Snapshot of noise and worker exposures in sand and gravel operations

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Abstract

Previous studies and research efforts have shown that noise-induced hearing loss (NIHL) is a problem in the U.S. mining industry. In response, researchers at the National Institute for Occupational Safety and Health (NIOSH) have been conducting a cross-sectional survey of equipment noise and worker noise exposures in the mining industry to estimate the potential for NIHL within the mining community. One commodity recently surveyed was the extraction of sand and gravel from surface pits and by dredging. To address the potential for NIHL in the sand and gravel industry, sound levels on and around the dredges and processing equipment were recorded to identify areas of high noise levels. Full-shift worker dosimetry, in conjunction with task observations, was documented to determine the relationship between exposure and source. This paper presents research examining noise on dredges used in several surface mine sand and gravel operations and in the processing facilities. Results indicate that there are areas on the dredges (crane, suction pumps and diesel engines) where sound levels greater than 90 dB(A) are present. In addition, crushers and screens used in the processing of the sand and gravel also generate sound levels greater than 90 dB(A). Although no surveyed worker exceeded the Mine Safety and Health Administration's (MSHA's) permissible exposure level (PEL) of 90 dB(A) eight-hour time-weighted average (TWA8), laborers, mechanics, oilers, helpers, pickers and greasers are the workers most likely to be exposed to hazardous sound levels and to thus develop NIHL over time.

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 is found throughout the industry. A National Institute for Occupational Safety and Health (NIOSH) analysis of NIHL among miners illustrates the extent of NIHL in the mining industry. This analysis of several thousand audiograms indicates the number of miners with hearing impairments (defined as an average hearing threshold level of 25 dB or greater for the frequencies 1,000, 2,000, 3,000 and 4,000 Hz) increased with age until age 50, at which time 49 percent of the metal/nonmetal and 90 percent of the coal miners had a hearing impairment (NIOSH, 1996, 1997).

Another NIOSH study looked specifically at noise exposure and hearing loss among sand and gravel miners (Landen et al., 2004). These studies were conducted at 24 surface and nine dredge operations. The results revealed that 69 percent of the miners' noise exposures exceeded the NIOSH recommended exposure limit (REL) of (85 dB, A-weighted, as an eight-hour time-weighted average (TWA8)). In addition, 41 percent exceeded MSHA's action level for enrollment in a hearing conservation program. Landen also reported that hearing protection use was low, with 48 percent of the subjects reporting that they never used hearing protection. To address NIHL issues in all mining, MSHA has published Health Standards for Occupational Noise Exposure (Federal Register, 1999). Requirements of the new standard include:

- the adoption of an Occupational Safety and Health Administration (OSHA)-like Hearing Conservation Program (HCP),
- enrollment in the HCP for workers exposed above an action level of 85 dB(A) eight-hour time weighted average (TWA8),
- reduction of worker exposures to or below a permissible exposure level (PEL) of 90 dB(A) TWA8 or equivalently a dose of 100 percent,
- no reduction in noise exposure being allowed due to the use of personal hearing protection and
- a requirement that mine operators use all feasible engineering and administrative controls to reduce noise exposures.

NIOSH responded to the problem of noise overexposure in the mining industry by conducting an extensive cross-sectional survey of noise sources and worker noise exposures. Initially, these surveys were conducted in surface and underground (room and pillar and longwall) coal mines, coal preparation plants, stone (aggregate) mines and crushing and processing facilities. Recently, these surveys have expanded to sand and gravel mines, including dredging and their associated crushing, sizing and processing facilities. According to MSHA, in 2005 there were more than 7,000 sand and gravel operations (approximately 6,200 surface and 800 dredges) in the United States disbursed as shown in Fig. 1. Employment in the sand and gravel industry exceeded 45,000 workers, with an average of six employees per mine. These surveys are designed to monitor worker noise dose, measure equipment sound levels and understand the noise source/

worker dose relationship. This is accomplished through full-shift dosimetry readings, equipment sound profiles and worker task observations where possible.

