Case study using task-based, noise-exposure assessment methods to evaluate miner noise hazards

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Introduction

In 1993, otologists Robert and Joseph Sataloff stated that, "hearing loss due to occupational noise exposure is our most prevalent industrial malady" (Dembe, 1996). Ironically, excessive noise has long been known to detrimentally affect hearing. In 1700, Ramazzini in *De Morbis Artificium Diatriba* described how workers who hammer copper "have their ears so injured by that perpetual din ... that workers of this class become hard of hearing, and if they grow old at this work, completely deaf" (Wright, 1964). Prior to the Industrial Revolution, comparatively few people were exposed to high levels of noise in the workplace. With the advent of steam power during the Industrial Revolution, large-scale occupational noise exposure began. In 1874, the prevalence of hearing loss in workers who fabricated steam boilers was so high that the problem was known as "boiler-maker's deafness."

Similarly, in the mining industry, whether using explosives, pounding on metal with hammers or operating modern mechanized equipment, noise is ever present. One of the first investigations of noise in underground coal mines was conducted in 1938 by the Safety in Mines Research Establishment in the United Kingdom. Because sound level meters were not available at the time, the results of that study were only qualitative. However, with the technological advances occurring by the 1960s, much more was known about the noise levels emitted by various mining machines, and efforts to reduce the noise were being made (Crocker, 1985). Current day use of computers and subsequent changes in sound meters and data-logging dosimeters have added significantly to the quantification of noise. Finally, in an effort to reduce occupational exposures, standards resulting from the 1969 Federal Coal Mine Health and Safety Act and the subsequent 1977 Federal Mine Safety and Health Act addressed noise as a significant health hazard. These acts established a limit on occupational noise exposure of 90 decibels (dB) over an eight-hour workday in the mining industry.

Unfortunately, these efforts have not been sufficient to reduce the incidence of hearing loss among miners. Based on noise exposure data provided by the U.S. Bureau of Mines, the National Institute for Occupational Health and Safety (NIOSH) studied the loss of hearing among coal miners reflected in its publication 76-172. NIOSH found that 48% of miners at age 48 had significant hearing loss. In another study conducted in 1996, again by NIOSH, indicated that 90% of coal miners over the age of 48 had significant hearing loss. Hearing loss is still prevalent in the coal-mining industry.

Background

Many methods to sample noise and noise exposure exist and, with advances in computer technology, are simple to perform. For example, sound levels can be taken by using a digital meter, or data-logging dosimeters can be used to evaluate an entire workday's amount of noise exposure. Even the different frequencies constituting a noise can be easily separated using a handheld electronic meter. While operating sampling equipment is relatively easy, actually performing these measurements in an underground coal mine can be very challenging. Furthermore, knowing which method will adequately describe the noise exposures in a specific mine may not be obvious.

Comprehensive noise sampling is the logical first

Abstract

Excessive noise has long been a hazard in the coal-mining industry. Studies conducted during the mid-1970s and mid-1990s consistently show that hearing loss within the mining industry persists, in spite of regulatory requirements and sampling technology advances. When the U.S. Mine Safety and Health Administration's new health standards to protect miners from hearing loss took effect in September 2000, the potential developed to reevaluate sampling approaches with regard to noise-source hazards, such as task-based methods. This paper describes results from a Pennsylvania State University research project now being conducted at an underground coal mine. Each occupation was reviewed, and a list of tasks or processes performed by each was generated. Traditional personal noise dosimetry, static sound pressure levels and equipment sound mappings have been performed. Job tasks indicating the greatest levels of daily noise exposure and contributions to noise dose have been identified and will be discussed.

