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Full Length Research Paper

Methodology of the community noise environmental quality assessment: A case study of Indian iron ore mining complex

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Community noise is a term used generally to refer to noise exposure outside the industrial work place. This paper highlights the procedure of determining the noise environmental quality in residential/ commercial/ sensitive areas situated near the industrial (iron ore mining) complex. The noise environmental qualities (NEQ) for each locality were determine from value function curves developed for each noise impact parameters identified. The study reveals that almost all the areas register noise stress situations as the observed resultant noise environmental quality [NEQ(R)] at all the locations exceeding the desirable noise environmental quality [NEQ(R)] of the corresponding locations. The poor noise environmental quality and its associated harmful consequences demand incorporation of effective noise control mechanism in order to reduce the noise stress significantly.

Key words: Noise, impact assessment, iron ore mining.

INTRODUCTION

Complaints about community noise continue to increase throughout the world. Effect of noise on health may arise as a direct consequence of exposure to noise or development of adverse reactions leading to annoyance and dissatisfaction. Job documented the relation between effect of noise with hearing loss and community reaction (Job, 1988). The community reactions are often characterised as annoyance, disturbance, dissatisfaction, frustration and agitation (Job, 1993). The major negative effects of such are disturbance of rest-and-sleep and general annoyance.

It is very difficult to assess the noise environmental quality for a particular community, as it is the subjective response of the exposed population. This is because the impact of a particular noise varies from person to person. However the subjective evaluation of the expert judgement may be replaced by objective measurement with the help of certain physical properties of the noise. This seems to be closely related to a scale for rating the subjective effects. For the last three decades a number of researchers (Cantrell et al., 1974; Hall et al., 1981; Schultz, 1982; Lazarus, 1987) worked on this aspect so as to frame suitable noise rating schemes for the evaluation of the subjective responses of an exposed population.

The subjective response of the exposed population depends on the various factors (Hall et al., 1981; Raw and Griffith, 1985; Bjorkman, 1991; Vos, 1992; Bradley, 1994; Kryter, 1970; Beranek, 1971; Kryter, 1962; Spoor, 1967; Pearson, 1974; Hinchcliffe, 1959) like human factors: age, sex, exposure history, health state and acoustical factors: frequency composition, impulsiveness, directivity, intermittence, duration, occurrence time etc.

Brief details of the study area

The community area selected for noise impact assessment study is near one of the largest iron ore mine in India (Bailadila Iron Ore-Mining Complex) Bailadila Iron Ore Mine is situated at Kirandul village in the district of Dantewada (Chattisgarh). The Latitude and longitude of the mine area ranges from 18° 32' 32" N to 19° 36' 05" N and 81° 13' 00" E to 81° 14' 30" E respectively. It consists

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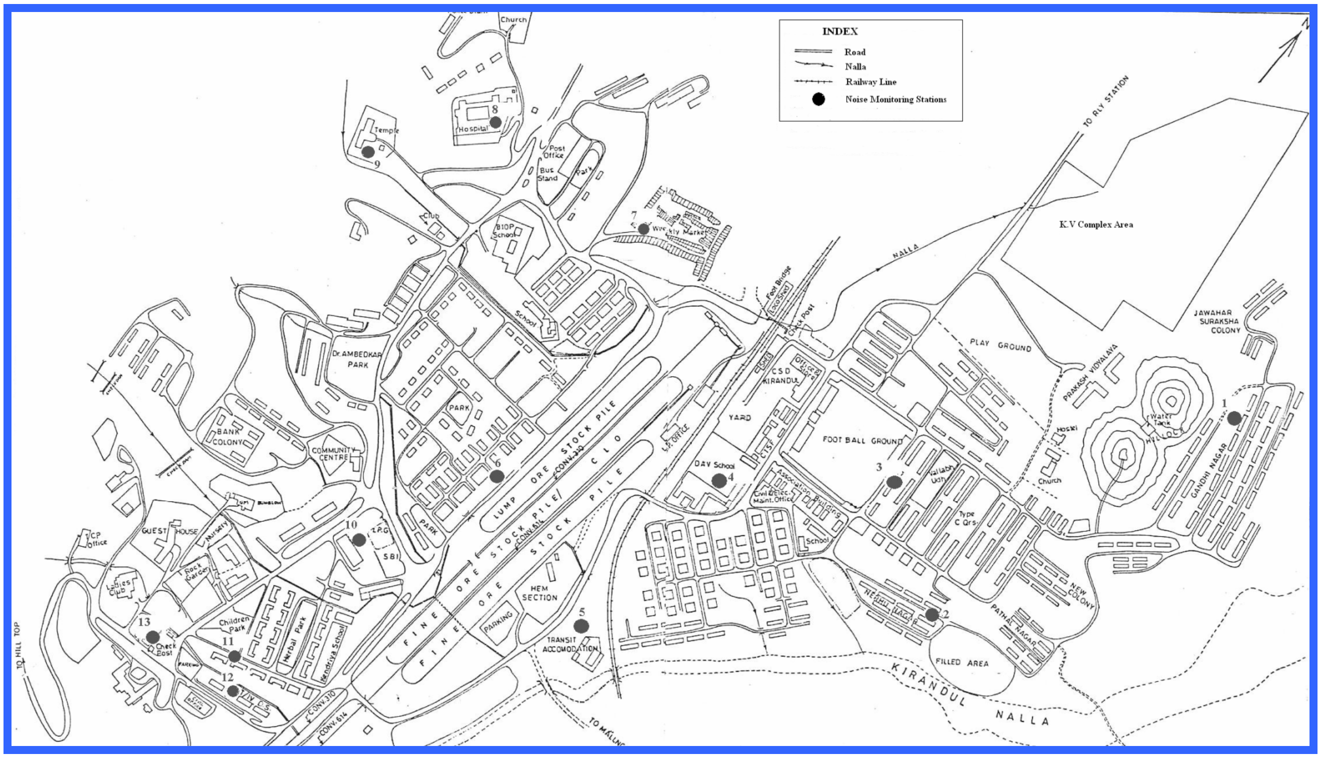