Scope of research

Background. Noise surveys were conducted at nine sand and gravel operations, including three surface pits, five dredges and eight processing plants. Three dredges were mechanical navigation dredges (river-based, also known as hoist boats) that employ a crane and clam bucket to remove river bottom material, and two dredges were electric hydraulic cutter head mining dredges (land-based) that employ a rotating cutter head and suction to remove the sand material from the pit. Table 1 lists the specific characteristics of each operation. The operations were located in Arizona, New Jersey and Pennsylvania. In total, dosimetry for 75 workers (MSHA PELs) and 101 equipment noise profiles were completed. Noise doses were recorded for equipment operators, crushing plant operators, crusher operator, dredge/crane operators, boat pilots and deck hands, technicians, mechanics and laborers. The equipment noise profiles included stationary and mobile mining equipment, control rooms, dredges, cranes, towboats and crushing and screening facilities. In addition, the mobile equipment was monitored for noise inside and outside the cabs to determine the effectiveness of the cabs at protecting the operators from engine and operational noise.

Instrumentation and data collection. The instrumentation used in the studies included personal dosimeters and sound level meters (SLM). Worker noise-exposures were monitored using Quest Q-400 Noise Dosimeters.[1] Workers donned dosimeters for their full work shifts. The microphone was located at the middle of the shoulder per MSHA recommendations (MSHA 2000). The dosimeter was set to monitor an MSHA PEL of 100 percent or a 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).

Equipment and area sound levels were recorded using a Quest Model 2900 SLM and a Brüel & Kjær 2260 Investigator. The SLM and Investigator were mounted side-by-side on a tripod, with the microphone located 1.5 m (5 ft) from the floor/ground (approximately ear height), angled at 70º from the source (per manufacturer recommendations) and facing the sound source. Measurements were made on a 1- to 2-m (3- to 6-ft) grid, at a distance of approximately 1 to 2 m (3 to 6 ft) from the equipment. Measurements were made to delineate the near-field and far-field equipment sound levels. An A-weighted equivalent sound pressure level (Leq) was recorded at each location. The parameter of interest for these studies was the average integrated sound level accumulated during a specified measurement period or Leq 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 sound level and duration (NIOSH, 1998). A slow response rate with an averaging time of 10 seconds was employed, with most readings being recorded during a 30-second period. Measurements made around the cranes (dredges) and

FIGURE 1

Distribution of sand and gravel operations in the United States.

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

Table 1

Characteristics of sand and gravel operations surveyed.

Dredge	Location	Type	Product	Processing facilities	Approximate production, st/yr	Number of employees
S&G1	Land	Pit	Sand and gravel	Land, Both[2]	1,000,000	25-30
S&G2	Land	None[1]	Sand and gravel	Land, Wet	400,000	7
S&G3	River	Dredge, Crane	Sand and gravel	On Board, Wet	350,000	14
S&G4	Land	Pit	Sand and gravel	Land, Dry	120,000	7
S&G5	Land	Dredge, Suction	Primarily sand	Land, Wet	1,200,000	11
S&G6	Land	Dredge, Suction	Primarily sand	Land, Wet	400,000	10
S&G7	Land	Pit	Sand and gravel	Land, Wet	180,000	7
S&G8	River	Dredge, Crane	Sand and gravel	Land, Wet[3]	200,000	25
S&G9	River	Dredge, Crane	Sand and gravel	Land, Wet	140,000	9

[1]None – No mining occurred at this site. Material for processing is trucked from two off-site pits.
[2]Both – Material processed both dry and wet.
[3]Land-based processing facilities were not surveyed at this site.

FIGURE 2

Example of dosimeter outside mobile equipment.

FIGURE 3

Navigational dredge with on-board processing.

processing facilities were used to generate sound profile plots. Although sound is a logarithmic quantity, the plots were generated linearly. It is believed that linear sound profile plots are adequate for describing the sound levels around mining equipment solely for the purpose of alerting mine workers of areas to avoid, minimizing their noise exposures.

Results

Worker noise exposure. Workers at each site wore dosimeters for a full shift to provide noise exposure data. When two production shifts were used, workers on both shifts were surveyed. Table 2 lists the worker dose levels that were measured, including the inside/outside cab dose levels for evaluation of cab effectiveness in preventing exposure to engine and equipment operation noise. A typical dosimeter location for outside cab measurements is shown in Fig. 2.