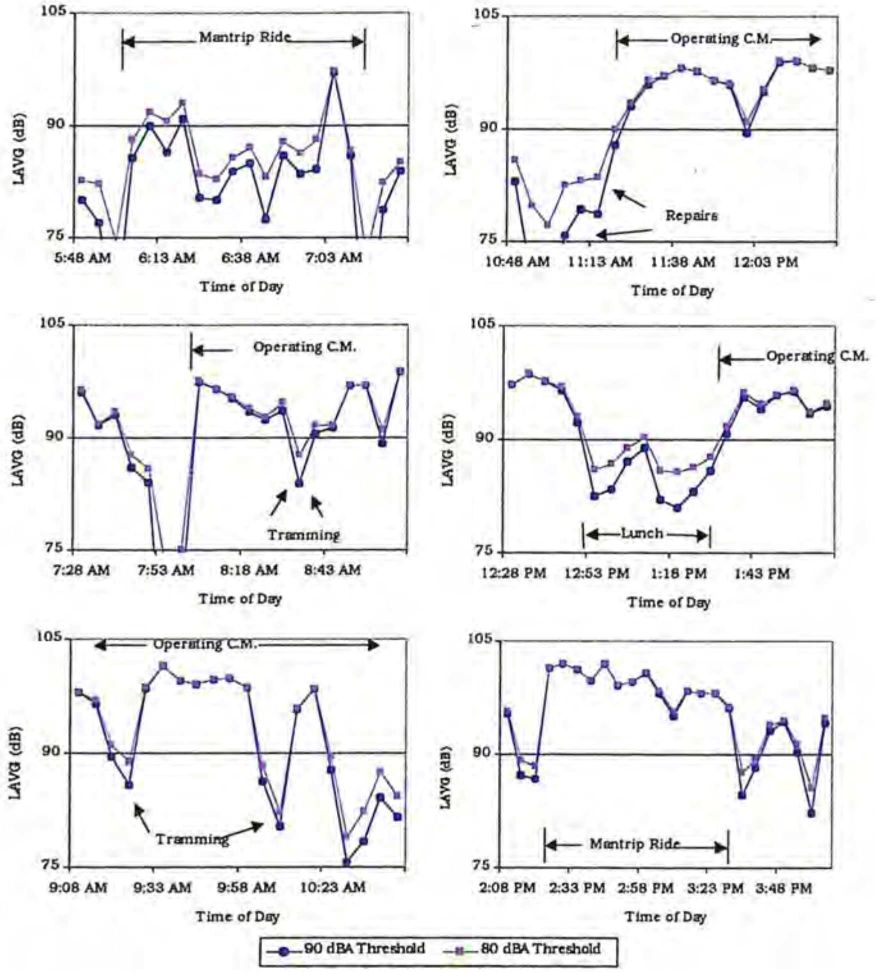
TABLE 1

Job titles, noise sources and risk codes.

Title	Duties	Noise source	Risk code
Crew leader	Roams and verifies operation of all facets of his section. Checks ventilation and methane	Proximity to miner or roof bolters	II
Continuous miner operator	Operates the continuous miner Assists with moving cables and hoses.	Continuous miner	I
Section mechanic	Fixes any mechanical equipment in place. Splices cables and relieves shuttle car operators as needed.	Proximity to other equipment or powered tools	II
Shuttle car operator	Hauls coal from continuous miner to belt. Cars are conveyer fed.	Shuttle car and proximity to miner	I
Roof bolters	Uses roof bolting machine to drill holes and install roof bolts. Also, transports machine from one location to another.	Roof bolt machine	I
Utilityman	Operates scoop machine to clean up mined areas after roof bolts are in place. Rock dusts newly mined area and gets supplies from belt area for roof bolters.	Movement of coal with scoop and proximity to other equipment	II
Crew outby people	Relieves roof bolters or shuttle car operators as needed. Builds stopping and crips. Delivers rock dust using scoop vehicles.	Roof bolting machine, proximity to other equipment	II
Belt cleaners	Cleans up spilled coal off belts, greases around belt drives and troubleshoots downed belts.	Shoveling coal and proximity to drive belts	III
Trackman	Installs all track in mine. Uses sledge or axe to pound metal clip ties used to attach sections of rail.	Pounding metal rails with sledge	III
Stone crew	Operates Unihauler/stone miner (no water spray). Builds cribs/posts or hoses as needed.	Stone miner	II
Rock dusters	Uses battery-operated POD Duster to apply rock dust to mine interior.	POD duster	II
Pumper	Checks and maintains all mine pumps. Verifies status of wet areas.	Proximity to other equipment	III
Electrician	Services all cap lamps and performs general maintenance in house. Use own service area to work on equipment.	Electrical/pneumatic equipment	III
Supplyman	Operates battery-driven haulage equipment to move supplies from belt to drop point.	Proximity to other equipment	III
Beltwalker	Exams all mine belts for wear and repair.	Proximity to other equipment	III
Firebosses	Examines all mine air courses. Checks sealed areas and roof falls. Performs preshift gas and oxygen analysis.	Proximity to other equipment	III
Beltman	Installs or retrieves mine belts as required. Splices parts together.	Electrical/pneumatic equipment	III
Maintenance	Repairs broken equipment from previous day. Performs preventive maintenance as needed.	Grinders/welders or other powered equipment.	II
Midnight utilities	Performs any left over roof bolting, cleans up face areas and finishes rock dusting.	Roof bolt machine/POD equipment or scooping coal.	II
Roller changer	Changes rollers for belt assembly.	Electrical/pneumatic equipment.	III

