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Degree of association of industrial noise with the heavy earth moving machineries in a chromite mining complex at Odisha, India

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Abstract

The present study reports the systematic noise monitoring inside the work zone area of a chromite mining complex for the Heavy duty, Medium duty and Light duty vehicles in summer 2008 and winter 2009 to estimate the degree of association among the heavy earth moving machineries (HEMMs). The Chi-square test reveals that 0.757 is the degree of association between the heavy duty vehicles ($p<0.05$) and noise levels, 0.928 and 0.354 are the degree of association for the medium duty vehicles ($p<0.10$) and light duty vehicles ($p<0.05$), respectively. The dozer operators are found to be exposed to the highest noise levels as well the other workmen who are engaged in the mining activities in and around the dozers. Since, the value 0.928 is the maximum for all the HEMMs and is exhibited for the medium duty vehicles, it can be concluded that confirmation of strong association between the noise levels and the dozers.

Keywords: Noise pollution, mining industry, Odisha, India.

Introduction

While extracting ore and overburden from the mine quarry, lot of heavy earth moving machineries (HEMMs) are deployed in the mine quarry and are mainly responsible for the high noise generation in the work places as well in the vicinity. During transportation of loaded ore to the material yard, overburden to the OB dump yard and also to the mined out areas for concurrent backfilling, the dumpers create lot of frictional energy when tyres rub with the ground surface, release sound energy from the exhaust of the silencer, etc. (Gorai *et al.*, 2006). The pay loader has also similar activities viz., starting of motor, digging hard surface with bucket, etc. which are affecting the quality of the working areas due to high noise situation. The sound energy of drilling machine is also highly associated with start of compressor and impact between drill bit and ground surface (Pal & Saxena, 2000). The noise exposure of the workmen in the coal preparation plant has also been shown to have a strong relation with noise exposure in excess of 90 dBA (Vipperman *et al.,* 2001). The study also reveals that the main sources of noise in the Neyveli Lignite mines (India) are significant with respect to the industrial activities and movement of HEMMs (Sinha & Sridharan, 2003). The impact of the falling ore on the chute of the transfer station has been identified to generate noise of the order of 100 dBA is highly associated with the low frequency noise (Guo & Pan, 2004). A strong relationship also exists between the uncertainty creep effect in a simple gas turbine plant and the overall noise levels of the plant (Parzych & Putnam, 2006). Noise generation inside a variety of passenger vehicles over the frequency range 2-16 kHz is strongly associated with the frequency level below 20 Hz (Bryan, 1976). Therefore, different activities during mining operations have been studied and identified the tasks which are strongly related to high noise generation (Suter, 1992; Pathak *et al.*, 1999). This high noise levels in the industrial areas are strongly associated with noise induced hearing loss of the industrial workers (Amedofu, 2002). Similarly, the degree of annoyance has also high relevance with the traffic noise (Sato *et al.*, 1999). Therefore, in the present study, an attempt has been made to estimate the degree of association of the noise levels generated from the heavy duty, medium duty and lightly duty vehicles with the objectives: To test if the noise levels of the HEMMs are identical to the test value (NPR, 2000); To test if there exists a significant difference among the heavy duty, medium duty and light duty vehicles deployed in the mines with respect to the time of monitoring; To test the independence of the heavy duty, medium duty and light duty vehicles with respect to noise levels during the period of noise survey; If there exists the dependence relation then to determine the degree of association between the attributes.

Materials and methods

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.

Noise measurements

Digital Sound Level Meter (Model: 4226) of M & K, Denmark (Bruel & Kjaer) make was used during the whole period of noise survey. The sound level meter was placed at 1.2 to 1.5 meters above the ground surface and free from any obstacles or any reflecting objects and 7 meters away from the point source. Measurement was carried out in clear sky weather and sustained wind to avoid background noise level difference of more than 10 dBA (Heimann, 2003). The air temperature was in the range from 19.38-34.31 ^{0}C and the wind velocity was less than 1.02 m/s.