Two general conclusions can be made from these data. First, all worker doses were below the MSHA PEL of 100 percent (0.19 percent to 90.02 percent, Table 2). There were two workers, a plant man and a belt picker, who accumulated dose levels around 90 percent. The plant man was responsible for cleaning around the processing equipment, including while the plant was operating. Much of the equipment generates sound levels greater than 90 dB(A), thus this worker's noise dose was not unexpected. The belt picker worked on the dredge that utilized on-board processing. The worker was located in a crudely built shanty located next to the belt carrying material from the grizzly to the processing facility. This worker's job was to pick wood and other debris from the belt. Because the shanty had little if any noise controls in place, the picker was subject to the sound levels generated by the nearby processing equipment. Again, his measured dose was not unexpected. Secondly, a comparison of the interior and exterior mobile equipment dose levels indicates that the equipment cabs provided

Table 2

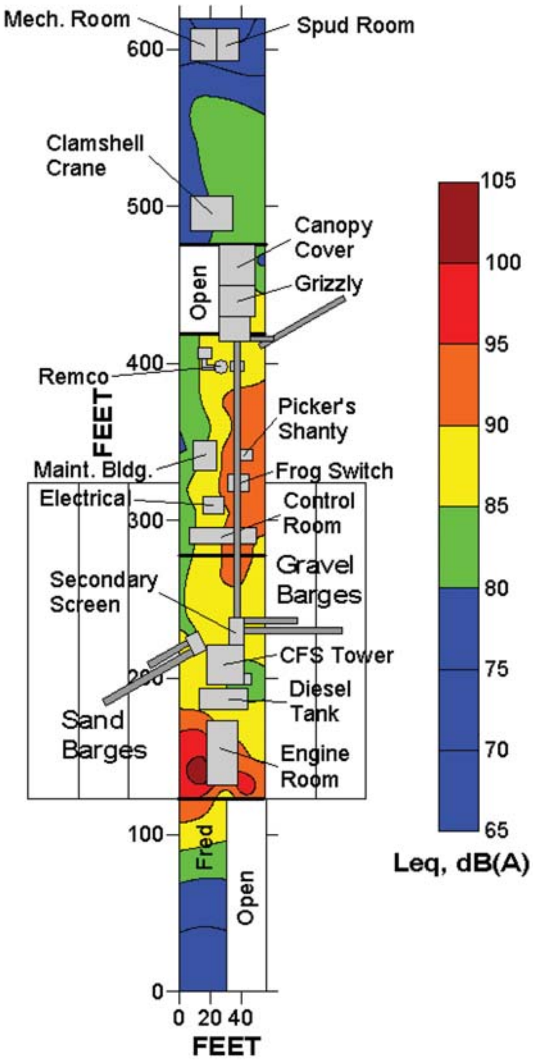
MSHA PEL noise dose for sand and gravel workers.

Job title	Number of recorded doses	Worker range of MSHA PEL dose, %	Outside cab range of of MSHA PEL dose, %
FEL operator	17	0.19-51.83	27.21-244.31
Laborer/utility man	7	16.81-63.05	ND[2]
Dredge operator/trainee (CR[1])	7	2.32-10.74	ND
Plant operator (CR)	6	1.72-10.45	ND
Plant man	6	28.79-90.02	ND
Crane operator	6	3.06-26.36	48.20-109.81
Haul truck operator	5	10.32-50.27	63.12-121.99
Boat pilot	4	8.58-43.58	ND
Crusher operator	3	3.66-41.20	ND
Technician	3	0.83-15.39	ND
Shopman/maintenance man	3	5.95-38.56	ND
Belt picker	2	23.71-89.96	ND
Dredge oiler	2	8.67-11.27	ND
Water truck operator	2	14.6-59.13	ND
Deck hand	1	4.74	ND
Scale man	1	1.67	ND

[1]CR = Control room
[2]ND = Not determined

FIGURE 4

Sound profile plot for a navigational dredge with on-board processing.