Figure 1. Ambient noise monitoring locations.

of 2 pits, namely Pit No. 1 (Deposit-14) and Pit No. 2 (deposit 11C) and is spread over 3 mining lease holds, namely deposit 14 mining lease, deposit 14 non-mineralized mining lease and deposit 11C mining lease. Besides the mining activities and the operation of HEMM (heavy earth moving machineries) there are 2 screening plants, 2 crushing plants, 1 loading plant and 1 tertiary crushing plant in operation.

Locations for ambient noise monitoring

In this study one station identified for each individual locality and the total numbers of stations were 13 for noise monitoring. The selected locations associated with major noise sources like ore handling plants, vehicular movement and workshop activities. Figure 1 displays the ambient noise monitoring locations.

METHODOLOGY APPLIED

To determine the noise environmental quality (NEQ) for a locality on the basis of noise impact parameters, value function curves developed for each individual noise impact parameters identified. The noise environmental quality (NEQ) value ranges from 0 to 1 with 0 representing a very poor NEQ and 1 an excellent NEQ respectively. The value function curves show the dose effect/ dose response relationship between noise doses and the effect of these doses on the exposed persons or their response to the doses. Based on personal experience and interaction with the exposed persons, the noise impact parameters were identified: temporary deafness (temporary threshold shift), disturbance in speech/conversation, annoyance and irritation, disturbance in sleep, disturbance in alertness/ concentration.

In order to evaluate the relative ranking and weightage of the impact parameters selected above, expert views were considered through Delphi technique (Linstone and Turrof, 1875). The Delphi approach is essentially a method for obtaining a consensus from a group. The objective of this approach is to obtain a reliable consensus of opinion from a group of experts that can be used to quantify the subjective judgment with minimum undesirable aspects of group interaction.

At the first round of questionnaire survey, 300 experts (from leading academic institutions, research institutions, statutory control agencies, medical professionals and mining organizations) were supplied with a format [appendix 1] asking for 'unranked pair-wise comparison' of the impact parameters. Also they were asked to give their comments for possible inclusion or exclusion of any parameter with justification. The responses of the 113 experts were come and these response data thoroughly scrutinized and accordingly the ranking of the impact parameters was obtained.

In the second round of survey questionnaire format [appendix 2] were sent to the same experts for ranked pair-wise comparison and the responses come from 109 experts. The compilation of this survey led to the evaluation of relative weightage of the already ranked impact parameters. Accordingly, the mean relative weightage of the impact parameters was evaluated. The relative ranking and relative weightage obtained from the first phase and second phase of questionnaire survey are shown in Table 1.

After finalizing the importance of individual noise impact parameters, the relationships between individual parameters and NEQ value were evaluated using available global research resources. Based on the availability dose-response relationship for each individual parameter, appropriate NEQ values were assigned for the parameters.

