below low fence frequencies (0.5, 1, and 2 kHz), moderate flat sloping hearing loss from 2 to 6 kHz, a small notch at 6 kHz and then a slight recovery at 8 kHz for almost all subgroups. However, there is no clear sign of a dip or a notch at the characteristic 4 kHz frequency. Therefore, the Pearson Chi-square test was used to estimate the association of hearing loss with different subject groups.

Table 4 describes the Chi-square test for the various subject categories. The hearing threshold levels for all subjects were divided into two groups (viz., ≤ 25 dB HL and > 25 dB HL) to identify the degree of hearing loss at 4, 6 and 8 kHz and to form an 'n x k' table for the three demographic categories separately. We found that the expected number in the cell was less than 5 in the 20–30 age group, 0–5, 5–10, and > 35 years experience groups at 4, 6, and 8 kHz and also the residential and silence zone at 4 and 6 kHz. As the Pearson

Table 2: Age, experience, and hearing threshold of subjects, n = 500

Category	Subjects		Age (years)		Experience (years)		Hearing Threshold Levels (dB HL)					
							4.0 kHz		6.0 kHz		8.0 kHz	
	n	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)												
20–30	013	02.6	29.92	0.28	10.54	0.78	16.15	3.00	18.08	4.35	15.77	5.34
30–40	168	33.6	36.02	2.61	12.85	3.17	18.45	6.19	20.74	7.53	17.59	7.28
40–50	208	41.6	45.38	2.72	18.04	4.73	22.16	6.63	24.18	7.33	23.09	8.19
50–60	111	22.2	53.87	2.36	26.81	7.60	25.60	8.53	26.40	7.64	27.15	8.29
Experience (years)												
0–5	02	0.4	37.50	3.54	4.00	1.41	20.00	7.07	22.50	3.54	25.00	0.00
5–10	56	11.4	35.21	5.41	9.911	0.29	17.50	5.52	19.46	7.44	15.89	5.76
10–15	174	34.6	39.73	5.77	13.09	1.39	20.11	6.83	22.13	7.94	19.22	8.35
15–20	127	25.4	44.91	4.81	17.63	1.34	22.72	8.23	24.06	7.10	23.65	7.96
20–25	59	5.8	47.73	3.75	22.61	1.39	22.54	6.46	24.41	6.95	23.90	7.94
25–30	29	11.8	51.00	2.38	27.59	1.48	25.17	8.61	27.93	9.40	27.41	9.03
30–35	45	9.0	54.67	2.44	33.29	1.31	23.78	6.17	25.56	6.18	27.60	7.44
> 35	08	2.4	55.63	2.67	36.50	0.53	29.38	6.78	30.00	9.26	29.38	7.29
Working Area/Zone												
W	262	52.4	42.53	7.08	16.82	6.29	20.95	6.95	22.77	7.55	21.25	8.53
A	128	25.6	44.41	8.15	19.62	8.52	22.34	8.57	23.83	8.61	22.66	9.40
B	65	13.0	45.71	7.45	19.45	8.07	21.92	7.32	24.15	7.84	21.95	8.41
C	20	04.0	47.40	7.13	20.85	7.77	23.50	7.86	24.50	6.63	25.00	8.02
D	25	05.0	44.44	5.42	16.82	4.91	21.00	4.75	24.20	6.74	23.00	6.71
Total	500	100	43.72	7.45	18.05	7.28	21.53	7.42	23.40	7.80	21.90	8.67

Table 3: Noise levels (in dBA) of different areas of the mines

Category of Area/ Zone	L_{10}				L_{90}				Le_{q}			
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Industrial	58.15	84.37	68.56	10.7	52.78	70.64	60.03	7.62	53.31	72.29	60.94	7.97
Commercial	71.62	90.58	78.78	8.16	56.79	77.30	64.64	8.68	58.33	78.65	66.13	8.58
Residential	66.60	88.83	75.04	8.16	55.81	72.07	63.02	6.95	57.91	72.86	64.25	6.86
Silence Zone	64.76	73.69	69.48	4.49	58.78	66.01	61.69	3.82	59.46	67.02	62.58	3.95
Work Zone[a]												
Large HEMMs	72.29	104.04	84.65	10.5	65.47	96.47	77.91	9.03	65.88	97.23	78.72	8.98
Medium HEMMs	87.18	100.72	93.86	6.28	76.42	94.50	85.34	6.76	77.50	95.12	86.19	6.69
Light HEMMs	82.15	89.52	84.79	4.27	74.50	82.74	78.22	3.54	74.53	83.42	78.76	3.83
Blasting area	74.04	79.50	76.39	2.81	52.66	63.92	58.38	5.63	54.79	65.51	60.16	5.36
Haul Roads	–	79.51	–	–	–	69.24	–	–	–	70.28	–	–
COBP area	65.63	83.54	73.04	9.35	58.56	73.81	67.46	7.94	54.79	74.79	67.82	7.70
Cabin of HEMMs	60.62	100.92	87.93	13.5	56.01	100.14	84.75	15.3	56.48	100.56	85.03	15.0

[a] 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.

