Noise assessment of stone/aggregate mines: six case studies

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Introduction

Exposure to noise and noise-induced hearing loss (NIHL) continues to be problematic for the U.S. mining industry. The problem is particularly severe because large, noisy equipment dominates the industry. Studies have shown that 70 percent to 90 percent of all miners have NIHL great enough to be classified as a hearing disability (NIOSH, 1996). To address the issue, the U.S. Mine Safety and Health Administration (MSHA) published Health Standards for Occupational Noise Exposure (*Federal Register*, 1999). The new regulations 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 (TWA8) and a permissible exposure level (PEL) of 90 dB(A) TWA8. The regulations also state that a miner's noise exposure shall not be adjusted because of the use of personal hearing protection, and that all feasible engineering and administrative controls must be used for noise exposure reduction.

The U.S. National Institute for Occupational Safety and Health (NIOSH) has responded to this problem in a number of ways, including conducting a cross-sectional survey of noise sources and worker noise exposures in the mining industry. Initially, these surveys were conducted in surface and underground (continuous and longwall) coal mines, in coal preparation plants and in sand and gravel mines. Recently, this has included surveying stone (aggregate) mining and crushing and processing facilities. The mine sites were selected primarily through personal contacts within the mining industry. Participation in the surveys was voluntary for the mine sites, but 100 percent of the mines contacted participated. All the surveys were completed between May and October 2005. The surveys are designed to monitor worker dose, to measure equipment sound levels and to understand the noise source/worker dose relationship. This is accomplished through full-shift dosimetry readings, equipment noise profiles and, where possible, worker task observations.

Abstract

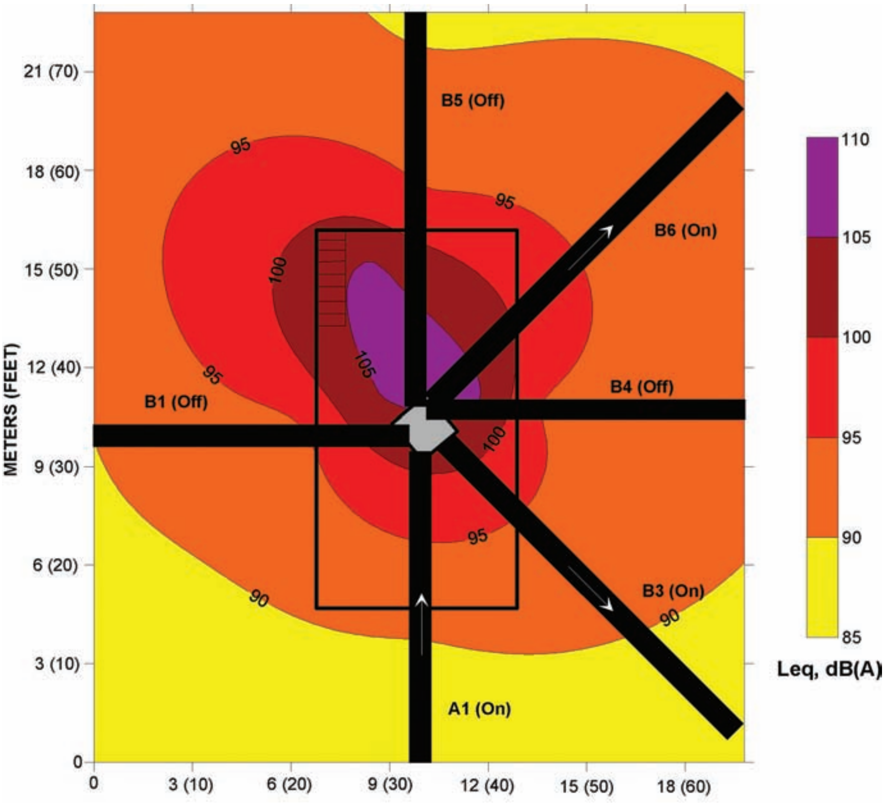
The U.S. National Institute for Occupational Safety and Health (NIOSH) is conducting a cross-sectional survey of equipment sound levels and worker noise exposures in the stone/aggregate mining industry. Six stone/aggregate mines (three surface and three underground) were recently surveyed, and the findings are presented here. The surveys consisted of sound-level measurements conducted around various equipment and machinery (including stone processing and crushing equipment) and full-shift dose measurements to determine worker noise exposures. The findings identify the equipment and machinery that are likely to cause worker overexposures and identify the workers found to be experiencing overexposures. In addition, the benefit of cabs in reducing mobile equipment operator noise exposure is discussed.

