MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Practical Use of Area Noise Measurements in Stone, Sand, and Gravel (SSG) mines

Azman, Amanda[1]
Brian Kim[2]
National Institute for Occupational Safety and Health (NIOSH)
626 Cochrans Mill Road
Pittsburgh PA 15236

ABSTRACT

Despite the requirement for hearing conservation programs, hearing loss caused by occupational noise exposure is a frequent occurrence in the mining industry. Recent surveillance initiatives indicate that stone, sand, and gravel (SSG) mining operations may be at a greater risk for occupational noise overexposure and hearing loss than other mining commodities. As part of a larger investigation into the effectiveness of hearing loss prevention programs, NIOSH personnel have collected area noise data at three surface stone, sand, and gravel operations. The operational characteristics of the mines, as well as their final consumer product, varied. Sound contour maps were developed from these data. These maps were provided to the participating mines with specific recommendations to modify worker movement throughout the mine or to modify job procedures to reduce miner noise dose. In addition, positive reinforcement was given regarding the use of signage, personal protective equipment (PPE), and worker training at these sites. This paper discusses the use of area noise data, especially sound contour maps, to improve hearing loss prevention programs at stone, sand, and gravel mine sites. The focus is on the integration of sound contour maps with other components of hearing loss prevention programs, especially training and the use of hearing protection, for increased effectiveness and efficiency.

Keywords: Noise, Hearing Conservation Program, Sound Contour Maps
I-INCE Classification of Subject Number: 30

1. INTRODUCTION

Noise over-exposure has been pervasive in the mining industry since occupational exposures were first tracked. In 1976, the National Institute for Occupational Safety and Health (NIOSH) estimated that 70% to 90% of coal miners will develop hearing loss by the age of 60[1]. In 1981, an assessment 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 dBA[2]. In a subsequent assessment by

1. AAzman@cdc.gov
2. BKim1@cdc.gov

NIOSH in 1996, it was estimated that nearly 90% of miners had developed hearing impairment by age 50[3]. The prevalence of noise-induced hearing loss in the mining industry was about 24% to 27% during the time period of 1991 to 2004[4]. A similar estimate of this prevalence was reported for the period of 1997 to 2005[5]. Due to the continued noise overexposure experienced by miners, and their subsequent occupational hearing loss, hearing conservation programs (HCPs) have become a requirement across the mining industry.

Hearing conservation programs (HCPs) are a culmination of comprehensive, coordinated efforts to determine the noise exposure of workers on the job and then implement specific controls to mitigate their noise exposure. These efforts will lessen the worker's chance of incurring occupational hearing loss. HCP's are required by federal and state agencies when workers have noise exposures exceeding the Mine Safety and Health Administration (MSHA)[6] or Occupational Safety and Health Administration (OSHA) action levels.

Despite regulations and best efforts of employers, occupational hearing loss continues to be prevalent across mining operations. A recent analysis of MSHA data shows more reportable cases of occupational hearing loss at stone, sand, and gravel (SSG) mines than at nonmetal and metal mines[7]. Furthermore, although both surface and underground SSG mines have the same incident rate of 2.5 cases of hearing loss per 10,000 miners, surface mines employ approximately 30 times more workers than underground mines, consequently greatly increasing the total number of affected individuals[7].

As part of a broader study to evaluate hearing conservation program implementation effectiveness at mine sites, personnel from the National Institute for Occupational Safety and Health collected area noise measurements at three surface SSG mines. Acoustic maps showing the overall sound pressure levels measured throughout a specific working area were created and provided to the mines. This paper describes the collection of the area noise data and the guidance provided by NIOSH to the mines for using the acoustic maps as a part of their comprehensive hearing conservation programs.

2. DATA COLLECTION

Areas affected by high noise levels with a high number of operators or workers were chosen for the noise assessments. Areas with no worker foot traffic or those primarily occupied by cabbed vehicles were not included in the assessments regardless of their noise levels. Data were collected using a Larson Davis LxT sound level meter on 1-meter and 2-meter spacing grids, at a height of 1.5 meters from the floor during normal business operation in the areas of interest. Along with sound level data, positional coordinates were also taken at each measurement point. The sound level data were then spatially interpolated and plotted on a two-dimensional plane to produce an overhead noise map of the affected area to show the sound distribution and levels throughout the given space. These acoustic maps, along with some suggested administrative controls, were later provided as guidance documents for the participating mines to use as they saw fit within the working spaces at their facilities to reduce noise exposure of workers and improve overall hearing conservation program outcomes.

