Noise levels of heavy earth moving machineries in a chromite mining complex of Odisha, India: An assessment and analysis

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Abstract: The present study describes a systematic noise monitoring inside the working zone of the chromite mining complex for the Heavy duty, Medium duty and Light duty vehicles in summer 2008 and winter 2009. The present study aims at estimating the noise levels of different heavy earth moving machineries (HEMMs) and tests the significant difference among them. The Analysis of Variance (ANOVA) reveals that the equivalent noise level differs with respect to time of monitoring and the types of HEMMs at 1% level of significance. The Post hoc analysis of multiple comparisons of means shows that L_{eq} level is the most influential during the 1st part of the time of monitoring for the Pay Loader (H1). In case of the dozer (M3), L_{eq} is the most significant during the 3rd part of the time of monitoring. Similarly, L_{eq} level of the Drilling Machine (L2) is found to be the most influential during the 1st part of the time of monitoring. The equivalent noise levels of Pay Loader (H1) and the Dozer (M3) exceed the prescribed limits during the period of monitoring.

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1. Introduction

The high noise levels are experienced due to noise generation from the different machineries. **Mathew (1968)** evaluated the noise levels in agricultural fields and identifies that field machinery with power hand tools are mainly responsible to generate high noise levels. The annoying effects **Gjestland and Oftedal (1980)** from such machines may be attributed to high noise levels and exposure time. **Mukherjee et al. (1995)** found that 64% machines provide noise level more than 90 dBA in the shop floor and non-shop floor areas of a watch non-factoring machine. However, **Prince et al. (1997)** suggested that due to uncertainty in quantifying risks below 85 dBA, new data collection efforts should focus on better characterization of dose-response and longitudinal hearing surveys that include workers exposed to 8 hour time weighted noise levels below 85 dBA. **Madhu et al. (1999)** found that even in large scale and small scale industries, workers exposed to 100 dBA, do not exhibit any occupational health hazards. **Das et al. (1999)** found highest noise levels in residential areas at Jaipur, Rajasthan, India, and attributed to increase urbanization. Similarly, **Murthy et al. (1999)** found noise levels of 108.6 dBA near control panel of the diesel engine of a DG plant. **Pandya and Srivastava (1999)** found that evening is the noisiest time of day of commercial areas of Jabalpur city, India**. Bauer and Kohler (2000)** investigated that one worker whose responsibility is to monitor the equipment and "home clean" the plant is slightly over-exposed, even he spends only half the shift in the plant. **Singh et al. (2000)** found that the in silence zone, the noise levels exceed the limit prescribed. **Amedofu (2004)** found that the noise levels exceed 75 dBA in a surface gold mine. **Kisku et al. (2002)** found that rock breaker recorded the highest noise levels with 73.1± 4.2 to 89.5 ± 10.1 dBA of a Bauxite mines. **Ahmed (2004)** suggested that questions addressing noise exposure and hearing loss might be a useful tool for screening subjects exposed to high noise level where faculties for an objective assessment of noise exposure and hearing loss are not available. **Griefahn and Spreng (2004)** suggested that during night time, the critical limit of noise level must not exceed due to air traffic and shall be tolerated for limited time.

Objectives of the study:

1. To test if the noise levels of the HEMMs conforms to the standards **(Maiti, 2003).**
2. To estimate the noise levels of HEMMs with respect to Heavy duty, Medium duty and Light duty vehicles.
3. To test whether there exists any significant difference among the Heavy duty, Medium duty and Light duty vehicles deployed in the mines for the duration of monitoring.
4. To estimate the most significant HEMMs contributing high noise in the work zone with respect to time of monitoring.

2. Materials and Method

2.1 Study Area

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

2.2 Noise Measurement

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 a rigid stand at 1.2 to 1.5 m above the ground surface, and 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 **(Heimann, 2003).**

2.3 Noise Parameters

The noise levels were quantified in terms of different sound levels such as L_{10}, L_{90} and L_{eq} to know the variation of noise levels at a particular station and are defined as below:

L_{10}: Maximum noise level exceeding 10% of monitoring time.

L_{90}: Minimum noise level exceeding 90% of monitoring time and is also known as background noise.

