Limestone mining — is it noisy or not?

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Abstract

U.S. National Institute for Occupational Safety and Health (NIOSH) researchers are conducting a cross-sectional survey of equipment noise and worker noise exposures in the mining industry. Surface and underground limestone is one commodity recently surveyed. The sound levels of mining and processing equipment were recorded to identify noise sources. Full-shift worker noise exposures were completed to determine the exposure of various occupations. This article presents the results of the noise research conducted in both underground and surface limestone mines, detailing the equipment likely to cause worker overexposures, and the occupations experiencing overexposures. Implications for worker noise exposure reduction are also reported.

Introduction

Noise is present throughout the mining industry. Continued exposure to high noise levels (NIOSH recommended exposure limit (REL) of 85 dB(A) as a eight-hour time-weighted average (TWA) (NIOSH, 1998)) can cause damage to the inner ear. The eventual result is a permanent shift in hearing thresholds, which is known as noise-induced hearing loss (NIHL). NIHL is the most common occupational disease in the United States today, with 30 million workers exposed to excessive sound levels or toxicants that are potentially hazardous to their hearing (NIOSH, 1996a). The problem is particularly severe in all areas of mining (surface, processing plants and underground) where large, noisy equipment predominates. Studies indicate that 70 percent to 90 percent of all miners have NIHL great enough to be classified as a hearing disability (NIOSH, 1996b). An analysis of NIHL in miners presents a snapshot of the extent of NIHL in the mining industry (Fig. 1) (NIOSH, 1996b). This analysis of a private company's 20,022 audiograms indicates that the number of miners with hearing impairments (defined as an average hearing threshold level of 25 dB or greater for the frequencies 1,000, 2,000, 3,000 and 4000 Hz) increased exponentially with age until age 50, at which time 60 percent to 90 percent of the miners had a hearing impairment (NIOSH, 1996b, 1997).

Despite extensive work with engineering controls in the 1970s and 1980s, NIHL is still a problem in the mining industry (*Federal Register*, 1996). To address this issue, the U.S. Mine Safety and Health Administration (MSHA) published "Health Standards for Occupational Noise Exposure" (*Federal Register*, 1999). Requirements of the new regulation include the adoption of a hearing conservation program similar to that of the U.S. Occupational Safety and Health Administration (OSHA), with an "Action Level" of 85 dB(A) eight-hour time weighted average (TWA_8) and a permissible exposure level (PEL) of 90 dB(A) TWA_8. The new regulations also state that a miner's noise exposure measurement shall not be adjusted because of the use of personal hearing protection, and the requirement to use all feasible engineering and administrative controls for noise exposure reduction.

In an attempt to reduce NIHL in the mining industry, NIOSH researchers have been conducting noise surveys in mining, including the limestone industry. The surveys

FIGURE 1

Hearing impairment in coal miners, metal/nonmetal miners and non-exposed males (males that never worked in the mining industry) (NIOSH, 1996b, 1997).

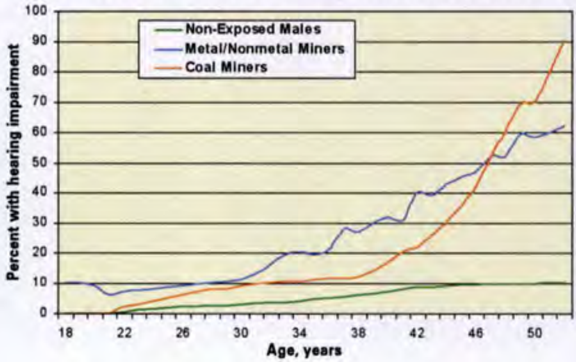


FIGURE 2

Sound level meters.

FIGURE 3

Location of the dosimeter outside of the haul truck.

FIGURE 4

Joy Axivane fan in underground limestone mine.

are designed to monitor worker dose, measure equipment sound levels, and to understand the noise source/worker dose relationship. This was accomplished through full-shift dosimetry readings, equipment noise profiles, and where possible, worker task observations.

Scope of research

Background. Noise surveys were conducted in one surface and three underground limestone mines located in eastern and western Pennsylvania and in northern Maryland. In total, 43 worker noise exposures (MSHA PELs) and 71 equipment noise profiles were completed. Noise exposure measurements were taken for equipment operators, crushing plant operators, crusher operators, drill operators, scaler operators, blasters, mechanics and laborers. The equipment noise profiles included stationary and mobile underground and surface mining equipment, control rooms and crushing and screening facilities. In addition, the mobile equipment was monitored for noise (dose) inside and outside the cabs simply to delineate the effectiveness of the cabs to protect the operators from engine/operational noise exposure.

