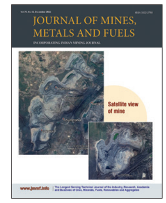
Journal of Mines, Metals and Fuels, *70(12) : 629-634; 2022. DOI: 10.18311/jmmf/2022/32319*

INFORMATICS JOURNALS

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*



Development of Noise Maps for Opencast Coal Mines Using Measured Noise and GPS Data

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Abstract

Noise is a serious health hazard in the mining industry. Different sources like drilling, blasting, crushing, excavation, transportation, etc. are responsible for heavy noise generation inside the mines. It is a statutory requirement of every industry, including mine to maintain noise levels within prescribed limits to avoid noise-related health and environmental issues. This study attempted to measure the noise level of various locations within mine premises. The measured data showed that the noise level at the drilling area, the working area near the coalface, and the overburden removal area were far above the warning limit of 85 dB(A) as prescribed by DGMS, 2011. Noise maps were prepared by using ArcGIS to show different noise-affected areas inside the mines.

Keywords: *ArcGIS, DGMS, Noise Level, Noise Map*

1.0 Introduction

Mining is very important for the economic growth of the country. During mining, the miners are exposed to a number of hazards during the working hours including excessive noise. Noise is defined as sound without agreeable musical quality or as unwanted sound. Noise is generated in opencast mines from different sources like drilling, blasting, excavation, crushing, grinding, transportation, HEMM (Heavy Earth Moving Machineries), etc[1]. Further implementation of high mechanisation generates massive amounts of noise. In opencast mines, most of the mining machinery produces noise levels in the range of 90-115 dB(A).

Exposure to noise for a long time may affect human beings in many ways, including sleep disturbance, noise-induced hearing loss (NIHL), annoyance and irritation, speech and conversation problems, etc[2–4]. The most common effect of overexposure to noise is the loss of hearing, which has profound social and occupational impacts on affected individuals and substantially reduces quality of life. Hearing Loss (HL) can be defined as "the decibel difference between a patient's thresholds of audibility and that for a person having normal hearing at a given frequency"[5]. In the mining industry, hearing loss or hearing damage is considered a serious health problem, as reported by various health organizations like the U.S. Hearing loss can impair the quality of life through a reduction in the ability to communicate with each other. The effects of noise on human beings often present conflicting results because of the variety of factors and variables that can affect and/or interfere with the determination of the actual effects. Considering the negative effects of noise, it is essential to take control measures at different levels to minimise the risk to workers. Noise can be controlled at different levels of generation,

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like the source, path, and receiver. Overall, it affects the general health of human being[6]. To adopt proper control measure strategy, identification of different sources of noise is essential.

It is always better to control the noise at the source. But it is not always possible to do so. For this reason, identification of the most affected areas inside the mine is essential to implement the control strategy at those places and reduce the exposure level of workers. Further, in mining conditions, measuring the noise level at all locations within the mine premises becomes extremely difficult. A 'noise map' is a map of an area, that is coloured according to the noise levels in the area. The geographic presentation of information associated with noise levels and noise exposure, as well as related information on the effect on the influenced population, is known as noise mapping. Sometimes the noise levels are shown by contour lines, which show the boundaries between different noise levels in an area. Use of noise mapping to sources as a capability of utilization, both at the design stage as well as in noise reduction[7]. Utilizing a GIS with other available spatial data can enhance the accuracy and visualization of noise maps[8]. Cho, *et al.*, introduced a system to easily produce a noise map using noise and GPS data measured simultaneously and noise map was produced with the help of GIS software[9]. The noise pollution scenario of Guwahati city at various locations was assessed, i.e., commercial zones, residential zones and silence zones using a Sound Level Meter (SLM) and noise mapping was done using the Geographic Information System (GIS) technique[10]. This paper mainly focuses on to prepare noise maps in two opencast coalmines by taking measured equivalent sound pressure level values and GPS coordinates for different noise affected areas inside the mine. Noise mapping was performed using ArcGIS software.