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

The following equation was used to evaluate L_{10}, L_{90} and L_{eq} **(Irwin and Graf, 1939):**

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

Where

L_{av} = Average noise level, dBA

L_i = the ith sound pressure level, dBA

i = 1, 2, 3,……,N

N = No. of readings for each parameter

2.4 Survey of Point Source

Systematic noise monitoring was conducted during day time for all the HEMMs viz., Heavy duty, Medium duty and Light duty vehicles during summer 2008 and winter 2009 continuously for one week and the details of noise monitoring stations are given in Table-1. Between two consecutive readings, a time gap of 60 s and 15 s was followed in summer and winter, respectively. Depending upon the running of the HEMMs, the monitoring of noise levels was carried out between 0.5 to 3.0 hours. The noise levels have been quantified in terms of different sound levels such as L_{10}, L_{90} and L_{eq}.

To meet the research objectives, the data so obtained were analyzed through SPSS (16.0) package under Window–XP environment. Generalized Linear Model ANOVA, Post hoc analysis, Tukey HSD Multiple comparison for mean difference and t-test were used as statistical tools to meet the objectives. The monitoring time (Table-1) of all the HEMMs has been divided into three equal parts such as 1st, 2nd and 3rd parts of the monitoring (Tables-3 & 4) to evaluate the most significant duration among three parts through ANOVA.

Table-1: Details of noise monitoring stations

Sl. No.	Vehicle Code	Equipment	Time of monitoring, hrs
Monitoring season: Summer 2008			
i. Heavy Duty Vehicles			
1.	H1	Pay loader	09.45-11:00
2.	H2	JCB	11:00-13:00
3.	H3	Shovel with Rock Breaker	11:00-11:30
4.	H4	Shovel with Rock Breaker	11:00-12:30
5.	H5	Poclain	14:45-16:45
ii. Medium Duty Vehicles			
6.	M1	Dozer	10:00-11:30
7.	M2	Dozer	10:15-11:15
8.	M3	Dozer	11:45-12:15
9.	M4	Dozer	15:15-16:30
10.	M5	Dozer	15:30-16:30
iii. Light Duty Vehicles			

Sl. No.	Vehicle Code	Equipment	Time of monitoring, hrs
11.	L1	Drilling Machine	09:30-12:15
12.	L2	Drilling Machine	09:45-10.45
13.	L3	Drilling Machine	16:30-17:15
Monitoring season: Winter 2009			
i. Heavy Duty Vehicles			
14.	H6	Poclain	09:30-11:00
15.	H7	Shovel with Rock Breaker	09:30-13:00
16.	H8	Volvo EC	14:00-16:30
17.	H9	Giant Excavators	14:00-17:30
ii. Medium Duty Vehicles			
18.	M6	Dozer	10:30-13:00
19.	M7	Dozer	10:30-13:00
20.	M8	Dozer	14:30-17:30
21.	M9	Dozer	14:45-17:00
22.	M10	Dozer	14:45-17:15
iii. Light Duty Vehicles			
23.	L4	Drilling Machine	09:30-13:00
24.	L5	Drilling Machine	14:30-17:00

3. Results

3.1 Statistical Analysis

Table-2: t-test of all the HEMMs: Test value is 85 dBA **(Maiti, 2003).**

a. Heavy Duty Vehicles and equivalent noise levels

Vehicle Code	L_{10}	L_{90}	L_{eq}	SD	t-value	*p*
H6	69.57	65.47	65.88	2.74	-138.86	<0.01
H8	84.04	79.85	80.23	2.89	-40.38	<0.01
H7	85.00	79.02	79.65	3.66	-42.08	<0.01
H5	78.16	71.53	72.24	3.62	-38.77	<0.01
H9	90.21	80.19	81.19	4.74	-23.34	<0.01
H2	72.29	72.04	73.24	6.60	-16.68	<0.01
H3	88.40	72.53	74.12	11.22	-05.31	<0.01
H4	90.13	84.05	84.69	3.34	-00.69	<0.01
H1	104.04	96.49	97.23	5.47	18.83	<0.01

H_0: L_{eq} levels of all the heavy duty vehicles are identical with the test value.
H_1: L_{eq} levels of all the heavy duty vehicles are not identical with the test value.

Since $p<0.01$, with respect to all the heavy duty vehicles, the hypothesis (H_0) is rejected at 1% level of significance.

b. Medium Duty Vehicles and equivalent noise levels

Vehicle Code	L_{10}	L_{90}	L_{eq}	SD	t-value	*p*
M6	88.62	78.14	79.04	5.22	-26.85	<0.01
M9	87.18	79.55	80.32	4.35	-26.07	<0.01
M10	89.69	79.18	80.23	5.59	-20.51	<0.01
M5	86.50	76.42	77.50	4.37	-12.84	<0.01
M7	91.47	85.48	86.02	5.02	04.79	<0.01
M3	105.27	93.88	94.98	5.54	10.04	<0.01
M1	97.53	89.00	89.90	4.36	10.96	<0.01
M8	93.94	85.80	86.65	3.67	11.41	<0.01
M4	97.66	91.49	92.14	3.29	18.90	<0.01
M2	100.72	94.50	95.12	2.89	24.98	<0.01

H_0: L_{eq} levels of all the medium duty vehicles are identical with the test value.
H_1: L_{eq} levels of all the medium duty vehicles are not identical with the test value.