3. RESULTS

A brief description of each mine, the areas of interest, and results of the noise assessments are provided below.

3.1 Mine 1

Mine 1 is an open pit quarry and processing plant in which rock is mined, crushed and screened to various commercial sizes. Blasting takes place in the pit to free the ore, which is then conveyed to the processing plant for crushing and other processes. The products are then bagged and palletized for commercialization. The processing plant uses two bagging methods: an automatic bagging machine for sand and "fine stone" and a manual bagging machine for the larger stone. Three areas were of interest for this study: 1) the automatic bagging, 2) the manual bagging and 3) the rotary drying areas.

Figure 1 shows the automatic bagging area in mine 1. This is located inside of a building dedicated to bagging and palletizing. In this area a worker is stationed to place empty bags on the machine where the bags are filled by mechanized actions and then automatically conveyed for palletizing. This image shows one bag placer in the background and a bag stocker in the foreground. The acoustic map is shown in Figure 2 with the noise measurement locations indicated by the x notations. There is a high volume of foot and small industrial vehicle traffic through the area. A concentration of high noise is shown near the automatic bagging machine, circled in black, as indicated by the darker red color on the acoustic map.

Figure 1: Automatic bagging area

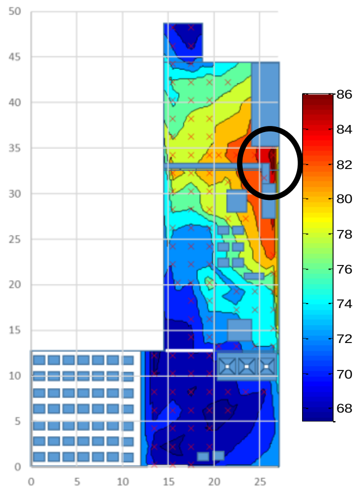

Figure 2: Acoustic map of bagging building

Figure 3 shows the manual bagging area at mine 1. This area is located in a separate room, but within the same building as the automatic bagging machine. In this area, a worker places an empty bag under a large hopper, through which the bag is filled, and then the same worker places the bag on a small conveyer. The bag is conveyed to another area for manual palletizing by two additional workers, and forklift transport for shipping. Once each pallet is full, one of these workers transports the pallet from the area with a forklift. This worker also ensures that the necessary supplies are available for the entire operation. The acoustic map is shown in Figure 4 with the measurement locations indicated by the X notations. There is not high foot traffic in this area. However, the workers operating the machine and palletizing the bags stay in this area throughout their shifts, except while operating the forklift.

Figure 3: Manual bagging area

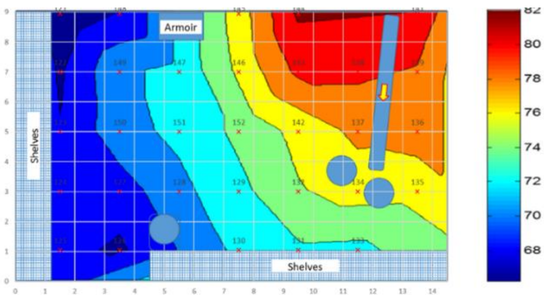

Figure 4: Acoustic map of manual bagging room

Figure 5 shows the rotary dryer, which is used to dry large aggregate before it is sent for bagging. This dryer is located in a separate room, directly adjacent to the automatic bagging area. Workers will often walk through the area to exit the building through a garage door type opening (not visible in photo) to access the back of this building. Although the area is enclosed, workers frequently pass through. The acoustic map for this area is shown in Figure 6. Should workers use this as a path through the facility, they walk directly through the high noise areas, shown in red. One can also note that the sound levels quickly diminish as one exits through the open garage door.

Figure 5: Large rotary dryer

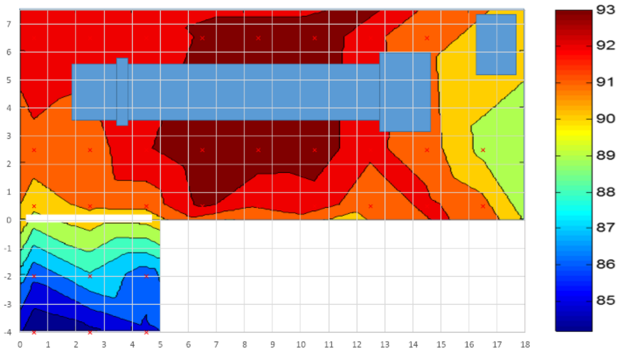

Figure 6: Acoustic map of rotary dryer room

3.2 Mine 2

Mine 2 is a surface sand mine with a remote surface quarry. The ore is extracted from an open pit, then conveyed to two processing buildings for crushing and washing, and drying operations. After drying, the final product, sand, is loaded onto trucks or train for final haulage. There is no bagging process at this mine. Sand, primarily for use in other industrial processes, is the only consumer product from this mine. Areas inside and directly adjacent to the main processing building were of interest for this study.

