Application of noise mapping in an Indian opencast mine for effective noise management

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ABSTRACT

So far as mining industry is concerned, noise pollution is not new. It is generated from operation of equipment and plants for excavation and transport of minerals which affects mine employees as well as population residing in nearby areas.

Although in the Recommendations of Tenth Conference on Safety in Mines, noise mapping has been made mandatory in Indian mines still mining industry are not giving proper importance on producing noise maps of mines. Noise mapping is preferred for visualization and its propagation in the form of noise contours so that preventive measures are planned and implemented.

The study was conducted in an opencast mine in Central India. Sound sources were identified and noise measurements were carried out according to national and international standards. Considering source locations along with noise levels and other meteorological, geographical factors as inputs, noise maps were generated by Predictor LimA software. Results were evaluated in the light of Central Pollution Control Board norms as to whether noise exposure in the residential and industrial area were within prescribed limits or not. An analytical assessment has been presented.

INTRODUCTION

All the unit operation in surface mining, e.g., drilling, blasting, excavation and loading, transportation, reclamation and processing involve numerous noise-generating activities. Introduction of mechanization and large-scale machinery has undoubtedly accentuated the problem in recent years. The availability of large diameter, high capacity pneumatic drills, bulk blasting, etc. are identified as noise prone activities. In-pit crushing system with mobile crusher and large capacity materials handling plants are being installed to facilitate speedy handling of large quantities. All these activities are major sources of noise in and around surface mining complexes.

Noise as an environmental factor has important implications for the exposed population. The obvious implication is, of course, the potential for noise-induced hearing loss. In addition, noise produces other health effects, influences work performance, and makes communications more difficult. Besides, the fauna (wild life) in the forests and other areas surrounding the mines/industrial complexes are being affected by the noise generated due to mining activities.

In order to combat this, many countries and communities have introduced laws and regulations making it a legal requirement to measure occupational and community noise levels in and around mining/industrial complexes for maintaining acceptable noise environment. In order to implement the noise rules and regulation it is necessary to undertake appropriate analysis of noisy mining/industrial operations so as to evolve reduced-noise situations. In European countries noise mapping is carried out after every 5 years based on noise indicators L_{den} and L_{night} for industry, railway and road traffic sources [1,2].

In India, Wazir (2011) prepared noise map of Guwahati city at various locations i.e. commercial zone, residential zones and silence zone using GIS. The noise levels were predicted using interpolation techniques and the results were compared with the limits stipulated by the Central Pollution Control Board (CPCB) and Bureau of Indian Standard (BIS) [3].

The noise field near mining complex results from various noise sources employed in that complex. The impact of noise in the mining complex depends upon the sound power level of the noise generators, prevailing geo-mining conditions and the meteorological parameters of that complex. The noise sources in any heavy earth moving machinery (HEMM) are located at different positions and they work in different cycles. To assess the noise level in terms of daily noise exposure in such areas is challenging as the sound energy is generated by a number of noise sources simultaneously in a random pattern. The noise levels need to be studied as an integrated effect of various activities, their working environments, geo-mining parameters and the prevailing geographic and meteorological parameters. In the mining condition the equipment locations and environment continuously changes as the mining activity progress. The mining industry, therefore, must have access to techniques and prediction systems to assess the noise levels associated with their activities, and to have the ability to design their operations with due consideration to noise environment.

In short, evaluation of noise status in mining complex demands consideration of type of noise sources, spatial pattern of noise propagation, complex geographical conditions which are mostly responsible for reflection, refraction or absorption of sound waves as well as meteorological factors [4]. Therefore, for a snapshot of noise level of a particular area many parameters influencing the noise levels are to be considered in an integrated information system [5].

Even though instances of application of noise mapping practices in mines are available from few countries including Australia, the subject is considered new in Indian mines and mineral industries [6] [7].

Unlike other major countries practically no work has been done in Indian mines for effective noise management in the working environment although noise limits have become increasingly stringent over the years. Responding to such environmental stressor Director General of Mine Safety (DGMS) have issued specific directives and recommended prescribed noise limits based on ILO code of practice. DGMS has circulated Recommendations of 10th national conference on safety in Mines (2007) where it has been stipulated that Noise Mapping should be made mandatory of various places in the mine premises based on the various machines being used in concerned mines along with personal noise dosimetry of individual workmen exposed to noise level above 85 dB(A) [8]. Under this circumstances,

necessary efforts has been initiated to evaluate noise mapping in a large surface mine so as to pinpoint appropriate measures for noise management in surface mining.