FIGURE 1

Noise dosimetry time history for a continuous miner operator. (Each data point represents the average sound level (LAVG) of a five-minute sampling interval and 5 dB exchange rate when the dosimeter was set to have a threshold of 90 and 80 dBA).



step when implementing a hearing-conservation program. First, through proper noise-exposure assessment, workers know when the noise levels are sufficiently high to cause hearing damage, necessitating the use of hearing protection. Noise surveys indicate that squealing bearings or banging metal parts are the leading noise contributors. Dosimetry facilitates the assessment of those people significantly exposed to a whole day's worth of noise and, subsequently, who should be periodically evaluated with an audiogram to track their hearing. Finally, through octave-band analysis, dominant sound frequencies can be quantified and effectively controlled, resulting in noise-level reduction.

The current NIOSH hearing-conservation recommendations exceed attempts to merely conserve hearing by focusing on prevention of occupational noise-induced hearing loss (NIHL). NIOSH recommends the implementation of a hearing-loss prevention program (HLPP). It includes exposure assessment, engineering and administrative controls, proper use of hearing protectors, audiometric evaluation, education and motivation, record keeping and program audits and evaluations.

Incorporating many of NIOSH's recommendations, the U.S. Mine Safety and Health Administration (MSHA) enacted the Occupational Noise Exposure Final Rule in September 2000 in an effort to address the hearing-loss problem in the mining industry. However, as previously noted, many of these recommendations have problems. Among other things, the MSHA rule has a performance-based requirement that all mine operators are to establish a system to effectively evaluate each miner's noise exposure (MSHA, 1999). This charges each mine operator to develop his or her own system as appropriate. To complicate matters, NIOSH's recommendations specifically acknowledged that, although exposure monitoring strategies for air contaminants rely mainly on statistical methods, these may not be appropriate for occupational noise exposure assessment and that a task-based approach may be more useful. More research is needed (NIOSH, 1998).

During the late 1990s, Valoski and Seiler of MSHA presented a talk entitled "Comparison of coal mine occupational exposures collected at two threshold sound levels." The talk addressed coal miner noise exposures using the 80 and 90 dBA threshold limits to ascertain compliance with the MSHA regulations. The talk showed great variations in noise exposures within the same job description. A task-based approach may indicate or quantify contributors to the overall noise dose. In addition, the American Industrial Hygiene Association published a formal strategy for task-based exposure assessment methods for the assessment of occupational exposures (Mulhausen and Damiano, 1998).

Miners typically perform several different tasks during the course of a work shift. And the different tasks may have significantly different noise exposures. To sample noise that varies throughout a workshift, dosimetry is the commonly accepted method. Additionally, a task-based exposure monitoring strategy will be employed so noise-generating job tasks are accurately reflected on daily noise profiles. In instances where a miner performs essentially only one task for the majority of the workday (continuous miner operator), only one task may be evaluated during a single sample. However, a section leader or mechanic may perform several different tasks throughout the mine during the course of the workday, and any or all may be contributing to the individual's overall noise dose for a given day. The mining industry has been aware of the impact of specific work tasks on occupational noise exposure for some time — pneumatic bolters (Lamonica et al., 1971;

Bobick and Giardino, 1976) and the mantrip (Lamonica et al., 1971; Sanders and Peay, 1988).