2.0 Materials and Methods

2.1 Noise Measurement

The measurement of SPL was carried out using an Extech octave band analyzer. The instrument is capable of logging data at an interval of 2-seconds. At each point, the measurement was taken for about 10 minutes, and the equivalent sound pressure level was taken into consideration. Likewise, the SPL was measured at different locations inside the mine premises. The octave band analyzer having accuracy of ±1 dB at various frequencies between 25 Hz and 10kHz in A-weighted scale as recommended by the acoustic standard (ISO: 1996-2, 2007)[11]. Sound pressure level data were collected at 1.5 m height above ground level using a real-time octave and analyzer according to ISO: 9613-2:1996 standards[12]. Sound pressure levels were measured in L_{eq} as specified by the 1996-2:2007, which has recognized L_{eq} as an international standard for measuring environmental noise in 1978 (ISO: 1996-2, 2007). Noise levels at various workplaces examined and were compared to respective standards.

2.2 Methodology of Noise Mapping

At each and every location of noise measurements, geographic coordinates were collected with the help of a Garmin GPS instrument in degree-minute-second format. ArcMap is a GIS mapping package within ArcGIS that offers a centralized data management facility and is compatible with commercial noise software. It is important as the data needed for undertaking measured noise level, noise effect and visualization studies can be stored in a centralized database. Data can be imported from noise software to ArcGIS via the data exchange system.

The collected latitudes and longitudes were converted into decimal format. Interpolation of noise was carried out using Kriging and the Inverse Distance Weighting (IDW) method. Kriging interpolation is also known as Gaussian process regression; it computes the weighted average of the known values of the function in the neighborhood of the point.

All the input data, which affects the propagation of sound, was imported into the noise mapping software (ArcGIS). KML file was used for background boundary for noise mapping, which was imported from Google earth pro. By using geo, processing tool of ArcGIS interpolation of points and their respective sound pressure level values was carried out. The flow chart for the noise mapping process is shown in Figure 1.

3.0 Results and Discussions

According to CPCB, guidelines the noise level limits specified for different zones are shown in Table 1. Since the predicted noise levels of different workplaces were to be compared to CPCB and DGMS guidelines, the authors

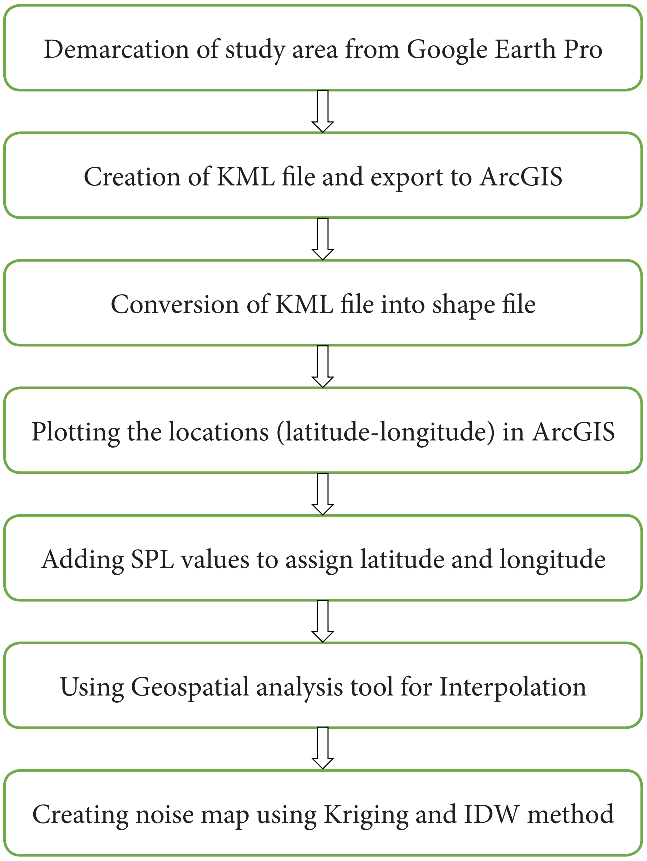

Figure 1. The flow chart of noise mapping process.

used overall permissible L_{Aeq} (equivalent) values based on noise levels set by DGMS as 90 dB (A) level with a 5 dB exchange rate, as described in Table 2[13,14]. All the computed values were based on a complete 8 h exposure period. Different color codes indicate different L_{Aeq} (equivalent) noise levels in dB (A) in the noisemap.