STUDY AREA

The research study was conducted in a mechanized opencast limestone mine located in central India. Presently mine is operating in three blocks i.e. new pit, old pit and Deosari mine [Figure 1]. The Mining lease area comprises of about 1520.22 ha. All the mining operations are done by deployment of heavy earth moving machineries like dumpers, shovels, excavators, drill machine, dozers, etc. The mining work is carried out in two shifts beginning from 7:00AM to 3:00PM and again from 4:00 PM to 12:00 PM. In addition there is general shift which is from 9:00 AM to 5:00 PM. Daily input requirement of plant is about 10,000T. On an average, six dumpers, 3 shovels, 1 drilling machine and 1 dozer are deployed in a shift of eight hours in new and old pit whereas 3 backhoe, 5-6 tippers and one dozer are deployed in deosari mine for a production target of 5,000T per shift.

There exist a number of villages surrounding the mine. As such, inhabitants of these villages are directly or indirectly affected by the noise coming out from various operation sources of the mine. Mehgaon village and mine colony are situated at the northern side whereas Deosari village is on the southern part of the mine. There exists a running conveyor belt carrying limestone ore and passing through 50-100 meters of mine residential colony [Figure 1].

Figure 1: Google view of study area (Source: Google earth)

This research study has been initiated to develop noise map of mining area by identifying dominant noise sources that are responsible for adverse impact on the mine environment and

surrounding localities. This also facilitates in pinpointing action plans for noise management in a significant manner.

METHODOLOGY

Identification of Noise Sources and measurement of Noise

The most important noise sources in mines are shovels, excavators, drilling machines, dumper, and dozers. Crusher plants and conveyor belts which are the part of mining process are also the sources of noise. All these different sound sources which contribute overall noise in and around the mines are identified and categorized it as a point source, line source, moving source and area source. The choice of source type whether the particular heavy machine is of point, line, area or moving source depends on source receiver distance. Heavy machines like dumpers and tippers are moving sources of noise in mines. In contrast, certain sources are stationary, e.g., crusher plants, screening plants, drill machines, etc. Crushers were treated as stationary area source. Shovels, backhoe, drilling machines and dozers were considered as point sources and belt conveyors were represented as line source (Table 1).

Table 1: Noise sources in the study area*

Sources	Equipment	Total Nos.
Point Source	Shovel (Excavator)	3
	Drilling Machine	1
	Backhoe	3
	Dozer	1
Line Source	Conveyor Belt	1
Area Source	Crusher Plants	1
Moving Source	Dumpers	6
	Tippers	4-5
*Note: Equipment distribution is shown as required in one shift		

Sound pressure level was recorded from respective sources with the help of Casella make Type 1 Sound Level Meter. Measurements were carried out in well defined positions around the noise sources according to various national and international standards. For example ISO 6395:2008 was used for noise measurements of shovel, drill machine and dozer machine, IS 3028:1998 for dumpers, ISO 8297:1994 for crusher plant and other standards like ISO 1996-1:2003, ISO-2:2007, ISO 9613-1:1993 & ISO 9613-2:1996 were used. Line source such as belt conveyors were considered as a series of uncorrelated line section. The centre of each section is considered as a point source and measurement were taken in the same way as taken for point sources [9,10,11,12,13,14,15].

At each and every location of noise sources geographic coordinates were collected with the help of Trimble make GPS. In addition, meteorological parameters like temperature, wind speed, wind angle and humidity were collected.

Conversion of Acoustic Pressure to Acoustic Power

For calculating noise maps for industrial or mining area with prediction software, the software requires sound power data of each relevant noise sources points. This is achieved by measuring sound pressure level around the identified noise sources of mines. Acoustic Determinator is a tool to find out sound power level of respective noise sources by measuring sound pressure levels using reverse engineering methods in accordance with ISO 8297 and other similar guidelines [16].

GIS Software

Surface plan of the mine leasehold area along with nearest residential areas were taken from the mines in .dwg file format for detailed and close verification of the features through AUTOCAD. Noise sources were projected and plotted on the surface plan with the help of their corresponding GPS data. Thus point locations and shapes of crusher plant, dumper haul roads, locations of shovels & drills were digitized through ARCMAP 10.2 and stored as shape files [17].