Table 1

MSHA PEL noise dose for limestone mine workers.

Occupation	Number of recorded doses	Worker range of MSHA PEL dose, percent	Outside cab range of MSHA PEL dose, percent
Haul truck operator	11	0.59 to 49.69	65.92 to 187.54
FEL operator	9	0.34 to 64.21	59.04 to 262.79
Drill operator	3	24.57 to 31.38	293.74 to 487.26
Scaler	3	1.18 to 50.23	162.32 to 208.96
Water truck operator	1	35.81	ND[1]
Crusher operator	3	5.85 to 13.36	ND
Blaster/blaster helper	4	13.27 to 28.64	ND
Crushing plant operator	3	0.90 to 32.30	ND
Plant helper/laborer[2]	5	17.50 to 119.272	ND
Mechanic	1	8.94	ND

[1]ND = Not determined.
[2]Laborer using air wrench resulting in MSHA PEL dose of 119.27 percent.

Instrumentation and data collection. The instrumentation consisted of two basic sound monitoring instruments: personal dosimeters and sound level meters (SLM). Worker noise exposure was monitored using Quest[1] Q-400 Noise Dosimeters. The workers donned a dosimeter for their full work shifts. The microphone was located at the middle of the shoulder per MSHA recommen-

[1]Reference to brand names does not imply endorsement by NIOSH.

FIGURE 5

Sound contour plot for Joy Axivane fan.

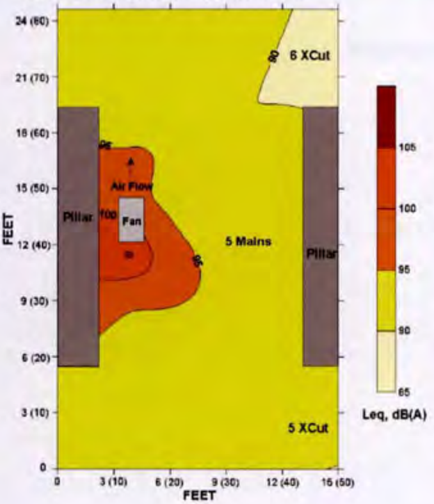
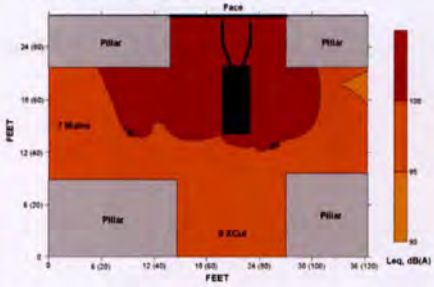


FIGURE 6

Sound contour plot for face drill.



dations (CFR, 1998). The dosimeter was set to monitor an MSHA PEL of 100 percent or a TWA_8 of 90 dB(A). (Specific parameters of this setting include A-weighting, 90 dB threshold and criterion levels, 5-dB Exchange rate, slow response and a 140 dB upper limit.)

Equipment noise profiles and area sound levels were recorded using a Quest Model 2900 SLM in combination with a Bruel & Kjaer 2260 Investigator. The SLM and Investigator were mounted side-by-side on a tripod (Fig. 2), with the microphone 1.5 m (5 ft) from the mine floor (approximate ear height), angled at 70E from the source (per manufacturer recommendations), and facing the sound source. Measurements were made on a 1- to 2-m (3- to 6-ft) grid at a distance of approximately 1 to 2 m (3 to 6 ft) from the equipment. Sufficient measurements were made to delineate the sound levels both near and far from the equipment. The instruments were set up to monitor the A weighted linear equivalent continuous sound pressure level (Leq), a linear one-third octave band frequency noise spectrum, a Linear Leq and a C-weighted sound level. Of most importance was the Leq sound level, in decibels (dB), which is the average sound level for a measurement period based on a 3-dB exchange rate. The 3-dB exchange rate is the method most firmly supported by scientific evidence for assessing hearing impairment as a function of noise level and duration (NIOSH, 1998). Measurements collected using a 3-dB exchange rate will result in slightly higher measured sound levels than if the MSHA noise standard requirement of a 5-dB exchange rate were used. A slow response rate with an averaging time of 10 seconds was employed, with most readings being recorded over a 30-second period.

Mine characteristics. The four limestone mines surveyed included one surface and three underground mines. A similar mining sequence was used at all the mines. The sequence included drilling the face or bench, blasting the rock and extraction using front-end loaders and haul trucks. The blasted material was transported to the crush-

Table 2

Sound level measurements at limestone mines surveyed.