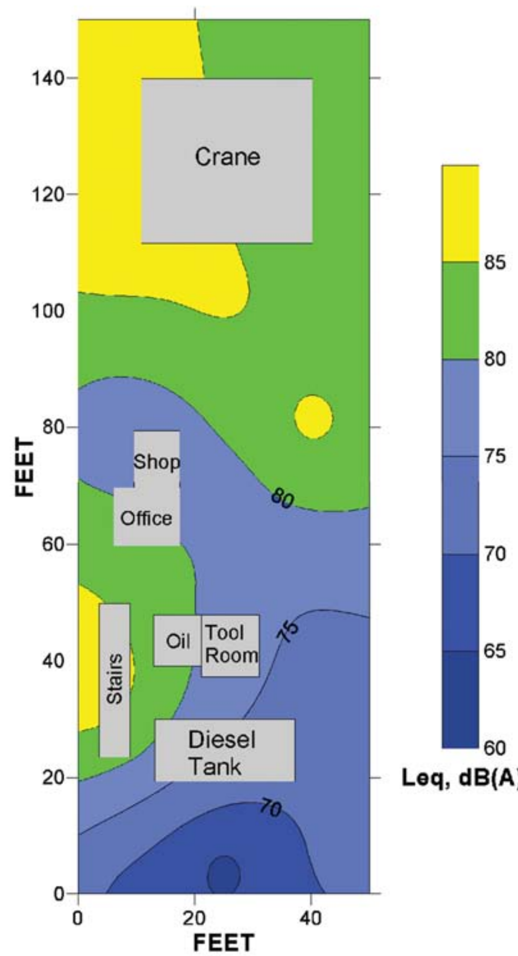
sufficient protection from noise for the operators. The front-end loader (FEL), crane and haul-truck operators all had MSHA PEL noise dose levels below 52 percent, yet the outside dose levels were as high as 245 percent. This illustrates that the cabs were protecting the opera-

FIGURE 5

Navigational dredge without on-board processing.

FIGURE 6

Sound profile plot for a navigational dredge without on-board processing.



tors from equipment operational noise.

Equipment/area noise measurements. Sound-level measurements were taken around all stationary equipment, such as the conveyor belts and conveyor belt drives, crushers, screens, cranes, towboats and mobile equipment, including front-end loaders and trucks. Table 3 lists the results of the sound level measurements for both the processing equipment and dredges. For convenience, equipment such as screens, crushers and belt drives are combined by category, even though they varied widely in size and product throughput.

FIGURE 7

Electric hydraulic cutter head mining dredge.

FIGURE 8

Sound profile plot for and electric hydraulic cutter head mining dredge.

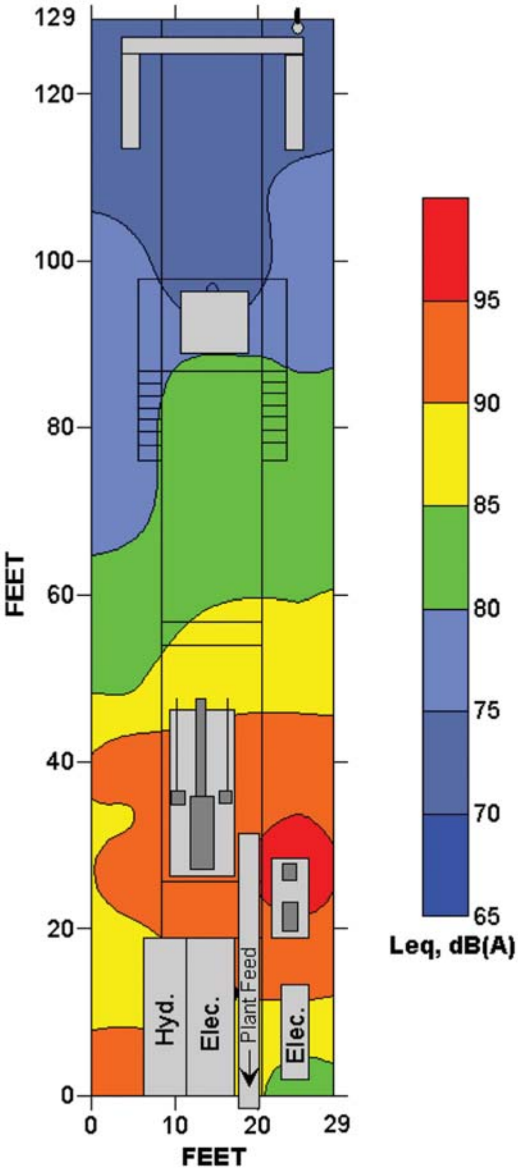


FIGURE 9

AC51 cone crusher.