Noise Modeling

For determining the sound pressure level at any receiver point, basic propagation equations were followed as described in ISO 9613-2 (Eq.1 below).

$$L_{fT}(DW) = L_w + D_c - A \qquad (1)$$

Where,

L_w is the octave band sound power level, in decibels, produced by point sound source relative to a reference sound power of one picowatt (1pW)

D_c is the directivity correction, in decibels, that describes the extent by which the equivalent continuous sound pressure level from the point sound source deviates in a specified direction from the level of an omni-directional point sound source producing sound power level L_w; Dc equals the directivity index D1 of the point sound source plus an index DΩ that accounts for sound propagation into solid angles less than 4π steradians; for an omni-directional point sound source radiating into free space, Dc = 0dB;

A is the octave band attenuation, in decibels, that occurs during propagation from the point sound source to the receiver.

The attenuation term A in the (Eq.1) is given by the (Eq. 2)

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \qquad (2)$$

Where,

A_{div} is the attenuation due to geometrical divergence

A_{atm} is the attenuation due to atmospheric absorption

A_{gr} is the attenuation due to the ground effect

A_{bar} is the attenuation due to a barrier

A_{misc} is the attenuation due to miscellaneous other effects

Sources of other types such as line source or area source are treated as composite sources made of many point sources in various configurations hence the above relation is extensively used for all noise sources.

Noise Prediction Software and Noise Map

All the input data mentioned above which affect the propagation of sound were imported in noise prediction software (Predictor LimA V9.10) for calculation [18]. Predictor LimA was programmed to calculate noise levels at 10m x 10m grid intersections using Harmonoise and ISO 9613-2 calculation method.

Validation/calibration points

Three locations inside the mining lease area and one location near the residential area close to the mine lease boundary were considered as calibration points. The observed data were collected from these points so as to validate the model. These observed data were not incorporated into the model for any purpose during calculation of noise propagation.

RESULTS AND DISCUSSION

Noise maps were generated using Predictor LimA software using two principal methods which are extensively used i.e. Harmonoise and ISO 9613-2 calculation methods. The study considered same basic inputs for both the methods. According to CPCB (Central Polluion Control Board) guidelines the noise levels for different zones are shown in Table 2 [19].

Table 2: CPCB Ambient air quality standards in respect of noise* and corresponding L_{dn} values

Area Code	Category of Area Zone	Limits in dB (A) Leq		
		Day time (1)	Night Time (2)	L_{dn}
A	Industrial Area	75	70	73.87
B	Commercial Area	65	55	-
C	Residential Area	55	45	53.23
D	Silence Area	50	40	-
*The noise Polluion (Regulation and Control) Rules, 2000				

Definitions of span of day and night in CPCB guidelines in India are different from what has been described in the European Noise Directive (END). Incidentally, the calculation methods within Predictor LimA using Harmonoise and ISO 9613-1: 2003 protocol use time periods which are by default in accordance with the END [see Table 3]. Of course, Predictor V 9.10 offers flexibility to allow user defined calculation periods. Since the predicted noise levels using Harmonoise and ISO 9613-2 were to be compared with CPCB guidelines, the authors used overall permissible L_{dn} values based on combining the day and night noise levels set by CPCB as described in Table 1. Day and night spans were set following the CPCB guidelines. Later on L_{den} values computed by Predictor LimA were compared with L_{dn} limiting values calculated from CPCB guidelines. All the computed values are based on a complete 24 hours exposure period.

Table 3: Definitions of day, evening and night periods in CPCB guidelines and END

Time Period	Central Pollution Control Board (CPCB)	Hours	European Noise Directive (END)	Hours
Day	06:00AM to 10:00PM	16	07:00AM to 07:00PM	12
Evening	-	-	07:00PM to 11:00PM	4
Night	10:00PM to 06:00AM	8	11:00PM to 07:00AM	8

The main noise indicators for noise mapping are L_{day}, $L_{evening}$, L_{night} and L_{den} (day-evening-night) [12] (END, 2002). Different color codes indicate different Lden noise levels in dB(A). Noise levels ranging from 50-55 dB(A) and 55- 60 dB(A) are indicated by different shades of green, 60-65 dB(A), 65 -70 dB(A), 70-75 dB(A) and 75-80 dB(A) are indicated by different shades of yellow, 80-85 dB(A), 85-90 dB(A) and 90-95 dB(A) are indicated by different shades of red while the noise level ranging from 95-100 dB(A) is indicated in dark violet bands (Figures 2 & 3).