Instrumentation and data collection

Sound levels in the mines and processing facilities were measured using a Quest Model 2900 sound level meter (SLM) and Brüel & Kjær 2260 Investigator. The instruments were mounted side by side on a tripod, with the microphones 1.5 m (5 ft) from the floor (approximately ear height), angled at 70° from horizontal (in accordance with manufacturers' recommendations) and facing the noise source. An A-weighted equivalent sound pressure level (Leq) and one-third linear octave band frequencies were recorded at each location. Leq, which for these studies was the parameter of interest, is the average integrated sound level accumulated during a specified measurement period using 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). A slow response rate with an averaging time (length of measurement) of 30 seconds was also employed. Measurements were made around the fans, stationary equipment and processing facilities. Both near and far field measurements were recorded. The term "near" describes measurements made

FIGURE 1

Sound profile plot for the primary screening tower.

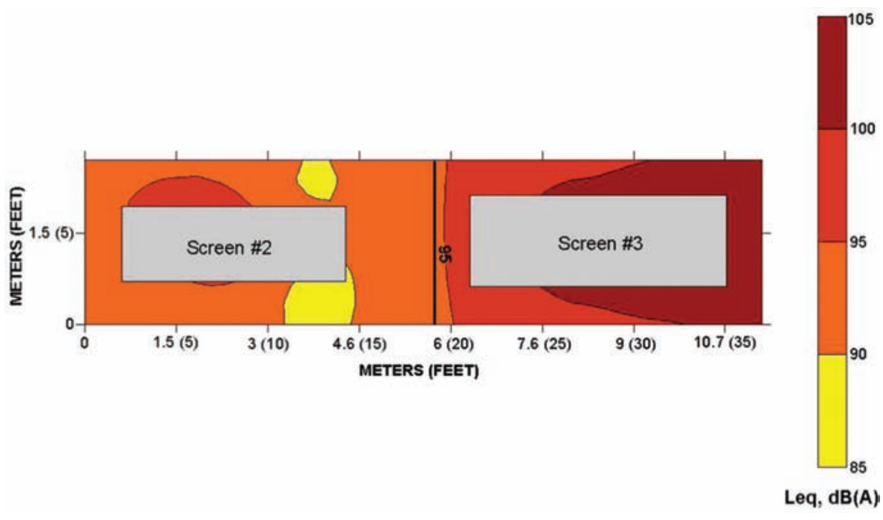


within 1 to 2 m (3 to 6 ft) of the noise source while the "far" measurements were those taken farther than 2 m (6 ft) from the source.

Worker noise exposure was monitored using Quest Q-400 noise dosimeters. The dosimeters were set to monitor an MSHA permissible exposure level (PEL) of 100 percent or an eight-hour time-weighted average (TWA8) 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.) Where possible, noise dose was recorded inside and outside mobile equipment to determine efficiency of cabs to prevent operator noise exposure from engine and operational noise.

FIGURE 2

Sound profile plot for Telsman screens 2 and 3.



Case studies

Case study No. 1 — surface limestone mine

Mine characteristics: This study site consisted of one surface pit and accompanying rock processing facilities that mine and process approximately 1.13 Mt (1.25 million st) annually of crushed stone and lime products. Mining consists of bench drilling and blasting (by a contractor), and mining the limestone rock. The blasted rock is mined using front-end loaders (FELs) loading into 45.4-, 49.9- or 54.4-t- (50-, 55- or 60-st-) capacity haul trucks for removal from the pit. The haul trucks dump into a primary crusher located near the pit entrance. After passing through the primary crusher, the rock is transported by belt to the crushing and screening facilities, resulting in the desired product sizes. The daily mining and processing operations average 5.44 to 6.35 kt (6,000 to 7,000 st) of rock. Approximately 25 workers are located in the surface quarry, and 10 are located in the plant (crushing facilities). The worker classifications include FEL operator, haul-truck operator, primary crusher operator, control-room operator, plant operator, plant helper laborer and water-truck operator.

Equipment and plant sound levels: Table 1 lists the range of sound levels measured around various processing equipment and indicates that the sound levels varied greatly throughout the plants. The highest sound levels were recorded at the primary screening tower, surge tunnel, secondary crusher, secondary screening tower and the fourth level of the agricultural lime crusher. Most of the recorded readings were 93 dB(A) or less. A sound profile plot for the primary screening tower is illustrated in Fig. 1. The measurements ranged from 87 to 96 dB(A) outside the building and 105 to 107 dB(A) inside the screening tower.

Worker exposure: Worker noise exposure was collected using dosimeters worn by the workers for the full (10-hr) shift. Six occupations that were surveyed included the operators of haul trucks, front-end loaders, primary crusher and the control rooms. Plant helpers and operators were also monitored. Results of the worker dose measurements are shown in Table 2. In addition to worker dose, a dosimeter was placed outside the cab on the front end loaders (FEL) and on the haulage trucks. This provided the exposure that would occur without the protection of cabs. Although the mining and processing equipment sound level measurements suggest that there were areas that are noisy and workers could be over-exposed to noise, because the workers are in cabs or control rooms, all the workers that were monitored experienced doses well below the MSHA PEL of 100 percent (or a TWA of 90 dB(A)).

Table 1

Sound level measurements, case study No. 1, surface limestone.