FIGURE 10

Sound profile plot for AC51 cone crusher.

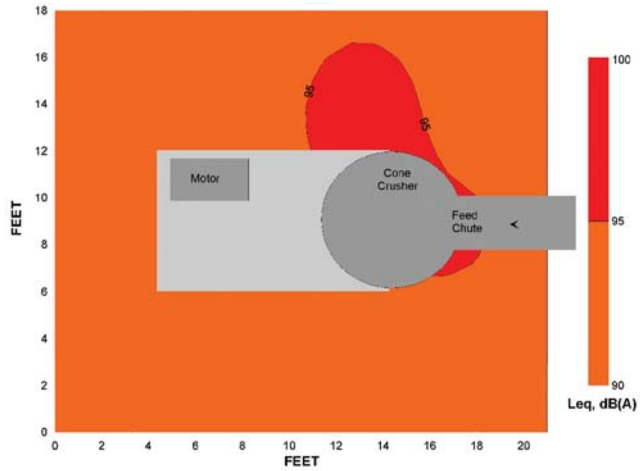


FIGURE 11

Primary triple-deck screen.

The sound levels varied widely because of the size and throughput just mentioned, because of equipment age and condition and because the ranges include measurements taken at varying distances from the stationary equipment.

Dredges. To illustrate the sound levels measured on the dredges, several examples are included. Figures 3 and 4 include a photograph and sound profile plot of the sound levels on a mechanical navigation dredge with on-board processing. Figure 4 illustrates that outside the diesel engine room is the noisiest, but also that the barge areas containing the processing equipment have sound levels above 90 dB(A).

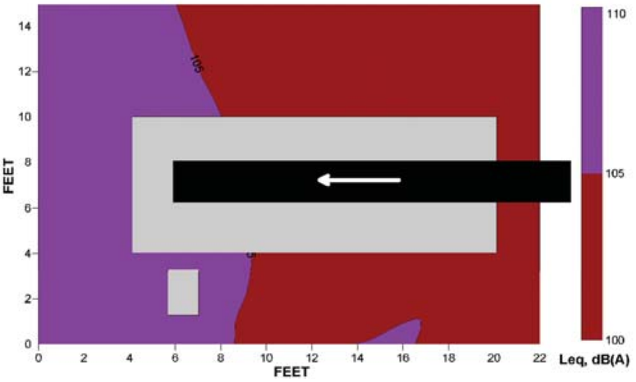
Figures 5 and 6 include a photograph and sound profile plot of the sound levels on a navigational dredge that dumps material directly into barges. Figure 6 illustrates that, in general, the noise levels are below 90 dB(A). Noise levels above 90 dB(A) were recorded in the crane engine room and diesel engine room.

Figures 7 and 8 include a photograph and sound profile plot of the sound levels on an electric hydraulic cutter head mining dredge, with an underwater suction pump and a cutter basket that extracts sand from the bottom of the pit, then pumps the sand/water mix back to the processing facilities. Figure 8 illustrates that the sound levels are generally below 90 dB(A), except near the freshwater pumps and the DC electric motor driving the underwater suction pumps at the rear of the dredge. The sound-level measurements on all the dredges indicate the areas where exposure to noise should be limited (near the diesel engines of the barge and crane and on-board processing facilities) and where overexposures could be minimized (control room, offices, and crane operators cab).

Towboats. At the three river-based dredges towboats were used to move the loaded and empty barges between the dredge and processing plants/storage yard. Because these towboats generally push only one barge at a time, they are small by comparison to the towboats that normally ply the rivers around Pittsburgh, PA. Table 3 includes the range of sound levels measured on the towboats. The measurements revealed that the pilothouses were quiet (<74 dB(A)), the diesel engine rooms were noisy (110 dB(A)), and the deck area was quiet (< 80 dB(A)), except near the engine rooms and exhaust mufflers (100 dB(A)).

FIGURE 12

Sound profile plot for primary triple-deck screen.



