



Mining Hearing Conservation Programs: Do They Really Prevent Hearing Loss?

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ABSTRACT

Hearing Conservation Programs (HCPs) have been required by federal regulation in mining environments since the year 2000. Yet, the prevalence of hearing loss remains high in the mining industry in the United States. A variety of noise control solutions, as well as behavioral interventions, have been developed in recent years by research organizations, manufacturers, and other entities. There is a large selection of hearing protection devices commercially available to the public and no shortage of for-hire audiometric test services. The availability of resources should allow for the prevention of continued occupational hearing loss in mining; however, the current prevalence of hearing loss leads to question if perhaps there are shortcomings in the effective execution of existing HCPs. Further, can the existing HCPs be modified to yield better results? A review of currently available literature to date as well as recent data analyses conducted by the National Institute for Occupational Safety and Health (NIOSH) is presented in this paper. In addition, potential solutions for increasing the effectiveness of HCPs in mining, with applicability to other heavy industries, are discussed here. Such solutions will include greater worker involvement, improved training practices, and integration of hearing protection fit testing into existing hearing conservation programs.

1 INTRODUCTION

Noise exposure has been ubiquitous in the mining industry since occupational exposures were first tracked. In 1976, the National Institute for Occupational Safety and Health (NIOSH) estimated 70% to 90% of coal miners will develop hearing loss by the age of 60¹. 1981, an assessment

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performed by the United States Environmental Protection Agency (EPA) estimated that around 47% of miners were exposed to the time-weighted average (TWA) sound level above 85 dBA². In a subsequent assessment by NIOSH in 1996, it was estimated that nearly 90% of miners have developed hearing impairment by age 50³. The prevalence of noise-induced hearing loss in the mining industry was about 24% to 27% during the time period of 1991 to 2000⁴. A similar estimate of this prevalence was reported for the period of 1997 to 2003⁵.

Hearing conservation programs are a culmination of comprehensive, coordinated efforts to determine the noise exposure of workers on the job, followed by specific steps to lessen that noise exposure. These efforts, in turn, will lessen the worker's chance of incurring an occupational hearing loss. Implementation of an HCP is required by federal and state agencies when certain work conditions are present. HCPs are required at worksites where the workers have noise exposures exceeding the MSHA (Mine Safety and Health Administration) or OSHA (Occupational Safety and Health Administration) action level. Aside from this legal requirement, conscientious employers often want to protect their workers from noise and potential occupational hearing loss.

In 2000, MSHA published a revised rule on noise controls and hearing loss prevention in the mining industry⁶. Implementation of a hearing conservation program (HCP) became a requirement if sound levels at the worksite exceed 85 dBA. The following five elements are now required per this MSHA regulation: noise monitoring, use of hearing protection, audiometric testing, worker training, and program recordkeeping. However, there is limited guidance regarding how these elements are to be integrated or enacted into working practices. Although not falling under the direct purview of "hearing conservation program elements," as per the MSHA regulation, engineering controls were identified and recognized by MSHA as the most effective way to reduce noise and subsequent noise exposure of miners, and have had a greater influence per the new rule.

It is important to note that NIOSH recommends seven key elements for execution of a successful hearing conservation program: noise monitoring, engineering and administrative controls, audiometric evaluation, use of hearing protection, education and motivation, recordkeeping, and program evaluation. These seven elements include the five required elements by MSHA, but also include engineering controls as an element of an HCP, rather than focusing on noise controls in addition to, or separately from, the HCP. Also, the importance of understanding program effectiveness through a system of program evaluation is recognized and recommended. The general consensus is that all components must be efficiently acted upon for true success of the HCP. If any one of these components is missing or lacking in quality, the overall success of the program will suffer.

To determine the success of hearing conservation programs as a whole, a description of relevant research on the topic is provided in the sections that follow. The topic areas address the overall application of hearing conservation programs, as well as detailed evaluations of some of the specific elements of these programs. From this analysis, we can begin to understand the effect of these programs on reducing noise-induced hearing loss in mining and what changes should be implemented to improve that effect.