Plant	Equipment	Location	Range Leq, dB(A)
Primary	Screening tower B(N)	Inside	105-107
Primary	Screening tower B(N)	Outside	87-96
Primary	Surge tunnel, surge to sec. crusher	In tunnel	88-101
Secondary	Secondary crusher	Ground level	89-93
Secondary	Secondary crusher	Upper level	97-99
Secondary	Compressor bldg.	Inside, door open	89
Secondary	Compressor bldg.	Inside, door closed	90
Secondary	Compressor bldg.	Outside	91
Secondary	152.4 cm (60 in.) hydrocyclone crushers	Ground level	82-90
Secondary	152.4 cm (60 in.) hydrocyclone crushers	Upper level	84-95
Secondary	Control room	Inside control room	72
Secondary	Screening tower E(N)	Inside	100-106
Ag Lime	Screening tower and control room	Second level	86-99
Ag Lime	Screening tower and control room	Third level	90-93
Ag Lime	Screening tower and control room	Fourth level	91-93
Ag Lime	Screening tower and control room	Inside control room	65
Ag Lime	Screening tower and control room	Fifth level	91-92
Ag Lime	Screening tower and control room	Sixth level	91-93
Ag Lime	Screening tower and control room	Seventh level	91
Ag Lime	Crusher	Ground level outside	76-90
Ag Lime	Crusher	Second level	87-89
Ag Lime	Crusher	Third level	88-89
Ag Lime	Crusher	Fourth level	81-102
Ag Lime	C3 belt tunnel	Inside	77-88
Quarry	Primary crusher	Inside control room	67
Quarry	Primary crusher	Outside	72-95
Primary	Primary plant	Area (No. 71,72,74)	74-79
Secondary	Secondary plant	Area (No. 64-70,83,84)	72-81
Ag Lime	Ag lime plant	Area (No. 73,75-82)	67-83

Case studies No. 2 and No. 3 — surface granite mines

Mine characteristics: This complex consisted of two surface pits and rock processing facilities that mine and process approximately 1.36 Mt (1.5 million st) annually of crushed stone products. Mining consists of contractor-completed bench drilling and blasting, and mining of the granite gneiss rock. The blasted rock is mined using front-end loaders (FELs) loading into 36.3-t- (40-st-) capacity haul trucks for removal from the pit. The haul trucks dump into a primary crusher located near each pit. After passing through the primary crusher, the rock is transported by conveyor belt to the crushing and screening facilities, resulting in the desired product sizes. Approximately 33 workers are located at the combined surface quarries and crushing facilities. The worker classifications involved in the mining and processing operations include operators of FELs, haul trucks, primary crusher and processing plant.

Equipment and plant sound levels — Case study No. 2: The processing facilities consisted of three stationary plants (A, B and C). Measurements were taken around transfer points, belts, crushers and screens, control rooms, miscellaneous buildings and at the primary crusher. Table 3 lists the results of the sound-level measurements around the stationary equipment and indicates that the sound levels varied greatly throughout the plants. The locations where high sound levels (greater than 90 dB(A)) were recorded included the screens and crushers in Plant A, the screening tower and primary crusher in Plant B and the screen, crusher and tunnel in Plant C. An example of

Table 2

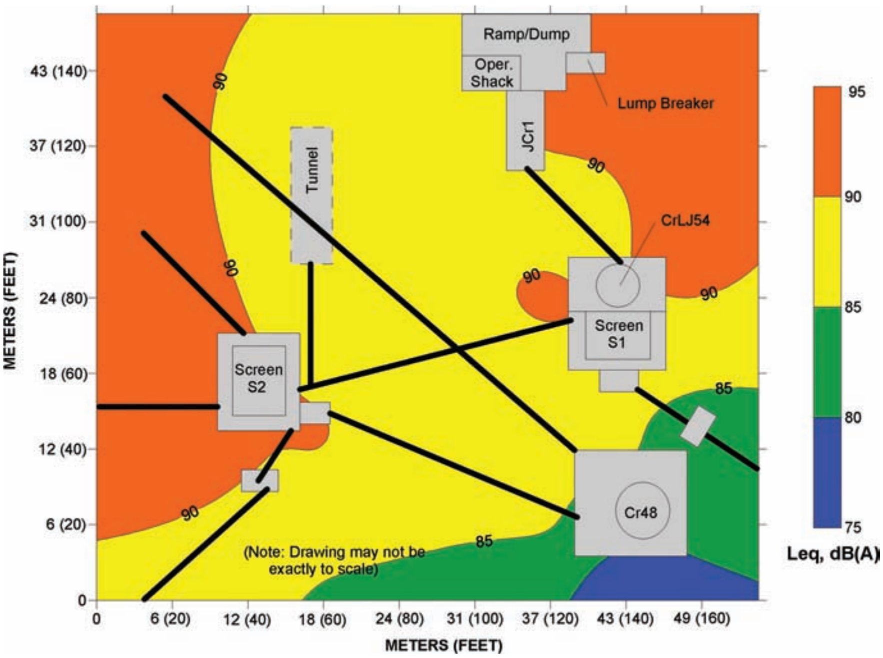
Worker exposure, case study No. 1.