Since $p<0.01$, with respect to all the medium duty vehicles, the hypothesis (H_0) is rejected at 1% level of significance.

c. Light Duty Vehicles and noise levels

Vehicle Code	L_{10}	L_{90}	L_{eq}	SD	t-value	*p*
L4	80.22	74.98	75.51	2.81	-98.37	<0.01
L5	82.89	78.26	78.72	2.70	-54.01	<0.01
L1	82.15	74.53	74.50	5.09	-25.02	<0.01
L3	89.52	80.60	81.65	4.14	-05.22	<0.01
L2	89.17	82.74	83.42	4.41	-02.67	<0.01

H_0: L_{eq} levels of all the light duty vehicles are identical with the test value.
H_1: L_{eq} levels of all the light duty vehicles are not identical with the test value.

Since $p<0.01$, with respect to all the medium duty vehicles, the hypothesis (H_0) is rejected at 1% level of significance.

Table-3: ANOVA for different HEMMs and time of Monitoring

a. Heavy Duty Vehicles

Vehicle Code	L_{eq}, dBA Part of time of monitoring			Tests of between-Subjects effects			
	1st	2nd	3rd	Source of variation	F	*p*	Remarks
H1	99.16	95.79	96.76	Time of monitoring	124.34	<0.01	sig.*
H2	71.51	71.86	73.32	Equipment	2761.00	<0.01	sig.*
H3	62.31	79.82	80.20				
H4	84.61	84.91	84.57				
H5	71.71	78.12	72.67				
H6	66.24	65.78	65.42	* The equivalent noise levels are not identical with respect to time of monitoring and also with the heavy duty vehicles.			
H7	79.68	81.15	78.13				
H8	80.06	80.29	80.47				
H9	80.58	81.17	81.84				

H_0: L_{eq} levels for all the heavy duty vehicles are identical with respect to HEMMs and also the time of monitoring.
H_1: L_{eq} levels for all the heavy duty vehicles are not identical with respect to HEMMs and also the time of monitoring.

Since $p<0.01$, the L_{eq} levels with respect to all the HEMMs, the hypothesis is rejected at 1% level of significance and also for the time of monitoring.

b. Medium Duty Vehicles

Vehicle Code	L_{eq}, dBA Part of time of monitoring			Tests of between-Subjects effects			
	1st	2nd	3rd	Source of variation	F	*p*	Remarks
M1	90.60	90.80	88.30	Time of monitoring	473.39	<0.01	sig. *
M2	96.56	94.03	94.70	Equipment	5025.00	<0.01	sig. *
M3	97.93	96.80	90.64				
M4	92.30	93.25	90.92				
M5	77.94	77.91	76.60				
M6	80.84	75.99	80.30	* The equivalent noise level is dependent on the time of monitoring and also with the medium duty vehicles.			
M7	88.68	88.15	81.26				
M8	87.22	87.27	85.46				
M9	79.72	79.86	81.37				
10	79.72	80.34	80.65				

H_0: L_{eq} levels of all the medium duty vehicles are identical with respect to time of monitoring.
H_1: L_{eq} levels for all the medium duty vehicles differ with respect to time of monitoring.

Since p<0.01, L_{eq} levels with respect to all the medium duty vehicles, the hypothesis is rejected at 1% level of significance and also for the time of monitoring.

c. Light Duty Vehicles

Vehicle Code	L_{eq}, dBA Part of time of monitoring			Tests of between-Subjects effects			
	1st	2nd	3rd	Source of variation	F	*p*	Remarks
L1	73.14	73.21	77.15	Time of monitoring	22.00	<0.01	sig. *
L2	77.40	79.12	79.72	Equipment	1813.00	<0.01	sig. *
L3	85.26	83.13	80.98	* The equivalent noise level is dependent on the time of monitoring and also with the light duty vehicles.			
L4	75.34	75.34	75.84				
L5	83.49	81.03	80.48				

H_0: L_{eq} levels of all the light duty vehicles are identical with respect to time of monitoring.
H_1: L_{eq} levels for all the light duty vehicles differ with respect to time of monitoring.

Since p<0.01, the L_{eq} levels with respect to all the light duty vehicles, the hypothesis is rejected at 1% level of significance and also for the time of monitoring.