Table 1. Details of noise monitoring stations and t-test: Test value is 85 dBA (NPR, 2000)

a. Monitoring season: summer				
Station Code	Equipment	Time of monitoring, hours	L_{eq}, dBA	p
i. Heavy Duty Vehicles				
H1	Pay loader	09.45-11:00	97.23	<0.01
H2	JCB	11:00-13:00	72.24	<0.01
H3	Shovel with Rock Breaker	11:00-11:30	73.24	<0.01
H4	Shovel with Rock Breaker	11:00-12:30	84.69	<0.01
H5	Poclain	14:45-16:45	74.12	<0.01
ii. Medium Duty Vehicles				
M1	Dozer	10:00-11:30	89.90	<0.01
M2	Dozer	10:15-11:15	95.12	<0.01
M3	Dozer	11:45-12:15	94.98	<0.01
M4	Dozer	15:15-16:30	92.14	<0.01
M5	Dozer	15:30-16:30	77.50	<0.01
iii. Light Duty Vehicles				
L1	Drilling Machine	09:30-12:15	74.50	<0.01
L2	Drilling Machine	09:45-10.45	83.42	<0.01
L3	Drilling Machine	16:30-17:15	81.65	<0.01
b. Monitoring season: winter				
i. Heavy Duty Vehicles				
H6	Poclain	09:30-11:00	65.88	<0.01
H7	Shovel with Rock Breaker	09:30-13:00	79.65	<0.01
H8	Volvo EC	14:00-16:30	80.23	<0.01
H9	Giant excavators	14:00-17:30	81.19	<0.01
ii. Medium Duty Vehicles				
M6	Dozer	10:30-13:00	79.04	<0.01
M7	Dozer	10:30-13:00	86.02	<0.01
M8	Dozer	14:30-17:30	86.65	<0.01
M9	Dozer	14:45-17:00	80.32	<0.01
M10	Dozer	14:45-17:15	80.23	<0.01
iii. Light Duty Vehicles				
L4	Drilling Machine	09:30-13:00	75.51	<0.01
L5	Drilling Machine	14:30-17:00	78.72	<0.01

H_0: L_{eq} levels of all the HEMMs are identical with the test value. H_1: L_{eq} levels of all the HEMMs are not identical with the test value. Since, $p<0.01$, with respect to all the HEMMs (Heavy, Medium and Light duty vehicles), the hypothesis (H_0) is rejected at 1% level of significance. So, it may be inferred that the noise levels of all the HEMMs differ significantly at the test value equal to 85 dBA (NPR, 2000).

Survey of point source noise

Systematic noise monitoring was conducted during day time for all the Heavy Earth Moving Machineries (HEMMs) viz., Heavy duty, Medium duty and Light duty vehicles during summer 2008 and winter 2009 and the details of noise monitoring equipment were given in Table 1. Between two consecutive readings, a time gap of 60 seconds was followed in summer and 15 seconds in winter seasons was followed to minimize any monitoring shortcoming that made during summer. Depending upon the working of the HEMMs, the monitoring of noise levels was carried out between 0.5 to 3.0 hours.

Noise parameters

The noise levels were quantified in terms of its equivalent noise levels, L_{eq} to know the variation of noise levels with respect to a particular station. While doing the Chi-square test, the noise levels have been divided by taking the value of L_{90} as the splitting point during the period of monitoring. The definition of L_{90} and L_{eq} is as given below:

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_{90} and L_{eq} (Irwin & Graf, 1939):

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

Where

L_{av} = Average noise level, dBA

L_i = the ith sound pressure level, dBA

i = 1, 2, 3, ...,N

N = Number of readings for each parameter

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, Tukey HSD Multiple comparison for mean difference and Student's t-test were used as statistical tools to meet the objectives.

Results

Table 1 presents the details of noise monitoring stations. The hypothesis (H_0) is rejected for all the Heavy, Medium and Light duty vehicles at 1% level of significance. Thus, it is concluded that the equivalent noises level of all the HEMMs are not equal to the test value of 85 dBA (NPR, 2000) at 1% level of significance.

Table 2 indicates that the noise levels vary with respect to different types of HEMMs and also the time of monitoring at 1% level of significance.

Table 3 (a) exhibits the Chi-square test of independence of the noise levels of the heavy duty vehicles at different time of monitoring. It is found that the noise levels and the heavy duty vehicles are dependent at 5% level of significance ($p<0.05$) and the degree of association is 0.757 (Cramer's V) for the equipment H3, Shovel with Rock Breaker. Though, there exists degree of association between the noise level with the equipment H4, Shovel but, is not dependent and also the equipment H6, the Poclain at 5% level of significance.

As presented in Table 3 (b), the noise levels and the medium duty vehicles are dependent at 5% level of significance ($p<0.05$) and the degree of association is 0.928 for the equipment M5, the dozer. However, the noise level is independent with the dozer (M1) and also the dozer (M10) at 5% level of significance.