Occupation	Number of recorded doses	Worker range MSHA PEL dose, %	Outside cab range MSHA PEL dose, %
Haul truck operator	3	2.7-14.8	65.9-114.1
FEL operator	3	0.7-41.3	59.0-65.6
Primary crusher operator	1	13.4	NA
Plant operator	1	0.9	NA
Plant helper	3	17.5-33.4	NA
Ag lime control room operator	1	8.2	NA

NA = not applicable

FIGURE 3

Sound profile plot for portable plant.



the sound levels measured is illustrated in Fig. 2, which is the sound profile plot for screens 2 and 3 in Plant A. Sound levels from 88 to a little more than 100 dB(A) were recorded.

Worker exposure – Case study No. 2: Workers wore dosimeters for a full shift (10 to 10.5 hrs) to provide noise-exposure data. Dosimeters were also placed outside the cabs of the mobile equipment. Table 4 lists the worker doses for the employees at the site. No worker experienced a dose above the MSHA PEL of 100 percent. Table 4 illustrates that for the mobile equipment operators, a reasonable amount of protection from the exterior noise generated by the engines and equipment operation is provided by the cabs. Only the operator of Truck 68 had a dose near 100 percent (98 percent), which was the result of the truck's outside dose of 396 percent and some unknown engine, transmission or exhaust noise problem that was able to enter the cab.

Equipment and plant sound levels – Case study No. 3: Measurements were taken in the plant known as the portable plant. Forty-six sound level measurements were taken around the transfer points, belts, crushers and screens, the control room and the primary pit crusher. Table 5 lists and Fig. 3 illustrates the results of the sound-level measurements around the stationary equipment. The data indicate that the sound levels varied greatly throughout the portable plant. The locations where high sound levels (greater than 90 dB(A)) were recorded included Screens S1 and S2 and Crushers JCr1 and CrLJ54.

Worker exposure – Case study No. 3: Workers wore dosimeters for a full shift (9.5 to 10.5 hrs) to provide noise exposure data. Table 6 lists the worker doses for the employees at the site. No worker experienced a dose above the MSHA PEL of 100 percent. Table 6 illustrates that, for the mobile equipment operators, the cabs are providing sufficient protection from the exterior noise generated by the engines and equipment operation.

Case studies No. 4 and No. 5 — underground limestone/sandstone mines

Mine characteristics: This operation consists of two underground mines and a common rock processing facility. Mining consists of face drilling, shooting and mining the main limestone bench, followed by drilling, shooting and removing the limestone floor rock. In addition, in some areas, the sandstone below the limestone is also mined. The blasted rock is loaded by front-end loader into 45.4- or 54.4-t- (50- or 60-st-) capacity haul trucks for removal from the mine. The haul trucks dump into one of two primary crushers, which are located midway between the two mines' portals. After passing through

Table 3

Sound level measurements, case study No. 2, surface granite.

Plant	equipment	Location	Range Leq, dB(A)
A	Belts, transfer points, bins	Ground level	78-91
	Crusher CrT57	Outside	94-97
	Crusher CrLJ45, Eljay	Outside	98-99
	Screen #S2, Telsman	Outside	88-99
	Screen #S3, AEI	Inside	100-102
	Ortner wash plant, W1	Outside	81-85
	Control room	Inside	74
	Control room	Outside	93
B	Belts, transfer points, bins	Ground level	72-88
	Screening tower, screen #S1	Inside	98-112
	Primary jaw crusher, B JCr1	Outside control room	93
	Primary jaw crusher, B JCr1	Inside control room	75
	Primary jaw crusher, B JCr1	Lower levels	88-105
	Electric room	Inside	58
	Oil and pump room	Inside	64
C	Belts, transfer points, bins	Ground level	75-96
	Crusher CrT52	Outside	99-102
	Screen #S6	Outside	85-94
	Electric room	Inside	68
	Tunnel, C10B belt	Inside tunnel	85-97

the primary crusher, the rock moves by conveyor belt either to the secondary crushing facilities or directly to a stockpile for loading and sale to end users. Rock sent to the secondary crushing facility passes through a series of crushers and screens, resulting in the desired product sizes. The combined annual production from both mines is about 1.36 Mt (1.5 million st) of mostly crushed limestone and some sandstone. A total of 43 workers are located at the site, working two shifts per day. The worker classifications include operators of FELs, haul trucks, jaw crusher, drill, scaler, plant and water truck. Other classifications include supervisor, mechanic, blaster and blaster helper, laborer and utility man.

Table 4

Worker exposure, case study No. 2.