Table-4: Post Hoc Tests Multiple Comparisons for different HEMMs and time of Monitoring

a. Heavy Duty Vehicles

Vehicle Code		Absolute mean difference	*p*	Time of monitoring		Absolute mean difference	*p*	Remarks
(I)	(J)	(I-J)		(K)	(L)	(K-L)		
H1*`	H2	25.02	<0.01	1st*	2nd	**1.93**	<0.01	sig. *
	H3	22.19	<0.01		3rd	1.43	<0.01	sig.
	H4	12.56	<0.01	2nd	3rd	0.49	<0.01	sig.
	H5	22.99	<0.01	* The equivalent noise level is the most influential for the equipment H1, the Pay Loader and also the 1st part of the time of monitoring at 1% level of significance.				
	H6	**31.44**	<0.01*					
H6	H2	06.42	<0.01					
	H3	09.25	<0.01					
	H4	18.88	<0.01					
	H5	08.45	<0.01					

b. Medium Duty Vehicles

Vehicle Code		Absolute mean difference	*p*	Time of monitoring		Absolute mean difference	*p*	Remarks
(I)	(J)	(I-J)		(K)	(L)	(K-L)		
M2	M3	0.12	<0.01	1st	2nd	0.68	<0.01	sig.
	M5	17.62	<0.01		3rd*	**2.31**	<0.01	sig.*
	M6	16.01	<0.01	2nd	3rd	1.63	<0.01	sig.
	M9	14.79	<0.01					
	M10	14.87	<0.01					
M3*	M5	**17.74**	<0.01*	* The equivalent noise level is the most influential for the equipment M3, the Dozer and the 3rd part of the time of monitoring at 1% level of significance.				
	M6	16.12	<0.01					
	M9	14.91	<0.01					
	M10	14.99	<0.01					
M5	M6	01.61	<0.01					
	M9	02.83	<0.01					
	M10	02.75	<0.01					

c. Light Duty Vehicles

Vehicle Code		Absolute mean difference	p	Time of monitoring		Absolute mean difference	p	Remarks
(I)	(J)	(I-J)		(K)	(L)	(K-L)		
L1	L2	**8.61**	<0.01*	1st	2nd*	**0.66**	<0.01	sig.*
	L3	7.14	<0.01		3rd	0.32	<0.01	sig.
	L4	0.96	<0.01	2nd	3rd	0.34	<0.01	sig.
	L5	4.21	<0.01					
L2	L3	1.47	<0.01					
	L4	7.65	<0.01					
	L5	4.40	<0.01					
L3	L4	6.18	<0.01					
	L5	2.92	<0.01					
L4	L5	3.25	<0.01					

* The equivalent noise level is the most influential during the 2nd part of the time of monitoring and also the equipment L2, the drilling machine at 1% level of significance.

4. Discussion

From Table-2, the hypothesis (H_0) is rejected for all the Heavy, Medium and Light duty vehicles at 1% level of significance, so, it may inferred that the noise levels of all the HEMMs differ significantly at the test value equal to 85 dBA, standards **(Maiti, 2003).**

In Table-2 (a), L_{10} value of the heavy duty vehicles viz., H1, H3, H4, H7 and H9 exceeds 85 dBA, the prescribed limits. Also L_{90}, the back ground noise level of only one heavy duty vehicle viz., the Pay Loader (H1) exceeds even 90 dBA. The analysis (t-test) reveals that at 1% level of significance, L_{eq} of the Pay Loader (H1) exceeds 85 dBA, the prescribed standards (Maiti, 2003). In Table-2 (b), L_{10} value of all the medium duty vehicles exceeds 85 dBA. The Student's t-test reveals that for the dozers M1, M2, M3, M4 and M7 and M8, L_{eq} levels exceed the prescribed limits of 85 dBA and also L_{90}. Similarly, in Table-2 (c), L_{10} value of the drilling machines L2 and L3, light duty vehicles exceeds the prescribed limits. The Student's t-test reveals that all the drilling machines conform to the prescribed limits of 85 dBA at 1% level of significance.

From Table-3, it is found that the hypothesis (H_0) is rejected for all the Heavy, Medium and Light duty vehicles at 1% level of significance, so it may be concluded that various HEMMs differ significantly with respect to their respective time of monitoring. The Post hoc analysis of multiple comparisons of means (Tukey HSD) is given in Table-4 and indicated the most influential vehicle which is mainly responsible for the high noise generation during the period of monitoring in the chromite mining complex.