After computation using ISO 9613-2 method (Figure 2) it was observed that the noise level inside crusher plant was in the range 100 - 95 dB (A) forming irregular noise contours. As we move apart from crusher plant noise level around the crusher plant was found to be in the range of 95 - 90 dB(A) forming irregular contour measuring major axis 55m and minor axis 13m. It further reduced to 90-85 dB(A) measuring major axis 80m and minor axis 25m. Noise level around shovel No. 1 is 85-80 dB(A) forming radius of 7m whereas at shovel No. 2 it was found to be 80-75 dB(A) forming irregular contour having major axis 16m and minor axis 12m. Both Shovel No.1 and Shovel No. 2 were working on new pit. Noise level around Drill machine ranging from 90-85dB(A) where as around shovel No. 3 it was found to be in the range of 85-80dB(A). Overall noise contours around Shovel No. 3 and Drill machine which was working on old pit was found to be 80 – 75 dB(A) forming elliptical shape measuring major axis 61 m and minor axis 38m contour. Noise level around dozer was found to be in the range of 90-85 dB(A) measuring major axis 8m and minor axis 5m. Noise level at Deosari mines near Backhoe 1, & 3 was found to be 80-75 dB(A) having diameter of 15 m whereas at around Backhoe no. 3 noise level was ranging from 90-85 dB(A) forming major axis 8m and minor axis 5m. Overall noise level along the haul road fall in the range of 60-70 dB(A). Noise levels on both sides of conveyor belts was between 85 and 80dB(A).

After using Harmonoise method (Figure 3) it was observed that the noise level inside crusher plant was in the range 95-90 dB(A) forming irregular noise contours. As we move away noise level around the crusher plant was found to be in the range of 90-85 dB(A) forming irregular contour measuring major axis 66m and minor axis 12m. Noise level around shovel No. 1 is 80-75 dB(A) having radius of 10 m whereas at shovel No. 2 it was found to be 75-70 dB(A) forming radius of 12m. Noise level around Drill machine ranging from 90-85 dB(A) forming irregular shape measuring major axis 8m and minor axis 4m whereas at the same old pit shovel No. 3 was working producing noise contour of 85 – 80 dB(A). Noise level around dozer was found to be in the range of 90-85 dB(A) measuring major axis 5m and minor axis 2m. It reduced to 85-80dB(A) forming major axis 13m and minor axis 8m. Noise level at Deosari mine around Backhoe No. 1 and 2 noise levels were found to be 80-75 dB(A) forming iregular shape whereas at Backhoe no. 2 noise level was 90-85 dB(A) forming irregular shape measuring major axis 5m and minor axis 2m. As we moved from Backhoe no. 2 noise level reduced to 85-80 dB(A) forming major axis 12m and minor axis 7m. Overall noise level along the haul road was in the range of 60-70dB(A). Noise levels on both sides of conveyor belt was between 85 and 80dB(A).

Further predicted noise level was plotted verses observed values at selected calibration or validation points within the study area. Correlation analysis showed that the predicted values and observed values in both Harmonoise and ISO 9613-2 methods had positive correlation (r^2 = 0.97 & r^2 =0.96 respectively) (Fig 4 & 5).

Several models are used for study of outdoor sound propagation. It is nevertheless difficult to produce a unanimous decision as to which calculation method performs better because each of them has certain differences in its use of input parameters for calculation of attenuation. It depends on the number of correction factors the calculation method includes which influence on attenuation of sound propagation.

We have reported several studies related to noise mapping of the mining and its surrounding area. Our previous study has shown noise propagation through noise mapping in the mining area through ISO 9613-2 calculation method [20]. However, in our present study we intended to present different methods for noise mapping for mining industry. Harmonoise was much more detailed in implementation was found slightly better in this study.Based on that standard framework or guidelines can be suggested to carry out noise calculation and conduct mapping for mining industry.