It is common to use dosimetry to provide a single number, which represents a person's overall daily noise exposure. This number may not adequately explain what is significantly contributing to the total dose. By combining dosimetry data and task analysis, subtle noise sources may be identified and evaluated as to their overall contribution. Therefore, this paper is a preliminary summary of findings using task-based noise-exposure assessment methods and dosimetry data to evaluate and reduce hazardous noise exposures to underground coal miners.

TABLE 2

Noise reduction after elimination of noise contributed by the mantrip and significant production noise source.

Job name (TWA, dBA)	Task	TWA reduction
Continuous miner operator (96.6 dBA)	1. CM operation1	9.5 dBA
	2. Mantrip	1.0 dBA
Roof Bolter (92.2 dBA)	1. Bolting	17.4dBA
	2. Mantrip	1.3 dBA
Shuttle car operator (91.4 dBA)	1. Car operation	20 dBA
	2. Mantrip	0.6 dBA
Beltman (90.6 dBA	1. Splicing	5.8 dBA
	2. Mantrip	2.1 dBA
Mechanic (87.1 dBA)	1. Mantrip	9.4 dBA
	2. Near other equipment	Nominal
Crew leader (86.6 dBA)	1. Near equipment	4.3 dBA
	2. Mantrip	1.9 dBA

Experimental procedures

Identification. Prior to sampling, an interview with the mine's safety representative was conducted to list all employee job codes and noise-producing tasks in each code identified. This listing serves as the task sheet against which the subsequent noise samples are referenced. As part of the preliminary assessment, jobs were qualitatively evaluated as to how much noise exposure each job was expected to have during a typical workday. Table 1 is a summary of this assessment. Each job was then placed into one of three categories:

- Category I jobs had noise exposures that were expected to exceed the 90-decibel A-weighted criteria.
- Category II jobs had exposures lower than the 90-decibel A-weighted criteria but greater than the 85-decibel A-weighted Action Level.
- Category III jobs had noise exposures less than the 85-decibel A-weighted Action Level.

All noise levels are based on an eight-hour time-weighted average.

Sampling protocol. Prior to the sampling of the miners, an introduction and brief overview of the purpose of the noise sampling was presented. All dosimeters and dosimeter calibrators used met the ANSI S1.25-1991 (R1997) and ANSI S1.40-1984 (R1997) standards, respectively. They were laboratory-calibrated within the previous 12 months. Dosimetry was performed in the hearing zone, a 305-mm- (12-in.-) radius sphere encompassing the miner's head. To avoid interference of air movement over the microphone, all dosimeters were equipped with foam wind screens that were attached to the microphones with Velcro and a rubber band. Noise results are reported without regard to the type of hearing protection employed.

Field calibration, using a 1,000-Hertz frequency acoustic calibrator, was performed prior to and directly following all sampling. All field calibration results were within ±0.2 decibels of the calibrator's value.

Both the MSHA Permissible Exposure Level and Action Level parameter values were programmed into each dosimeter as follows.

Dosimeter A settings:

- Weighting = A
- Threshold = 90 dBA
- Exchange rate = 5 dBA
- Criteria = 90 dBA
- Microphone response = slow
- Sampling range = 90 to 140 dBA

Dosimeter B settings:

- Weighting = A
- Threshold = 80 dBA
- Exchange rate = 5 dBA
- Criteria = 90 dBA
- Microphone response = slow
- Sampling range = 80 to 130 dBA

Logged sound-level measurements (LAVG) were graphed. Tasks from the initial qualitative survey and a post-shift miner interview were recorded. Figure 1 shows a typical graph of logged values for a continuous miner operator, with significant tasks indicated for the shift. Of note is the time spent in the mantrip. The continuous miner operator is being exposed to noise levels in excess of 90 dBA while not performing any job tasks. In addition, all of the miners in the production crew are riding the mantrip, not just the miner operator.