Table 1. Mean rankings and the relative weightage of noise impact parameters.

Parameters	Rank	Mean relative importance (cumulative)	Mean relative weightage (RW)
Annoyance and Irritation	1	1	34.36
Disturbance in alertness and concentration	2	0.81	27.99
Disturbance in sleep	3	0.57	19.55
Disturbance in speech conversation	4	0.33	11.24
Temporary deafness (threshold shift)	5	0.20	6.86
Total		2.91	100

Table 2. Dose-response relationship of annoyance and irritation.

Sound Pressure Level in dB (A)	Effects	Noise environmental quality
100.00	Severe annoyance and Irritation	0.02
90.00	Annoyance Factor is high and certain physiological changes often occur	0.08
85.00	Vigorous community action	0.10
75.00	Still strong complaints can be expected	0.30
73.00	Strong appeals to local official to stop noise	0.40
66.00	Wide spread complaints or single threat of legal action	0.50
60.00	Sporadic complaints	0.70
55.00	Still annoys to sensitive people	0.90
40.00	Very acceptable to all	0.96
30.00	Introduces additional problem	0.90

Table 3. Dose-response relationship of alertness and concentration.

Sound pressure level in dB (A)	Effects	Noise environmental quality
100.00	Serious Reduction in Alertness/ Concentration	0.05
90.00	Alertness and mental decrements will be frequent	0.20
85.00	Some alertness and cognitive performance decrements can be expected	0.30
80.00	Difficult to think/ concentrate after about 1hr.	0.40
72.00	Clearly stressful.	0.55
65.00	Causes stress reactions, the inability to concentrate and even bad moods.	0.70
60.00	The ability to pay attention may well be difficult to nonexistent.	0.80
50.00	Acceptable to most people	0.95
40.00	Quiet rural area, Very quiet library so easy to concentrate.	0.99

The relation between the 5 harmful parameters and its impacts evaluated from the literature are shown in Tables 2 to 6 (Gyr and Grandjean, 1984; Kryter, 1985; Langdon and Buller, 1977; Lukas, 1975; Page, 1977; Weinstein, 1982; Woodson, 1981; Berglund and Magrab Lindvall, 1995; Sinha et al., 2003; Wilson Report 1963; USEPA, 1974).

Based on these relationships, noise environmental quality corresponding to different noise level has been assigned. These relationships (Tables 2- 6) are used to develop the noise value function curves for each parameter through SPSS (Statistical Package for Social Sciences) package (Figures 2 to 6). The value function curves and their corresponding equation were evaluated on the

Table 4. Dose-response relationship of sleep disturbance.

Sound pressure level in dB (A)	Effects	Noise environmental quality
100.00	No Sleep, Nearly everyone awakens	0.01
95.00	98 % people awakens	0.03
90.00	97 % people awakens	0.05
85.00	95 % people awakens	0.09
80.00	93 % people awakens	0.15
75.00	90 % people awakens	0.25
70.00	86 % people awakens	0.35
55.00	Awakens about 50 % of the population about 50 % of the time	0.60
50.00	Numerous Complaints. 25 % of the population awakens or delayed in falling asleep	0.70
40.00	Occasional Complaints. A few people may have sleep problem. Probability of being awakened is 5 %	0.90
30.00	Comfortable for sleeping	1.00

Table 5. Dose-response relationship of speech conversation problem.

Sound pressure level in dB(A)	Effects	Noise environmental quality
100.00	Speech Conversation is impossible 1.5 m.	0.01
95.00	Speech conversation is extremely difficulty even from 0.4 m	0.12
90.00	Shout for conversation even from 0.6 m	0.22
85.00	Normal voice form (30 cm apart)	0.31
80.00	Speech conversation is difficult (30.48 cm apart)	0.38
75.00	Too noisy for adequate telephone conversation, a raised voice is required for conversation from 60.96 cm apart	0.46
70.00	Upper level for normal conversation (within 30.48 cm apart)	0.54
65.00	Intermittent personal conversation is acceptable	0.63
60.00	Acceptable for social conversation and sedentary recreational activities.	0.73
55.00	99 % sentence intelligibility from 1m apart	0.85
50.00	Normal conversation is possible at distance up to 2.44 m	0.99

basis of best-fit situation through coefficient of correlation.