Table 3: Comparison between predicted and observed noise levels using Harmonoise (L_{den}) calculation method

		Predicted Noise Level in dB(A)	Measured Noise Level in dB(A)	Difference in Noise Level in dB(A)
Industrial Area	Near Mine Office	64	62	2
	Near Entry Gate	76	73.8	2.2
Residential Area	Mines Colony	69	65.49	3.51
	Near Deosari village	47	51.9	4.9
Mean ± SD				**3.15±1.34**

Table 4: Comparison between predicted and observed noise levels using ISO 9613-2 (L_{den}) calculation method

		Predicted Noise Level in dB(A)	Measured Noise Level in dB(A)	Difference in Noise Level in dB(A)
Industrial Area	Near Mine Office	66	62	4
	Near Entry Gate	78	73.8	4.2
Residential Area	Mines Colony	73	65.49	7.5
	Near Deosari Village	52	51.9	0.1
Mean ± SD				**3.95±3.03**
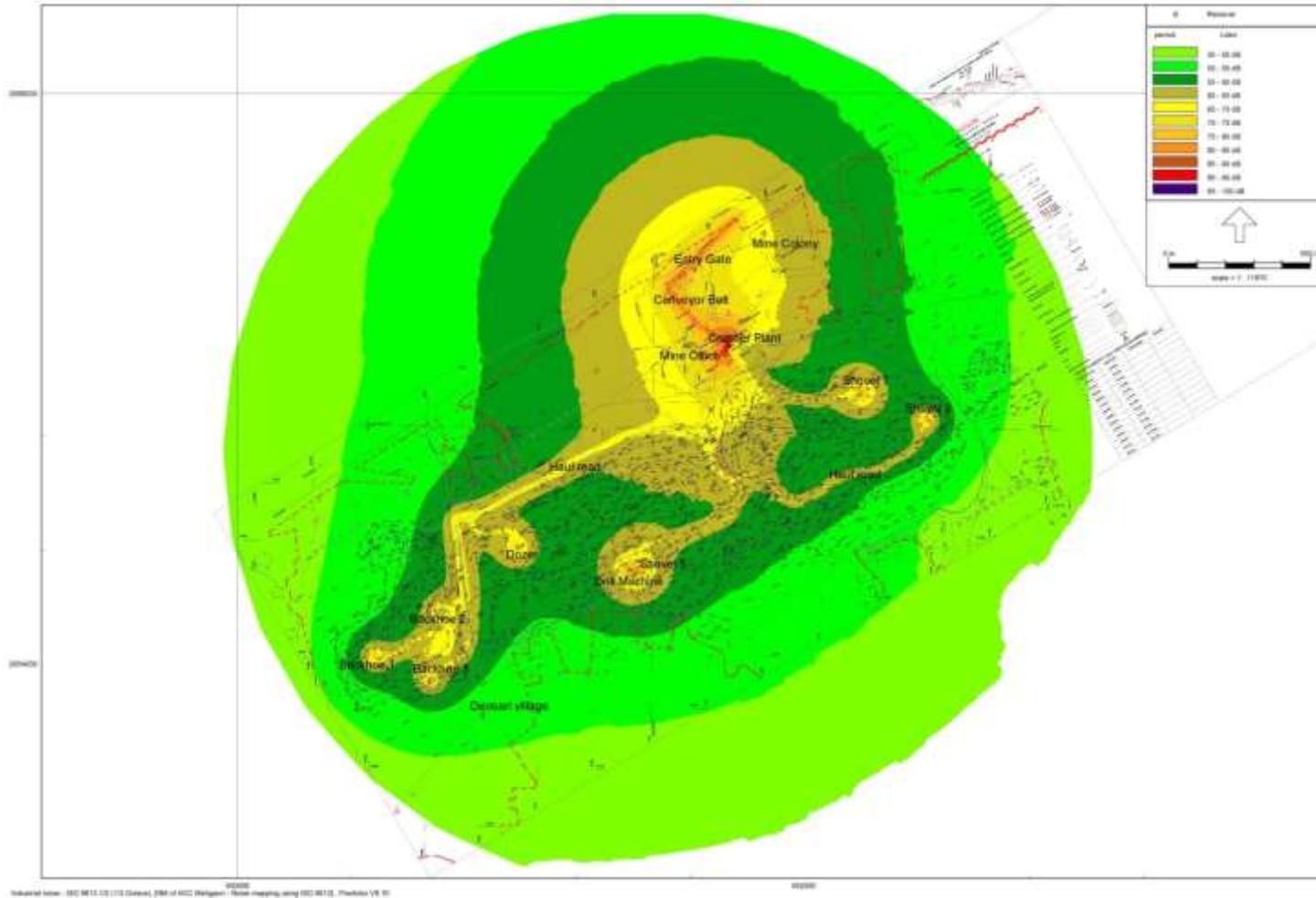