Processing plants. The processing-plant equipment consisted of screens, crushers, conveyor belts, cyclones, sand classifiers and screws, miscellaneous buildings (shops, electrical, compressor, etc.), cranes and control rooms. In addition, front-end loaders and haul trucks were used at the surface sand and gravel operations and in the processing facilities. Table 3 contains a summary of the sound levels measured in all the processing facilities. The cranes that removed material from the barges and deposited the material into a hopper had similar sound levels as the cranes on the dredges. Sound levels measured in the cabs were slightly higher (82 to 88 dB(A)), while the engine room sound levels were nearly identical (up to 107 dB(A)). Based on these results, it is recommended that as little work as possible should be done in the crane engine rooms while operating.

An Allis-Chalmers (AC51), 1.8-m- (6-ft-) diameter cone crusher is illustrated in Fig. 9. The sound profile plot for this crusher is shown in Fig. 10 and reveals that sound levels approaching 100 dB(A) were present. An example of an older screen that is processing river dredged sand and gravel is illustrated in Fig. 11. The sound profile plot for the primary triple-deck screen is shown in Fig. 12 and reveals that sound levels between 105 and 110 dB(A) were present. Two screens, processing primarily sand, are shown in Fig. 13. The fact that they are processing sand and small gravel and using urethane screen cloth to control noise, keeps the sound levels generally below 90 dB(A) (Fig. 14). Finally, Fig. 15 illustrates

Table 3

Sound level measurement at sand and gravel sites surveyed.

Area	Equipment	Location	Leq range, dB(A)[1]
	Crane, operators cab	Inside	76-85
	Crane, engine room	Inside	102-107
	Office, tool room, misc. rooms	Inside	64-89
	Diesel motor	Inside	103
Dredge	Barge area	Outside	64-102
	Control room	Inside	66-76
	Control room	Outside	69-84
	Suction pump drive motors	Outside	83-96
	Hydraulic pump room	Inside	98
	Electrical room	Inside	92
	Pilothouse	Inside	67-74
	Deck	Outside	75-100
Towboat	Auxiliary rooms	Inside	76-83
	Engine room	Inside	110
	Crane, operators cab	Inside	82-88
	Crane, engine room	Inside	92-107
	Crushers	Area	81-112
	Control rooms	Inside	56-79
	Control rooms	Outside	73-83
Plant	Screens	Area	77-108
	Cyclones	Area	81-88
	Belts, drives, transfers	Area	62-95
	Sand classifiers	Area	76-89
	Misc. buildings, trailers	Inside	51-89
	Scale house	Inside	51-72
	Sand screws	Area	81-88
	Plant area noise	Ground level	61-97

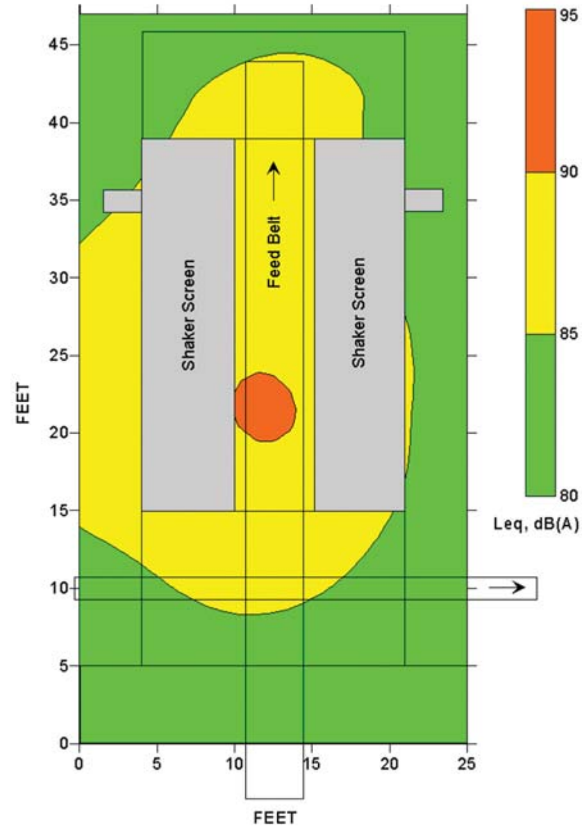
[1]Measured with a 3-dB exchange rate.

FIGURE 13

Diester 1.8- x 6.1-m (6- x 20-ft) shaker screens.