Similarly, as shown in Table 3 (c), all the light duty vehicles are having positive relationship with the noise levels at 5% level of significance ($p<0.05$) and the degree

Table 2. ANOVA for different HEMMs and time of Monitoring (Dependent variable: Equivalent noise levels)

Table 2 a. Heavy Duty Vehicles

Vehicle code	L_{eq}, dBA – Part of time of monitoring			Tests of between-Subjects effects		
	1st	2nd	3rd	Source of interaction	F	p
H1	99.16	95.79	96.76	Time of monitoring	124.34	<0.01*
H2	71.51	71.86	73.32			
H3	62.31	79.82	80.20	Equipment	2761.0	<0.01*
H4	84.61	84.91	84.57			
H5	71.71	78.12	72.67	* The equivalent noise levels are not identical with respect to time of monitoring and also with the heavy duty vehicles.		
H6	66.24	65.78	65.42			
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 of all the heavy duty vehicles are identical with respect to the time of monitoring. H_1: L_{eq} levels of all the heavy duty vehicles are not identical with respect to the time of monitoring. The hypothesis is rejected at 1% level of significance ($p<0.01$) for the L_{eq} levels with respect to all the heavy duty vehicles and also for the time of monitoring.

Table 2 b. Medium Duty Vehicles

Vehicle code	L_{eq}, dBA – Part of time of monitoring			Tests of between-Subjects effects		
	1st	2nd	3rd	Source of interaction	F	p
M1	90.60	90.80	88.30	Time of monitoring	473.39	<0.01*
M2	96.56	94.03	94.70			
M3	97.93	96.80	90.64	Equipment	5025.0	<0.01*
M4	92.30	93.25	90.92			
M5	77.94	77.91	76.60	*The equivalent noise levels are not identical with respect to the time of monitoring and also with the medium duty vehicles.		
M6	80.84	75.99	80.30			
M7	88.68	88.15	81.26			
M8	87.22	87.27	85.46			
M9	79.72	79.86	81.37			
M10	79.72	80.34	80.65			

H_0: L_{eq} levels of all the medium duty vehicles are identical with respect to the time of monitoring. H_1: L_{eq} levels for all the medium duty vehicles are not identical with respect to the time of monitoring. The hypothesis is rejected at 1% level of significance ($p<0.01$) for the L_{eq} levels with respect to all the medium duty vehicles and also for the time of monitoring.

of association is 0.345 for the drilling machine (L2). Independent relation exists between the drilling machine (L3) and the noise levels and also the drilling machine (L4) at 5% level of significance.

Discussions

As presented in Table 3 (a), the Chi-square test of independence shows that the noise levels and the heavy duty vehicles are dependent at 5% level of significance and the maximumdegree of association is 0.757 for the Shovel with Rock Breaker (H3), L_{eq}=73.24 dBA. Pal and Saxena (2000) investigated that the heavy duty vehicles and noise levels are dependent at different time of the day in the coal mines of KDH OCP, Dakra OCP and Muraidih OCP, Dhanbad, India. The study reveals that the Shovel with Rock Breaker exhibited noise levels more than 90 dBA and was mainly associated with the dominant frequencies viz., 25 Hz, 31.5 Hz, 315 Hz, 400 Hz and 500 Hz. The study further reveals that the noise sources are mainly influential at engine, silencer, track chain, etc. Sinha and Sridharan (2003) have opined that the major sources of noise in the coal mines are due to the movement of different vehicles. Kisku *et al*. (2002) agreed to the present study and found that the noise levels of the heavy duty vehicles are dependent. The highest noise levels of Rock Breaker found to be 89.4±10.1 dBA in summer at 1.65 m from the equipment. Mukherjee *et al*. (1995) also associated the noise levels of a watch manufacturing plant to be strong with different types of machines of the shop floor. The study reveals that 64.28% of the shop floor machines generate noise levels more than 90 dBA. Oyedepo, (2010) also presented that hammer mill machine from mineral crushing mills generates the highest average noise level of 98.4 dBA.

The Chi-square test of independence shows that the noise generation in the chromite mining complex is dependent with different dozers at 5% level of significance and the maximum degree of association is 0.928 for the dozer (M3), L_{eq}= 94.98 dBA. Pal and Saxena (2000) studied that the noise levels are strongly associated with engine exhaust, movement of track chain, and cutting of hard surface with bucket, etc. of the dozer at the dominant frequency of 125 Hz, 160, 200 Hz, 800 Hz and 1.0 kHz of KDH OCP, KT OCP and Muraidih OCP of North Karnapura mining complex. Kisku *et al.* (2002) also studied that the noise level of ripper Dozer of a Bauxite mines was found to be 75.0±8.12 dBA in summer at 1.65 m from the equipment. Pederson *et al*. (2008) associated the increasing noise levels of wind turbine with the risk of being annoyed in outdoors to be high.