Chi-square test is robust enough for this sample size, there is no serious disadvantage in the present study (1).

The Pearson Chi-square test was performed for the subject categories by assuming the following hypothesis: The age group, experience group and the working group are independent of hearing loss at the 4, 6, and 8 kHz test frequencies.

Given that $P < 0.01$, the hypothesis was rejected at the 1% level of significance for the age group and experience group at the 4, 6 and 8 kHz test frequencies. However, the Pearson Chi-square test was rejected at the 5% level of significance for the working area group at 6 kHz because $P < 0.05$ but was accepted at 4 and 8 kHz.

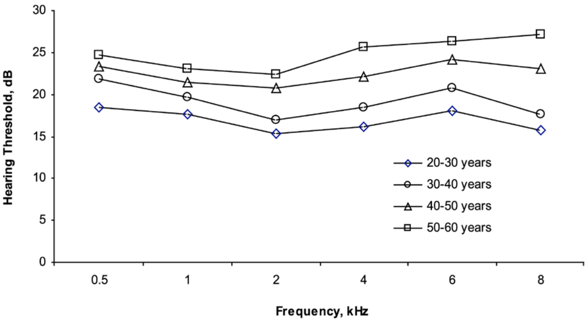

Figure 1: Hearing Threshold Vs. age.

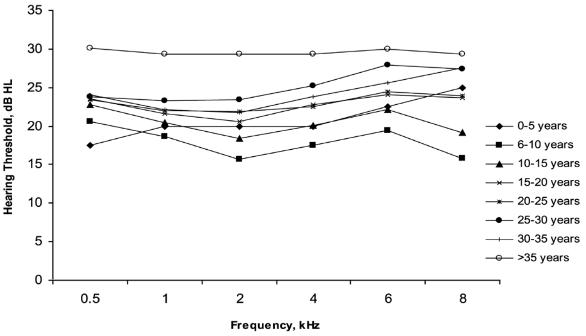

Figure 2: Hearing Threshold Vs. experience.

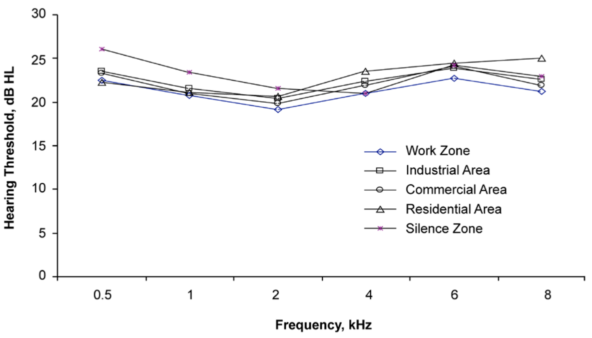

Figure 3: Hearing Threshold Vs. work stations.

The Pearson Chi-square test revealed an association between hearing loss and the age groups for all test frequencies (4, 6, and 8 kHz), and the degree of association varied from 0.22 to 0.27. There was also a relationship between hearing loss and the years of work experience, with the degree of association between 0.22 and 0.30. Similarly, the hearing threshold was also associated with working at the various workstations, and the value of the association was between 0.08 and 0.14. Hearing loss was associated with age and work experience for the 4, 6, and 8 kHz frequencies and with the subjects' different working areas for the 6 kHz frequency only.

Discussion

Table 3 shows that the maximum Leq level exceeded 90 dBA for all areas except the industrial area as did L_{90}, the background noise level. Similarly, the maximum noise levels were found to be more than 90 dBA for large and medium HEMMs, both at 7 m away from the equipment and at the operator's position. It may be inferred from this that the subjects, particularly the HEMMs operators, are overexposed to noise during the course of their working shift. In addition, the L_{10} value for the large HEMMs was found to be more than 100 dBA. Therefore, it may be inferred that the subjects are exposed to such high noise levels that they may suffer from hearing loss during the work shift at different areas of the mine.

The maximum association between hearing loss and age for 8.0 kHz implies that hearing loss increases with age and noise frequency. The maximum association between hearing loss and work experience for 4.0 kHz indicates a dip at the characteristic frequency. The maximum association between hearing loss and workstation occurred at 6.0 kHz instead of at the characteristic 4 kHz frequency. Therefore, it may be inferred that a number of the subjects may have been exposed to areas with high noise levels in the 6.0 kHz frequency.