Data analysis. Stored values were downloaded to a computer and the time-weighted averages (TWA) were recomputed using a spreadsheet application. Significant noise events or tasks were identified and evaluated in several of the underground miners' information. Specifically, the noise contribution of the mantrip, the continuous mining machine, roof bolting machine and the shuttle car were evaluated. Finally, mantrip data were reviewed and a hypothetical scenario of noise reduction potential was performed.

Analysis and discussion of results

The highest sample values taken for each of the continuous miner operators, roof bolters, shuttle car operators, mechanics, section leaders and beltmen were further evaluated. Each set of logged LAVGs was graphed and significant noise events were identified. To

TABLE 3

Noise reduction after elimination of significant nonproduction noise sources.

Job (TWA, dBA)	Task	Noise reduction, dBA
Continuous miner operator operator (96.6)	1. Mantrip	1.0
	2. Distance from miner	19.5
Roofbolter (92.2 dBA)	Mantrip	1.3
Shuttlecar operator (91.4 dBA)	Mantrip	0.6
Underground mechanic (87.1)	Mantrip	9.4
Crew leader (86.6 dBA)	1. Mantrip	1.9
	2. Proximity to other equipment	4.3
Rock duster (84.5 dBA)	Venting pneumatic vent unit	0.6
Belt cleaner (89.3 dBA)	Proximity to belt drive units	3.5
Beltman (90.6 dBA)	1. Mantrip usage	2.1
	2. Applying belt splices with handheld hammer	5.8
Midnight utilities (85.2 dBA)	1. Mantrip	2.1
	2. Other production jobs	19.7
Outby person (86.0 dBA)	1. Movement of materials	0.8
	2. Mantrip usage	14.1
Underground supplyman (89.2 dBA)	1. Mantrip usage	8.5
	2. Proximity to other equipment	2.1
Utilityman (87.2 dBA)	1. Mantrip	5.0
	2. Proximity to continuous miner	2.7
	3. Proximity to bolter	1.1
Belt brakeman (89.8 dBA)	1. Sitting in machinery space	1.4
	2. Applying brake	12.8
Front-end loader operator (79.1 dBA)	1. Leaving door open	7.8
	2. Standing near PA system	0.5
	3. Standing near operating loader	1
Outside supplyman (82.1 dBA)	Use of noninsulated loader	6.2

quantify the noise, each task contributing to the overall daily exposure-logged dosimetry values was reduced below the dosimeter's threshold level of 90 dBA and the daily TWA was recalculated. Table 2 is a summary of results after the noise from the respective significant noise sources and the mantrip were removed. The results indicate that the mantrip ride does contribute to a miner's overall daily noise exposure. Logically, the percentage of the overall noise exposure contributed by any single task increases as the daily noise-exposure decreases. In addition, in the case of the mechanic (who uses the mantrip to get parts throughout the workday), the mantrip represented the most significant noise contributor.

Another use of the data-logging capability of the modern dosimeter is performance of hypothetical scenarios. Table 3 shows the results of a hypothetical scenario using individual daily samples taken for different production crewmembers. The scenario reduced the LAVGs contributed by the mantrip by five decibels. Thus, simulating the effect on daily noise exposures if damping material or another equivalent noise-reduction method were employed on the mine's mantrip cars. A 1% to 5% reduction in noise exposure can be realized for many of the underground miners who use the mantrip car as their mode of transportation into and out of the mine.

Conclusions and recommendations

Using task-based exposure assessment methods, the mantrip ride was identified as a potentially significant noise source for underground coal miners. The amount of noise contributed by the mantrip was quantified through noise dosimetry data. From these data, a hypothetical scenario was performed to show that a significant overall impact was possible using moderate noise-reduction measures. Utilization of task-base noise-exposure assessment methodology coupled with time-study techniques and readily available electronic noise dosimeters may give a powerful tool for mine operators to understand, quantify and effectively reduce occupational noise exposures. As technology improves, dosimeters will log more information (octave band information) and be even easier to use. ■

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