Similarly, the noise levels and the drilling machine of the chromite mining complex are dependent at 5% level of significanc and the maximum degree of association is 0.345 for the drilling machine, L3, L_{eq}= 81.65 dBA. Pal and Saxena, 2000 surveyed that the high noise levels in the drilling machine are mainly related to the start of compressor, pulling of chain, impact between drill bit and strata, etc at the dominant frequencies of 80 Hz, 100 Hz, 160 Hz, 500 Hz and 1.0 Hz in KDH OCP, Dakra OCP and Muraidih OCP coal mines. Kisku *et al*. (2002) found noise levels of Master Driller to be 77.9±5.6 dBA in summer at 1.65 m from the equipment. Oyedepo (2010) showed that the equivalent noise levels of the Vibratory Crushing machine were 101.4 dBA. Pal and Saxena (2000) and Sensogut (2007) found that the noise levels of different drilling machines were exceeding the noise level of 85 dBA (NPR, 2000).

Table 2 c. Light Duty Vehicles

Vehicle code	L_{eq}, dBA			Tests of between-Subjects effects		
	Part of time of monitoring					
	1st	2nd	3rd	Source of variation	F	p
L1	73.14	73.21	77.15	Time of monitoring	22.00	<0.01*
L2	77.40	79.12	79.72			
L3	85.26	83.13	80.98			
L4	75.34	75.34	75.84	Equipment	1813.0	<0.01*
L5	83.49	81.03	80.48			

*The equivalent noise levels are not identical with respect to the time of monitoring and also with the light duty vehicles.

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

Conclusions

The Chi-square test reveals that the maximum degree of association between the heavy duty vehicles and noise levels is 0.757, the degree of association for the medium duty vehicles and light duty vehicles are 0.928 and 0.354, respectively. The value 0.928 is the maximum for all the HEMMs and is exhibited for the medium duty vehicles. Hence, there exists strong association of noise levels with dozers, the medium duty vehicles. The dozer operators are highly exposed to the high noise levels as well the other workmen who are involved in mining activities in and around the dozers. The working area of the dozer operators should be regularly changed to the less noisy area and ear protective devices should be provided to the subjects working in the mines quarry. Besides, periodical maintenance of all the HEMMs should be done to reduce noise emissions in the mine quarry as well in the neighbourhood.

References

1. Amedofu GA (2002) Hearing impairment among workers in a surface Gold Mining Company in Ghanna. *Afr. J. Health Sci*. 9, 91-97.
2. Bryan ME (1976) A tentative criterion for acceptable noise levels in passenger vehicles. *J. Sound Vib*. 48, 525-535.
3. Gorai AK, Mukhopadhya AK and Pal AK (2006) Control of noise problems in the Bailadila Iron Ore Mine, India. *J. Min. Geo*. 42, 21-34.
4. Guo J and Pan J (2004) Control of ore transfer station noise at a mining site. Acoustics 2004 Transportation Noise and Vibration-The New Millennium, Australia,