FIGURE 14

Sound profile plot for Diester 1.8- x 6.1-m (6- x 20-ft) shaker screens.



the sound levels for an entire plant. In general, the sound levels are below 90 dB(A) except in the area around the No. 1 primary screen and 1.5-m (60-in.) crusher.

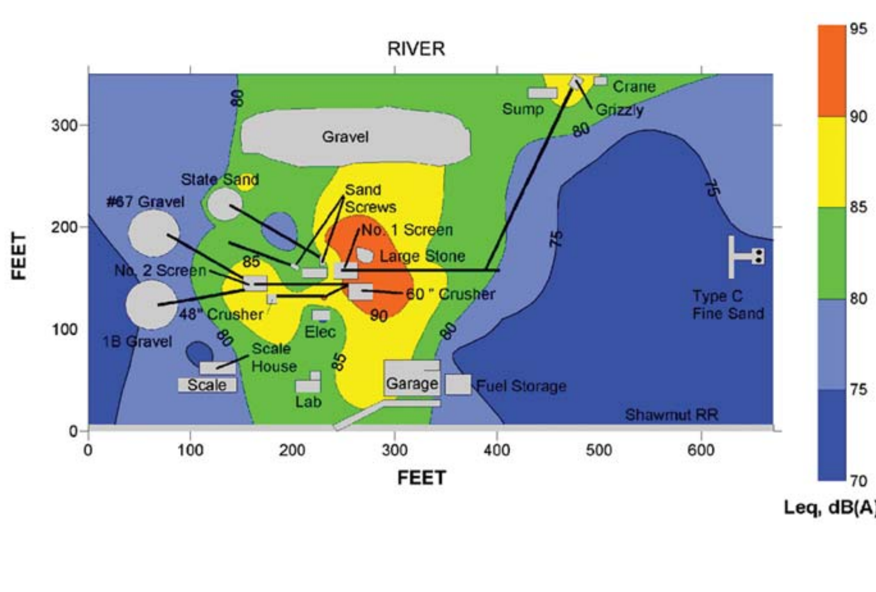
Discussion

Considering the high noise levels that the mining, dredging and processing equipment generate, the large number of sand and gravel operations in the United States and the more than 45,000 employees, the concern for preventing NIHL is significant. Sound levels as high as 112 dB(A) were recorded near crushers, 108 dB(A) near screens, 107 dB(A) in the engine rooms of the cranes and up to 97 dB(A) in the plant areas. Over time, exposure to these noise levels for even short durations could result in permanent hearing loss. Fortunately, the results of this research effort indicate that workers are avoiding high noise areas as revealed by the relatively low dose levels recorded. In general, all but three of the doses recorded were less than 60 percent with only two approaching the MSHA PEL of 100 percent (89.96 percent and 90.2 percent), as shown in Table 2.

Because most employees are in cabs or control rooms, they are protected from noise overexposure, as illustrated by the results of the dose measurements. For those workers who must spend time in the processing plants and engine rooms, it would be prudent to restrict time spent in and around the screens and crushers in the plants and the pumps and motors on the dredges and to require mobile equipment operators to keep all doors and windows closed while the equipment is in operation. All workers should be made aware of the sound levels around all equipment and in the plants and dredges and should be instructed to use hearing protection based on NIOSH's recommended exposure limit (REL) of 85 dB, A-weighted, as an 8-hour time-weighted average (TWA8) (NIOSH, 1998). 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. Because the length of exposure can vary and/or is not known prior to entering a high sound area, the potential adverse effects on

FIGURE 15

Sound profile plot for entire plant.



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

The sound level measurements on all the dredges indicate that workers should limit their exposure near the diesel engines of the barge and crane, and on-board processing facilities. Similarly, on the towboats, the diesel engines are noisy and should be avoided when possible. When it is necessary to be near the engines, workers should wear appropriate hearing protection. In addition, based on the measured sound levels, it is recommended that as little work as possible should be done in the crane engine rooms while they are operating.

It is also important that hearing-protection devices (HPDs) are used in high noise areas, even though workers are limiting their exposures as evidenced by the lack of MSHA PEL doses over 100 percent. Finally, HPDs are only a temporary substitute for effective engineering and administrative noise controls. Noise-induced hearing loss will be eliminated only through a coordinated effort of applying noise controls and HPD use for exposure reduction.

Disclaimer

The findings and discussions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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