2 HEARING CONSERVATION PROGRAMS

2.1 Initial Changes after the New Rule

After the HCP requirement was introduced by legislation, average noise levels in the mining industry decreased by 2 dB and long-term noise levels continuously reduced at a rate of 3.8 dB/year^{7, 8}. Comparing the average noise level before and after 2000, the reduction was 2.7 dB in coal mines, 2.9 dB in metal mines, and 6.5 dB in nonmetal mines⁹. The frequency of excessive

exposure to hazardous noise level was also reduced. The percentage of MSHA inspection records that were above 90 dB before and after 2000 was reduced by 7.1%, 18.9%, and 19.8% in coal, metal, and nonmetal mines, respectively⁹.

A recent Cochrane systematic review⁸ focusing on the effectiveness of intervention to prevent occupational noise-induced hearing loss reviewed all randomized control trials, controlled before-after studies, and interrupted time-series studies up to October 2016 and found that overall the HCP (including all industries) showed favorable but nonsignificant effects for preventing occupational hearing loss⁸. The review concluded that average HCPs do not reduce hearing loss risk below a level that is equivalent to the level for workers who are exposed to 85 dBA, which is equal to the action level (AL) to initiate miners/workers' enrollment in a HCP.

Despite the regulation for implementation of HCPs, the prevalence of noise-induced hearing loss in the mining industry remains one of the highest among all industries even after the year 2000^{4,5,10,11}. The prevalence of tinnitus reported in 2007 as a leading indicator of noise-induced hearing loss is also the highest in the mining industry, with more than 10% of the mining population reporting this problem¹². A significant proportion of noise inspection samples showed sound levels above the permissible limits (PEL) of 90 dBA, even after 2000. Also, excessive noise exposure was reported for 11.5% of inspections in coal mines, 9.9% in metal mines, and 3.8% in nonmetal mines⁹.

2.2 Changes by Sector

As mentioned earlier, noise exposure has been reduced in all mining sectors after implementing the noise rule with the requirement of hearing conservation programs. The effectiveness of HCPs is heterogeneous across sectors. Nonmetal mines showed the greatest reduction in average noise exposure levels and percentage of excessive exposure, followed by metal mines with the second greatest reduction in exposure levels. Coal mines were shown to have the least effective reduction of noise exposure.

The remaining excessive risk of noise exposure and hearing loss, as well as the discrepancy of the program effectiveness across mining sectors, indicate the need for evaluating the currently implemented HCPs in the mining industry. The overall goal is to maximize the impact of the HCP on hearing loss prevention and secure the achieved favorable trend of noise and hearing loss reduction. Less ideal hearing loss prevention, as experienced through continued overexposures, could be a result of deficiencies in HCP implementation, varying degrees of efforts towards full implementation, or the appropriateness of the chosen practices.

Since 2000, a total of 13,434 citations were issued to mines regarding noise controls and hearing loss prevention. On average, for each year each coal mines received approximately 1.8 noise-related citations, and each noncoal mine received 1.5 citations¹³. Among coal mines, nearly three-quarters of the noise-related citations were issued due to miner noise exposure greater than the PEL set by MSHA while among noncoal mines the highest proportion of citations was issued for exceeding the AL requirements. In other words, the noncoal mines failed to enroll the exposed miners in a hearing conservation program (HCP) when their exposure level was above the stated AL. In noncoal mines, 47% of the received citations were given because of AL requirements, in comparison to 45% given due to noise exposure above PEL. Besides the possibility of noncompliance, this could also be due to an unsuccessfully implemented noise monitoring system that either failed to identify high risk trades/jobs or failed to follow up with the changes in exposure levels resulting from operational process change, machine replacement, etc. Noncompliance to the audiometric testing requirement was also higher in noncoal than in coal mines¹³. Given the lack of adequate details of the HCP implemented in mines in general, it is unclear what aspect of

audiometric testing is non-compliant – the act of audiometric testing within 6 months of employee enrollment in an HCP, proper follow up activities, annual audiometric exams, or lack of proper notification of hearing loss.