Figure 2 shows the value function curve for annoyance and irritation. At 100 dB (A) (Leq), poor NEQ value indicates severe annoyance and irritation. When the Leq value decreases NEQ gradually increases up to 85 dB (A) and then the NEQ increases little bit with faster rate up to 55 dB (A). The NEQ value attains a maximum of (0.96) at about 40 dB (A). However, when the Leq further decreases, the NEQ deteriorates, indicating additional problems due to excessive calm situation.

The value function curve for disturbance in alertness/concentration (Figure 3) shows the NEQ increasing more or less linearly in the range of 100 dB (A) to 50 dB (A). After that the NEQ value increases comparatively slowly with the decreasing of Leq. The maximum value shows at 40 dB (A).

The value function curve for sleep disturbance (Figure 4) shows a lower rate of increase of NEQ value from 100 dB (A) to about 70 dB (A); thereafter, the rate of increase is comparatively more when Leq value further decreases. It attains a maximum value of 1.00 at 30 dB (A).

The value function curve for speech conversation (Figure 5) shows three distinct situations. From 100 dB (A) to 80 dB (A), the NEQ increases at a faster rate, followed by a more or less linear increasing rate up to 60 dB (A). The NEQ value increases with faster rate when the Leq decreases from 60 dB (A) to 50 dB (A) and get the maximum satisfaction. Thereafter the NEQ value is constant with the decreasing of Leq value.

For temporary threshold shift, the curve (Figure 6) shows the NEQ is near about zero at Leq 100 dB (A). This increases steadily as Leq decreases and attains the maximum value of 0.95 at 65 dB (A).

The value function equations developed for all the parameters are shown in Table 7. The overall noise environmental quality is represented by the NEQ(R), which takes into account the combined effect of all the NEQ with respect to 5 impact parameters.

The overall quality of noise environment is represented by the NEQ(R) (resultant NEQ) value as expressed below.

Table 6. Dose-response relationship of temporary noise deafness.

Sound pressure level in dB(A)	Effects	Noise environmental quality
100.00	Temporary hearing loss (300 – 1200 Hz) occurs invariably	0.03
95.00	Temporary hearing loss (300-1200 Hz) often occurs	0.20
90.00	Some THL (300-1200 Hz) Occurs	0.40
85.00	Can be harmful to the ear	0.55
80.00	Effect is very low	0.68
75.00	Occasional Complaints	0.79
70.00	May effect in long exposure	0.88
65.00	Safe limit	0.95

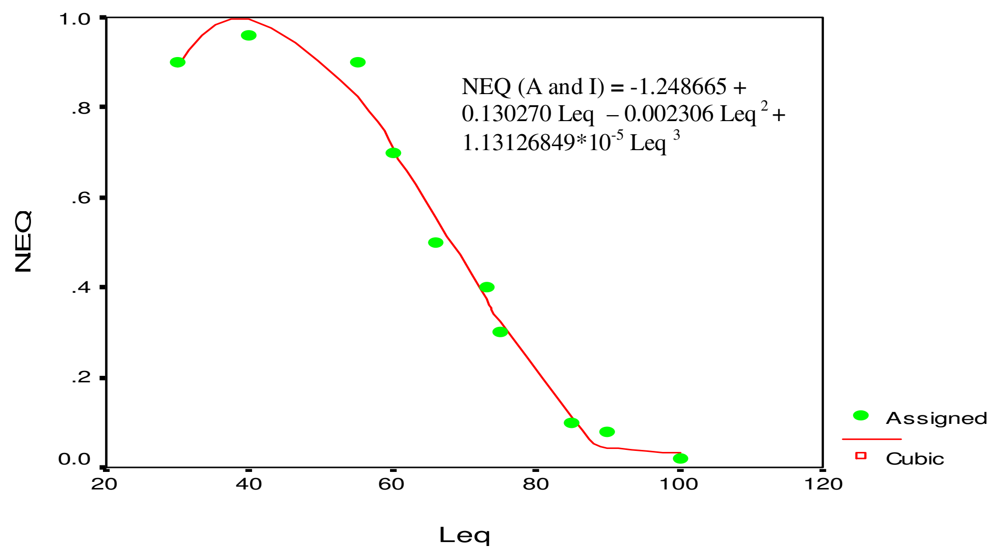

Figure 2. Value function curve for annoyance and irritation.