Occupation	Number of recorded doses	Worker range MSHA PEL dose, %	Outside cab range MSHA PEL dose, %
Haul truck operator (65,66,68)	3	3.0-98.0	111.0-396.1
FEL operator (27,32,34)	3	0.4-28.3	33.0-284.8
Primary crusher operator (B J Cr1)	1	2.0	NA
Bin truck operator (7)	1	10.2	22.2

NA = not applicable

Equipment and plant sound levels: Measurements were taken around the main and auxiliary fans, primary jaw crushers (old and new), semi-stationary equipment and near the crushers and screens located at the secondary crushing facilities. Table 7 lists the results of the sound level measurements around the stationary and semi-stationary equipment and indicates that in most locations, sound levels greater than 90 dB(A) were present. The highest sound levels were recorded near the fans and the No. 1 cone crusher located in the secondary crushing plant. The only locations where sound levels were consistently less than 90 dB(A) were in the primary crusher operator's control booth, in the secondary crusher operator's control room, in the electrical room below the secondary crusher control room and above the sand plant.

The underground face equipment included a Tamrock floor drill and Cannon face drill (both diesel) and a Gradall scaler. Sound levels around these three pieces of equipment were high, ranging from 89 to 103 dB(A). However, the sound level measured inside the enclosed cab of the Cannon face drill was only 83 dB(A). Figures 4 and 5 include a photograph and a sound profile plot of a JOY Axivane 18.8 kw (25-hp) fan. The sound levels near the fan ranged from 90 to 106 dB(A). Another example is illustrated in Figs. 6 and 7, which are a photograph and sound contour plot for a Tamrock Ranger 500 floor drill. Figure 7 illustrates that sound levels up to 102 dB(A) were recorded near the drill.

Worker exposure: Workers at the mine wore dosimeters for a full shift (10 to 10.5 hrs) to provide noise exposure data. Table 8 lists the worker doses for both surface and underground employees. In all cases, except one of the laborers, no worker experienced a dose above the MSHA PEL of 100 percent. The one laborer experienced a dose above 100 percent because he was operating an air wrench while installing sheet metal on the protective canopy at the entrance to mine No. 2. His exposure resulted from a combination of noise sources that included the air wrench, compressor and

FIGURE 4

JOY Axivane 18.6 kw (25-hp) fan (Bauer and Babich,

Table 5

Sound level measurements, case study No. 3, surface granite.

Plant	Equipment	Location	Range Leq, dB(A)
Portable	Belts, transfer points, bins	Ground level	77-94
	Crusher CrLJ55, El-Jay	Outside	92-97
	Screen #S1	Outside	88-91
	Screen #S2	Outside	97-104
	Primary crusher, P JCr1	Outside	88-92
	Control room	Inside	71

Table 6

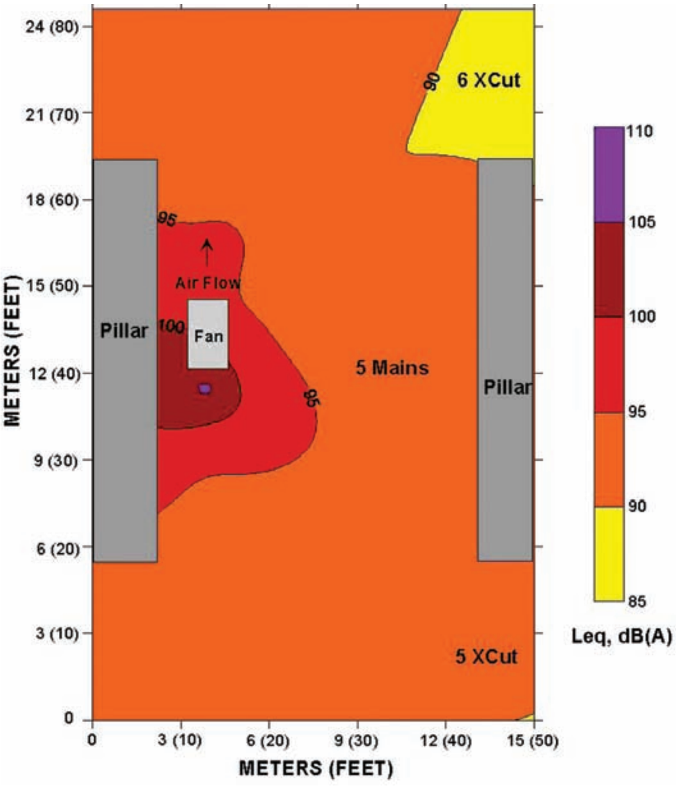
Worker exposure, case study No. 3.

Occupation	Number of recorded doses	Worker range MSHA PEL dose, %	Outside cab range MSHA PEL dose, %
Haul truck operator (69)	1	11.7	118.2
FEL operator (24, 25)	2	13.5-25.4	154.4-159.0
Primary crusher operator (P J Cr1)	1	20.4	NA

NA = not applicable

FIGURE 5

Sound profile plot for Joy Axivane 25-hp fan.



mobile equipment entering and exiting the mine. Table 8 also illustrates that for the mobile equipment operators the cabs are providing a reasonable amount of protection from the exterior noise generated by the engines and equipment operation.