As for variances in their citations, it is unknown the degree to which the different MSHA required elements of an HCP were implemented in mines. Furthermore, it is unknown if all components of an HCP are of equal importance to successfully prevent hearing loss, or if one or a combination of a few play a more critical role. It is possible that a deficiency in some elements may not influence the health outcomes the same way as others. Heyer et al.¹⁴ found that only the enforcement of the use of hearing protection devices was significantly associated with hearing loss reduction among the three evaluated HCP elements—audiometric testing, noise monitoring, and hearing protection devices. Noise monitoring was only associated with hearing loss reduction in male workers but not female¹⁴.

NIOSH has developed a checklist to assist hearing conservation program manager compliance with federal regulations. One study compared the implemented HCPs in three industrial plants, based on the OSHA compliance checklist (which is also applicable to MSHA regulations). The degree of deficiency in the HCP implementation in one of the three evaluated plants was the poorest of those evaluated plants in many aspects, including lowest rate of use of hearing protection devices (HPDs), most sporadic audiometric testing, and most lacking of a formal program audit mechanism. However, that same plant actively invested in improving engineering controls and instituted a “buy quiet” policy, reducing the proportion of workers exposed to noise greater than 85 dBA over time, although the exposure exceeding 85 dBA was still observed in a number of departments in the plant¹⁵. This indicates that certain elements of a HCP may be more likely to lead to change than other elements. A recent NIOSH-funded study found that while the cost of HPDs and audiometric testing were greater than training costs¹⁶, measureable hearing loss in workers was found to be significantly associated with HPDs, fit-testing with follow up training, and standard threshold shift (STS) was associated with HPD fit-testing alone or HPD fit-testing incorporated with a training session¹⁷.

As can be noted from these examples, evaluating the success of HCPs can be difficult due to variances in measurement technique as well as the methods of implementing the program elements. There are a variety of practices in implementing an HCP, and the MSHA noise rule does not specify the most optimal practice but rather the minimum practice for each component⁶. Even though it is still inconclusive which practices are most effective, a number of studies highlight some of the merits of various approaches or practices of implementing each component in an HCP to prevent hearing loss.

3 STUDIES BY HCP ELEMENT

3.1 Continuous Noise Monitoring

The MSHA rule requires mine operators to establish an effective system of monitoring noise exposure. However, it is up to the mine operator to decide which approach they would like to follow: use their own noise sampling records either through a salaried health and safety professional or an external contractor; use an outside agency’s inspection data; or use records from their insurance carriers. Any of these activities would bring a mine into compliance⁶ with the MSHA requirement. Noise monitoring conducted using both personal and area sampling approaches was found to be associated with lower rates of high-frequency hearing loss than solely relying on personal sampling¹⁸. Moreover, the commonly used measure (average noise level from HCP noise monitoring) for determining the subsequent action of noise control or hearing loss

prevention was only shown to have a moderate to low correlation with STS ($r=0.47$). Interestingly, the trend of the exposure from the previous 10 years revealed a relatively higher correlation ($r=0.54$)¹⁷.

3.2 Noise Controls

One of the important revisions in the MSHA rule is the emphasis of the priority of engineering controls over administrative controls and personal protection efforts, although NOT as a required element of hearing conservation programs. The reduction of noise levels since 2000 can be partially contributed to the engineering noise control efforts conducted in the mining industry. The replacement of mining equipment with quieter new equipment, installation of acoustic panels and curtains, damping material and silencers, equipment design changes such as ducting, and acoustic enclosures all have been shown to reduce noise levels, with the mean reduction being 19.7 dB, 11.1 dB, 7 dB, 3.4 dB, and 11.8dB, respectively^{8,19}. The long-term effectiveness of these engineering controls remains unclear. Evaluating the effect of miners' aging in conjunction with these noise controls was often missing from the engineering control studies. Machine and equipment maintenance (e.g. sharpening blades, lubricating, or replacing worn parts etc.) is another approach to reduce noise levels, with an estimated effectiveness of about 3 dB¹⁹⁻²¹.