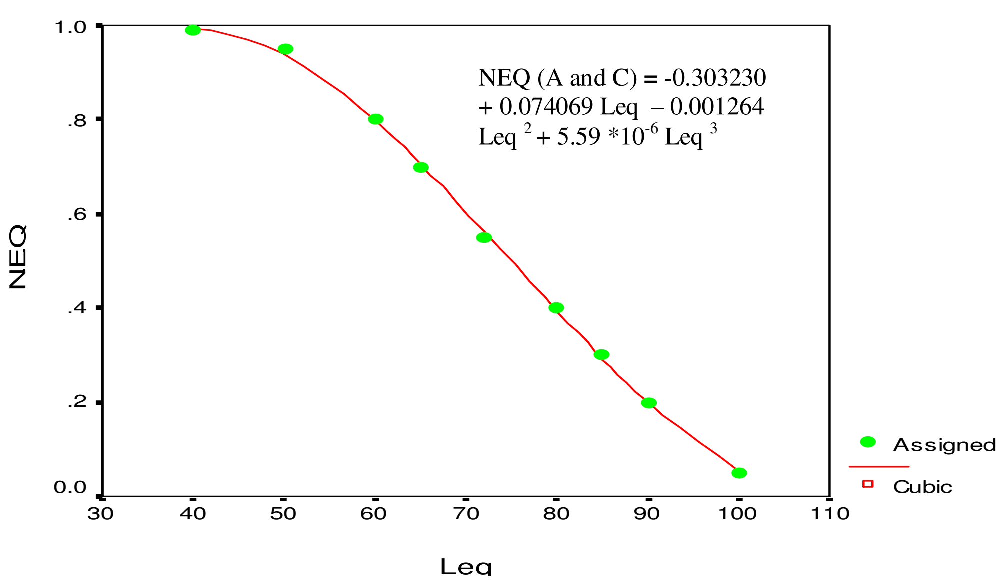

Figure 3. Value function curve for alertness and concentration.

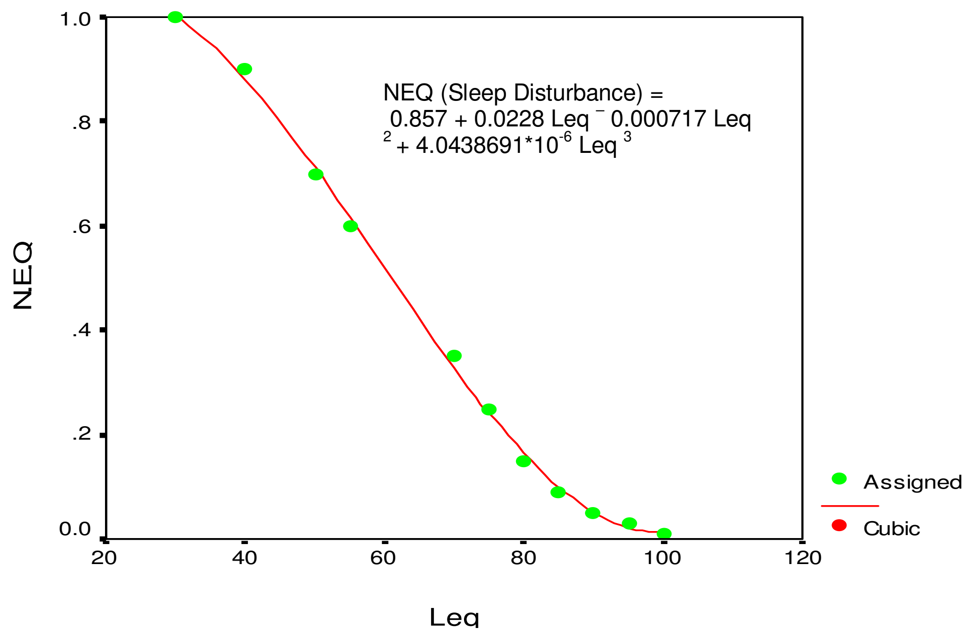

Figure 4. Value function curve for sleep disturbance.