Equipment	Location	Range Leq, dB(A)[3]
Fans, main and auxiliary	UG[1]	75 to 109
Tamrock Ranger 500 floor drill	UG	91 to 102
Oldenburg Cannon face drill	UG	93 to 103
Gardner Denver MK45H face drill	UG	86 to 109
Gradall 5110 scaler	UG	89 to 98
Gradall XL4300 II scaler	UG	89 to 94
Blasters bucket truck	UG	76 to 81
Gorman-Rupp diesel water pump	UG	89 to 98
Jaw crushers	S[2]	72 to 102
Jaw crusher control rooms	S	67 to 82
Cone crushers	S	82 to 107
Plant control rooms	S	65 to 72
Screens, single deck	S	90 to 103
Screens, double deck	S	86 to 111
Screening towers	S	86 to 107
Belt drives	S	81 to 101
Surge tunnels with belts	S	87 to 101
Compressor building	S	89 to 91
Plant area noise	S	67 to 101

[1]UG = Underground
[2]S = Surface
[3]Measured at a 3 dB exchange rate rather than MSHA required 5 dBs.

ing and screening facilities where it was processed into various sized aggregate for use in concrete and asphalt production, or for sale to end users. Mine production ranged from 318 kt/a to 1.36 Mt/a (350,000 to 1.5 million stpy) of raw product, or 1.27 kt to 8.1 kt/d (1,400 to 9,000 stpd). Employment at the mine sites ranged from 10 to 43 employees. The underground mines would be considered large opening, with heights in excess of 6 m (20 ft) and widths in excess of 12 m (40 ft). Underground equipment was both diesel and electric powered. No belts or crushers were located underground, but all mine sites had crushers, screens and surface belt facilities.

Results

Worker noise exposure. Workers at each site wore dosimeters for a full shift to provide noise exposure data. Table 1 lists the worker doses measured, including the outside cab doses for evaluation of cab effectiveness in preventing exposures from engine noise and equipment operation. A typical dosimeter location for outside cab measurements is shown in Fig. 3.

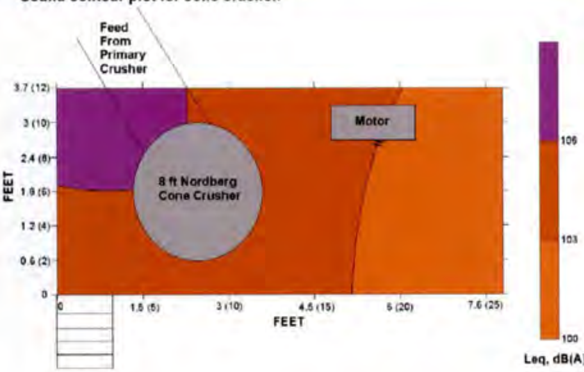
Two general conclusions can be made from these data. First, all worker doses were below the MSHA PEL of 100 percent (0.34 percent to 64.21 percent, Table 1) except for one of the laborers (119.27 percent). This worker spent a significant portion of the shift using an air wrench to tighten bolts while installing a sheet metal protective canopy at the drift mouth. His exposure included not only the air wrench and compressor, but also the mobile equipment entering and exiting the mine. Secondly, a comparison of the interior and exterior mobile equipment doses indicates that the equipment cabs are providing sufficient protection from noise for the operators.

FIGURE 7

Nordberg cone crusher.

FIGURE 8

Sound contour plot for cone crusher.



Equipment/area noise measurements. Sound level measurements were taken around all stationary equipment such as belts and belt drives, crushers, screens, ventilation fans and around semistationary mobile equipment, including scalers and face and floor drills. Table 2 lists the results of the sound-level measurements for both the surface and underground equipment. For convenience, equipment such as screens, crushers and belt drives are lumped together by category, even though they varied widely in size and product throughput. The sound levels varied widely because of the size and throughput just mentioned, but also because of equipment age, size and condition and because the ranges include measurements taken at varying distances from the stationary equipment.

To illustrate the sound level measurements, several examples are included. Figures 4 and 5 include a photo and contour plot of sound levels around a Joy Axivane fan used for auxiliary ventilation underground. Sound levels up to 105 dB(A) were recorded adjacent to the fan and below 90 dB(A) at a distance of approximately 15 m (50 ft) from the fan.

Figure 6 is a sound-level contour plot for a newer (less than 10-years old) Oldenburg Cannon face drill. The plot illustrates that even at a distance of 24 m (79 ft), the sound levels are still 95 dB(A).

A Nordberg cone crusher (age

and number of rebuilds unknown) is illustrated in Fig. 7. This crusher receives crushed rock from the primary jaw crusher. The contour plot illustrates that sound levels from 100 to 106 dB(A) were present on the platform around the crusher (Fig. 8). A pair of screens positioned side-by-side is shown in Fig. 9. The sound levels around these screens ranged from 85 to 97 dB(A) (Fig. 10). Figure 11 is an overall view of the surface crushing and sizing facilities for one of the underground mines. Figure 12 is the sound contour plot for this area, with all measurements made at ground level. It illustrates where the higher sound levels are and where hearing protection devices (HPD) should be used.