Figure 7 is an overhead layout view of the processing building at mine 2. Because of the size of the building, it was divided into three sections for measuring and display purposes. Figure 8 shows the top floor of the processing building, divided into three areas where area sound measurements were obtained. Area B, containing the rod mill (shown in the top left), is indicated by the darker red color. Workers often walk directly past this area to go from the office building to the warehouse and crusher buildings. Figure 9 is a close-up photograph of the rod mill located on the second floor of the processing building. Ore is dumped into the rod mill, crushed, then exits through the opening in the front. This machine produced noise levels in excess of 100 dB while in operation.

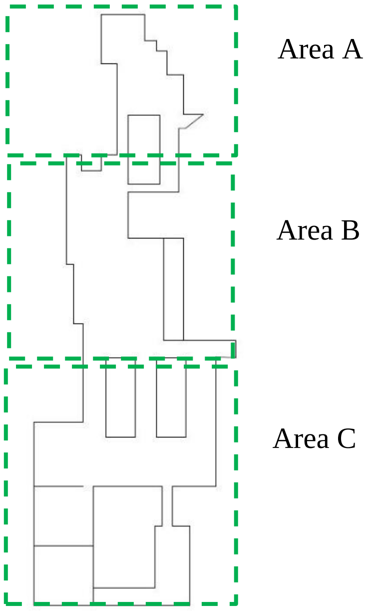

Figure 7: Overhead layout view of processing building

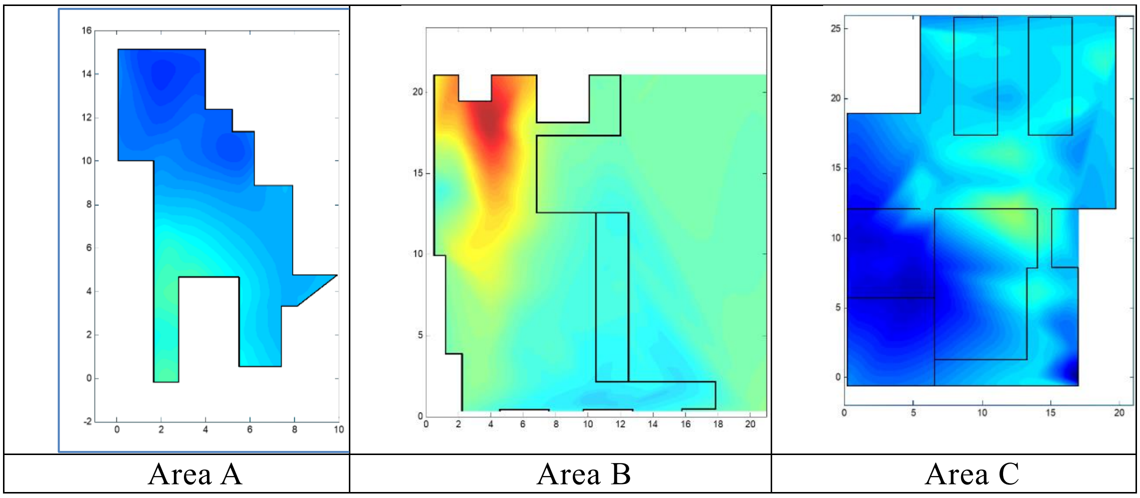

Figure 8: Acoustic map of processing building, divided into three areas

Figure 9: Rod mill located inside the processing building

Figure 10 is a panoramic view of the area outside the processing building, the large rotary dryer, and the crusher/storage buildings located at mine 2. This area is heavily travelled by foot and vehicle traffic. Workers will occasionally congregate near the stairs or doors of any of the buildings. Figure 11 shows the area noise map at this location. The highest noise levels were found at the base of the stairs to the flame room of the rotary dryer and in between the rotary dryer and the upper exit from the processing building.