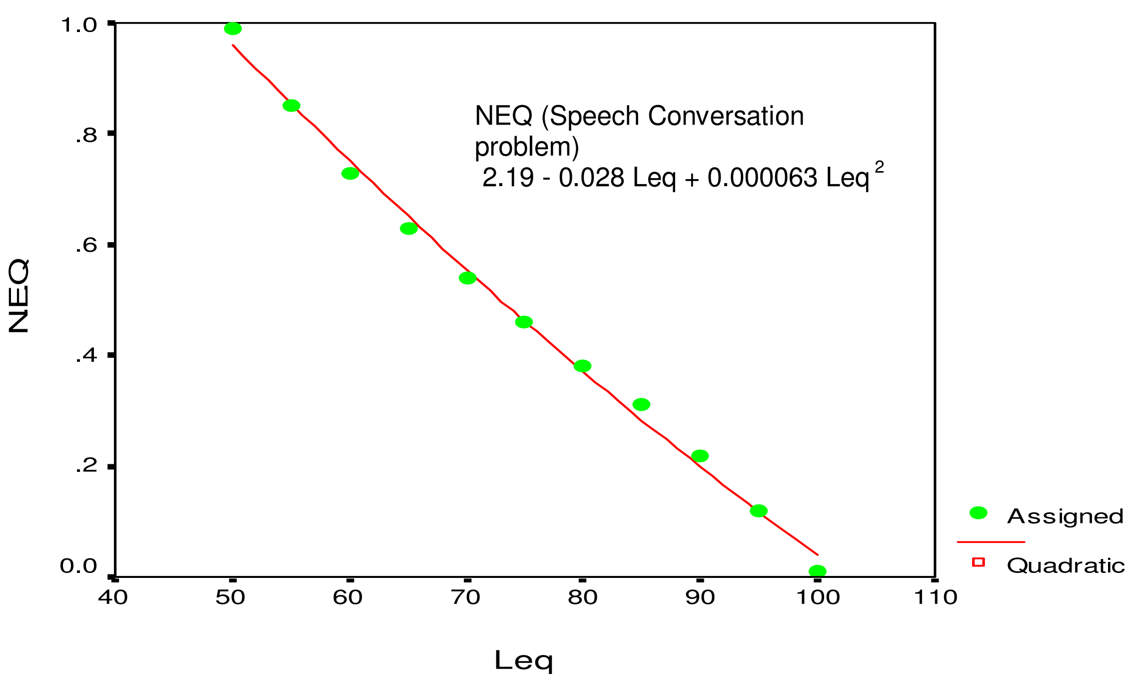

Figure 5. Value function curve for speech conversation problem.

$$NEQ(R) = \sum_{i=1}^{5} NEQ_i * RW_i$$

Where; NEQ_i - noise environment quality value of i^{th} parameter and RW_i - relative weightage of the i^{th} parameter.

The existing noise environmental quality was calculated on the basis of sound pressure level found in the monitoring areas and was compared with the desired values. The desired values were calculated on the basis of permissible noise level provided by the statutory bodies. In this paper the permissible values were taken as per the central pollution control board (CPCB), India. The permissible values for the commercial area, residential area and sensitive area are 65, 55 and 50 dB (A) respectively. The same can be determined for any other countries as par their permissible noise norms for different areas. The desired noise environmental quality