Table-4 (a) shows the Pay Loader (H1) as the most influential heavy duty vehicle generating noise during 1st part of the monitoring at 1% significance level. Similarly, considering 8 hours exposure time, the L_{10} indicates that the noise exposure of the operators should not be more than 48 minutes in the Pay Loader. As depicted in Table-1 (a), the Pay Loader on the day of monitoring, worked only for 45 minutes and did not run the rest of the day. **Pal and Saxena (2000)** found that 1.9 m^3 HM Terex Pay Loader was having noise level more than 90 dBA at alarming frequency range 125-250 Hz in the coal mines of KDH OCP, Dakra OCP and Muraidih OCP. This high noise was attributed to the noise of motor, digging with bucket, etc. In the present study, the 1st part of the monitoring is the most influential, it may be inferred that the activities like starting of motor and bucket digging activities may be the major contributors of the high noise levels at this alarming frequency and thus high L_{eq} of the Pay Loader. **Pal and Saxena (2000)** have also investigated that L_{10} of 1.9 m^3 Pay Loader was 101.2 dBA while loading to tripping truck and in the present work, the same Pay Loader (H1) is found to generate the same noise level. The study of **Kisku et al. (2002)** reveals that the Rock Breaker was the highest noise level with 73.1±4.2 to 89.5±10.1 dBA in a Bauxite mine. **Amedofu (2004)** also found that the noise level was more than 85 dBA in the Mess area of a surface Gold Mines with exposure duration of 8 hours.

In Table-4 (b), the dozer M3 is the most influential equipment generating noise during 3rd part of the monitoring. The L_{eq} level of the dozers M1, M2, M3, M4, M7 and M8 exceeds the prescribed limits of 85 dBA. **Sensogut (2007)** examined that 60% of the workers were exposed to more than the prescribed limits for the exposure period of 8 hours at the mine surface workplace in Turkey. **Kisku and Bhargava (2006)** have also investigated that the noise level in the work zone area of a Thermal Power plant was also exceeding the prescribed limits. Similarly, **Vardhan et al. (2004)** studied in a coal mines that the high noise level recorded between 125-2000 Hz for all the dozers. The study made by **Pal and Saxena (2000)** exhibits that L_{eq} of 90-100 dBA was in the alarming frequency range of 125-1000 Hz and attributed to the engine exhaust, track chain, blade, etc. of the dozers in the coal mines of KDH OCP, Dakra OCP, KT OCP, Muraidih OCP and Block II OCP. In the present study, the dozers M1, M2, M3, M4, M7 and M8 are the most significant and L_{eq} was found to be in the range of 86-95 dBA. Similarly, M5 was the quietest among all the dozers and did not exceed the prescribed limits.

In Table-4 (c), the most influential vehicle is the Drilling Machine (L2), the light duty vehicle during 2nd part of the time of monitoring at 1% significance level. However, L_{eq} of all the drilling machines did not exceed the prescribed limits. L_{10} value of the drilling machines L2 and L3 was around 90 dBA and exceeded the prescribed noise levels for around 10 minutes during the time of monitoring. **Sensogut (2007)** found that L_{eq} of the Pneumatic drilling machine of a coal mines in Turkey was 91-92 dBA. However, the study made by **Pal and Saxena (2000)** did not agree with the present findings. The study reveals that the high L_{eq} (85-100 dBA) of all the drilling machines is due to start of the compressor, pulling down of chain, impact between the drill bit and the strata, etc. at an alarming frequency range of 63-2000 kHz. The most dominating frequencies where high noise levels recorded were 100 Hz, 200 Hz, 0.5 kHz, 1.0 kHz and 2.0 kHz.

5. Conclusions

1. The equivalent noise level is different with respect to time of monitoring and the types of HEMMs at 1% level of significance.

2. The equivalent noise level is the most influential during the 1st part of the time of monitoring and the Pay Loader (H1), the heavy duty vehicles are found to be the most significant at 1% level of significance. High noise generation may be due to the activities like start of motor, digging with bucket, etc. The L_{eq} recorded during the time of monitoring exceeded both warning limits and danger limits.

3. The equivalent noise level is the most influential during the 3rd part of the time of monitoring and the dozer (M3), the medium duty vehicle are found significant at 1% level of significance and the main noise sources of noise generation were engine exhaust, track chain, blade, etc. The L_{eq} recorded during the time.

4. The equivalent noise level is the most influential during the 1st part of the time of monitoring and the Drilling Machine (L2), the light duty vehicle are found significant at 1% level of significance and may be attributed to start of the compressor, pulling down of chain and impact between the drill bit and the strata. The L_{eq} recorded during the time of monitoring did not exceed the prescribed limits.

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