Case study No. 6 — underground limestone mine

Mine characteristics: This operation consists of an underground mine and surface rock-processing facilities. Mining consists of face drilling, shooting and mining the main bench, with some mining of the floor rock. Using front-end loaders, the blasted rock is loaded into 31.8-t- (35-st-) capacity haul trucks for transport from the mine to the primary crusher. After passing through the primary crusher, the rock is transferred by belt to the crushing facility consisting of a shaker, screen and/or cone crusher to obtain the desired product sizes. Annual production for this operation is about 317.5 kt (350,000 st). From 10 to 12 workers are located at the site, working one shift per day. The worker classifications include the operators of FELs, haul trucks, crusher, drills, scaler and water truck. Other classifications include mechanic and blaster and blaster helper.

Equipment and plant sound levels: Measurements were taken around the primary jaw crusher, semi-stationary equipment and near the crushers and screens located at the crushing facilities. Table 9 lists the results of the sound-level measurements. The results indicate that a wide range of sound levels were present. In the mine, the sound levels were consistently less than 90 dB(A) around

Table 7

Sound level measurements, case study No. 4 and No. 5, underground limestone and sandstone.

Mine	Equipment	Location	Range Leq, dB(A)
No. 1	Fan systems 66HPAV2S, 1.5 m (5 ft) aux. fan	15 mains at 25 XCut	88-104
No. 1	Main fan (1.5 m (5 ft exhaust))	17 XCut in B mains	75-84
No. 1	Joy M96-50D exhaust fan	G mains at 24 XCut	86-109
No. 1	Tamrock ranger 500 floor drill	19 XCut in 9 mains	91-102
No. 2	Main fan (3.7 m (12 ft intake))	7 Mains	95-101
No. 2	Main fan (2.4 m (8 ft exhaust))	1 XCut, in 1 main	84-109
No. 2	Joy Axivane M36-26-1770 fan	5 Main at 5 XCut	90-106
No. 2	Oldenburg cannon face drill	9 XCut in 7 mains	93-103
No. 2	Gradall 5110 scaler	8 Mains at 5 XCut	89-98
Surface	Old jaw crusher (outside)	Outside control booth	83-102
Surface	Old jaw crusher (inside control booth)	Inside control booth	82
Surface	New jaw crusher (outside)	Outside control booth	84-102
Surface	New jaw crusher (inside control booth)	Inside control booth	74
Sec. Crusher	No. 1 cone crusher (2.4 m (8 ft Nordberg))	Bottom of main belt	101-107
Sec. Crusher	No. 2 cone crusher (2.4 m (8 ft))	Below main screen	99-101
Sec. Crusher	No. 3 cone crusher (Symons portable)	Adjacent to No. 2 crusher	95-98
Sec. Crusher	No. 4 lower crusher (1.8 m (6 ft))	Middle of sec. crush. plant	90-96
Sec. Crusher	Main 2.4 x 6.1 m (8 x 20 ft) screen	Above No. 2 crusher	90-99
Sec. Crusher	No. 1 & 2 double screens	Middle of sec. crush. plant	86-98
Sec. Crusher	Sand plant	Bottom of sec. crush. plant	77-98
Sec. Crusher	Control room (outside)	Outside control room	83
Sec. Crusher	Control room (inside)	Inside control room	69
Sec. Crusher	Electrical room (inside)	Below control room	75

the bucket truck and more than 90 dB(A) near the water pump, scaler and face drill. The face drill had the highest measured sound levels, ranging from 86 to 105 dB(A) (Fig. 8). In the processing facilities, sound levels above 90 dB(A) were recorded nearly everywhere except in the jaw crusher control room and at the belt drives (Fig. 9).

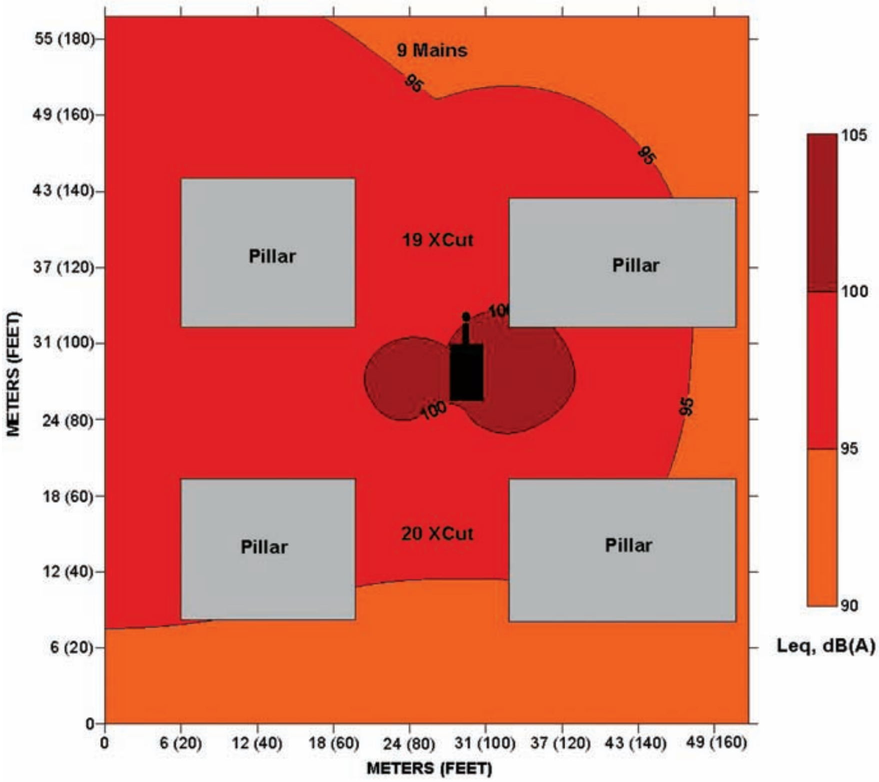
Worker exposure: Workers at the mine wore dosimeters for a full shift (9.5 to 10.5 hrs) to provide noise exposure data. Table 10 lists the worker doses for both surface and underground employees. In all cases, no worker experienced a dose above the MSHA PEL of 100 percent. Table 10 also illustrates for the mobile equipment operators that the cabs are providing a reasonable amount of protection from the exterior noise generated by the engines and equipment operation.