Figure 2: Noise Map of a mine using ISO 9613-2 calculation method
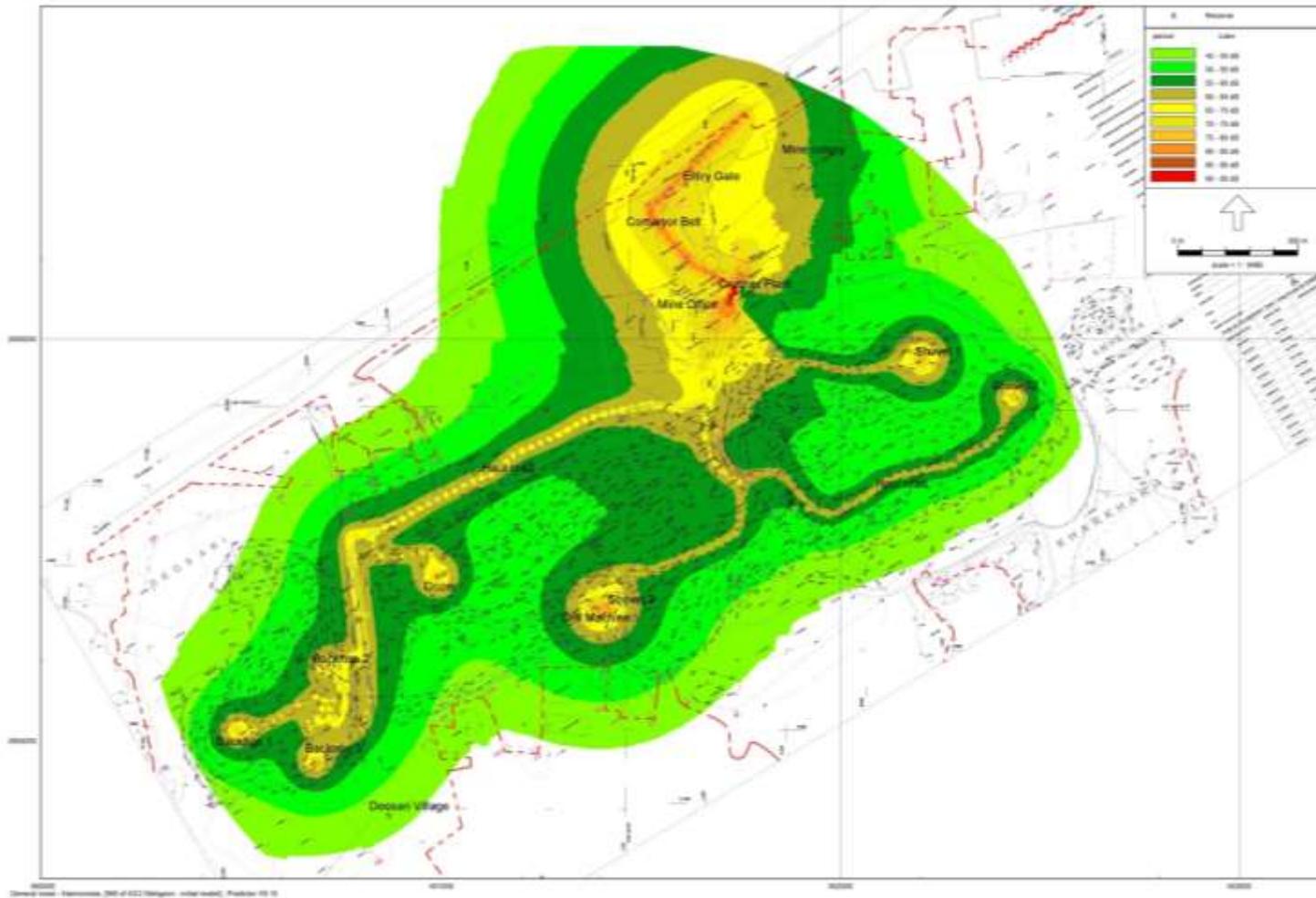
**Figure 3:** Noise Map of a mine using Harmonoise calculation method
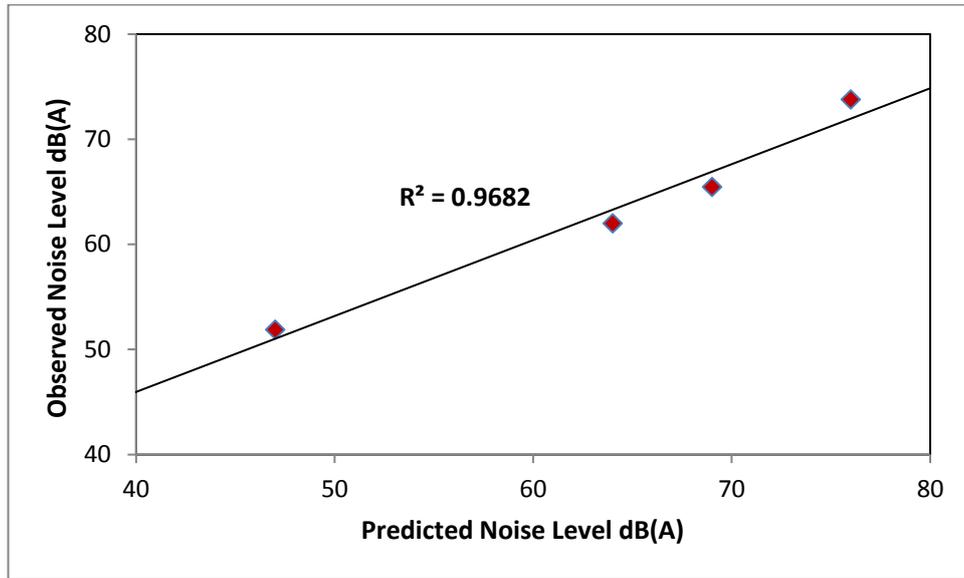
Figure 4: Correlation between predicted noise and observed noise level by Harmonoise calculation method
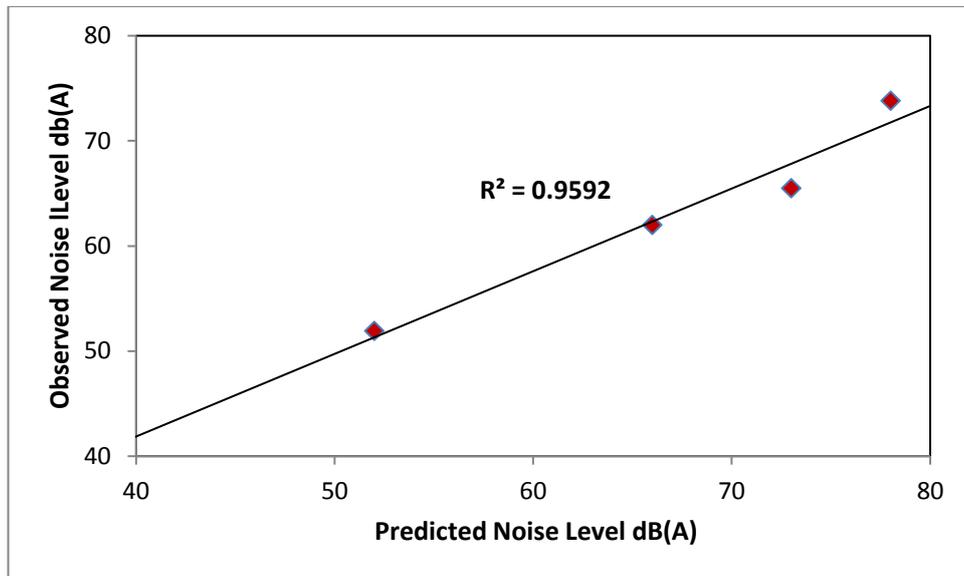

Figure 5: Correlation between predicted noise and observed noise level by ISO 9613-2 calculation method

CONCLUSIONS

- Indian government does not have general noise policies on noise mapping.

- DGMS have issued specific directives for conducting noise mapping studies in mine environment. There is still confusion between Noise zoning and noise mapping. Awareness and training programs are required.

- Noise mapping is considered as a specialized subject and requires specific skills supported by appropriate hardware and software both.

- The environmental policy/legislations in regard to noise mapping in Industry/ Mines are not detailed like European Directive. Hence, specific directive may be issued by the government of India. Even though Harmonoise seemed better, a preferred method will depend on variety of input variables.

- The cost implications for establishing and maintaining noise mapping laboratory are very high. So, this will not be feasible for small organisation. Hence, it is advisable to establish noise mapping facilities at different location/ universities and institutions so that the technical services can be extended to whole of the country.

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