3.3 Audiometric Testing

The MSHA rule for audiometric testing does not specify the licensing requirement, the criterion for evaluating the credentials for the professionals conducting audiometric testing, the location of the testing (in-room versus trailer), nor the time of the testing (during versus before the shift)⁶. In one study, audiometric testing conducted before the shift was associated with lower high-frequency hearing loss than during or after the shift¹⁸. A few potential issues are associated with using external providers with mobile audiometry: high background noise from internal and external sources (van engine running during the test, vibration noise from loading dock, workers entering and exiting the test booth), frequency of changing the provider and its effect on the consistency of the test, and concern for the quality of the test¹⁵. No significant difference in cases of identified hearing loss was found between companies relying on a physician or audiologist to determine work-relatedness of hearing loss and other professionals²⁰. Comments received from focus group interviews often revealed that workers/miners care about their audiometric results, despite a fair number of them (mostly miners) who stated that they never receive the results of their audiograms and are thus unaware of their hearing status. Some also commented on the way they receive audiometric results and displayed an interest in a face-to-face notification, rather than through common mailing practices^{15, 22}.

3.4 Use of Hearing Protection Devices (HPDs)

The MSHA rule defines the sound levels at which miners should use HPDs, the sound level when dual hearing protection is required, and the minimum number of the types of HPDs (≥ 2 types of earplugs and ≥ 2 types of earmuffs). However, it does not provide recommendations on HPD selection. The Cochrane review found that providing the wearer with verbal instructions for proper use of HPDs increased sound attenuation from 0.5 kHz to 8 kHz by 7.98 dB for earplugs but only 0.83 dB for earmuffs⁸. However, there are perceived advantages and disadvantages to both earplugs and earmuffs^{23, 24}. The type of hearing protection device generally preferred by miners

as well as the type that most effectively protects miners from noise overexposure is a subject that requires further evaluation.

Another perception or misunderstanding often held by workers is that HPDs cause interference with verbal communication or warning signals such as emergency or back up alarms. These beliefs often hinder voluntary use as well as the mandatory use of HPDs. They feel that lack of auditory awareness caused by HPD use will lead to other dangerous situations during their work activities. This is especially true in the mining industry where hearing “roof talk” and warning signals, such as vehicle backup alarms, is critical. In this case, HPDs with flat attenuation across frequencies might show some merit. However, many miners and other workers in heavy industries are unaware of this type of hearing protection technology.

Fit testing is not required by the MSHA rule, but has shown beneficial results in reducing hearing loss¹⁷. Fit testing can promote appropriate donning of HPDs. Instruction and appropriate fit will improve the overall effectiveness of the HPD and alleviate miners’ doubts about the benefit of HPDs. Integrating HPD fit testing in hearing loss protection will provide engagement with miners regarding their personal preferences of type or brand of HPDs to promote voluntary and continuous use of HPDs.

3.5 Administrative Controls

A variety of noise monitoring devices equipped with sound level indicators are commercially available. Some of these devices can provide warning to miners when they are exposed to hazardous levels, and others provide direct visual reading of the level. This has the potential to improve self-protection behavior in miners. How this will affect miners’ behavior in self-protection and the impact on reducing the negative health outcomes have not been fully investigated. Moreover, the European construction noise directive (79/113/EEC) requires manufacturers to label the sound power level or sound pressure level at the operator’s position on machines. This approach may increase the recognition of the hazard and awareness of hearing loss risk.