Figure 10: Area outside the processing building, rotary dryer, and storage/crushing building.

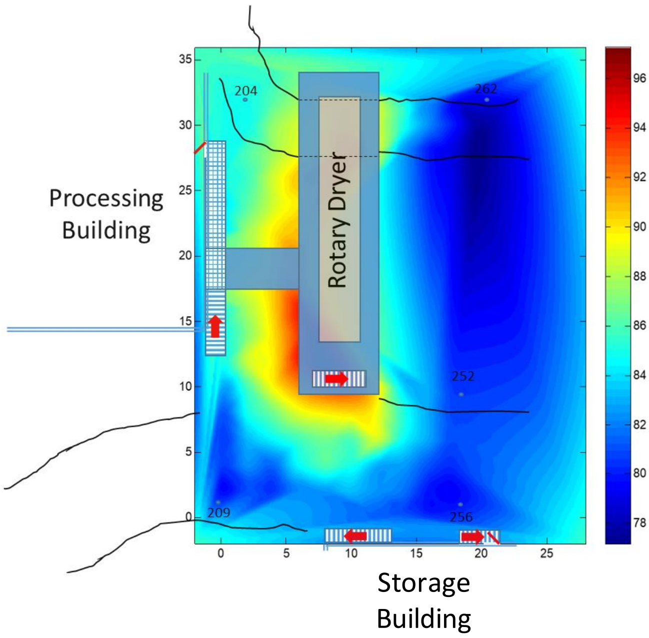

Figure 11: Acoustic map of outside area near the rotary dryer

3.3 Mine 3

Mine 3 is an underground limestone quarry with surface processing operations. The limestone is dumped into a primary crusher, then sorted into appropriate sizes via several conveyors and screeners before stockpiling. The final consumer products, primarily crushed aggregate for construction, are stockpiled and then hauled from the mine via truck. The primary conveyor and primary and secondary crushing/screening areas were of interest at this mine. Although the final stockpiling area likely has high noise levels, there is limited foot traffic and essentially only cabbed vehicle traffic, thus noise assessment was not performed in this area. Figure 12 is a photograph of the primary conveyor, taken from the ground near the primary crusher (not visible in this photo). In the distance, the primary screen is shown. Due to the large size of this area (approximately 150 meters long) measurements were taken on a 4-meter x 2-meter grid. Figure 13 shows the acoustic map along the length of the conveyor. The darker red, near the primary dump point and crusher, indicate the highest noise levels in this area.

Figure 12: Primary conveyor with primary screen in far distance.

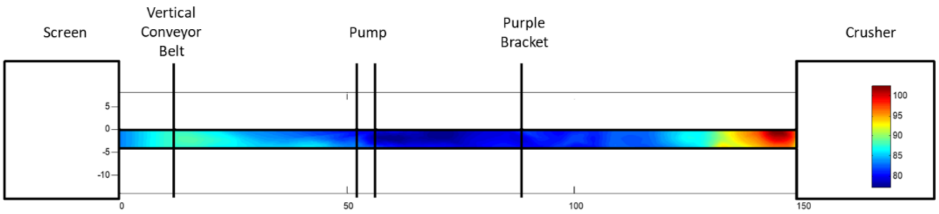

Figure 13: Acoustic map of primary conveyor

Figure 14 shows the outside area near the secondary crusher/screening operation. After screening at the primary screen, as shown previously in Figure 13, the ore is conveyed to this set of crushers/screens for further separation. The building to the left in the photo in Figure 14 houses an operator control booth. The entrance to the control booth is on the far left side of the building, not shown in the photo. Figure 15 is the acoustic map for this location. The darker red area is directly in the path of any foot or vehicle traffic, and, although not shown on this image, the high noise levels extend approximately another 10 meters beyond this image due to continued processing and conveying mechanisms taking place beyond the screen tower.

Figure 14: Outside area near the secondary crusher/screener

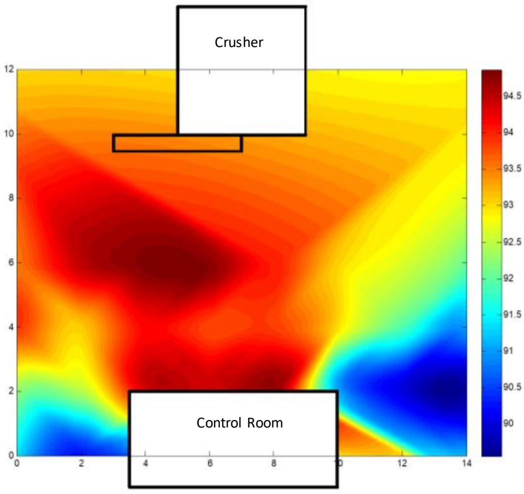

Figure 15: Acoustic map of the outside area near the secondary crusher/screener.