As indicated in Table 4, the Chi-square test of independence revealed that hearing loss and age were dependent, with a degree of association of 0.27 at 8 kHz. Franks (20) has shown that 90% of coal miners and 49% of metal/non-metal miners undergo a hearing loss by the age of 50. Johansson et al., (11) have also shown a strong

Table 4: Pearson Chi-square test of the subjects (n = 500)

Category	**% age of subjects at**		**$\chi2^*$**	***P* (2-tailed)**
	≤ 25 dB HL	**> 25 dB HL**		
a. Subjects profiles and status of hearing loss at 4.0 kHz				
Age (years)				
20–30	100.0	0.0	32.82	0.001
30–40	94.1	5.9		
40–50	81.2	18.8		
50–60	69.4	30.6		
Experience (years)				
0–5	100.0	0.0	44.92	0.001
5–10	96.4	3.6		
10–15	89.1	10.9		
15–20	77.2	22.8		
20–25	79.7	20.3		
25–30	79.3	20.7		
30–35	82.2	17.8		
> 35	12.5	87.5		
Working Area/Zone				
W	84.7	15.3	3.15	0.534
A	79.7	20.3		
B	81.5	18.5		
C	85.0	15.0		
D	92.0	8.0		
b. Subjects profiles and status of hearing loss at 6.0 kHz				
Age (years)				
20–30	92.3	7.7	23.80	0.001
30–40	87.5	12.5		
40–50	71.6	28.4		
50–60	64.9	35.1		
Experience (years)				
0–5	100.0	0.0	24.68	0.001
5–10	87.5	12.5		
10–15	83.9	16.1		
15–20	70.1	29.9		
20-25	71.2	28.8		
25–30	62.1	37.9		
30–35	68.9	31.1		
> 35	37.5	62.5		
Working Area/Zone				
W	81.3	18.7	9.89	0.042
A	71.1	28.9		
B	72.3	27.7		
C	60.0	40.0		
D	68.0	32.0		

Category	% age of subjects at		χ2*	*P* (2-tailed)
	≤ 25 dB HL	> 25 dB HL		
c. Subjects profiles and status of hearing loss at 8.0 kHz				
Age (years)				
20–30	92.3	7.7	35.5	0.001
30–40	90.5			
40–50	75.0			
50–60	61.3			
Experience (years)				
0–5	100.0	0.0	33.39	0.001
5–10	92.9	7.1		
10–15	85.6	14.4		
15–20	71.6	28.4		
20–25	74.6	25.4		
25–30	65.5	34.5		
30–35	62.2	37.8		
> 35	37.5	62.5		
Working Area/Zone				
W	79.0	21.0	3.24	0.518
A	75.0	25.0		
B	81.5	18.5		
C	65.0	35.0		
D	76.0	24.0		

NB: * Chi-square value.

association between hearing threshold levels and age. They also demonstrated that reductions in hearing threshold levels start more rapidly in the 50-year age group for frequencies over 3 kHz. Edwards (21) demonstrated a strong association between hearing loss and age in a study of gold miners. Furthermore, it has been shown that the average deterioration in the pure tone threshold of gold miners is 14.16 dB for every ten years at 6 kHz. Thus, it can be concluded that the subjects' hearing threshold is positively associated with age for the 8 kHz frequency. This finding also indicates that hearing loss continues every 10 years up to the age of 50 to 60 years.

There is also a relationship between hearing loss and the length of time of job exposure at the 1% level of significance, with a maximum degree of association of 0.30 at 4 kHz, the characteristic frequency. Celik et al., (4) have found that workers at a hydroelectric power plant demonstrate hearing loss within the first 10 years of noise exposure and that there is a slight progression in the following years in the frequency range of 4 to 6 kHz. Abbate et al., (13) are in agreement with the present study and found that noise-induced hearing loss is observed in occupational exposure exceeding 17 years at 4 kHz in two bottling plants. However, the present study reveals that subjects' hearing loss increases with every 5 years of working experience in an open cast chromite mine at 4 kHz.

Similarly, hearing loss and working at different stations are dependent at the 5% level of significance, with a maximum association of 0.14 at 6 kHz, where the notch is found. The work zone was found to be the most significant factor affecting the subjects' hearing loss for 6 kHz at the 5% level of significance. Spencer et al. (22) agree with these findings and have shown that there is a strong association between noise exposure and heavy construction equipment operators. Edwards (21) showed that there is also a strong association between hearing loss and rock drillers, the most severely affected of whom are gold mine workers.

Conclusion

In our study population, the maximum noise levels for large and medium HEMMs and inside the HEMM cabins were found to be more than 95 dBA. This indicates that the operators in that particular chromite mine of Odisha, India, were exposed to noise levels exceeding 95 dBA for more than 10% of the monitoring time. The subjects' hearing loss was also found to increase for every 10-year age interval and for every 5 years of work experience exposed to high fence frequencies. The subjects' age and experience were significantly associated with hearing loss at all levels for 4.0, 6.0, and 8.0 kHz frequencies, with a higher percentage of older and more experienced workers experiencing hearing loss.

Authors' Contribution

Conception and design, analysis and interpretation of the data, drafting of the article, provision of study materials or patients, and collection and assembly of data: SK
Conception and design, analysis and interpretation of the data, critical revision of the article for important intellectual content, and statistical expertise: RG
Conception and design, analysis and interpretation of the data, critical revision of the article for important intellectual content, final approval of the article, provision of study materials or patients, and statistical expertise: SB

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