Table 1. Definitions of Day, Evening and Night Periods in CPCB Guidelines and European Noise Directive[15]

Time period	Central pollution Control Board (CPCB)	Hours	European Noise Directive (END)	Hours
Day	06.00 AM to 10.00 PM	16	07.00 AM to 07.00 PM	12
Evening	-	-	07.00 PM to 11.00 PM	4
Night	10.00 PM to 06.00 AM	8	11.00 PM to 07.00 AM	8

Table 2. Permissible noise levels adopted by ISO and DGMS (ISO 1996-2:2007, 2007; DGMS, 2011)[16]

Maximum Exposure Time (hour) per Working Day	Noise level	
	ISO Code	OSHA / DGMS Code
8	90	90
4	93	95
2	96	100
1	99	105
0.5	102	110
0.25	105	115

Table 3. CPCB noise standard (Noise rules, 2000)[17]

Area code	Category of Area /Zone	Limits(L_{eq})in dB (A)	
		Day time	Night Time
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence Zone	50	40

To describe zones disregarding noise standards, existing noise levels monitored in this study were compared to the DGMS standards. The noise levels for different zones according to CPCB (Central Pollution Control Board) guidelines are shown in Table 3.

3.1 Noise Measurement and Noise Mapping at Mine-A

3.1.1 Description of the Study Area

Mine-A islocated in the district of Jharsuguda of Odisha state. The map of the Mine-A is shown in Figure 2.

Figure 2. Satellite view of Mine-A.

3.1.2 Noise Mapping in Mine-A

Two hundred measurements were taken at twelve different locations in Mine-A, those were: haul road, project officer office, dumper parking, viewpoint near south dump yard, departmental overburden face, workshop, overburden removal area, the working area near coal face, departmental south dumping site, drill point near, overburden removal area near coal face, overburden site near dumper parking, haul road, dumper parking, viewpoint near south dump yard, departmental overburden face, workshop, overburden removal area, coal face, departmental south dumping site, electric drill machine near overburden face, overburden removal area near coal face, overburden site near dumper parking.

The noise environment that a miner suffers and the compliance with the current regulation can be derived from the analysis of below pie chart. From the above results of average equivalent A-weighted level, it is clear that 60.5% of miners working inside mine-A exceed the warning limit of 85 dB (A) prescribed by DGMS, in which the miners working at the workshop, overburden removal area, the working area near coal face, drilling site, dumping site are above the danger limit of 90 dB (A) prescribed by DGMS, 2011. This indicates that the noise levels to which the miners are exposed are too high. The noise map generated by using the kriging method of Mine-A is presented in Figure 3 and the noise map generated by using the IDW method is shown in Figure 4. The distribution of SPL in different ranges of Mine-A is presented in Figure 5.

From noise measurement in Mine-A, it was observed that sound pressure levels at different locations lie in different ranges like haul road (75.1-78.4) dB(A), project officer office (67.5-72.8) dB(A), dumper parking (75.8-83) dB(A), viewpoint (70.6-80.9) dB(A), overburden removal area (85.6-92.5) dB(A), workshop (84.5-94) dB(A), working area near coal face (89.3-92.4) dB(A), dump yard (91.6-100.5) dB(A), drilling area (85.7-99.4) dB(A). From the above, it was observed that sound pressure level values at the haul road, dumper parking, overburden removal area, workshop, the working area near coal face, dump yard and drilling area in Mine-A were above the warning limit of 85 dB (A) as prescribed by DGMS, 2011.

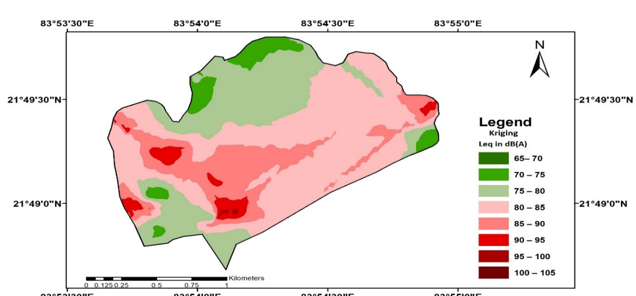

Figure 3. Noise map of Mine-A by using Kriging method.