4. DISCUSSION

The acoustic maps delivered to the three mines provided information for educating workers on the best navigation paths through the facility and the need to wear proper hearing protection, to reduce their occupational noise exposure. It is important to note that the sound level scales are not equal for each of the acoustic maps. The scales are based on the maximum and minimum measured noise levels in those areas. Therefore, one cannot easily compare data between the maps visually. Keeping this in mind, the individual maps should be used as guidance at those specific areas, rather than for comparison of areas.

At mine 1, several workers pass regularly through the automatic bagging area for work activities or as a short-cut to access other parts of the facility. These workers might assume that the worker operating the bagging machine is the only one at risk for noise overexposure. While it is correct that the bagging machine operators are likely overexposed during their shifts, high noise levels persist in the areas near that machine during operation as well. While occupying these areas, workers sometimes can be performing tasks other than the bagging machine operation, having conversations, or walking through to get to their next work area, and are subsequently exposed to the noise generated from the bagging machine. Furthermore, although it is the primary noise source, the automatic bagging mechanism is not the only noise producing equipment in this area; there is a system of conveyors and electric motors among other secondary sources which produce high noise levels as well. When entering the building, workers often walk in from an adjacent garage door, directly past the automatic bagging mechanism, and through another adjacent door at the far end of the building, to exit through the rotary dryer room. The noise exposure of those workers would be reduced by choosing an alternate path around the outside of the building or through the far end entrance of the bagging building. Posting the acoustic maps marked with proposed safe and restricted transit paths through the area at the main garage entrance could be a useful tool to reduce noise exposure in this area.

The worker noise exposure in the manual bagging area in mine 1 is not as easily improved by posting the acoustic map and suggestions for modification of worker routes. The loudest noise in this area is produced by the hopper that fills the bags. Three workers are in this area during manual bagging. However, the mine has properly arranged the schedule of the three workers tasked with manual bagging. They alternate by pallet, so that each miner is exposed to the noise from the bagging mechanism for 1/3 of their shift. They spend the rest of the time palletizing the filled bags in lower noise areas or operating the forklift to move the pallets. This is a positive use of administrative controls already in place at mine 1. In addition, the acoustic map does clearly show that as distance from the bagging mechanism is increased, the noise levels decrease. So, whenever possible, workers and others in the area should remain as far from the bagging mechanism as possible.

The acoustic maps from mine 2 (Figures 8 and 11) are perhaps the most useful for reducing worker noise exposure. The map shown in Figure 8 can be used to detail the path through the processing building, directly past the rod mill, taken by almost all workers accessing other buildings, as shown below in Figure 16. Hazardous walking areas, due to flowing water from processing ore, as well as wet sand and mud, are avoided by going through the building. The acoustic map and typical worker navigation path was shown to mine management and addressed by the installation of a walkway along the outside. This walkway allowed for workers to avoid the wet sand and flowing water while traversing the area on foot, as well as reduce their noise exposure from the inside of the processing building. Use of this pathway, rather than the stairs provided an additional benefit, although outside of the scope of the current research, by reducing potential slipping/falling hazards associated with ascending and descending wet, metal stairs. Figure 17 shows the wet areas with flowing water before (A) and after (B) installation of a walkway through the area.

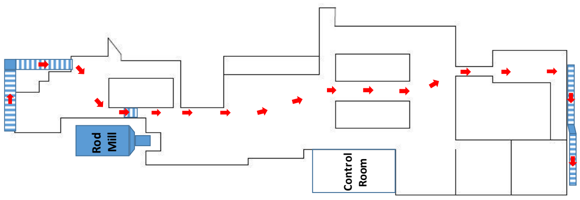

Figure 16: The path of workers commonly taken at mine 2, directly past the rod mill