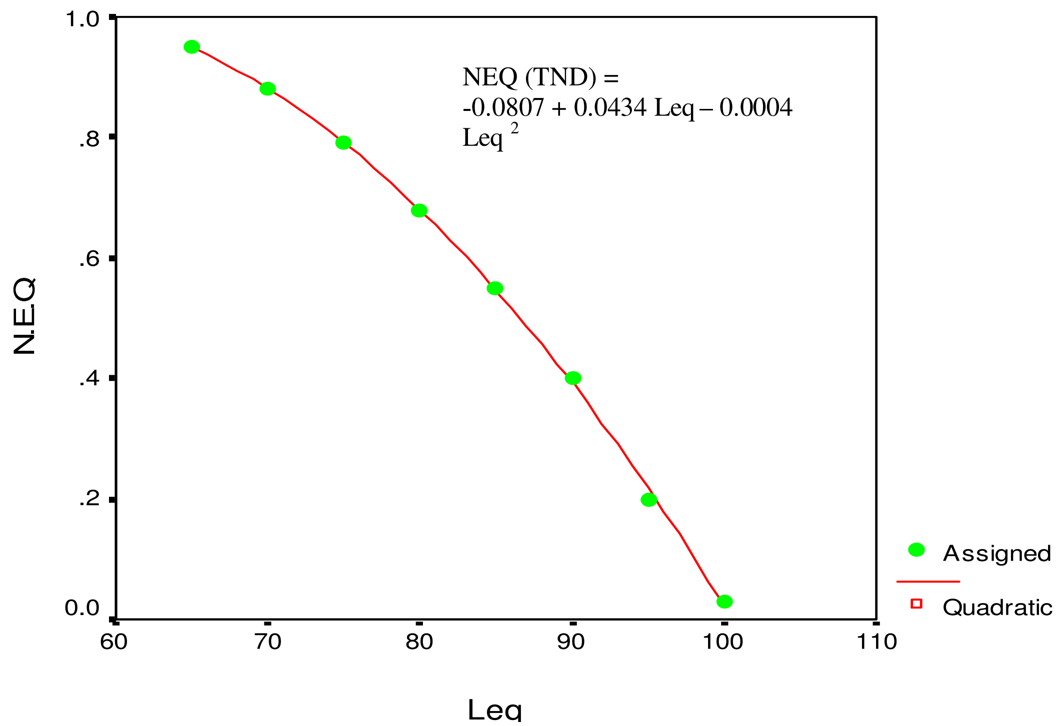

Figure 6. Value function curve for temporary threshold shift.

Table 7. Value function equations.

Parameters	Value function equations
Annoyance and Irritation	NEQ (A and I) = - 1.248665 + 0.130270*Leq – 0.002306* Leq^2 + 1.13126849*10^{-5} * Leq^3
Disturbance in alertness and concentration	NEQ (A and C) = -0.303230 + 0.074069 *Leq – 0.001264 *Leq^2 + 5.59 *10^{-6} * Leq^3
Disturbance in sleep	NEQ (Sleep Disturbance) = 0.857 + 0.0228* Leq ‾ 0.000717* Leq^2 +4.0438691*10^{-6} Leq^3
Disturbance in speech conversation	NEQ (Speech Conv.) = 2.19 - 0.028*Leq + 0.000063* Leq^2
Temporary Noise Deafness	NEQ (TND) =- 0.0807 + 0.0434* Leq – 0.004* Leq^2

thus calculated for commercial area, residential area and sensitive area 0.62, 0.82 and 0.90 respectively.

Evaluation of correction factor

In order to evaluate the correction factor in terms of excess dB (A) to be added with the observed/ monitored noise level in order to incorporate the additional effect/ impact due to high frequency composition and impulsiveness.

A third round of questionnaires [appendix 3] was sent to the selected expert group for their expert opinion in order to evaluate suitable weightage/value in terms of an increase in Leq for incorporating dominant frequency composition and impulsiveness. The responses come from 93 experts in the third round of questionnaire survey. The mean values for Low Frequency Dominance (L.F.D), Medium Frequency Dominance (M.F.D), High Frequency Dominance (H.F.D), Low Degree of Impulsiveness (L.D.I), Medium Degree of Impulsiveness (M.D.I) and High Degree of Impulsiveness (H.D.I) are 0, 0.86, 2.34, 0, 0.98 and 2.36 respectively.

RESULTS

Table 8 displays the average ambient noise levels with standard deviations at different residential, commercial and sensitive areas of Bailadila Iron Ore mining Complex. The Leq values of different areas during daytime were found to be in the range 51.9 to 63.6 dB (A). On the other hand, during nighttime, the Leq values were in the range of 46.1 to 63.3 dB (A). On the basis of mean day-time noise level (Leq(d)) [6 A.M-10 P.M] and night-time noise level (Leq(n))[10 P.M- 6 A.M], day-night equivalent level (Ldn) values were calculated and found to be in the range

Table 8. Ambient noise levels at different strategic location of Bailadila iron ore mining complex.

St. No.	Locations	Location category	Leq in day-time	Leq in night-time	Ldn in dB (A)	Dominant frequency	Adjusted Ldn	NEQ (R)	Desired NEQ(R)
1	Gandhi Nagar Colony	R	57.5 ± 1.1	52.4 ± 0.6	60.0	L.F.D	60.0	0.73	0.82
2	Nehru colony	R	53.8 ± 1.6	46.1 ± 0.9	54.8	L.F.D	54.8	0.82	0.82
3	Football ground colony	R	56.6 ± 1.3	52.5 ± 0.9	59.8	L.F.D	59.8	0.73	0.82

of 54.8 to 69.7 dB (A). All the residential colonies registered higher Leq values [Ldn- 59.8 to 69.7], with respect to the prescribed limit of Central Pollution Control Board (CPCB) of India [Leq(d): 55 dB(A), Leq(n): 45, Ldn: 55 dB(A)] except one location (Nehru colony). The higher values were mainly attributed due to plant operation (Type IV double storey colony and ET hostel), operation

of heavy earth moving machineries (HEMM), work-shop(Transit accommodation), loading plant operation, plying of vehicles, colony activities. Similarly, the noise situation of all the sensitive areas were observed [Ldn-61.5 to 62.9 dB(A)] exceeding noise norm set by CPCB, India [Leq(d): 50 dB(A), Leq(n): 40 dB(A), Ldn: 50 dB(A)]. However noise situation in the all the commercial areas were found within the permissible limit [Leq(d): 65 dB(A), Leq(n): 55, Ldn: 65 dB(A)] or in the border line. All the areas except shopping centre during night time low frequency dominant noise were prevailed.