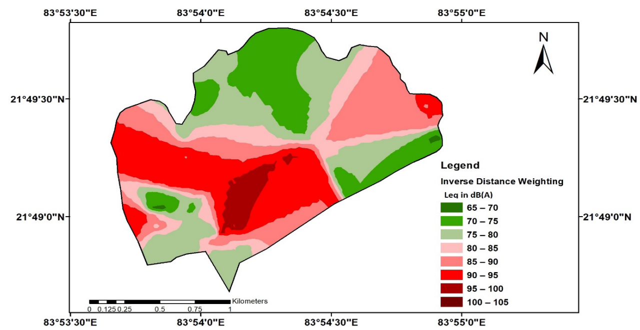

Figure 4. Noise map of Mine-A by using IDW method.

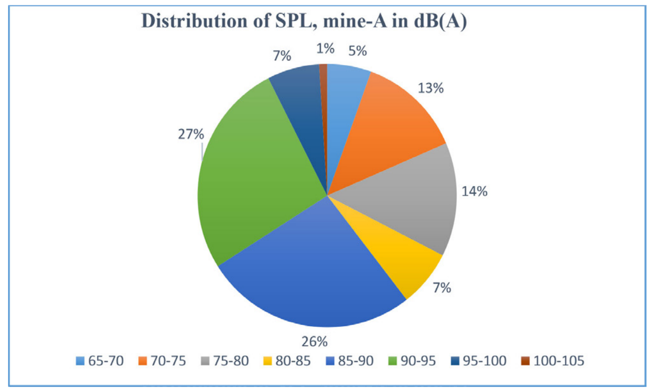

Figure 5. Distribution of SPL in different ranges in dB(A) at Mine-A.

In Mine-A, the maximum measured Sound Pressure Level was 100.5 dB (A) at the dump yard and the minimum was 67.5 dB (A) at the project officer's office.

3.2 Noise Measurement and Noise Mapping at Mine-B

3.2.1 Description of the Study Area

Mine-B is located in the Jharsuguda district in Odisha. The view of the Mine-Bis shown in Figure 6.

3.2.2 Noise Mapping in Mine-B

Two hundred fifty measurements were taken at eleven different locations in Mine-B. Those were: overburden

Figure 6. Satellite view of Mine-B.

removal area near quarry no.4, overburden removal area near coal patch at quarry no.4, project officer office, workshop, total station near overburden dump at quarry no.5, working area at quarry no.5, haul road, haul road, light weight vehicle road, overburden removal area near quarry no.3, dumper parking near quarry no.1.

From the above results of average equivalent A-weighted level, it is clear that 24% of miners working inside Mine-B exceed the warning limit of 85 dB (A) prescribed by DGMS, in which the miners working at coal stock, overburden removal area, the working area near coal face, drilling site are above the danger limit of 90 dB (A) prescribed by DGMS. The noise map generated by using the kriging method of mine-B is shown in Figure 7 and the noise map generated by using the IDW method is shown in Figure 8. The distribution of SPL in different ranges of mine-B is presented in Figure 9.

From noise measurement data of Mine-B, it was observed that noise levels at different locations are in different ranges like coal stock (74.2-94.2) dB(A), overburden removal area (87.5-91.2) dB(A), Project officer office (54.5-64.8) dB(A), workshop (62.1-84.6) dB(A), viewpoint (67-78.9) dB(A), working area near coal face (74-93.1) dB(A), haul road (77.9- 89.4) dB(A),

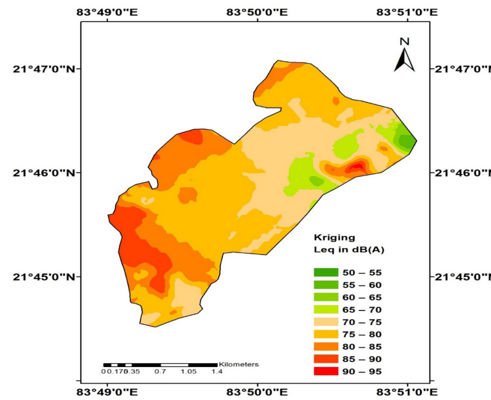

Figure 7. Noise map of Mine-B by using Kriging method.