Figure 17 A: Flowing water and wet sandy areas

Figure 17 B: Pedestrian walkway installed

The acoustic map from mine 2 near the rotary dryer provided useful noise level information to the workers for a heavily travelled pathway. For example, exiting the processing building and walking near the rotary dryer to enter the storage building was a common pathway. However, this exposes the worker to the high noise level generated by the flame and the propane hiss of the dryer. The workers will incur less noise exposure when they keep to the right of the stairs and make a direct path to the storage building, then turn left to enter the building. While this path may take some additional time (20-30 seconds) to traverse, it drastically reduces noise exposure. Workers also often congregate in this area for communication; if they move approximately 10 meters diagonally from the rotary dryer, it is much quieter, resulting in less noise exposure and improved communication conditions. Moving to the back side of the dryer, away from the processing building, has a similar effect because of a partial enclosure installed along the back of the dryer. These images and pathways were effectively communicated to the workers through the sound contour maps. Placing these maps near the rotary dryer or near the entrance to the processing building provides ready access of visual information to workers.

Noise measurements taken at mine 3 were all outdoors. In general, other than the ore extraction, all processes at this mine are outdoors, with most of the operators housed inside booths or rooms. Due to the layout of the mine and the geography of the area, the work process starts at the top of a hill and progresses towards the bottom, following a single road along the path of ore processing. Two areas indicated potential for improvement based on the integration of the sound contour maps. The first was the primary conveyor, which conveys the ore from the primary dumping point after crushing to the first set of screens. This conveyor, approximately 150 meters in length, is often a pathway for workers going between the two areas. Although noise is produced along the entire length of this conveyor, the loudest and most hazardous area is near the dump point/primary crusher. Workers on foot walk near this area to descend from the operator tower located above. While there is not necessarily an alternate path available, workers can be cognizant to avoid unnecessary time spent in this area. Moving 10 meters up the hill towards the operator booth, or 10 meters down the conveyor, can drastically reduce the sound levels and subsequent noise exposure.

The second area of concern at mine 3 is near the secondary crushing/screening deck. There is a protective operator booth in which the operator remains entirely inside. However, there also is high foot and small vehicle traffic (fork lifts, skid steers, etc.) in the area. While going around the far side of the booth, away from the screen, would reduce the worker's noise exposure, they must still circle back into the highest noise area to continue along the path to the next working area. It is important that the workers use their hearing protection and keep cabs closed in this area, despite their specific tasks. If prolonged occupancy of the area is necessary, it should be done inside the operator booth. The acoustic maps indicate that there is no safe place for verbal communication in this area when the crusher/screen is operational. The mine exhibits good practice regarding noise levels, signage, and availability of a booth for operation and communication. The geography of the mine simply does not allow for many alternate paths throughout the working areas of mine 3.

6. CONCLUSIONS

Acoustic maps can be integrated into hearing conservation programs or other safety initiatives at job sites to compliment the activities previously taken regarding worker noise exposure. These documents can be effectively used during hands-on training activities or posted near areas with high noise levels or where changing a route through a facility will reduce noise exposure. It is understood that daily fluctuations in noise exposure will occur for specific areas and for individual workers. However, acoustic maps can serve as guidance for modifying working routes and specific employee locations throughout their shifts.

5. REFERENCES

1. NIOSH (2016) Noise and Hearing Loss Prevention, National Institute for Occupational Safety and Health. Available at: https://www.cdc.gov/niosh/topics/noise/ (Accessed: 12 December 2016)
2. Tak S, Calvert G (2008) Hearing difficulty attributable to employment by industry and occupation: an analysis of the National Health Interview Survey--United States, 1997 to 2003. J Occup Environ Med 50: 46–56
3. Tak S, Davis RR, Calvert GM (2009) Exposure to hazardous workplace noise and use of hearing protection devices among U.S. workers-NHANES, 1999-2004. Am J Ind Med 52(5): 358–371. doi: 10.1002/ajim.20690
4. Masterson EA, Deddens JA, Themann CL, Bertke S, and Calvert GM, (2015) Trends in worker hearing loss by industry sector, 1981-2010. Am J Ind Med, 58(4), 392–401.
5. Tak S and Calvert GM (2008) Hearing difficulty attributable to employment by industry and occupation: an analysis of the National Health Interview Survey--United States, 1997 to 2003, J. Occup. Environ. Med., 50, 46–56.
6. Mine Safety and Health Administration, (1999) Health standards for occupational noise exposure. Mine Safety and Health Administration (MSHA), Labor. Final rule, Federal Register, 1999 Sep 13;64 (176), 49548–49, 634.

7. Sun K; Azman AS (2018) Evaluating hearing loss risks in the mining industry through MSHA citations. J Occup Environ Hyg 15(3): 246-262.