Research implications

Even though only one worker overexposure was recorded, there are some important implications of this research with respect to NIHL in the mining industry. The differences between dose measurements inside and outside the mobile equipment cabs suggest that proper maintenance of the cab's noise controls (windows, door and panel gaskets, acoustical materials and mufflers) and keeping the doors and windows closed during operation is essential to limiting operator exposure.

The equipment and area noise measurements confirm that areas of high sound levels are present in underground and surface limestone mines. As such, high sound areas should be clearly marked. All workers should be made aware of these locations and should be instructed to wear hearing protection at all times when working in these areas. Finally, there is some equipment, such as the fans, drills, screens and crushers, that would benefit from the application of engineering noise controls. The engineering noise controls could include but not be limited to modifications such as silencers, mufflers, resilient linings, application of damping material and, of course, replacement with quieter equipment. This would help to minimize the potential for exposure of workers in the immediate vicinity during equipment operation.

Summary

The noise measurements indicate that limestone mining can be noisy. But exposure monitoring reported here indicates that the mine operators and workers are avoiding overexposures to noise. The mobile equipment used underground and on the surface can generate high sound levels but the cabs are effectively shielding the op-

FIGURE 9

Double screens.

FIGURE 10

Sound contour plot for double screens.

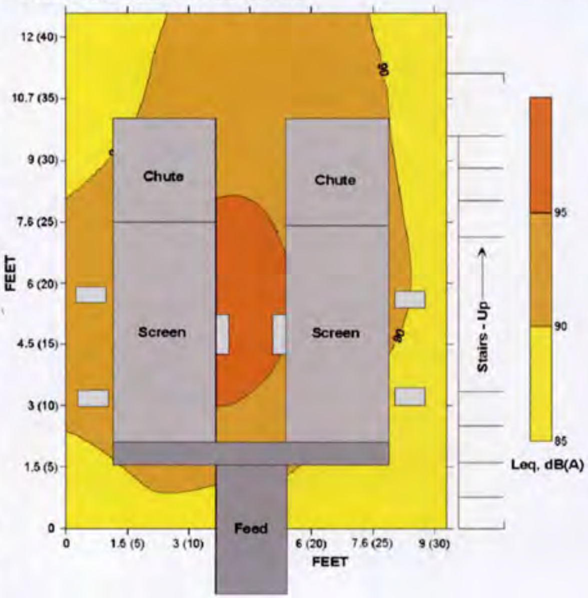


FIGURE 11

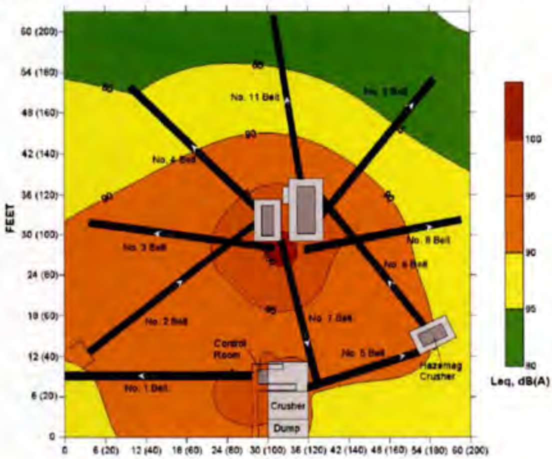
Surface crushing and sizing facilities.

erators from the noise. The crushing and grinding facilities are also noisy but workers seem to limit their activity in these areas, thus avoiding overexposure.

The highest sound level (109 dB(A)) was recorded near the underground fans and face drill. Travel near these pieces of equipment while they are operating should be limited and should include the wearing of appropriate hearing protection. An appropriate HPD is one that a worker will wear consistently when noise levels are above 85 dB(A), that is comfortable, is inserted and/or worn correctly and is kept clean and maintained.

FIGURE 12

Sound contour plot for surface facilities.



Research now shows that the noise reduction rating (NRR) of most HPDs must be derated under normal use. The NIOSH Noise Criteria document (NIOSH, 1998) suggests derating earmuffs by 25 percent, foam plugs by 50 percent and molded (flanged) plugs by 70 percent. Derating is still only a rough guide and actual protection can vary. Finally, MSHA noise regulations require the wearing of dual protection whenever a miner's noise exposure exceeds a TWA8 of 105 dB(A). ■

Disclaimer

The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. National Institute for Occupational Safety and Health.

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