FIGURE 6

Tamrock floor drill.

FIGURE 7

Sound profile plot for Tamrock floor drill.



Implications for exposure reduction

The sound level measurements suggest that there are areas that are noisy and could subject workers to overexposure to noise. Nearly all workers monitored experienced doses well below the MSHA PEL of 100 percent (or a TWA of 90 dB(A)), even though equipment sound levels were generally above 90 dB(A). These exposure results do not suggest that the workers are "safe" from noise-induced hearing loss, only that the workers are limiting their time of exposure near these high noise sources. Health surveillance of hearing by use of audiometry and exposure monitoring is essential, both base-line and after noise exposure if NIHL is to be reduced in the mining industry.

One laborer experienced a dose of 119 percent while using an air wrench to install a protective canopy at the portal of an underground mine. Mobile equipment and crusher operators were protected from overexposure to noise as illustrated by the results of the dose measurements because the cabs and control rooms had sufficient acoustical treatments to prevent equipment sound levels from reaching the operators. Although only one worker was overexposed, the prevalence of noisy equipment suggests that engineering and administrative noise controls could be used to reduce sound levels and noise ex-

Table 8

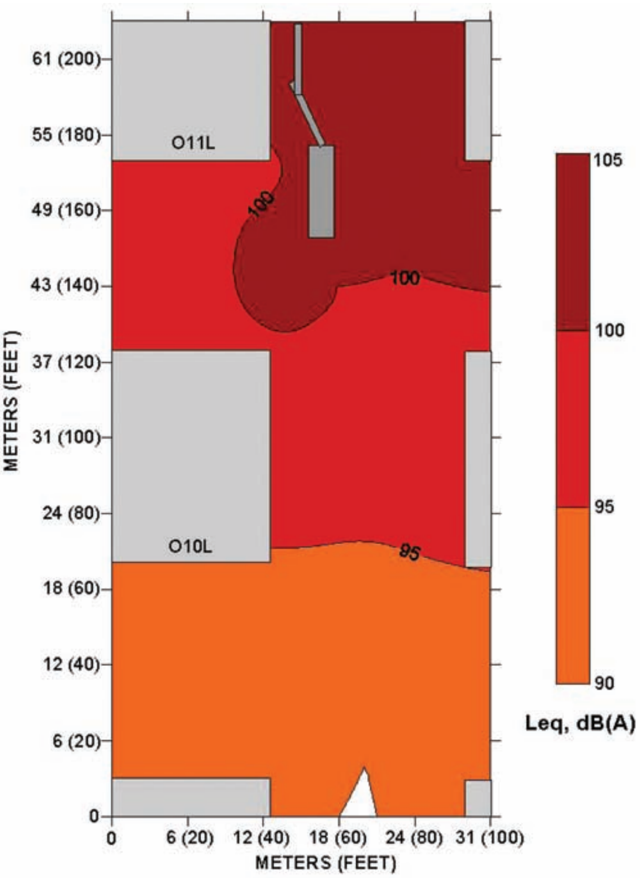
Worker exposure, case studies No. 4 and No. 5.

Occupation	Number of recorded doses	Worker range MSHA PEL dose, %	Outside cab range MSHA PEL dose, %
Haul truck operator	6	0.6- 9.5	81.6-187.5
FEL operator	4	2.9-64.2	141.7-262.8
Drill operator	2	26.8-31.4	293.7-487.3
Scaler	2	1.1-1.20	187.8-209.0
Crusher operator	1	5.9	ND
Blaster/blaster helper	2	27.3-28.6	ND
Water truck operator	1	35.8	ND
Laborer	2	59.0-119.3	NA
Sec. crush. plant oper.	1	32.3	NA
Mechanic	1	8.9	NA

ND = not determined
NA = not applicable

FIGURE 8

Sound profile plot for Gardner Denver MK45H face drill.



posures. The use of acoustic material inside cabs, control rooms, screening towers and compressor buildings should be considered. Crushers and other stationary equipment may be addressed using mass-loaded barrier curtains and enclosures. Screen modifications can include acoustically treated decking and new suspension screens, as well. Underground fan systems should be equipped with silencers, muffler ducts, treated fan vanes and quiet motor technology (MSHA, 1999). Administrative controls such as job rotation, worker relocation and improved equipment operation can limit exposure to high sound levels and reduce worker noise exposures.