3.6 Training

Finally, the MSHA rule for the training component in HCPs requires a number of essential components: the purpose and the value of the use of HPDs; the advantages and disadvantages of each of the HPD types; the care, fitting, and use of HPDs; the tasks in maintaining noise controls, etc.⁶ However, identifying and dispelling the “myths” of HPD use and tailoring the message to the audience will likely be viewed as more acceptable and likely to lead to improvement of HPD use. As mentioned previously, miners have concerns about the hindrance of communication by the use of HPDs. One study found that when study participants (coal miners) who wore HPDs challenged their teammates to use HPDs, too, several teammates who were previously reluctant found that the device did not hinder communication after taking some time to “get used” to the sound²⁴. Another myth is that miners do not perceive a threat to their hearing if their own operation is quiet but the immediate environment is loud. It was found that workers employed by companies with a moderate to low percentage of noise-overexposed workers are at a greater risk of occupational hearing loss²⁵. These are only a few examples of generic myths shared by this population. Tailored messages to specifically address the myths and barriers at a particular mining site yield a greater effect.

Also, the rule does not specify the forms of training required. Frank et al.²⁶ reported that miners are not influenced by traditional presentations of facts, figures, and regulations. They conducted a study using a mixed training of classroom presentation, followed by active learning with problem-solving questions and computer-based training (CD and video) and with tailored

real-life scenarios. Although the STS rate remained relatively low, the use of HPDs was not as high expected²⁶. Other studies explored the differences of effectiveness among positive, negative, and neutral messages on the use of HPDs and hearing protective behavior among coal miners^{24, 27, and 28}. It was found that a positive message regarding the use of occupational hearing protection (e.g., the sound of falling leaves is relaxing. Always wear hearing protection on the job.) is associated significantly with self-reported change in wearing hearing protection more regularly, stronger behavioral intention, and less perceived manipulation and message distortion at 6-week follow-up than a negative message (e.g., Peace and quiet is not an option when your ears ring all the time. It always helps to wear hearing protection.)²⁷. This highlights the importance of tailoring potential messages in a more positive than negative manner to increase adoption of that message.

4 DISCUSSION

The above studies include only some of the reported effective practices implemented in mining or other industries. Many of the studies show some promising effect; however, it is inconclusive whether these observed positive impacts can be applied to all mining companies. For one last example, a company reported a successful hearing conservation program that involved a DVD message, personalized hard hat sticker, noise dosimeter monitoring to ensure audiograms are indeed conducted after a 14-hr noise-free period, fit testing, provision for a broad range of HPDs, proactive engineering control projects, “buy quiet” program, use of personal noise indicator badges, and bimonthly audits. The company implemented the same mixed practices to its mining, refinery, and smelting facilities and found the hearing loss rates reduced faster in mining than in refineries and smelters.²⁹ This suggests that achieving the greatest reduction of hearing loss rate in the mining industry may require a particular combination of practices in HCPs to target the barriers and needs in this sector. The collective effectiveness from different combinations of practices of HCP components still needs to be fully investigated.

5 CONCLUSION

One can see that despite the implementation of rules requiring hearing conservation programs at mines there is a large discrepancy in how those programs are implemented and the extent to which they truly reduce the incidence of occupational hearing loss. Specific research regarding audiometric testing and the use of audiometric results by the mines is needed to not only determine the occurrence of hearing loss but also to determine if the testing system itself is effective in identifying and preventing occupational hearing loss. Providing area noise information can help mobile workers navigate through their occupational space in a way that helps to reduce or eliminate exposure to hazardous noise.

NIOSH’s Pittsburgh Mining Research Division is currently investigating these topics so that improved guidance can be provided to the mining industry. Due to the variety of methods for HCP implementation and the various measurement methods of the individual elements that constitute hearing conservation programs, it remains difficult to truly determine their effectiveness. Until more specific methods are developed, noting the occurrence of standard threshold shifts (STS) and compliance rates with audiometric testing are most likely the methods that should be continued for documenting the performance of individual HCPs. The major disadvantage of these two factors is that they are lagging indicators rather than leading indicators. So the merit of evaluating individual elements such as noise monitoring, noise control efforts, fit testing and training could provide some sort of leading information allowing for appropriate modification and remediation as needed. A

more time-intensive, yet accurate, method would be an evaluation based on individual elements by some constant metric; however, this remains as a recommendation, rather than a requirement.

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