Table 8 displays the summarized results. Table 8 also contains the NEQ(R) along with adjusted Ldn after considering dominance frequency and impulsiveness factor.

DISCUSSION

Since the noise environmental quality is a subjective matter and needs to quantify to assess the noise environmental quality of any place. In this paper noise environmental quality has been quantified in the range of 0 to 1 (0 indicates poor noise environmental quality and the quality is improved with the increase in the value of noise environmental quality)

In the above study, among the 13 monitoring stations, 8 are situated in residential zones, 2 are in commercial zones and the remaining 3 are in sensitive zones. Among the eight residential zones only one (Nehru Colony) zone has maintained the desired noise environmental quality (0.82) for the residential zone. The remaining 7 residential zones indicated lower NEQ(R) in comparison to the desired value of 0.82. Station 12 (Type IV double storied colony) had the worse situation [NEQ(R) = 0.524].

Among the two commercial zones, 1 (Market complex) has maintained the desired noise environmental quality (0.62) for the commercial category whereas the other (Shopping centre) showed less value in comparison to the required limit for the commercial category.

All the sensitive locations had poor noise environmental quality [0.67 -0.70] in comparison to the desired level of noise environmental quality [0.90]. Thus, the existing noise environmental quality [NEQ(R)] for most of the areas are lesser than their respective desired noise environmental quality [NEQ(R)] indicates the poor noise environmental quality in the areas. The zones, where the existing noise environmental quality [NEQ(R)] is more than the desired noise environmental quality [NEQ(R)], indicates good noise environmental quality.

Conclusion

Systematic noise monitoring study and impact assessment through value function curves revealed that overall noise environmental quality [NEQ(R)] of the different residential, commercial and sensitive areas near the iron ore mining complex was not good.

The noise stress of almost all the residential areas (except Nehru colony) and sensitive areas are high as the evaluated NEQ(R) of the areas were less in comparison to the desirable limit of indicative permissible value. As such, it is quite necessary to take some effective noise control mechanism so as to reduce the noise stress significantly.

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Appendix 1. First round of survey questionnaire format.

Following broad harmful effects are identified due to noise exposure.
Noise deafness (temporary)
Disturbance in speech conversation
Annoyance and irritation
Disturbance of sleep
Disturbance in alertness/concentration
Pair-wise comparison

Impact Parameters	Assign value (0 or 1)															Total	Relative rank
Noise deafness (T)	0	0	0	0	1											1	5
Disturbance in sleep	1					1	0	0	1							3	3
Disturbance in speech conversation		1				0				0	0	1				2	4
Annoyance and irritation			1				1			1			1	1		5	1
Disturbance in alertness and concentration				1				1			1		0		1	4	2
Dummy					0				0			0		0	0	0	0

[Questionnaire format filled by a particular expert]

Appendix 2. Second round of survey questionnaire format.

Please fill up the following parametric importance unit using a decimal value x where 0 < x <1.

Parametric Importance Unit

S/No	Parameters	Importance				Cumulative importance	Weightage factor (%)
1	Annoyance and irritation	1				1	30.6
2	Disturbance in alertness and concentration	0.9	1			0.9	27.6
3	Disturbance in sleep		0.6	1		0.54	16.5
4	Disturbance in speech conversation			0.8	1	0.432	13.5
5	Temporary deafness (temporary threshold shift)				0.9	0.3888	11.8
						3.2608	100

[Questionnaire format filled by a particular expert]

Appendix 3. Third round of survey questionnaire format.
Correction factor for different frequency composition and impulsiveness situations.

Characteristics of existing noise	Excess dB (A) to be considered		
Frequency composition	Low frequency dominance Nil	Medium frequency dominance 0.82	High frequency dominance 2.30
Degree of Impulsiveness	Low degree of impulsiveness Nil	Medium degree of impulsiveness 0.96	High degree of impulsiveness 2.39

[Questionnaire format filled by a particular expert]