It would be prudent to restrict time spent in and around the crushing and screening facilities because sound levels as high as 112 dB(A) were recorded. Mobile and semi-mobile (such as drills) equipment operators should be required to keep all doors and windows closed while the equipment is in operation because outside doses up to 487 percent were measured.

All workers should be made aware of the sound levels around all equipment and in the processing plants and be instructed to utilize hearing protection based on NIOSH's recommended exposure limit (REL) of 85 dB, A-weighted, as an 8-hour time-weighted average (TWA8). Exposures at or above this REL are hazardous, creating an excess risk of developing occupational NIHL. For workers whose noise exposures equal or exceed 85 dB(A), NIOSH recommends proper use of hearing protection, among other assessment, training and prevention approaches. Any area that has a sound level of 85 dB(A) or higher has the potential to exceed the NIOSH REL depending on the exposure time (NIOSH, 1998). Because the length of exposure can vary and/or is not known prior to entering a high sound area, the potential adverse ef-

Table 9

Sound level measurements, case study No. 6, undergound limestone.

Mine/surface	Equipment	Location	Range Leq, dB(A)
Mine	Blaster's bucket truck	Adjacent to and around	76-81
Mine	Gorman-Rupp diesel water pump	Adjacent to and around	89-98
Mine	Gardner Denver MK45H face drill	Adjacent to and around	86-109
Mine	Gradall XL4300 II scaler	6.1-12.2 m (20-40 ft) away	89-94
Surface	Jaw crusher (upper level)	Outside control booth	91-99
Surface	Jaw crusher (lower level)	Below control room	89-93
Surface	Jaw crusher (control booth)	Inside control booth	73
Surface	Small Tyler double shaker screen	Adjacent to and around	104-111
Surface	Large Tyler screen	Adjacent to and around	94-103
Surface	Hazemag cone crusher	Adjacent to and around	96-102
Surface	Tunnel	Just inside by belt	93
Surface	No. 1 belt drive	Next to drive motor	89
Surface	No. 2 belt drive	Next to drive motor	101
Surface	No. 4 belt drive	Next to drive motor	85
Surface	No. 6 belt drive	Next to drive motor	94
Surface	No. 8 belt drive	Next to drive motor	85
Surface	No. 9 belt drive	Next to drive motor	81
Surface	No. 11 belt drive	Next to drive motor	82
Surface	Ground level	On ground	89-101

fects on a worker's hearing are also not known, and thus it makes sense to use hearing protection when in areas where the sound levels are 85 dB(A) or greater.

Finally, workers should realize that any exposure that results in an MSHA PEL dose above zero percent indicates that during their shift they encountered sound levels above 90 dB(A). Because each individual reacts differently to high noise, there is no assurance that a dose below the MSHA PEL of 100 percent is safe and will not cause hearing loss. In addition, when the TWA of a worker exceeds 85 dB(A), the MSHA Action Level is exceeded and the worker must be enrolled in a hearing conservation program. Therefore, wearing hearing protection is a good idea at all times while operating equipment or working in the crushing and screening facilities.

Table 10

Worker exposure, case study No. 6.

Occupation	Number of recorded doses	Worker range MSHA PEL dose, %	Outside cab range MSHA PEL dose, %
Haul truck operator	2	38.5 and 49.7	168.7 and 175.3
FEL operator (inside)	1	0.3	89.4
FEL operator (outside)	1	14.3	107.2
Drill operator	1	24.6	437.3
Scaler operator	1	50.2	162.3
Crusher operator	1	9.7	219.4
Blaster/Blaster helper	2	13.3 and 15.2	0.7

Summary

Stone (aggregate) mining can be noisy and can subject workers to overexposures if they are not in cabs or control rooms. Sound-level measurements indicted that screens, crushers, drills, fans and mobile equipment generate sound levels high enough to be potential sources of worker overexposure depending on time of exposure. Fortunately, exposure measurements revealed that nearly all workers were avoiding exposures as revealed by doses under the MSHA PEL of 100 percent. Only one laborer was overexposed, a result of operating an air wrench for much of his shift. It can be concluded that mine operators and workers are successfully avoiding noise exposures through a combination of training, hazard awareness, engineering noise controls and administrative noise controls. ■

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Disclaimer

The findings and conclusions in this report have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

FIGURE 9

Sound profile plot of processing facilities (Bauer and Babich, 2006).