Table 3. Cross-classification of background noise level (%) of different HEMMs

Code	Percentage of occurrences						Chi-Square Test statistics		
	Part of time of monitoring								
	1st		2nd		3rd				
	≤ L_{90}	>L_{90}	≤ L_{90}	>L_{90}	≤ L_{90}	>L_{90}	χ^{2*}	p	$V^{\#}$
a. Chi-Square Test for Heavy Duty Vehicles									
H3	33.33	00.00	06.67	23.33	06.67	30.00	17.18	<0.05	**0.757**
H1	01.41	32.39	15.49	19.72	11.27	19.72	10.66	<0.05	0.387
H2	17.36	15.70	15.70	17.36	04.13	29.75	16.80	<0.05	0.373
H7	11.03	22.30	06.83	26.50	18.47	14.87	75.05	<0.05	0.300
H5	14.75	18.85	00.82	15.57	15.57	34.43	09.49	<0.05	0.279
H4	08.47	23.73	11.86	20.34	15.25	20.34	01.81	NS	0.178
H9	17.47	15.70	17.12	16.88	12.87	19.95	11.61	<0.05	0.117
H8	16.67	16.67	12.42	20.92	13.56	19.77	07.26	<0.05	0.109
H6	10.61	19.70	24.49	36.36	03.79	05.05	01.18	NS	0.055
*NB: *Chi-square value, # Cramer's V*									
b. Chi-Square Test for the Medium Duty Vehicles									
M5	33.93	00.00	30.36	03.57	00.00	32.14	48.21	<0.05	**0.928**
M3	03.23	29.03	00.00	32.26	25.81	09.68	16.04	<0.05	0.719
M7	01.82	31.45	03.64	29.64	25.82	07.64	272.3	<0.05	0.704
M2	07.84	25.49	23.53	07.84	21.57	13.73	09.51	<0.05	0.432
M6	09.71	23.56	24.82	08.45	10.97	22.48	95.11	<0.05	0.414
M4	13.16	19.74	09.21	23.68	19.74	14.47	04.68	NS	0.248
M9	16.67	16.67	17.52	15.82	09.52	23.81	27.44	<0.05	0.217
M8	11.76	21.52	15.17	18.11	19.20	14.24	21.14	<0.05	0.181
M1	10.53	22.11	11.58	22.11	15.79	17.89	01.68	NS	0.133
M10	12.93	20.34	12.59	20.69	13.79	19.66	00.50	NS	0.029
c. Chi-Square Test for the Light Duty Vehicles									
L2	05.36	26.79	14.29	19.64	19.64	14.29	06.68	<0.05	**0.345**
L1	19.73	13.61	19.73	13.61	08.16	25.17	15.76	<0.05	0.327
L5	19.22	14.05	13.49	23.48	06.84	22.92	44.28	<0.05	0.286
L3	09.52	23.81	19.05	14.29	19.05	14.29	03.06	NS	0.270
L4	16.88	16.41	16.17	17.12	14.17	19.24	04.22	NS	0.071

Australian Acoustical Society. 1, 277-287.
5. Heimann D (2003) Meteorological aspect in modeling noise propagation outdoors. Euro Noise, Naples.
6. Irwin JD and Graf ER (1939) Industrial Noise and Vibration Control. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. pp: 16.
7. Kisku GC, Barman SC, Kidwai KK and Bhargava SK (2002) Environmental impact of noise levels in and around opencast bauxite mine. *J. Environ. Biol*. 23, 51-56.
8. Mukherjee AK, Nag DP, Kakde Y, Prakash MN and Rao SR (1995) Noise level monitoring in a Watch Factory in Bangalore. *Indian J. Occup. Ind. Med*. 41, 2-44.
9. NPR (2000): The Noise Pollution (Regulation and Control) Rules, 2000 of Ministry of Environment and Forests, Government of India.
10. Oyedepo OS (2010) Evaluation and analysis of noise levels in Ilorin metropolis, Nigeria. *Environ. Monit. Ass*. 160, 563-577.
11. Pal AK and Saxena NC (2000) Development of noise indices for coal mining complexes. An ENVIS Monogram, Ministry of Environment and Forests, India.
12. Parzych DJ and Putnam RA (2006) Modelling uncertainty creep due to variability in model constituents. Proceedings in Inter-Noise 2006, Honolulu, Hawaii, USA.
13. Pathak K, Durucan S and Kunimatsu S (1999) Activity accounting technique for environmental noise assessment in mechanized surface mining. *Environ. Monit. Ass*. 56, 241-256.
14. Pederson E, Bouma J, Bakker J and Berg FVD (2008) Response to wind turbine noise in the Netherlands. Euronoise, Acoustics-2008, 29 June-4 July, Paris.
15. Sato T, Yano T, Björkman M and Rylander R (1999) Road traffic noise annoyance in relation to average noise level, Number of events and maximum noise. *J. Sound Vib*. 233, 775-784.
16. Sensogut C (2007) Occupational Noise in Mines and its control-A Case Study. *Polish J. Environ. Studies*. 16, 939-942.
17. Sinha S and Sridharan PV (2003) Present and Future Assessment of noise level in the Neyveli Region. *J. Environ. Studies Policy.* 2, 1-13.
18. Suter AH (1992) Communication and job performance in Noise: A Review. ASHA Monographs No. 28. Rockville, American Speech-Language-Hearing Association.
19. Vipperman JS, Bauer ER and Babisch DR (2001) Survey of noise in coal preparation plants. *J. Acoust. Soc. Am*. 110, 2752-2765.