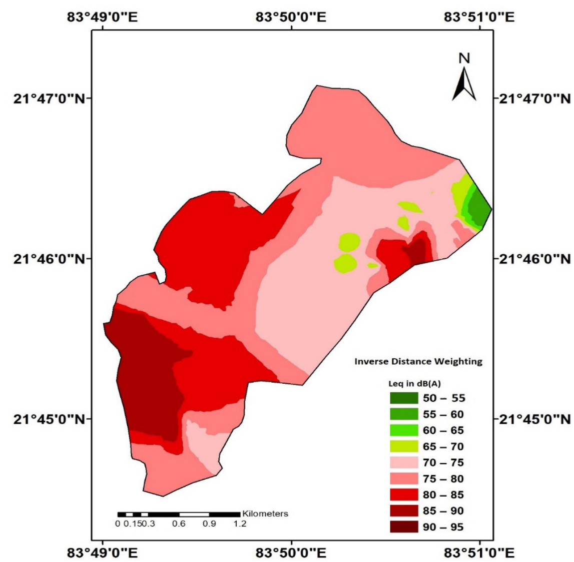

Figure 8. Noise map of Mine-B by using IDW method.

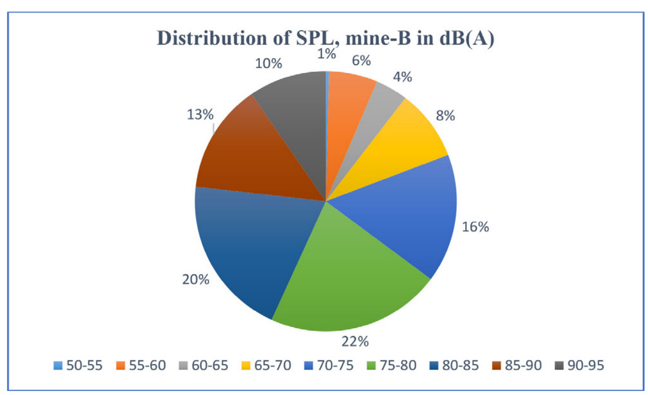

Figure 9. Distribution of SPL in different ranges in dB (A) at Mine-B.

lightweight vehicle road (65.8-73.2) dB(A), dumper parking (70.1-79.5) dB(A). From the above data, it was observed that sound pressure level values at coal stock, overburden removal area, the working area near coal face and haul road in Mine-B are above the warning limit of 85 dB(A) prescribed by DGMS, 2011.

4.0 Conclusions

The noise mapping application in the mines was aimed to interpolate noise levels with GPS variables and produce noise levels plotting and noise map of the coal mines. Accuracy was a major issue in plotting and was committed in enhancing the accuracy of interpolation, noise calculation, and noise effect studies. Noise contours generated from the different interpolation techniques were cross-validated using the RMSE of each interpolation method. The interpolation, which shows low RMSE, was treated as the best interpolation among others. In this research kriging interpolation was found to be more accurate than other interpolation methods. It was observed that the predicted noise levels were higher near HEMM and might have a negative impact on the hearing impairment of the workers in the long run. There were many areas in the mines where the noise level is high. Proper preventive control measures are to be implemented before any further expansion program is implemented. With the existing regulation standards, mine officials can identify the regions violating the standards to devise noise mitigation measures and study alternative solutions. Emphasis rested on assimilating measured noise data and their positioning with a GIS. It can be concluded that a GIS-based noise map can help us with the noise management process. Workers working near drill machines and shovels should wear Personal Protective Equipment (PPE) because of exposure to the high level of noise. Emphasis was laid on integrating measured noise data and their positioning with a GIS. It can be concluded that GIS-based noise studies have more potential to enhance the visualisation of noise maps.

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